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Introduction

This Ecma Standard defines the ECMAScript 2024 Language. It is the fifteenth edition of the ECMAScript Language Specification. Since publication of the first edition in 1997, ECMAScript has grown to be one of the world's most widely used general-purpose programming languages. It is best known as the language embedded in web browsers but has also been widely adopted for server and embedded applications.

ECMAScript is based on several originating technologies, the most well-known being JavaScript (Netscape) and JScript (Microsoft). The language was invented by Brendan Eich at Netscape and first appeared in that company's Navigator 2.0 browser. It has appeared in all subsequent browsers from Netscape and in all browsers from Microsoft starting with Internet Explorer 3.0.


That Ecma Standard was submitted to ISO/IEC JTC 1 for adoption under the fast-track procedure, and approved as international standard ISO/IEC 16262, in April 1998. The Ecma General Assembly of June 1998 approved the second edition of ECMA-262 to keep it fully aligned with ISO/IEC 16262. Changes between the first and the second edition are editorial in nature.


After publication of the third edition, ECMAScript achieved massive adoption in conjunction with the World Wide Web where it has become the programming language that is supported by essentially all web browsers. Significant work was done to develop a fourth edition of ECMAScript. However, that work was not completed and not published as the fourth edition of ECMAScript but some of it was incorporated into the development of the sixth edition.

The fifth edition of ECMAScript (published as ECMA-262 5th edition) codified de facto interpretations of the language specification that have become common among browser implementations and added support for new features that had emerged since the publication of the third edition. Such features include accessor properties, reflective creation and inspection of objects, program control of property attributes, additional array manipulation functions, support for the JSON object encoding format, and a strict mode that provides enhanced error checking and program security. The fifth edition was adopted by the Ecma General Assembly of December 2009.


Focused development of the sixth edition started in 2009, as the fifth edition was being prepared for publication. However, this was preceded by significant experimentation and language enhancement design efforts dating to the publication of the third edition in 1999. In a very real sense, the completion of the sixth edition is the culmination of a fifteen year effort. The goals for this edition included providing better support for large applications, library creation, and for use of ECMAScript as a compilation target for other languages. Some of its major enhancements included modules, class declarations, lexical block scoping, iterators and generators, promises for asynchronous programming, destructuring patterns, and proper tail calls. The ECMAScript library of built-ins was expanded to support additional data abstractions including maps, sets, and arrays of binary numeric values as well as additional support for Unicode supplementary characters in strings and regular expressions. The built-ins were also made extensible via subclassing. The sixth edition provides the foundation for regular, incremental language and library enhancements. The sixth edition was adopted by the General Assembly of June 2015.

ECMAScript 2016 was the first ECMAScript edition released under Ecma TC39's new yearly release cadence and open development process. A plain-text source document was built from the ECMAScript 2015 source document to serve as the base for further development entirely on GitHub. Over the year of this standard's development, hundreds of pull requests and issues were filed representing thousands of bug fixes, editorial fixes and other
improvements. Additionally, numerous software tools were developed to aid in this effort including Ecmarkup, Ecmarkdown, and Grammarkdown. ES2016 also included support for a new exponentiation operator and adds a new method to `Array.prototype` called `includes`.

ECMAScript 2017 introduced Async Functions, Shared Memory, and Atomics along with smaller language and library enhancements, bug fixes, and editorial updates. Async functions improve the asynchronous programming experience by providing syntax for promise-returning functions. Shared Memory and Atomics introduce a new memory model that allows multi-agent programs to communicate using atomic operations that ensure a well-defined execution order even on parallel CPUs. It also included new static methods on Object: `Object.values`, `Object.entries`, and `Object.getOwnPropertyDescriptors`.

ECMAScript 2018 introduced support for asynchronous iteration via the AsyncIterator protocol and async generators. It also included four new regular expression features: the `dotAll` flag, named capture groups, Unicode property escapes, and look-behind assertions. Lastly it included object rest and spread properties.

ECMAScript 2019 introduced a few new built-in functions: `flat` and `flatMap` on `Array.prototype` for flattening arrays, `Object.fromEntries` for directly turning the return value of `Object.entries` into a new Object, and `trimStart` and `trimEnd` on `String.prototype` as better-named alternatives to the widely implemented but non-standard `String.prototype.trimLeft` and `trimRight` built-ins. In addition, it included a few minor updates to syntax and semantics. Updated syntax included optional catch binding parameters and allowing `U+2028` (LINE SEPARATOR) and `U+2029` (PARAGRAPH SEPARATOR) in string literals to align with JSON. Other updates included requiring that `Array.prototype.sort` be a stable sort, requiring that `JSON.stringify` return well-formed UTF-8 regardless of input, and clarifying `Function.prototype.toString` by requiring that it either return the corresponding original source text or a standard placeholder.

ECMAScript 2020, the 11th edition, introduced the `matchAll` method for Strings, to produce an iterator for all match objects generated by a global regular expression; `import()`, a syntax to asynchronously import Modules with a dynamic specifier; `BigInt`, a new number primitive for working with arbitrary precision integers; `Promise.allSettled`, a new Promise combinator that does not short-circuit; `globalThis`, a universal way to access the global `this` value; dedicated `export * as ns from 'module'` syntax for use within modules; increased standardization of `for-in` enumeration order; `import.meta`, a host-populated object available in Modules that may contain contextual information about the Module; as well as adding two new syntax features to improve working with “nullish” values (`undefined` or `null`): nullish coalescing, a value selection operator; and optional chaining, a property access and function invocation operator that short-circuits if the value to access/ invoke is nullish.

ECMAScript 2021, the 12th edition, introduced the `replaceAll` method for Strings; `Promise.any`, a Promise combinator that short-circuits when an input value is fulfilled; `AggregateError`, a new Error type to represent multiple errors at once; logical assignment operators (`??=`, `&=&`, `||=`); `WeakRef`, for referring to a target object without preserving it from garbage collection, and `FinalizationRegistry`, to manage registration and un-registration of cleanup operations performed when target objects are garbage collected; separators for numeric literals (`1_000`); and `Array.prototype.sort` was made more precise, reducing the amount of cases that result in an implementation-defined sort order.

ECMAScript 2022, the 13th edition, introduced top-level `await`, allowing the `keyword` to be used at the top level of modules; new class elements: public and private instance fields, public and private static fields, private instance methods and accessors, and private static methods and accessors; static blocks inside classes, to perform per-class evaluation initialization; the `#x in obj` syntax, to test for presence of private fields on objects; regular expression match indices via the `/d` flag, which provides start and end indices for matched substrings; the `cause` property on `Error` objects, which can be used to record a causation chain in errors; the `at` method for Strings, Arrays, and `TypedArrays`, which allows relative indexing; and `Object.hasOwnProperty`, a convenient alternative to `Object.prototype.hasOwnProperty`.

ECMAScript 2023, the 14th edition, introduced the `toSorted`, `toReversed`, `with`, `findLast`, and `findLastIndex` methods on `Array.prototype` and `TypedArray.prototype`, as well as the `toSpliced` method on `Array.prototype`; added support for `#1` comments at the beginning of files to better facilitate executable ECMAScript files; and allowed the use of most Symbols as keys in weak collections.
ECMAScript 2024, the 15th edition, added facilities for resizing and transferring ArrayBuffers and SharedArrayBuffers; added a new RegExp `/v` flag for creating RegExps with more advanced features for working with sets of strings; and introduced the Promise.withResolvers convenience method for constructing Promises, the Object.groupBy and Map.groupBy methods for aggregating data, the Atomics.waitFor method for asynchronously waiting for a change to shared memory, and the String.prototype.isWellFormed and String.prototype.toWellFormed methods for checking and ensuring that strings contain only well-formed Unicode.

Dozens of individuals representing many organizations have made very significant contributions within Ecma TC39 to the development of this edition and to the prior editions. In addition, a vibrant community has emerged supporting TC39’s ECMAScript efforts. This community has reviewed numerous drafts, filed thousands of bug reports, performed implementation experiments, contributed test suites, and educated the world-wide developer community about ECMAScript. Unfortunately, it is impossible to identify and acknowledge every person and organization who has contributed to this effort.

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About this Specification

The document at https://tc39.es/ecma262/ is the most accurate and up-to-date ECMAScript specification. It contains the content of the most recent yearly snapshot plus any finished proposals <https://github.com/tc39/proposals/blob/HEAD/finished-proposals.md> (those that have reached Stage 4 in the proposal process <https://tc39.es/process-document/> and thus are implemented in several implementations and will be in the next practical revision) since that snapshot was taken.

This document is available as a single page and as multiple pages.

Contributing to this Specification

This specification is developed on GitHub with the help of the ECMAScript community. There are a number of ways to contribute to the development of this specification:

GitHub Repository: https://github.com/tc39/ecma262
Test Suite: Test262 <https://github.com/tc39/test262>

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ECMAScript® 2024 Language Specification

1 Scope

This Standard defines the ECMAScript 2024 general-purpose programming language.

2 Conformance

A conforming implementation of ECMAScript must provide and support all the types, values, objects, properties, functions, and program syntax and semantics described in this specification.

A conforming implementation of ECMAScript must interpret source text input in conformance with the latest version of the Unicode Standard and ISO/IEC 10646.

A conforming implementation of ECMAScript that provides an application programming interface (API) that supports programs that need to adapt to the linguistic and cultural conventions used by different human languages and countries must implement the interface defined by the most recent edition of ECMA-402 that is compatible with this specification.

A conforming implementation of ECMAScript may provide additional types, values, objects, properties, and functions beyond those described in this specification. In particular, a conforming implementation of ECMAScript may provide properties not described in this specification, and values for those properties, for objects that are described in this specification.

A conforming implementation of ECMAScript may support program and regular expression syntax not described in this specification. In particular, a conforming implementation of ECMAScript may support program syntax that makes use of any “future reserved words” noted in subclause 12.7.2 of this specification.

A conforming implementation of ECMAScript must not implement any extension that is listed as a Forbidden Extension in subclause 17.1.

A conforming implementation of ECMAScript must not redefine any facilities that are not implementation-defined, implementation-approximated, or host-defined.

A conforming implementation of ECMAScript may choose to implement or not implement Normative Optional subclauses. If any Normative Optional behaviour is implemented, all of the behaviour in the containing Normative Optional clause must be implemented. A Normative Optional clause is denoted in this specification with the words "Normative Optional" in a coloured box, as shown below.

NORMATIVE OPTIONAL

2.1 Example Normative Optional Clause Heading

Example clause contents.

A conforming implementation of ECMAScript must implement Legacy subclauses, unless they are also marked as Normative Optional. All of the language features and behaviours specified within Legacy subclauses have one or more undesirable characteristics. However, their continued usage in existing applications prevents their removal from this specification. These features are not considered part of the core ECMAScript language. Programmers should not use or assume the existence of these features and behaviours when writing new ECMAScript code.
3 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.


The Unicode Standard.
https://unicode.org/versions/latest


ECMA-402, *ECMAScript Internationalization API Specification*, specifically the annual edition corresponding to this edition of this specification.

ECMA-404, *The JSON Data Interchange Format*.

4 Overview

This section contains a non-normative overview of the ECMAScript language.

ECMAScript is an object-oriented programming language for performing computations and manipulating computational objects within a host environment. ECMAScript as defined here is not intended to be computationally self-sufficient; indeed, there are no provisions in this specification for input of external data or output of computed results. Instead, it is expected that the computational environment of an ECMAScript program will provide not only the objects and other facilities described in this specification but also certain environment-specific objects, whose description and behaviour are beyond the scope of this specification except to indicate that they may provide certain properties that can be accessed and certain functions that can be called from an ECMAScript program.

ECMAScript was originally designed to be used as a scripting language, but has become widely used as a general-purpose programming language. A scripting language is a programming language that is used to manipulate, customize, and automate the facilities of an existing system. In such systems, useful functionality is already available through a user interface, and the scripting language is a mechanism for exposing that functionality to program control. In this way, the existing system is said to provide a host environment of objects and facilities, which completes the capabilities of the scripting language. A scripting language is intended for use by both professional and non-professional programmers.
ECMAScript was originally designed to be a Web scripting language, providing a mechanism to enliven Web pages in browsers and to perform server computation as part of a Web-based client-server architecture. ECMAScript is now used to provide core scripting capabilities for a variety of host environments. Therefore the core language is specified in this document apart from any particular host environment.

ECMAScript usage has moved beyond simple scripting and it is now used for the full spectrum of programming tasks in many different environments and scales. As the usage of ECMAScript has expanded, so have the features and facilities it provides. ECMAScript is now a fully featured general-purpose programming language.

4.1 Web Scripting

A web browser provides an ECMAScript host environment for client-side computation including, for instance, objects that represent windows, menus, pop-ups, dialog boxes, text areas, anchors, frames, history, cookies, and input/output. Further, the host environment provides a means to attach scripting code to events such as change of focus, page and image loading, unloading, error and abort, selection, form submission, and mouse actions. Scripting code appears within the HTML and the displayed page is a combination of user interface elements and fixed and computed text and images. The scripting code is reactive to user interaction, and there is no need for a main program.

A web server provides a different host environment for server-side computation including objects representing requests, clients, and files; and mechanisms to lock and share data. By using browser-side and server-side scripting together, it is possible to distribute computation between the client and server while providing a customized user interface for a Web-based application.

Each Web browser and server that supports ECMAScript supplies its own host environment, completing the ECMAScript execution environment.

4.2 Hosts and Implementations

To aid integrating ECMAScript into host environments, this specification defers the definition of certain facilities (e.g., abstract operations), either in whole or in part, to a source outside of this specification. Editorially, this specification distinguishes the following kinds of deferrals.

An implementation is an external source that further defines facilities enumerated in Annex D or those that are marked as implementation-defined or implementation-approximated. In informal use, an implementation refers to a concrete artefact, such as a particular web browser.

An implementation-defined facility is one that defers its definition to an external source without further qualification. This specification does not make any recommendations for particular behaviours, and conforming implementations are free to choose any behaviour within the constraints put forth by this specification.

An implementation-approximated facility is one that defers its definition to an external source while recommending an ideal behaviour. While conforming implementations are free to choose any behaviour within the constraints put forth by this specification, they are encouraged to strive to approximate the ideal. Some mathematical operations, such as Math.exp, are implementation-approximated.

A host is an external source that further defines facilities listed in Annex D but does not further define other implementation-defined or implementation-approximated facilities. In informal use, a host refers to the set of all implementations, such as the set of all web browsers, that interface with this specification in the same way via Annex D. A host is often an external specification, such as WHATWG HTML (https://html.spec.whatwg.org/). In other words, facilities that are host-defined are often further defined in external specifications.

A host hook is an abstract operation that is defined in whole or in part by an external source. All host hooks must be listed in Annex D. A host hook must conform to at least the following requirements:

- It must return either a normal completion or a throw completion.

A host-defined facility is one that defers its definition to an external source without further qualification and is listed in Annex D. Implementations that are not hosts may also provide definitions for host-defined facilities.
A *host environment* is a particular choice of definition for all *host-defined* facilities. A *host environment* typically includes objects or functions which allow obtaining input and providing output as *host-defined* properties of the *global object*.

This specification follows the editorial convention of always using the most specific term. For example, if a facility is *host-defined*, it should not be referred to as *implementation-defined*.

Both *hosts* and implementations may interface with this specification via the language types, specification types, *abstract operations*, grammar productions, intrinsic objects, and intrinsic symbols defined herein.

### 4.3 ECMAScript Overview

The following is an informal overview of ECMAScript—not all parts of the language are described. This overview is not part of the standard proper.

ECMAScript is object-based: basic language and *host* facilities are provided by objects, and an ECMAScript program is a cluster of communicating objects. In ECMAScript, an *object* is a collection of zero or more *properties* each with *attributes* that determine how each property can be used—for example, when the *Writable* attribute for a property is set to *false*, any attempt by executed ECMAScript code to assign a different value to the property fails. Properties are containers that hold other objects, *primitive values*, or *functions*. A *primitive value* is a member of one of the following built-in types: *Undefined*, *Null*, *Boolean*, *Number*, *BigInt*, *String*, and *Symbol*; an *object* is a member of the built-in type *Object*; and a *function* is a callable object. A function that is associated with an object via a property is called a *method*.

ECMAScript defines a collection of *built-in objects* that round out the definition of ECMAScript entities. These built-in objects include the *global object*; objects that are fundamental to the *runtime semantics* of the language including *Object*, *Function*, *Boolean*, *Symbol*, and various *Error* objects; objects that represent and manipulate numeric values including *Math*, *Number*, and *Date*; the text processing objects *String* and *RegExp*; objects that are indexed collections of values including *Array* and nine different kinds of *Typed Arrays* whose elements all have a specific numeric data representation; keyed collections including *Map* and *Set* objects; objects supporting structured data including the *JSON* object, *ArrayBuffer*, *SharedArrayBuffer*, and *DataView*; objects supporting control abstractions including generator functions and *Promise* objects; and reflection objects including *Proxy* and *Reflect*.

ECMAScript also defines a set of built-in *operators*. ECMAScript operators include various unary operations, multiplicative operators, additive operators, bitwise shift operators, relational operators, equality operators, binary bitwise operators, binary logical operators, assignment operators, and the comma operator.

Large ECMAScript programs are supported by *modules* which allow a program to be divided into multiple sequences of statements and declarations. Each module explicitly identifies declarations it uses that need to be provided by other modules and which of its declarations are available for use by other modules.

ECMAScript syntax intentionally resembles Java syntax. ECMAScript syntax is relaxed to enable it to serve as an easy-to-use scripting language. For example, a variable is not required to have its type declared nor are types associated with properties, and defined functions are not required to have their declarations appear textually before calls to them.

#### 4.3.1 Objects

Even though ECMAScript includes syntax for class definitions, ECMAScript objects are not fundamentally class-based such as those in C++, Smalltalk, or Java. Instead objects may be created in various ways including via a literal notation or via *constructors* which create objects and then execute code that initializes all or part of them by assigning initial values to their properties. Each *constructor* is a function that has a property named "*prototype" that is used to implement *prototype-based inheritance* and *shared properties*. Objects are created by using *constructors* in *new* expressions; for example, *new* *Date*(2009, 11) creates a new Date object. Invok-
ing a constructor without using new has consequences that depend on the constructor. For example, Date() produces a string representation of the current date and time rather than an object.

Every object created by a constructor has an implicit reference (called the object's prototype) to the value of its constructor's "prototype" property. Furthermore, a prototype may have a non-null implicit reference to its prototype, and so on; this is called the prototype chain. When a reference is made to a property in an object, that reference is to the property of that name in the first object in the prototype chain that contains a property of that name. In other words, first the object mentioned directly is examined for such a property; if that object contains the named property, that is the property to which the reference refers; if that object does not contain the named property, the prototype for that object is examined next; and so on.

![Figure 1: Object/Prototype Relationships](image)

In a class-based object-oriented language, in general, state is carried by instances, methods are carried by classes, and inheritance is only of structure and behaviour. In ECMAScript, the state and methods are carried by objects, while structure, behaviour, and state are all inherited.

All objects that do not directly contain a particular property that their prototype contains share that property and its value. Figure 1 illustrates this:

**CF** is a constructor (and also an object). Five objects have been created by using new expressions: `cf1`, `cf2`, `cf3`, `cf4`, and `cf5`. Each of these objects contains properties named "q1" and "q2". The dashed lines represent the implicit prototype relationship; so, for example, `cf3`'s prototype is `CFp`. The constructor, **CF**, has two properties itself, named "P1" and "P2", which are not visible to `CFp`, `cf1`, `cf2`, `cf3`, `cf4`, or `cf5`. The property named "CFP1" in `CFp` is shared by `cf1`, `cf2`, `cf3`, `cf4`, and `cf5` (but not by **CF**), as are any properties found in `CFp`'s implicit prototype chain that are not named "q1", "q2", or "CFP1". Notice that there is no implicit prototype link between **CF** and `CFp`.

Unlike most class-based object languages, properties can be added to objects dynamically by assigning values to them. That is, constructors are not required to name or assign values to all or any of the constructed object's properties. In the above diagram, one could add a new shared property for `cf1`, `cf2`, `cf3`, `cf4`, and `cf5` by assigning a new value to the property in `CFp`.

Although ECMAScript objects are not inherently class-based, it is often convenient to define class-like abstractions based upon a common pattern of constructor functions, prototype objects, and methods. The ECMAScript built-in objects themselves follow such a class-like pattern. Beginning with ECMAScript 2015, the ECMAScript language includes syntactic class definitions that permit programmers to concisely define objects that conform to the same class-like abstraction pattern used by the built-in objects.
4.3.2 The Strict Variant of ECMAScript

The ECMAScript Language recognizes the possibility that some users of the language may wish to restrict their usage of some features available in the language. They might do so in the interests of security, to avoid what they consider to be error-prone features, to get enhanced error checking, or for other reasons of their choosing. In support of this possibility, ECMAScript defines a strict variant of the language. The strict variant of the language excludes some specific syntactic and semantic features of the regular ECMAScript language and modifies the detailed semantics of some features. The strict variant also specifies additional error conditions that must be reported by throwing error exceptions in situations that are not specified as errors by the non-strict form of the language.

The strict variant of ECMAScript is commonly referred to as the *strict mode* of the language. Strict mode selection and use of the strict mode syntax and semantics of ECMAScript is explicitly made at the level of individual ECMAScript source text units as described in 11.2.2. Because strict mode is selected at the level of a syntactic source text unit, strict mode only imposes restrictions that have local effect within such a source text unit. Strict mode does not restrict or modify any aspect of the ECMAScript semantics that must operate consistently across multiple source text units. A complete ECMAScript program may be composed of both strict mode and non-strict mode ECMAScript source text units. In this case, strict mode only applies when actually executing code that is defined within a strict mode source text unit.

In order to conform to this specification, an ECMAScript implementation must implement both the full unrestricted ECMAScript language and the strict variant of the ECMAScript language as defined by this specification. In addition, an implementation must support the combination of unrestricted and strict mode source text units into a single composite program.

4.4 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

4.4.1 implementation-approximated

an implementation-approximated facility is defined in whole or in part by an external source but has a recommended, ideal behaviour in this specification

4.4.2 implementation-defined

an implementation-defined facility is defined in whole or in part by an external source to this specification

4.4.3 host-defined

same as implementation-defined

| NOTE | Editorially, see clause 4.2. |

4.4.4 type

set of data values as defined in clause 6

4.4.5 primitive value

member of one of the types Undefined, Null, Boolean, Number, BigInt, Symbol, or String as defined in clause 6

| NOTE | A primitive value is a datum that is represented directly at the lowest level of the language implementation. |
4.4.6 object

member of the type Object

**NOTE** An object is a collection of properties and has a single prototype object. The prototype may be **null**.

4.4.7 constructor

function object that creates and initializes objects

**NOTE** The value of a constructor's "prototype" property is a prototype object that is used to implement inheritance and shared properties.

4.4.8 prototype

object that provides shared properties for other objects

**NOTE** When a constructor creates an object, that object implicitly references the constructor's "prototype" property for the purpose of resolving property references. The constructor's "prototype" property can be referenced by the program expression `constructor.prototype`, and properties added to an object's prototype are shared, through inheritance, by all objects sharing the prototype. Alternatively, a new object may be created with an explicitly specified prototype by using the **Object.create** built-in function.

4.4.9 ordinary object

object that has the default behaviour for the essential internal methods that must be supported by all objects

4.4.10 exotic object

object that does not have the default behaviour for one or more of the essential internal methods

**NOTE** Any object that is not an ordinary object is an exotic object.

4.4.11 standard object

object whose semantics are defined by this specification

4.4.12 built-in object

object specified and supplied by an ECMAScript implementation

**NOTE** Standard built-in objects are defined in this specification. An ECMAScript implementation may specify and supply additional kinds of built-in objects.

4.4.13 undefined value

primitive value used when a variable has not been assigned a value
4.4.14 Undefined type

type whose sole value is the **undefined** value

4.4.15 null value

primitive value that represents the intentional absence of any object value

4.4.16 Null type

type whose sole value is the **null** value

4.4.17 Boolean value

member of the **Boolean type**

**NOTE** There are only two Boolean values, **true** and **false**.

4.4.18 Boolean type

type consisting of the primitive values **true** and **false**

4.4.19 Boolean object

member of the **Object type** that is an instance of the standard built-in Boolean **constructor**

**NOTE** A Boolean object is created by using the Boolean **constructor** in a **new** expression, supplying a Boolean value as an argument. The resulting object has an internal slot whose value is the Boolean value. A Boolean object can be coerced to a Boolean value.

4.4.20 String value

primitive value that is a **finite** ordered sequence of zero or more 16-bit unsigned **integer** values

**NOTE** A String value is a member of the **String type**. Each **integer** value in the sequence usually represents a single 16-bit unit of UTF-16 text. However, ECMAScript does not place any restrictions or requirements on the values except that they must be 16-bit unsigned **integers**.

4.4.21 String type

set of all possible String values

4.4.22 String object

member of the **Object type** that is an instance of the standard built-in String **constructor**

**NOTE** A String object is created by using the String **constructor** in a **new** expression, supplying a String value as an argument. The resulting object has an internal slot whose value is the String value. A String object can be coerced to a String value by calling the String **constructor** as a function (**22.1.1.1**).
4.4.23 Number value

primitive value corresponding to a double-precision 64-bit binary format IEEE 754-2019 value

```
NOTE

A Number value is a member of the Number type and is a direct representation of a number.
```

4.4.24 Number type

set of all possible Number values including the special “Not-a-Number” (NaN) value, positive infinity, and negative infinity

4.4.25 Number object

member of the Object type that is an instance of the standard built-in Number constructor

```
NOTE

A Number object is created by using the Number constructor in a new expression, supplying a Number value as an argument. The resulting object has an internal slot whose value is the Number value. A Number object can be coerced to a Number value by calling the Number constructor as a function (21.1.1.1).
```

4.4.26 Infinity

Number value that is the positive infinite Number value

4.4.27 NaN

Number value that is an IEEE 754-2019 “Not-a-Number” value

4.4.28 BigInt value

primitive value corresponding to an arbitrary-precision integer value

4.4.29 BigInt type

set of all possible BigInt values

4.4.30 BigInt object

member of the Object type that is an instance of the standard built-in BigInt constructor

4.4.31 Symbol value

primitive value that represents a unique, non-String Object property key

4.4.32 Symbol type

set of all possible Symbol values

4.4.33 Symbol object

member of the Object type that is an instance of the standard built-in Symbol constructor
4.4.34 function
member of the Object type that may be invoked as a subroutine

NOTE In addition to its properties, a function contains executable code and state that determine how it behaves when invoked. A function's code may or may not be written in ECMAScript.

4.4.35 built-in function
built-in object that is a function

NOTE Examples of built-in functions include parseInt and Math.exp. A host or implementation may provide additional built-in functions that are not described in this specification.

4.4.36 built-in constructor
built-in function that is a constructor

NOTE Examples of built-in constructors include Object and Function. A host or implementation may provide additional built-in constructors that are not described in this specification.

4.4.37 property
part of an object that associates a key (either a String value or a Symbol value) and a value

NOTE Depending upon the form of the property the value may be represented either directly as a data value (a primitive value, an object, or a function object) or indirectly by a pair of accessor functions.

4.4.38 method
function that is the value of a property

NOTE When a function is called as a method of an object, the object is passed to the function as its this value.

4.4.39 built-in method
method that is a built-in function

NOTE Standard built-in methods are defined in this specification. A host or implementation may provide additional built-in methods that are not described in this specification.

4.4.40 attribute
internal value that defines some characteristic of a property

4.4.41 own property
property that is directly contained by its object
property of an object that is not an own property but is a property (either own or inherited) of the object’s prototype.

4.5 Organization of This Specification

The remainder of this specification is organized as follows:

Clause 5 defines the notational conventions used throughout the specification.

Clauses 6 through 10 define the execution environment within which ECMAScript programs operate.

Clauses 11 through 17 define the actual ECMAScript programming language including its syntactic encoding and the execution semantics of all language features.

Clauses 18 through 28 define the ECMAScript standard library. They include the definitions of all of the standard objects that are available for use by ECMAScript programs as they execute.

Clause 29 describes the memory consistency model of accesses on SharedArrayBuffer-backed memory and methods of the Atomics object.

5 Notational Conventions

5.1 Syntactic and Lexical Grammars

5.1.1 Context-Free Grammars

A context-free grammar consists of a number of productions. Each production has an abstract symbol called a nonterminal as its left-hand side, and a sequence of zero or more nonterminal and terminal symbols as its right-hand side. For each grammar, the terminal symbols are drawn from a specified alphabet.

A chain production is a production that has exactly one nonterminal symbol on its right-hand side along with zero or more terminal symbols.

Starting from a sentence consisting of a single distinguished nonterminal, called the goal symbol, a given context-free grammar specifies a language, namely, the (perhaps infinite) set of possible sequences of terminal symbols that can result from repeatedly replacing any nonterminal in the sequence with a right-hand side of a production for which the nonterminal is the left-hand side.

5.1.2 The Lexical and RegExp Grammars

A lexical grammar for ECMAScript is given in clause 12. This grammar has as its terminal symbols Unicode code points that conform to the rules for SourceCharacter defined in 11.1. It defines a set of productions, starting from the goal symbol InputElementDiv, InputElementTemplateTail, InputElementRegExp, InputElementRegExpOrTemplateTail, or InputElementHashbangOrRegExp, that describe how sequences of such code points are translated into a sequence of input elements.

Input elements other than white space and comments form the terminal symbols for the syntactic grammar for ECMAScript and are called ECMAScript tokens. These tokens are the reserved words, identifiers, literals, and punctuators of the ECMAScript language. Moreover, line terminators, although not considered to be tokens, also become part of the stream of input elements and guide the process of automatic semicolon insertion (12.10). Simple white space and single-line comments are discarded and do not appear in the stream of input elements for the syntactic grammar. A MultiLineComment (that is, a comment of the form /*...*/) regardless of whether it spans more than one line is likewise simply discarded if it contains no line terminator; but if a MultiLineComment contains one or more line terminators, then it is replaced by a single line terminator, which becomes part of the stream of input elements for the syntactic grammar.
A RegExp grammar for ECMAScript is given in 22.2.1. This grammar also has as its terminal symbols the code points as defined by SourceCharacter. It defines a set of productions, starting from the goal symbol Pattern, that describe how sequences of code points are translated into regular expression patterns.

Productions of the lexical and RegExp grammars are distinguished by having two colons “::” as separating punctuation. The lexical and RegExp grammars share some productions.

### 5.1.3 The Numeric String Grammar

A numeric string grammar appears in 7.1.4.1. It has as its terminal symbols SourceCharacter, and is used for translating Strings into numeric values starting from the goal symbol StringNumericLiteral (which is similar to but distinct from the lexical grammar for numeric literals).

Productions of the numeric string grammar are distinguished by having three colons “::::” as punctuation, and are never used for parsing source text.

### 5.1.4 The Syntactic Grammar

The syntactic grammar for ECMAScript is given in clauses 13 through 16. This grammar has ECMAScript tokens defined by the lexical grammar as its terminal symbols (5.1.2). It defines a set of productions, starting from two alternative goal symbols Script and Module, that describe how sequences of tokens form syntactically correct independent components of ECMAScript programs.

When a stream of code points is to be parsed as an ECMAScript Script or Module, it is first converted to a stream of input elements by repeated application of the lexical grammar; this stream of input elements is then parsed by a single application of the syntactic grammar. The input stream is syntactically in error if the tokens in the stream of input elements cannot be parsed as a single instance of the goal nonterminal (Script or Module), with no tokens left over.

When a parse is successful, it constructs a parse tree, a rooted tree structure in which each node is a Parse Node. Each Parse Node is an instance of a symbol in the grammar; it represents a span of the source text that can be derived from that symbol. The root node of the parse tree, representing the whole of the source text, is an instance of the parse’s goal symbol. When a Parse Node is an instance of a nonterminal, it is also an instance of some production that has that nonterminal as its left-hand side. Moreover, it has zero or more children, one for each symbol on the production’s right-hand side: each child is a Parse Node that is an instance of the corresponding symbol.

New Parse Nodes are instantiated for each invocation of the parser and never reused between parses even of identical source text. Parse Nodes are considered the same Parse Node if and only if they represent the same span of source text, are instances of the same grammar symbol, and resulted from the same parser invocation.

---

**NOTE 1** Parsing the same String multiple times will lead to different Parse Nodes. For example, consider:

```javascript
let str = "1 + 1;";
 eval(str);
 eval(str);
```

Each call to `eval` converts the value of `str` into ECMAScript source text and performs an independent parse that creates its own separate tree of Parse Nodes. The trees are distinct even though each parse operates upon a source text that was derived from the same String value.

**NOTE 2** Parse Nodes are specification artefacts, and implementations are not required to use an analogous data structure.

Productions of the syntactic grammar are distinguished by having just one colon “;” as punctuation.
The syntactic grammar as presented in clauses 13 through 16 is not a complete account of which token sequences are accepted as a correct ECMAScript Script or Module. Certain additional token sequences are also accepted, namely, those that would be described by the grammar if only semicolons were added to the sequence in certain places (such as before line terminator characters). Furthermore, certain token sequences that are described by the grammar are not considered acceptable if a line terminator character appears in certain "awkward" places.

In certain cases, in order to avoid ambiguities, the syntactic grammar uses generalized productions that permit token sequences that do not form a valid ECMAScript Script or Module. For example, this technique is used for object literals and object destructuring patterns. In such cases a more restrictive supplemental grammar is provided that further restricts the acceptable token sequences. Typically, an early error rule will then state that, in certain contexts, "P must cover an N", where P is a Parse Node (an instance of the generalized production) and N is a nonterminal from the supplemental grammar. This means:

1. The sequence of tokens originally matched by P is parsed again using N as the goal symbol. If N takes grammatical parameters, then they are set to the same values used when P was originally parsed.
2. If the sequence of tokens can be parsed as a single instance of N, with no tokens left over, then:
   1. We refer to that instance of N (a Parse Node, unique for a given P) as "the N that is covered by P".
   2. All Early Error rules for N and its derived productions also apply to the N that is covered by P.
3. Otherwise (if the parse fails), it is an early Syntax Error.

5.1.5 Grammar Notation

5.1.5.1 Terminal Symbols

In the ECMAScript grammars, some terminal symbols are shown in fixed-width font. These are to appear in a source text exactly as written. All terminal symbol code points specified in this way are to be understood as the appropriate Unicode code points from the Basic Latin block, as opposed to any similar-looking code points from other Unicode ranges. A code point in a terminal symbol cannot be expressed by a UnicodeEscapeSequence.

In grammars whose terminal symbols are individual Unicode code points (i.e., the lexical, RegExp, and numeric string grammars), a contiguous run of multiple fixed-width code points appearing in a production is a simple shorthand for the same sequence of code points, written as standalone terminal symbols.

For example, the production:

\[ HexIntegerLiteral :: 0x HexDigits \]

is a shorthand for:

\[ HexIntegerLiteral :: 0 \times HexDigits \]

In contrast, in the syntactic grammar, a contiguous run of fixed-width code points is a single terminal symbol.

Terminal symbols come in two other forms:

- In the lexical and RegExp grammars, Unicode code points without a conventional printed representation are instead shown in the form "<ABBREV>" where "ABBREV" is a mnemonic for the code point or set of code points. These forms are defined in Unicode Format-Control Characters, White Space, and Line Terminators.
- In the syntactic grammar, certain terminal symbols (e.g. IdentifierName and RegularExpressionLiteral) are shown in italics, as they refer to the nonterminals of the same name in the lexical grammar.
Nonterminal symbols are shown in italic type. The definition of a nonterminal (also called a “production”) is introduced by the name of the nonterminal being defined followed by one or more colons. (The number of colons indicates to which grammar the production belongs.) One or more alternative right-hand sides for the nonterminal then follow on succeeding lines. For example, the syntactic definition:

```
WhileStatement : 
    while ( Expression ) Statement
```

states that the nonterminal `WhileStatement` represents the token `while`, followed by a left parenthesis token, followed by an `Expression`, followed by a right parenthesis token, followed by a `Statement`. The occurrences of `Expression` and `Statement` are themselves nonterminals. As another example, the syntactic definition:

```
ArgumentList : 
    AssignmentExpression
    ArgumentList , AssignmentExpression
```

states that an `ArgumentList` may represent either a single `AssignmentExpression` or an `ArgumentList`, followed by a comma, followed by an `AssignmentExpression`. This definition of `ArgumentList` is recursive, that is, it is defined in terms of itself. The result is that an `ArgumentList` may contain any positive number of arguments, separated by commas, where each argument expression is an `AssignmentExpression`. Such recursive definitions of nonterminals are common.

### 5.1.5.3 Optional Symbols

The subscripted suffix “opt”, which may appear after a terminal or nonterminal, indicates an optional symbol. The alternative containing the optional symbol actually specifies two right-hand sides, one that omits the optional element and one that includes it. This means that:

```
VariableDeclaration : 
    BindingIdentifier Initializer_opt
```

is a convenient abbreviation for:

```
VariableDeclaration : 
    BindingIdentifier
    BindingIdentifier Initializer
```

and that:

```
ForStatement : 
    for ( LexicalDeclaration Expression_opt ; Expression_opt ) Statement
```

is a convenient abbreviation for:

```
ForStatement : 
    for ( LexicalDeclaration ; Expressionopt ) Statement
    for ( LexicalDeclaration Expression ; Expressionopt ) Statement
```

which in turn is an abbreviation for:

```
ForStatement : 
    for ( LexicalDeclaration ; ) Statement
    for ( LexicalDeclaration ; Expression ) Statement
    for ( LexicalDeclaration Expression ; ) Statement
    for ( LexicalDeclaration Expression ; Expression ) Statement
```
so, in this example, the nonterminal *ForStatement* actually has four alternative right-hand sides.

### 5.1.5.4 Grammatical Parameters

A production may be parameterized by a subscripted annotation of the form “\([\text{parameters}]\)”, which may appear as a suffix to the nonterminal symbol defined by the production. “\(\text{parameters}\)” may be either a single name or a comma separated list of names. A parameterized production is shorthand for a set of productions defining all combinations of the parameter names, preceded by an underscore, appended to the parameterized nonterminal symbol. This means that:

\[
\text{StatementList}\[\text{Return}\] : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

is a convenient abbreviation for:

\[
\text{StatementList} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

\[
\text{StatementList}_{\text{Return}} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

and that:

\[
\text{StatementList}\[\text{Return, In}\] : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

is an abbreviation for:

\[
\text{StatementList} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

\[
\text{StatementList}_{\text{Return}} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

\[
\text{StatementList}_{\text{In}} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

\[
\text{StatementList}_{\text{Return, In}} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}
\]

Multiple parameters produce a combinatory number of productions, not all of which are necessarily referenced in a complete grammar.

References to nonterminals on the right-hand side of a production can also be parameterized. For example:

\[
\text{StatementList} : \\
\text{ReturnStatement} \\
\text{ExpressionStatement}\[\text{+In}\]
\]
is equivalent to saying:

```
StatementList : 
   ReturnStatement
   ExpressionStatement_In
```

and:

```
StatementList : 
   ReturnStatement
   ExpressionStatement[-In]
```

is equivalent to:

```
StatementList : 
   ReturnStatement
   ExpressionStatement
```

A nonterminal reference may have both a parameter list and an “opt” suffix. For example:

```
VariableDeclaration : 
   BindingIdentifier Initializer[++In] opt
```

is an abbreviation for:

```
VariableDeclaration : 
   BindingIdentifier
   BindingIdentifier Initializer_In
```

Prefixing a parameter name with “?” on a right-hand side nonterminal reference makes that parameter value dependent upon the occurrence of the parameter name on the reference to the current production's left-hand side symbol. For example:

```
VariableDeclaration[?In] : 
   BindingIdentifier Initializer[?In]
```

is an abbreviation for:

```
VariableDeclaration : 
   BindingIdentifier Initializer
```

```
VariableDeclaration_In : 
   BindingIdentifier Initializer_In
```

If a right-hand side alternative is prefixed with “[+parameter]” that alternative is only available if the named parameter was used in referencing the production's nonterminal symbol. If a right-hand side alternative is prefixed with “[-parameter]” that alternative is only available if the named parameter was not used in referencing the production's nonterminal symbol. This means that:

```
StatementList[Return] : 
   [+Return] ReturnStatement
   ExpressionStatement
```

is an abbreviation for:

```
StatementList : 
   ExpressionStatement
```
StatementList_Return :
   ReturnStatement
   ExpressionStatement

and that:

StatementList[Return] :
   [-Return] ReturnStatement
   ExpressionStatement

is an abbreviation for:

StatementList :
   ReturnStatement
   ExpressionStatement

StatementList_Return :
   ExpressionStatement

5.1.5.5 one of

When the words “one of” follow the colon(s) in a grammar definition, they signify that each of the terminal symbols on the following line or lines is an alternative definition. For example, the lexical grammar for ECMAScript contains the production:

NonZeroDigit :: one of
   1 2 3 4 5 6 7 8 9

which is merely a convenient abbreviation for:

NonZeroDigit ::
   1
   2
   3
   4
   5
   6
   7
   8
   9

5.1.5.6 [empty]

If the phrase “[empty]” appears as the right-hand side of a production, it indicates that the production’s right-hand side contains no terminals or nonterminals.

5.1.5.7 Lookahead Restrictions

If the phrase “[lookahead = seq]” appears in the right-hand side of a production, it indicates that the production may only be used if the token sequence seq is a prefix of the immediately following input token sequence. Similarly, “[lookahead ∈ set]”, where set is a finite non-empty set of token sequences, indicates that the production may only be used if some element of set is a prefix of the immediately following token sequence. For convenience, the set can also be written as a nonterminal, in which case it represents the set of all token sequences to which that
nonterminal could expand. It is considered an editorial error if the nonterminal could expand to infinitely many distinct token sequences.

These conditions may be negated. "[lookahead ≠ seq]" indicates that the containing production may only be used if seq is not a prefix of the immediately following input token sequence, and "[lookahead ∉ set]" indicates that the production may only be used if no element of set is a prefix of the immediately following token sequence.

As an example, given the definitions:

```plaintext
DecimalDigit :: one of 0 1 2 3 4 5 6 7 8 9

DecimalDigits ::
    DecimalDigit
    DecimalDigits DecimalDigit
```

the definition:

```plaintext
LookaheadExample ::
    n [lookahead ∉ {1, 3, 5, 7, 9}] DecimalDigits
    DecimalDigit [lookahead ∉ DecimalDigit]
```

matches either the letter n followed by one or more decimal digits the first of which is even, or a decimal digit not followed by another decimal digit.

Note that when these phrases are used in the syntactic grammar, it may not be possible to unambiguously identify the immediately following token sequence because determining later tokens requires knowing which lexical goal symbol to use at later positions. As such, when these are used in the syntactic grammar, it is considered an editorial error for a token sequence seq to appear in a lookahead restriction (including as part of a set of sequences) if the choices of lexical goal symbols to use could change whether or not seq would be a prefix of the resulting token sequence.

5.1.5.8 [no LineTerminator here]

If the phrase “[no LineTerminator here]” appears in the right-hand side of a production of the syntactic grammar, it indicates that the production is a restricted production: it may not be used if a LineTerminator occurs in the input stream at the indicated position. For example, the production:

```plaintext
ThrowStatement :
    throw [no LineTerminator here] Expression ;
```

indicates that the production may not be used if a LineTerminator occurs in the script between the throw token and the Expression.

Unless the presence of a LineTerminator is forbidden by a restricted production, any number of occurrences of LineTerminator may appear between any two consecutive tokens in the stream of input elements without affecting the syntactic acceptability of the script.

5.1.5.9 but not

The right-hand side of a production may specify that certain expansions are not permitted by using the phrase “but not” and then indicating the expansions to be excluded. For example, the production:

```plaintext
Identifier ::
    IdentifierName but not ReservedWord
```

means that the nonterminal Identifier may be replaced by any sequence of code points that could replace IdentifierName provided that the same sequence of code points could not replace ReservedWord.
5.1.5.10 Descriptive Phrases

Finally, a few nonterminal symbols are described by a descriptive phrase in sans-serif type in cases where it would be impractical to list all the alternatives:

SourceCharacter ::=
    any Unicode code point

5.2 Algorithm Conventions

The specification often uses a numbered list to specify steps in an algorithm. These algorithms are used to precisely specify the required semantics of ECMAScript language constructs. The algorithms are not intended to imply the use of any specific implementation technique. In practice, there may be more efficient algorithms available to implement a given feature.

Algorithms may be explicitly parameterized with an ordered, comma-separated sequence of alias names which may be used within the algorithm steps to reference the argument passed in that position. Optional parameters are denoted with surrounding brackets ([ , name ]) and are no different from required parameters within algorithm steps. A rest parameter may appear at the end of a parameter list, denoted with leading ellipsis (, ...name). The rest parameter captures all of the arguments provided following the required and optional parameters into a List. If there are no such additional arguments, that List is empty.

Algorithm steps may be subdivided into sequential substeps. Substeps are indented and may themselves be further divided into indented substeps. Outline numbering conventions are used to identify substeps with the first level of substeps labelled with lowercase alphabetic characters and the second level of substeps labelled with lowercase roman numerals. If more than three levels are required these rules repeat with the fourth level using numeric labels. For example:

1. Top-level step
   a. Substep.
   b. Substep.
      i. Subsubstep.
         1. Subsubsubstep
            a. Subsubsubstep
            i. Subsubsubsubstep

A step or substep may be written as an “if” predicate that conditions its substeps. In this case, the substeps are only applied if the predicate is true. If a step or substep begins with the word “else”, it is a predicate that is the negation of the preceding “if” predicate step at the same level.

A step may specify the iterative application of its substeps.

A step that begins with “Assert:” asserts an invariant condition of its algorithm. Such assertions are used to make explicit algorithmic invariants that would otherwise be implicit. Such assertions add no additional semantic requirements and hence need not be checked by an implementation. They are used simply to clarify algorithms.

Algorithm steps may declare named aliases for any value using the form “Let x be someValue”. These aliases are reference-like in that both x and someValue refer to the same underlying data and modifications to either are visible to both. Algorithm steps that want to avoid this reference-like behaviour should explicitly make a copy of the right-hand side: “Let x be a copy of someValue” creates a shallow copy of someValue.

Once declared, an alias may be referenced in any subsequent steps and must not be referenced from steps prior to the alias’s declaration. Aliases may be modified using the form “Set x to someOtherValue”.

5.2.1 Abstract Operations

In order to facilitate their use in multiple parts of this specification, some algorithms, called abstract operations, are named and written in parameterized functional form so that they may be referenced by name from within other algorithms. Abstract operations are typically referenced using a functional application style such
as OperationName(arg1, arg2). Some abstract operations are treated as polymorphically dispatched methods of class-like specification abstractions. Such method-like abstract operations are typically referenced using a method application style such as someValue.OperationName(arg1, arg2).

5.2.2 Syntax-Directed Operations

A *syntax-directed operation* is a named operation whose definition consists of algorithms, each of which is associated with one or more productions from one of the ECMAScript grammars. A production that has multiple alternative definitions will typically have a distinct algorithm for each alternative. When an algorithm is associated with a grammar production, it may reference the terminal and nonterminal symbols of the production alternative as if they were parameters of the algorithm. When used in this manner, nonterminal symbols refer to the actual alternative definition that is matched when parsing the source text. The *source text matched by* a grammar production or *Parse Node* derived from it is the portion of the source text that starts at the beginning of the first terminal that participated in the match and ends at the end of the last terminal that participated in the match.

When an algorithm is associated with a production alternative, the alternative is typically shown without any "[ ]" grammar annotations. Such annotations should only affect the syntactic recognition of the alternative and have no effect on the associated semantics for the alternative.

Syntax-directed operations are invoked with a parse node and, optionally, other parameters by using the conventions on steps 1, 3, and 4 in the following algorithm:

1. Let status be SyntaxDirectedOperation of SomeNonTerminal.
2. Let someParseNode be the parse of some source text.
4. Perform SyntaxDirectedOperation of someParseNode with argument "value".

Unless explicitly specified otherwise, all *chain productions* have an implicit definition for every operation that might be applied to that production’s left-hand side nonterminal. The implicit definition simply reapplies the same operation with the same parameters, if any, to the *chain production’s* sole right-hand side nonterminal and then returns the result. For example, assume that some algorithm has a step of the form: “Return Evaluation of Block” and that there is a production:

    Block : { StatementList }

but the Evaluation operation does not associate an algorithm with that production. In that case, the Evaluation operation implicitly includes an association of the form:

**Runtime Semantics:** Evaluation

    Block : { StatementList }

1. Return Evaluation of StatementList.

5.2.3 Runtime Semantics

Algorithms which specify semantics that must be called at runtime are called *runtime semantics*. Runtime semantics are defined by abstract operations or syntax-directed operations.

5.2.3.1 Completion (completionRecord)

The abstract operation Completion takes argument completionRecord (a Completion Record) and returns a Completion Record. It is used to emphasize that a Completion Record is being returned. It performs the following steps when called:

1. Assert: completionRecord is a Completion Record.
2. Return completionRecord.
5.2.3.2 Throw an Exception

Algorithms steps that say to throw an exception, such as

1. Throw a **TypeError** exception.

mean the same things as:

1. Return **ThrowCompletion** (a newly created **TypeError** object).

5.2.3.3 ReturnIfAbrupt

Algorithms steps that say or are otherwise equivalent to:

1. **ReturnIfAbrupt**(argument).

mean the same thing as:

1. **Assert**: argument is a **Completion Record**.
2. If argument is an abrupt completion, return **Completion**(argument).
3. Else, set argument to argument.[[Value]].

Algorithms steps that say or are otherwise equivalent to:

1. **ReturnIfAbrupt**(AbstractOperation()).

mean the same thing as:

1. Let hygienicTemp be AbstractOperation().
2. **Assert**: hygienicTemp is a **Completion Record**.
3. If hygienicTemp is an abrupt completion, return **Completion**(hygienicTemp).
4. Else, set hygienicTemp to hygienicTemp.[[Value]].

Where hygienicTemp is ephemeral and visible only in the steps pertaining to ReturnIfAbrupt.

Algorithms steps that say or are otherwise equivalent to:

1. Let result be AbstractOperation(ReturnIfAbrupt(argument)).

mean the same thing as:

1. **Assert**: argument is a **Completion Record**.
2. If argument is an abrupt completion, return **Completion**(argument).
3. Else, set argument to argument.[[Value]].
4. Let result be AbstractOperation(argument).

5.2.3.4 ReturnIfAbrupt Shorthands

Invocations of abstract operations and syntax-directed operations that are prefixed by ? indicate that ReturnIfAbrupt should be applied to the resulting Completion Record. For example, the step:

1. ? OperationName().

is equivalent to the following step:

1. ReturnIfAbrupt(OperationName()).

Similarly, for method application style, the step:

1. ? someValue.OperationName().
is equivalent to:

1. `ReturnIfAbrupt(someValue.OperationName())`.

Similarly, prefix `!` is used to indicate that the following invocation of an abstract or syntax-directed operation will never return an abrupt completion and that the resulting Completion Record’s `[[Value]]` field should be used in place of the return value of the operation. For example, the step:

1. Let `val` be `!` OperationName().

is equivalent to the following steps:

1. Let `val` be OperationName().
2. Assert: `val` is a normal completion.
3. Set `val` to `val`.`[[Value]]`.

Syntax-directed operations for runtime semantics make use of this shorthand by placing `!` or `?` before the invocation of the operation:

1. Perform `!` SyntaxDirectedOperation of `NonTerminal`.

5.2.3.5 Implicit Normal Completion

In algorithms within abstract operations which are declared to return a Completion Record, and within all built-in functions, the returned value is first passed to `NormalCompletion`, and the result is used instead. This rule does not apply within the Completion algorithm or when the value being returned is clearly marked as a Completion Record in that step; these cases are:

- when the result of applying Completion, NormalCompletion, or ThrowCompletion is directly returned
- when the result of constructing a Completion Record is directly returned

It is an editorial error if a Completion Record is returned from such an abstract operation through any other means. For example, within these abstract operations,

1. Return `true`.

means the same things as any of

1. Return `NormalCompletion(true)`.

or

1. Let `completion` be `NormalCompletion(true)`.
2. Return `Completion(completion)`.

or

1. Return `Completion Record { [[Type]]: NORMAL, [[Value]]: true, [[Target]]: EMPTY }`.

Note that, through the `ReturnIfAbrupt` expansion, the following example is allowed, as within the expanded steps, the result of applying Completion is returned directly in the abrupt case and the implicit `NormalCompletion` application occurs after unwrapping in the normal case.

1. Return `? completion`.

The following example would be an editorial error because a Completion Record is being returned without being annotated in that step.

1. Let `completion` be `NormalCompletion(true)`.
2. Return `completion`.
5.2.4 Static Semantics

Context-free grammars are not sufficiently powerful to express all the rules that define whether a stream of input elements form a valid ECMAScript Script or Module that may be evaluated. In some situations additional rules are needed that may be expressed using either ECMAScript algorithm conventions or prose requirements. Such rules are always associated with a production of a grammar and are called the static semantics of the production.

Static Semantic Rules have names and typically are defined using an algorithm. Named Static Semantic Rules are associated with grammar productions and a production that has multiple alternative definitions will typically have for each alternative a distinct algorithm for each applicable named static semantic rule.

A special kind of static semantic rule is an Early Error Rule. Early error rules define early error conditions (see clause 17) that are associated with specific grammar productions. Evaluation of most early error rules are not explicitly invoked within the algorithms of this specification. A conforming implementation must, prior to the first evaluation of a Script or Module, validate all of the early error rules of the productions used to parse that Script or Module. If any of the early error rules are violated the Script or Module is invalid and cannot be evaluated.

5.2.5 Mathematical Operations

This specification makes reference to these kinds of numeric values:

- **Mathematical values**: Arbitrary real numbers, used as the default numeric type.
- **Extended mathematical values**: Mathematical values together with $+\infty$ and $-\infty$.
- **Numbers**: IEEE 754-2019 double-precision floating point values.
- **BigInts**: ECMAScript language values representing arbitrary integers in a one-to-one correspondence.

In the language of this specification, numerical values are distinguished among different numeric kinds using subscript suffixes. The subscript \( F \) refers to Numbers, and the subscript \( Z \) refers to BigInts. Numeric values without a subscript suffix refer to mathematical values.

Numeric operators such as $+$, $\times$, $=$, and $\geq$ refer to those operations as determined by the type of the operands. When applied to mathematical values, the operators refer to the usual mathematical operations. When applied to extended mathematical values, the operators refer to the usual mathematical operations over the extended real numbers; indeterminate forms are not defined and their use in this specification should be considered an editorial error. When applied to Numbers, the operators refer to the relevant operations within IEEE 754-2019. When applied to BigInts, the operators refer to the usual mathematical operations applied to the mathematical value of the BigInt.

In general, when this specification refers to a numerical value, such as in the phrase, "the length of \( y \)" or "the integer represented by the four hexadecimal digits \( \ldots \)", without explicitly specifying a numeric kind, the phrase refers to a mathematical value. Phrases which refer to a Number or a BigInt value are explicitly annotated as such; for example, "the Number value for the number of code points in \( \ldots \)" or "the BigInt value for \( \ldots \)."

Numeric operators applied to mixed-type operands (such as a Number and a mathematical value) are not defined and should be considered an editorial error in this specification.

This specification denotes most numeric values in base 10; it also uses numeric values of the form 0x followed by digits 0-9 or A-F as base-16 values.

When the term integer is used in this specification, it refers to a mathematical value which is in the set of integers, unless otherwise stated. When the term integral Number is used in this specification, it refers to a Number value whose mathematical value is in the set of integers.

Conversions between mathematical values and Numbers or BigInts are always explicit in this document. A conversion from a mathematical value or extended mathematical value \( x \) to a Number is denoted as "the Number value for \( x \)" or \( \mathbb{R}(x) \), and is defined in 6.1.6.1. A conversion from an integer \( x \) to a BigInt is denoted as "the BigInt value for \( x \)" or \( \mathbb{Z}(x) \). A conversion from a Number or BigInt \( x \) to a mathematical value is denoted as "the mathematical value of \( x \)" or \( \mathbb{R}(x) \). The mathematical value of \( +0_\mathbb{R} \) and \( -0_\mathbb{R} \) is the mathematical value \( 0 \). The mathematical value of non-finite values is not defined. The extended mathematical value of \( x \) is the mathematical value of \( x \) for finite values, and is $+\infty$ and $-\infty$ for $+\infty_\mathbb{R}$ and $-\infty_\mathbb{R}$ respectively; it is not defined for NaN.
The mathematical function \( \text{abs}(x) \) produces the absolute value of \( x \), which is \(-x\) if \( x < 0 \) and otherwise is \( x \) itself.

The mathematical function \( \text{min}(x_1, x_2, \ldots, x_N) \) produces the mathematically smallest of \( x_1 \) through \( x_N \). The mathematical function \( \text{max}(x_1, x_2, \ldots, x_N) \) produces the mathematically largest of \( x_1 \) through \( x_N \). The domain and range of these mathematical functions are the extended mathematical values.

The notation \(^*x\) modulo \( y\) \(^*(y \text{ must be finite and non-zero})\) computes a value \( k \) of the same sign as \( y \) (or zero) such that \( \text{abs}(k) < \text{abs}(y) \) and \( x - k = q \times y \) for some integer \( q \).

The phrase "the result of clamping \( x \) between lower and upper" (where \( x \) is an extended mathematical value and lower and upper are mathematical values such that lower \( \leq \) upper) produces lower if \( x < \) lower, produces upper if \( x > \) upper, and otherwise produces \( x \).

The mathematical function \( \text{floor}(x) \) produces the largest integer \( \leq x \) (closest to \( +\infty \) that is not larger than \( x \).

\[ \text{floor}(x) = x - (x \mod 1) \]

The mathematical function \( \text{truncate}(x) \) removes the fractional part of \( x \) by rounding towards zero, producing \( -\text{floor}(-x) \) if \( x < 0 \) and otherwise producing \( \text{floor}(x) \).

Mathematical functions \( \text{min} \), \( \text{max} \), \( \text{abs} \), \( \text{floor} \), and \( \text{truncate} \) are not defined for Numbers and BigInts, and any usage of those methods that have non-mathematical value arguments would be an editorial error in this specification.

An interval from lower bound \( a \) to upper bound \( b \) is a possibly-infinite, possibly-empty set of numeric values of the same numeric type. Each bound will be described as either inclusive or exclusive, but not both. There are four kinds of intervals, as follows:

- An interval from \( a \) (inclusive) to \( b \) (inclusive), also called an inclusive interval from \( a \) to \( b \), includes all values \( x \) of the same numeric type such that \( a \leq x \leq b \), and no others.
- An interval from \( a \) (inclusive) to \( b \) (exclusive) includes all values \( x \) of the same numeric type such that \( a \leq x < b \), and no others.
- An interval from \( a \) (exclusive) to \( b \) (inclusive) includes all values \( x \) of the same numeric type such that \( a < x \leq b \), and no others.
- An interval from \( a \) (exclusive) to \( b \) (exclusive) includes all values \( x \) of the same numeric type such that \( a < x < b \), and no others.

For example, the interval from 1 (inclusive) to 2 (exclusive) consists of all mathematical values between 1 and 2, including 1 and not including 2. For the purpose of defining intervals, \(-\infty \leq a < \infty \), so, for example, an inclusive interval with a lower bound of \( +\infty \) includes \( +\infty \) but not \( -\infty \). \( \infty \) is never included in an interval.

5.2.6 Value Notation

In this specification, ECMAScript language values are displayed in bold. Examples include null, true, or "hello". These are distinguished from ECMAScript source text such as Function.prototype.apply or let n = 42;

5.2.7 Identity

In this specification, both specification values and ECMAScript language values are compared for equality. When comparing for equality, values fall into one of two categories. Values without identity are equal to other values without identity if all of their innate characteristics are the same — characteristics such as the magnitude of an integer or the length of a sequence. Values without identity may be manifest without prior reference by fully describing their characteristics. In contrast, each value with identity is unique and therefore only equal to itself. Values with identity are like values without identity but with an additional unguessable, unchangeable, universally-unique characteristic called identity. References to existing values with identity cannot be manifest simply by describing them, as the identity itself is indescribable; instead, references to these values must be explicitly passed from one place to another. Some values with identity are mutable and therefore can have their characteristics (except their
(identity) changed in-place, causing all holders of the value to observe the new characteristics. A value without identity is never equal to a value with identity.

From the perspective of this specification, the word “is” is used to compare two values for equality, as in “If bool is true, then ...”, and the word “contains” is used to search for a value inside lists using equality comparisons, as in “If list contains a Record r such that r.[[Foo]] is true, then ...”. The specification identity of values determines the result of these comparisons and is axiomatic in this specification.

From the perspective of the ECMAScript language, language values are compared for equality using the SameValue abstract operation and the abstract operations it transitively calls. The algorithms of these comparison abstract operations determine language identity of ECMAScript language values.

For specification values, examples of values without specification identity include, but are not limited to: mathematical values and extended mathematical values; ECMAScript source text, surrogate pairs, Directive Prologues, etc; UTF-16 code units; Unicode code points; enums; abstract operations, including syntax-directed operations, host hooks, etc; and ordered pairs. Examples of specification values with specification identity include, but are not limited to: any kind of Records, including Property Descriptors, PrivateElements, etc; Parse Nodes; Lists; Sets and Relations; Abstract Closures; Data Blocks; Private Names; execution contexts and execution context stacks; agent signifiers; and WaiterList Records.

Specification identity agrees with language identity for all ECMAScript language values except Symbol values produced by Symbol.for. The ECMAScript language values without specification identity and without language identity are undefined, null, Booleans, Strings, Numbers, and BigInts. The ECMAScript language values with specification identity and language identity are Symbols not produced by Symbol.for and Objects. Symbol values produced by Symbol.for have specification identity, but not language identity.

6 ECMAScript Data Types and Values

Algorithms within this specification manipulate values each of which has an associated type. The possible value types are exactly those defined in this clause. Types are further subclassified into ECMAScript language types and specification types.

Within this specification, the notation “Type(x)” is used as shorthand for “the type of x” where “type” refers to the ECMAScript language and specification types defined in this clause.

6.1 ECMAScript Language Types

An ECMAScript language type corresponds to values that are directly manipulated by an ECMAScript programmer using the ECMAScript language. The ECMAScript language types are Undefined, Null, Boolean, String, Symbol, Number, BigInt, and Object. An ECMAScript language value is a value that is characterized by an ECMAScript language type.

6.1.1 The Undefined Type

The Undefined type has exactly one value, called undefined. Any variable that has not been assigned a value has the value undefined.

6.1.2 The Null Type

The Null type has exactly one value, called null.

6.1.3 The Boolean Type

The Boolean type represents a logical entity having two values, called true and false.
6.1.4 The String Type

The String type is the set of all ordered sequences of zero or more 16-bit unsigned integer values ("elements") up to a maximum length of $5^{53} - 1$ elements. The String type is generally used to represent textual data in a running ECMAScript program, in which case each element in the String is treated as a UTF-16 code unit value. Each element is regarded as occupying a position within the sequence. These positions are indexed with non-negative integers. The first element (if any) is at index 0, the next element (if any) at index 1, and so on. The length of a String is the number of elements (i.e., 16-bit values) within it. The empty String has length zero and therefore contains no elements.

ECMAScript operations that do not interpret String contents apply no further semantics. Operations that do interpret String values treat each element as a single UTF-16 code unit. However, ECMAScript does not restrict the value of or relationships between these code units, so operations that further interpret String contents as sequences of Unicode code points encoded in UTF-16 must account for ill-formed subsequences. Such operations apply special treatment to every code unit with a numeric value in the inclusive interval from 0xD800 to 0xDBFF (defined by the Unicode Standard as a leading surrogate, or more formally as a high-surrogate code unit) and every code unit with a numeric value in the inclusive interval from 0xDC00 to 0xDFFF (defined as a trailing surrogate, or more formally as a low-surrogate code unit) using the following rules:

- A code unit that is not a leading surrogate and not a trailing surrogate is interpreted as a code point with the same value.
- A sequence of two code units, where the first code unit \( c_1 \) is a leading surrogate and the second code unit \( c_2 \) a trailing surrogate, is a surrogate pair and is interpreted as a code point with the value \( (c_1 - 0x8000) \times 0x400 + (c_2 - 0xDC00) + 0x10000 \). (See 11.1.3)
- A code unit that is a leading surrogate or trailing surrogate, but is not part of a surrogate pair, is interpreted as a code point with the same value.

The function \( \text{String.prototype.normalize} \) (see 22.1.3.15) can be used to explicitly normalize a String value. \( \text{String.prototype.localeCompare} \) (see 22.1.3.12) internally normalizes String values, but no other operations implicitly normalize the strings upon which they operate. Operation results are not language- and/or locale-sensitive unless stated otherwise.

NOTE The rationale behind this design was to keep the implementation of Strings as simple and high-performing as possible. If ECMAScript source text is in Normalized Form C, string literals are guaranteed to also be normalized, as long as they do not contain any Unicode escape sequences.

In this specification, the phrase "the string-concatenation of \( A, B, \ldots \)" (where each argument is a String value, a code unit, or a sequence of code units) denotes the String value whose sequence of code units is the concatenation of the code units (in order) of each of the arguments (in order).

The phrase "the substring of \( S \) from \( \text{inclusiveStart} \) to \( \text{exclusiveEnd} \)" (where \( S \) is a String value or a sequence of code units and \( \text{inclusiveStart} \) and \( \text{exclusiveEnd} \) are integers) denotes the String value consisting of the consecutive code units of \( S \) beginning at index \( \text{inclusiveStart} \) and ending immediately before index \( \text{exclusiveEnd} \) (which is the empty String when \( \text{inclusiveStart} = \text{exclusiveEnd} \)). If the "to" suffix is omitted, the length of \( S \) is used as the value of \( \text{exclusiveEnd} \).

The phrase "the ASCII word characters" denotes the following String value, which consists solely of every letter and number in the Unicode Basic Latin block along with U+005F (LOW LINE): "ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789_". For historical reasons, it has significance to various algorithms.

6.1.4.1 StringIndexOf( string, searchValue, fromIndex )

The abstract operation StringIndexOf takes arguments \( \text{string} \) (a String), \( \text{searchValue} \) (a String), and \( \text{fromIndex} \) (a non-negative integer) and returns an integer. It performs the following steps when called:

1. Let \( \text{len} \) be the length of \( \text{string} \).
2. If \( \text{searchValue} \) is the empty String and \( \text{fromIndex} \leq \text{len} \), return \( \text{fromIndex} \).
3. Let \( \text{searchLen} \) be the length of \( \text{searchValue} \).
4. For each integer \( i \) such that \( \text{fromIndex} \leq i \leq \text{len} - \text{searchLen} \), in ascending order, do
   a. Let \( \text{candidate} \) be the substring of \( \text{string} \) from \( i \) to \( i + \text{searchLen} \).
   b. If \( \text{candidate} \) is \( \text{searchValue} \), return \( i \).
5. Return -1.

NOTE 1 If \( \text{searchValue} \) is the empty String and \( \text{fromIndex} \leq \) the length of \( \text{string} \), this algorithm returns \( \text{fromIndex} \). The empty String is effectively found at every position within a string, including after the last code unit.

NOTE 2 This algorithm always returns -1 if \( \text{fromIndex} + \) the length of \( \text{searchValue} \) > the length of \( \text{string} \).

6.1.5 The Symbol Type

The Symbol type is the set of all non-String values that may be used as the key of an Object property (6.1.7). Each possible Symbol value is unique and immutable.

Each Symbol value immutably holds an associated value called \([\text{Description}]\) that is either undefined or a String value.

6.1.5.1 Well-Known Symbols

Well-known symbols are built-in Symbol values that are explicitly referenced by algorithms of this specification. They are typically used as the keys of properties whose values serve as extension points of a specification algorithm. Unless otherwise specified, well-known symbols values are shared by all realms (9.3).

Within this specification a well-known symbol is referred to by using a notation of the form @@name, where “name” is one of the values listed in Table 1.

<table>
<thead>
<tr>
<th>Specification Name</th>
<th>[[Description]]</th>
<th>Value and Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>@@asyncIterator</td>
<td>&quot;Symbol.asyncIterator&quot;</td>
<td>A method that returns the default AsyncIterator for an object. Called by the semantics of the for-await-of statement.</td>
</tr>
<tr>
<td>@@hasInstance</td>
<td>&quot;Symbol.hasInstance&quot;</td>
<td>A method that determines if a constructor object recognizes an object as one of the constructor's instances. Called by the semantics of the instanceof operator.</td>
</tr>
<tr>
<td>@@isConcatSpreadable</td>
<td>&quot;Symbol.isConcatSpreadable&quot;</td>
<td>A Boolean valued property that if true indicates that an object should be flattened to its array elements by Array.prototype.concat.</td>
</tr>
<tr>
<td>@@iterator</td>
<td>&quot;Symbol.iterator&quot;</td>
<td>A method that returns the default Iterator for an object. Called by the semantics of the for-of statement.</td>
</tr>
<tr>
<td>@@match</td>
<td>&quot;Symbol.match&quot;</td>
<td>A regular expression method that matches the regular expression against a string. Called by the String.prototype.match method.</td>
</tr>
</tbody>
</table>

Table 1: Well-known Symbols
Table 1: Well-known Symbols (continued)

<table>
<thead>
<tr>
<th>Specification Name</th>
<th>[[Description]]</th>
<th>Value and Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>@@matchAll</td>
<td>&quot;Symbol.matchAll&quot;</td>
<td>A regular expression method that returns an iterator, that yields matches of the regular expression against a string. Called by the String.prototype.matchAll method.</td>
</tr>
<tr>
<td>@@replace</td>
<td>&quot;Symbol.replace&quot;</td>
<td>A regular expression method that replaces matched substrings of a string. Called by the String.prototype.replace method.</td>
</tr>
<tr>
<td>@@search</td>
<td>&quot;Symbol.search&quot;</td>
<td>A regular expression method that returns the index within a string that matches the regular expression. Called by the String.prototype.search method.</td>
</tr>
<tr>
<td>@@species</td>
<td>&quot;Symbol.species&quot;</td>
<td>A function valued property that is the constructor function that is used to create derived objects.</td>
</tr>
<tr>
<td>@@split</td>
<td>&quot;Symbol.split&quot;</td>
<td>A regular expression method that splits a string at the indices that match the regular expression. Called by the String.prototype.split method.</td>
</tr>
<tr>
<td>@@toPrimitive</td>
<td>&quot;Symbol.toPrimitive&quot;</td>
<td>A method that converts an object to a corresponding primitive value. Called by the ToPrimitive abstract operation.</td>
</tr>
<tr>
<td>@@toStringTag</td>
<td>&quot;Symbol.toStringTag&quot;</td>
<td>A String valued property that is used in the creation of the default string description of an object. Accessed by the built-in method Object.prototype.toString.</td>
</tr>
<tr>
<td>@@unscopables</td>
<td>&quot;Symbol.unscopables&quot;</td>
<td>An object valued property whose own and inherited property names are property names that are excluded from the with environment bindings of the associated object.</td>
</tr>
</tbody>
</table>

6.1.6 Numeric Types

ECMAScript has two built-in numeric types: Number and BigInt. The following abstract operations are defined over these numeric types. The "Result" column shows the return type, along with an indication if it is possible for some invocations of the operation to return an abrupt completion.

Table 2: Numeric Type Operations

<table>
<thead>
<tr>
<th>Operation</th>
<th>Example source</th>
<th>Invoked by the Evaluation semantics of ...</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number::unaryMinus</td>
<td>-x</td>
<td>Unary - Operator</td>
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Because the numeric types are in general not convertible without loss of precision or truncation, the ECMAScript language provides no implicit conversion among these types. Programmers must explicitly call `Number` and `BigInt` functions to convert among types when calling a function which requires another type.

**NOTE** The first and subsequent editions of ECMAScript have provided, for certain operators, implicit numeric conversions that could lose precision or truncate. These legacy implicit conversions are maintained for backward compatibility, but not provided for `BigInt` in order to minimize opportunity for programmer error, and to leave open the option of generalized value types in a future edition.

**6.1.6.1 The Number Type**

The `Number` type has exactly 18,437,736,874,454,810,627 (that is, $2^{64} - 2^{53} + 3$) values, representing the double-precision 64-bit format IEEE 754-2019 values as specified in the IEEE Standard for Binary Floating-Point Arithmetic, except that the 9,007,199,254,740,990 (that is, $2^{53} - 2$) distinct “Not-a-Number” values of the IEEE Standard are represented in ECMAScript as a single special `NaN` value. (Note that the `NaN` value is produced by the program expression `NaN`.) In some implementations, external code might be able to detect a difference between various Not-a-Number values, but such behaviour is implementation-defined; to ECMAScript code, all `NaN` values are indistinguishable from each other.

**NOTE** The bit pattern that might be observed in an `ArrayBuffer` (see 25.1) or a `SharedArrayBuffer` (see 25.2) after a `Number` value has been stored into it is not necessarily the same as the internal representation of that `Number` value used by the ECMAScript implementation.

There are two other special values, called **positive Infinity** and **negative Infinity**. For brevity, these values are also referred to for expository purposes by the symbols $+\infty_F$ and $-\infty_F$, respectively. (Note that these two infinite Number values are produced by the program expressions `+Infinity` (or simply `Infinity`) and `-Infinity`.)
The other 18,437,736,874,454,810,624 (that is, $2^{64} - 2^{53}$) values are called the finite numbers. Half of these are positive numbers and half are negative numbers; for every finite positive Number value there is a corresponding negative value having the same magnitude.

Note that there is both a positive zero and a negative zero. For brevity, these values are also referred to for expository purposes by the symbols $+\theta_F$ and $-\theta_F$, respectively. (Note that these two different zero Number values are produced by the program expressions $+0$ (or simply $0$) and $-0$.)

The 18,437,736,874,454,810,622 (that is, $2^{64} - 2^{53} - 2$) finite non-zero values are of two kinds:

- 18,428,729,675,200,69,632 (that is, $2^{64} - 2^{54}$) of them are normalized, having the form $s \times m \times 2^e$ where $s$ is 1 or -1, $m$ is an integer in the interval from $2^{52}$ (inclusive) to $2^{53}$ (exclusive), and $e$ is an integer in the inclusive interval from -1074 to 971.

- The remaining 9,007,199,254,740,990 (that is, $2^{53} - 2$) values are denormalized, having the form $s \times m \times 2^e$ where $s$ is 1 or -1, $m$ is an integer in the interval from 0 (exclusive) to $2^{52}$ (exclusive), and $e$ is -1074.

Note that all the positive and negative integers whose magnitude is no greater than $2^{53}$ are representable in the Number type. The integer 0 has two representations in the Number type: $+\theta_F$ and $-\theta_F$.

A finite number has an odd significand if it is non-zero and the integer $m$ used to express it (in one of the two forms shown above) is odd. Otherwise, it has an even significand.

In this specification, the phrase “the Number value for $x$” where $x$ represents an exact real mathematical quantity (which might even be an irrational number such as $\pi$) means a Number value chosen in the following manner. Consider the set of all finite values of the Number type, with $-\theta_F$ removed and with two additional values added to it that are not representable in the Number type, namely $2^{1024}$ (which is $+1 \times 2^{53} \times 2^{971}$) and $-2^{1024}$ (which is $-1 \times 2^{53} \times 2^{971}$). Choose the member of this set that is closest in value to $x$. If two values of the set are equally close, then the one with an even significand is chosen; for this purpose, the two extra values $2^{1024}$ and $-2^{1024}$ are considered to have even significands. Finally, if $2^{1024}$ was chosen, replace it with $+\infty_F$; if $-2^{1024}$ was chosen, replace it with $-\infty_F$; if $+\theta_F$ was chosen, replace it with $-\theta_F$ if and only if $x < 0$; any other chosen value is used unchanged. The result is the Number value for $x$. (This procedure corresponds exactly to the behaviour of the IEEE 754-2019 roundTiesToEven mode.)

The Number value for $+\infty$ is $+\infty_F$, and the Number value for $-\infty$ is $-\infty_F$.

Some ECMAScript operators deal only with integers in specific ranges such as the inclusive interval from $-2^{31}$ to $2^{31} - 1$ or the inclusive interval from 0 to $2^{16} - 1$. These operators accept any value of the Number type but first convert each such value to an integer value in the expected range. See the descriptions of the numeric conversion operations in 7.1.

6.1.6.1.1 Number::unaryMinus ( x )

The abstract operation Number::unaryMinus takes argument $x$ (a Number) and returns a Number. It performs the following steps when called:

1. If $x$ is NaN, return NaN.
2. Return the result of negating $x$; that is, compute a Number with the same magnitude but opposite sign.
6.1.6.1.2 Number::bitwiseNOT ( x )

The abstract operation Number::bitwiseNOT takes argument x (a Number) and returns an integral Number. It performs the following steps when called:

1. Let oldValue be ! ToInt32(x).
2. Return the result of applying bitwise complement to oldValue. The mathematical value of the result is exactly representable as a 32-bit two's complement bit string.

6.1.6.1.3 Number::exponentiate ( base, exponent )

The abstract operation Number::exponentiate takes arguments base (a Number) and exponent (a Number) and returns a Number. It returns an implementation-approximated value representing the result of raising base to the exponent power. It performs the following steps when called:

1. If exponent is NaN, return NaN.
2. If exponent is either +0𝔽 or -0𝔽, return 1𝔽.
3. If base is NaN, return NaN.
4. If base is +∞𝔽, then
   a. If exponent > +0𝔽, return +∞𝔽. Otherwise, return +0𝔽.
5. If base is -∞𝔽, then
   a. If exponent > +0𝔽, then
      i. If exponent is an odd integral Number, return -∞ Financing. Otherwise, return +∞ Financing.
   b. Else,
      i. If exponent is an odd integral Number, return -0 Financing. Otherwise, return +0 Financing.
6. If base is +0 Financing, then
   a. If exponent > +0 Financing, return +0 Financing. Otherwise, return +∞ Financing.
7. If base is -0 Financing, then
   a. If exponent > +0 Financing, then
      i. If exponent is an odd integral Number, return -0 Financing. Otherwise, return +0 Financing.
   b. Else,
      i. If exponent is an odd integral Number, return -∞ Financing. Otherwise, return +∞ Financing.
8. Assert: base is finite and is neither +0 Financing nor -0 Financing.
9. If exponent is +∞ Financing, then
   a. If abs(R(base)) > 1, return +∞ Financing.
   b. If abs(R(base)) = 1, return NaN.
   c. If abs(R(base)) < 1, return +0 Financing.
10. If exponent is -∞ Financing, then
    a. If abs(R(base)) > 1, return +0 Financing.
    b. If abs(R(base)) = 1, return NaN.
    c. If abs(R(base)) < 1, return +∞ Financing.
11. Assert: exponent is finite and is neither +0 Financing nor -0 Financing.
12. If base < 0 Financing and exponent is not an integral Number, return NaN.
13. Return an implementation-approximated Number value representing the result of raising R(base) to the R(exponent) power.

**NOTE**  The result of base ** exponent when base is 1 Financing or -1 Financing and exponent is +∞ Financing or -∞ Financing, or when base is 1 Financing and exponent is NaN, differs from IEEE 754-2019. The first edition of ECMAScript specified a result of NaN for this operation, whereas later revisions of IEEE 754 specified 1 Financing. The historical ECMAScript behaviour is preserved for compatibility reasons.
The abstract operation Number::multiply takes arguments \( x \) (a Number) and \( y \) (a Number) and returns a Number. It performs multiplication according to the rules of IEEE 754-2019 binary double-precision arithmetic, producing the product of \( x \) and \( y \). It performs the following steps when called:

1. If \( x \) is \( \text{NaN} \) or \( y \) is \( \text{NaN} \), return \( \text{NaN} \).
2. If \( x \) is either \( +\infty \) or \( -\infty \), then
   a. If \( y \) is either \( +0 \) or \( -0 \), return \( \text{NaN} \).
   b. If \( y > +0 \), return \( x \).
   c. Return \(-x\).
3. If \( y \) is either \( +\infty \) or \( -\infty \), then
   a. If \( x \) is either \( +0 \) or \( -0 \), return \( \text{NaN} \).
   b. If \( x > +0 \), return \( y \).
   c. Return \(-y\).
4. If \( x \) is \( -0 \), then
   a. If \( y \) is \( -0 \) or \( y < -0 \), return \( +0 \).
   b. Else, return \(-0 \).
5. If \( y \) is \( -0 \), then
   a. If \( x < -0 \), return \( +0 \).
   b. Else, return \(-0 \).
6. Return \( \mathbb{F}(\mathbb{R}(x) \times \mathbb{R}(y)) \).

**NOTE** Finite-precision multiplication is commutative, but not always associative.

The abstract operation Number::divide takes arguments \( x \) (a Number) and \( y \) (a Number) and returns a Number. It performs division according to the rules of IEEE 754-2019 binary double-precision arithmetic, producing the quotient of \( x \) and \( y \) where \( x \) is the dividend and \( y \) is the divisor. It performs the following steps when called:

1. If \( x \) is \( \text{NaN} \) or \( y \) is \( \text{NaN} \), return \( \text{NaN} \).
2. If \( x \) is either \( +\infty \) or \( -\infty \), then
   a. If \( y \) is either \( +\infty \) or \( -\infty \), return \( \text{NaN} \).
   b. If \( y > +\infty \), return \( x \).
   c. Return \(-x\).
3. If \( y \) is \( +\infty \), then
   a. If \( x \) is \( +0 \) or \( x > +0 \), return \( +0 \). Otherwise, return \(-0 \).
4. If \( y \) is \( -\infty \), then
   a. If \( x \) is \( +0 \) or \( x > +0 \), return \(-0 \). Otherwise, return \(+0 \).
5. If \( x \) is either \( +0 \) or \( -0 \), then
   a. If \( y \) is either \( +0 \) or \( -0 \), return \( \text{NaN} \).
   b. If \( y > +0 \), return \( x \).
   c. Return \(-x\).
6. If \( y \) is \( +0 \), then
   a. If \( x > +0 \), return \( +\infty \). Otherwise, return \(-\infty \).
7. If \( y \) is \( -0 \), then
   a. If \( x > +0 \), return \(-\infty \). Otherwise, return \(+\infty \).
8. Return \( \mathbb{F}(\mathbb{R}(x) / \mathbb{R}(y)) \).
The abstract operation `Number::remainder(n, d)` takes arguments `n` (a Number) and `d` (a Number) and returns a Number. It yields the remainder from an implied division of its operands where `n` is the dividend and `d` is the divisor. It performs the following steps when called:

1. If `n` is `NaN` or `d` is `NaN`, return `NaN`.
2. If `n` is either `+∞` or `-∞`, return `NaN`.
3. If `d` is either `+∞` or `-∞`, return `n`.
4. If `d` is either `+0` or `-0`, return `NaN`.
5. If `n` is either `+0` or `-0`, return `n`.
6. Assert: `n` and `d` are finite and non-zero.
7. Let `quotient` be `R(n) / R(d)`.
8. Let `q` be `truncate(quotient)`.
9. Let `r` be `R(n) - (R(d) × q)`.
10. If `r = 0` and `n < -0`, return `-0`.
11. Return `𝔽(r)`.

**NOTE 1** In C and C++, the remainder operator accepts only integral operands; in ECMAScript, it also accepts floating-point operands.

**NOTE 2** The result of a floating-point remainder operation as computed by the `%` operator is not the same as the “remainder” operation defined by IEEE 754-2019. The IEEE 754-2019 “remainder” operation computes the remainder from a rounding division, not a truncating division, and so its behaviour is not analogous to that of the usual integer remainder operator. Instead the ECMAScript language defines `%` on floating-point operations to behave in a manner analogous to that of the Java integer remainder operator; this may be compared with the C library function fmod.

### 6.1.6.1.7 Number::add(x, y)

The abstract operation `Number::add` takes arguments `x` (a Number) and `y` (a Number) and returns a Number. It performs addition according to the rules of IEEE 754-2019 binary double-precision arithmetic, producing the sum of its arguments. It performs the following steps when called:

1. If `x` is `NaN` or `y` is `NaN`, return `NaN`.
2. If `x` is `+∞` and `y` is `-∞`, return `NaN`.
3. If `x` is `-∞` and `y` is `+∞`, return `NaN`.
4. If `x` is either `+∞` or `-∞`, return `x`.
5. If `y` is either `+∞` or `-∞`, return `y`.
6. Assert: `x` and `y` are both finite.
7. Return `𝔽(R(x) + R(y))`.

**NOTE** Finite-precision addition is commutative, but not always associative.

### 6.1.6.1.8 Number::subtract(x, y)

The abstract operation `Number::subtract` takes arguments `x` (a Number) and `y` (a Number) and returns a Number. It performs subtraction, producing the difference of its operands; `x` is the minuend and `y` is the subtrahend. It performs the following steps when called:

1. Return `Number::add(x, Number::unaryMinus(y))`.

**NOTE** It is always the case that `x - y` produces the same result as `x + (-y)`.
6.1.6.1.9 Number::leftShift ( x, y )

The abstract operation Number::leftShift takes arguments x (a Number) and y (a Number) and returns an integral Number. It performs the following steps when called:

1. Let Inum be !ToInt32(x).
2. Let rnum be !ToUint32(y).
3. Let shiftCount be \( R(rnum) \mod 32 \).
4. Return the result of left shifting Inum by shiftCount bits. The mathematical value of the result is exactly representable as a 32-bit two’s complement bit string.

6.1.6.1.10 Number::signedRightShift ( x, y )

The abstract operation Number::signedRightShift takes arguments x (a Number) and y (a Number) and returns an integral Number. It performs the following steps when called:

1. Let Inum be !ToInt32(x).
2. Let rnum be !ToUint32(y).
3. Let shiftCount be \( R(rnum) \mod 32 \).
4. Return the result of performing a sign-extending right shift of Inum by shiftCount bits. The most significant bit is propagated. The mathematical value of the result is exactly representable as a 32-bit two’s complement bit string.

6.1.6.1.11 Number::unsignedRightShift ( x, y )

The abstract operation Number::unsignedRightShift takes arguments x (a Number) and y (a Number) and returns an integral Number. It performs the following steps when called:

1. Let Inum be !ToUint32(x).
2. Let rnum be !ToUint32(y).
3. Let shiftCount be \( R(rnum) \mod 32 \).
4. Return the result of performing a zero-filling right shift of Inum by shiftCount bits. Vacated bits are filled with zero. The mathematical value of the result is exactly representable as a 32-bit unsigned bit string.

6.1.6.1.12 Number::lessThan ( x, y )

The abstract operation Number::lessThan takes arguments x (a Number) and y (a Number) and returns a Boolean or undefined. It performs the following steps when called:

1. If x is NaN, return undefined.
2. If y is NaN, return undefined.
3. If x is y, return false.
4. If x is +\( \infty \) and y is -\( \infty \), return false.
5. If x is -\( \infty \) and y is +\( \infty \), return false.
6. If x is +\( \infty \), return false.
7. If y is +\( \infty \), return true.
8. If y is -\( \infty \), return false.
9. If x is -\( \infty \), return true.
10. Assert: x and y are finite.
11. If \( R(x) < R(y) \), return true. Otherwise, return false.

6.1.6.1.13 Number::equal ( x, y )

The abstract operation Number::equal takes arguments x (a Number) and y (a Number) and returns a Boolean. It performs the following steps when called:

1. If x is NaN, return false.
2. If y is NaN, return false.
If $x$ is $y$, return true.
If $x$ is $+\theta_F$ and $y$ is $-\theta_F$, return true.
If $x$ is $-\theta_F$ and $y$ is $+\theta_F$, return true.
6. Return false.

6.1.6.1.14 Number::sameValue (x, y)

The abstract operation Number::sameValue takes arguments $x$ (a Number) and $y$ (a Number) and returns a Boolean. It performs the following steps when called:

1. If $x$ is NaN and $y$ is NaN, return true.
2. If $x$ is $+\theta_F$ and $y$ is $-\theta_F$, return false.
3. If $x$ is $-\theta_F$ and $y$ is $+\theta_F$, return false.
4. If $x$ is $y$, return true.
5. Return false.

6.1.6.1.15 Number::sameValueZero (x, y)

The abstract operation Number::sameValueZero takes arguments $x$ (a Number) and $y$ (a Number) and returns a Boolean. It performs the following steps when called:

1. If $x$ is NaN and $y$ is NaN, return true.
2. If $x$ is $+\theta_F$ and $y$ is $-\theta_F$, return true.
3. If $x$ is $-\theta_F$ and $y$ is $+\theta_F$, return true.
4. If $x$ is $y$, return true.
5. Return false.

6.1.6.1.16 NumberBitwiseOp (op, x, y)

The abstract operation NumberBitwiseOp takes arguments $op$ (&, ^, or |), $x$ (a Number), and $y$ (a Number) and returns an integral Number. It performs the following steps when called:

1. Let $lnum$ be $\lfloor x \rfloor$.
2. Let $rnum$ be $\lfloor y \rfloor$.
3. Let $lbits$ be the 32-bit two's complement bit string representing $\mathbb{R}(lnum)$.
4. Let $rbits$ be the 32-bit two's complement bit string representing $\mathbb{R}(rnum)$.
5. If $op$ is &,
   a. Let $result$ be the result of applying the bitwise AND operation to $lbits$ and $rbits$.
6. Else if $op$ is ^,
   a. Let $result$ be the result of applying the bitwise exclusive OR (XOR) operation to $lbits$ and $rbits$.
7. Else,
   a. Assert: $op$ is |.
   b. Let $result$ be the result of applying the bitwise inclusive OR operation to $lbits$ and $rbits$.
8. Return the Number value for the integer represented by the 32-bit two's complement bit string $result$.

6.1.6.1.17 Number::bitwiseAND (x, y)

The abstract operation Number::bitwiseAND takes arguments $x$ (a Number) and $y$ (a Number) and returns an integral Number. It performs the following steps when called:

1. Return NumberBitwiseOp(&, x, y).

6.1.6.1.18 Number::bitwiseXOR (x, y)

The abstract operation Number::bitwiseXOR takes arguments $x$ (a Number) and $y$ (a Number) and returns an integral Number. It performs the following steps when called:

1. Return NumberBitwiseOp(^, x, y).
6.1.6.1.19 Number::bitwiseOR ( x, y )

The abstract operation Number::bitwiseOR takes arguments x (a Number) and y (a Number) and returns an integral Number. It performs the following steps when called:

1. Return NumberBitwiseOp(1, x, y).

6.1.6.1.20 Number::toString ( x, radix )

The abstract operation Number::toString takes arguments x (a Number) and radix (an integer in the inclusive interval from 2 to 36) and returns a String. It represents x as a String using a positional numeral system with radix radix. The digits used in the representation of a number using radix r are taken from the first r code units of "0123456789abcdefghijklmnopqrstuvwxyz" in order. The representation of numbers with magnitude greater than or equal to 1r never includes leading zeroes. It performs the following steps when called:

1. If x is NaN, return "NaN".
2. If x is either +0F or -0F, return "0".
3. If x < -0F, return the string-concatenation of ".-" and Number::toString(-x, radix).
4. If x is +0F, return "Infinity".
5. Let n, k, and s be integers such that k ≥ 1, radixk-1 ≤ s < radixk, (s × radix)k-1 is x, and k is as small as possible. Note that k is the number of digits in the representation of s using radix radix, that s is not divisible by radix, and that the least significant digit of s is not necessarily uniquely determined by these criteria.
6. If radix ≠ 10 or n is in the inclusive interval from -5 to 21, then
   a. If n ≥ k, then
      i. Return the string-concatenation of:
         • the code units of the k digits of the representation of s using radix radix
         • n - k occurrences of the code unit 0x0030 (DIGIT ZERO)
   b. Else if n > 0, then
      i. Return the string-concatenation of:
         • the code units of the most significant n digits of the representation of s using radix radix
         • the code unit 0x0030 (DIGIT ZERO)
         • the code unit 0x002E (FULL STOP)
         • the code units of the remaining k - n digits of the representation of s using radix radix
   c. Else,
      i. Assert: n ≤ 0.
      ii. Return the string-concatenation of:
         • the code unit 0x0030 (DIGIT ZERO)
         • the code unit 0x002E (FULL STOP)
         • -n occurrences of the code unit 0x0030 (DIGIT ZERO)
         • the code units of the k digits of the representation of s using radix radix
7. NOTE: In this case, the input will be represented using scientific E notation, such as 1.2e+3.
8. Assert: radix is 10.
9. If n < 0, then
   a. Let exponentSign be the code unit 0x002D (HYPHEN-MINUS).
10. Else,
    a. Let exponentSign be the code unit 0x002B (PLUS SIGN).
11. If k = 1, then
    a. Return the string-concatenation of:
       • the code unit of the single digit of s
       • the code unit 0x0065 (LATIN SMALL LETTER E)
       • exponentSign
       • the code units of the decimal representation of abs(n - 1)
12. Return the string-concatenation of:
    ◦ the code unit of the most significant digit of the decimal representation of s
    ◦ the code unit 0x002E (FULL STOP)
    ◦ the code units of the remaining k - 1 digits of the decimal representation of s
    ◦ the code unit 0x0065 (LATIN SMALL LETTER E)
    ◦ exponentSign
    ◦ the code units of the decimal representation of abs(n - 1)
NOTE 1  The following observations may be useful as guidelines for implementations, but are not part of the normative requirements of this Standard:

- If x is any Number value other than \(-\mathbb{F}\), then \(\text{ToNumber(ToString(x))}\) is x.
- The least significant digit of s is not always uniquely determined by the requirements listed in step 5.

NOTE 2  For implementations that provide more accurate conversions than required by the rules above, it is recommended that the following alternative version of step 5 be used as a guideline:

5. Let \(n, k, \text{ and } s\) be integers such that \(k \geq 1\), \(\text{radix}^{k-1} \leq s < \text{radix}^k\), \(F(s \times \text{radix}^{n-k})\) is x, and \(k\) is as small as possible. If there are multiple possibilities for \(s\), choose the value of \(s\) for which \(s \times \text{radix}^{n-k}\) is closest in value to \(\mathbb{R}(x)\). If there are two such possible values of \(s\), choose the one that is even. Note that \(k\) is the number of digits in the representation of \(s\) using \(\text{radix} \text{radix}\) and that \(s\) is not divisible by \(\text{radix}\).

NOTE 3  Implementers of ECMAScript may find useful the paper and code written by David M. Gay for binary-to-decimal conversion of floating-point numbers:


6.1.6.2 The BigInt Type

The BigInt type represents an integer value. The value may be any size and is not limited to a particular bit-width. Generally, where not otherwise noted, operations are designed to return exact mathematically-based answers. For binary operations, Bigints act as two’s complement binary strings, with negative numbers treated as having bits set infinitely to the left.

6.1.6.2.1 BigInt::unaryMinus ( x )

The abstract operation BigInt::unaryMinus takes argument \(x\) (a BigInt) and returns a BigInt. It performs the following steps when called:

1. If \(x\) is \(0\), return \(0\).
2. Return \(-x\).

6.1.6.2.2 BigInt::bitwiseNOT ( x )

The abstract operation BigInt::bitwiseNOT takes argument \(x\) (a BigInt) and returns a BigInt. It returns the one's complement of \(x\). It performs the following steps when called:

1. Return \(-x - 1\).
6.1.6.2.3 BigInt::exponentiate (base, exponent)

The abstract operation BigInt::exponentiate takes arguments base (a BigInt) and exponent (a BigInt) and returns either a normal completion containing a BigInt or a throw completion. It performs the following steps when called:

1. If exponent < 0 \(\mathbb{Z}\), throw a RangeError exception.
2. If base is 0 \(\mathbb{Z}\) and exponent is 0 \(\mathbb{Z}\), return 1 \(\mathbb{Z}\).
3. Return base raised to the power exponent.

6.1.6.2.4 BigInt::multiply (x, y)

The abstract operation BigInt::multiply takes arguments x (a BigInt) and y (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return \(x \times y\).

**NOTE** Even if the result has a much larger bit width than the input, the exact mathematical answer is given.

6.1.6.2.5 BigInt::divide (x, y)

The abstract operation BigInt::divide takes arguments x (a BigInt) and y (a BigInt) and returns either a normal completion containing a BigInt or a throw completion. It performs the following steps when called:

1. If y is 0 \(\mathbb{Z}\), throw a RangeError exception.
2. Let quotient be \(\mathbb{R}(x) / \mathbb{R}(y)\).
3. Return \(\mathbb{Z}(\text{truncate}(\text{quotient}))\).

6.1.6.2.6 BigInt::remainder (n, d)

The abstract operation BigInt::remainder takes arguments n (a BigInt) and d (a BigInt) and returns either a normal completion containing a BigInt or a throw completion. It performs the following steps when called:

1. If d is 0 \(\mathbb{Z}\), throw a RangeError exception.
2. If n is 0 \(\mathbb{Z}\), return 0 \(\mathbb{Z}\).
3. Let quotient be \(\mathbb{R}(n) / \mathbb{R}(d)\).
4. Let q be \(\mathbb{Z}(\text{truncate}(\text{quotient}))\).
5. Return n - (d \times q).

**NOTE** The sign of the result is the sign of the dividend.

6.1.6.2.7 BigInt::add (x, y)

The abstract operation BigInt::add takes arguments x (a BigInt) and y (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return x + y.

6.1.6.2.8 BigInt::subtract (x, y)

The abstract operation BigInt::subtract takes arguments x (a BigInt) and y (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return x - y.
6.1.6.2.9 BigInt::leftShift (x, y)

The abstract operation BigInt::leftShift takes arguments x (a BigInt) and y (a BigInt) and returns a BigInt. It performs the following steps when called:

1. If \( y < 0 \), then
   a. Return \( \mathbb{Z}(\text{floor}(\mathbb{R}(x) / 2^\mathbb{R}(y))) \).
2. Return \( x \times 2^y \).

**NOTE**  Semantics here should be equivalent to a bitwise shift, treating the BigInt as an infinite length string of binary two's complement digits.

6.1.6.2.10 BigInt::signedRightShift (x, y)

The abstract operation BigInt::signedRightShift takes arguments x (a BigInt) and y (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return BigInt::leftShift(x, -y).

6.1.6.2.11 BigInt::unsignedRightShift (x, y)

The abstract operation BigInt::unsignedRightShift takes arguments x (a BigInt) and y (a BigInt) and returns a throw completion. It performs the following steps when called:

1. Throw a TypeError exception.

6.1.6.2.12 BigInt::lessThan (x, y)

The abstract operation BigInt::lessThan takes arguments x (a BigInt) and y (a BigInt) and returns a Boolean. It performs the following steps when called:

1. If \( \mathbb{R}(x) < \mathbb{R}(y) \), return true; otherwise return false.

6.1.6.2.13 BigInt::equal (x, y)

The abstract operation BigInt::equal takes arguments x (a BigInt) and y (a BigInt) and returns a Boolean. It performs the following steps when called:

1. If \( \mathbb{R}(x) = \mathbb{R}(y) \), return true; otherwise return false.

6.1.6.2.14 BinaryAnd (x, y)

The abstract operation BinaryAnd takes arguments x (0 or 1) and y (0 or 1) and returns 0 or 1. It performs the following steps when called:

1. If \( x = 1 \) and \( y = 1 \), return 1.
2. Else, return 0.

6.1.6.2.15 BinaryOr (x, y)

The abstract operation BinaryOr takes arguments x (0 or 1) and y (0 or 1) and returns 0 or 1. It performs the following steps when called:

1. If \( x = 1 \) or \( y = 1 \), return 1.
2. Else, return 0.
6.1.6.2.16 BinaryXor (x, y)

The abstract operation BinaryXor takes arguments \( x \) (0 or 1) and \( y \) (0 or 1) and returns 0 or 1. It performs the following steps when called:

1. If \( x = 1 \) and \( y = 0 \), return 1.
2. Else if \( x = 0 \) and \( y = 1 \), return 1.
3. Else, return 0.

6.1.6.2.17 BigIntBitwiseOp (op, x, y)

The abstract operation BigIntBitwiseOp takes arguments \( op \) (&, ^, or |), \( x \) (a BigInt), and \( y \) (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Set \( x \) to \( \mathbb{R}(x) \).
2. Set \( y \) to \( \mathbb{R}(y) \).
3. Let \( result \) be 0.
4. Let \( shift \) be 0.
5. Repeat, until \((x = 0 \text{ or } x = -1) \) and \((y = 0 \text{ or } y = -1)\),
   a. Let \( xDigit \) be \( x \) modulo 2.
   b. Let \( yDigit \) be \( y \) modulo 2.
   c. If \( op \) is &, then
      i. Set \( result \) to \( result + 2^{shift} \times \text{BinaryAnd}(xDigit, yDigit) \).
   d. Else if \( op \) is |, then
      i. Set \( result \) to \( result + 2^{shift} \times \text{BinaryOr}(xDigit, yDigit) \).
   e. Else,
      i. Assert: \( op \) is ^.
      ii. Set \( result \) to \( result + 2^{shift} \times \text{BinaryXor}(xDigit, yDigit) \).
   f. Set \( shift \) to \( shift + 1 \).
   g. Set \( x \) to \((x - xDigit) / 2 \).
   h. Set \( y \) to \((y - yDigit) / 2 \).
6. If \( op \) is &,
   a. Let \( tmp \) be \( \text{BinaryAnd}(x \text{ modulo } 2, y \text{ modulo } 2) \).
7. Else if \( op \) is |,
   a. Let \( tmp \) be \( \text{BinaryOr}(x \text{ modulo } 2, y \text{ modulo } 2) \).
8. Else,
   a. Assert: \( op \) is ^.
   b. Let \( tmp \) be \( \text{BinaryXor}(x \text{ modulo } 2, y \text{ modulo } 2) \).
9. If \( tmp \neq 0 \),
   a. Set \( result \) to \( result - 2^{shift} \).
   b. NOTE: This extends the sign.
10. Return the BigInt value for \( result \).

6.1.6.2.18 BigInt::bitwiseAND (x, y)

The abstract operation BigInt::bitwiseAND takes arguments \( x \) (a BigInt) and \( y \) (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return BigIntBitwiseOp(&, x, y).

6.1.6.2.19 BigInt::bitwiseXOR (x, y)

The abstract operation BigInt::bitwiseXOR takes arguments \( x \) (a BigInt) and \( y \) (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return BigIntBitwiseOp(^, x, y).
6.1.6.2.20 BigInt::bitwiseOR (x, y)

The abstract operation BigInt::bitwiseOR takes arguments x (a BigInt) and y (a BigInt) and returns a BigInt. It performs the following steps when called:

1. Return BigIntBitwiseOp(|, x, y).

6.1.6.2.21 BigInt::toString (x, radix)

The abstract operation BigInt::toString takes arguments x (a BigInt) and radix (an integer in the inclusive interval from 2 to 36) and returns a String. It represents x as a String using a positional numeral system with radix radix. The digits used in the representation of a BigInt using radix r are taken from the first r code units of "0123456789abcdefghijklmnopqrstuvwxyz" in order. The representation of BigInts other than 0 in \( \mathbb{Z} \) never includes leading zeroes. It performs the following steps when called:

1. If \( x < 0 \), return the string-concatenation of "-" and BigInt::toString(-x, radix).
2. Return the String value consisting of the representation of x using radix radix.

6.1.7 The Object Type

Each instance of the Object type, also referred to simply as "an Object", represents a collection of properties. Each property is either a data property, or an accessor property:

- A data property associates a key value with an ECMAScript language value and a set of Boolean attributes.
- An accessor property associates a key value with one or two accessor functions, and a set of Boolean attributes. The accessor functions are used to store or retrieve an ECMAScript language value that is associated with the property.

The properties of an object are uniquely identified using property keys. A property key is either a String or a Symbol. All Strings and Symbols, including the empty String, are valid as property keys. A property name is a property key that is a String.

An integer index is a property name n such that CanonicalNumericIndexString(n) returns an integral Number in the inclusive interval from +0 \( \mathbb{R} \) to 2^{53} - 1. An array index is an integer index n such that CanonicalNumericIndexString(n) returns an integral Number in the inclusive interval from +0 \( \mathbb{R} \) to 2^{32} - 2.

NOTE Every non-negative safe integer has a corresponding integer index. Every 32-bit unsigned integer except 2^{32} - 1 has a corresponding array index. "-0" is neither an integer index nor an array index.

Property keys are used to access properties and their values. There are two kinds of access for properties: get and set, corresponding to value retrieval and assignment, respectively. The properties accessible via get and set access includes both own properties that are a direct part of an object and inherited properties which are provided by another associated object via a property inheritance relationship. Inherited properties may be either own or inherited properties of the associated object. Each own property of an object must each have a key value that is distinct from the key values of the other own properties of that object.

All objects are logically collections of properties, but there are multiple forms of objects that differ in their semantics for accessing and manipulating their properties. Please see 6.1.7.2 for definitions of the multiple forms of objects.

In addition, some objects are callable; these are referred to as functions or function objects and are described further below. All functions in ECMAScript are members of the Object type.

6.1.7.1 Property Attributes

Attributes are used in this specification to define and explain the state of Object properties as described in Table 3. Unless specified explicitly, the initial value of each attribute is its Default Value.
### Table 3: Attributes of an Object property

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Types of property for which it is present</th>
<th>Value Domain</th>
<th>Default Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Value]]</td>
<td>data property</td>
<td>an ECMAScript language value</td>
<td>undefined</td>
<td>The value retrieved by a get access of the property.</td>
</tr>
<tr>
<td>[[Writable]]</td>
<td>data property</td>
<td>a Boolean</td>
<td>false</td>
<td>If false, attempts by ECMAScript code to change the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>property's [[Value]] attribute using [[Set]] will not</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>succeed.</td>
</tr>
<tr>
<td>[[Get]]</td>
<td>accessor property</td>
<td>an Object or undefined</td>
<td>undefined</td>
<td>If the value is an Object it must be a function object.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The function's [[Call]] internal method (Table 5) is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>called with an empty arguments list to retrieve the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>property value each time a get access of the property</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>is performed.</td>
</tr>
<tr>
<td>[[Set]]</td>
<td>accessor property</td>
<td>an Object or undefined</td>
<td>undefined</td>
<td>If the value is an Object it must be a function object.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The function's [[Call]] internal method (Table 5) is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>called with an arguments list containing the assigned</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>value as its sole argument each time a set access of</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>the property is performed. The effect of a property's</td>
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<td></td>
<td></td>
<td>[[Set]] internal method may, but is not required to,</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>have an effect on the value returned by subsequent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>calls to the property's [[Get]] internal method.</td>
</tr>
<tr>
<td>[[Enumerable]]</td>
<td>data property or accessor property</td>
<td>a Boolean</td>
<td>false</td>
<td>If true, the property will be enumerated by a for-in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>enumeration (see 14.7.5). Otherwise, the property is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>said to be non-enumerable.</td>
</tr>
<tr>
<td>[[Configurable]]</td>
<td>data property or accessor property</td>
<td>a Boolean</td>
<td>false</td>
<td>If false, attempts to delete the property, change it</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>from a data property to an accessor property or from</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>an accessor property to a data property, or make any</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>changes to its attributes (other than replacing an</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>existing [[Value]] or setting [[Writable]] to false)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>will fail.</td>
</tr>
</tbody>
</table>

#### 6.1.7.2 Object Internal Methods and Internal Slots

The actual semantics of objects, in ECMAScript, are specified via algorithms called *internal methods*. Each object in an ECMAScript engine is associated with a set of internal methods that defines its runtime behaviour. These internal methods are not part of the ECMAScript language. They are defined by this specification purely for expository purposes. However, each object within an implementation of ECMAScript must behave as specified by the internal methods associated with it. The exact manner in which this is accomplished is determined by the implementation.

Internal method names are polymorphic. This means that different object values may perform different algorithms when a common internal method name is invoked upon them. That actual object upon which an internal method is invoked is the “target” of the invocation. If, at runtime, the implementation of an algorithm attempts to use an internal method of an object that the object does not support, a `TypeError` exception is thrown.

Internal slots correspond to internal state that is associated with objects and used by various ECMAScript specification algorithms. Internal slots are not object properties and they are not inherited. Depending upon the specific...
internal slot specification, such state may consist of values of any ECMAScript language type or of specific ECMAScript specification type values. Unless explicitly specified otherwise, internal slots are allocated as part of the process of creating an object and may not be dynamically added to an object. Unless specified otherwise, the initial value of an internal slot is the value undefined. Various algorithms within this specification create objects that have internal slots. However, the ECMAScript language provides no direct way to associate internal slots with an object.

All objects have an internal slot named [[PrivateElements]], which is a List of PrivateElements. This List represents the values of the private fields, methods, and accessors for the object. Initially, it is an empty List.

Internal methods and internal slots are identified within this specification using names enclosed in double square brackets [[ ]].

Table 4 summarizes the essential internal methods used by this specification that are applicable to all objects created or manipulated by ECMAScript code. Every object must have algorithms for all of the essential internal methods. However, all objects do not necessarily use the same algorithms for those methods.

An ordinary object is an object that satisfies all of the following criteria:

- For the internal methods listed in Table 4, the object uses those defined in 10.1.
- If the object has a [[Call]] internal method, it uses either the one defined in 10.2.1 or the one defined in 10.3.1.
- If the object has a [[Construct]] internal method, it uses either the one defined in 10.2.2 or the one defined in 10.3.2.

An exotic object is an object that is not an ordinary object.

This specification recognizes different kinds of exotic objects by those objects’ internal methods. An object that is behaviourally equivalent to a particular kind of exotic object (such as an Array exotic object or a bound function exotic object), but does not have the same collection of internal methods specified for that kind, is not recognized as that kind of exotic object.

The “Signature” column of Table 4 and other similar tables describes the invocation pattern for each internal method. The invocation pattern always includes a parenthesized list of descriptive parameter names. If a parameter name is the same as an ECMAScript type name then the name describes the required type of the parameter value. If an internal method explicitly returns a value, its parameter list is followed by the symbol “→” and the type name of the returned value. The type names used in signatures refer to the types defined in clause 6 augmented by the following additional names. “any” means the value may be any ECMAScript language type.

In addition to its parameters, an internal method always has access to the object that is the target of the method invocation.

An internal method implicitly returns a Completion Record, either a normal completion that wraps a value of the return type shown in its invocation pattern, or a throw completion.

<table>
<thead>
<tr>
<th>Internal Method</th>
<th>Signature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[GetPrototypeOf]]</td>
<td>( ) → Object</td>
<td>Determine the object that provides inherited properties for this object. A null value indicates that there are no inherited properties.</td>
</tr>
<tr>
<td>[[SetPrototypeOf]]</td>
<td>(Object</td>
<td>Null) → Boolean</td>
</tr>
<tr>
<td>[[IsExtensible]]</td>
<td>( ) → Boolean</td>
<td>Determine whether it is permitted to add additional properties to this object.</td>
</tr>
</tbody>
</table>
Table 4: Essential Internal Methods (continued)

<table>
<thead>
<tr>
<th>Internal Method</th>
<th>Signature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[PreventExtensions]]</td>
<td>( ) → Boolean</td>
<td>Control whether new properties may be added to this object. Returns true if the operation was successful or false if the operation was unsuccessful.</td>
</tr>
<tr>
<td>[[GetOwnProperty]]</td>
<td>(propertyKey) → Undefined</td>
<td>Returns a Property Descriptor for the own property of this object whose key is propertyKey, or undefined if no such property exists.</td>
</tr>
<tr>
<td>[[DefineOwnProperty]]</td>
<td>(propertyKey, PropertyDescriptor) → Boolean</td>
<td>Create or alter the own property, whose key is propertyKey, to have the state described by PropertyDescriptor. Return true if that property was successfully created/updated or false if the property could not be created or updated.</td>
</tr>
<tr>
<td>[[HasProperty]]</td>
<td>(propertyKey) → Boolean</td>
<td>Return a Boolean value indicating whether this object already has either an own or inherited property whose key is propertyKey.</td>
</tr>
<tr>
<td>[[Get]]</td>
<td>(propertyKey, Receiver) → any</td>
<td>Return the value of the property whose key is propertyKey from this object. If any ECMAScript code must be executed to retrieve the property value, Receiver is used as the this value when evaluating the code.</td>
</tr>
<tr>
<td>[[Set]]</td>
<td>(propertyKey, value, Receiver) → Boolean</td>
<td>Set the value of the property whose key is propertyKey to value. If any ECMAScript code must be executed to set the property value, Receiver is used as the this value when evaluating the code. Returns true if the property value was set or false if it could not be set.</td>
</tr>
<tr>
<td>[[Delete]]</td>
<td>(propertyKey) → Boolean</td>
<td>Remove the own property whose key is propertyKey from this object. Return false if the property was not deleted and is still present. Return true if the property was deleted or is not present.</td>
</tr>
<tr>
<td>[[OwnPropertyKeys]]</td>
<td>( ) → List of property keys</td>
<td>Return a List whose elements are all of the own property keys for the object.</td>
</tr>
</tbody>
</table>

Table 5 summarizes additional essential internal methods that are supported by objects that may be called as functions. A function object is an object that supports the [[Call]] internal method. A constructor is an object that supports the [[Construct]] internal method. Every object that supports [[Construct]] must support [[Call]]; that is, every constructor must be a function object. Therefore, a constructor may also be referred to as a constructor function or constructor function object.
Table 5: Additional Essential Internal Methods of Function Objects

<table>
<thead>
<tr>
<th>Internal Method</th>
<th>Signature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Call]]</td>
<td>(any, a List of any) → any</td>
<td>Executes code associated with this object. Invoked via a function call expression. The arguments to the internal method are a <code>this</code> value and a <code>List</code> whose elements are the arguments passed to the function by a call expression. Objects that implement this internal method are callable.</td>
</tr>
<tr>
<td>[[Construct]]</td>
<td>(a List of any, Object) → Object</td>
<td>Creates an object. Invoked via the <code>new</code> operator or a <code>super</code> call. The first argument to the internal method is a <code>List</code> whose elements are the arguments of the constructor invocation or the <code>super</code> call. The second argument is the object to which the <code>new</code> operator was initially applied. Objects that implement this internal method are called constructors. A function object is not necessarily a constructor and such non-constructor function objects do not have a [[Construct]] internal method.</td>
</tr>
</tbody>
</table>

The semantics of the essential internal methods for ordinary objects and standard exotic objects are specified in clause 10. If any specified use of an internal method of an exotic object is not supported by an implementation, that usage must throw a `TypeError` exception when attempted.

6.1.7.3 Invariants of the Essential Internal Methods

The Internal Methods of Objects of an ECMAScript engine must conform to the list of invariants specified below. Ordinary ECMAScript Objects as well as all standard exotic objects in this specification maintain these invariants. ECMAScript Proxy objects maintain these invariants by means of runtime checks on the result of traps invoked on the `[[ProxyHandler]]` object.

Any implementation provided exotic objects must also maintain these invariants for those objects. Violation of these invariants may cause ECMAScript code to have unpredictable behaviour and create security issues. However, violation of these invariants must never compromise the memory safety of an implementation.

An implementation must not allow these invariants to be circumvented in any manner such as by providing alternative interfaces that implement the functionality of the essential internal methods without enforcing their invariants.

Definitions:

- The target of an internal method is the object upon which the internal method is called.
- A target is non-extensible if it has been observed to return `false` from its `[[IsExtensible]]` internal method, or `true` from its `[[PreventExtensions]]` internal method.
- A non-existent property is a property that does not exist as an own property on a non-extensible target.
- All references to SameValue are according to the definition of the SameValue algorithm.

Return value:

The value returned by any internal method must be a Completion Record with either:

- `[[Type]] = NORMAL`, `[[Target]] = EMPTY`, and `[[Value]] = a value of the "normal return type" shown below for that internal method, or
- `[[Type]] = THROW`, `[[Target]] = EMPTY`, and `[[Value]] = any ECMAScript language value`.

NOTE 1 An internal method must not return a `continue completion`, a `break completion`, or a `return completion`. 
[[GetPrototypeOf]] ( )

- The normal return type is either Object or Null.
- If target is non-extensible, and [[GetPrototypeOf]] returns a value \( V \), then any future calls to [[GetPrototypeOf]] should return the SameValue as \( V \).

NOTE 2  An object's prototype chain should have finite length (that is, starting from any object, recursively applying the [[GetPrototypeOf]] internal method to its result should eventually lead to the value null). However, this requirement is not enforceable as an object level invariant if the prototype chain includes any exotic objects that do not use the ordinary object definition of [[GetPrototypeOf]]. Such a circular prototype chain may result in infinite loops when accessing object properties.

[[SetPrototypeOf]] ( \( V \))

- The normal return type is Boolean.
- If target is non-extensible, [[SetPrototypeOf]] must return false, unless \( V \) is the SameValue as the target's observed [[GetPrototypeOf]] value.

[[IsExtensible]] ( )

- The normal return type is Boolean.
- If [[IsExtensible]] returns false, all future calls to [[IsExtensible]] on the target must return false.

[[PreventExtensions]] ( )

- The normal return type is Boolean.
- If [[PreventExtensions]] returns true, all future calls to [[IsExtensible]] on the target must return false and the target is now considered non-extensible.

[[GetOwnProperty]] ( \( P \))

- The normal return type is either Property Descriptor or Undefined.
- If the Type of the return value is Property Descriptor, the return value must be a fully populated Property Descriptor.
- If \( P \) is described as a non-configurable, non-writable own data property, all future calls to [[GetOwnProperty]] ( \( P \)) must return Property Descriptor whose [[Value]] is SameValue as \( P \)'s [[Value]] attribute.
- If \( P \)'s attributes other than [[Writable]] and [[Value]] may change over time, or if the property might be deleted, then \( P \)'s [[Configurable]] attribute must be true.
- If the [[Writable]] attribute may change from false to true, then the [[Configurable]] attribute must be true.
- If the target is non-extensible and \( P \) is non-existent, then all future calls to [[GetOwnProperty]] (\( P \)) on the target must describe \( P \) as non-existent (i.e. [[GetOwnProperty]](\( P \)) must return undefined).

NOTE 3  As a consequence of the third invariant, if a property is described as a data property and it may return different values over time, then either or both of the [[Writable]] and [[Configurable]] attributes must be true even if no mechanism to change the value is exposed via the other essential internal methods.

[[DefineOwnProperty]] ( \( P, Desc \))

- The normal return type is Boolean.
- [[DefineOwnProperty]] must return false if \( P \) has previously been observed as a non-configurable own property of the target, unless either:
  1. \( P \) is a writable data property. A non-configurable writable data property can be changed into a non-configurable non-writable data property.
  2. All attributes of \( Desc \) are the SameValue as \( P \)'s attributes.
• [[DefineOwnProperty]] \((P, \text{Desc})\) must return \textbf{false} if target is non-extensible and \(P\) is a non-existent own property. That is, a non-extensible target object cannot be extended with new properties.

\[
\text{[[HasProperty]]} (P)
\]

• The normal return type is \textbf{Boolean}.
• If \(P\) was previously observed as a non-configurable own data or \textit{accessor property} of the target, [[HasProperty]] must return \textbf{true}.

\[
\text{[[Get]]} (P, \text{Receiver})
\]

• The normal return type is any \textbf{ECMAScript language type}.
• If \(P\) was previously observed as a non-configurable, non-writable own \textit{data property} of the target with value \(V\), then [[Get]] must return the \textit{SameValue as} \(V\).
• If \(P\) was previously observed as a non-configurable own \textit{accessor property} of the target whose [[Get]] attribute is \textit{undefined}, the [[Get]] operation must return \textit{undefined}.

\[
\text{[[Set]]} (P, V, \text{Receiver})
\]

• The normal return type is \textbf{Boolean}.
• If \(P\) was previously observed as a non-configurable, non-writable own \textit{data property} of the target, then [[Set]] must return \textbf{false} unless \(V\) is the \textit{SameValue as} \(P\)’s [[Value]] attribute.
• If \(P\) was previously observed as a non-configurable own \textit{accessor property} of the target whose [[Set]] attribute is \textit{undefined}, the [[Set]] operation must return \textbf{false}.

\[
\text{[[Delete]]} (P)
\]

• The normal return type is \textbf{Boolean}.
• If \(P\) was previously observed as a non-configurable own data or \textit{accessor property} of the target, [[Delete]] must return \textbf{false}.

\[
\text{[[OwnPropertyKeys]]} ()
\]

• The normal return type is \textbf{List}.
• The returned \textbf{List} must not contain any duplicate entries.
• The Type of each element of the returned \textbf{List} is either \textit{String} or \textit{Symbol}.
• The returned \textbf{List} must contain at least the keys of all non-configurable own properties that have previously been observed.
• If the target is non-extensible, the returned \textbf{List} must contain only the keys of all own properties of the target that are observable using [[GetOwnProperty]].

\[
\text{[[Call]]} ()
\]

• The normal return type is any \textbf{ECMAScript language type}.

\[
\text{[[Construct]]} ()
\]

• The normal return type is \textbf{Object}.
• The target must also have a [[Call]] internal method.
6.1.7.4 Well-Known Intrinsic Objects

Well-known intrinsics are built-in objects that are explicitly referenced by the algorithms of this specification and which usually have realm-specific identities. Unless otherwise specified each intrinsic object actually corresponds to a set of similar objects, one per realm.

Within this specification a reference such as `%name%` means the intrinsic object, associated with the current realm, corresponding to the name. A reference such as `%name.a.b%` means, as if the "b" property of the value of the "a" property of the intrinsic object `%name%` was accessed prior to any ECMAScript code being evaluated. Determination of the current realm and its intrinsics is described in 9.4. The well-known intrinsics are listed in Table 6.

<table>
<thead>
<tr>
<th>Intrinsic Name</th>
<th>Global Name</th>
<th>ECMAScript Language Association</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>%AggregateError%</code></td>
<td>AggregateError</td>
<td>The <code>AggregateError</code> constructor (20.5.7.1)</td>
</tr>
<tr>
<td><code>%Array%</code></td>
<td>Array</td>
<td>The Array constructor (23.1.1)</td>
</tr>
<tr>
<td><code>%ArrayBuffer%</code></td>
<td>ArrayBuffer</td>
<td>The ArrayBuffer constructor (25.1.4)</td>
</tr>
<tr>
<td><code>%ArrayIteratorPrototype%</code></td>
<td></td>
<td>The prototype of Array iterator objects (23.1.5)</td>
</tr>
<tr>
<td><code>%AsyncFromSyncIteratorPrototype%</code></td>
<td></td>
<td>The prototype of async-from-sync iterator objects (27.1.4)</td>
</tr>
<tr>
<td><code>%AsyncFunction%</code></td>
<td></td>
<td>The constructor of async function objects (27.7.1)</td>
</tr>
<tr>
<td><code>%AsyncGeneratorFunction%</code></td>
<td></td>
<td>The constructor of async iterator objects (27.4.1)</td>
</tr>
<tr>
<td><code>%AsyncIteratorPrototype%</code></td>
<td></td>
<td>An object that all standard built-in async iterator objects indirectly inherit from</td>
</tr>
<tr>
<td><code>%Atoms%</code></td>
<td>Atomics</td>
<td>The <code>Atoms</code> object (25.4)</td>
</tr>
<tr>
<td><code>%BigInt%</code></td>
<td>BigInt</td>
<td>The BigInt constructor (21.2.1)</td>
</tr>
<tr>
<td><code>%BigInt64Array%</code></td>
<td>BigInt64Array</td>
<td>The BigInt64Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%BigUint64Array%</code></td>
<td>BigUint64Array</td>
<td>The BigUint64Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%Boolean%</code></td>
<td>Boolean</td>
<td>The Boolean constructor (20.3.1)</td>
</tr>
<tr>
<td><code>%DataView%</code></td>
<td>DataView</td>
<td>The DataView constructor (25.3.2)</td>
</tr>
<tr>
<td><code>%Date%</code></td>
<td>Date</td>
<td>The Date constructor (21.4.2)</td>
</tr>
<tr>
<td><code>%decodeURI%</code></td>
<td>decodeURI</td>
<td>The <code>decodeURI</code> function (19.2.6.1)</td>
</tr>
<tr>
<td><code>%decodeURIComponent%</code></td>
<td>decodeURIComponent</td>
<td>The <code>decodeURIComponent</code> function (19.2.6.2)</td>
</tr>
<tr>
<td><code>%encodeURI%</code></td>
<td>encodeURI</td>
<td>The <code>encodeURI</code> function (19.2.6.3)</td>
</tr>
<tr>
<td><code>%encodeURIComponent%</code></td>
<td>encodeURIComponent</td>
<td>The <code>encodeURIComponent</code> function (19.2.6.4)</td>
</tr>
<tr>
<td><code>%Error%</code></td>
<td>Error</td>
<td>The Error constructor (20.5.1)</td>
</tr>
<tr>
<td>Intrinsic Name</td>
<td>Global Name</td>
<td>ECMAScript Language Association</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td><code>%eval%</code></td>
<td>eval</td>
<td>The eval function (19.2.1)</td>
</tr>
<tr>
<td><code>%EvalError%</code></td>
<td>EvalError</td>
<td>The EvalError constructor (20.5.5.1)</td>
</tr>
<tr>
<td><code>%FinalizationRegistry%</code></td>
<td>FinalizationRegistry</td>
<td>The FinalizationRegistry constructor (26.2.1)</td>
</tr>
<tr>
<td><code>%Float32Array%</code></td>
<td>Float32Array</td>
<td>The Float32Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%Float64Array%</code></td>
<td>Float64Array</td>
<td>The Float64Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%ForInIteratorPrototype%</code></td>
<td></td>
<td>The prototype of For-In iterator objects (14.7.5.10)</td>
</tr>
<tr>
<td><code>%Function%</code></td>
<td>Function</td>
<td>The Function constructor (20.2.1)</td>
</tr>
<tr>
<td><code>%GeneratorFunction%</code></td>
<td></td>
<td>The constructor of Generators (27.3.1)</td>
</tr>
<tr>
<td><code>%Int8Array%</code></td>
<td>Int8Array</td>
<td>The Int8Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%Int16Array%</code></td>
<td>Int16Array</td>
<td>The Int16Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%Int32Array%</code></td>
<td>Int32Array</td>
<td>The Int32Array constructor (23.2)</td>
</tr>
<tr>
<td><code>%isFinite%</code></td>
<td>isFinite</td>
<td>The isFinite function (19.2.2)</td>
</tr>
<tr>
<td><code>%isNaN%</code></td>
<td>isNaN</td>
<td>The isNaN function (19.2.3)</td>
</tr>
<tr>
<td><code>%IteratorPrototype%</code></td>
<td></td>
<td>An object that all standard built-in iterator objects indirectly inherit from</td>
</tr>
<tr>
<td><code>%JSON%</code></td>
<td>JSON</td>
<td>The JSON object (25.5)</td>
</tr>
<tr>
<td><code>%Map%</code></td>
<td>Map</td>
<td>The Map constructor (24.1.1)</td>
</tr>
<tr>
<td><code>%MapIteratorPrototype%</code></td>
<td></td>
<td>The prototype of Map iterator objects (24.1.5)</td>
</tr>
<tr>
<td><code>%Math%</code></td>
<td>Math</td>
<td>The Math object (21.3)</td>
</tr>
<tr>
<td><code>%Number%</code></td>
<td>Number</td>
<td>The Number constructor (21.1.1)</td>
</tr>
<tr>
<td><code>%Object%</code></td>
<td>Object</td>
<td>The Object constructor (20.1.1)</td>
</tr>
<tr>
<td><code>%parseFloat%</code></td>
<td>parseFloat</td>
<td>The parseFloat function (19.2.4)</td>
</tr>
<tr>
<td><code>%parseInt%</code></td>
<td>parseInt</td>
<td>The parseInt function (19.2.5)</td>
</tr>
<tr>
<td><code>%Promise%</code></td>
<td>Promise</td>
<td>The Promise constructor (27.2.3)</td>
</tr>
<tr>
<td><code>%Proxy%</code></td>
<td>Proxy</td>
<td>The Proxy constructor (28.2.1)</td>
</tr>
<tr>
<td><code>%RangeError%</code></td>
<td>RangeError</td>
<td>The RangeError constructor (20.5.5.2)</td>
</tr>
<tr>
<td><code>%ReferenceError%</code></td>
<td>ReferenceError</td>
<td>The ReferenceError constructor (20.5.5.3)</td>
</tr>
<tr>
<td><code>%Reflect%</code></td>
<td>Reflect</td>
<td>The Reflect object (28.1)</td>
</tr>
<tr>
<td><code>%RegExp%</code></td>
<td>RegExp</td>
<td>The RegExp constructor (22.2.4)</td>
</tr>
</tbody>
</table>
### Table 6: Well-Known Intrinsic Objects (continued)

<table>
<thead>
<tr>
<th>Intrinsic Name</th>
<th>Global Name</th>
<th>ECMAScript Language Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>%RegExpStringIteratorPrototype%</td>
<td></td>
<td>The prototype of RegExp String Iterator objects (22.2.9)</td>
</tr>
<tr>
<td>%Set%</td>
<td>Set</td>
<td>The Set constructor (24.2.1)</td>
</tr>
<tr>
<td>%SetIteratorPrototype%</td>
<td></td>
<td>The prototype of Set iterator objects (24.2.5)</td>
</tr>
<tr>
<td>%SharedArrayBuffer%</td>
<td>SharedArrayBuffer</td>
<td>The SharedArrayBuffer constructor (25.2.3)</td>
</tr>
<tr>
<td>%String%</td>
<td>String</td>
<td>The String constructor (22.1.1)</td>
</tr>
<tr>
<td>%StringIteratorPrototype%</td>
<td></td>
<td>The prototype of String iterator objects (22.1.5)</td>
</tr>
<tr>
<td>%Symbol%</td>
<td>Symbol</td>
<td>The Symbol constructor (20.4.1)</td>
</tr>
<tr>
<td>%SyntaxError%</td>
<td>SyntaxError</td>
<td>The SyntaxError constructor (20.5.5.4)</td>
</tr>
<tr>
<td>%ThrowTypeError%</td>
<td></td>
<td>A function object that unconditionally throws a new instance of %TypeError%</td>
</tr>
<tr>
<td>%TypedArray%</td>
<td></td>
<td>The super class of all typed Array constructors (23.2.1)</td>
</tr>
<tr>
<td>%TypeError%</td>
<td>TypeError</td>
<td>The TypeError constructor (20.5.5.5)</td>
</tr>
<tr>
<td>%Uint8Array%</td>
<td>Uint8Array</td>
<td>The Uint8Array constructor (23.2)</td>
</tr>
<tr>
<td>%Uint8ClampedArray%</td>
<td>Uint8ClampedArray</td>
<td>The Uint8ClampedArray constructor (23.2)</td>
</tr>
<tr>
<td>%Uint16Array%</td>
<td>Uint16Array</td>
<td>The Uint16Array constructor (23.2)</td>
</tr>
<tr>
<td>%Uint32Array%</td>
<td>Uint32Array</td>
<td>The Uint32Array constructor (23.2)</td>
</tr>
<tr>
<td>%URIError%</td>
<td>URIError</td>
<td>The URIError constructor (20.5.5.6)</td>
</tr>
<tr>
<td>%WeakMap%</td>
<td>WeakMap</td>
<td>The WeakMap constructor (24.3.1)</td>
</tr>
<tr>
<td>%WeakRef%</td>
<td>WeakRef</td>
<td>The WeakRef constructor (26.1.1)</td>
</tr>
<tr>
<td>%WeakSet%</td>
<td>WeakSet</td>
<td>The WeakSet constructor (24.4.1)</td>
</tr>
</tbody>
</table>

**NOTE** Additional entries in Table 97.

### 6.2 ECMAScript Specification Types

A specification type corresponds to meta-values that are used within algorithms to describe the semantics of ECMAScript language constructs and ECMAScript language types. The specification types include Reference, List, Completion Record, Property Descriptor, Environment Record, Abstract Closure, and Data Block. Specification type values are specification artefacts that do not necessarily correspond to any specific entity within an ECMAScript implementation. Specification type values may be used to describe intermediate results of ECMAScript expression evaluation but such values cannot be stored as properties of objects or values of ECMAScript language variables.
6.2.1 The Enum Specification Type

Enums are values which are internal to the specification and not directly observable from ECMAScript code. Enums are denoted using a SANS-SERIF typeface. For instance, a Completion Record’s [[Type]] field takes on values like NORMAL, RETURN, or THROW. Enums have no characteristics other than their name. The name of an enum serves no purpose other than to distinguish it from other enums, and implies nothing about its usage or meaning in context.

6.2.2 The List and Record Specification Types

The List type is used to explain the evaluation of argument lists (see 13.3.8) in new expressions, in function calls, and in other algorithms where a simple ordered list of values is needed. Values of the List type are simply ordered sequences of list elements containing the individual values. These sequences may be of any length. The elements of a list may be randomly accessed using 0-origin indices. For notational convenience an array-like syntax can be used to access List elements. For example, arguments[2] is shorthand for saying the 3rd element of the List arguments.

When an algorithm iterates over the elements of a List without specifying an order, the order used is the order of the elements in the List.

For notational convenience within this specification, a literal syntax can be used to express a new List value. For example, «1, 2» defines a List value that has two elements each of which is initialized to a specific value. A new empty List can be expressed as « ».

In this specification, the phrase "the list-concatenation of A, B, ..." (where each argument is a possibly empty List) denotes a new List value whose elements are the concatenation of the elements (in order) of each of the arguments (in order).

The Record type is used to describe data aggregations within the algorithms of this specification. A Record type value consists of one or more named fields. The value of each field is an ECMAScript language value or specification value. Field names are always enclosed in double brackets, for example [[Value]].

For notational convenience within this specification, an object literal-like syntax can be used to express a Record value. For example, { [[Field1]]: 42, [[Field2]]: false, [[Field3]]: EMPTY } defines a Record value that has three fields, each of which is initialized to a specific value. Field name order is not significant. Any fields that are not explicitly listed are considered to be absent.

In specification text and algorithms, dot notation may be used to refer to a specific field of a Record value. For example, if R is the record shown in the previous paragraph then R.[[Field2]] is shorthand for “the field of R named [[Field2]]”.

Schema for commonly used Record field combinations may be named, and that name may be used as a prefix to a literal Record value to identify the specific kind of aggregations that is being described. For example: PropertyDescriptor { [[Value]]: 42, [[Writable]]: false, [[Configurable]]: true }.

6.2.3 The Set and Relation Specification Types

The Set type is used to explain a collection of unordered elements for use in the memory model. It is distinct from the ECMAScript collection type of the same name. To disambiguate, instances of the ECMAScript collection are consistently referred to as "Set objects" within this specification. Values of the Set type are simple collections of elements, where no element appears more than once. Elements may be added to and removed from Sets. Sets may be unioned, intersected, or subtracted from each other.

The Relation type is used to explain constraints on Sets. Values of the Relation type are Sets of ordered pairs of values from its value domain. For example, a Relation on events is a set of ordered pairs of events. For a Relation R and two values a and b in the value domain of R, a R b is shorthand for saying the ordered pair (a, b) is a member of R. A Relation is least with respect to some conditions when it is the smallest Relation that satisfies those conditions.
A strict partial order is a Relation value \( R \) that satisfies the following.

- For all \( a, b, \) and \( c \) in \( R \)'s domain:
  - It is not the case that \( a R a \), and
  - If \( a R b \) and \( b R c \), then \( a R c \).

**NOTE 1** The two properties above are called irreflexivity and transitivity, respectively.

A strict total order is a Relation value \( R \) that satisfies the following.

- For all \( a, b, \) and \( c \) in \( R \)'s domain:
  - \( a \) is \( b \) or \( a R b \) or \( b R a \), and
  - It is not the case that \( a R a \), and
  - If \( a R b \) and \( b R c \), then \( a R c \).

**NOTE 2** The three properties above are called totality, irreflexivity, and transitivity, respectively.

### 6.2.4 The Completion Record Specification Type

The Completion Record specification type is used to explain the runtime propagation of values and control flow such as the behaviour of statements (break, continue, return and throw) that perform nonlocal transfers of control.

Completion Records have the fields defined in **Table 7**.

**Table 7: Completion Record Fields**

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Type]]</td>
<td>NORMAL, BREAK, CONTINUE, RETURN, or THROW</td>
<td>The type of completion that occurred.</td>
</tr>
<tr>
<td>[[Value]]</td>
<td>any value except a Completion Record</td>
<td>The value that was produced.</td>
</tr>
<tr>
<td>[[Target]]</td>
<td>a String or EMPTY</td>
<td>The target label for directed control</td>
</tr>
<tr>
<td></td>
<td>transfers.</td>
<td></td>
</tr>
</tbody>
</table>

The following shorthand terms are sometimes used to refer to Completion Records.

- **normal completion** refers to any Completion Record with a [[Type]] value of NORMAL.
- **break completion** refers to any Completion Record with a [[Type]] value of BREAK.
- **continue completion** refers to any Completion Record with a [[Type]] value of CONTINUE.
- **return completion** refers to any Completion Record with a [[Type]] value of RETURN.
- **throw completion** refers to any Completion Record with a [[Type]] value of THROW.
- **abrupt completion** refers to any Completion Record with a [[Type]] value other than NORMAL.
- A **normal completion containing** some type of value refers to a normal completion that has a value of that type in its [[Value]] field.

Callable objects that are defined in this specification only return a normal completion or a throw completion. Returning any other kind of Completion Record is considered an editorial error.

**Implementation-defined** callable objects must return either a normal completion or a throw completion.
6.2.4.1 NormalCompletion (value)

The abstract operation NormalCompletion takes argument value (any value except a Completion Record) and returns a normal completion. It performs the following steps when called:

1. Return Completion Record { [[Type]]: NORMAL, [[Value]]: value, [[Target]]: EMPTY }.

6.2.4.2 ThrowCompletion (value)

The abstract operation ThrowCompletion takes argument value (an ECMAScript language value) and returns a throw completion. It performs the following steps when called:

1. Return Completion Record { [[Type]]: THROW, [[Value]]: value, [[Target]]: EMPTY }.

6.2.4.3 UpdateEmpty (completionRecord, value)

The abstract operation UpdateEmpty takes arguments completionRecord (a Completion Record) and value (any value except a Completion Record) and returns a Completion Record. It performs the following steps when called:

1. Assert: If completionRecord is either a return completion or a throw completion, then completionRecord.([[Value]]) is not EMPTY.
2. If completionRecord.([[Value]]) is not EMPTY, return ? completionRecord.
3. Return Completion Record { [[Type]]: completionRecord.([[Type]]), [[Value]]: value, [[Target]]: completionRecord.([[Target]]) }.

6.2.5 The Reference Record Specification Type

The Reference Record type is used to explain the behaviour of such operators as delete, typeof, the assignment operators, the super keyword and other language features. For example, the left-hand operand of an assignment is expected to produce a Reference Record.

A Reference Record is a resolved name or property binding; its fields are defined by Table 8.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Base]]</td>
<td>an ECMAScript language value, an Environment Record, or UNRESOLVABLE</td>
<td>The value or Environment Record which holds the binding. A [[Base]] of UNRESOLVABLE indicates that the binding could not be resolved.</td>
</tr>
<tr>
<td>[[ReferencedName]]</td>
<td>a String, a Symbol, or a Private Name</td>
<td>The name of the binding. Always a String if [[Base]] value is an Environment Record.</td>
</tr>
<tr>
<td>[[Strict]]</td>
<td>a Boolean</td>
<td>true if the Reference Record originated in strict mode code, false otherwise.</td>
</tr>
<tr>
<td>[[ThisValue]]</td>
<td>an ECMAScript language value or EMPTY</td>
<td>If not EMPTY, the Reference Record represents a property binding that was expressed using the super keyword; it is called a Super Reference Record and its [[Base]] value will never be an Environment Record. In that case, the [[ThisValue]] field holds the this value at the time the Reference Record was created.</td>
</tr>
</tbody>
</table>

The following abstract operations are used in this specification to operate upon Reference Records:
6.2.5.1 IsPropertyReference (V)

The abstract operation IsPropertyReference takes argument V (a Reference Record) and returns a Boolean. It performs the following steps when called:

1. If V.[[Base]] is UNRESOLVABLE, return false.
2. If V.[[Base]] is an Environment Record, return false; otherwise return true.

6.2.5.2 IsUnresolvableReference (V)

The abstract operation IsUnresolvableReference takes argument V (a Reference Record) and returns a Boolean. It performs the following steps when called:

1. If V.[[Base]] is UNRESOLVABLE, return true; otherwise return false.

6.2.5.3 IsSuperReference (V)

The abstract operation IsSuperReference takes argument V (a Reference Record) and returns a Boolean. It performs the following steps when called:

1. If V.[[ThisValue]] is not EMPTY, return true; otherwise return false.

6.2.5.4 IsPrivateReference (V)

The abstract operation IsPrivateReference takes argument V (a Reference Record) and returns a Boolean. It performs the following steps when called:

1. If V.[[ReferencedName]] is a Private Name, return true; otherwise return false.

6.2.5.5 GetValue (V)

The abstract operation GetValue takes argument V (a Reference Record or an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. If V is not a Reference Record, return V.
2. If IsUnresolvableReference(V) is true, throw a ReferenceError exception.
3. If IsPropertyReference(V) is true, then
   a. Let baseObj be ? ToObject(V.[[Base]]).
   b. If IsPrivateReference(V) is true, then
      i. Return ? PrivateGet(baseObj, V.[[ReferencedName]]).
   c. Return ? baseObj.[[Get]](V.[[ReferencedName]], V.[[Strict]]) (see 9.1).
4. Else,
   a. Let base be V.[[Base]].
   b. Assert: base is an Environment Record.
   c. Return ? base.GetBindingValue(V.[[ReferencedName]], V.[[Strict]]) (see 9.1).

NOTE The object that may be created in step 3.a is not accessible outside of the above abstract operation and the ordinary object [[Get]] internal method. An implementation might choose to avoid the actual creation of the object.
6.2.5.6 PutValue \((V, W)\)

The abstract operation PutValue takes arguments \(V\) (a Reference Record or an ECMAScript language value) and \(W\) (an ECMAScript language value) and returns either a normal completion containing UNUSED or an abrupt completion. It performs the following steps when called:

1. If \(V\) is not a Reference Record, throw a ReferenceError exception.
2. If IsUnresolvableReference\((V)\) is true, then
   a. If \(V.\text{[[Strict]]}\) is true, throw a ReferenceError exception.
   b. Let \(\text{globalObj}\) be GetGlobalObject().
   c. Perform ? Set(\(\text{globalObj}, V.\text{[[ReferencedName]]}, W, \text{false}\)).
   d. Return UNUSED.
3. If IsPropertyReference\((V)\) is true, then
   a. Let \(\text{baseObj}\) be ? ToObject\((V.\text{[[Base]]})\).
   b. If IsPrivateReference\((V)\) is true, then
      i. Return ? PrivateSet\((\text{baseObj}, V.\text{[[ReferencedName]]}, W)\).
   c. Let \(\text{succeeded}\) be ? baseObj.\text{[[Set]]}(V.\text{[[ReferencedName]]}, W, GetThisValue\((V)\)).
   d. If \(\text{succeeded}\) is false and \(V.\text{[[Strict]]}\) is true, throw a TypeError exception.
   e. Return UNUSED.
4. Else,
   a. Let \(\text{base}\) be \(V.\text{[[Base]]}\).
   b. Assert: \(\text{base}\) is an Environment Record.
   c. Return ? base.\text{SetMutableBinding}(V.\text{[[ReferencedName]]}, W, V.\text{[[Strict]]}) (see 9.1).

NOTE The object that may be created in step 3.a is not accessible outside of the above abstract operation and the ordinary object \text{[[Set]]} internal method. An implementation might choose to avoid the actual creation of that object.

6.2.5.7 GetThisValue \((V)\)

The abstract operation GetThisValue takes argument \(V\) (a Reference Record) and returns an ECMAScript language value. It performs the following steps when called:

1. Assert: IsPropertyReference\((V)\) is true.
2. If IsSuperReference\((V)\) is true, return \(V.\text{[[ThisValue]]}\); otherwise return \(V.\text{[[Base]]}\).

6.2.5.8 InitializeReferencedBinding \((V, W)\)

The abstract operation InitializeReferencedBinding takes arguments \(V\) (a Reference Record) and \(W\) (an ECMAScript language value) and returns either a normal completion containing UNUSED or an abrupt completion. It performs the following steps when called:

1. Assert: IsUnresolvableReference\((V)\) is false.
2. Let \(\text{base}\) be \(V.\text{[[Base]]}\).
3. Assert: \(\text{base}\) is an Environment Record.
4. Return ? base.\text{InitializeBinding}(V.\text{[[ReferencedName]]}, W).

6.2.5.9 MakePrivateReference \((\text{baseValue}, \text{privateIdentifier})\)

The abstract operation MakePrivateReference takes arguments \(\text{baseValue}\) (an ECMAScript language value) and \(\text{privateIdentifier}\) (a String) and returns a Reference Record. It performs the following steps when called:

1. Let \(\text{privEnv}\) be the running execution context’s PrivateEnvironment.
2. Assert: \(\text{privEnv}\) is not null.
3. Let \(\text{privateName}\) be ResolvePrivateIdentifier\((\text{privEnv}, \text{privateIdentifier})\).
4. Return the Reference Record \{ [[Base]]: \text{baseValue}, [[ReferencedName]]: \text{privateName}, [[Strict]]: true, [[ThisValue]]: EMPTY \}.
6.2.6 The Property Descriptor Specification Type

The Property Descriptor type is used to explain the manipulation and reification of Object property attributes. A Property Descriptor is a Record with zero or more fields, where each field's name is an attribute name and its value is a corresponding attribute value as specified in 6.1.7.1. The schema name used within this specification to tag literal descriptions of Property Descriptor records is “PropertyDescriptor”.

Property Descriptor values may be further classified as data Property Descriptors and accessor Property Descriptors based upon the existence or use of certain fields. A data Property Descriptor is one that includes any fields named either [[Value]] or [[Writable]]. An accessor Property Descriptor is one that includes any fields named either [[Get]] or [[Set]]. Any Property Descriptor may have fields named [[Enumerable]] and [[Configurable]]. A Property Descriptor value may not be both a data Property Descriptor and an accessor Property Descriptor; however, it may be neither (in which case it is a generic Property Descriptor). A fully populated Property Descriptor is one that is either an accessor Property Descriptor or a data Property Descriptor and that has all of the corresponding fields defined in Table 3.

The following abstract operations are used in this specification to operate upon Property Descriptor values:

6.2.6.1 IsAccessorDescriptor (Desc)

The abstract operation IsAccessorDescriptor takes argument Desc (a Property Descriptor or undefined) and returns a Boolean. It performs the following steps when called:

1. If Desc is undefined, return false.
2. If Desc has a [[Get]] field, return true.
3. If Desc has a [[Set]] field, return true.
4. Return false.

6.2.6.2 IsDataDescriptor (Desc)

The abstract operation IsDataDescriptor takes argument Desc (a Property Descriptor or undefined) and returns a Boolean. It performs the following steps when called:

1. If Desc is undefined, return false.
2. If Desc has a [[Value]] field, return true.
3. If Desc has a [[Writable]] field, return true.
4. Return false.

6.2.6.3 IsGenericDescriptor (Desc)

The abstract operation IsGenericDescriptor takes argument Desc (a Property Descriptor or undefined) and returns a Boolean. It performs the following steps when called:

1. If Desc is undefined, return false.
2. If IsAccessorDescriptor(Desc) is true, return false.
3. If IsDataDescriptor(Desc) is true, return false.
4. Return true.

6.2.6.4 FromPropertyDescriptor (Desc)

The abstract operation FromPropertyDescriptor takes argument Desc (a Property Descriptor or undefined) and returns an Object or undefined. It performs the following steps when called:

1. If Desc is undefined, return undefined.
2. Let obj be OrdinaryObjectCreate(%Object.prototype%).
3. Assert: obj is an extensible ordinary object with no own properties.
4. If Desc has a [[Value]] field, then
   a. Perform ! CreateDataPropertyOrThrow(obj, "value", Desc.[[Value]]).
5. If `Desc` has a `[[Writable]]` field, then
   a. Perform ! `CreateDataPropertyOrThrow(obj, "writable", Desc.[[Writable]])`.
6. If `Desc` has a `[[Get]]` field, then
   a. Perform ! `CreateDataPropertyOrThrow(obj, "get", Desc.[[Get]])`.
7. If `Desc` has a `[[Set]]` field, then
   a. Perform ! `CreateDataPropertyOrThrow(obj, "set", Desc.[[Set]])`.
8. If `Desc` has an `[[Enumerable]]` field, then
   a. Perform ! `CreateDataPropertyOrThrow(obj, "enumerable", Desc.[[Enumerable]])`.
9. If `Desc` has a `[[Configurable]]` field, then
   a. Perform ! `CreateDataPropertyOrThrow(obj, "configurable", Desc.[[Configurable]])`.
10. Return `obj`.

6.2.6.5 ToPropertyDescriptor ( Obj )

The abstract operation ToPropertyDescriptor takes argument `Obj` (an ECMAScript language value) and returns either a normal completion containing a Property Descriptor or a throw completion. It performs the following steps when called:

1. If `Obj` is not an Object, throw a `TypeError` exception.
2. Let `desc` be a new Property Descriptor that initially has no fields.
3. Let `hasEnumerable` be `? HasProperty(Obj, "enumerable")`.
4. If `hasEnumerable` is `true`, then
   a. Let `enumerable` be `ToBoolean(Obj.get("enumerable"))`.
   b. Set `desc.[[Enumerable]]` to `enumerable`.
5. Let `hasConfigurable` be `? HasProperty(Obj, "configurable")`.
6. If `hasConfigurable` is `true`, then
   a. Let `configurable` be `ToBoolean(Obj.get("configurable"))`.
   b. Set `desc.[[Configurable]]` to `configurable`.
7. Let `hasValue` be `? HasProperty(Obj, "value")`.
8. If `hasValue` is `true`, then
   a. Let `value` be `Obj.get("value")`.
   b. Set `desc.[[Value]]` to `value`.
9. Let `hasWritable` be `? HasProperty(Obj, "writable")`.
10. If `hasWritable` is `true`, then
    a. Let `writable` be `ToBoolean(Obj.get("writable"))`.
    b. Set `desc.[[Writable]]` to `writable`.
11. Let `hasGet` be `? HasProperty(Obj, "get")`.
12. If `hasGet` is `true`, then
    a. Let `getter` be `Obj.get("get")`.
    b. If `IsCallable(getter)` is `false` and `getter` is not `undefined`, throw a `TypeError` exception.
    c. Set `desc.[[Get]]` to `getter`.
13. Let `hasSet` be `? HasProperty(Obj, "set")`.
14. If `hasSet` is `true`, then
    a. Let `setter` be `Obj.get("set")`.
    b. If `IsCallable(setter)` is `false` and `setter` is not `undefined`, throw a `TypeError` exception.
    c. Set `desc.[[Set]]` to `setter`.
15. If `desc` has a `[[Get]]` field or `desc` has a `[[Set]]` field, then
    a. If `desc` has a `[[Value]]` field or `desc` has a `[[Writable]]` field, throw a `TypeError` exception.
16. Return `desc`.

6.2.6.6 CompletePropertyDescriptor ( Desc )

The abstract operation CompletePropertyDescriptor takes argument `Desc` (a Property Descriptor) and returns UNUSED. It performs the following steps when called:

1. Let `like` be the Record (`[[Value]]: undefined, [[Writable]]: false, [[Get]]: undefined, [[Set]]: undefined, [[Enumerable]]: false, [[Configurable]]: false`).
2. If `IsGenericDescriptor(Desc)` is `true` or `IsDataDescriptor(Desc)` is `true`, then
   a. If `Desc` does not have a `[[Value]]` field, set `Desc.[[Value]]` to `like.[[Value]]`.
   b. If `Desc` does not have a `[[Writable]]` field, set `Desc.[[Writable]]` to `like.[[Writable]]`.
3. Else,
   a. If Desc does not have a [[Get]] field, set Desc.[[Get]] to like.[[Get]].
   b. If Desc does not have a [[Set]] field, set Desc.[[Set]] to like.[[Set]].
4. If Desc does not have an [[Enumerable]] field, set Desc.[[Enumerable]] to like.[[Enumerable]].
5. If Desc does not have a [[Configurable]] field, set Desc.[[Configurable]] to like.[[Configurable]].
6. Return UNUSED.

6.2.7 The Environment Record Specification Type

The Environment Record type is used to explain the behaviour of name resolution in nested functions and blocks. This type and the operations upon it are defined in 9.1.

6.2.8 The Abstract Closure Specification Type

The Abstract Closure specification type is used to refer to algorithm steps together with a collection of values. Abstract Closures are meta-values and are invoked using function application style such as closure(arg1, arg2). Like abstract operations, invocations perform the algorithm steps described by the Abstract Closure.

In algorithm steps that create an Abstract Closure, values are captured with the verb "capture" followed by a list of aliases. When an Abstract Closure is created, it captures the value that is associated with each alias at that time. In steps that specify the algorithm to be performed when an Abstract Closure is called, each captured value is referred to by the alias that was used to capture the value.

If an Abstract Closure returns a Completion Record, that Completion Record must be either a normal completion or a throw completion.

Abstract Closures are created inline as part of other algorithms, shown in the following example.

1. Let addend be 41.
2. Let closure be a new Abstract Closure with parameters (x) that captures addend and performs the following steps when called:
   a. Return x + addend.
3. Let val be closure(1).
4. Assert: val is 42.

6.2.9 Data Blocks

The Data Block specification type is used to describe a distinct and mutable sequence of byte-sized (8 bit) numeric values. A byte value is an integer in the inclusive interval from 0 to 255. A Data Block value is created with a fixed number of bytes that each have the initial value 0.

For notational convenience within this specification, an array-like syntax can be used to access the individual bytes of a Data Block value. This notation presents a Data Block value as a 0-originated integer-indexed sequence of bytes. For example, if db is a 5 byte Data Block value then db[2] can be used to access its 3rd byte.

A data block that resides in memory that can be referenced from multiple agents concurrently is designated a Shared Data Block. A Shared Data Block has an identity (for the purposes of equality testing Shared Data Block values) that is address-free: it is tied not to the virtual addresses the block is mapped to in any process, but to the set of locations in memory that the block represents. Two data blocks are equal only if the sets of the locations they contain are equal; otherwise, they are not equal and the intersection of the sets of locations they contain is empty. Finally, Shared Data Blocks can be distinguished from Data Blocks.

The semantics of Shared Data Blocks is defined using Shared Data Block events by the memory model. Abstract operations below introduce Shared Data Block events and act as the interface between evaluation semantics and the event semantics of the memory model. The events form a candidate execution, on which the memory model acts as a filter. Please consult the memory model for full semantics.

Shared Data Block events are modeled by Records, defined in the memory model.
The following abstract operations are used in this specification to operate upon Data Block values:

### 6.2.9.1 CreateByteDataBlock (size)

The abstract operation CreateByteDataBlock takes argument size (a non-negative integer) and returns either a normal completion containing a Data Block or a throw completion. It performs the following steps when called:

1. If size > $2^{53} - 1$, throw a RangeError exception.
2. Let db be a new Data Block value consisting of size bytes. If it is impossible to create such a Data Block, throw a RangeError exception.
3. Set all of the bytes of db to 0.
4. Return db.

### 6.2.9.2 CreateSharedByteDataBlock (size)

The abstract operation CreateSharedByteDataBlock takes argument size (a non-negative integer) and returns either a normal completion containing a Shared Data Block or a throw completion. It performs the following steps when called:

1. Let db be a new Shared Data Block value consisting of size bytes. If it is impossible to create such a Shared Data Block, throw a RangeError exception.
2. Let execution be the [[CandidateExecution]] field of the surrounding agent's Agent Record.
3. Let eventsRecord be the Agent Events Record of execution. [[EventsRecords]] whose [[AgentSignifier]] is AgentSignifier().
4. Let zero be « 0 ».
5. For each index i of db, do
   a. Append WriteSharedMemory { [[Order]]: INIT, [[NoTear]]: true, [[Block]]: db, [[ByteIndex]]: i, [[ElementSize]]: 1, [[Payload]]: zero } to eventsRecord. [[EventList]].

### 6.2.9.3 CopyDataBlockBytes (toBlock, toIndex, fromBlock, fromIndex, count)

The abstract operation CopyDataBlockBytes takes arguments toBlock (a Data Block or a Shared Data Block), toIndex (a non-negative integer), fromBlock (a Data Block or a Shared Data Block), fromIndex (a non-negative integer), and count (a non-negative integer) and returns UNUSED. It performs the following steps when called:

1. Assert: fromBlock and toBlock are distinct values.
2. Let fromSize be the number of bytes in fromBlock.
3. Assert: fromIndex + count ≤ fromSize.
4. Let toSize be the number of bytes in toBlock.
5. Assert: toIndex + count ≤ toSize.
6. Repeat, while count > 0,
   a. If fromBlock is a Shared Data Block, then
      i. Let execution be the [[CandidateExecution]] field of the surrounding agent's Agent Record.
      ii. Let eventsRecord be the Agent Events Record of execution. [[EventsRecords]] whose [[AgentSignifier]] is AgentSignifier().
      iii. Let bytes be a List whose sole element is a nondeterministically chosen byte value.
      iv. NOTE: In implementations, bytes is the result of a non-atomic read instruction on the underlying hardware. The nondeterminism is a semantic prescription of the memory model to describe observable behaviour of hardware with weak consistency.
      v. Let readEvent be ReadSharedMemory { [[Order]]: UNORDERED, [[NoTear]]: true, [[Block]]: fromBlock, [[ByteIndex]]: fromIndex, [[ElementSize]]: 1 }.
      vi. Append readEvent to eventsRecord. [[EventList]].
      vii. Append Chosen Value Record { [[Event]]: readEvent, [[ChosenValue]]: bytes } to execution. [[CandidateExecution]].
viii. If `toBlock` is a Shared Data Block, then
    1. Append `WriteSharedMemory` { `[[Order]]`: UNORDERED, `[[NoTear]]`: true, `[[Block]]`: `toBlock`, `[[ByteIndex]]`: `toIndex`, `[[ElementSize]]`: 1, `[[Payload]]`: `bytes` } to `eventsRecord`[`[[EventList]]`].
ix. Else,
    1. Set `toBlock[toIndex]` to `bytes[0]`.
b. Else,
i. Assert: `toBlock` is not a Shared Data Block.
ii. Set `toBlock[toIndex]` to `fromBlock[fromIndex]`.
c. Set `tolIndex` to `tolIndex + 1`.
d. Set `fromIndex` to `fromIndex + 1`.
e. Set `count` to `count - 1`.
7. Return UNUSED.

6.2.10 The PrivateElement Specification Type

The PrivateElement type is a Record used in the specification of private class fields, methods, and accessors. Although Property Descriptors are not used for private elements, private fields behave similarly to non-configurable, non-enumerable, writable data properties, private methods behave similarly to non-configurable, non-enumerable, non-writable data properties, and private accessors behave similarly to non-configurable, non-enumerable accessor properties.

Values of the PrivateElement type are Record values whose fields are defined by Table 9. Such values are referred to as PrivateElements.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Values of the <code>[[Kind]]</code> field for which it is present</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[Key]]</code></td>
<td>All</td>
<td>a Private Name</td>
<td>The name of the field, method, or accessor.</td>
</tr>
<tr>
<td><code>[[Kind]]</code></td>
<td>All</td>
<td>FIELD, METHOD, or ACCESSOR</td>
<td>The kind of the element.</td>
</tr>
<tr>
<td><code>[[Value]]</code></td>
<td>FIELD and METHOD</td>
<td>an ECMAScript language value</td>
<td>The value of the field.</td>
</tr>
<tr>
<td><code>[[Get]]</code></td>
<td>ACCESSOR</td>
<td>a function object or undefined</td>
<td>The getter for a private accessor.</td>
</tr>
<tr>
<td><code>[[Set]]</code></td>
<td>ACCESSOR</td>
<td>a function object or undefined</td>
<td>The setter for a private accessor.</td>
</tr>
</tbody>
</table>

6.2.11 The ClassFieldDefinition Record Specification Type

The ClassFieldDefinition type is a Record used in the specification of class fields.

Values of the ClassFieldDefinition type are Record values whose fields are defined by Table 10. Such values are referred to as ClassFieldDefinition Records.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[Name]]</code></td>
<td>a Private Name, a String, or a Symbol</td>
<td>The name of the field.</td>
</tr>
<tr>
<td><code>[[Initializer]]</code></td>
<td>an ECMAScript function object or EMPTY</td>
<td>The initializer of the field, if any.</td>
</tr>
</tbody>
</table>
6.2.12 Private Names

The *Private Name* specification type is used to describe a globally unique value (one which differs from any other Private Name, even if they are otherwise indistinguishable) which represents the key of a private class element (field, method, or accessor). Each Private Name has an associated immutable `[[Description]]` which is a `String` value. A Private Name may be installed on any ECMAScript object with `PrivateFieldAdd` or `PrivateMethodOrAccessorAdd`, and then read or written using `PrivateGet` and `PrivateSet`.

6.2.13 The ClassStaticBlockDefinition Record Specification Type

A `ClassStaticBlockDefinition` Record is a `Record` value used to encapsulate the executable code for a class static initialization block.

ClassStaticBlockDefinition Records have the fields listed in Table 11.

Table 11: `ClassStaticBlockDefinition Record` Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[BodyFunction]]</code></td>
<td>an ECMAScript function object</td>
<td>The function object to be called during static initialization of a class.</td>
</tr>
</tbody>
</table>

7 Abstract Operations

These operations are not a part of the ECMAScript language; they are defined here solely to aid the specification of the semantics of the ECMAScript language. Other, more specialized abstract operations are defined throughout this specification.

7.1 Type Conversion

The ECMAScript language implicitly performs automatic type conversion as needed. To clarify the semantics of certain constructs it is useful to define a set of conversion abstract operations. The conversion abstract operations are polymorphic; they can accept a value of any ECMAScript language type. But no other specification types are used with these operations.

The `BigInt` type has no implicit conversions in the ECMAScript language; programmers must call `BigInt` explicitly to convert values from other types.

7.1.1 ToPrimitive ( `input [ , preferredType ]` )

The abstract operation `ToPrimitive` takes argument `input` (an ECMAScript language value) and optional argument `preferredType` (STRING or NUMBER) and returns either a normal completion containing an ECMAScript language value or a throw completion. It converts its `input` argument to a non-Object type. If an object is capable of converting to more than one primitive type, it may use the optional hint `preferredType` to favour that type. It performs the following steps when called:

1. If `input` is an `Object`, then
   a. Let `exoticToPrim` be `? GetMethod(input, `@@toPrimitive`).
   b. If `exoticToPrim` is not `undefined`, then
      i. If `preferredType` is not present, then
       1. Let `hint` be "default".
      ii. Else if `preferredType` is STRING, then
       1. Let `hint` be "string".
      iii. Else,
        1. Assert: `preferredType` is NUMBER.
        2. Let `hint` be "number".
      iv. Let `result` be `? Call(exoticToPrim, input, « hint »`).

   otherwise
   a. Let `fn` be the runtime function associated with `input`.
   b. Let `params` be the arguments of `fn`.
   c. Let `unwrappedResult` be `? CallProperties(fn, `params`).
   d. Let `result` be `! resultOfCall(unwrappedResult)`. © Ecma International 2024
v. If result is not an Object, return result.
vi. Throw a TypeError exception.
c. If preferredType is not present, let preferredType be NUMBER.
d. Return ? OrdinaryToPrimitive(input, preferredType).

2. Return input.

7.1.1.1 OrdinaryToPrimitive ( O, hint )

The abstract operation OrdinaryToPrimitive takes arguments O (an Object) and hint (STRING or NUMBER) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. If hint is STRING, then
   a. Let methodNames be « "toString", "valueOf" ».
2. Else,
   a. Let methodNames be « "valueOf", "toString" ».
3. For each element name of methodNames, do
   a. Let method be ? Get(O, name).
   b. If IsCallable(method) is true, then
      i. Let result be ? Call(method, O).
      ii. If result is not an Object, return result.
4. Throw a TypeError exception.

7.1.2 ToBoolean ( argument )

The abstract operation ToBoolean takes argument argument (an ECMAScript language value) and returns a Boolean. It converts argument to a value of type Boolean. It performs the following steps when called:

1. If argument is a Boolean, return argument.
2. If argument is one of undefined, null, +0𝔽, -0𝔽, NaN, 0ℤ, or the empty String, return false.
3. NOTE: This step is replaced in section B.3.6.1.
4. Return true.

7.1.3 ToNumeric ( value )

The abstract operation ToNumeric takes argument value (an ECMAScript language value) and returns either a normal completion containing either a Number or a BigInt, or a throw completion. It returns value converted to a Number or a BigInt. It performs the following steps when called:

1. Let primValue be ? ToPrimitive(value, NUMBER).
2. If primValue is a BigInt, return primValue.
3. Return ? ToNumber(primValue).

7.1.4 ToNumber ( argument )

The abstract operation ToNumber takes argument argument (an ECMAScript language value) and returns either a normal completion containing a Number or a throw completion. It converts argument to a value of type Number. It performs the following steps when called:

1. If argument is a Number, return argument.
2. If argument is either a Symbol or a BigInt, throw a TypeError exception.
3. If argument is undefined, return NaN.
4. If argument is either null or false, return +0𝔽.
5. If argument is true, return 1₣.
6. If argument is a String, return StringToNumber(argument).
7. Assert: argument is an Object.
8. Let primValue be ? ToPrimitive(argument, NUMBER).
9. Assert: primValue is not an Object.
10. Return ? ToNumber(primValue).

7.1.4.1 ToNumber Applied to the String Type

The abstract operation StringToNumber specifies how to convert a String value to a Number value, using the following grammar.

Syntax

```
StringNumericLiteral ::= StrWhiteSpaceopt
                     StrWhiteSpaceopt StrNumericLiteral StrWhiteSpaceopt

StrWhiteSpace ::= StrWhiteSpaceChar StrWhiteSpaceopt

StrWhiteSpaceChar ::=WhiteSpace
                     LineTerminator

StrNumericLiteral ::= StrDecimalLiteral
                     NonDecimalIntegerLiteral[^Sep]

StrDecimalLiteral ::= StrUnsignedDecimalLiteral
                     + StrUnsignedDecimalLiteral
                     - StrUnsignedDecimalLiteral

StrUnsignedDecimalLiteral ::= Infinity
                           . DecimalDigits[^Sep] ExponentPart[^Sep] opt
                           DecimalDigits[^Sep] ExponentPart[^Sep] opt
```

All grammar symbols not explicitly defined above have the definitions used in the Lexical Grammar for numeric literals (12.9.3)

NOTE Some differences should be noted between the syntax of a StringNumericLiteral and a NumericLiteral:

- A StringNumericLiteral may include leading and/or trailing white space and/or line terminators.
- A StringNumericLiteral that is decimal may have any number of leading 0 digits.
- A StringNumericLiteral that is decimal may include a + or - to indicate its sign.
- A StringNumericLiteral that is empty or contains only white space is converted to +0₣.
- Infinity and -Infinity are recognized as a StringNumericLiteral but not as a NumericLiteral.
- A StringNumericLiteral cannot include a BigIntLiteralSuffix.
- A StringNumericLiteral cannot include a NumericLiteralSeparator.
7.1.4.1.1 StringToNumber (str)

The abstract operation StringToNumber takes argument str (a String) and returns a Number. It performs the following steps when called:

1. Let text be StringToCodePoints(str).
2. Let literal be ParseText(text, StringNumericLiteral).
3. If literal is a List of errors, return NaN.
4. Return StringNumericValue of literal.

7.1.4.1.2 Runtime Semantics: StringNumericValue

The syntax-directed operation StringNumericValue takes no arguments and returns a Number.

NOTE The conversion of a StringNumericLiteral to a Number value is similar overall to the determination of the NumericValue of a NumericLiteral (see 12.9.3), but some of the details are different.

It is defined piecewise over the following productions:

StringNumericLiteral :: StrWhiteSpaceopt

1. Return +0𝔽.

StringNumericLiteral :: StrWhiteSpaceopt StrNumericLiteral StrWhiteSpaceopt

1. Return StringNumericValue of StrNumericLiteral.

StrNumericLiteral :: NonDecimalIntegerLiteral

1. Return 𝔽(MV of NonDecimalIntegerLiteral).

StrDecimalLiteral :: - StrUnsignedDecimalLiteral

1. Let a be StringNumericValue of StrUnsignedDecimalLiteral.
2. If a is +0𝔽, return -0𝔽.

StrUnsignedDecimalLiteral :: Infinity

1. Return +∞𝔽.

StrUnsignedDecimalLiteral :: DecimalDigits . DecimalDigitsopt ExponentPartopt

1. Let a be MV of the first DecimalDigits.
2. If the second DecimalDigits is present, then
   a. Let b be MV of the second DecimalDigits.
   b. Let n be the number of code points in the second DecimalDigits.
3. Else,
   a. Let b be 0.
   b. Let n be 0.
4. If ExponentPart is present, let e be MV of ExponentPart. Otherwise, let e be 0.
5. Return RoundMVResult((a + (b × 10ⁿ)) × 10ⁿ).

StrUnsignedDecimalLiteral :: . DecimalDigits ExponentPartopt

1. Let b be MV of DecimalDigits.
2. If ExponentPart is present, let e be MV of ExponentPart. Otherwise, let e be 0.
3. Let \( n \) be the number of code points in \( \text{DecimalDigits} \).

4. Return \( \text{RoundMVResult}(b \times 10^{e - n}) \).

\[
\text{StrUnsignedDecimalLiteral} ::= \text{DecimalDigits} \, \text{ExponentPart}^{\text{opt}}
\]

1. Let \( a \) be MV of \( \text{DecimalDigits} \).

2. If \( \text{ExponentPart} \) is present, let \( e \) be MV of \( \text{ExponentPart} \). Otherwise, let \( e \) be 0.

3. Return \( \text{RoundMVResult}(a \times 10^{e}) \).

The abstract operation \( \text{RoundMVResult} \) takes argument \( n \) (a mathematical value) and returns a Number. It converts \( n \) to a Number in an implementation-defined manner. For the purposes of this abstract operation, a digit is significant if it is not zero or there is a non-zero digit to its left and there is a non-zero digit to its right. For the purposes of this abstract operation, "the mathematical value denoted by" a representation of a mathematical value is the inverse of "the decimal representation of" a mathematical value. It performs the following steps when called:

1. If the decimal representation of \( n \) has 20 or fewer significant digits, return \( \mathbb{F}(n) \).

2. Let \( \text{option1} \) be the mathematical value denoted by the result of replacing each significant digit in the decimal representation of \( n \) after the 20th with a 0 digit.

3. Let \( \text{option2} \) be the mathematical value denoted by the result of replacing each significant digit in the decimal representation of \( n \) after the 20th with a 0 digit and then incrementing it at the 20th position (with carrying as necessary).

4. Let \( \text{chosen} \) be an implementation-defined choice of either \( \text{option1} \) or \( \text{option2} \).

5. Return \( \mathbb{F}(\text{chosen}) \).

The abstract operation \( \text{ToIntegerOrInfinity} \) takes argument \( \text{argument} \) (an ECMAScript language value) and returns either a normal completion containing either an integer, \( +\infty \), or \( -\infty \), or a throw completion. It converts \( \text{argument} \) to an integer representing its Number value with fractional part truncated, or to \( +\infty \) or \( -\infty \) when that Number value is infinite. It performs the following steps when called:

1. Let \( \text{number} \) be \( \text{ToNumber}(\text{argument}) \).

2. If \( \text{number} \) is not finite or \( \text{number} \) is either \( +0 \mathbb{F} \) or \( -0 \mathbb{F} \), return \( +0 \mathbb{F} \).

3. If \( \text{number} \) is \( +\infty \mathbb{F} \), return \( +\infty \).

4. If \( \text{number} \) is \( -\infty \mathbb{F} \), return \( -\infty \).

5. Return \( \text{truncate}(\mathbb{R}(\text{number})) \).

**NOTE** \( \mathbb{F}(\text{ToIntegerOrInfinity}(x)) \) never returns \( -0 \mathbb{F} \) for any value of \( x \). The truncation of the fractional part is performed after converting \( x \) to a mathematical value.

The abstract operation \( \text{ToInt32} \) takes argument \( \text{argument} \) (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It converts \( \text{argument} \) to one of \( 2^{32} \) integral Number values in the inclusive interval from \( \mathbb{F}(-2^{31}) \) to \( \mathbb{F}(2^{31} \times 1) \). It performs the following steps when called:

1. Let \( \text{number} \) be \( \text{ToNumber}(\text{argument}) \).

2. If \( \text{number} \) is not finite or \( \text{number} \) is either \( +0 \mathbb{F} \) or \( -0 \mathbb{F} \), return \( +0 \mathbb{F} \).

3. Let \( \text{int} \) be \( \text{truncate}(\mathbb{R}(\text{number})) \).

4. Let \( \text{int32bit} \) be \( \text{int} \) modulo \( 2^{32} \).

5. If \( \text{int32bit} \geq 2^{31} \), return \( \mathbb{F}(\text{int32bit} \times 2^{32}) \); otherwise return \( \mathbb{F}(\text{int32bit}) \).
NOTE Given the above definition of ToInt32:

- The ToInt32 abstract operation is idempotent: if applied to a result that it produced, the second application leaves that value unchanged.
- ToInt32(ToInt32(x)) is the same value as ToInt32(x) for all values of x. (It is to preserve this latter property that \(+\infty F\) and \(-\infty F\) are mapped to \(+\infty F\).)
- ToInt32 maps \(-0 F\) to \(+0 F\).

### 7.1.7 ToUint32 (argument)

The abstract operation ToUint32 takes argument argument (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It converts argument to one of \(2^{32}\) integral Number values in the inclusive interval from \(+0 F\) to \(F(2^{32} - 1)\). It performs the following steps when called:

1. Let number be \(?\ ToNumber\(\text{(argument)}\).\)
2. If number is not finite or number is either \(+0 F\) or \(-0 F\), return \(+0 F\).
3. Let int be truncate(\(R\(\text{(number)}\)).\)
4. Let int32bit be int modulo \(2^{32}\).
5. Return \(F\(\text{(int32bit)}\).\)

NOTE Given the above definition of ToUint32:

- Step 5 is the only difference between ToUint32 and ToInt32.
- The ToUint32 abstract operation is idempotent: if applied to a result that it produced, the second application leaves that value unchanged.
- ToUint32(ToInt32(x)) is the same value as ToUint32(x) for all values of x. (It is to preserve this latter property that \(+\infty F\) and \(-\infty F\) are mapped to \(+\infty F\).)
- ToUint32 maps \(-0 F\) to \(+0 F\).

### 7.1.8 ToInt16 (argument)

The abstract operation ToInt16 takes argument argument (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It converts argument to one of \(2^{16}\) integral Number values in the inclusive interval from \(+0 F\) to \(F(2^{16} - 1)\). It performs the following steps when called:

1. Let number be \(?\ ToNumber\(\text{(argument)}\).\)
2. If number is not finite or number is either \(+0 F\) or \(-0 F\), return \(+0 F\).
3. Let int be truncate(\(R\(\text{(number)}\)).\)
4. Let int16bit be int modulo \(2^{16}\).
5. If int16bit \(\geq 2^{15}\), return \(\text{F(int16bit} - 2^{16})\); otherwise return \(\text{F(int16bit)}\).

### 7.1.9 ToUint16 (argument)

The abstract operation ToUint16 takes argument argument (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It converts argument to one of \(2^{16}\) integral Number values in the inclusive interval from \(+0 F\) to \(F(2^{16} - 1)\). It performs the following steps when called:

1. Let number be \(?\ ToNumber\(\text{(argument)}\).\)
2. If number is not finite or number is either \(+0 F\) or \(-0 F\), return \(+0 F\).
3. Let int be truncate(\(R\(\text{(number)}\)).\)
4. Let \( \text{int16bit} \) be \( \text{int} \mod 2^{16} \).
5. Return \( \mathbb{F}(\text{int16bit}) \).

**NOTE**
Given the above definition of ToUint16:

- The substitution of \( 2^{16} \) for \( 2^{32} \) in step 4 is the only difference between ToUint32 and ToUint16.
- ToUint16 maps \( -0 \mathbb{F} \) to \( +0 \mathbb{F} \).

### 7.1.10 ToInt8 (argument)

The abstract operation ToInt8 takes argument \( \text{argument} \) (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It converts \( \text{argument} \) to one of \( 2^8 \) integral Number values in the inclusive interval from \( -128 \mathbb{F} \) to \( 127 \mathbb{F} \). It performs the following steps when called:

1. Let \( \text{number} \) be \( \text{ToNumber}(\text{argument}) \).
2. If \( \text{number} \) is not finite or \( \text{number} \) is either \( +0 \mathbb{F} \) or \( -0 \mathbb{F} \), return \( +0 \mathbb{F} \).
3. Let \( \text{int} \) be \( \text{truncate}(\mathbb{R}(\text{number})) \).
4. Let \( \text{int8bit} \) be \( \text{int} \mod 2^8 \).
5. If \( \text{int8bit} \geq 2^7 \), return \( \mathbb{F}(\text{int8bit} - 2^8) \); otherwise return \( \mathbb{F}(\text{int8bit}) \).

### 7.1.11 ToUint8 (argument)

The abstract operation ToUint8 takes argument \( \text{argument} \) (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It converts \( \text{argument} \) to one of \( 2^8 \) integral Number values in the inclusive interval from \( +0 \mathbb{F} \) to \( 255 \mathbb{F} \). It performs the following steps when called:

1. Let \( \text{number} \) be \( \text{ToNumber}(\text{argument}) \).
2. If \( \text{number} \) is not finite or \( \text{number} \) is either \( +0 \mathbb{F} \) or \( -0 \mathbb{F} \), return \( +0 \mathbb{F} \).
3. Let \( \text{int} \) be \( \text{truncate}(\mathbb{R}(\text{number})) \).
4. Let \( \text{int8bit} \) be \( \text{int} \mod 2^8 \).
5. Return \( \mathbb{F}(\text{int8bit}) \).

### 7.1.12 ToUint8Clamp (argument)

The abstract operation ToUint8Clamp takes argument \( \text{argument} \) (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It clamps and rounds \( \text{argument} \) to one of \( 2^8 \) integral Number values in the inclusive interval from \( +0 \mathbb{F} \) to \( 255 \mathbb{F} \). It performs the following steps when called:

1. Let \( \text{number} \) be \( \text{ToNumber}(\text{argument}) \).
2. If \( \text{number} \) is \( \text{NaN} \), return \( +0 \mathbb{F} \).
3. Let \( \text{mv} \) be the extended mathematical value of \( \text{number} \).
4. Let \( \text{clamped} \) be the result of clamping \( \text{mv} \) between \( 0 \) and \( 255 \).
5. Let \( f \) be \( \text{floor}(\text{clamped}) \).
6. If \( \text{clamped} < f + 0.5 \), return \( \mathbb{F}(f) \).
7. If \( \text{clamped} > f + 0.5 \), return \( \mathbb{F}(f + 1) \).
8. If \( f \) is even, return \( \mathbb{F}(f) \). Otherwise, return \( \mathbb{F}(f + 1) \).

**NOTE**
Unlike most other ECMAScript integer conversion operations, ToUint8Clamp rounds rather than truncates non-integral values. It also uses “round half to even” tie-breaking, which differs from the “round half up” tie-breaking of \( \text{Math} . \text{round} \).
7.1.13 ToBigInt (argument)

The abstract operation ToBigInt takes argument argument (an ECMAScript language value) and returns either a normal completion containing a BigInt or a throw completion. It converts argument to a BigInt value, or throws if an implicit conversion from Number would be required. It performs the following steps when called:

1. Let prim be ? ToPrimitive(argument, NUMBER).
2. Return the value that prim corresponds to in Table 12.

Table 12: BigInt Conversions

<table>
<thead>
<tr>
<th>Argument Type</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undefined</td>
<td>Throw a TypeError exception.</td>
</tr>
<tr>
<td>Null</td>
<td>Throw a TypeError exception.</td>
</tr>
<tr>
<td>Boolean</td>
<td>Return 1n if prim is true and 0n if prim is false.</td>
</tr>
<tr>
<td>BigInt</td>
<td>Return prim.</td>
</tr>
<tr>
<td>Number</td>
<td>Throw a TypeError exception.</td>
</tr>
</tbody>
</table>
| String        | 1. Let n be StringToBigInt(prim).  
                  2. If n is undefined, throw a SyntaxError exception.  
                  3. Return n. |
| Symbol        | Throw a TypeError exception. |

7.1.14 StringToBigInt (str)

The abstract operation StringToBigInt takes argument str (a String) and returns a BigInt or undefined. It performs the following steps when called:

1. Let text be StringToCodePoints(str).
2. Let literal be ParseText(text, StringIntegerLiteral).
3. If literal is a List of errors, return undefined.
4. Let mv be the MV of literal.
5. Assert: mv is an integer.
6. Return ℤ(mv).

7.1.14.1 StringIntegerLiteral Grammar

StringToBigInt uses the following grammar.

Syntax

\[
\text{StringIntegerLiteral} ::= \\
\text{StrWhiteSpace}^{\text{opt}} \\
\text{StrIntegerLiteral} \text{ StrWhiteSpace}^{\text{opt}}
\]

\[
\text{StrIntegerLiteral} ::= \\
\text{SignedInteger}[^\text{Sep}] \\
\text{NonDecimalIntegerLiteral}[^\text{Sep}]
\]
7.1.14.2 Runtime Semantics: MV

- The MV of `StringIntegerLiteral :: StrWhiteSpace opt` is 0.
- The MV of `StringIntegerLiteral :: StrWhiteSpace opt IntegerLiteral StrWhiteSpace opt` is the MV of `StrIntegerLiteral`.

7.1.15 ToBigInt64 (argument)

The abstract operation `ToBigInt64` takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing a BigInt or a throw completion. It converts `argument` to one of $2^{64}$ BigInt values in the inclusive interval from $\mathbb{Z}(-2^{63})$ to $\mathbb{Z}(2^{63} - 1)$. It performs the following steps when called:

1. Let \( n \) be \( ? \) `ToBigInt(argument)`.
2. Let \( \text{int64bit} \) be \( \mathbb{R}(n) \) modulo \( 2^{64} \).
3. If \( \text{int64bit} \geq 2^{63} \), return \( \mathbb{Z}(\text{int64bit} - 2^{64}) \); otherwise return \( \mathbb{Z}(\text{int64bit}) \).

7.1.16 ToBigUint64 (argument)

The abstract operation `ToBigUint64` takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing a BigUint or a throw completion. It converts `argument` to one of $2^{64}$ BigUint values in the inclusive interval from \( 0 \) to \( \mathbb{Z}(2^{64} - 1) \). It performs the following steps when called:

1. Let \( n \) be \( ? \) `ToBigInt(argument)`.
2. Let \( \text{int64bit} \) be \( \mathbb{R}(n) \) modulo \( 2^{64} \).
3. Return \( \mathbb{Z}(\text{int64bit}) \).

7.1.17 ToString (argument)

The abstract operation `ToString` takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing a String or a throw completion. It converts `argument` to a value of type String. It performs the following steps when called:

1. If `argument` is a String, return `argument`.
2. If `argument` is a Symbol, throw a `TypeError` exception.
3. If `argument` is `undefined`, return "undefined".
4. If `argument` is `null`, return "null".
5. If `argument` is `true`, return "true".
6. If `argument` is `false`, return "false".
7. If `argument` is a Number, return `Number::toString(argument, 10)`.
8. If `argument` is a BigInt, return `BigInt::toString(argument, 10)`.
9. Assert: `argument` is an Object.
10. Let `primValue` be \( ? \) `ToPrimitive(argument, STRING)`.
11. Assert: `primValue` is not an Object.
12. Return \( ? \) `ToString(primValue)`.

7.1.18 ToObject (argument)

The abstract operation `ToObject` takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing an Object or a throw completion. It converts `argument` to a value of type Object according to Table 13:
Table 13: **ToObject** Conversions

<table>
<thead>
<tr>
<th>Argument Type</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undefined</td>
<td>Throw a <strong>TypeError</strong> exception.</td>
</tr>
<tr>
<td>Null</td>
<td>Throw a <strong>TypeError</strong> exception.</td>
</tr>
<tr>
<td>Boolean</td>
<td>Return a new Boolean object whose [[BooleanData]] internal slot is set to <code>argument</code>. See 20.3 for a description of Boolean objects.</td>
</tr>
<tr>
<td>Number</td>
<td>Return a new Number object whose [[NumberData]] internal slot is set to <code>argument</code>. See 21.1 for a description of Number objects.</td>
</tr>
<tr>
<td>String</td>
<td>Return a new String object whose [[StringData]] internal slot is set to <code>argument</code>. See 22.1 for a description of String objects.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Return a new Symbol object whose [[SymbolData]] internal slot is set to <code>argument</code>. See 20.4 for a description of Symbol objects.</td>
</tr>
<tr>
<td>BigInt</td>
<td>Return a new BigInt object whose [[BigIntData]] internal slot is set to <code>argument</code>. See 21.2 for a description of BigInt objects.</td>
</tr>
<tr>
<td>Object</td>
<td>Return <code>argument</code>.</td>
</tr>
</tbody>
</table>

7.1.19 **ToPropertyKey** ( `argument` )

The abstract operation ToPropertyKey takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing a property key or a throw completion. It converts `argument` to a value that can be used as a property key. It performs the following steps when called:

1. Let `key` be ? `ToPrimitive(argument, STRING)`. 
2. If `key` is a Symbol, then 
   a. Return `key`. 
3. Return ! `ToString(key)`. 

7.1.20 **ToLength** ( `argument` )

The abstract operation ToLength takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing an integral Number or a throw completion. It clamps and truncates `argument` to an integral Number suitable for use as the length of an array-like object. It performs the following steps when called:

1. Let `len` be ? `ToIntegerOrInfinity(argument)`. 
2. If `len` ≤ 0, return +0𝔽. 
3. Return  𝔽(\text{min}(len, 2^{53} - 1)). 

7.1.21 **CanonicalNumericIndexString** ( `argument` )

The abstract operation CanonicalNumericIndexString takes argument `argument` (a String) and returns a Number or undefined. If `argument` is either "-0" or exactly matches the result of `ToString(n)` for some Number value `n`, it returns the respective Number value. Otherwise, it returns `undefined`. It performs the following steps when called:

1. If `argument` is "-0", return -0𝔽. 
2. Let `n` be ! `ToNumber(argument)`. 
3. If ! `ToString(n)` is `argument`, return `n`. 
4. Return `undefined`. 

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A canonical numeric string is any String value for which the CanonicalNumericIndexString abstract operation does not return undefined.

7.1.22 ToIndex (value)

The abstract operation ToIndex takes argument value (an ECMAScript language value) and returns either a normal completion containing a non-negative integer or a throw completion. It converts value to an integer and returns that integer if it is non-negative and corresponds with an integer index. Otherwise, it throws an exception. It performs the following steps when called:

1. Let integer be ToIntegerOrInfinity(value).
2. If integer is not in the inclusive interval from 0 to $2^{53} - 1$, throw a RangeError exception.
3. Return integer.

7.2 Testing and Comparison Operations

7.2.1 RequireObjectCoercible (argument)

The abstract operation RequireObjectCoercible takes argument argument (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It throws an error if argument is a value that cannot be converted to an Object using ToObject. It is defined by Table 14:

<table>
<thead>
<tr>
<th>Argument Type</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undefined</td>
<td>Throw a TypeError exception.</td>
</tr>
<tr>
<td>Null</td>
<td>Throw a TypeError exception.</td>
</tr>
<tr>
<td>Boolean</td>
<td>Return argument.</td>
</tr>
<tr>
<td>Number</td>
<td>Return argument.</td>
</tr>
<tr>
<td>String</td>
<td>Return argument.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Return argument.</td>
</tr>
<tr>
<td>BigInt</td>
<td>Return argument.</td>
</tr>
<tr>
<td>Object</td>
<td>Return argument.</td>
</tr>
</tbody>
</table>

7.2.2 IsArray (argument)

The abstract operation IsArray takes argument argument (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If argument is not an Object, return false.
2. If argument is an Array exotic object, return true.
3. If argument is a Proxy exotic object, then
   b. Let proxyTarget be argument.[[ProxyTarget]].
4. Return false.
7.2.3 IsCallable (argument)

The abstract operation IsCallable takes argument `argument` (an ECMAScript language value) and returns a Boolean. It determines if `argument` is a callable function with a `[[Call]]` internal method. It performs the following steps when called:

1. If `argument` is not an Object, return false.
2. If `argument` has a `[[Call]]` internal method, return true.
3. Return false.

7.2.4 IsConstructor (argument)

The abstract operation IsConstructor takes argument `argument` (an ECMAScript language value) and returns a Boolean. It determines if `argument` is a function object with a `[[Construct]]` internal method. It performs the following steps when called:

1. If `argument` is not an Object, return false.
2. If `argument` has a `[[Construct]]` internal method, return true.
3. Return false.

7.2.5 IsExtensible (O)

The abstract operation IsExtensible takes argument `O` (an Object) and returns either a normal completion containing a Boolean or a throw completion. It is used to determine whether additional properties can be added to `O`. It performs the following steps when called:

1. Return ? `O`.[[IsExtensible]]().

7.2.6 IsIntegralNumber (argument)

The abstract operation IsIntegralNumber takes argument `argument` (an ECMAScript language value) and returns a Boolean. It determines if `argument` is a finite integral Number value. It performs the following steps when called:

1. If `argument` is not a Number, return false.
2. If `argument` is not finite, return false.
3. If truncate(ℝ(`argument`)) ≠ ℝ(`argument`), return false.
4. Return true.

7.2.7 IsPropertyKey (argument)

The abstract operation IsPropertyKey takes argument `argument` (an ECMAScript language value) and returns a Boolean. It determines if `argument` is a value that may be used as a property key. It performs the following steps when called:

1. If `argument` is a String, return true.
2. If `argument` is a Symbol, return true.
3. Return false.

7.2.8 IsRegExp (argument)

The abstract operation IsRegExp takes argument `argument` (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If `argument` is not an Object, return false.
2. Let matcher be ? Get(`argument`, @@match).
3. If `matcher` is not undefined, return ToBoolean(`matcher`).
4. If `argument` has a `[[RegExpMatcher]]` internal slot, return true.
5. Return false.
The abstract operation IsStringWellFormedUnicode takes argument string (a String) and returns a Boolean. It interprets string as a sequence of UTF-16 encoded code points, as described in 6.1.4, and determines whether it is a well formed <http://www.unicode.org/glossary/#well_formed_code_unit_sequence> UTF-16 sequence. It performs the following steps when called:

1. Let len be the length of string.
2. Let k be 0.
3. Repeat, while k < len,
   a. Let cp be CodePointAt(string, k).
   b. If cp.[[IsUnpairedSurrogate]] is true, return false.
   c. Set k to k + cp.[[CodeUnitCount]].
4. Return true.

The abstract operation SameValue takes arguments x (an ECMAScript language value) and y (an ECMAScript language value) and returns a Boolean. It determines whether or not the two arguments are the same value. It performs the following steps when called:

1. If Type(x) is not Type(y), return false.
2. If x is a Number, then
   a. Return Number::sameValue(x, y).
3. Return SameValueNonNumber(x, y).

NOTE This algorithm differs from the IsStrictEqual Algorithm by treating all NaN values as equivalent and by differentiating +0_F from -0_F.

The abstract operation SameValueZero takes arguments x (an ECMAScript language value) and y (an ECMAScript language value) and returns a Boolean. It determines whether or not the two arguments are the same value (ignoring the difference between +0_F and -0_F). It performs the following steps when called:

1. If Type(x) is not Type(y), return false.
2. If x is a Number, then
   a. Return Number::sameValueZero(x, y).
3. Return SameValueNonNumber(x, y).

NOTE SameValueZero differs from SameValue only in that it treats +0_F and -0_F as equivalent.

The abstract operation SameValueNonNumber takes arguments x (an ECMAScript language value, but not a Number) and y (an ECMAScript language value, but not a Number) and returns a Boolean. It performs the following steps when called:

1. Assert: Type(x) is Type(y).
2. If x is either null or undefined, return true.
3. If x is a BigInt, then
   a. Return BigInt::equal(x, y).
4. If x is a String, then
   a. If x and y have the same length and the same code units in the same positions, return true; otherwise, return false.
5. If \( x \) is a Boolean, then
   a. If \( x \) and \( y \) are both \( \text{true} \) or both \( \text{false} \), return \( \text{true} \); otherwise, return \( \text{false} \).
6. NOTE: All other ECMAScript language values are compared by identity.
7. If \( x \) is \( y \), return \( \text{true} \); otherwise, return \( \text{false} \).

**NOTE 1** For expository purposes, some cases are handled separately within this algorithm even if it is unnecessary to do so.

**NOTE 2** The specifics of what "\( x \) is \( y \)" means are detailed in 5.2.7.

### 7.2.13 IsLessThan ( \( x, y, \text{LeftFirst} \) )

The abstract operation IsLessThan takes arguments \( x \) (an ECMAScript language value), \( y \) (an ECMAScript language value), and \( \text{LeftFirst} \) (a Boolean) and returns either a normal completion containing either a Boolean or undefined, or a throw completion. It provides the semantics for the comparison \( x < y \), returning true, false, or undefined (which indicates that at least one operand is NaN). The \( \text{LeftFirst} \) flag is used to control the order in which operations with potentially visible side-effects are performed upon \( x \) and \( y \). It is necessary because ECMAScript specifies left to right evaluation of expressions. If \( \text{LeftFirst} \) is true, the \( x \) parameter corresponds to an expression that occurs to the left of the \( y \) parameter's corresponding expression. If \( \text{LeftFirst} \) is false, the reverse is the case and operations must be performed upon \( y \) before \( x \). It performs the following steps when called:

1. If \( \text{LeftFirst} \) is true, then
   a. Let \( px \) be \( \text{ToPrimitive}(x, \text{NUMBER}) \).
   b. Let \( py \) be \( \text{ToPrimitive}(y, \text{NUMBER}) \).
2. Else,
   a. NOTE: The order of evaluation needs to be reversed to preserve left to right evaluation.
   b. Let \( py \) be \( \text{ToPrimitive}(y, \text{NUMBER}) \).
   c. Let \( px \) be \( \text{ToPrimitive}(x, \text{NUMBER}) \).
3. If \( px \) is a String and \( py \) is a String, then
   a. Let \( lx \) be the length of \( px \).
   b. Let \( ly \) be the length of \( py \).
   c. For each integer \( i \) such that \( 0 \leq i < \min(lx, ly) \), in ascending order, do
      i. Let \( cx \) be the numeric value of the code unit at index \( i \) within \( px \).
      ii. Let \( cy \) be the numeric value of the code unit at index \( i \) within \( py \).
      iii. If \( cx < cy \), return true.
      iv. If \( cx > cy \), return false.
   d. If \( lx < ly \), return true. Otherwise, return false.
4. Else,
   a. If \( px \) is a BigInt and \( py \) is a String, then
      i. Let \( ny \) be \( \text{StringToBigInt}(py) \).
      ii. If \( ny \) is undefined, return undefined.
      iii. Return BigInt::lessThan(\( px, ny \)).
   b. If \( px \) is a String and \( py \) is a BigInt, then
      i. Let \( nx \) be \( \text{StringToBigInt}(px) \).
      ii. If \( nx \) is undefined, return undefined.
      iii. Return BigInt::lessThan(\( nx, py \)).
   c. NOTE: Because \( px \) and \( py \) are primitive values, evaluation order is not important.
   d. Let \( nx \) be \( \text{ToNumeric}(px) \).
   e. Let \( ny \) be \( \text{ToNumeric}(py) \).
   f. If Type(\( nx \)) is Type(\( ny \)), then
      i. If \( nx \) is a Number, then
         1. Return Number::lessThan(\( nx, ny \)).
      ii. Else,
         1. Assert: \( nx \) is a BigInt.
         2. Return BigInt::lessThan(\( nx, ny \)).
   g. Assert: \( nx \) is a BigInt and \( ny \) is a Number, or \( nx \) is a Number and \( ny \) is a BigInt.
   h. If \( nx \) or \( ny \) is NaN, return undefined.
   i. If \( nx \) is -\( \infty \) or \( ny \) is +\( \infty \), return true.
j. If \( nx \) is \( +\infty \) or \( ny \) is \( -\infty \), return \textit{false}.

k. If \( \mathbb{R}(nx) < \mathbb{R}(ny) \), return \textit{true}; otherwise return \textit{false}.

\[ \text{If} \]

\[ \text{If} \]

\[ \text{If} \]

\[ \text{If} \]

\[ \text{If} \]

\[ \text{If} \]

\[ \text{If} \]

NOTE 1  Step 3 differs from step 1.c in the algorithm that handles the addition operator \(+ (13.15.3)\) by using the logical-and operation instead of the logical-or operation.

NOTE 2  The comparison of Strings uses a simple lexicographic ordering on sequences of UTF-16 code unit values. There is no attempt to use the more complex, semantically oriented definitions of character or string equality and collating order defined in the Unicode specification. Therefore String values that are canonically equal according to the Unicode Standard but not in the same normalization form could test as unequal. Also note that lexicographic ordering by \textit{code unit} differs from ordering by \textit{code point} for Strings containing surrogate pairs.

7.2.14 \textit{IsLooselyEqual} ( \( x, y \) )

The abstract operation \textit{IsLooselyEqual} takes arguments \( x \) (an ECMAScript language value) and \( y \) (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It provides the semantics for the == operator. It performs the following steps when called:

1. If \textit{Type}(\( x \)) is \textit{Type}(\( y \)), then
   a. Return \textit{IsStrictlyEqual}(\( x, y \)).
2. If \( x \) is \textit{null} and \( y \) is \textit{undefined}, return \textit{true}.
3. If \( x \) is \textit{undefined} and \( y \) is \textit{null}, return \textit{true}.
4. NOTE: This step is replaced in section B.3.6.2.
5. If \( x \) is a \textit{Number} and \( y \) is a \textit{String}, return \( \neg \textit{IsLooselyEqual}(x, \text{\texttt{ToNumber}}(y)) \).
6. If \( x \) is a \textit{String} and \( y \) is a \textit{Number}, return \( \neg \textit{IsLooselyEqual}(\text{\texttt{ToNumber}}(x), y) \).
7. If \( x \) is a \textit{BigInt} and \( y \) is a \textit{String}, then
   a. Let \( n \) be \textit{StringToBigInt}(\( y \)).
   b. If \( n \) is \textit{undefined}, return \textit{false}.
   c. Return \( \neg \textit{IsLooselyEqual}(x, n) \).
8. If \( x \) is a \textit{String} and \( y \) is a \textit{BigInt}, return \( \neg \textit{IsLooselyEqual}(y, x) \).
9. If \( x \) is a \textit{Boolean}, return \( \neg \textit{IsLooselyEqual}(\text{\texttt{ToNumber}}(x), y) \).
10. If \( y \) is a \textit{Boolean}, return \( \neg \textit{IsLooselyEqual}(x, \text{\texttt{ToNumber}}(y)) \).
11. If \( x \) is either a \textit{String}, a \textit{Number}, a \textit{BigInt}, or a \textit{Symbol} and \( y \) is an \textit{Object}, return \( \neg \textit{IsLooselyEqual}(x, \text{\texttt{ToPrimitive}}(y)) \).
12. If \( x \) is an \textit{Object} and \( y \) is either a \textit{String}, a \textit{Number}, a \textit{BigInt}, or a \textit{Symbol}, return \( \neg \textit{IsLooselyEqual}(\text{\texttt{ToPrimitive}}(x), y) \).
13. If \( x \) is a \textit{BigInt} and \( y \) is a \textit{Number}, or if \( x \) is a \textit{Number} and \( y \) is a \textit{BigInt}, then
   a. If \( x \) is not \textit{finite} or \( y \) is not \textit{finite}, return \textit{false}.
   b. If \( \mathbb{R}(x) = \mathbb{R}(y) \), return \textit{true}; otherwise return \textit{false}.
14. Return \textit{false}.

7.2.15 \textit{IsStrictlyEqual} ( \( x, y \) )

The abstract operation \textit{IsStrictlyEqual} takes arguments \( x \) (an ECMAScript language value) and \( y \) (an ECMAScript language value) and returns a \textit{Boolean}. It provides the semantics for the === operator. It performs the following steps when called:

1. If \textit{Type}(\( x \)) is not \textit{Type}(\( y \)), return \textit{false}.
2. If \( x \) is a \textit{Number}, then
   a. Return \textit{Number::equal}(\( x, y \)).
3. Return \textit{SameValueNonNumber}(\( x, y \)).

NOTE  This algorithm differs from the \textit{SameValue} Algorithm in its treatment of signed zeroes and NaNs.
7.3 Operations on Objects

7.3.1 MakeBasicObject (internalSlotsList)

The abstract operation MakeBasicObject takes argument internalSlotsList (a List of internal slot names) and returns an Object. It is the source of all ECMAScript objects that are created algorithmically, including both ordinary objects and exotic objects. It factors out common steps used in creating all objects, and centralizes object creation. It performs the following steps when called:

1. Let obj be a newly created object with an internal slot for each name in internalSlotsList.
2. Set obj's essential internal methods to the default ordinary object definitions specified in 10.1.
3. Assert: If the caller will not be overriding both obj's [[GetPrototypeOf]] and [[SetPrototypeOf]] essential internal methods, then internalSlotsList contains [[Prototype]].
4. Assert: If the caller will not be overriding all of obj's [[SetPrototypeOf]], [[IsExtensible]], and [[PreventExtensions]] essential internal methods, then internalSlotsList contains [[Extensible]].
5. If internalSlotsList contains [[Extensible]], set obj.[[Extensible]] to true.
6. Return obj.

NOTE Within this specification, exotic objects are created in abstract operations such as ArrayCreate and BoundFunctionCreate by first calling MakeBasicObject to obtain a basic, foundational object, and then overriding some or all of that object's internal methods. In order to encapsulate exotic object creation, the object's essential internal methods are never modified outside those operations.

7.3.2 Get (O, P)

The abstract operation Get takes arguments O (an Object) and P (a property key) and returns either a normal completion containing an ECMAScript language value or a throw completion. It is used to retrieve the value of a specific property of an object. It performs the following steps when called:


7.3.3 GetV (V, P)

The abstract operation GetV takes arguments V (an ECMAScript language value) and P (a property key) and returns either a normal completion containing an ECMAScript language value or a throw completion. It is used to retrieve the value of a specific property of an ECMAScript language value. If the value is not an object, the property lookup is performed using a wrapper object appropriate for the type of the value. It performs the following steps when called:

1. Let O be ?ToObject(V).

7.3.4 Set (O, P, V, Throw)

The abstract operation Set takes arguments O (an Object), P (a property key), V (an ECMAScript language value), and Throw (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It is used to set the value of a specific property of an object. V is the new value for the property. It performs the following steps when called:

2. If success is false and Throw is true, throw a TypeError exception.
3. Return UNUSED.
7.3.5 CreateDataProperty (O, P, V)

The abstract operation CreateDataProperty takes arguments O (an Object), P (a property key), and V (an ECMA-Script language value) and returns either a normal completion containing a Boolean or a throw completion. It is used to create a new own property of an object. It performs the following steps when called:

1. Let newDesc be the PropertyDescriptor { [[Value]]: V, [[Writable]]: true, [[Enumerable]]: true, [[Configurable]]: true }.
2. Return O.!![DefineOwnProperty](P, newDesc).

**NOTE** This abstract operation creates a property whose attributes are set to the same defaults used for properties created by the ECMAScript language assignment operator. Normally, the property will not already exist. If it does exist and is not configurable or if O is not extensible, !![DefineOwnProperty] will return false.

7.3.6 CreateDataPropertyOrThrow (O, P, V)

The abstract operation CreateDataPropertyOrThrow takes arguments O (an Object), P (a property key), and V (an ECMA-Script language value) and returns either a normal completion containing UNUSED or a throw completion. It is used to create a new own property of an object. It throws a TypeError exception if the requested property update cannot be performed. It performs the following steps when called:

2. If success is false, throw a TypeError exception.
3. Return UNUSED.

**NOTE** This abstract operation creates a property whose attributes are set to the same defaults used for properties created by the ECMAScript language assignment operator. Normally, the property will not already exist. If it does exist and is not configurable or if O is not extensible, !![DefineOwnProperty] will return false causing this operation to throw a TypeError exception.

7.3.7 CreateNonEnumerableDataPropertyOrThrow (O, P, V)

The abstract operation CreateNonEnumerableDataPropertyOrThrow takes arguments O (an Object), P (a property key), and V (an ECMA-Script language value) and returns UNUSED. It is used to create a new non-enumerable own property of an ordinary object. It performs the following steps when called:

1. Assert: O is an ordinary, extensible object with no non-configurable properties.
2. Let newDesc be the PropertyDescriptor { [[Value]]: V, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }.
3. Perform !![DefinePropertyOrThrow](O, P, newDesc).
4. Return UNUSED.

**NOTE** This abstract operation creates a property whose attributes are set to the same defaults used for properties created by the ECMAScript language assignment operator except it is not enumerable. Normally, the property will not already exist. If it does exist, !![DefinePropertyOrThrow] is guaranteed to complete normally.
7.3.8 DefinePropertyOrThrow \((O, P, desc)\)

The abstract operation DefinePropertyOrThrow takes arguments \(O\) (an Object), \(P\) (a property key), and \(desc\) (a Property Descriptor) and returns either a normal completion containing UNUSED or a throw completion. It is used to call the [[DefineOwnProperty]] internal method of an object in a manner that will throw a TypeError exception if the requested property update cannot be performed. It performs the following steps when called:

1. Let \(success\) be \(O.\[[\text{DefineOwnProperty}]\](P, desc).
2. If \(success\) is false, throw a TypeError exception.
3. Return UNUSED.

7.3.9 DeletePropertyOrThrow \((O, P)\)

The abstract operation DeletePropertyOrThrow takes arguments \(O\) (an Object) and \(P\) (a property key) and returns either a normal completion containing UNUSED or a throw completion. It is used to remove a specific own property of an object. It throws an exception if the property is not configurable. It performs the following steps when called:

1. Let \(success\) be \(O.\[[\text{Delete}]\](P).
2. If \(success\) is false, throw a TypeError exception.
3. Return UNUSED.

7.3.10 GetMethod \((V, P)\)

The abstract operation GetMethod takes arguments \(V\) (an ECMAScript language value) and \(P\) (a property key) and returns either a normal completion containing either a function object or undefined, or a throw completion. It is used to get the value of a specific property of an ECMAScript language value when the value of the property is expected to be a function. It performs the following steps when called:

1. Let \(func\) be \(\text{GetV}(V, P)\).
2. If \(func\) is either undefined or null, return undefined.
3. If IsCallable\((func)\) is false, throw a TypeError exception.
4. Return \(func\).

7.3.11 HasProperty \((O, P)\)

The abstract operation HasProperty takes arguments \(O\) (an Object) and \(P\) (a property key) and returns either a normal completion containing a Boolean or a throw completion. It is used to determine whether an object has a property with the specified property key. The property may be either own or inherited. It performs the following steps when called:

1. Return \(O.\[[\text{HasProperty}]\](P)\).

7.3.12 HasOwnProperty \((O, P)\)

The abstract operation HasOwnProperty takes arguments \(O\) (an Object) and \(P\) (a property key) and returns either a normal completion containing a Boolean or a throw completion. It is used to determine whether an object has an own property with the specified property key. It performs the following steps when called:

1. Let \(desc\) be \(O.\[[\text{GetProperty}]\](P)\).
2. If \(desc\) is undefined, return false.
3. Return true.

7.3.13 Call \((F, V [ , argumentsList ] )\)

The abstract operation Call takes arguments \(F\) (an ECMAScript language value) and \(V\) (an ECMAScript language value) and optional argument \(argumentsList\) (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion. It is used to call the [[Call]] internal
method of a function object. \( F \) is the function object, \( V \) is an ECMAScript language value that is the this value of the \([\text{Call}]\), and \( \text{argumentsList} \) is the value passed to the corresponding argument of the internal method. If \( \text{argumentsList} \) is not present, a new empty List is used as its value. It performs the following steps when called:

1. If \( \text{argumentsList} \) is not present, set \( \text{argumentsList} \) to a new empty List.
2. If \( \text{isCallable}(F) \) is false, throw a TypeError exception.
3. Return \( F.[[\text{Call}]](V, \text{argumentsList}) \).

7.3.14 \textbf{Construct} ( \( F \), \( \text{argumentsList} \), \( \text{newTarget} \) )

The abstract operation Construct takes argument \( F \) (a constructor) and optional arguments \( \text{argumentsList} \) (a List of ECMAScript language values) and \( \text{newTarget} \) (a constructor) and returns either a normal completion containing an Object or a throw completion. It is used to call the \([\text{Construct}]\) internal method of a function object. \( \text{argumentsList} \) and \( \text{newTarget} \) are the values to be passed as the corresponding arguments of the internal method. If \( \text{argumentsList} \) is not present, a new empty List is used as its value. If \( \text{newTarget} \) is not present, \( F \) is used as its value. It performs the following steps when called:

1. If \( \text{newTarget} \) is not present, set \( \text{newTarget} \) to \( F \).
2. If \( \text{argumentsList} \) is not present, set \( \text{argumentsList} \) to a new empty List.
3. Return \( F.[[\text{Construct}]](\text{argumentsList}, \text{newTarget}) \).

\textbf{NOTE} If \( \text{newTarget} \) is not present, this operation is equivalent to: \text{new} \( F(...)\text{argumentsList} \)

7.3.15 \textbf{SetIntegrityLevel} ( \( O \), \( level \) )

The abstract operation SetIntegrityLevel takes arguments \( O \) (an Object) and \( level \) (SEALED or FROZEN) and returns either a normal completion containing a Boolean or a throw completion. It is used to fix the set of own properties of an object. It performs the following steps when called:

1. Let \( \text{status} \) be \( O.[[\text{PreventExtensions}]]() \).
2. If \( \text{status} \) is false, return false.
3. Let \( \text{keys} \) be \( O.[[\text{OwnPropertyKeys}]]() \).
4. If \( level \) is SEALED, then
   a. For each element \( k \) of \( \text{keys} \), do
      i. Perform ? \text{DefinePropertyOrThrow}(O, k, \text{PropertyDescriptor} { [[\text{Configurable}]]: false })

5. Else,
   a. Assert: \( level \) is FROZEN.
   b. For each element \( k \) of \( \text{keys} \), do
      i. Let \( \text{currentDesc} \) be \( O.[[\text{GetOwnProperty}]](k) \).
      ii. If \( \text{currentDesc} \) is not undefined, then
         1. If \( \text{IsAccessorDescriptor}(\text{currentDesc}) \) is true, then
            a. Let \( \text{desc} \) be the \text{PropertyDescriptor} { [[\text{Configurable}]]: false }
         2. Else,
            a. Let \( \text{desc} \) be the \text{PropertyDescriptor} { [[\text{Configurable}]]: false, [[\text{Writable}]]: false }
         3. Perform ? \text{DefinePropertyOrThrow}(O, k, \text{desc})

6. Return true.

7.3.16 \textbf{TestIntegrityLevel} ( \( O \), \( level \) )

The abstract operation TestIntegrityLevel takes arguments \( O \) (an Object) and \( level \) (SEALED or FROZEN) and returns either a normal completion containing a Boolean or a throw completion. It is used to determine if the set of own properties of an object are fixed. It performs the following steps when called:

1. Let \( \text{extensible} \) be \( \text{IsExtensible}(O) \).
2. If \( \text{extensible} \) is true, return false.
3. NOTE: If the object is extensible, none of its properties are examined.
4. Let \( \text{keys} \) be \( O.[[\text{OwnPropertyKeys}]]() \).
5. For each element \( k \) of \( \text{keys} \), do

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a. Let `currentDesc` be `O.[[GetOwnProperty]](k)`.
b. If `currentDesc` is not `undefined`, then
   i. If `currentDesc.[[Configurable]]` is `true`, return `false`.
      ii. If `level` is `FROZEN` and `IsDataDescriptor(currentDesc)` is `true`, then
          1. If `currentDesc.[[Writable]]` is `true`, return `false`.
   6. Return `true`.

7.3.17 CreateArrayFromList ( `elements` )

The abstract operation CreateArrayFromList takes argument `elements` (a List of ECMAScript language values) and returns an Array. It is used to create an Array whose elements are provided by `elements`. It performs the following steps when called:

1. Let `array` be `ArrayCreate(0)`.
2. Let `n` be `0`.
3. For each element `e` of `elements`, do
   a. Perform `CreateDataPropertyOrThrow(array, !ToString(𝔽(n)), e)`.
   b. Set `n` to `n + 1`.
4. Return `array`.

7.3.18 LengthOfArrayLike ( `obj` )

The abstract operation LengthOfArrayLike takes argument `obj` (an Object) and returns either a normal completion containing a non-negative integer or a throw completion. It returns the value of the "length" property of an array-like object. It performs the following steps when called:

1. Return `ℝ(? ToLength(? Get(obj, "length")))`.

An array-like object is any object for which this operation returns a normal completion.

NOTE 1 Typically, an array-like object would also have some properties with integer index names. However, that is not a requirement of this definition.

NOTE 2 Arrays and String objects are examples of array-like objects.

7.3.19 CreateListFromArrayLike ( `obj` [, `elementTypes` ] )

The abstract operation CreateListFromArrayLike takes argument `obj` (an ECMAScript language value) and optional argument `elementTypes` (a List of names of ECMAScript Language Types) and returns either a normal completion containing a List of ECMAScript language values or a throw completion. It is used to create a List value whose elements are provided by the indexed properties of `obj`. `elementTypes` contains the names of ECMAScript Language Types that are allowed for element values of the List that is created. It performs the following steps when called:

1. If `elementTypes` is not present, set `elementTypes` to « Undefined, Null, Boolean, String, Symbol, Number, BigInt, Object ».
2. If `obj` is not an Object, throw a TypeError exception.
3. Let `len` be `? LengthOfArrayLike(obj)`.
4. Let `list` be a new empty List.
5. Let `index` be `0`.
6. Repeat, while `index < len`,
   a. Let `indexName` be `! ToString(𝔽(index))`.
   b. Let `next` be `? Get(obj, indexName)`.
   c. If `elementTypes` does not contain `Type(next)`, throw a TypeError exception.
   d. Append `next` to `list`.
   e. Set `index` to `index + 1`.
7. Return `list`.

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7.3.20 Invoke (V, P [, argumentsList ])

The abstract operation Invoke takes arguments V (an ECMAScript language value) and P (a property key) and optional argument argumentsList (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion. It is used to call a method property of an ECMAScript language value. V serves as both the lookup point for the property and the this value of the call. argumentsList is the list of arguments values passed to the method. If argumentsList is not present, a new empty List is used as its value. It performs the following steps when called:

1. If argumentsList is not present, set argumentsList to a new empty List.
2. Let func be ? GetV(V, P).

7.3.21 OrdinaryHasInstance (C, O)

The abstract operation OrdinaryHasInstance takes arguments C (an ECMAScript language value) and O (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It implements the default algorithm for determining if O inherits from the instance object inheritance path provided by C. It performs the following steps when called:

1. If IsCallable(C) is false, return false.
2. If C has a [[BoundTargetFunction]] internal slot, then
   a. Let BC be C.[[BoundTargetFunction]].
3. If O is not an Object, return false.
4. Let P be ? Get(C, "prototype").
5. If P is not an Object, throw a TypeError exception.
6. Repeat,
   a. Set O to ? O.[[GetPrototypeOf]]().
   b. If O is null, return false.
   c. If SameValue(P, O) is true, return true.

7.3.22 SpeciesConstructor (O, defaultConstructor)

The abstract operation SpeciesConstructor takes arguments O (an Object) and defaultConstructor (a constructor) and returns either a normal completion containing a constructor or a throw completion. It is used to retrieve the constructor that should be used to create new objects that are derived from O. defaultConstructor is the constructor to use if a constructor @@species property cannot be found starting from O. It performs the following steps when called:

1. Let C be ? Get(O, "constructor").
2. If C is undefined, return defaultConstructor.
3. If C is not an Object, throw a TypeError exception.
4. Let S be ? Get(C, @@species).
5. If S is either undefined or null, return defaultConstructor.
6. If IsConstructor(S) is true, return S.
7. Throw a TypeError exception.

7.3.23 EnumerableOwnProperties (O, kind)

The abstract operation EnumerableOwnProperties takes arguments O (an Object) and kind (KEY, VALUE, or KEY+VALUE) and returns either a normal completion containing a List of ECMAScript language values or a throw completion. It performs the following steps when called:

1. Let ownKeys be ? O.[[OwnPropertyKeys]]().
2. Let results be a new empty List.
3. For each element key of ownKeys, do
   a. If key is a String, then
i. Let desc be O.[[GetOwnProperty]](key).

ii. If desc is not undefined and desc.[[Enumerable]] is true, then
   1. If kind is KEY, then
      a. Append key to results.
   2. Else,
      a. Let value be ? Get(O, key).
      b. If kind is VALUE, then
         i. Append value to results.
      c. Else,
         i. Assert: kind is KEY+VALUE.
         ii. Let entry be CreateArrayFromList(« key, value »).
         iii. Append entry to results.

4. Return results.

7.3.24 GetFunctionRealm ( obj )

The abstract operation GetFunctionRealm takes argument obj (a function object) and returns either a normal completion containing a Realm Record or a throw completion. It performs the following steps when called:

1. If obj has a [[Realm]] internal slot, then
   a. Return obj.[[Realm]].
2. If obj is a bound function exotic object, then
   a. Let boundTargetFunction be obj.[[BoundTargetFunction]].
3. If obj is a Proxy exotic object, then
   b. Let proxyTarget be obj.[[ProxyTarget]].
4. Return the current Realm Record.

NOTE Step 4 will only be reached if obj is a non-standard function exotic object that does not have a [[Realm]] internal slot.

7.3.25 CopyDataProperties ( target, source, excludedItems )

The abstract operation CopyDataProperties takes arguments target (an Object), source (an ECMAScript language value), and excludedItems (a List of property keys) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. If source is either undefined or null, return UNUSED.
2. Let from be ! ToObject(source).
3. Let keys be ? from.[[OwnPropertyKeys]]().
4. For each element nextKey of keys, do
   a. Let excluded be false.
   b. For each element e of excludedItems, do
      i. If SameValue(e, nextKey) is true, then
         1. Set excluded to true.
   c. If excluded is false, then
      i. Let desc be ? from.[[GetOwnProperty]](nextKey).
      ii. If desc is not undefined and desc.[[Enumerable]] is true, then
         1. Let propValue be ? Get(from, nextKey).
         2. Perform ! CreateDataPropertyOrThrow(target, nextKey, propValue).
5. Return UNUSED.

NOTE The target passed in here is always a newly created object which is not directly accessible in case of an error being thrown.
The abstract operation `PrivateElementFind` takes arguments `O` (an Object) and `P` (a Private Name) and returns a `PrivateElement` or `EMPTY`. It performs the following steps when called:

1. If `O.([PrivateElements])` contains a `PrivateElement` `pe` such that `pe.([Key])` is `P`, then
   a. Return `pe`.
2. Return `EMPTY`.

The abstract operation `PrivateFieldAdd` takes arguments `O` (an Object), `P` (a Private Name), and `value` (an ECMAScript language value) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. If the host is a web browser, then
   a. Perform `HostEnsureCanAddPrivateElement(O)`.
2. Let `entry` be `PrivateElementFind(O, P)`.
3. If `entry` is not `EMPTY`, throw a `TypeError` exception.
4. Append `PrivateElement { ([Key]: P, [Kind]: FIELD, [Value]: value })` to `O.([PrivateElements])`.
5. Return UNUSED.

The abstract operation `PrivateMethodOrAccessorAdd` takes arguments `O` (an Object) and `method` (a Private Element) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. `Assert: method.([Kind])` is either METHOD or ACCESSOR.
2. If the host is a web browser, then
   a. Perform `HostEnsureCanAddPrivateElement(O)`.
3. Let `entry` be `PrivateElementFind(O, method.([Key]))`.
4. If `entry` is not `EMPTY`, throw a `TypeError` exception.
5. Append `method` to `O.([PrivateElements])`.
6. Return UNUSED.

NOTE: The values for private methods and accessors are shared across instances. This operation does not create a new copy of the method or accessor.

The `HostEnsureCanAddPrivateElement` takes argument `O` (an Object) and returns either a normal completion containing UNUSED or a throw completion. It allows host environments to prevent the addition of private elements to particular host-defined exotic objects.

An implementation of `HostEnsureCanAddPrivateElement` must conform to the following requirements:

- If `O` is not a host-defined exotic object, this abstract operation must return `NormalCompletion(UNUSED)` and perform no other steps.
- Any two calls of this abstract operation with the same argument must return the same kind of Completion Record.

The default implementation of `HostEnsureCanAddPrivateElement` is to return `NormalCompletion(UNUSED)`.

This abstract operation is only invoked by ECMAScript hosts that are web browsers.
7.3.30 **PrivateGet (O, P)**

The abstract operation PrivateGet takes arguments \( O \) (an Object) and \( P \) (a Private Name) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let \( entry \) be PrivateElementFind\((O, P)\).
2. If \( entry \) is EMPTY, throw a TypeError exception.
3. If \( entry.[[Kind]] \) is either FIELD or METHOD, then
   a. Return \( entry.[[Value]] \).
4. Assert: \( entry.[[Kind]] \) is ACCESSOR.
5. If \( entry.[[Get]] \) is undefined, throw a TypeError exception.
6. Let \( getter \) be \( entry.[[Get]] \).
7. Return ? Call\((getter, O)\).

7.3.31 **PrivateSet (O, P, value)**

The abstract operation PrivateSet takes arguments \( O \) (an Object), \( P \) (a Private Name), and \( value \) (an ECMAScript language value) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let \( entry \) be PrivateElementFind\((O, P)\).
2. If \( entry \) is EMPTY, throw a TypeError exception.
3. If \( entry.[[Kind]] \) is FIELD, then
   a. Set \( entry.[[Value]] \) to \( value \).
4. Else if \( entry.[[Kind]] \) is METHOD, then
   a. Throw a TypeError exception.
5. Else,
   a. Set \( entry.[[Kind]] \) to ACCESSOR.
   b. If \( entry.[[Set]] \) is undefined, throw a TypeError exception.
   c. Let \( setter \) be \( entry.[[Set]] \).
   d. Perform ? Call\((setter, O, « value »)\).
6. Return UNUSED.

7.3.32 **DefineField (receiver, fieldRecord)**

The abstract operation DefineField takes arguments \( receiver \) (an Object) and \( fieldRecord \) (a ClassFieldDefinition Record) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let \( fieldName \) be \( fieldRecord.[[Name]] \).
2. Let \( initializer \) be \( fieldRecord.[[Initializer]] \).
3. If \( initializer \) is not EMPTY, then
   a. Let \( initValue \) be ? Call\((initializer, receiver)\).
4. Else,
   a. Let \( initValue \) be undefined.
5. If \( fieldName \) is a Private Name, then
   a. Perform ? PrivateFieldAdd\((receiver, fieldName, initValue)\).
6. Else,
   a. Assert: IsPropertyKey\((fieldName)\) is true.
   b. Perform ? CreateDataPropertyOrThrow\((receiver, fieldName, initValue)\).
7. Return UNUSED.
7.3.33 InitializeInstanceElements (O, constructor)

The abstract operation InitializeInstanceElements takes arguments O (an Object) and constructor (an ECMA-Script function object) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let methods be the value of constructor.[[PrivateMethods]].
2. For each PrivateElement method of methods, do
3. Let fields be the value of constructor.[[Fields]].
4. For each element fieldRecord of fields, do
   a. Perform ? DefineField(O, fieldRecord).
5. Return UNUSED.

7.3.34 AddValueToKeyedGroup (groups, key, value)

The abstract operation AddValueToKeyedGroup takes arguments groups (a List of Records with fields [[Key]] (an ECMAScript language value) and [[Elements]] (a List of ECMAScript language values)), key (an ECMAScript language value), and value (an ECMAScript language value) and returns UNUSED. It performs the following steps when called:

1. For each Record { [[Key]], [[Elements]] } g of groups, do
   a. If SameValue(g.[[Key]], key) is true, then
      i. Assert: Exactly one element of groups meets this criterion.
      ii. Append value to g.[[Elements]].
      iii. Return UNUSED.
2. Let group be the Record { [[Key]: key, [[Elements]]: « value » }. 
3. Append group to groups.
4. Return UNUSED.

7.3.35 GroupBy (items, callbackfn, keyCoercion)

The abstract operation GroupBy takes arguments items (an ECMAScript language value), callbackfn (an ECMAScript language value), and keyCoercion (PROPERTY or ZERO) and returns a List of Records with fields [[Key]] (an ECMAScript language value) and [[Elements]] (a List of ECMAScript language values), or a throw completion. It performs the following steps when called:

2. If isCallable(callbackfn) is false, throw a TypeError exception.
3. Let groups be a new empty List.
4. Let iteratorRecord be ? GetIterator(items, SYNC).
5. Let k be 0.
6. Repeat,
   a. If k ≥ 2⁵³ - 1, then
      i. Let error be ThrowCompletion(a newly created TypeError object).
      ii. Return ? IteratorClose(iteratorRecord, error).
   b. Let next be ? IteratorStepValue(iteratorRecord).
   c. If next is DONE, then
      i. Return groups.
   d. Let value be next.
   e. Let key be Completion(Call(callbackfn, undefined, « value, F(k) »)).
   f. IfAbruptCloseIterator(key, iteratorRecord).
   g. If keyCoercion is PROPERTY, then
      i. Set key to Completion(ToPropertyKey(key)).
      ii. IfAbruptCloseIterator(key, iteratorRecord).
   h. Else,
      i. Assert: keyCoercion is ZERO.
      ii. If key is -0𝔽, set key to +0𝔽.
i. Perform `AddValueToKeyedGroup(groups, key, value)`.

j. Set \( k \) to \( k + 1 \).

### 7.4 Operations on Iterator Objects

See Common Iteration Interfaces (27.1).

#### 7.4.1 Iterator Records

An *Iterator Record* is a *Record* value used to encapsulate an Iterator or AsyncIterator along with the `next` method.

Iterator Records have the fields listed in Table 15.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[Iterator]]</code></td>
<td>an Object</td>
<td>An object that conforms to the <em>Iterator</em> or <em>AsyncIterator</em> interface.</td>
</tr>
<tr>
<td><code>[[NextMethod]]</code></td>
<td>an ECMAScript language value</td>
<td>The <code>next</code> method of the <code>[[Iterator]]</code> object.</td>
</tr>
<tr>
<td><code>[[Done]]</code></td>
<td>a Boolean</td>
<td>Whether the iterator has been closed.</td>
</tr>
</tbody>
</table>

#### 7.4.2 GetIteratorFromMethod ( `obj`, `method` )

The abstract operation `GetIteratorFromMethod` takes arguments `obj` (an ECMAScript language value) and `method` (a function object) and returns either a normal completion containing an Iterator Record or a throw completion. It performs the following steps when called:

1. Let `iterator` be \( ? \) `Call(method, obj)`.
2. If `iterator` is not an Object, throw a *TypeError* exception.
3. Let `nextMethod` be \( ? \) `Get(iterator, "next")`.
4. Let `iteratorRecord` be the Iterator Record \( \{ [[Iterator]]: \text{iterator}, [[NextMethod]]: \text{nextMethod}, [[Done]]: \text{false} \} \).
5. Return `iteratorRecord`.

#### 7.4.3 GetIterator ( `obj`, `kind` )

The abstract operation `GetIterator` takes arguments `obj` (an ECMAScript language value) and `kind` (SYNC or ASYNC) and returns either a normal completion containing an Iterator Record or a throw completion. It performs the following steps when called:

1. If `kind` is ASYNC, then
   a. Let `method` be \( ? \) `GetMethod(obj, @@asynciterator)`.
   b. If `method` is undefined, then
      i. Let `syncMethod` be \( ? \) `GetMethod(obj, @@iterator)`.
      ii. If `syncMethod` is undefined, throw a *TypeError* exception.
      iii. Let `syncIteratorRecord` be \( ? \) `GetIteratorFromMethod(obj, syncMethod)`.
      iv. Return `CreateAsyncFromSyncIterator(syncIteratorRecord)`.
2. Else,
   a. Let `method` be \( ? \) `GetMethod(obj, @@iterator)`.
3. If `method` is undefined, throw a *TypeError* exception.
4. Return \( ? \) `GetIteratorFromMethod(obj, method)`.
7.4.4 IteratorNext (iteratorRecord [ , value ])

The abstract operation IteratorNext takes argument iteratorRecord (an Iterator Record) and optional argument value (an ECMAScript language value) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. If value is not present, then
   a. Let result be ? Call(iteratorRecord.[[NextMethod]], iteratorRecord.[[Iterator]]).
2. Else,
   a. Let result be ? Call(iteratorRecord.[[NextMethod]], iteratorRecord.[[Iterator]], « value »).
3. If result is not an Object, throw a TypeError exception.
4. Return result.

7.4.5 IteratorComplete (iterResult)

The abstract operation IteratorComplete takes argument iterResult (an Object) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Return ToBoolean(? Get(iterResult, "done")).

7.4.6 IteratorValue (iterResult)

The abstract operation IteratorValue takes argument iterResult (an Object) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Return ? Get(iterResult, "value").

7.4.7 IteratorStep (iteratorRecord)

The abstract operation IteratorStep takes argument iteratorRecord (an Iterator Record) and returns either a normal completion containing either an Object or false, or a throw completion. It requests the next value from iteratorRecord.[[Iterator]] by calling iteratorRecord.[[NextMethod]] and returns either false indicating that the iterator has reached its end or the value from the IteratorResult object if a next value is available. It performs the following steps when called:

1. Let result be ? IteratorNext(iteratorRecord).
2. Let done be ? IteratorComplete(result).
3. If done is true, return false.
4. Return result.

7.4.8 IteratorStepValue (iteratorRecord)

The abstract operation IteratorStepValue takes argument iteratorRecord (an Iterator Record) and returns either a normal completion containing either an ECMAScript language value or DONE, or a throw completion. It requests the next value from iteratorRecord.[[Iterator]] by calling iteratorRecord.[[NextMethod]] and returns either DONE indicating that the iterator has reached its end or the value from the IteratorResult object if a next value is available. It performs the following steps when called:

1. Let result be Completion(IteratorNext(iteratorRecord)).
2. If result is a throw completion, then
   a. Set iteratorRecord.[[Done]] to true.
   b. Return ? result.
3. Set result to ! result.
4. Let done be Completion(IteratorComplete(result)).
5. If done is a throw completion, then
   a. Set iteratorRecord.[[Done]] to true.
6. Set done to ! done.
7. If \textit{done} is true, then
   a. Set \texttt{iteratorRecord}.[[Done]] to true.
   b. Return DONE.
8. Let \textit{value} be Completion(\texttt{Get(result, "value")}).
9. If \textit{value} is a throw completion, then
   a. Set \texttt{iteratorRecord}.[[Done]] to true.
10. Return ? \textit{value}.

7.4.9 \textbf{IteratorClose (} \texttt{iteratorRecord, completion} \textbf{)}

The abstract operation \texttt{IteratorClose} takes arguments \texttt{iteratorRecord} (an \texttt{Iterator Record}) and \texttt{completion} (a Completion Record) and returns a Completion Record. It is used to notify an iterator that it should perform any actions it would normally perform when it has reached its completed state. It performs the following steps when called:

1. \textbf{Assert:} \texttt{iteratorRecord}.[[Iterator]] is an Object.
2. Let \texttt{iterator} be \texttt{iteratorRecord}.[[Iterator]].
3. Let \texttt{innerResult} be Completion(\texttt{GetMethod(iterator, "return")}).
4. If \texttt{innerResult} is a normal completion, then
   a. Let \texttt{return} be \texttt{innerResult}.[[Value]].
   b. If \texttt{return} is undefined, return ? \texttt{completion}.
   c. Set \texttt{innerResult} to Completion(Call(\texttt{return}, \texttt{iterator})).
5. If \texttt{completion} is a throw completion, return ? \texttt{completion}.
6. If \texttt{innerResult} is a throw completion, return ? \texttt{innerResult}.
7. If \texttt{innerResult}.[[Value]] is not an Object, throw a \texttt{TypeError} exception.
8. Return ? \texttt{completion}.

7.4.10 \textbf{IfAbruptCloseIterator (} \texttt{value, iteratorRecord} \textbf{)}

\texttt{IfAbruptCloseIterator} is a shorthand for a sequence of algorithm steps that use an \texttt{Iterator Record}. An algorithm step of the form:

1. \texttt{IfAbruptCloseIterator(value, iteratorRecord)}.

means the same thing as:

1. \textbf{Assert:} \texttt{value} is a Completion Record.
2. If \texttt{value} is an abrupt completion, return ? \texttt{IteratorClose(iteratorRecord, value)}.
3. Else, set \texttt{value} to ! \texttt{value}.

7.4.11 \textbf{AsyncIteratorClose (} \texttt{iteratorRecord, completion} \textbf{)}

The abstract operation \texttt{AsyncIteratorClose} takes arguments \texttt{iteratorRecord} (an \texttt{Iterator Record}) and \texttt{completion} (a Completion Record) and returns a Completion Record. It is used to notify an async iterator that it should perform any actions it would normally perform when it has reached its completed state. It performs the following steps when called:

1. \textbf{Assert:} \texttt{iteratorRecord}.[[Iterator]] is an Object.
2. Let \texttt{iterator} be \texttt{iteratorRecord}.[[Iterator]].
3. Let \texttt{innerResult} be Completion(\texttt{GetMethod(iterator, "return")}).
4. If \texttt{innerResult} is a normal completion, then
   a. Let \texttt{return} be \texttt{innerResult}.[[Value]].
   b. If \texttt{return} is undefined, return ? \texttt{completion}.
   c. Set \texttt{innerResult} to Completion(Call(\texttt{return}, \texttt{iterator})).
   d. If \texttt{innerResult} is a normal completion, set \texttt{innerResult} to Completion(Await(innerResult.[[Value]]))).
5. If \texttt{completion} is a throw completion, return ? \texttt{completion}.
6. If \texttt{innerResult} is a throw completion, return ? \texttt{innerResult}.
7. If \texttt{innerResult}.[[Value]] is not an Object, throw a \texttt{TypeError} exception.
8. Return ? \texttt{completion}.
7.4.12 CreateIterResultObject (value, done)

The abstract operation CreateIterResultObject takes arguments value (an ECMAScript language value) and done (a Boolean) and returns an object that conforms to the IteratorResult interface. It creates an object that conforms to the IteratorResult interface. It performs the following steps when called:

1. Let obj be OrdinaryObjectCreate(%Object.prototype%).
2. Perform ! CreateDataPropertyOrThrow(obj, "value", value).
3. Perform ! CreateDataPropertyOrThrow(obj, "done", done).
4. Return obj.

7.4.13 CreateListIteratorRecord (list)

The abstract operation CreateListIteratorRecord takes argument list (a List of ECMAScript language values) and returns an Iterator Record. It creates an Iterator (27.1.1.2) object record whose next method returns the successive elements of list. It performs the following steps when called:

1. Let closure be a new Abstract Closure with no parameters that captures list and performs the following steps when called:
   a. For each element $E$ of list, do
      i. Perform ? GeneratorYield(CreateIterResultObject($E$, false)).
   b. Return NormalCompletion(undefined).
2. Let iterator be CreateIteratorFromClosure(closure, EMPTY, %IteratorPrototype%).
3. Return the Iterator Record { [[Iterator]]: iterator, [[NextMethod]]: %GeneratorFunction.prototype.prototype.next%, [[Done]]: false }.

NOTE The list iterator object is never directly accessible to ECMAScript code.

7.4.14 IteratorToList (iteratorRecord)

The abstract operation IteratorToList takes argument iteratorRecord (an Iterator Record) and returns either a normal completion containing a List of ECMAScript language values or a throw completion. It performs the following steps when called:

1. Let values be a new empty List.
2. Repeat,
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is DONE, then
      i. Return values.
   c. Append next to values.

8 Syntax-Directed Operations

In addition to those defined in this section, specialized syntax-directed operations are defined throughout this specification.

8.1 Runtime Semantics: Evaluation

The syntax-directed operation Evaluation takes no arguments and returns a Completion Record.

NOTE The definitions for this operation are distributed over the "ECMAScript Language" sections of this specification. Each definition appears after the defining occurrence of the relevant productions.
8.2 Scope Analysis

8.2.1 Static Semantics: BoundNames

The syntax-directed operation `BoundNames` takes no arguments and returns a `List` of Strings.

```
NOTE "default" is used within this specification as a synthetic name for a module's default export when it does not have another name. An entry in the module's [[Environment]] is created with that name and holds the corresponding value, and resolving the export named "default" by calling `ResolveExport(exportName[,resolveSet])` for the module will return a `ResolvedBindingRecord` whose [[BindingName]] is "default", which will then resolve in the module's [[Environment]] to the above-mentioned value. This is done only for ease of specification, so that anonymous default exports can be resolved like any other export. This "default" string is never accessible to ECMAScript code or to the module linking algorithm.
```

It is defined piecewise over the following productions:

- **`BindingIdentifier : Identifier`**
  1. Return a `List` whose sole element is the `StringValue` of `Identifier`.

- **`BindingIdentifier : yield`**
  1. Return `"yield"`.

- **`BindingIdentifier : await`**
  1. Return `"await"`.

- **`LexicalDeclaration : LetOrConst BindingList ;`**
  1. Return the `BoundNames` of `BindingList`.

- **`BindingList : BindingList , LexicalBinding`**
  1. Let `names1` be the `BoundNames` of `BindingList`.
  2. Let `names2` be the `BoundNames` of `LexicalBinding`.
  3. Return the list-concatenation of `names1` and `names2`.

- **`LexicalBinding : BindingIdentifier Initializeropt`**
  1. Return the `BoundNames` of `BindingIdentifier`.

- **`LexicalBinding : BindingPattern Initializer`**
  1. Return the `BoundNames` of `BindingPattern`.

- **`VariableDeclarationList : VariableDeclarationList , VariableDeclaration`**
  1. Let `names1` be `BoundNames` of `VariableDeclarationList`.
  2. Let `names2` be `BoundNames` of `VariableDeclaration`.
  3. Return the list-concatenation of `names1` and `names2`.

- **`VariableDeclaration : BindingIdentifier Initializeropt`**
  1. Return the `BoundNames` of `BindingIdentifier`.
**VariableDeclaration**: BindingPattern Initializer

1. Return the **BoundNames** of BindingPattern.

**ObjectBindingPattern**: {

1. Return a new empty List.

**ObjectBindingPattern**: {{ BindingPropertyList, BindingRestProperty }}

1. Let names1 be **BoundNames** of BindingPropertyList.
2. Let names2 be **BoundNames** of BindingRestProperty.
3. Return the list-concatenation of names1 and names2.

**ArrayBindingPattern**: [ Elisionopt ]

1. Return a new empty List.

ArrayBindingPattern: [ Elisionopt BindingRestElement ]

1. Return the **BoundNames** of BindingRestElement.

ArrayBindingPattern: [ BindingElementList, Elisionopt ]

1. Return the **BoundNames** of BindingElementList.

ArrayBindingPattern: [ BindingElementList, Elisionopt BindingRestElement ]

1. Let names1 be **BoundNames** of BindingElementList.
2. Let names2 be **BoundNames** of BindingRestElement.
3. Return the list-concatenation of names1 and names2.

**BindingPropertyList**: BindingPropertyList, BindingProperty

1. Let names1 be **BoundNames** of BindingPropertyList.
2. Let names2 be **BoundNames** of BindingProperty.
3. Return the list-concatenation of names1 and names2.

**BindingElementList**: BindingElementList, BindingElisionElement

1. Let names1 be **BoundNames** of BindingElementList.
2. Let names2 be **BoundNames** of BindingElisionElement.
3. Return the list-concatenation of names1 and names2.

**BindEllisionElement**: Elisionopt BindingElement

1. Return **BoundNames** of BindingElement.

**BindingProperty**: PropertyName : BindingElement

1. Return the **BoundNames** of BindingElement.

**SingleNameBinding**: BindingIdentifier Initializeropt

1. Return the **BoundNames** of BindingIdentifier.

**BindingElement**: BindingPattern Initializeropt

1. Return the **BoundNames** of BindingPattern.
ForDeclaration: LetOrConst ForBinding

1. Return the BoundNames of ForBinding.

FunctionDeclaration: function BindingIdentifier ( FormalParameters ) { FunctionBody }

1. Return the BoundNames of BindingIdentifier.

FunctionDeclaration: function ( FormalParameters ) { FunctionBody }

1. Return « "default" ».

FormalParameters: [empty]

1. Return a new empty List.

FormalParameters: FormalParameterList, FunctionRestParameter

1. Let names1 be BoundNames of FormalParameterList.
2. Let names2 be BoundNames of FunctionRestParameter.
3. Return the list-concatenation of names1 and names2.

FormalParameterList: FormalParameterList, FormalParameter

1. Let names1 be BoundNames of FormalParameterList.
2. Let names2 be BoundNames of FormalParameter.
3. Return the list-concatenation of names1 and names2.

ArrowParameters: CoverParenthesizedExpressionAndArrowParameterList

1. Let formals be the ArrowFormalParameters that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return the BoundNames of formals.

GeneratorDeclaration: function * BindingIdentifier ( FormalParameters ) { GeneratorBody }

1. Return the BoundNames of BindingIdentifier.

GeneratorDeclaration: function * ( FormalParameters ) { GeneratorBody }

1. Return « "default" ».

AsyncGeneratorDeclaration: async function * BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }

1. Return the BoundNames of BindingIdentifier.

AsyncGeneratorDeclaration: async function * ( FormalParameters ) { AsyncGeneratorBody }

1. Return « "default" ».

ClassDeclaration: class BindingIdentifier ClassTail

1. Return the BoundNames of BindingIdentifier.

ClassDeclaration: class ClassTail

1. Return « "default" ».
AsyncFunctionDeclaration : async function BindingIdentifier ( FormalParameters ) { AsyncFunctionBody }

1. Return the BoundNames of BindingIdentifier.

AsyncFunctionDeclaration : async function ( FormalParameters ) { AsyncFunctionBody }

1. Return ""default"".

CoverCallExpressionAndAsyncArrowHead : MemberExpression Arguments

1. Let head be the AsyncArrowHead that is covered by CoverCallExpressionAndAsyncArrowHead.
2. Return the BoundNames of head.

ImportDeclaration : import ImportClause FromClause ;

1. Return the BoundNames of ImportClause.

ImportDeclaration : import ModuleSpecifier ;

1. Return a new empty List.

ImportClause : ImportedDefaultBinding , NameSpaceImport

1. Let names1 be the BoundNames of ImportedDefaultBinding.
2. Let names2 be the BoundNames of NameSpaceImport.
3. Return the list-concatenation of names1 and names2.

ImportClause : ImportedDefaultBinding , NamedImports

1. Let names1 be the BoundNames of ImportedDefaultBinding.
2. Let names2 be the BoundNames of NamedImports.
3. Return the list-concatenation of names1 and names2.

NamedImports : { }

1. Return a new empty List.

ImportsList : ImportsList , ImportSpecifier

1. Let names1 be the BoundNames of ImportsList.
2. Let names2 be the BoundNames of ImportSpecifier.
3. Return the list-concatenation of names1 and names2.

ImportSpecifier : ModuleExportName as ImportedBinding

1. Return the BoundNames of ImportedBinding.

ExportDeclaration :

   export ExportFromClause FromClause ;
   export NamedExports ;

1. Return a new empty List.

ExportDeclaration : export VariableStatement

1. Return the BoundNames of VariableStatement.

ExportDeclaration : export Declaration

1. Return the BoundNames of Declaration.
ExportDeclaration : export default HoistableDeclaration

1. Let declarationNames be the BoundNames of HoistableDeclaration.
2. If declarationNames does not include the element "default", append "default" to declarationNames.
3. Return declarationNames.

ExportDeclaration : export default ClassDeclaration

1. Let declarationNames be the BoundNames of ClassDeclaration.
2. If declarationNames does not include the element "default", append "default" to declarationNames.
3. Return declarationNames.

ExportDeclaration : export default AssignmentExpression ;

1. Return « "default" ».

8.2.2 Static Semantics: DeclarationPart

The syntax-directed operation DeclarationPart takes no arguments and returns a Parse Node. It is defined piecewise over the following productions:

HoistableDeclaration : FunctionDeclaration
1. Return FunctionDeclaration.

HoistableDeclaration : GeneratorDeclaration
1. Return GeneratorDeclaration.

HoistableDeclaration : AsyncFunctionDeclaration
1. Return AsyncFunctionDeclaration.

HoistableDeclaration : AsyncGeneratorDeclaration
1. Return AsyncGeneratorDeclaration.

Declaration : ClassDeclaration
1. Return ClassDeclaration.

Declaration : LexicalDeclaration
1. Return LexicalDeclaration.

8.2.3 Static Semantics: IsConstantDeclaration

The syntax-directed operation IsConstantDeclaration takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

LexicalDeclaration : LetOrConst BindingList ;

1. Return IsConstantDeclaration of LetOrConst.

LetOrConst : let
1. Return false.

LetOrConst : const
1. Return true.
### Function Declaration

```
function BindingIdentifier ( FormalParameters ) { FunctionBody }
function ( FormalParameters ) { FunctionBody }
```

### Generator Declaration

```
function * BindingIdentifier ( FormalParameters ) { GeneratorBody }
function * ( FormalParameters ) { GeneratorBody }
```

### Async Generator Declaration

```
async function * BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }
async function * ( FormalParameters ) { AsyncGeneratorBody }
```

### Async Function Declaration

```
async function BindingIdentifier ( FormalParameters ) { AsyncFunctionBody }
async function ( FormalParameters ) { AsyncFunctionBody }
```

1. Return `false`.

### Class Declaration

```
class BindingIdentifier ClassTail
class ClassTail
```

1. Return `false`.

### Export Declaration

```
export ExportFromClause FromClause ;
export NamedExports ;
export default AssignmentExpression ;
```

1. Return `false`.

**NOTE**

It is not necessary to treat `export default AssignmentExpression` as a constant declaration because there is no syntax that permits assignment to the internal bound name used to reference a module's default object.

### 8.2.4 Static Semantics: LexicallyDeclaredNames

The syntax-directed operation `LexicallyDeclaredNames` takes no arguments and returns a `List` of Strings. It is defined piecewise over the following productions:

- **Block** :
  ```
  { } 
  ```
  1. Return a new empty `List`.

- **StatementList** :
  ```
  StatementList StatementListItem 
  ```
  1. Let `names1` be `LexicallyDeclaredNames` of `StatementList`.
  2. Let `names2` be `LexicallyDeclaredNames` of `StatementListItem`.
  3. Return the list-concatenation of `names1` and `names2`.

- **StatementListItem** :
  ```
  Declaration
  ```
  1. Return the `BoundNames` of `Declaration`.
CaseBlock : { }

1. Return a new empty List.

CaseBlock : { CaseClauses\textsubscript{opt} DefaultClause CaseClauses\textsubscript{opt} }

1. If the first CaseClauses is present, let \textit{names1} be the LexicallyDeclaredNames of the first CaseClauses.
2. Else, let \textit{names1} be a new empty List.
3. Let \textit{names2} be LexicallyDeclaredNames of DefaultClause.
4. If the second CaseClauses is present, let \textit{names3} be the LexicallyDeclaredNames of the second CaseClauses.
5. Else, let \textit{names3} be a new empty List.
6. Return the list-concatenation of \textit{names1}, \textit{names2}, and \textit{names3}.

CaseClauses : CaseClauses CaseClause

1. Let \textit{names1} be LexicallyDeclaredNames of CaseClauses.
2. Let \textit{names2} be LexicallyDeclaredNames of CaseClause.
3. Return the list-concatenation of \textit{names1} and \textit{names2}.

CaseClause : \texttt{case} Expression : StatementList\textsubscript{opt}

1. If the StatementList is present, return the LexicallyDeclaredNames of StatementList.
2. Return a new empty List.

DefaultClause : \texttt{default} : StatementList\textsubscript{opt}

1. If the StatementList is present, return the LexicallyDeclaredNames of StatementList.
2. Return a new empty List.

LabelledStatement : LabelIdentifier : LabelledItem

1. Return the LexicallyDeclaredNames of LabelledItem.

LabelledItem : Statement

1. Return a new empty List.

LabelledItem : FunctionDeclaration

1. Return \texttt{BoundNames} of FunctionDeclaration.

FunctionStatementList : [empty]

1. Return a new empty List.

FunctionStatementList : StatementList

1. Return the TopLevelLexicallyDeclaredNames of StatementList.

ClassStaticBlockStatementList : [empty]

1. Return a new empty List.

ClassStaticBlockStatementList : StatementList

1. Return the TopLevelLexicallyDeclaredNames of StatementList.

ConciseBody : ExpressionBody

1. Return a new empty List.
AsyncConciseBody : ExpressionBody

1. Return a new empty List.

Script : [empty]

1. Return a new empty List.

ScriptBody : StatementList

1. Return TopLevelLexicallyDeclaredNames of StatementList.

NOTE 1 At the top level of a Script, function declarations are treated like var declarations rather than like lexical declarations.

NOTE 2 The LexicallyDeclaredNames of a Module includes the names of all of its imported bindings.

ModuleItemList : ModuleItemList ModuleItem

1. Let names1 be LexicallyDeclaredNames of ModuleItemList.
2. Let names2 be LexicallyDeclaredNames of ModuleItem.
3. Return the list-concatenation of names1 and names2.

ModuleItem : ImportDeclaration

1. Return the BoundNames of ImportDeclaration.

ModuleItem : ExportDeclaration

1. If ExportDeclaration is export VariableStatement, return a new empty List.
2. Return the BoundNames of ExportDeclaration.

ModuleItem : StatementListItem

1. Return LexicallyDeclaredNames of StatementList.

NOTE 3 At the top level of a Module, function declarations are treated like lexical declarations rather than like var declarations.

8.2.5 Static Semantics: LexicallyScopedDeclarations

The syntax-directed operation LexicallyScopedDeclarations takes no arguments and returns a List of Parse Nodes. It is defined piecewise over the following productions:

StatementList : StatementList StatementListItem

1. Let declarations1 be LexicallyScopedDeclarations of StatementList.
2. Let declarations2 be LexicallyScopedDeclarations of StatementListItem.
3. Return the list-concatenation of declarations1 and declarations2.

StatementListItem : Statement

1. If Statement is Statement : LabelledStatement, return LexicallyScopedDeclarations of LabelledStatement.
2. Return a new empty List.

StatementListItem : Declaration

1. Return a List whose sole element is DeclarationPart of Declaration.
CaseBlock : { }

1. Return a new empty List.

CaseBlock : { CaseClauses opt DefaultClause CaseClauses opt }

1. If the first CaseClauses is present, let declarations1 be the LexicallyScopedDeclarations of the first CaseClauses.
2. Else, let declarations1 be a new empty List.
3. Let declarations2 be LexicallyScopedDeclarations of DefaultClause.
4. If the second CaseClauses is present, let declarations3 be the LexicallyScopedDeclarations of the second CaseClauses.
5. Else, let declarations3 be a new empty List.
6. Return the list-concatenation of declarations1, declarations2, and declarations3.

CaseClauses : CaseClauses CaseClause

1. Let declarations1 be LexicallyScopedDeclarations of CaseClauses.
2. Let declarations2 be LexicallyScopedDeclarations of CaseClause.
3. Return the list-concatenation of declarations1 and declarations2.

CaseClause : case Expression : StatementList opt

1. If the StatementList is present, return the LexicallyScopedDeclarations of StatementList.
2. Return a new empty List.

DefaultClause : default : StatementList opt

1. If the StatementList is present, return the LexicallyScopedDeclarations of StatementList.
2. Return a new empty List.

LabelledStatement : LabelIdentifier : LabelledItem

1. Return the LexicallyScopedDeclarations of LabelledItem.

LabelledItem : Statement

1. Return a new empty List.

LabelledItem : FunctionDeclaration

1. Return « FunctionDeclaration ».

FunctionStatementList : [empty]

1. Return a new empty List.

FunctionStatementList : StatementList

1. Return the TopLevelLexicallyScopedDeclarations of StatementList.

ClassStaticBlockStatementList : [empty]

1. Return a new empty List.

ClassStaticBlockStatementList : StatementList

1. Return the TopLevelLexicallyScopedDeclarations of StatementList.
ConciseBody : ExpressionBody

1. Return a new empty List.

AsyncConciseBody : ExpressionBody

1. Return a new empty List.

Script : [empty]

1. Return a new empty List.

ScriptBody : StatementList

1. Return TopLevelLexicallyScopedDeclarations of StatementList.

Module : [empty]

1. Return a new empty List.

ModuleItemList : ModuleItemList ModuleItem

1. Let declarations1 be LexicallyScopedDeclarations of ModuleItemList.
2. Let declarations2 be LexicallyScopedDeclarations of ModuleItem.
3. Return the list-concatenation of declarations1 and declarations2.

ModuleItem : ImportDeclaration

1. Return a new empty List.

ExportDeclaration : export ExportFromClause FromClause ;
export NamedExports ;
export VariableStatement

1. Return a new empty List.

ExportDeclaration : export Declaration

1. Return a List whose sole element is DeclarationPart of Declaration.

ExportDeclaration : export default HoistableDeclaration

1. Return a List whose sole element is DeclarationPart of HoistableDeclaration.

ExportDeclaration : export default ClassDeclaration

1. Return a List whose sole element is ClassDeclaration.

ExportDeclaration : export default AssignmentExpression ;

1. Return a List whose sole element is this ExportDeclaration.
8.2.6 Static Semantics: VarDeclaredNames

The syntax-directed operation VarDeclaredNames takes no arguments and returns a List of Strings. It is defined piecewise over the following productions:

Statement :
   EmptyStatement
   ExpressionStatement
   ContinueStatement
   BreakStatement
   ReturnStatement
   ThrowStatement
   DebuggerStatement

1. Return a new empty List.

Block : { }
1. Return a new empty List.

StatementList : StatementList StatementListItem
1. Let names1 be VarDeclaredNames of StatementList.
2. Let names2 be VarDeclaredNames of StatementListItem.
3. Return the list-concatenation of names1 and names2.

StatementListItem : Declaration
1. Return a new empty List.

VariableStatement : var VariableDeclarationList ;
1. Return BoundNames of VariableDeclarationList.

IfStatement : if ( Expression ) Statement else Statement
1. Let names1 be VarDeclaredNames of the first Statement.
2. Let names2 be VarDeclaredNames of the second Statement.
3. Return the list-concatenation of names1 and names2.

IfStatement : if ( Expression ) Statement
1. Return the VarDeclaredNames of Statement.

DoWhileStatement : do Statement while ( Expression ) ;
1. Return the VarDeclaredNames of Statement.

WhileStatement : while ( Expression ) Statement
1. Return the VarDeclaredNames of Statement.

ForStatement : for ( Expressionopt ; Expressionopt ; Expressionopt ) Statement
1. Return the VarDeclaredNames of Statement.

ForStatement : for ( var VariableDeclarationList ; Expressionopt ; Expressionopt ) Statement
1. Let names1 be BoundNames of VariableDeclarationList.
2. Let names2 be VarDeclaredNames of Statement.
3. Return the list-concatenation of names1 and names2.
ForStatement: \( \text{for} \ (\text{LexicalDeclaration Expressionopt } \; \text{Expressionopt} ) \text{ Statement} \)

1. Return the \text{VarDeclaredNames} of Statement.

ForInOfStatement:

\( \text{for} \ (\text{LeftHandSideExpression in Expression}) \text{ Statement} \)
\( \text{for} \ (\text{ForDeclaration in Expression}) \text{ Statement} \)
\( \text{for} \ (\text{LeftHandSideExpression of AssignmentExpression}) \text{ Statement} \)
\( \text{for} \ (\text{ForDeclaration of AssignmentExpression}) \text{ Statement} \)
\( \text{for} \ await \ (\text{LeftHandSideExpression of AssignmentExpression}) \text{ Statement} \)
\( \text{for} \ await \ (\text{ForDeclaration of AssignmentExpression}) \text{ Statement} \)

1. Return the \text{VarDeclaredNames} of Statement.

ForInOfStatement:

\( \text{for} \ (\text{var ForBinding in Expression}) \text{ Statement} \)
\( \text{for} \ (\text{var ForBinding of AssignmentExpression}) \text{ Statement} \)
\( \text{for} \ await \ (\text{var ForBinding of AssignmentExpression}) \text{ Statement} \)

1. Let \text{names1} be the \text{BoundNames} of ForBinding.
2. Let \text{names2} be the \text{VarDeclaredNames} of Statement.
3. Return the list-concatenation of \text{names1} and \text{names2}.

\textbf{NOTE} This section is extended by Annex B.3.5.

WithStatement: \( \text{with} \ (\text{Expression}) \text{ Statement} \)

1. Return the \text{VarDeclaredNames} of Statement.

SwitchStatement: \( \text{switch} \ (\text{Expression}) \text{ CaseBlock} \)

1. Return the \text{VarDeclaredNames} of CaseBlock.

CaseBlock: \{ \}

1. Return a new empty \text{List}.

\text{CaseBlock}: \{ \text{CaseClausesopt} \text{ DefaultClauase CaseClausesopt} \}

1. If the first \text{CaseClauses} is present, let \text{names1} be the \text{VarDeclaredNames} of the first \text{CaseClauses}.
2. Else, let \text{names1} be a new empty \text{List}.
3. Let \text{names2} be \text{VarDeclaredNames} of \text{DefaultClause}.
4. If the second \text{CaseClauses} is present, let \text{names3} be the \text{VarDeclaredNames} of the second \text{CaseClauses}.
5. Else, let \text{names3} be a new empty \text{List}.
6. Return the list-concatenation of \text{names1}, \text{names2}, and \text{names3}.

\text{CaseClauses}: \text{CaseClauses CaseClause}

1. Let \text{names1} be \text{VarDeclaredNames} of \text{CaseClauses}.
2. Let \text{names2} be \text{VarDeclaredNames} of \text{CaseClause}.
3. Return the list-concatenation of \text{names1} and \text{names2}.

\text{CaseClause}: \text{case Expression : StatementListopt}

1. If the \text{StatementList} is present, return the \text{VarDeclaredNames} of \text{StatementList}.
2. Return a new empty \text{List}.
DefaultClause : \texttt{default : StatementList}^{\text{opt}}

1. If the \texttt{StatementList} is present, return the \texttt{VarDeclaredNames} of \texttt{StatementList}.
2. Return a new empty \texttt{List}.

LabelledStatement : LabelIdentifier : LabelledItem

1. Return the \texttt{VarDeclaredNames} of \texttt{LabelledItem}.

LabelledItem : FunctionDeclaration

1. Return a new empty \texttt{List}.

TryStatement : \texttt{try} Block Catch

1. Let \texttt{name}^{1} be \texttt{VarDeclaredNames} of \texttt{Block}.
2. Let \texttt{name}^{2} be \texttt{VarDeclaredNames} of \texttt{Catch}.
3. Return the list-concatenation of \texttt{name}^{1} and \texttt{name}^{2}.

TryStatement : \texttt{try} Block Finally

1. Let \texttt{name}^{1} be \texttt{VarDeclaredNames} of \texttt{Block}.
2. Let \texttt{name}^{2} be \texttt{VarDeclaredNames} of \texttt{Finally}.
3. Return the list-concatenation of \texttt{name}^{1} and \texttt{name}^{2}.

TryStatement : \texttt{try} Block Catch Finally

1. Let \texttt{name}^{1} be \texttt{VarDeclaredNames} of \texttt{Block}.
2. Let \texttt{name}^{2} be \texttt{VarDeclaredNames} of \texttt{Catch}.
3. Let \texttt{name}^{3} be \texttt{VarDeclaredNames} of \texttt{Finally}.
4. Return the list-concatenation of \texttt{name}^{1}, \texttt{name}^{2}, and \texttt{name}^{3}.

Catch : \texttt{catch} ( \texttt{CatchParameter} ) Block

1. Return the \texttt{VarDeclaredNames} of \texttt{Block}.

FunctionStatementList : [\texttt{empty}]

1. Return a new empty \texttt{List}.

FunctionStatementList : StatementList

1. Return the \texttt{TopLevelVarDeclaredNames} of \texttt{StatementList}.

ClassStaticBlockStatementList : [\texttt{empty}]

1. Return a new empty \texttt{List}.

ClassStaticBlockStatementList : StatementList

1. Return the \texttt{TopLevelVarDeclaredNames} of \texttt{StatementList}.

ConciseBody : ExpressionBody

1. Return a new empty \texttt{List}.

AsyncConciseBody : ExpressionBody

1. Return a new empty \texttt{List}.
Script : [empty]

1. Return a new empty List.

ScriptBody : StatementList

1. Return TopLevelVarDeclaredNames of StatementList.

ModuleItemList : ModuleItemList ModuleItem

1. Let names1 be VarDeclaredNames of ModuleItemList.
2. Let names2 be VarDeclaredNames of ModuleItem.
3. Return the list-concatenation of names1 and names2.

ModuleItem : ImportDeclaration

1. Return a new empty List.

ModuleItem : ExportDeclaration

1. If ExportDeclaration is export VariableStatement, return BoundNames of ExportDeclaration.
2. Return a new empty List.

8.2.7 Static Semantics: VarScopedDeclarations

The syntax-directed operation VarScopedDeclarations takes no arguments and returns a List of Parse Nodes. It is defined piecewise over the following productions:

Statement :
  EmptyStatement
  ExpressionStatement
  ContinueStatement
  BreakStatement
  ReturnStatement
  ThrowStatement
  DebuggerStatement

1. Return a new empty List.

Block : { }

1. Return a new empty List.

StatementList : StatementList StatementListItem

1. Let declarations1 be VarScopedDeclarations of StatementList.
2. Let declarations2 be VarScopedDeclarations of StatementListItem.
3. Return the list-concatenation of declarations1 and declarations2.

StatementListItem : Declaration

1. Return a new empty List.

VariableDeclarationList : VariableDeclaration

1. Return « VariableDeclaration ».

VariableDeclarationList : VariableDeclarationList , VariableDeclaration

1. Let declarations1 be VarScopedDeclarations of VariableDeclarationList.
2. Return the list-concatenation of declarations1 and « VariableDeclaration ».
IfStatement : \textbf{if} ( Expression ) Statement \textbf{else} Statement

1. Let $\textit{declarations}^1$ be $\textit{VarScopedDeclarations}$ of the first Statement.
2. Let $\textit{declarations}^2$ be $\textit{VarScopedDeclarations}$ of the second Statement.
3. Return the list-concatenation of $\textit{declarations}^1$ and $\textit{declarations}^2$.

IfStatement : \textbf{if} ( Expression ) Statement

1. Return the $\textit{VarScopedDeclarations}$ of Statement.

DoWhileStatement : \textbf{do} Statement \textbf{while} ( Expression ) ;

1. Return the $\textit{VarScopedDeclarations}$ of Statement.

WhileStatement : \textbf{while} ( Expression ) Statement

1. Return the $\textit{VarScopedDeclarations}$ of Statement.

ForStatement : \textbf{for} ( Expression_{opt} ; Expression_{opt} ; Expression_{opt} ) Statement

1. Return the $\textit{VarScopedDeclarations}$ of Statement.

ForStatement : \textbf{for} ( \textit{var} VariableDeclarationList ; Expression_{opt} ; Expression_{opt} ) Statement

1. Let $\textit{declarations}^1$ be $\textit{VarScopedDeclarations}$ of $\textit{VariableDeclarationList}$.
2. Let $\textit{declarations}^2$ be $\textit{VarScopedDeclarations}$ of Statement.
3. Return the list-concatenation of $\textit{declarations}^1$ and $\textit{declarations}^2$.

ForStatement : \textbf{for} ( LexicalDeclaration Expression_{opt} ; Expression_{opt} ) Statement

1. Return the $\textit{VarScopedDeclarations}$ of Statement.

ForInOfStatement :
- \textbf{for} ( LeftHandSideExpression \textbf{in} Expression ) Statement
- \textbf{for} ( ForDeclaration \textbf{in} Expression ) Statement
- \textbf{for} ( LeftHandSideExpression \textbf{of} AssignmentExpression ) Statement
- \textbf{for} ( ForDeclaration \textbf{of} AssignmentExpression ) Statement
- \textbf{for await} ( LeftHandSideExpression \textbf{of} AssignmentExpression ) Statement
- \textbf{for await} ( ForDeclaration \textbf{of} AssignmentExpression ) Statement

1. Return the $\textit{VarScopedDeclarations}$ of Statement.

ForInOfStatement :
- \textbf{for} ( \textit{var} ForBinding \textbf{in} Expression ) Statement
- \textbf{for} ( \textit{var} ForBinding \textbf{of} AssignmentExpression ) Statement
- \textbf{for await} ( \textit{var} ForBinding \textbf{of} AssignmentExpression ) Statement

1. Let $\textit{declarations}^1$ be « ForBinding ».
2. Let $\textit{declarations}^2$ be $\textit{VarScopedDeclarations}$ of Statement.
3. Return the list-concatenation of $\textit{declarations}^1$ and $\textit{declarations}^2$.

\textbf{NOTE} This section is extended by Annex B.3.5.

WithStatement : \textbf{with} ( Expression ) Statement

1. Return the $\textit{VarScopedDeclarations}$ of Statement.
SwitchStatement : switch ( Expression ) CaseBlock

1. Return the VarScopedDeclarations of CaseBlock.

CaseBlock : { }

1. Return a new empty List.

CaseBlock : { CaseClauses opt DefaultClause CaseClauses opt }

1. If the first CaseClauses is present, let declarations1 be the VarScopedDeclarations of the first CaseClauses.
2. Else, let declarations1 be a new empty List.
3. Let declarations2 be VarScopedDeclarations of DefaultClause.
4. If the second CaseClauses is present, let declarations3 be the VarScopedDeclarations of the second CaseClauses.
5. Else, let declarations3 be a new empty List.
6. Return the list-concatenation of declarations1, declarations2, and declarations3.

CaseClauses : CaseClauses CaseClause

1. Let declarations1 be VarScopedDeclarations of CaseClauses.
2. Let declarations2 be VarScopedDeclarations of CaseClause.
3. Return the list-concatenation of declarations1 and declarations2.

CaseClause : case Expression : StatementList opt

1. If the StatementList is present, return the VarScopedDeclarations of StatementList.
2. Return a new empty List.

DefaultClause : default : StatementList opt

1. If the StatementList is present, return the VarScopedDeclarations of StatementList.
2. Return a new empty List.

LabelledStatement : LabelIdentifier : LabelledItem

1. Return the VarScopedDeclarations of LabelledItem.

LabelledItem : FunctionDeclaration

1. Return a new empty List.

TryStatement : try Block Catch

1. Let declarations1 be VarScopedDeclarations of Block.
2. Let declarations2 be VarScopedDeclarations of Catch.
3. Return the list-concatenation of declarations1 and declarations2.

TryStatement : try Block Finally

1. Let declarations1 be VarScopedDeclarations of Block.
2. Let declarations2 be VarScopedDeclarations of Finally.
3. Return the list-concatenation of declarations1 and declarations2.

TryStatement : try Block Catch Finally

1. Let declarations1 be VarScopedDeclarations of Block.
2. Let declarations2 be VarScopedDeclarations of Catch.
3. Let declarations3 be VarScopedDeclarations of Finally.
4. Return the list-concatenation of declarations1, declarations2, and declarations3.
Catch : `catch ( CatchParameter ) Block`
1. Return the `VarScopedDeclarations` of `Block`.

`FunctionStatementList` : [empty]
1. Return a new empty `List`.

`FunctionStatementList` : `StatementList`
1. Return the `TopLevelVarScopedDeclarations` of `StatementList`.

`ClassStaticBlockStatementList` : [empty]
1. Return a new empty `List`.

`ClassStaticBlockStatementList` : `StatementList`
1. Return the `TopLevelVarScopedDeclarations` of `StatementList`.

`ConciseBody` : `ExpressionBody`
1. Return a new empty `List`.

`AsyncConciseBody` : `ExpressionBody`
1. Return a new empty `List`.

`Script` : [empty]
1. Return a new empty `List`.

`ScriptBody` : `StatementList`
1. Return `TopLevelVarScopedDeclarations` of `StatementList`.

`Module` : [empty]
1. Return a new empty `List`.

`ModuleItemList` : `ModuleItemList ModuleItem`
1. Let `declarations1` be `VarScopedDeclarations` of `ModuleItemList`.
2. Let `declarations2` be `VarScopedDeclarations` of `ModuleItem`.
3. Return the list-concatenation of `declarations1` and `declarations2`.

`ModuleItem` : `ImportDeclaration`
1. Return a new empty `List`.

`ModuleItem` : `ExportDeclaration`
1. If `ExportDeclaration` is `export VariableStatement`, return `VarScopedDeclarations` of `VariableStatement`.
2. Return a new empty `List`.  

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8.2.8 Static Semantics: TopLevelLexicallyDeclaredNames

The syntax-directed operation `TopLevelLexicallyDeclaredNames` takes no arguments and returns a `List` of Strings. It is defined piecewise over the following productions:

```plaintext
StatementList : StatementList StatementListItem
1. Let `names1` be `TopLevelLexicallyDeclaredNames` of StatementList.
2. Let `names2` be `TopLevelLexicallyDeclaredNames` of StatementListItem.
3. Return the list-concatenation of `names1` and `names2`.
```

```plaintext
StatementListItem : Statement
1. Return a new empty `List`.
```

```plaintext
StatementListItem : Declaration
1. If `Declaration` is `Declaration` : `HoistableDeclaration`, then
   a. Return a new empty `List`.
2. Return the `BoundNames` of `Declaration`.
```

NOTE At the top level of a function, or script, function declarations are treated like var declarations rather than like lexical declarations.

8.2.9 Static Semantics: TopLevelLexicallyScopedDeclarations

The syntax-directed operation `TopLevelLexicallyScopedDeclarations` takes no arguments and returns a `List` of Parse Nodes. It is defined piecewise over the following productions:

```plaintext
StatementList : StatementList StatementListItem
1. Let `declarations1` be `TopLevelLexicallyScopedDeclarations` of StatementList.
2. Let `declarations2` be `TopLevelLexicallyScopedDeclarations` of StatementListItem.
3. Return the list-concatenation of `declarations1` and `declarations2`.
```

```plaintext
StatementListItem : Statement
1. Return a new empty `List`.
```

```plaintext
StatementListItem : Declaration
1. If `Declaration` is `Declaration` : `HoistableDeclaration`, then
   a. Return the `BoundNames` of `HoistableDeclaration`.
2. Return a new empty `List`.
```

8.2.10 Static Semantics: TopLevelVarDeclaredNames

The syntax-directed operation `TopLevelVarDeclaredNames` takes no arguments and returns a `List` of Strings. It is defined piecewise over the following productions:

```plaintext
StatementList : StatementList StatementListItem
1. Let `names1` be `TopLevelVarDeclaredNames` of StatementList.
2. Let `names2` be `TopLevelVarDeclaredNames` of StatementListItem.
3. Return the list-concatenation of `names1` and `names2`.
```

```plaintext
StatementListItem : Declaration
1. If `Declaration` is `Declaration` : `HoistableDeclaration`, then
   a. Return the `BoundNames` of `HoistableDeclaration`.
2. Return a new empty `List`.
StatementListItem : Statement

1. If Statement is LabelledStatement, return TopLevelVarDeclaredNames of Statement.
2. Return VarDeclaredNames of Statement.

NOTE At the top level of a function or script, inner function declarations are treated like var declarations.

LabelledStatement : LabelIdentifier : LabelledItem

1. Return the TopLevelVarDeclaredNames of LabelledItem.

LabelledItem : Statement

1. If Statement is LabelledStatement, return TopLevelVarDeclaredNames of Statement.
2. Return VarDeclaredNames of Statement.

LabelledItem : FunctionDeclaration

1. Return BoundNames of FunctionDeclaration.

8.2.11 Static Semantics: TopLevelVarScopedDeclarations

The syntax-directed operation TopLevelVarScopedDeclarations takes no arguments and returns a List of Parse Nodes. It is defined piecewise over the following productions:

StatementList : StatementList StatementListItem

1. Let declarations1 be TopLevelVarScopedDeclarations of StatementList.
2. Let declarations2 be TopLevelVarScopedDeclarations of StatementListItem.
3. Return the list-concatenation of declarations1 and declarations2.

StatementListItem : Statement

1. If Statement is LabelledStatement, return TopLevelVarScopedDeclarations of Statement.
2. Return VarScopedDeclarations of Statement.

StatementListItem : Declaration

1. If Declaration is HoistableDeclaration, then
   a. Let declaration be DeclarationPart of HoistableDeclaration.
   b. Return « declaration ».
2. Return a new empty List.

LabelledStatement : LabelIdentifier : LabelledItem

1. Return the TopLevelVarScopedDeclarations of LabelledItem.

LabelledItem : Statement

1. If Statement is LabelledStatement, return TopLevelVarScopedDeclarations of Statement.
2. Return VarScopedDeclarations of Statement.

LabelledItem : FunctionDeclaration

1. Return « FunctionDeclaration ».
8.3 Labels

8.3.1 Static Semantics: ContainsDuplicateLabels

The syntax-directed operation ContainsDuplicateLabels takes argument labelSet (a List of Strings) and returns a Boolean. It is defined piecewise over the following productions:

Statement :
- VariableStatement
- EmptyStatement
- ExpressionStatement
- ContinueStatement
- BreakStatement
- ReturnStatement
- ThrowStatement
- DebuggerStatement

Block :
- {
- }

StatementListItem :
- Declaration

1. Return false.

StatementList : StatementList StatementListItem

1. Let hasDuplicates be ContainsDuplicateLabels of StatementList with argument labelSet.
2. If hasDuplicates is true, return true.
3. Return ContainsDuplicateLabels of StatementListItem with argument labelSet.

IfStatement : if ( Expression ) Statement else Statement

1. Let hasDuplicate be ContainsDuplicateLabels of the first Statement with argument labelSet.
2. If hasDuplicate is true, return true.
3. Return ContainsDuplicateLabels of the second Statement with argument labelSet.

IfStatement : if ( Expression ) Statement

1. Return ContainsDuplicateLabels of Statement with argument labelSet.

DoWhileStatement : do Statement while ( Expression );

1. Return ContainsDuplicateLabels of Statement with argument labelSet.

WhileStatement : while ( Expression ) Statement

1. Return ContainsDuplicateLabels of Statement with argument labelSet.

ForStatement :
- for ( Expressionopt ; Expressionopt ; Expressionopt ) Statement
- for ( var VariableDeclarationList ; Expressionopt ; Expressionopt ) Statement
- for ( LexicalDeclaration Expressionopt ; Expressionopt ) Statement

1. Return ContainsDuplicateLabels of Statement with argument labelSet.
ForInOfStatement:
  for (LeftHandSideExpression in Expression) Statement
  for (var ForBinding in Expression) Statement
  for (ForDeclaration in Expression) Statement
  for await (LeftHandSideExpression of AssignmentExpression) Statement
  for await (var ForBinding of AssignmentExpression) Statement
  for await (ForDeclaration of AssignmentExpression) Statement

1. Return ContainsDuplicateLabels of Statement with argument labelSet.

NOTE This section is extended by Annex B.3.5.

WithStatement: with (Expression) Statement

1. Return ContainsDuplicateLabels of Statement with argument labelSet.

SwitchStatement: switch (Expression) CaseBlock

1. Return ContainsDuplicateLabels of CaseBlock with argument labelSet.

CaseBlock: {

1. Return false.

CaseBlock: {{ CaseClauses opt DefaultClause CaseClauses opt }

1. If the first CaseClauses is present, then
   a. If ContainsDuplicateLabels of the first CaseClauses with argument labelSet is true, return true.
2. If ContainsDuplicateLabels of DefaultClause with argument labelSet is true, return true.
3. If the second CaseClauses is not present, return false.
4. Return ContainsDuplicateLabels of the second CaseClauses with argument labelSet.

CaseClauses: CaseClauses CaseClause

1. Let hasDuplicates be ContainsDuplicateLabels of CaseClauses with argument labelSet.
2. If hasDuplicates is true, return true.
3. Return ContainsDuplicateLabels of CaseClause with argument labelSet.

CaseClause: case Expression : StatementList opt

1. If the StatementList is present, return ContainsDuplicateLabels of StatementList with argument labelSet.
2. Return false.

DefaultClause: default : StatementList opt

1. If the StatementList is present, return ContainsDuplicateLabels of StatementList with argument labelSet.
2. Return false.

LabelledStatement: LabelIdentifier : LabelledItem

1. Let label be the StringValue of LabelIdentifier.
2. If labelSet contains label, return true.
3. Let newLabelSet be the list-concatenation of labelSet and « label ».
4. Return ContainsDuplicateLabels of LabelledItem with argument newLabelSet.
LabelledItem : FunctionDeclaration

1. Return false.

TryStatement : try Block Catch

1. Let hasDuplicates be ContainsDuplicateLabels of Block with argument labelSet.
2. If hasDuplicates is true, return true.
3. Return ContainsDuplicateLabels of Catch with argument labelSet.

TryStatement : try Block Finally

1. Let hasDuplicates be ContainsDuplicateLabels of Block with argument labelSet.
2. If hasDuplicates is true, return true.
3. Return ContainsDuplicateLabels of Finally with argument labelSet.

TryStatement : try Block Catch Finally

1. If ContainsDuplicateLabels of Block with argument labelSet is true, return true.
2. If ContainsDuplicateLabels of Catch with argument labelSet is true, return true.
3. Return ContainsDuplicateLabels of Finally with argument labelSet.

Catch : catch ( CatchParameter ) Block

1. Return ContainsDuplicateLabels of Block with argument labelSet.

FunctionStatementList : [empty]

1. Return false.

ClassStaticBlockStatementList : [empty]

1. Return false.

ModuleItemList : ModuleItemList ModuleItem

1. Let hasDuplicates be ContainsDuplicateLabels of ModuleItemList with argument labelSet.
2. If hasDuplicates is true, return true.
3. Return ContainsDuplicateLabels of ModuleItem with argument labelSet.

ModuleItem :
  ImportDeclaration
  ExportDeclaration

1. Return false.

8.3.2 Static Semantics: ContainsUndefinedBreakTarget

The syntax-directed operation ContainsUndefinedBreakTarget takes argument labelSet (a List of Strings) and returns a Boolean. It is defined piecewise over the following productions:

Statement :
  VariableStatement
  EmptyStatement
  ExpressionStatement
  ContinueStatement
  ReturnStatement
  ThrowStatement
  DebuggerStatement
Block:
   { }
StatementListItem:
   Declaration

1. Return false.

StatementList:
   StatementList StatementListItem

1. Let hasUndefinedLabels be ContainsUndefinedBreakTarget of StatementList with argument labelSet.
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedBreakTarget of StatementListItem with argument labelSet.

IfStatement:
   if ( Expression ) Statement else Statement

1. Let hasUndefinedLabels be ContainsUndefinedBreakTarget of the first Statement with argument labelSet.
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedBreakTarget of the second Statement with argument labelSet.

IfStatement:
   if ( Expression ) Statement

DoWhileStatement:
   do Statement while ( Expression );

1. Return ContainsUndefinedBreakTarget of Statement with argument labelSet.

WhileStatement:
   while ( Expression ) Statement

1. Return ContainsUndefinedBreakTarget of Statement with argument labelSet.

ForStatement:
   for ( Expressionopt ; Expressionopt ; Expressionopt ) Statement
   for ( var VariableDeclarationList ; Expressionopt ; Expressionopt ) Statement
   for ( LexicalDeclaration Expressionopt ; Expressionopt ) Statement

1. Return ContainsUndefinedBreakTarget of Statement with argument labelSet.

ForInOfStatement:
   for ( LeftHandSideExpression in Expression ) Statement
   for ( var ForBinding in Expression ) Statement
   for ( ForDeclaration in Expression ) Statement
   for ( LeftHandSideExpression of AssignmentExpression ) Statement
   for ( var ForBinding of AssignmentExpression ) Statement
   for await ( LeftHandSideExpression of AssignmentExpression ) Statement
   for await ( var ForBinding of AssignmentExpression ) Statement
   for await ( ForDeclaration of AssignmentExpression ) Statement

1. Return ContainsUndefinedBreakTarget of Statement with argument labelSet.

NOTE This section is extended by Annex B.3.5.

BreakStatement:
   break ;

1. Return false.
BreakStatement: `break LabelIdentifier ;`

1. If `labelSet` does not contain the `StringValue` of `LabelIdentifier`, return `true`.
2. Return `false`.

WithStatement: `with ( Expression ) Statement`

1. Return `ContainsUndefinedBreakTarget` of `Statement` with argument `labelSet`.

SwitchStatement: `switch ( Expression ) CaseBlock`

1. Return `ContainsUndefinedBreakTarget` of `CaseBlock` with argument `labelSet`.

CaseBlock: `{ }`

1. Return `false`.

CaseBlock: `{ CaseClausesopt DefaultClause CaseClausesopt }`

1. If the first `CaseClauses` is present, then
   a. If `ContainsUndefinedBreakTarget` of the first `CaseClauses` with argument `labelSet` is `true`, return `true`.
2. If `ContainsUndefinedBreakTarget` of `DefaultClause` with argument `labelSet` is `true`, return `true`.
3. If the second `CaseClauses` is not present, return `false`.
4. Return `ContainsUndefinedBreakTarget` of the second `CaseClauses` with argument `labelSet`.

CaseClauses: `CaseClauses CaseClause`

1. Let `hasUndefinedLabels` be `ContainsUndefinedBreakTarget` of `CaseClauses` with argument `labelSet`.
2. If `hasUndefinedLabels` is `true`, return `true`.
3. Return `ContainsUndefinedBreakTarget` of `CaseClause` with argument `labelSet`.

CaseClause: `case Expression : StatementListopt`

1. If the `StatementList` is present, return `ContainsUndefinedBreakTarget` of `StatementList` with argument `labelSet`.
2. Return `false`.

DefaultClause: `default : StatementListopt`

1. If the `StatementList` is present, return `ContainsUndefinedBreakTarget` of `StatementList` with argument `labelSet`.
2. Return `false`.

LabelledStatement: `LabelIdentifier : LabelledItem`

1. Let `label` be the `StringValue` of `LabelIdentifier`.
2. Let `newLabelSet` be the list-concatenation of `labelSet` and `« label »`.
3. Return `ContainsUndefinedBreakTarget` of `LabelledItem` with argument `newLabelSet`.

LabelledItem: `FunctionDeclaration`

1. Return `false`.

TryStatement: `try Block Catch`

1. Let `hasUndefinedLabels` be `ContainsUndefinedBreakTarget` of `Block` with argument `labelSet`.
2. If `hasUndefinedLabels` is `true`, return `true`.
3. Return `ContainsUndefinedBreakTarget` of `Catch` with argument `labelSet`.
TryStatement : \texttt{try} Block Finally

1. Let \texttt{hasUndefinedLabels} be \texttt{ContainsUndefinedBreakTarget} of \texttt{Block} with argument \texttt{labelSet}.
2. If \texttt{hasUndefinedLabels} is \texttt{true}, return \texttt{true}.
3. Return \texttt{ContainsUndefinedBreakTarget} of \texttt{Finally} with argument \texttt{labelSet}.

TryStatement : \texttt{try} Block Catch Finally

1. If \texttt{ContainsUndefinedBreakTarget} of \texttt{Block} with argument \texttt{labelSet} is \texttt{true}, return \texttt{true}.
2. If \texttt{ContainsUndefinedBreakTarget} of \texttt{Catch} with argument \texttt{labelSet} is \texttt{true}, return \texttt{true}.
3. Return \texttt{ContainsUndefinedBreakTarget} of \texttt{Finally} with argument \texttt{labelSet}.

Catch : \texttt{catch} ( CatchParameter ) Block

1. Return \texttt{ContainsUndefinedBreakTarget} of \texttt{Block} with argument \texttt{labelSet}.

FunctionStatementList : [empty]

1. Return \texttt{false}.

ClassStaticBlockStatementList : [empty]

1. Return \texttt{false}.

ModuleItemList : ModuleItemList ModuleItem

1. Let \texttt{hasUndefinedLabels} be \texttt{ContainsUndefinedBreakTarget} of \texttt{ModuleItemList} with argument \texttt{labelSet}.
2. If \texttt{hasUndefinedLabels} is \texttt{true}, return \texttt{true}.
3. Return \texttt{ContainsUndefinedBreakTarget} of \texttt{ModuleItem} with argument \texttt{labelSet}.

ModuleItem :
  \hspace{1em} ImportDeclaration
  \hspace{1em} ExportDeclaration

1. Return \texttt{false}.

### 8.3.3 Static Semantics: \texttt{ContainsUndefinedContinueTarget}

The syntax-directed operation \texttt{ContainsUndefinedContinueTarget} takes arguments \texttt{iterationSet} (a \texttt{List} of Strings) and \texttt{labelSet} (a \texttt{List} of Strings) and returns a Boolean. It is defined piecewise over the following productions:

\texttt{Statement} :
  \hspace{1em} VariableStatement
  \hspace{1em} EmptyStatement
  \hspace{1em} ExpressionStatement
  \hspace{1em} BreakStatement
  \hspace{1em} ReturnStatement
  \hspace{1em} ThrowStatement
  \hspace{1em} DebuggerStatement

\texttt{Block} :
  \hspace{2em} \{ \} \hspace{2em}

\texttt{StatementList\texttt{Item}} :
  \hspace{2em} Declaration

1. Return \texttt{false}.

\texttt{Statement} : \texttt{BlockStatement}

1. Return \texttt{ContainsUndefinedContinueTarget} of \texttt{BlockStatement} with arguments \texttt{iterationSet} and « ».
BreakableStatement : IterationStatement

1. Let newIterationSet be the list-concatenation of iterationSet and labelSet.
2. Return ContainsUndefinedContinueTarget of IterationStatement with arguments newIterationSet and « ».

StatementList : StatementList StatementListItem

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of StatementList with arguments iterationSet and « ».
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedContinueTarget of StatementListItem with arguments iterationSet and « ».

IfStatement : if ( Expression ) Statement else Statement

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of the first Statement with arguments iterationSet and « ».
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedContinueTarget of the second Statement with arguments iterationSet and « ».

IfStatement : if ( Expression ) Statement

1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ».

DoWhileStatement : do Statement while ( Expression );

1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ».

WhileStatement : while ( Expression ) Statement

1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ».

ForStatement :

    for ( Expressionopt ; Expressionopt ; Expressionopt ) Statement
    for ( var VariableDeclarationList ; Expressionopt ; Expressionopt ) Statement
    for ( LexicalDeclaration Expressionopt ; Expressionopt ) Statement

1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ».

ForInOfStatement :

    for ( LeftHandSideExpression in Expression ) Statement
    for ( var ForBinding in Expression ) Statement
    for ( ForDeclaration in Expression ) Statement
    for ( LeftHandSideExpression of AssignmentExpression ) Statement
    for ( var ForBinding of AssignmentExpression ) Statement
    for ( ForDeclaration of AssignmentExpression ) Statement

1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ».

NOTE  This section is extended by Annex B.3.5.

ContinueStatement : continue ;

1. Return false.
ContinueStatement : continue LabelIdentifier ;

1. If iterationSet does not contain the StringValue of LabelIdentifier, return true.
2. Return false.

WithStatement : with ( Expression ) Statement

1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ». 

SwitchStatement : switch ( Expression ) CaseBlock

1. Return ContainsUndefinedContinueTarget of CaseBlock with arguments iterationSet and « ». 

CaseBlock : { } 

1. Return false. 

CaseBlock : { CaseClausesopt DefaultClause CaseClausesopt } 

1. If the first CaseClauses is present, then
   a. If ContainsUndefinedContinueTarget of the first CaseClauses with arguments iterationSet and « » is true, return true. 
2. If ContainsUndefinedContinueTarget of DefaultClause with arguments iterationSet and « » is true, return true. 
3. If the second CaseClauses is not present, return false. 
4. Return ContainsUndefinedContinueTarget of the second CaseClauses with arguments iterationSet and « ». 

CaseClauses : CaseClauses CaseClause

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of CaseClauses with arguments iterationSet and « ». 
2. If hasUndefinedLabels is true, return true. 
3. Return ContainsUndefinedContinueTarget of CaseClause with arguments iterationSet and « ». 

CaseClause : case Expression : StatementListopt 

1. If the StatementList is present, return ContainsUndefinedContinueTarget of StatementList with arguments iterationSet and « ». 
2. Return false. 

DefaultClause : default : StatementListopt 

1. If the StatementList is present, return ContainsUndefinedContinueTarget of StatementList with arguments iterationSet and « ». 
2. Return false. 

LabelledStatement : LabelIdentifier : LabelledItem

1. Let label be the StringValue of LabelIdentifier. 
2. Let newLabelSet be the list-concatenation of labelSet and « label ». 
3. Return ContainsUndefinedContinueTarget of LabelledItem with arguments iterationSet and newLabelSet. 

LabelledItem : FunctionDeclaration

1. Return false. 

TryStatement : try Block Catch

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of Block with arguments iterationSet and « ». 
2. If hasUndefinedLabels is true, return true. 
3. Return ContainsUndefinedContinueTarget of Catch with arguments iterationSet and « ». 

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TryStatement : try Block Finally

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of Block with arguments iterationSet and « ».
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedContinueTarget of Finally with arguments iterationSet and « ».

TryStatement : try Block Catch Finally

1. If ContainsUndefinedContinueTarget of Block with arguments iterationSet and « » is true, return true.
2. If ContainsUndefinedContinueTarget of Catch with arguments iterationSet and « » is true, return true.
3. Return ContainsUndefinedContinueTarget of Finally with arguments iterationSet and « ».

Catch : catch ( CatchParameter ) Block

1. Return ContainsUndefinedContinueTarget of Block with arguments iterationSet and « ».

FunctionStatementList : [empty]

1. Return false.

ClassStaticBlockStatementList : [empty]

1. Return false.

ModuleItemList : ModuleItemList ModuleItem

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of ModuleItemList with arguments iterationSet and « ».
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedContinueTarget of ModuleItem with arguments iterationSet and « ».

ModuleItem :

  ImportDeclaration
  ExportDeclaration

1. Return false.

8.4 Function Name Inference

8.4.1 Static Semantics: HasName

The syntax-directed operation HasName takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. If IsFunctionDefinition of expr is false, return false.
3. Return HasName of expr.

FunctionExpression :

  function ( FormalParameters ) { FunctionBody }

GeneratorExpression :

  function *( FormalParameters ) { GeneratorBody }

AsyncGeneratorExpression :

  async function *( FormalParameters ) { AsyncGeneratorBody }

AsyncFunctionExpression :

  async function ( FormalParameters ) { AsyncFunctionBody }

TryStatement : try Block Finally

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of Block with arguments iterationSet and « ».
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedContinueTarget of Finally with arguments iterationSet and « ».

TryStatement : try Block Catch Finally

1. If ContainsUndefinedContinueTarget of Block with arguments iterationSet and « » is true, return true.
2. If ContainsUndefinedContinueTarget of Catch with arguments iterationSet and « » is true, return true.
3. Return ContainsUndefinedContinueTarget of Finally with arguments iterationSet and « ».

Catch : catch ( CatchParameter ) Block

1. Return ContainsUndefinedContinueTarget of Block with arguments iterationSet and « ».

FunctionStatementList : [empty]

1. Return false.

ClassStaticBlockStatementList : [empty]

1. Return false.

ModuleItemList : ModuleItemList ModuleItem

1. Let hasUndefinedLabels be ContainsUndefinedContinueTarget of ModuleItemList with arguments iterationSet and « ».
2. If hasUndefinedLabels is true, return true.
3. Return ContainsUndefinedContinueTarget of ModuleItem with arguments iterationSet and « ».

ModuleItem :

  ImportDeclaration
  ExportDeclaration

1. Return false.

8.4 Function Name Inference

8.4.1 Static Semantics: HasName

The syntax-directed operation HasName takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. If IsFunctionDefinition of expr is false, return false.
3. Return HasName of expr.
ArrowFunction:
  ArrowParameters => ConciseBody
AsyncArrowFunction:
  async AsyncArrowBindingIdentifier => AsyncConciseBody
  CoverCallExpressionAndAsyncArrowHead => AsyncConciseBody
ClassExpression:
  class ClassTail

1. Return false.

FunctionExpression:
  function BindingIdentifier ( FormalParameters ) { FunctionBody }
GeneratorExpression:
  function * BindingIdentifier ( FormalParameters ) { GeneratorBody }
AsyncGeneratorExpression:
  async function * BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }
AsyncFunctionExpression:
  async function BindingIdentifier ( FormalParameters ) { AsyncFunctionBody }
ClassExpression:
  class BindingIdentifier ClassTail

1. Return true.

8.4.2 Static Semantics: IsFunctionDefinition

The syntax-directed operation IsFunctionDefinition takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return IsFunctionDefinition of expr.

PrimaryExpression:
  this
  IdentifierReference
  Literal
  ArrayLiteral
  ObjectLiteral
  RegularExpressionLiteral
  TemplateLiteral
MemberExpression:
  MemberExpression [ Expression ]
  MemberExpression . IdentifierName
  MemberExpression TemplateLiteral
  SuperProperty
  MetaProperty
  new MemberExpression Arguments
  MemberExpression . PrivateIdentifier
NewExpression:
  new NewExpression
LeftHandSideExpression:
  CallExpression
  OptionalExpression
UpdateExpression:
  LeftHandSideExpression ++
  LeftHandSideExpression --
    ++ UnaryExpression
    -- UnaryExpression
UnaryExpression:
  delete UnaryExpression
  void UnaryExpression
  typeof UnaryExpression
  + UnaryExpression
  - UnaryExpression
  ~ UnaryExpression
  ! UnaryExpression
  AwaitExpression
ExponentiationExpression:
  UpdateExpression ** ExponentiationExpression
MultiplicativeExpression:
  MultiplicativeExpression MultiplicativeOperator ExponentiationExpression
AdditiveExpression:
  AdditiveExpression + MultiplicativeExpression
  AdditiveExpression - MultiplicativeExpression
ShiftExpression:
  ShiftExpression << AdditiveExpression
  ShiftExpression >> AdditiveExpression
  ShiftExpression >>> AdditiveExpression
RelationalExpression:
  RelationalExpression < ShiftExpression
  RelationalExpression > ShiftExpression
  RelationalExpression <= ShiftExpression
  RelationalExpression >= ShiftExpression
  RelationalExpression instanceof ShiftExpression
  RelationalExpression in ShiftExpression
  PrivateIdentifier in ShiftExpression
EqualityExpression:
  EqualityExpression == RelationalExpression
  EqualityExpression != RelationalExpression
  EqualityExpression === RelationalExpression
  EqualityExpression !== RelationalExpression
BitwiseANDExpression:
  BitwiseANDExpression & EqualityExpression
BitwiseXORExpression:
  BitwiseXORExpression ^ BitwiseANDExpression
BitwiseORExpression:
  BitwiseORExpression | BitwiseXORExpression
LogicalANDExpression:
  LogicalANDExpression & BitwiseORExpression
LogicalORExpression:
  LogicalORExpression || LogicalANDExpression
CoalesceExpression:
  CoalesceExpressionHead ?? BitwiseORExpression
ConditionalExpression:
  ShortCircuitExpression ? AssignmentExpression : AssignmentExpression
AssignmentExpression:
  YieldExpression
  LeftHandSideExpression = AssignmentExpression
  LeftHandSideExpression AssignmentOperator AssignmentExpression
  LeftHandSideExpression & &= AssignmentExpression
  LeftHandSideExpression ||= AssignmentExpression
  LeftHandSideExpression ??= AssignmentExpression

Expression:
  Expression , AssignmentExpression

1. Return false.

AssignmentExpression:
  ArrowFunction
  AsyncArrowFunction
FunctionExpression:
  function BindingIdentifier opt ( FormalParameters ) { FunctionBody }
GeneratorExpression:
  function * BindingIdentifier opt ( FormalParameters ) { GeneratorBody }
AsyncGeneratorExpression:
  async function * BindingIdentifier opt ( FormalParameters ) { AsyncGeneratorBody }
AsyncFunctionExpression:
  async function BindingIdentifier opt ( FormalParameters ) { AsyncFunctionBody }
ClassExpression:
  class BindingIdentifier opt ClassTail

1. Return true.

8.4.3 Static Semantics: IsAnonymousFunctionDefinition ( expr )

The abstract operation IsAnonymousFunctionDefinition takes argument expr (an AssignmentExpression Parse Node, an Initializer Parse Node, or an Expression Parse Node) and returns a Boolean. It determines if its argument is a function definition that does not bind a name. It performs the following steps when called:

1. If IsFunctionDefinition of expr is false, return false.
2. Let hasName be HasName of expr.
3. If hasName is true, return false.
4. Return true.

8.4.4 Static Semantics: IsIdentifierRef

The syntax-directed operation IsIdentifierRef takes no arguments and returns a Boolean. It is defined piecewise over the following productions:
PrimaryExpression : IdentifierReference

1. Return true.
8.4.5 Runtime Semantics: NamedEvaluation

The syntax-directed operation NamedEvaluation takes argument name (a property key or a Private Name) and returns either a normal completion containing a function object or an abrupt completion. It is defined piecewise over the following productions:

PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList

MemberExpression : MemberExpression [ Expression ]
MemberExpression . IdentifierName
MemberExpression TemplateLiteral
SuperProperty
MetaProperty
new MemberExpression Arguments
MemberExpression . PrivateIdentifier

NewExpression : new NewExpression

LeftHandSideExpression : CallExpression
OptionalExpression

1. Return false.

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.

ParenthesizedExpression : ( Expression )

1. Assert: IsAnonymousFunctionDefinition( Expression ) is true.

FunctionExpression : function ( FormalParameters ) { FunctionBody }

1. Return InstantiateOrdinaryFunctionExpression of FunctionExpression with argument name.

GeneratorExpression : function * ( FormalParameters ) { GeneratorBody }

1. Return InstantiateGeneratorFunctionExpression of GeneratorExpression with argument name.

AsyncGeneratorExpression : async function * ( FormalParameters ) { AsyncGeneratorBody }

1. Return InstantiateAsyncGeneratorFunctionExpression of AsyncGeneratorExpression with argument name.
AsyncFunctionExpression : async function ( FormalParameters ) { AsyncFunctionBody }

1. Return InstantiateAsyncFunctionExpression of AsyncFunctionExpression with argument name.

ArrowFunction : ArrowParameters => ConciseBody

1. Return InstantiateArrowFunctionExpression of ArrowFunction with argument name.

AsyncArrowFunction :
   async AsyncArrowBindingIdentifier => AsyncConciseBody
   CoverCallExpressionAndAsyncArrowHead => AsyncConciseBody

1. Return InstantiateAsyncArrowFunctionExpression of AsyncArrowFunction with argument name.

ClassExpression : class ClassTail

1. Let value be ? ClassDefinitionEvaluation of ClassTail with arguments undefined and name.
2. Set value.[[SourceText]] to the source text matched by ClassExpression.
3. Return value.

8.5 Contains

8.5.1 Static Semantics: Contains

The syntax-directed operation Contains takes argument symbol (a grammar symbol) and returns a Boolean.

Every grammar production alternative in this specification which is not listed below implicitly has the following default definition of Contains:

1. For each child node child of this Parse Node, do
   a. If child is an instance of symbol, return true.
   b. If child is an instance of a nonterminal, then
      i. Let contained be the result of child Contains symbol.
      ii. If contained is true, return true.
2. Return false.

FunctionDeclaration :
   function BindingIdentifier ( FormalParameters ) { FunctionBody }
   function ( FormalParameters ) { FunctionBody }

FunctionExpression :
   function BindingIdentifier_opt ( FormalParameters ) { FunctionBody }

GeneratorDeclaration :
   function * ( BindingIdentifier ( FormalParameters ) { GeneratorBody }
   function * ( FormalParameters ) { GeneratorBody }

GeneratorExpression :
   function * BindingIdentifier_opt ( FormalParameters ) { GeneratorBody }

AsyncGeneratorDeclaration :
   async function * BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }
   async function * ( FormalParameters ) { AsyncGeneratorBody }

AsyncGeneratorExpression :
   async function * BindingIdentifier_opt ( FormalParameters ) { AsyncGeneratorBody }

AsyncFunctionDeclaration :
   async function BindingIdentifier ( FormalParameters ) { AsyncFunctionBody }
   async function ( FormalParameters ) { AsyncFunctionBody }
AsyncFunctionExpression :
  async function BindingIdentifieropt ( FormalParameters ) { AsyncFunctionBody }

1. Return false.

NOTE 1 Static semantic rules that depend upon substructure generally do not look into function definitions.

ClassTail : ClassHeritageopt { ClassBody }

1. If symbol is ClassBody, return true.
2. If symbol is ClassHeritage, then
   a. If ClassHeritage is present, return true; otherwise return false.
3. If ClassHeritage is present, then
   a. If ClassHeritage Contains symbol is true, return true.
4. Return the result of ComputedPropertyContains of ClassBody with argument symbol.

NOTE 2 Static semantic rules that depend upon substructure generally do not look into class bodies except for PropertyNames.

ClassStaticBlock : static { ClassStaticBlockBody }

1. Return false.

NOTE 3 Static semantic rules that depend upon substructure generally do not look into static initialization blocks.

ArrowFunction : ArrowParameters => ConciseBody

1. If symbol is not one of NewTarget, SuperProperty, SuperCall, super, or this, return false.
2. If ArrowParameters Contains symbol is true, return true.
3. Return ConciseBody Contains symbol.

ArrowParameters : CoverParenthesizedExpressionAndArrowParameterList

1. Let formals be the ArrowFormalParameters that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return formals Contains symbol.

AsyncArrowFunction : async AsyncArrowBindingIdentifier => AsyncConciseBody

1. If symbol is not one of NewTarget, SuperProperty, SuperCall, super, or this, return false.
2. Return AsyncConciseBody Contains symbol.

AsyncArrowFunction : CoverCallExpressionAndAsyncArrowHead => AsyncConciseBody

1. If symbol is not one of NewTarget, SuperProperty, SuperCall, super, or this, return false.
2. Let head be the AsyncArrowHead that is covered by CoverCallExpressionAndAsyncArrowHead.
3. If head Contains symbol is true, return true.
4. Return AsyncConciseBody Contains symbol.

NOTE 4 Contains is used to detect new.target, this, and super usage within an ArrowFunction or AsyncArrowFunction.
PropertyDefinition : MethodDefinition

1. If `symbol` is `MethodDefinition`, return `true`.
2. Return the result of `ComputedPropertyContains` of `MethodDefinition` with argument `symbol`.

LiteralPropertyName : IdentifierName

1. Return `false`.

MemberExpression : MemberExpression . IdentifierName

1. If `MemberExpression Contains symbol` is `true`, return `true`.
2. Return `false`.

SuperProperty : `super` . IdentifierName

1. If `symbol` is the `ReservedWord` `super`, return `true`.
2. Return `false`.

CallExpression : CallExpression . IdentifierName

1. If `CallExpression Contains symbol` is `true`, return `true`.
2. Return `false`.

OptionalChain : `?` . IdentifierName

1. Return `false`.

OptionalChain : OptionalChain . IdentifierName

1. If `OptionalChain Contains symbol` is `true`, return `true`.
2. Return `false`.

8.5.2 Static Semantics: ComputedPropertyContains

The syntax-directed operation `ComputedPropertyContains` takes argument `symbol` (a grammar symbol) and returns a Boolean. It is defined piecewise over the following productions:

```
ClassElementName : PrivatIdentifier

PropertyName : LiteralPropertyName

1. Return `false`.

PropertyDefinition : ComputedPropertyName
1. Return the result of `ComputedPropertyName Contains symbol`.

MethodDefinition :
  ClassElementName ( UniqueFormalParameters ) { FunctionBody }
  get ClassElementName ( ) { FunctionBody }
  set ClassElementName ( PropertySetParameterList ) { FunctionBody }

1. Return the result of `ComputedPropertyContains` of `ClassElementName` with argument `symbol`.

GeneratorMethod : ★ ClassElementName ( UniqueFormalParameters ) { GeneratorBody }
1. Return the result of `ComputedPropertyContains` of `ClassElementName` with argument `symbol`.
```
AsyncGeneratorMethod : async ★ ClassElementName ( UniqueFormalParameters ) { AsyncGeneratorBody }

1. Return the result of ComputedPropertyContains of ClassElementName with argument symbol.

ClassElementList : ClassElementList ClassElement

1. Let inList be ComputedPropertyContains of ClassElementList with argument symbol.
2. If inList is true, return true.
3. Return the result of ComputedPropertyContains of ClassElement with argument symbol.

ClassElement : ClassStaticBlock

1. Return false.

ClassElement : ;

1. Return false.

AsyncMethod : async ClassElementName ( UniqueFormalParameters ) { AsyncFunctionBody }

1. Return the result of ComputedPropertyContains of ClassElementName with argument symbol.

FieldDefinition : ClassElementName Initializer\opt

1. Return the result of ComputedPropertyContains of ClassElementName with argument symbol.

8.6 Miscellaneous

These operations are used in multiple places throughout the specification.

8.6.1 Runtime Semantics: InstantiateFunctionObject

The syntax-directed operation InstantiateFunctionObject takes arguments env (an Environment Record) and privateEnv (a PrivateEnvironment Record or null) and returns an ECMAScript function object. It is defined piecewise over the following productions:

FunctionDeclaration :
  function BindingIdentifier ( FormalParameters ) { FunctionBody }
  function ( FormalParameters ) { FunctionBody }

1. Return InstantiateOrdinaryFunctionObject of FunctionDeclaration with arguments env and privateEnv.

GeneratorDeclaration :
  function ★ BindingIdentifier ( FormalParameters ) { GeneratorBody }
  function ★ ( FormalParameters ) { GeneratorBody }

1. Return InstantiateGeneratorFunctionObject of GeneratorDeclaration with arguments env and privateEnv.

AsyncGeneratorDeclaration :
  async function ★ BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }
  async function ★ ( FormalParameters ) { AsyncGeneratorBody }

1. Return InstantiateAsyncGeneratorFunctionObject of AsyncGeneratorDeclaration with arguments env and privateEnv.
AsyncFunctionDeclaration:
  async function BindingIdentifier ( FormalParameters ) { AsyncFunctionBody }
  async function ( FormalParameters ) { AsyncFunctionBody }

1. Return InstantiateAsyncFunctionObject of AsyncFunctionDeclaration with arguments env and privateEnv.

8.6.2 Runtime Semantics: BindingInitialization

The syntax-directed operation BindingInitialization takes arguments value (an ECMAScript language value) and environment (an Environment Record or undefined) and returns either a normal completion containing UNUSED or an abrupt completion.

NOTE undefined is passed for environment to indicate that a PutValue operation should be used to assign the initialization value. This is the case for var statements and formal parameter lists of some non-strict functions (See 10.2.11). In those cases a lexical binding is hoisted and preinitialized prior to evaluation of its initializer.

It is defined piecewise over the following productions:

BindingIdentifier : Identifier
  1. Let name be StringValue of Identifier.
  2. Return ? InitializeBoundName(name, value, environment).

BindingIdentifier : yield

BindingIdentifier : await

BindingPattern : ObjectBindingPattern

BindingPattern : ArrayBindingPattern
  1. Let iteratorRecord be ? GetIterator(value, SYNC).
  2. Let result be Completion(IteratorBindingInitialization of ArrayBindingPattern with arguments iteratorRecord and environment).
  3. If iteratorRecord.[[Done]] is false, return ? IteratorClose(iteratorRecord, result).
  4. Return ? result.

ObjectBindingPattern : { }
  1. Return UNUSED.

ObjectBindingPattern :
  { BindingPropertyList }
  { BindingPropertyList , }
  1. Perform ? PropertyBindingInitialization of BindingPropertyList with arguments value and environment.
  2. Return UNUSED.
ObjectBindingPattern : { BindingRestProperty }

1. Let excludedNames be a new empty List.
2. Return ? RestBindingInitialization of BindingRestProperty with arguments value, environment, and excludedNames.

ObjectBindingPattern : { BindingPropertyList, BindingRestProperty }

1. Let excludedNames be ? PropertyBindingInitialization of BindingPropertyList with arguments value and environment.
2. Return ? RestBindingInitialization of BindingRestProperty with arguments value, environment, and excludedNames.

8.6.2.1 InitializeBoundName ( name, value, environment )

The abstract operation InitializeBoundName takes arguments name (a String), value (an ECMAScript language value), and environment (an Environment Record or undefined) and returns either a normal completion containing UNUSED or an abrupt completion. It performs the following steps when called:

1. If environment is not undefined, then
   a. Perform ! environment.InitializeBinding(name, value).
   b. Return UNUSED.
2. Else,
   a. Let lhs be ? ResolveBinding(name).

8.6.3 Runtime Semantics: IteratorBindingInitialization

The syntax-directed operation IteratorBindingInitialization takes arguments iteratorRecord (an Iterator Record) and environment (an Environment Record or undefined) and returns either a normal completion containing UNUSED or an abrupt completion.

NOTE When undefined is passed for environment it indicates that a PutValue operation should be used to assign the initialization value. This is the case for formal parameter lists of non-strict functions. In that case the formal parameter bindings are preinitialized in order to deal with the possibility of multiple parameters with the same name.

It is defined piecewise over the following productions:

ArrayBindingPattern : [ ]

1. Return UNUSED.

ArrayBindingPattern : [ Elision ]


ArrayBindingPattern : [ Elisionopt BindingRestElement ]

1. If Elision is present, then
2. Return ? IteratorBindingInitialization of BindingRestElement with arguments iteratorRecord and environment.

ArrayBindingPattern : [ BindingElementList, Elision ]

1. Perform ? IteratorBindingInitialization of BindingElementList with arguments iteratorRecord and environment.
ArrayBindingPattern : [ BindingElementList , Elisionopt BindingRestElement ]

1. Perform ? IteratorBindingInitialization of BindingElementList with arguments iteratorRecord and environment.
2. If Elision is present, then
3. Return ? IteratorBindingInitialization of BindingRestElement with arguments iteratorRecord and environment.

BindingElementList : BindingElementList , BindingElisionElement

1. Perform ? IteratorBindingInitialization of BindingElementList with arguments iteratorRecord and environment.
2. Return ? IteratorBindingInitialization of BindingElisionElement with arguments iteratorRecord and environment.

BindingElisionElement : Elision BindingElement

2. Return ? IteratorBindingInitialization of BindingElement with arguments iteratorRecord and environment.

SingleNameBinding : BindingIdentifier Initializeropt

1. Let bindingId be StringValue of BindingIdentifier.
2. Let lhs be ? ResolveBinding(bindingId, environment).
3. Let v be undefined.
4. If iteratorRecord.[[Done]] is false, then
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is not DONE, then
      i. Set v to next.
5. If Initializer is present and v is undefined, then
   a. If IsAnonymousFunctionDefinition(Initializer) is true, then
      i. Set v to ? NamedEvaluation of Initializer with argument bindingId.
   b. Else,
      i. Let defaultValue be ? Evaluation of Initializer.
      ii. Set v to ? GetValue(defaultValue).
6. If environment is undefined, return ? PutValue(lhs, v).

BindingElement : BindingPattern Initializeropt

1. Let v be undefined.
2. If iteratorRecord.[[Done]] is false, then
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is not DONE, then
      i. Set v to next.
3. If Initializer is present and v is undefined, then
   b. Set v to ? GetValue(defaultValue).

BindingRestElement : . . . BindingIdentifier

1. Let lhs be ? ResolveBinding(StringValue of BindingIdentifier, environment).
2. Let A be ![ArrayCreator](θ).
3. Let n be 0.
4. Repeat,
   a. Let next be DONE.
   b. If iteratorRecord.[[Done]] is false, then
      i. Set next to ? IteratorStepValue(iteratorRecord).
   c. If next is DONE, then
If `environment` is `undefined`, return `PutValue(lhs, A)`.
If `environment` is `undefined`, return `InitializeReferencedBinding(lhs, A)`.
Perform `CreateDataPropertyOrThrow(A, !ToString(F(n)), next)`.
Set `n` to `n + 1`.

**BindingRestElement**: ... **BindingPattern**
1. Let `A` be `ArrayCreate(0)`.
2. Let `n` be `0`.
3. Repeat,
   a. Let `next` be `DONE`.
   b. If `iteratorRecord`.[[Done]] is `false`, then
      i. Set `next` to `? IteratorStepValue(iteratorRecord)`.
   c. If `next` is `DONE`, then
      i. Return `BindingInitialization of BindingPattern with arguments A and environment`.
   d. Perform `CreateDataPropertyOrThrow(A, !ToString(F(n)), next)`.
   e. Set `n` to `n + 1`.

**FormalParameters**: `[empty]`
1. Return `UNUSED`.

**FormalParameters**: FormalParameterList, FunctionRestParameter
1. Perform `IteratorBindingInitialization of FormalParameterList with arguments iteratorRecord and environment`.
2. Return `IteratorBindingInitialization of FunctionRestParameter with arguments iteratorRecord and environment`.

**FormalParameterList**: FormalParameterList, FormalParameter
1. Perform `IteratorBindingInitialization of FormalParameterList with arguments iteratorRecord and environment`.
2. Return `IteratorBindingInitialization of FormalParameter with arguments iteratorRecord and environment`.

**ArrowParameters**: BindingIdentifier
1. Let `v` be `undefined`.
2. Assert: `iteratorRecord`.[[Done]] is `false`.
3. Let `next` be `? IteratorStepValue(iteratorRecord)`.
4. If `next` is not `DONE`, then
   a. Set `v` to `next`.
5. Return `BindingInitialization of BindingIdentifier with arguments v and environment`.

**ArrowParameters**: CoverParenthesizedExpressionAndArrowParameterList
1. Let `formals` be the `ArrowFormalParameters` that is covered by `CoverParenthesizedExpressionAndArrowParameterList`.
2. Return `IteratorBindingInitialization of formals with arguments iteratorRecord and environment`.

**AsyncArrowBindingIdentifier**: BindingIdentifier
1. Let `v` be `undefined`.
2. Assert: `iteratorRecord`.[[Done]] is `false`.
3. Let `next` be `? IteratorStepValue(iteratorRecord)`.
4. If `next` is not `DONE`, then
   a. Set `v` to `next`.
5. Return `BindingInitialization of BindingIdentifier with arguments v and environment`.
8.6.4 Static Semantics: AssignmentTargetType

The syntax-directed operation AssignmentTargetType takes no arguments and returns SIMPLE or INVALID. It is defined piecewise over the following productions:

IdentifierReference : Identifier

1. If this IdentifierReference is contained in strict mode code and StringValue of Identifier is either "eval" or "arguments", return INVALID.
2. Return SIMPLE.

IdentifierReference :
  yield
  await

CallExpression :
  CallExpression [ Expression ]
  CallExpression . IdentifierName
  CallExpression . PrivatIdentifier

MemberExpression :
  MemberExpression [ Expression ]
  MemberExpression . IdentifierName
  SuperProperty
  MemberExpression . PrivatIdentifier

1. Return SIMPLE.

PrimaryExpression :
  CoverParenthesizedExpressionAndArrowParameterList

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return AssignmentTargetType of expr.

PrimaryExpression :
  this
  Literal
  ArrayLiteral
  ObjectLiteral
  FunctionExpression
  ClassExpression
  GeneratorExpression
  AsyncFunctionExpression
  AsyncGeneratorExpression
  RegularExpressionLiteral
  TemplateLiteral

CallExpression :
  CoverCallExpressionAndAsyncArrowHead
  SuperCall
  ImportCall
  CallExpression Arguments
  CallExpression TemplateLiteral

NewExpression :
  new NewExpression

MemberExpression :
  MemberExpression TemplateLiteral
  new MemberExpression Arguments
NewTarget:
   new . target
ImportMeta:
   import . meta
LeftHandSideExpression:
   OptionalExpression
UpdateExpression:
   LeftHandSideExpression ++
   LeftHandSideExpression --
   ++ UnaryExpression
   -- UnaryExpression
UnaryExpression:
   delete UnaryExpression
   void UnaryExpression
   typeof UnaryExpression
   + UnaryExpression
   - UnaryExpression
   ~ UnaryExpression
   ! UnaryExpression
   AwaitExpression
ExponentiationExpression:
   UpdateExpression ** ExponentiationExpression
MultiplicativeExpression:
   MultiplicativeExpression MultiplicativeOperator ExponentiationExpression
AdditiveExpression:
   AdditiveExpression + MultiplicativeExpression
   AdditiveExpression - MultiplicativeExpression
ShiftExpression:
   ShiftExpression << AdditiveExpression
   ShiftExpression >> AdditiveExpression
   ShiftExpression >>> AdditiveExpression
RelationalExpression:
   RelationalExpression < ShiftExpression
   RelationalExpression > ShiftExpression
   RelationalExpression <= ShiftExpression
   RelationalExpression instanceof ShiftExpression
   RelationalExpression in ShiftExpression
   PrivateIdentifier in ShiftExpression
EqualityExpression:
   EqualityExpression == RelationalExpression
   EqualityExpression != RelationalExpression
   EqualityExpression === RelationalExpression
   EqualityExpression !== RelationalExpression
BitwiseANDExpression:
   BitwiseANDExpression & EqualityExpression
BitwiseXORExpression:
   BitwiseXORExpression ^ BitwiseANDExpression
BitwiseORExpression:
   BitwiseORExpression | BitwiseXORExpression
LogicalANDExpression:
   LogicalANDExpression && BitwiseORExpression
LogicalORExpression : LogicalORExpression || LogicalANDExpression
CoalesceExpression :
  CoalesceExpressionHead ?? BitwiseORExpression
ConditionalExpression :
  ShortCircuitExpression ? AssignmentExpression : AssignmentExpression
AssignmentExpression :
  YieldExpression
  ArrowFunction
  AsyncArrowFunction
  LeftHandSideExpression = AssignmentExpression
  LeftHandSideExpression AssignmentOperator AssignmentExpression
  LeftHandSideExpression &= AssignmentExpression
  LeftHandSideExpression ||= AssignmentExpression
  LeftHandSideExpression ??= AssignmentExpression

Expression :
  Expression , AssignmentExpression

1. Return INVALID.

8.6.5 Static Semantics: PropName

The syntax-directed operation PropName takes no arguments and returns a String or EMPTY. It is defined piecewise over the following productions:
PropertyDefinition : IdentifierReference
  1. Return StringValue of IdentifierReference.

PropertyDefinition : ... AssignmentExpression
  1. Return EMPTY.

PropertyDefinition : PropertyName : AssignmentExpression
  1. Return PropName of PropertyName.

LiteralPropertyName : IdentifierName
  1. Return StringValue of IdentifierName.

LiteralPropertyName : StringLiteral
  1. Return the SV of StringLiteral.

LiteralPropertyName : NumericLiteral
  1. Let \( nbr \) be the NumericValue of NumericLiteral.
  2. Return ! ToString(\( nbr \)).

ComputedPropertyName : [ AssignmentExpression ]
  1. Return EMPTY.
MethodDefinition:

```
ClassElementName ( UniqueFormalParameters ) { FunctionBody }
get ClassElementName ( ) { FunctionBody }
set ClassElementName ( PropertySetParameterList ) { FunctionBody }
```

1. Return PropName of ClassElementName.

GeneratorMethod:

```
★ ClassElementName ( UniqueFormalParameters ) { GeneratorBody }
```

1. Return PropName of ClassElementName.

AsyncGeneratorMethod:

```
async ★ ClassElementName ( UniqueFormalParameters ) {
AsyncGeneratorBody
}
```

1. Return PropName of ClassElementName.

ClassElement:

```
ClassStaticBlock
```

1. Return EMPTY.

```
ClassElement
```

1. Return EMPTY.

AsyncMethod:

```
async ClassElementName ( UniqueFormalParameters ) {
AsyncFunctionBody
}
```

1. Return PropName of ClassElementName.

FieldDefinition:

```
ClassElementName Initializer\opt
```

1. Return PropName of ClassElementName.

```
ClassElementName : PrivateIdentifier
```

1. Return EMPTY.

9 Executable Code and Execution Contexts

9.1 Environment Records

*Environment Record* is a specification type used to define the association of *Identifiers* to specific variables and functions, based upon the lexical nesting structure of ECMAScript code. Usually an Environment Record is associated with some specific syntactic structure of ECMAScript code such as a *FunctionDeclaration*, a *BlockStatement*, or a *Catch* clause of a *TryStatement*. Each time such code is evaluated, a new Environment Record is created to record the identifier bindings that are created by that code.

Every Environment Record has an `[[OuterEnv]]` field, which is either `null` or a reference to an outer Environment Record. This is used to model the logical nesting of Environment Record values. The outer reference of an (inner) Environment Record is a reference to the Environment Record that logically surrounds the inner Environment Record. An outer Environment Record may, of course, have its own outer Environment Record. An Environment Record may serve as the outer environment for multiple inner Environment Records. For example, if a *FunctionDeclaration* contains two nested *FunctionDeclarations* then the Environment Records of each of the nested functions will have as their outer Environment Record the Environment Record of the current evaluation of the surrounding function.

Environment Records are purely specification mechanisms and need not correspond to any specific artefact of an ECMAScript implementation. It is impossible for an ECMAScript program to directly access or manipulate such values.
9.1.1 The Environment Record Type Hierarchy

Environment Records can be thought of as existing in a simple object-oriented hierarchy where Environment Record is an abstract class with three concrete subclasses: Declarative Environment Record, Object Environment Record, and Global Environment Record. Function Environment Records and Module Environment Records are subclasses of Declarative Environment Record.

- Environment Record (abstract)
  - A Declarative Environment Record is used to define the effect of ECMAScript language syntactic elements such as FunctionDeclarations, VariableDeclarations, and Catch clauses that directly associate identifier bindings with ECMAScript language values.
  - A Function Environment Record corresponds to the invocation of an ECMAScript function object, and contains bindings for the top-level declarations within that function. It may establish a new this binding. It also captures the state necessary to support super method invocations.
  - A Module Environment Record contains the bindings for the top-level declarations of a Module. It also contains the bindings that are explicitly imported by the Module. Its [[OuterEnv]] is a Global Environment Record.
  - An Object Environment Record is used to define the effect of ECMAScript elements such as WithStatement that associate identifier bindings with the properties of some object.
  - A Global Environment Record is used for Script global declarations. It does not have an outer environment; its [[OuterEnv]] is null. It may be prepopulated with identifier bindings and it includes an associated global object whose properties provide some of the global environment's identifier bindings. As ECMA-Script code is executed, additional properties may be added to the global object and the initial properties may be modified.

The Environment Record abstract class includes the abstract specification methods defined in Table 16. These abstract methods have distinct concrete algorithms for each of the concrete subclasses.

Table 16: Abstract Methods of Environment Records

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>HasBinding(N)</td>
<td>Determine if an Environment Record has a binding for the String value N. Return true if it does and false if it does not.</td>
</tr>
<tr>
<td>CreateMutableBinding(N, D)</td>
<td>Create a new but uninitialized mutable binding in an Environment Record. The String value N is the text of the bound name. If the Boolean argument D is true the binding may be subsequently deleted.</td>
</tr>
<tr>
<td>CreateImmutableBinding(N, S)</td>
<td>Create a new but uninitialized immutable binding in an Environment Record. The String value N is the text of the bound name. If S is true then attempts to set it after it has been initialized will always throw an exception, regardless of the strict mode setting of operations that reference that binding.</td>
</tr>
<tr>
<td>InitializeBinding(N, V)</td>
<td>Set the value of an already existing but uninitialized binding in an Environment Record. The String value N is the text of the bound name. V is the value for the binding and is a value of any ECMAScript language type.</td>
</tr>
<tr>
<td>SetMutableBinding(N, V, S)</td>
<td>Set the value of an already existing mutable binding in an Environment Record. The String value N is the text of the bound name. V is the value for the binding and may be a value of any ECMAScript language type. S is a Boolean flag. If S is true and the binding cannot be set throw a TypeError exception.</td>
</tr>
</tbody>
</table>
Table 16: Abstract Methods of Environment Records (continued)

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>GetBindingValue(N, S)</td>
<td>Returns the value of an already existing binding from an Environment Record. The String value $N$ is the text of the bound name. $S$ is used to identify references originating in strict mode code or that otherwise require strict mode reference semantics. If $S$ is true and the binding does not exist throw a ReferenceError exception. If the binding exists but is uninitialized a ReferenceError is thrown, regardless of the value of $S$.</td>
</tr>
<tr>
<td>DeleteBinding(N)</td>
<td>Delete a binding from an Environment Record. The String value $N$ is the text of the bound name. If a binding for $N$ exists, remove the binding and return true. If the binding exists but cannot be removed return false. If the binding does not exist return true.</td>
</tr>
<tr>
<td>HasThisBinding()</td>
<td>Determine if an Environment Record establishes a this binding. Return true if it does and false if it does not.</td>
</tr>
<tr>
<td>HasSuperBinding()</td>
<td>Determine if an Environment Record establishes a super method binding. Return true if it does and false if it does not.</td>
</tr>
<tr>
<td>WithBaseObject()</td>
<td>If this Environment Record is associated with a with statement, return the with object. Otherwise, return undefined.</td>
</tr>
</tbody>
</table>

9.1.1.1 Declarative Environment Records

Each Declarative Environment Record is associated with an ECMAScript program scope containing variable, constant, let, class, module, import, and/or function declarations. A Declarative Environment Record binds the set of identifiers defined by the declarations contained within its scope.

The behaviour of the concrete specification methods for Declarative Environment Records is defined by the following algorithms.

9.1.1.1.1 HasBinding (N)

The HasBinding concrete method of a Declarative Environment Record $envRec$ takes argument $N$ (a String) and returns a normal completion containing a Boolean. It determines if the argument identifier is one of the identifiers bound by the record. It performs the following steps when called:

1. If $envRec$ has a binding for $N$, return true.
2. Return false.

9.1.1.1.2 CreateMutableBinding (N, D)

The CreateMutableBinding concrete method of a Declarative Environment Record $envRec$ takes arguments $N$ (a String) and $D$ (a Boolean) and returns a normal completion containing UNUSED. It creates a new mutable binding for the name $N$ that is uninitialized. A binding must not already exist in this Environment Record for $N$. If $D$ is true, the new binding is marked as being subject to deletion. It performs the following steps when called:

1. Assert: $envRec$ does not already have a binding for $N$.
2. Create a mutable binding in $envRec$ for $N$ and record that it is uninitialized. If $D$ is true, record that the newly created binding may be deleted by a subsequent DeleteBinding call.
3. Return UNUSED.
9.1.1.1.3 CreateImmutableBinding ( N, S )

The CreateImmutableBinding concrete method of a Declarative Environment Record envRec takes arguments N (a String) and S (a Boolean) and returns a normal completion containing UNUSED. It creates a new immutable binding for the name N that is uninitialized. A binding must not already exist in this Environment Record for N. If S is true, the new binding is marked as a strict binding. It performs the following steps when called:

1. Assert: envRec does not already have a binding for N.
2. Create an immutable binding in envRec for N and record that it is uninitialized. If S is true, record that the newly created binding is a strict binding.
3. Return UNUSED.

9.1.1.1.4 InitializeBinding ( N, V )

The InitializeBinding concrete method of a Declarative Environment Record envRec takes arguments N (a String) and V (an ECMAScript language value) and returns a normal completion containing UNUSED. It is used to set the bound value of the current binding of the identifier whose name is N to the value V. An uninitialized binding for N must already exist. It performs the following steps when called:

1. Assert: envRec must have an uninitialized binding for N.
2. Set the bound value for N in envRec to V.
3. Record that the binding for N in envRec has been initialized.
4. Return UNUSED.

9.1.1.1.5 SetMutableBinding ( N, V, S )

The SetMutableBinding concrete method of a Declarative Environment Record envRec takes arguments N (a String), V (an ECMAScript language value), and S (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It attempts to change the bound value of the current binding of the identifier whose name is N to the value V. A binding for N normally already exists, but in rare cases it may not. If the binding is an immutable binding, a TypeError is thrown if S is true. It performs the following steps when called:

1. If envRec does not have a binding for N, then
   a. If S is true, throw a ReferenceError exception.
   d. Return UNUSED.
2. If the binding for N in envRec is a strict binding, set S to true.
3. If the binding for N in envRec has not yet been initialized, then
   a. Throw a ReferenceError exception.
4. Else if the binding for N in envRec is a mutable binding, then
   a. Change its bound value to V.
5. Else,
   a. Assert: This is an attempt to change the value of an immutable binding.
   b. If S is true, throw a TypeError exception.
6. Return UNUSED.

NOTE An example of ECMAScript code that results in a missing binding at step 1 is:

```javascript
function f() { eval("var x; x = (delete x, 0);"); }
```
9.1.1.1.6 GetBindingValue \((N, S)\)

The GetBindingValue concrete method of a Declarative Environment Record `envRec` takes arguments \(N\) (a String) and \(S\) (a Boolean) and returns either a normal completion containing an ECMAScript language value or a throw completion. It returns the value of its bound identifier whose name is \(N\). If the binding exists but is uninitialized a `ReferenceError` is thrown, regardless of the value of \(S\). It performs the following steps when called:

1. **Assert**: `envRec` has a binding for \(N\).
2. If the binding for \(N\) in `envRec` is an uninitialized binding, throw a `ReferenceError` exception.
3. Return the value currently bound to \(N\) in `envRec`.

9.1.1.1.7 DeleteBinding \((N)\)

The DeleteBinding concrete method of a Declarative Environment Record `envRec` takes argument \(N\) (a String) and returns a normal completion containing a Boolean. It can only delete bindings that have been explicitly designated as being subject to deletion. It performs the following steps when called:

1. **Assert**: `envRec` has a binding for \(N\).
2. If the binding for \(N\) in `envRec` cannot be deleted, return `false`.
3. Remove the binding for \(N\) from `envRec`.
4. Return `true`.

9.1.1.1.8 HasThisBinding \((\)\)

The HasThisBinding concrete method of a Declarative Environment Record `envRec` takes no arguments and returns `false`. It performs the following steps when called:

1. Return `false`.

**NOTE** A regular Declarative Environment Record (i.e., one that is neither a Function Environment Record nor a Module Environment Record) does not provide a `this` binding.

9.1.1.1.9 HasSuperBinding \((\)\)

The HasSuperBinding concrete method of a Declarative Environment Record `envRec` takes no arguments and returns `false`. It performs the following steps when called:

1. Return `false`.

**NOTE** A regular Declarative Environment Record (i.e., one that is neither a Function Environment Record nor a Module Environment Record) does not provide a `super` binding.

9.1.1.1.10 WithBaseObject \((\)\)

The WithBaseObject concrete method of a Declarative Environment Record `envRec` takes no arguments and returns `undefined`. It performs the following steps when called:

1. Return `undefined`.

9.1.1.2 Object Environment Records

Each Object Environment Record is associated with an object called its binding object. An Object Environment Record binds the set of string identifier names that directly correspond to the property names of its binding object. Property keys that are not strings in the form of an `IdentifierName` are not included in the set of bound identifiers. Both own and inherited properties are included in the set regardless of the setting of their `[[Enumerable]]` attribute.
Because properties can be dynamically added and deleted from objects, the set of identifiers bound by an Object Environment Record may potentially change as a side-effect of any operation that adds or deletes properties. Any bindings that are created as a result of such a side-effect are considered to be a mutable binding even if the Writable attribute of the corresponding property is false. Immutable bindings do not exist for Object Environment Records.

Object Environment Records created for with statements (14.11) can provide their binding object as an implicit this value for use in function calls. The capability is controlled by a Boolean [[IsWithEnvironment]] field.

Object Environment Records have the additional state fields listed in Table 17.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[BindingObject]]</td>
<td>an Object</td>
<td>The binding object of this Environment Record.</td>
</tr>
<tr>
<td>[[IsWithEnvironment]]</td>
<td>a Boolean</td>
<td>Indicates whether this Environment Record is created for a with statement.</td>
</tr>
</tbody>
</table>

The behaviour of the concrete specification methods for Object Environment Records is defined by the following algorithms.

9.1.1.2.1 HasBinding (N)

The HasBinding concrete method of an Object Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It determines if its associated binding object has a property whose name is N. It performs the following steps when called:

1. Let bindingObject be envRec.([[BindingObject]]).
2. Let foundBinding be ? HasProperty(bindingObject, N).
3. If foundBinding is false, return false.
4. If envRec.([[IsWithEnvironment]]) is false, return true.
5. Let unscopables be ? Get(bindingObject, @@unscopables).
6. If unscopables is an Object, then
   a. Let blocked be ToBoolean(?? Get(unscopables, N)).
   b. If blocked is true, return false.
7. Return true.

9.1.1.2.2 CreateMutableBinding (N, D)

The CreateMutableBinding concrete method of an Object Environment Record envRec takes arguments N (a String) and D (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It creates in an Environment Record's associated binding object a property whose name is N and initializes it to the value undefined. If D is true, the new property's [[Configurable]] attribute is set to true; otherwise it is set to false. It performs the following steps when called:

1. Let bindingObject be envRec.([[BindingObject]]).
2. Perform ? DefinePropertyOrThrow(bindingObject, N, PropertyDescriptor { [[Value]]: undefined, [[Writable]]: true, [[Enumerable]]: true, [[Configurable]]: D }).
3. Return UNUSED.

NOTE Normally envRec will not have a binding for N but if it does, the semantics of DefinePropertyOrThrow may result in an existing binding being replaced or shadowed or cause an abrupt completion to be returned.
9.1.1.2.3 CreateImmutableBinding (N, S)

The CreateImmutableBinding concrete method of an Object Environment Record is never used within this specification.

9.1.1.2.4 InitializeBinding (N, V)

The InitializeBinding concrete method of an Object Environment Record envRec takes arguments N (a String) and V (an ECMAScript language value) and returns either a normal completion containing UNUSED or a throw completion. It is used to set the bound value of the current binding of the identifier whose name is N to the value V. It performs the following steps when called:

2. Return UNUSED.

NOTE In this specification, all uses of CreateMutableBinding for Object Environment Records are immediately followed by a call to InitializeBinding for the same name. Hence, this specification does not explicitly track the initialization state of bindings in Object Environment Records.

9.1.1.2.5 SetMutableBinding (N, V, S)

The SetMutableBinding concrete method of an Object Environment Record envRec takes arguments N (a String), V (an ECMAScript language value), and S (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It attempts to set the value of the Environment Record's associated binding object's property whose name is N to the value V. A property named N normally already exists but if it does not or is not currently writable, error handling is determined by S. It performs the following steps when called:

1. Let bindingObject be envRec.[[BindingObject]].
2. Let stillExists be ? HasProperty(bindingObject, N).
3. If stillExists is false and S is true, throw a ReferenceError exception.
5. Return UNUSED.

9.1.1.2.6 GetBindingValue (N, S)

The GetBindingValue concrete method of an Object Environment Record envRec takes arguments N (a String) and S (a Boolean) and returns either a normal completion containing an ECMAScript language value or a throw completion. It returns the value of its associated binding object's property whose name is N. The property should already exist but if it does not the result depends upon S. It performs the following steps when called:

1. Let bindingObject be envRec.[[BindingObject]].
2. Let value be ? HasProperty(bindingObject, N).
3. If value is false, then
   a. If S is false, return undefined; otherwise throw a ReferenceError exception.

9.1.1.2.7 DeleteBinding (N)

The DeleteBinding concrete method of an Object Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It can only delete bindings that correspond to properties of the environment object whose [[Configurable]] attribute have the value true. It performs the following steps when called:

1. Let bindingObject be envRec.[[BindingObject]].
9.1.1.2.8 HasThisBinding ()

The HasThisBinding concrete method of an Object Environment Record \(\text{envRec}\) takes no arguments and returns false. It performs the following steps when called:

1. Return false.

**NOTE** Object Environment Records do not provide a **this** binding.

9.1.1.2.9 HasSuperBinding ()

The HasSuperBinding concrete method of an Object Environment Record \(\text{envRec}\) takes no arguments and returns false. It performs the following steps when called:

1. Return false.

**NOTE** Object Environment Records do not provide a **super** binding.

9.1.1.2.10 WithBaseObject ()

The WithBaseObject concrete method of an Object Environment Record \(\text{envRec}\) takes no arguments and returns an Object or undefined. It performs the following steps when called:

1. If \(\text{envRec}.[[\text{IsWithEnvironment}]]\) is true, return \(\text{envRec}.[[\text{BindingObject}]]\).
2. Otherwise, return undefined.

9.1.1.3 Function Environment Records

A Function Environment Record is a Declarative Environment Record that is used to represent the top-level scope of a function and, if the function is not an ArrowFunction, provides a **this** binding. If a function is not an ArrowFunction function and references **super**, its Function Environment Record also contains the state that is used to perform **super** method invocations from within the function.

Function Environment Records have the additional state fields listed in Table 18.

Table 18: Additional Fields of Function Environment Records

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>([\text{ThisValue}])</td>
<td>an ECMAScript language value</td>
<td>This is the <strong>this</strong> value used for this invocation of the function.</td>
</tr>
<tr>
<td>([\text{ThisBindingStatus}])</td>
<td>LEXICAL, INITIALIZED, or UNINITIALIZED</td>
<td>If the value is LEXICAL, this is an ArrowFunction and does not have a local <strong>this</strong> value.</td>
</tr>
<tr>
<td>([\text{FunctionObject}])</td>
<td>an ECMAScript function object</td>
<td>The function object whose invocation caused this Environment Record to be created.</td>
</tr>
<tr>
<td>([\text{NewTarget}])</td>
<td>an Object or undefined</td>
<td>If this Environment Record was created by the ([\text{Construct}]) internal method, ([\text{NewTarget}]) is the value of the ([\text{Construct}]) <strong>newTarget</strong> parameter. Otherwise, its value is undefined.</td>
</tr>
</tbody>
</table>
Function Environment Records support all of the Declarative Environment Record methods listed in Table 16 and share the same specifications for all of those methods except for HasThisBinding and HasSuperBinding. In addition, Function Environment Records support the methods listed in Table 19:

Table 19: Additional Methods of Function Environment Records

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>BindThisValue(V)</td>
<td>Set the [[ThisValue]] and record that it has been initialized.</td>
</tr>
<tr>
<td>GetThisBinding()</td>
<td>Return the value of this Environment Record's this binding. Throws a ReferenceError if the this binding has not been initialized.</td>
</tr>
<tr>
<td>GetSuperBase()</td>
<td>Return the object that is the base for super property accesses bound in this Environment Record. The value undefined indicates that such accesses will produce runtime errors.</td>
</tr>
</tbody>
</table>

The behaviour of the additional concrete specification methods for Function Environment Records is defined by the following algorithms:

9.1.1.3.1 BindThisValue (V)

The BindThisValue concrete method of a Function Environment Record envRec takes argument V (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Assert: envRec.[[ThisBindingStatus]] is not LEXICAL.
2. If envRec.[[ThisBindingStatus]] is INITIALIZED, throw a ReferenceError exception.
3. Set envRec.[[ThisValue]] to V.
4. Set envRec.[[ThisBindingStatus]] to INITIALIZED.
5. Return V.

9.1.1.3.2 HasThisBinding ()

The HasThisBinding concrete method of a Function Environment Record envRec takes no arguments and returns a Boolean. It performs the following steps when called:

1. If envRec.[[ThisBindingStatus]] is LEXICAL, return false; otherwise, return true.

9.1.1.3.3 HasSuperBinding ()

The HasSuperBinding concrete method of a Function Environment Record envRec takes no arguments and returns a Boolean. It performs the following steps when called:

1. If envRec.[[ThisBindingStatus]] is LEXICAL, return false.
2. If envRec.[[FunctionObject]].[[HomeObject]] is undefined, return false; otherwise, return true.

9.1.1.3.4 GetThisBinding ()

The GetThisBinding concrete method of a Function Environment Record envRec takes no arguments and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Assert: envRec.[[ThisBindingStatus]] is not LEXICAL.
2. If envRec.[[ThisBindingStatus]] is UNINITIALIZED, throw a ReferenceError exception.
3. Return envRec.[[ThisValue]].
9.1.1.3.5 GetSuperBase ( )

The GetSuperBase concrete method of a Function Environment Record \( envRec \) takes no arguments and returns either a normal completion containing either an Object, null, or undefined, or a throw completion. It performs the following steps when called:

1. Let \( home \) be \( envRec.[[FunctionObject]].[[HomeObject]] \).
2. If \( home \) is undefined, return undefined.
3. Assert: home is an Object.
4. Return \( ? \ home .[[GetPrototypeOf]]() \).

9.1.1.4 Global Environment Records

A Global Environment Record is used to represent the outermost scope that is shared by all of the ECMAScript Script elements that are processed in a common realm. A Global Environment Record provides the bindings for built-in globals (clause 19), properties of the global object, and for all top-level declarations (8.2.9, 8.2.11) that occur within a Script.

A Global Environment Record is logically a single record but it is specified as a composite encapsulating an Object Environment Record and a Declarative Environment Record. The Object Environment Record has as its base object the global object of the associated Realm Record. This global object is the value returned by the Global Environment Record's GetThisBinding concrete method. The Object Environment Record component of a Global Environment Record contains the bindings for all built-in globals (clause 19) and all bindings introduced by a FunctionDeclaration, GeneratorDeclaration, AsyncFunctionDeclaration, AsyncGeneratorDeclaration, or VariableStatement contained in global code. The bindings for all other ECMAScript declarations in global code are contained in the Declarative Environment Record component of the Global Environment Record.

Properties may be created directly on a global object. Hence, the Object Environment Record component of a Global Environment Record may contain both bindings created explicitly by FunctionDeclaration, GeneratorDeclaration, AsyncFunctionDeclaration, AsyncGeneratorDeclaration, or VariableDeclaration declarations and bindings created implicitly as properties of the global object. In order to identify which bindings were explicitly created using declarations, a Global Environment Record maintains a list of the names bound using its CreateGlobalVarBinding and CreateGlobalFunctionBinding concrete methods.

Global Environment Records have the additional fields listed in Table 20 and the additional methods listed in Table 21.

**Table 20: Additional Fields of Global Environment Records**

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[]ObjectRecord]]</td>
<td>an Object Environment Record</td>
<td>Binding object is the global object. It contains global built-in bindings as well as FunctionDeclaration, GeneratorDeclaration, AsyncFunctionDeclaration, AsyncGeneratorDeclaration, and VariableDeclaration bindings in global code for the associated realm.</td>
</tr>
<tr>
<td>[[]GlobalThisValue]]</td>
<td>an Object</td>
<td>The value returned by this in global scope. Hosts may provide any ECMAScript Object value.</td>
</tr>
<tr>
<td>[[]DeclarativeRecord]]</td>
<td>a Declarative Environment Record</td>
<td>Contains bindings for all declarations in global code for the associated realm code except for FunctionDeclaration, GeneratorDeclaration, AsyncFunctionDeclaration, AsyncGeneratorDeclaration, and VariableDeclaration bindings.</td>
</tr>
<tr>
<td>[[]VarNames]]</td>
<td>a List of Strings</td>
<td>The string names bound by FunctionDeclaration, GeneratorDeclaration, AsyncFunctionDeclaration, AsyncGeneratorDeclaration, and VariableDeclaration declarations in global code for the associated realm.</td>
</tr>
</tbody>
</table>
### Table 21: Additional Methods of Global Environment Records

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>GetThisBinding()</td>
<td>Return the value of this Environment Record's this binding.</td>
</tr>
<tr>
<td>HasVarDeclaration (N)</td>
<td>Determines if the argument identifier has a binding in this Environment Record that was created using a VariableDeclaration, FunctionDeclaration, GeneratorDeclaration, AsyncFunctionDeclaration, or AsyncGeneratorDeclaration.</td>
</tr>
<tr>
<td>HasLexicalDeclaration (N)</td>
<td>Determines if the argument identifier has a binding in this Environment Record that was created using a lexical declaration such as a LexicalDeclaration or a ClassDeclaration.</td>
</tr>
<tr>
<td>HasRestrictedGlobalProperty (N)</td>
<td>Determines if the argument is the name of a global object property that may not be shadowed by a global lexical binding.</td>
</tr>
<tr>
<td>CanDeclareGlobalVar (N)</td>
<td>Determines if a corresponding CreateGlobalVarBinding call would succeed if called for the same argument N.</td>
</tr>
<tr>
<td>CanDeclareGlobalFunction (N)</td>
<td>Determines if a corresponding CreateGlobalFunctionBinding call would succeed if called for the same argument N.</td>
</tr>
<tr>
<td>CreateGlobalVarBinding(N, D)</td>
<td>Used to create and initialize to undefined a global var binding in the [[ObjectRecord]] component of a Global Environment Record. The binding will be a mutable binding. The corresponding global object property will have attribute values appropriate for a var. The String value N is the bound name. If D is true, the binding may be deleted. Logically equivalent to CreateMutableBinding followed by a SetMutableBinding but it allows var declarations to receive special treatment.</td>
</tr>
<tr>
<td>CreateGlobalFunctionBinding(N, V, D)</td>
<td>Create and initialize a global function binding in the [[ObjectRecord]] component of a Global Environment Record. The binding will be a mutable binding. The corresponding global object property will have attribute values appropriate for a function. The String value N is the bound name. V is the initialization value. If the Boolean argument D is true, the binding may be deleted. Logically equivalent to CreateMutableBinding followed by a SetMutableBinding but it allows function declarations to receive special treatment.</td>
</tr>
</tbody>
</table>

The behaviour of the concrete specification methods for Global Environment Records is defined by the following algorithms.

#### 9.1.1.4.1 HasBinding (N)

The HasBinding concrete method of a Global Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It determines if the argument identifier is one of the identifiers bound by the record. It performs the following steps when called:

1. Let DclRec be envRec.][[DeclarativeRecord]].
2. If ! DclRec.HasBinding(N) is true, return true.
3. Let ObjRec be envRec.][[ObjectRecord]].

#### 9.1.1.4.2 CreateMutableBinding (N, D)

The CreateMutableBinding concrete method of a Global Environment Record envRec takes arguments N (a String) and D (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It creates a new mutable binding for the name N that is uninitialized. The binding is created in the associated
DeclarativeRecord. A binding for \( N \) must not already exist in the DeclarativeRecord. If \( D \) is true, the new binding is marked as being subject to deletion. It performs the following steps when called:

1. Let \( DclRec \) be \( envRec.\{[\text{DeclarativeRecord}]\} \).
2. If ! \( DclRec.\text{HasBinding}(N) \) is \( \text{true} \), throw a \text{TypeError} exception.
3. Return ! \( DclRec.\text{CreateMutableBinding}(N, D) \).

9.1.1.4.3 CreateImmutableBinding ( \( N, S \) )

The CreateImmutableBinding concrete method of a Global Environment Record \( envRec \) takes arguments \( N \) (a String) and \( S \) (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It creates a new immutable binding for the name \( N \) that is uninitialized. A binding must not already exist in this Environment Record for \( N \). If \( S \) is \( \text{true} \), the new binding is marked as a strict binding. It performs the following steps when called:

1. Let \( DclRec \) be \( envRec.\{[\text{DeclarativeRecord}]\} \).
2. If ! \( DclRec.\text{HasBinding}(N) \) is \( \text{true} \), throw a \text{TypeError} exception.
3. Return ! \( DclRec.\text{CreateImmutableBinding}(N, S) \).

9.1.1.4.4 InitializeBinding ( \( N, V \) )

The InitializeBinding concrete method of a Global Environment Record \( envRec \) takes arguments \( N \) (a String) and \( V \) (an ECMAScript language value) and returns either a normal completion containing UNUSED or a throw completion. It is used to set the bound value of the current binding of the identifier whose name is \( N \) to the value \( V \). An uninitialized binding for \( N \) must already exist. It performs the following steps when called:

1. Let \( DclRec \) be \( envRec.\{[\text{DeclarativeRecord}]\} \).
2. If ! \( DclRec.\text{HasBinding}(N) \) is \( \text{true} \), then
   a. Return ! \( DclRec.\text{InitializeBinding}(N, V) \).
3. Assert: If the binding exists, it must be in the Object Environment Record.
4. Let \( ObjRec \) be \( envRec.\{[\text{ObjectRecord}]\} \).
5. Return ? \( ObjRec.\text{InitializeBinding}(N, V) \).

9.1.1.4.5 SetMutableBinding ( \( N, V, S \) )

The SetMutableBinding concrete method of a Global Environment Record \( envRec \) takes arguments \( N \) (a String), \( V \) (an ECMAScript language value), and \( S \) (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It attempts to change the bound value of the current binding of the identifier whose name is \( N \) to the value \( V \). If the binding is an immutable binding and \( S \) is \( \text{true} \), a \text{TypeError} is thrown. A property named \( N \) normally already exists but if it does not or is not currently writable, error handling is determined by \( S \). It performs the following steps when called:

1. Let \( DclRec \) be \( envRec.\{[\text{DeclarativeRecord}]\} \).
2. If ! \( DclRec.\text{HasBinding}(N) \) is \( \text{true} \), then
   a. Return ? \( DclRec.\text{SetMutableBinding}(N, V, S) \).
3. Let \( ObjRec \) be \( envRec.\{[\text{ObjectRecord}]\} \).
4. Return ? \( ObjRec.\text{SetMutableBinding}(N, V, S) \).

9.1.1.4.6 GetBindingValue ( \( N, S \) )

The GetBindingValue concrete method of a Global Environment Record \( envRec \) takes arguments \( N \) (a String) and \( S \) (a Boolean) and returns either a normal completion containing an ECMAScript language value or a throw completion. It returns the value of its bound identifier whose name is \( N \). If the binding is an uninitialized binding throw a \text{ReferenceError} exception. A property named \( N \) normally already exists but if it does not or is not currently writable, error handling is determined by \( S \). It performs the following steps when called:

1. Let \( DclRec \) be \( envRec.\{[\text{DeclarativeRecord}]\} \).
2. If ! \( DclRec.\text{HasBinding}(N) \) is \( \text{true} \), then
   a. Return ? \( DclRec.\text{GetBindingValue}(N, S) \).
3. Let ObjRec be envRec.[[ObjectRecord]].

9.1.1.4.7 DeleteBinding (N)

The DeleteBinding concrete method of a Global Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It can only delete bindings that have been explicitly designated as being subject to deletion. It performs the following steps when called:

1. Let DclRec be envRec.[[DeclarativeRecord]].
2. If ! DclRec.HasBinding(N) is true, then
3. Let ObjRec be envRec.[[ObjectRecord]].
4. Let globalObject be ObjRec.[[BindingObject]].
5. Let existingProp be ? HasOwnProperty(globalObject, N).
6. If existingProp is true, then
   b. If status is true and envRec.[[VarNames]] contains N, then
      i. Remove N from envRec.[[VarNames]].
   c. Return status.
7. Return true.

9.1.1.4.8 HasThisBinding ( )

The HasThisBinding concrete method of a Global Environment Record envRec takes no arguments and returns true. It performs the following steps when called:

1. Return true.

NOTE Global Environment Records always provide a this binding.

9.1.1.4.9 HasSuperBinding ( )

The HasSuperBinding concrete method of a Global Environment Record envRec takes no arguments and returns false. It performs the following steps when called:

1. Return false.

NOTE Global Environment Records do not provide a super binding.

9.1.1.4.10 WithBaseObject ( )

The WithBaseObject concrete method of a Global Environment Record envRec takes no arguments and returns undefined. It performs the following steps when called:

1. Return undefined.

9.1.1.4.11 GetThisBinding ( )

The GetThisBinding concrete method of a Global Environment Record envRec takes no arguments and returns a normal completion containing an Object. It performs the following steps when called:

1. Return envRec.[[GlobalThisValue]].
9.1.1.4.12 HasVarDeclaration (N)

The HasVarDeclaration concrete method of a Global Environment Record envRec takes argument N (a String) and returns a Boolean. It determines if the argument identifier has a binding in this record that was created using a VariableStatement or a FunctionDeclaration. It performs the following steps when called:

1. Let varDeclaredNames be envRec.[[VarNames]].
2. If varDeclaredNames contains N, return true.
3. Return false.

9.1.1.4.13 HasLexicalDeclaration (N)

The HasLexicalDeclaration concrete method of a Global Environment Record envRec takes argument N (a String) and returns a Boolean. It determines if the argument identifier has a binding in this record that was created using a lexical declaration such as a LexicalDeclaration or a ClassDeclaration. It performs the following steps when called:

1. Let DclRec be envRec.[[DeclarativeRecord]].

9.1.1.4.14 HasRestrictedGlobalProperty (N)

The HasRestrictedGlobalProperty concrete method of a Global Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It determines if the argument identifier is the name of a property of the global object that must not be shadowed by a global lexical binding. It performs the following steps when called:

1. Let ObjRec be envRec.[[ObjectRecord]].
2. Let globalObject be ObjRec.[[BindingObject]].
3. Let existingProp be ? globalObject.[[GetOwnProperty]](N).
4. If existingProp is undefined, return false.
5. If existingProp.[[Configurable]] is true, return false.
6. Return true.

NOTE Properties may exist upon a global object that were directly created rather than being declared using a var or function declaration. A global lexical binding may not be created that has the same name as a non-configurable property of the global object. The global property "undefined" is an example of such a property.

9.1.1.4.15 CanDeclareGlobalVar (N)

The CanDeclareGlobalVar concrete method of a Global Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It determines if a corresponding CreateGlobalVarBinding call would succeed if called for the same argument N. Redundant var declarations and var declarations for pre-existing global object properties are allowed. It performs the following steps when called:

1. Let ObjRec be envRec.[[ObjectRecord]].
2. Let globalObject be ObjRec.[[BindingObject]].
3. Let hasProperty be ? HasOwnProperty(globalObject, N).
4. If hasProperty is true, return true.
9.1.1.4.16 CanDeclareGlobalFunction ( N )

The CanDeclareGlobalFunction concrete method of a Global Environment Record envRec takes argument N (a String) and returns either a normal completion containing a Boolean or a throw completion. It determines if a corresponding CreateGlobalFunctionBinding call would succeed if called for the same argument N. It performs the following steps when called:

1. Let ObjRec be envRec.[[ObjectRecord]].
2. Let globalObject be ObjRec.[[BindingObject]].
3. Let existingProp be ? globalObject.[[GetOwnProperty]](N).
4. If existingProp is undefined, return ? IsExtensible(globalObject).
5. If existingProp.[[Configurable]] is true, return true.
6. If IsDataDescriptor(existingProp) is true and existingProp has attribute values { [[Writable]]: true, [[Enumerable]]: true }, return true.
7. Return false.

9.1.1.4.17 CreateGlobalVarBinding ( N, D )

The CreateGlobalVarBinding concrete method of a Global Environment Record envRec takes arguments N (a String) and D (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It creates and initializes a mutable binding in the associated Object Environment Record and records the bound name in the associated [[VarNames]] List. If a binding already exists, it is reused and assumed to be initialized. It performs the following steps when called:

1. Let ObjRec be envRec.[[ObjectRecord]].
2. Let globalObject be ObjRec.[[BindingObject]].
3. Let hasProperty be ? HasOwnProperty(globalObject, N).
5. If hasProperty is false and extensible is true, then
6. If envRec.[[VarNames]] does not contain N, then
   a. Append N to envRec.[[VarNames]].
7. Return UNUSED.

9.1.1.4.18 CreateGlobalFunctionBinding ( N, V, D )

The CreateGlobalFunctionBinding concrete method of a Global Environment Record envRec takes arguments N (a String), V (an ECMAScript language value), and D (a Boolean) and returns either a normal completion containing UNUSED or a throw completion. It creates and initializes a mutable binding in the associated Object Environment Record and records the bound name in the associated [[VarNames]] List. If a binding already exists, it is replaced. It performs the following steps when called:

1. Let ObjRec be envRec.[[ObjectRecord]].
2. Let globalObject be ObjRec.[[BindingObject]].
3. Let existingProp be ? globalObject.[[GetOwnProperty]](N).
4. If existingProp is undefined or existingProp.[[Configurable]] is true, then
   a. Let desc be the PropertyDescriptor { [[Value]]: V, [[Writable]]: true, [[Enumerable]]: true, [[Configurable]]: D }.
5. Else,
   a. Let desc be the PropertyDescriptor { [[Value]]: V }.
8. If envRec.[[VarNames]] does not contain N, then
   a. Append N to envRec.[[VarNames]].
9. Return UNUSED.
Global function declarations are always represented as own properties of the global object. If possible, an existing own property is reconfigured to have a standard set of attribute values. Step 7 is equivalent to what calling the InitializeBinding concrete method would do and if globalObject is a Proxy will produce the same sequence of Proxy trap calls.

9.1.1.5 Module Environment Records

A Module Environment Record is a Declarative Environment Record that is used to represent the outer scope of an ECMAScript Module. In addition to normal mutable and immutable bindings, Module Environment Records also provide immutable import bindings which are bindings that provide indirect access to a target binding that exists in another Environment Record.

Module Environment Records support all of the Declarative Environment Record methods listed in Table 16 and share the same specifications for all of those methods except for GetBindingValue, DeleteBinding, HasThisBinding and GetThisBinding. In addition, Module Environment Records support the methods listed in Table 22:

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>CreateImportBinding(N, M, N2)</td>
<td>Create an immutable indirect binding in a Module Environment Record. The String value N is the text of the bound name. M is a Module Record, and N2 is a binding that exists in M's Module Environment Record.</td>
</tr>
<tr>
<td>GetThisBinding()</td>
<td>Return the value of this Environment Record's this binding.</td>
</tr>
</tbody>
</table>

The behaviour of the additional concrete specification methods for Module Environment Records are defined by the following algorithms:

9.1.1.5.1 GetBindingValue ( N, S )

The GetBindingValue concrete method of a Module Environment Record envRec takes arguments N (a String) and S (a Boolean) and returns either a normal completion containing an ECMAScript language value or a throw completion. It returns the value of its bound identifier whose name is N. However, if the binding is an indirect binding the value of the target binding is returned. If the binding exists but is uninitialized a ReferenceError is thrown. It performs the following steps when called:

1. Assert: S is true.
2. Assert: envRec has a binding for N.
3. If the binding for N is an indirect binding, then
   a. Let M and N2 be the indirection values provided when this binding for N was created.
   b. Let targetEnv be M.[[Environment]].
   c. If targetEnv is EMPTY, throw a ReferenceError exception.
   d. Return ? targetEnv.GetBindingValue(N2, true).
4. If the binding for N in envRec is an uninitialized binding, throw a ReferenceError exception.
5. Return the value currently bound to N in envRec.

NOTE S will always be true because a Module is always strict mode code.

9.1.1.5.2 DeleteBinding ( N )

The DeleteBinding concrete method of a Module Environment Record is never used within this specification.
9.1.1.5.3 HasThisBinding ()

The HasThisBinding concrete method of a Module Environment Record envRec takes no arguments and returns true. It performs the following steps when called:

1. Return true.

9.1.1.5.4 GetThisBinding ()

The GetThisBinding concrete method of a Module Environment Record envRec takes no arguments and returns a normal completion containing undefined. It performs the following steps when called:

1. Return undefined.

9.1.1.5.5 CreateImportBinding (N, M, N2)

The CreateImportBinding concrete method of a Module Environment Record envRec takes arguments N (a String), M (a Module Record), and N2 (a String) and returns UNUSED. It creates a new initialized immutable indirect binding for the name N. A binding must not already exist in this Environment Record for N. N2 is the name of a binding that exists in M's Module Environment Record. Accesses to the value of the new binding will indirectly access the bound value of the target binding. It performs the following steps when called:

1. Assert: envRec does not already have a binding for N.
2. Assert: When M.[[Environment]] is instantiated, it will have a direct binding for N2.
3. Create an immutable indirect binding in envRec for N that references M and N2 as its target binding and record that the binding is initialized.
4. Return UNUSED.

9.1.2 Environment Record Operations

The following abstract operations are used in this specification to operate upon Environment Records:

9.1.2.1 GetIdentifierReference (env, name, strict)

The abstract operation GetIdentifierReference takes arguments env (an Environment Record or null), name (a String), and strict (a Boolean) and returns either a normal completion containing a Reference Record or a throw completion. It performs the following steps when called:

1. If env is null, then
   a. Return the Reference Record { [[Base]]: UNRESOLVABLE, [[ReferencedName]]: name, [[Strict]]: strict, [[ThisValue]]: EMPTY }.
2. Let exists be ? env.HasBinding(name).
3. If exists is true, then
   a. Return the Reference Record { [[Base]]: env, [[ReferencedName]]: name, [[Strict]]: strict, [[ThisValue]]: EMPTY }.
4. Else,
   a. Let outer be env.[[OuterEnv]].
   b. Return ? GetIdentifierReference(outer, name, strict).
9.1.2.2 NewDeclarativeEnvironment (E)

The abstract operation NewDeclarativeEnvironment takes argument E (an Environment Record or null) and returns a Declarative Environment Record. It performs the following steps when called:

1. Let env be a new Declarative Environment Record containing no bindings.
2. Set env.[[OuterEnv]] to E.
3. Return env.

9.1.2.3 NewObjectEnvironment (O, W, E)

The abstract operation NewObjectEnvironment takes arguments O (an Object), W (a Boolean), and E (an Environment Record or null) and returns an Object Environment Record. It performs the following steps when called:

1. Let env be a new Object Environment Record.
2. Set env.[[BindingObject]] to O.
3. Set env.[[IsWithEnvironment]] to W.
4. Set env.[[OuterEnv]] to E.
5. Return env.

9.1.2.4 NewFunctionEnvironment (F, newTarget)

The abstract operation NewFunctionEnvironment takes arguments F (an ECMAScript function object) and newTarget (an Object or undefined) and returns a Function Environment Record. It performs the following steps when called:

1. Let env be a new Function Environment Record containing no bindings.
2. Set env.[[FunctionObject]] to F.
3. If F.[[ThisMode]] is LEXICAL, set env.[[ThisBindingStatus]] to LEXICAL.
4. Else, set env.[[ThisBindingStatus]] to UNINITIALIZED.
5. Set env.[[NewTarget]] to newTarget.
6. Set env.[[OuterEnv]] to F.[[Environment]].
7. Return env.

9.1.2.5 NewGlobalEnvironment (G, thisValue)

The abstract operation NewGlobalEnvironment takes arguments G (an Object) and thisValue (an Object) and returns a Global Environment Record. It performs the following steps when called:

1. Let objRec be NewObjectEnvironment(G, false, null).
2. Let dclRec be NewDeclarativeEnvironment(null).
3. Let env be a new Global Environment Record.
4. Set env.[[ObjectRecord]] to objRec.
5. Set env.[[GlobalThisValue]] to thisValue.
6. Set env.[[DeclarativeRecord]] to dclRec.
7. Set env.[[VarNames]] to a new empty List.
8. Set env.[[OuterEnv]] to null.

9.1.2.6 NewModuleEnvironment (E)

The abstract operation NewModuleEnvironment takes argument E (an Environment Record) and returns a Module Environment Record. It performs the following steps when called:

1. Let env be a new Module Environment Record containing no bindings.
2. Set env.[[OuterEnv]] to E.
3. Return env.
## 9.2 PrivateEnvironment Records

A **PrivateEnvironment Record** is a specification mechanism used to track **Private Names** based upon the lexical nesting structure of **ClassDeclarations** and **ClassExpressions** in ECMAScript code. They are similar to, but distinct from, **Environment Records**. Each **PrivateEnvironment Record** is associated with a **ClassDeclaration** or **ClassExpression**. Each time such a class is evaluated, a new **PrivateEnvironment Record** is created to record the **Private Names** declared by that class.

Each **PrivateEnvironment Record** has the fields defined in Table 23.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[OuterPrivateEnvironment]]</td>
<td>a PrivateEnvironment Record or null</td>
<td>The <strong>PrivateEnvironment Record</strong> of the nearest containing class. <strong>null</strong> if the class with which this PrivateEnvironment Record is associated is not contained in any other class.</td>
</tr>
<tr>
<td>[[Names]]</td>
<td>a List of Private Names</td>
<td>The <strong>Private Names</strong> declared by this class.</td>
</tr>
</tbody>
</table>

### 9.2.1 PrivateEnvironment Record Operations

The following abstract operations are used in this specification to operate upon **PrivateEnvironment Records**:

#### 9.2.1.1 NewPrivateEnvironment ( outerPrivEnv )

The abstract operation **NewPrivateEnvironment** takes argument **outerPrivEnv** (a **PrivateEnvironment Record** or **null**) and returns a **PrivateEnvironment Record**. It performs the following steps when called:

1. Let *names* be a new empty List.
2. Return the **PrivateEnvironment Record** { [[OuterPrivateEnvironment]]: outerPrivEnv, [[Names]]: names }.

#### 9.2.1.2 ResolvePrivateIdentifier ( privEnv, identifier )

The abstract operation **ResolvePrivateIdentifier** takes arguments **privEnv** (a **PrivateEnvironment Record**) and **identifier** (a String) and returns a **Private Name**. It performs the following steps when called:

1. Let *names* be privEnv.[[Names]].
2. For each **Private Name** **pn** of *names*, do
   a. If **pn**.[[Description]] is **identifier**, then
      i. Return **pn**.
3. Let outerPrivEnv be privEnv.[[OuterPrivateEnvironment]].
4. Assert: outerPrivEnv is not **null**.
5. Return ResolvePrivateIdentifier(outerPrivEnv, identifier).

### 9.3 Realms

Before it is evaluated, all ECMAScript code must be associated with a **realm**. Conceptually, a **realm** consists of a set of intrinsic objects, an ECMAScript global environment, all of the ECMAScript code that is loaded within the scope of that global environment, and other associated state and resources.

A **realm** is represented in this specification as a **Realm Record** with the fields specified in Table 24:
Table 24: **Realm Record** Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[AgentSignifier]]</td>
<td>an agent signifier</td>
<td>The agent that owns this realm</td>
</tr>
<tr>
<td>[[Intrinsics]]</td>
<td>a Record whose field names are intrinsic keys and whose values are objects</td>
<td>The intrinsic values used by code associated with this realm</td>
</tr>
<tr>
<td>[[GlobalObject]]</td>
<td>an Object or undefined</td>
<td>The global object for this realm</td>
</tr>
<tr>
<td>[[GlobalEnv]]</td>
<td>a Global Environment Record</td>
<td>The global environment for this realm</td>
</tr>
<tr>
<td>[[TemplateMap]]</td>
<td>a List of Records with fields [[Site]] (a TemplateLiteral Parse Node) and [[Array]] (an Array)</td>
<td>Template objects are canonicalized separately for each realm using its Realm Record’s [[TemplateMap]]. Each [[Site]] value is a Parse Node that is a TemplateLiteral. The associated [[Array]] value is the corresponding template object that is passed to a tag function.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>NOTE 1</strong> Once a Parse Node becomes unreachable, the corresponding [[Array]] is also unreachable, and it would be unobservable if an implementation removed the pair from the [[TemplateMap]] list.</td>
</tr>
<tr>
<td>[[LoadedModules]]</td>
<td>a List of Records with fields [[Specifier]] (a String) and [[Module]] (a Module Record)</td>
<td>A map from the specifier strings imported by this realm to the resolved Module Record. The list does not contain two different Records with the same [[Specifier]].</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>NOTE 2</strong> As mentioned in HostLoadImportedModule (16.2.1.8 Note 1), [[LoadedModules]] in Realm Records is only used when running an import() expression in a context where there is no active script or module.</td>
</tr>
<tr>
<td>[[HostDefined]]</td>
<td>anything (default value is undefined)</td>
<td>Field reserved for use by hosts that need to associate additional information with a Realm Record.</td>
</tr>
</tbody>
</table>

9.3.1 **CreateRealm ( )**

The abstract operation CreateRealm takes no arguments and returns a Realm Record. It performs the following steps when called:

1. Let realmRec be a new Realm Record.
2. Perform CreateIntrinsics(realmRec).
3. Set realmRec. [[AgentSignifier]] to AgentSignifier().
4. Set realmRec. [[GlobalObject]] to undefined.
5. Set realmRec. [[GlobalEnv]] to undefined.
6. Set realmRec. [[TemplateMap]] to a new empty List.
7. Return realmRec.
9.3.2 CreateIntrinsics (realmRec)

The abstract operation CreateIntrinsics takes argument realmRec (a Realm Record) and returns UNUSED. It performs the following steps when called:

1. Set realmRec.[[Intrinsics]] to a new Record.
2. Set fields of realmRec.[[Intrinsics]] with the values listed in Table 6. The field names are the names listed in column one of the table. The value of each field is a new object value fully and recursively populated with property values as defined by the specification of each object in clauses 19 through 28. All object property values are newly created object values. All values that are built-in function objects are created by performing CreateBuiltInFunction(steps, length, name, slots, realmRec, prototype) where steps is the definition of that function provided by this specification, name is the initial value of the function’s "name" property, length is the initial value of the function’s "length" property, slots is a list of the names, if any, of the function’s specified internal slots, and prototype is the specified value of the function’s [[Prototype]] internal slot. The creation of the intrinsics and their properties must be ordered to avoid any dependencies upon objects that have not yet been created.
4. Return UNUSED.

9.3.3 SetRealmGlobalObject (realmRec, globalObj, thisValue)

The abstract operation SetRealmGlobalObject takes arguments realmRec (a Realm Record), globalObj (an Object or undefined), and thisValue (an Object or undefined) and returns UNUSED. It performs the following steps when called:

1. If globalObj is undefined, then
   a. Let intrinsics be realmRec.[[Intrinsics]].
   b. Set globalObj to OrdinaryObjectCreate(intrinsics.[[%Object.prototype%]]).
2. Assert: globalObj is an Object.
3. If thisValue is undefined, set thisValue to globalObj.
4. Set realmRec.[[GlobalObject]] to globalObj.
5. Let newGlobalEnv be NewGlobalEnvironment(globalObj, thisValue).
6. Set realmRec.[[GlobalEnv]] to newGlobalEnv.
7. Return UNUSED.

9.3.4 SetDefaultGlobalBindings (realmRec)

The abstract operation SetDefaultGlobalBindings takes argument realmRec (a Realm Record) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Let global be realmRec.[[GlobalObject]].
2. For each property of the Global Object specified in clause 19, do
   a. Let name be the String value of the property name.
   b. Let desc be the fully populated data Property Descriptor for the property, containing the specified attributes for the property. For properties listed in 19.2, 19.3, or 19.4 the value of the [[Value]] attribute is the corresponding intrinsic object from realmRec.
   c. Perform ? DefinePropertyOrThrow(global, name, desc).
3. Return global.

9.4 Execution Contexts

An execution context is a specification device that is used to track the runtime evaluation of code by an ECMA-Script implementation. At any point in time, there is at most one execution context per agent that is actually executing code. This is known as the agent’s running execution context. All references to the running execution context in this specification denote the running execution context of the surrounding agent.

The execution context stack is used to track execution contexts. The running execution context is always the top element of this stack. A new execution context is created whenever control is transferred from the executable code associated with the currently running execution context to executable code that is not associated with that
execution context. The newly created execution context is pushed onto the stack and becomes the running execution context.

An execution context contains whatever implementation specific state is necessary to track the execution progress of its associated code. Each execution context has at least the state components listed in Table 25.

Table 25: State Components for All Execution Contexts

<table>
<thead>
<tr>
<th>Component</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>code evaluation state</td>
<td>Any state needed to perform, suspend, and resume evaluation of the code associated with this execution context.</td>
</tr>
<tr>
<td>Function</td>
<td>If this execution context is evaluating the code of a function object, then the value of this component is that function object. If the context is evaluating the code of a Script or Module, the value is null.</td>
</tr>
<tr>
<td>Realm</td>
<td>The Realm Record from which associated code accesses ECMAScript resources.</td>
</tr>
<tr>
<td>ScriptOrModule</td>
<td>The Module Record or Script Record from which associated code originates. If there is no originating script or module, as is the case for the original execution context created in InitializeHostDefinedRealm, the value is null.</td>
</tr>
</tbody>
</table>

Evaluation of code by the running execution context may be suspended at various points defined within this specification. Once the running execution context has been suspended a different execution context may become the running execution context and commence evaluating its code. At some later time a suspended execution context may again become the running execution context and continue evaluating its code at the point where it had previously been suspended. Transition of the running execution context status among execution contexts usually occurs in stack-like last-in/first-out manner. However, some ECMAScript features require non-LIFO transitions of the running execution context.

The value of the Realm component of the running execution context is also called the current Realm Record. The value of the Function component of the running execution context is also called the active function object.

ECMAScript code execution contexts have the additional state components listed in Table 26.

Table 26: Additional State Components for ECMAScript Code Execution Contexts

<table>
<thead>
<tr>
<th>Component</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>LexicalEnvironment</td>
<td>Identifies the Environment Record used to resolve identifier references made by code within this execution context.</td>
</tr>
<tr>
<td>VariableEnvironment</td>
<td>Identifies the Environment Record that holds bindings created by VariableStatements within this execution context.</td>
</tr>
<tr>
<td>PrivateEnvironment</td>
<td>Identifies the PrivateEnvironment Record that holds Private Names created by ClassElements in the nearest containing class. null if there is no containing class.</td>
</tr>
</tbody>
</table>

The LexicalEnvironment and VariableEnvironment components of an execution context are always Environment Records.

Execution contexts representing the evaluation of Generators have the additional state components listed in Table 27.
Table 27: Additional State Components for Generator Execution Contexts

<table>
<thead>
<tr>
<th>Component</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>The Generator that this execution context is evaluating.</td>
</tr>
</tbody>
</table>

In most situations only the running execution context (the top of the execution context stack) is directly manipulated by algorithms within this specification. Hence when the terms “LexicalEnvironment”, and “VariableEnvironment” are used without qualification they are in reference to those components of the running execution context.

An execution context is purely a specification mechanism and need not correspond to any particular artefact of an ECMAScript implementation. It is impossible for ECMAScript code to directly access or observe an execution context.

9.4.1 GetActiveScriptOrModule ( )

The abstract operation GetActiveScriptOrModule takes no arguments and returns a Script Record, a Module Record, or null. It is used to determine the running script or module, based on the running execution context. It performs the following steps when called:

1. If the execution context stack is empty, return null.
2. Let ec be the topmost execution context on the execution context stack whose ScriptOrModule component is not null.
3. If no such execution context exists, return null. Otherwise, return ec's ScriptOrModule.

9.4.2 ResolveBinding ( name [, env ] )

The abstract operation ResolveBinding takes argument name (a String) and optional argument env (an Environment Record or undefined) and returns either a normal completion containing a Reference Record or a throw completion. It is used to determine the binding of name. env can be used to explicitly provide the Environment Record that is to be searched for the binding. It performs the following steps when called:

1. If env is not present or env is undefined, then
   a. Set env to the running execution context’s LexicalEnvironment.
2. Assert: env is an Environment Record.
3. If the source text matched by the syntactic production that is being evaluated is contained in strict mode code, let strict be true; else let strict be false.

NOTE: The result of ResolveBinding is always a Reference Record whose [[ReferencedName]] field is name.

9.4.3 GetThisEnvironment ( )

The abstract operation GetThisEnvironment takes no arguments and returns an Environment Record. It finds the Environment Record that currently supplies the binding of the keyword this. It performs the following steps when called:

1. Let env be the running execution context's LexicalEnvironment.
2. Repeat,
   a. Let exists be env.HasThisBinding().
   b. If exists is true, return env.
   c. Let outer be env.([OuterEnv]).
   d. Assert: outer is not null.
   e. Set env to outer.
The loop in step 2 will always terminate because the list of environments always ends with the global environment which has a this binding.

9.4.4 ResolveThisBinding ( )

The abstract operation ResolveThisBinding takes no arguments and returns either a normal completion containing an ECMAScript language value or a throw completion. It determines the binding of the keyword this using the LexicalEnvironment of the running execution context. It performs the following steps when called:

1. Let envRec be GetThisEnvironment().
2. Return ? envRec.GetThisBinding().

9.4.5 GetNewTarget ( )

The abstract operation GetNewTarget takes no arguments and returns an Object or undefined. It determines the NewTarget value using the LexicalEnvironment of the running execution context. It performs the following steps when called:

1. Let envRec be GetThisEnvironment().
2. Assert: envRec has a [[NewTarget]] field.
3. Return envRec.[[NewTarget]].

9.4.6 GetGlobalObject ( )

The abstract operation GetGlobalObject takes no arguments and returns an Object. It returns the global object used by the currently running execution context. It performs the following steps when called:

1. Let currentRealm be the current Realm Record.
2. Return currentRealm.[[GlobalObject]].

9.5 Jobs and Host Operations to Enqueue Jobs

A Job is an Abstract Closure with no parameters that initiates an ECMAScript computation when no other ECMAScript computation is currently in progress.

Jobs are scheduled for execution by ECMAScript host environments in a particular agent. This specification describes the host hooks HostEnqueueGenericJob, HostEnqueueFinalizationRegistryCleanupJob, HostEnqueuePromiseJob, and HostEnqueueTimeoutJob to schedule jobs. The host hooks in this specification are organized by the additional constraints imposed on the scheduling of jobs. Hosts may define additional abstract operations which schedule jobs. Such operations accept a Job Abstract Closure and a realm (a Realm Record or null) as parameters. If a Realm Record is provided, these operations schedule the job to be performed at some future time in the provided realm, in the agent that owns the realm. If null is provided instead for the realm, then the job does not evaluate ECMAScript code. Their implementations must conform to the following requirements:

- At some future point in time, when there is no running context in the agent for which the job is scheduled and that agent’s execution context stack is empty, the implementation must:
  1. Perform any host-defined preparation steps.
  2. Invoke the Job Abstract Closure.
  3. Perform any host-defined cleanup steps, after which the execution context stack must be empty.
- Only one Job may be actively undergoing evaluation at any point in time in an agent.
- Once evaluation of a Job starts, it must run to completion before evaluation of any other Job starts in an agent.
- The Abstract Closure must return a normal completion, implementing its own handling of errors.
NOTE 1  **Host environments** are not required to treat **Jobs** uniformly with respect to scheduling. For example, web browsers and Node.js treat Promise-handling **Jobs** as a higher priority than other work; future features may add **Jobs** that are not treated at such a high priority.

At any particular time, `scriptOrModule` (a **Script Record**, a **Module Record**, or `null`) is the **active script or module** if all of the following conditions are true:

- The **GetActiveScriptOrModule**() is `scriptOrModule`.
- If `scriptOrModule` is a **Script Record** or **Module Record**, let `ec` be the topmost **execution context** on the execution context stack whose **ScriptOrModule** component is `scriptOrModule`. The **Realm** component of `ec` is `scriptOrModule`\\([\[Realm\]]\\).

At any particular time, an execution is **prepared to evaluate ECMAScript code** if all of the following conditions are true:

- The **execution context stack** is not empty.
- The **Realm** component of the topmost **execution context** on the execution context stack is a **Realm Record**.

NOTE 2  **Host environments** may prepare an execution to evaluate code by pushing **execution contexts** onto the execution context stack. The specific steps are implementation-defined.

The specific choice of **Realm** is up to the **host environment**. This initial execution context and **Realm** is only in use before any callback function is invoked. When a callback function related to a **Job**, like a Promise handler, is invoked, the invocation pushes its own execution context and **Realm**.

Particular kinds of **Jobs** have additional conformance requirements.

### 9.5.1 JobCallback Records

A **JobCallback Record** is a **Record** value used to store a **function object** and a **host-defined value**. Function objects that are invoked via a **Job** enqueued by the **host** may have additional **host-defined context**. To propagate the state, **Job Abstract Closures** should not capture and call function objects directly. Instead, use **HostMakeJobCallback** and **HostCallJobCallback**.

NOTE  The WHATWG HTML specification ([https://html.spec.whatwg.org/](https://html.spec.whatwg.org/)), for example, uses the **host-defined** value to propagate the incumbent settings object for Promise callbacks.

**JobCallback Records** have the fields listed in **Table 28**.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[Callback]]</code></td>
<td>a function object</td>
<td>The function to invoke when the <strong>Job</strong> is invoked.</td>
</tr>
<tr>
<td><code>[[HostDefined]]</code></td>
<td>anything (default value is <code>EMPTY</code>)</td>
<td>Field reserved for use by <strong>hosts</strong>.</td>
</tr>
</tbody>
</table>

### 9.5.2 HostMakeJobCallback ( `callback` )

The **host-defined** abstract operation **HostMakeJobCallback** takes argument `callback` (a **function object**) and returns a **JobCallback Record**.

An implementation of **HostMakeJobCallback** must conform to the following requirements:

- It must return a **JobCallback Record** whose `[[Callback]]` field is `callback`. 
The default implementation of HostMakeJobCallback performs the following steps when called:

1. Return the `JobCallback Record { [[Callback]]: callback, [[HostDefined]]: EMPTY }`.

ECMAScript hosts that are not web browsers must use the default implementation of HostMakeJobCallback.

NOTE: This is called at the time that the callback is passed to the function that is responsible for its being eventually scheduled and run. For example, `promise.then(thenAction)` calls `MakeJobCallback on thenAction` at the time of invoking `Promise.prototype.then`, not at the time of scheduling the reaction `Job`.

9.5.3 HostCallJobCallback (`jobCallback, V, argumentsList`)

The host-defined abstract operation HostCallJobCallback takes arguments `jobCallback` (a `JobCallback Record`), `V` (an ECMAScript language value), and `argumentsList` (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion.

An implementation of HostCallJobCallback must conform to the following requirements:

- It must perform and return the result of `Call(jobCallback.[[Callback]], V, argumentsList)`.

NOTE: This requirement means that hosts cannot change the `[[Call]]` behaviour of function objects defined in this specification.

The default implementation of HostCallJobCallback performs the following steps when called:

1. Assert: `IsCallable(jobCallback.[[Callback]])` is `true`.
2. Return `? Call(jobCallback.[[Callback]], V, argumentsList)`.

ECMAScript hosts that are not web browsers must use the default implementation of HostCallJobCallback.

9.5.4 HostEnqueueGenericJob (`job, realm`)

The host-defined abstract operation HostEnqueueGenericJob takes arguments `job` (a `Job Abstract Closure`) and `realm` (a `Realm Record`) and returns UNUSED. It schedules `job` in the realm `realm` in the agent signified by `realm.[[AgentSignifier]]` to be performed at some future time. The `Abstract Closures` used with this algorithm are intended to be scheduled without additional constraints, such as priority and ordering.

An implementation of HostEnqueueGenericJob must conform to the requirements in 9.5.

9.5.5 HostEnqueuePromiseJob (`job, realm`)

The host-defined abstract operation HostEnqueuePromiseJob takes arguments `job` (a `Job Abstract Closure`) and `realm` (a `Realm Record` or `null`) and returns UNUSED. It schedules `job` to be performed at some future time. The `Abstract Closures` used with this algorithm are intended to be related to the handling of Promises, or otherwise, to be scheduled with equal priority to Promise handling operations.

An implementation of HostEnqueuePromiseJob must conform to the requirements in 9.5 as well as the following:

- If `realm` is not `null`, each time `job` is invoked the implementation must perform implementation-defined steps such that execution is prepared to evaluate ECMAScript code at the time of `job`’s invocation.
- Let `scriptOrModule` be `GetActiveScriptOrModule()` at the time HostEnqueuePromiseJob is invoked. If `realm` is not `null`, each time `job` is invoked the implementation must perform implementation-defined steps such that `scriptOrModule` is the active script or module at the time of `job`’s invocation.
- Jobs must run in the same order as the HostEnqueuePromiseJob invocations that scheduled them.
NOTE

The realm for Jobs returned by NewPromiseResolveThenableJob is usually the result of calling GetFunctionRealm on the then function object. The realm for Jobs returned by NewPromiseReactionJob is usually the result of calling GetFunctionRealm on the handler if the handler is not undefined. If the handler is undefined, realm is null. For both kinds of Jobs, when GetFunctionRealm completes abnormally (i.e. called on a revoked Proxy), realm is the current Realm Record at the time of the GetFunctionRealm call. When the realm is null, no user ECMAScript code will be evaluated and no new ECMAScript objects (e.g. Error objects) will be created. The WHATWG HTML specification (https://html.spec.whatwg.org/), for example, uses realm to check for the ability to run script and for the entry concept.

9.5.6 HostEnqueueTimeoutJob (timeoutJob, realm, milliseconds)

The host-defined abstract operation HostEnqueueTimeoutJob takes arguments timeoutJob (a Job Abstract Closure), realm (a Realm Record), and milliseconds (a non-negative finite Number) and returns UNUSED. It schedules timeoutJob in the realm realm in the agent signified by realm.[[AgentSignifier]] to be performed after at least milliseconds milliseconds.

An implementation of HostEnqueueTimeoutJob must conform to the requirements in 9.5.

9.6 InitializeHostDefinedRealm ()

The abstract operation InitializeHostDefinedRealm takes no arguments and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let realm be CreateRealm().
2. Let newContext be a new execution context.
3. Set the Function of newContext to null.
4. Set the Realm of newContext to realm.
5. Set the ScriptOrModule of newContext to null.
6. Push newContext onto the execution context stack; newContext is now the running execution context.
7. If the host requires use of an exotic object to serve as realm’s global object, let global be such an object created in a host-defined manner. Otherwise, let global be undefined, indicating that an ordinary object should be created as the global object.
8. If the host requires that the this binding in realm’s global scope return an object other than the global object, let thisValue be such an object created in a host-defined manner. Otherwise, let thisValue be undefined, indicating that realm’s global this binding should be the global object.
9. Perform SetRealmGlobalObject(realm, global, thisValue).
11. Create any host-defined global object properties on globalObj.
12. Return UNUSED.

9.7 Agents

An agent comprises a set of ECMAScript execution contexts, an execution context stack, a running execution context, an Agent Record, and an executing thread. Except for the executing thread, the constituents of an agent belong exclusively to that agent.

An agent’s executing thread executes algorithmic steps on the agent’s execution contexts independently of other agents, except that an executing thread may be used as the executing thread by multiple agents, provided none of the agents sharing the thread have an Agent Record whose [[CanBlock]] field is true.

NOTE 1 Some web browsers share a single executing thread across multiple unrelated tabs of a browser window, for example.
While an agent’s executing thread is executing algorithmic steps, the agent is the surrounding agent for those steps. The steps use the surrounding agent to access the specification-level execution objects held within the agent: the running execution context, the execution context stack, and the Agent Record’s fields.

An agent signifier is a globally-unique opaque value used to identify an Agent.

Table 29: Agent Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[LittleEndian]]</td>
<td>a Boolean</td>
<td>The default value computed for the isLittleEndian parameter when it is needed by the algorithms GetValueFromBuffer and SetValueInBuffer. The choice is implementation-defined and should be the alternative that is most efficient for the implementation. Once the value has been observed it cannot change.</td>
</tr>
<tr>
<td>[[CanBlock]]</td>
<td>a Boolean</td>
<td>Determines whether the agent can block or not.</td>
</tr>
<tr>
<td>[[Signifier]]</td>
<td>an agent signifier</td>
<td>Uniquely identifies the agent within its agent cluster.</td>
</tr>
<tr>
<td>[[IsLockFree1]]</td>
<td>a Boolean</td>
<td>true if atomic operations on one-byte values are lock-free, false otherwise.</td>
</tr>
<tr>
<td>[[IsLockFree2]]</td>
<td>a Boolean</td>
<td>true if atomic operations on two-byte values are lock-free, false otherwise.</td>
</tr>
<tr>
<td>[[IsLockFree8]]</td>
<td>a Boolean</td>
<td>true if atomic operations on eight-byte values are lock-free, false otherwise.</td>
</tr>
<tr>
<td>[[CandidateExecution]]</td>
<td>a candidate execution Record</td>
<td>See the memory model.</td>
</tr>
<tr>
<td>[[KeptAlive]]</td>
<td>a List of either Objects or Symbols</td>
<td>Initially a new empty List, representing the list of objects and/or symbols to be kept alive until the end of the current Job</td>
</tr>
</tbody>
</table>

Once the values of [[Signifier]], [[IsLockFree1]], and [[IsLockFree2]] have been observed by any agent in the agent cluster they cannot change.

NOTE 2 The values of [[IsLockFree1]] and [[IsLockFree2]] are not necessarily determined by the hardware, but may also reflect implementation choices that can vary over time and between ECMAScript implementations.

There is no [[IsLockFree4]] field: 4-byte atomic operations are always lock-free.

In practice, if an atomic operation is implemented with any type of lock the operation is not lock-free. Lock-free does not imply wait-free: there is no upper bound on how many machine steps may be required to complete a lock-free atomic operation.

That an atomic access of size n is lock-free does not imply anything about the (perceived) atomicity of non-atomic accesses of size n, specifically, non-atomic accesses may still be performed as a sequence of several separate memory accesses. See ReadSharedMemory and WriteSharedMemory for details.
NOTE 3  An agent is a specification mechanism and need not correspond to any particular artefact of an ECMAScript implementation.

9.7.1 AgentSignifier ( )

The abstract operation AgentSignifier takes no arguments and returns an agent signifier. It performs the following steps when called:

1. Let AR be the Agent Record of the surrounding agent.
2. Return AR.[[Signifier]].

9.7.2 AgentCanSuspend ( )

The abstract operation AgentCanSuspend takes no arguments and returns a Boolean. It performs the following steps when called:

1. Let AR be the Agent Record of the surrounding agent.
2. Return AR.[[CanBlock]].

NOTE  In some environments it may not be reasonable for a given agent to suspend. For example, in a web browser environment, it may be reasonable to disallow suspending a document's main event handling thread, while still allowing workers' event handling threads to suspend.

9.8 Agent Clusters

An agent cluster is a maximal set of agents that can communicate by operating on shared memory.

NOTE 1 Programs within different agents may share memory by unspecified means. At a minimum, the backing memory for SharedArrayBuffers can be shared among the agents in the cluster.

There may be agents that can communicate by message passing that cannot share memory; they are never in the same agent cluster.

Every agent belongs to exactly one agent cluster.

NOTE 2 The agents in a cluster need not all be alive at some particular point in time. If agent A creates another agent B, after which A terminates and B creates agent C, the three agents are in the same cluster if A could share some memory with B and B could share some memory with C.

All agents within a cluster must have the same value for the [[LittleEndian]] field in their respective Agent Records.

NOTE 3 If different agents within an agent cluster have different values of [[LittleEndian]] it becomes hard to use shared memory for multi-byte data.

All agents within a cluster must have the same values for the [[IsLockFree1]] field in their respective Agent Records; similarly for the [[IsLockFree2]] field.

All agents within a cluster must have different values for the [[Signifier]] field in their respective Agent Records.

An embedding may deactivate (stop forward progress) or activate (resume forward progress) an agent without the agent's knowledge or cooperation. If the embedding does so, it must not leave some agents in the cluster active while other agents in the cluster are deactivated indefinitely.
NOTE 4 The purpose of the preceding restriction is to avoid a situation where an agent deadlocks or starves because another agent has been deactivated. For example, if an HTML shared worker that has a lifetime independent of documents in any windows were allowed to share memory with the dedicated worker of such an independent document, and the document and its dedicated worker were to be deactivated while the dedicated worker holds a lock (say, the document is pushed into its window’s history), and the shared worker then tries to acquire the lock, then the shared worker will be blocked until the dedicated worker is activated again, if ever. Meanwhile other workers trying to access the shared worker from other windows will starve.

The implication of the restriction is that it will not be possible to share memory between agents that don’t belong to the same suspend/wake collective within the embedding.

NOTE 5 Examples of that type of termination are: operating systems or users terminating agents that are running in separate processes; the embedding itself terminating an agent that is running in-process with the other agents when per-agent resource accounting indicates that the agent is runaway.

Each of the following specification values, and values transitively reachable from them, belong to exactly one agent cluster.

- candidate execution Record
- Shared Data Block
- WaiterList Record

Prior to any evaluation of any ECMAScript code by any agent in a cluster, the [[CandidateExecution]] field of the Agent Record for all agents in the cluster is set to the initial candidate execution. The initial candidate execution is an empty candidate execution whose [[EventsRecords]] field is a List containing, for each agent, an Agent Events Record whose [[AgentSignifier]] field is that agent’s agent signifier, and whose [[EventList]] and [[AgentSynchronizesWith]] fields are empty Lists.

NOTE 6 All agents in an agent cluster share the same candidate execution in its Agent Record’s [[CandidateExecution]] field. The candidate execution is a specification mechanism used by the memory model.

NOTE 7 An agent cluster is a specification mechanism and need not correspond to any particular artefact of an ECMAScript implementation.

9.9 Forward Progress

For an agent to make forward progress is for it to perform an evaluation step according to this specification.

An agent becomes blocked when its running execution context waits synchronously and indefinitely for an external event. Only agents whose Agent Record’s [[CanBlock]] field is true can become blocked in this sense. An unblocked agent is one that is not blocked.

Implementations must ensure that:

- every unblocked agent with a dedicated executing thread eventually makes forward progress
- in a set of agents that share an executing thread, one agent eventually makes forward progress
an agent does not cause another agent to become blocked except via explicit APIs that provide blocking.

**NOTE** This, along with the liveness guarantee in the memory model, ensures that all SEQ-CST writes eventually become observable to all agents.

### 9.10 Processing Model of WeakRef and FinalizationRegistry Targets

#### 9.10.1 Objectives

This specification does not make any guarantees that any object or symbol will be garbage collected. Objects or symbols which are not live may be released after long periods of time, or never at all. For this reason, this specification uses the term "may" when describing behaviour triggered by garbage collection.

The semantics of WeakRefs and FinalizationRegistries is based on two operations which happen at particular points in time:

- When `WeakRef.prototype.deref` is called, the referent (if `undefined` is not returned) is kept alive so that subsequent, synchronous accesses also return the same value. This list is reset when synchronous work is done using the `ClearKeptObjects` abstract operation.
- When an object or symbol which is registered with a FinalizationRegistry becomes unreachable, a call of the FinalizationRegistry's cleanup callback may eventually be made, after synchronous ECMAScript execution completes. The FinalizationRegistry cleanup is performed with the `CleanupFinalizationRegistry` abstract operation.

Neither of these actions (`ClearKeptObjects` or `CleanupFinalizationRegistry`) may interrupt synchronous ECMAScript execution. Because hosts may assemble longer, synchronous ECMAScript execution runs, this specification defers the scheduling of `ClearKeptObjects` and `CleanupFinalizationRegistry` to the host environment.

Some ECMAScript implementations include garbage collector implementations which run in the background, including when ECMAScript is idle. Letting the host environment schedule `CleanupFinalizationRegistry` allows it to resume ECMAScript execution in order to run finalizer work, which may free up held values, reducing overall memory usage.

#### 9.10.2 Liveness

For some set of objects and/or symbols S a hypothetical WeakRef-oblivious execution with respect to S is an execution whereby the abstract operation `WeakRefDeref` of a WeakRef whose referent is an element of S always returns `undefined`.

**NOTE 1** WeakRef-obliviousness, together with liveness, capture two notions. One, that a WeakRef itself does not keep its referent alive. Two, that cycles in liveness does not imply that a value is live. To be concrete, if determining v's liveness depends on determining the liveness of a WeakRef referent, r, r's liveness cannot assume v's liveness, which would be circular reasoning.

**NOTE 2** WeakRef-obliviousness is defined on sets of objects or symbols instead of individual values to account for cycles. If it were defined on individual values, then a WeakRef referent in a cycle will be considered live even though its identity is only observed via other WeakRef referents in the cycle.

**NOTE 3** Colloquially, we say that an individual object or symbol is live if every set containing it is live.

At any point during evaluation, a set of objects and/or symbols S is considered live if either of the following conditions is met:

- Any element in S is included in any agent's [[KeptAlive]] List.
• There exists a valid future hypothetical WeakRef-oblivious execution with respect to $S$ that observes the identity of any value in $S$.

**NOTE 4** The second condition above intends to capture the intuition that a value is live if its identity is observable via non-WeakRef means. A value's identity may be observed by observing a strict equality comparison or observing the value being used as key in a Map.

**NOTE 5** Presence of an object or a symbol in a field, an internal slot, or a property does not imply that the value is live. For example if the value in question is never passed back to the program, then it cannot be observed.

This is the case for keys in a WeakMap, members of a WeakSet, as well as the $[[\text{WeakRefTarget}]]$ and $[[\text{UnregisterToken}]]$ fields of a FinalizationRegistry Cell record.

The above definition implies that, if a key in a WeakMap is not live, then its corresponding value is not necessarily live either.

**NOTE 6** Liveness is the lower bound for guaranteeing which WeakRefs engines must not empty. Liveness as defined here is undecidable. In practice, engines use conservative approximations such as reachability. There is expected to be significant implementation leeway.

### 9.10.3 Execution

At any time, if a set of objects and/or symbols $S$ is not live, an ECMAScript implementation may perform the following steps atomically:

1. For each element value of $S$, do
   a. For each WeakRef ref such that ref.$[[\text{WeakRefTarget}]]$ is value, do
      i. Set ref.$[[\text{WeakRefTarget}]]$ to EMPTY.
   b. For each FinalizationRegistry $fg$ such that $fg.$[[Cells]]$ contains a Record $cell$ such that $cell.$[[WeakRefTarget]]$ is value, do
      i. Set $cell.$[[WeakRefTarget]]$ to EMPTY.
      ii. Optionally, perform HostEnqueueFinalizationRegistryCleanupJob($fg$).
   c. For each WeakMap $map$ such that $map.$[[WeakMapData]]$ contains a Record $r$ such that $r.$[[Key]]$ is value, do
      i. Set $r.$[[Key]]$ to EMPTY.
      ii. Set $r.$[[Value]]$ to EMPTY.
   d. For each WeakSet $set$ such that $set.$[[WeakSetData]]$ contains value, do
      i. Replace the element of $set.$[[WeakSetData]]$ whose value is value with an element whose value is EMPTY.
NOTE 1 Together with the definition of liveness, this clause prescribes optimizations that an implementation may apply regarding WeakRefs.

It is possible to access an object without observing its identity. Optimizations such as dead variable elimination and scalar replacement on properties of non-escaping objects whose identity is not observed are allowed. These optimizations are thus allowed to observably empty WeakRefs that point to such objects.

On the other hand, if an object's identity is observable, and that object is in the [[WeakRefTarget]] internal slot of a WeakRef, optimizations such as rematerialization that observably empty the WeakRef are prohibited.

Because calling HostEnqueueFinalizationRegistryCleanupJob is optional, registered objects in a FinalizationRegistry do not necessarily hold that FinalizationRegistry live. Implementations may omit FinalizationRegistry callbacks for any reason, e.g., if the FinalizationRegistry itself becomes dead, or if the application is shutting down.

NOTE 2 Implementations are not obligated to empty WeakRefs for maximal sets of non-live objects or symbols.

If an implementation chooses a non-live set $S$ in which to empty WeakRefs, this definition requires that it empties WeakRefs for all values in $S$ simultaneously. In other words, it is not conformant for an implementation to empty a WeakRef pointing to a value $v$ without emptying out other WeakRefs that, if not emptied, could result in an execution that observes the value of $v$.

9.10 Host Hooks

9.10.4.1 HostEnqueueFinalizationRegistryCleanupJob (.finalizationRegistry )

The host-defined abstract operation HostEnqueueFinalizationRegistryCleanupJob takes argument finalizationRegistry (a FinalizationRegistry) and returns UNUSED.

Let cleanupJob be a new Job Abstract Closure with no parameters that captures finalizationRegistry and performs the following steps when called:

1. Let cleanupResult be Completion(CleanupFinalizationRegistry(finalizationRegistry)).
2. If cleanupResult is an abrupt completion, perform any host-defined steps for reporting the error.
3. Return UNUSED.

An implementation of HostEnqueueFinalizationRegistryCleanupJob schedules cleanupJob to be performed at some future time, if possible. It must also conform to the requirements in 9.5.

9.11 ClearKeptObjects ( )

The abstract operation ClearKeptObjects takes no arguments and returns UNUSED. ECMAScript implementations are expected to call ClearKeptObjects when a synchronous sequence of ECMAScript executions completes. It performs the following steps when called:

1. Let agentRecord be the surrounding agent's Agent Record.
2. Set agentRecord.KeptAlive to a new empty List.
3. Return UNUSED.
9.12 AddToKeptObjects ( value )

The abstract operation AddToKeptObjects takes argument value (an Object or a Symbol) and returns UNUSED. It performs the following steps when called:

1. Let agentRecord be the surrounding agent's Agent Record.
2. Append value to agentRecord.[[KeptAlive]].
3. Return UNUSED.

NOTE When the abstract operation AddToKeptObjects is called with a target object or symbol, it adds the target to a list that will point strongly at the target until ClearKeptObjects is called.

9.13 CleanupFinalizationRegistry ( finalizationRegistry )

The abstract operation CleanupFinalizationRegistry takes argument finalizationRegistry (a FinalizationRegistry) and returns either a normal completion containing unused or a throw completion. It performs the following steps when called:

1. Assert: finalizationRegistry has [[Cells]] and [[CleanupCallback]] internal slots.
2. Let callback be finalizationRegistry.[[CleanupCallback]].
3. While finalizationRegistry.[[Cells]] contains a Record cell such that cell.[[WeakRefTarget]] is EMPTY, an implementation may perform the following steps:
   a. Choose any such cell.
   b. Remove cell from finalizationRegistry.[[Cells]].
   c. Perform ? HostCallJobCallback(callback, undefined, « cell.[[HeldValue]] »).
4. Return UNUSED.

9.14 CanBeHeldWeakly ( v )

The abstract operation CanBeHeldWeakly takes argument v (an ECMAScript language value) and returns a Boolean. It returns true if and only if v is suitable for use as a weak reference. Only values that are suitable for use as a weak reference may be a key of a WeakMap, an element of a WeakSet, the target of a WeakRef, or one of the targets of a FinalizationRegistry. It performs the following steps when called:

1. If v is an Object, return true.
2. If v is a Symbol and KeyForSymbol(v) is undefined, return true.
3. Return false.

NOTE A language value without language identity can be manifested without prior reference and is unsuitable for use as a weak reference. A Symbol value produced by Symbol.for, unlike other Symbol values, does not have language identity and is unsuitable for use as a weak reference. Well-known symbols are likely to never be collected, but are nonetheless treated as suitable for use as a weak reference because they are limited in number and therefore manageable by a variety of implementation approaches. However, any value associated to a well-known symbol in a live WeakMap is unlikely to be collected and could "leak" memory resources in implementations.

10 Ordinary and Exotic Objects Behaviours

10.1 Ordinary Object Internal Methods and Internal Slots

All ordinary objects have an internal slot called [[Prototype]]. The value of this internal slot is either null or an object and is used for implementing inheritance. Assume a property named P is missing from an ordinary object O but exists on its [[Prototype]] object. If P refers to a data property on the [[Prototype]] object, O inherits it for get access, making it behave as if P was a property of O. If P refers to a writable data property on the [[Prototype]]
object, set access of \( P \) on \( O \) creates a new data property named \( P \) on \( O \). If \( P \) refers to a non-writable data property on the [[Prototype]] object, set access of \( P \) on \( O \) fails. If \( P \) refers to an accessor property on the [[Prototype]] object, the accessor is inherited by \( O \) for both get access and set access.

Every ordinary object has a Boolean-valued [[Extensible]] internal slot which is used to fulfill the extensibility-related internal method invariants specified in 6.1.7.3. Namely, once the value of an object's [[Extensible]] internal slot has been set to false, it is no longer possible to add properties to the object, to modify the value of the object's [[Prototype]] internal slot, or to subsequently change the value of [[Extensible]] to true.

In the following algorithm descriptions, assume \( O \) is an ordinary object, \( P \) is a property key value, \( V \) is any ECMAScript language value, and \( Desc \) is a Property Descriptor record.

Each ordinary object internal method delegates to a similarly-named abstract operation. If such an abstract operation depends on another internal method, then the internal method is invoked on \( O \) rather than calling the similarly-named abstract operation directly. These semantics ensure that exotic objects have their overridden internal methods invoked when ordinary object internal methods are applied to them.

10.1.1 [[GetPrototypeOf]] ( )

The [[GetPrototypeOf]] internal method of an ordinary object \( O \) takes no arguments and returns a normal completion containing either an Object or null. It performs the following steps when called:

1. Return OrdinaryGetPrototypeOf(\( O \)).

10.1.1.1 OrdinaryGetPrototypeOf ( \( O \) )

The abstract operation OrdinaryGetPrototypeOf takes argument \( O \) (an Object) and returns an Object or null. It performs the following steps when called:

1. Return \( O.\text{[[Prototype]]} \).

10.1.2 [[SetPrototypeOf]] ( \( V \) )

The [[SetPrototypeOf]] internal method of an ordinary object \( O \) takes argument \( V \) (an Object or null) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. Return OrdinarySetPrototypeOf(\( O, V \)).

10.1.2.1 OrdinarySetPrototypeOf ( \( O, V \) )

The abstract operation OrdinarySetPrototypeOf takes arguments \( O \) (an Object) and \( V \) (an Object or null) and returns a Boolean. It performs the following steps when called:

1. Let \( current \) be \( O.\text{[[Prototype]]} \).
2. If SameValue(\( V, current \)) is true, return true.
3. Let \( extensible \) be \( O.\text{[[Extensible]]} \).
4. If \( extensible \) is false, return false.
5. Let \( p \) be \( V \).
6. Let \( done \) be false.
7. Repeat, while \( done \) is false,
   a. If \( p \) is null, then
      i. Set \( done \) to true.
   b. Else if SameValue(\( p, O \)) is true, then
      i. Return false.
   c. Else,
      i. If \( p.\text{[[GetPrototypeOf]]} \) is not the ordinary object internal method defined in 10.1.1, set \( done \) to true.
      ii. Else, set \( p \) to \( p.\text{[[Prototype]]} \).
8. Set \( O.\text{[[Prototype]]} \) to \( V \).
9. Return true.
10.1.3 [[IsExtensible]] ()

The [[IsExtensible]] internal method of an ordinary object \( O \) takes no arguments and returns a normal completion containing a Boolean. It performs the following steps when called:

1. Return \( \text{OrdinaryIsExtensible}(O) \).

10.1.3.1 OrdinaryIsExtensible ( \( O \) )

The abstract operation OrdinaryIsExtensible takes argument \( O \) (an Object) and returns a Boolean. It performs the following steps when called:

1. Return \( O.([[\text{Extensible}]]). \)

10.1.4 [[PreventExtensions]] ()

The [[PreventExtensions]] internal method of an ordinary object \( O \) takes no arguments and returns a normal completion containing \( \text{true} \). It performs the following steps when called:

1. Return \( \text{OrdinaryPreventExtensions}(O) \).

10.1.4.1 OrdinaryPreventExtensions ( \( O \) )

The abstract operation OrdinaryPreventExtensions takes argument \( O \) (an Object) and returns \( \text{true} \). It performs the following steps when called:

1. Set \( O.([[\text{Extensible}]]) \) to \( \text{false} \).
2. Return \( \text{true} \).

10.1.5 [[GetOwnProperty]] ( \( P \) )

The [[GetOwnProperty]] internal method of an ordinary object \( O \) takes argument \( P \) (a property key) and returns a normal completion containing either a Property Descriptor or \( \text{undefined} \). It performs the following steps when called:

1. Return \( \text{OrdinaryGetOwnProperty}(O, P) \).

10.1.5.1 OrdinaryGetOwnProperty ( \( O, P \) )

The abstract operation OrdinaryGetOwnProperty takes arguments \( O \) (an Object) and \( P \) (a property key) and returns a Property Descriptor or \( \text{undefined} \). It performs the following steps when called:

1. If \( O \) does not have an own property with key \( P \), return \( \text{undefined} \).
2. Let \( D \) be a newly created Property Descriptor with no fields.
3. Let \( X \) be \( O \)'s own property whose key is \( P \).
4. If \( X \) is a data property, then
   a. Set \( D.([[\text{Value}]]) \) to the value of \( X \)'s [[Value]] attribute.
   b. Set \( D.([[\text{Writable}]]) \) to the value of \( X \)'s [[Writable]] attribute.
5. Else,
   a. Assert: \( X \) is an accessor property.
   b. Set \( D.([[\text{Get}]]) \) to the value of \( X \)'s [[Get]] attribute.
   c. Set \( D.([[\text{Set}]]) \) to the value of \( X \)'s [[Set]] attribute.
6. Set \( D.\text{[Enumerable]} \) to the value of \( X \)’s \( \text{[Enumerable]} \) attribute.
7. Set \( D.\text{[Configurable]} \) to the value of \( X \)’s \( \text{[Configurable]} \) attribute.
8. Return \( D \).

10.1.6 \([[\text{DefineOwnProperty}]]) \((P, \text{Desc})\)

The \([[\text{DefineOwnProperty}]]) internal method of an ordinary object \( O \) takes arguments \( P \) (a property key) and \( \text{Desc} \) (a Property Descriptor) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Return \( \text{OrdinaryDefineOwnProperty}(O, P, \text{Desc}) \).

10.1.6.1 \(\text{OrdinaryDefineOwnProperty} \((O, P, \text{Desc})\)\)

The abstract operation \( \text{OrdinaryDefineOwnProperty} \) takes arguments \( O \) (an Object), \( P \) (a property key), and \( \text{Desc} \) (a Property Descriptor) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Let \( \text{current} \) be \( O.\text{[[GetOwnProperty]]}(P) \).
2. Let \( \text{extensible} \) be \( \text{IsExtensible}(O) \).
3. Return \( \text{ValidateAndApplyPropertyDescriptor}(O, P, \text{extensible}, \text{Desc}, \text{current}) \).

10.1.6.2 \(\text{IsCompatiblePropertyDescriptor} \((\text{Extensible}, \text{Desc}, \text{Current})\)\)

The abstract operation \( \text{IsCompatiblePropertyDescriptor} \) takes arguments \( \text{Extensible} \) (a Boolean), \( \text{Desc} \) (a Property Descriptor), and \( \text{Current} \) (a Property Descriptor or undefined) and returns a Boolean. It performs the following steps when called:

1. Return \( \text{ValidateAndApplyPropertyDescriptor}(\text{undefined}, \text{""}, \text{Extensible}, \text{Desc}, \text{Current}) \).

10.1.6.3 \(\text{ValidateAndApplyPropertyDescriptor} \((O, P, \text{extensible}, \text{Desc}, \text{current})\)\)

The abstract operation \( \text{ValidateAndApplyPropertyDescriptor} \) takes arguments \( O \) (an Object or undefined), \( P \) (a property key), \( \text{extensible} \) (a Boolean), \( \text{Desc} \) (a Property Descriptor), and \( \text{current} \) (a Property Descriptor or undefined) and returns a Boolean. It returns true if and only if \( \text{Desc} \) can be applied as the property of an object with specified extensibility and current property \( \text{current} \) while upholding invariants. When such application is possible and \( O \) is not undefined, it is performed for the property named \( P \) (which is created if necessary). It performs the following steps when called:

1. Assert: \( \text{IsPropertyKey}(P) \) is true.
2. If \( \text{current} \) is undefined, then
   a. If \( \text{extensible} \) is false, return false.
   b. If \( O \) is undefined, return true.
   c. If \( \text{IsAccessorDescriptor}(\text{Desc}) \) is true, then
      i. Create an own accessor property named \( P \) of object \( O \) whose [[Get]], [[Set]], [[Enumerable]], and [[Configurable]] attributes are set to the value of the corresponding field in \( \text{Desc} \) if \( \text{Desc} \) has that field, or to the attribute’s default value otherwise.
      d. Else,
         i. Create an own data property named \( P \) of object \( O \) whose [[Value]], [[Writable]], [[Enumerable]], and [[Configurable]] attributes are set to the value of the corresponding field in \( \text{Desc} \) if \( \text{Desc} \) has that field, or to the attribute’s default value otherwise.
   d. Return true.
3. Assert: \( \text{current} \) is a fully populated Property Descriptor.
4. If \( \text{Desc} \) does not have any fields, return true.
5. If \( \text{current}.\text{[[Configurable]]} \) is false, then
   a. If \( \text{Desc} \) has a [[Configurable]] field and \( \text{Desc}.\text{[[Configurable]]} \) is true, return false.
   b. If \( \text{Desc} \) has an [[Enumerable]] field and \( \text{Desc}.\text{[[Enumerable]]} \) is not \( \text{current}.\text{[[Enumerable]]} \), return false.
   c. If \( \text{IsGenericDescriptor}(\text{Desc}) \) is false and \( \text{IsAccessorDescriptor}(\text{current}) \) is not \( \text{IsAccessorDescriptor}(\text{current}) \), return false.
d. If IsAccessorDescriptor(\(current\)) is \textbf{true}, then
   i. If \(Desc\) has a \([[\text{Get}]]\) field and SameValue(\(Desc.[[\text{Get}]], current.[[\text{Get}]]\)) is \textbf{false}, return \textbf{false}.
   ii. If \(Desc\) has a \([[\text{Set}]]\) field and SameValue(\(Desc.[[\text{Set}]], current.[[\text{Set}]]\)) is \textbf{false}, return \textbf{false}.

e. Else if \(current.[[[\text{Writable}]]]\) is \textbf{false}, then
   i. If \(Desc\) has a \([[\text{Writable}]]\) field and \(Desc.[[[\text{Writable}]]]\) is \textbf{true}, return \textbf{false}.
   ii. If \(Desc\) has a \([[\text{Value}]]\) field and SameValue(\(Desc.[[[\text{Value}]], current.[[[\text{Value}]]]\)) is \textbf{false}, return \textbf{false}.

6. If \(O\) is not \textbf{undefined}, then
   a. If IsDataDescriptor(\(current\)) is \textbf{true} and IsAccessorDescriptor(\(Desc\)) is \textbf{true}, then
      i. If \(Desc\) has a \([[\text{Configurable}]]\) field, let \(configurable\) be \(Desc.[[[\text{Configurable}]]]\); else let \(configurable\) be current.\([[\text{Configurable}]]\).
      ii. If \(Desc\) has a \([[\text{Enumerable}]]\) field, let \(enumerable\) be \(Desc.[[[\text{Enumerable}]]]\); else let \(enumerable\) be current.\([[\text{Enumerable}]]\).
      iii. Replace the property named \(P\) of object \(O\) with an accessor property whose \([[\text{Configurable}]]\) and \([[\text{Enumerable}]]\) attributes are set to \textbf{true} and \textbf{true}, respectively, and whose \([\text{Get}]\) and \([\text{Set}]\) attributes are set to the value of the corresponding field in \(Desc\) if \(Desc\) has that field, or to the attribute's default value otherwise.
   b. Else if IsAccessorDescriptor(\(current\)) is \textbf{true} and IsDataDescriptor(\(Desc\)) is \textbf{true}, then
      i. If \(Desc\) has a \([[\text{Configurable}]]\) field, let \(configurable\) be \(Desc.[[[\text{Configurable}]]]\); else let \(configurable\) be current.\([[\text{Configurable}]]\).
      ii. If \(Desc\) has a \([[\text{Enumerable}]]\) field, let \(enumerable\) be \(Desc.[[[\text{Enumerable}]]]\); else let \(enumerable\) be current.\([[\text{Enumerable}]]\).
      iii. Replace the property named \(P\) of object \(O\) with a data property whose \([[\text{Configurable}]]\) and \([[\text{Enumerable}]]\) attributes are set to \textbf{true} and \textbf{true}, respectively, and whose \([\text{Value}]\) and \([\text{Writable}]\) attributes are set to the value of the corresponding field in \(Desc\) if \(Desc\) has that field, or to the attribute's default value otherwise.
   c. Else,
      i. For each field of \(Desc\), set the corresponding attribute of the property named \(P\) of object \(O\) to the value of the field.

7. Return \textbf{true}.

10.1.7 \([[\text{HasProperty}}]] ( \(P\) )

The \([[\text{HasProperty}]]\) internal method of an ordinary object \(O\) takes argument \(P\) (a \textit{property key}) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Return ? OrdinaryHasProperty(\(O, P\)).

10.1.7.1 OrdinaryHasProperty ( \(O, P\) )

The abstract operation OrdinaryHasProperty takes arguments \(O\) (an Object) and \(P\) (a \textit{property key}) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Let \(\text{hasOwn}\) be \(O.[[[\text{GetOwnProperty}}]](P)\).
2. If \(\text{hasOwn}\) is not \textbf{undefined}, return \textbf{true}.
3. Let \(parent\) be \(O.[[[\text{GetPrototypeOf}}]]()\).
4. If \(parent\) is not \textbf{null}, then
5. Return \textbf{false}.

10.1.8 \([[\text{Get}}]] ( \(P, Receiver\) )

The \([[\text{Get}]]\) internal method of an ordinary object \(O\) takes arguments \(P\) (a \textit{property key}) and \(Receiver\) (an ECMA-Script language value) and returns either a normal completion containing an ECMA-Script language value or a throw completion. It performs the following steps when called:

1. Return ? OrdinaryGet(\(O, P, Receiver\)).
10.1.8.1 OrdinaryGet ( O, P, Receiver )

The abstract operation OrdinaryGet takes arguments O (an Object), P (a property key), and Receiver (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

2. If desc is undefined, then
   a. Let parent be ? O.[[GetPrototypeOf]]().
   b. If parent is null, return undefined.
3. If IsDataDescriptor(desc) is true, return desc.[[Value]].
4. Assert: IsAccessorDescriptor(desc) is true.
5. Let getter be desc.[[Get]].
6. If getter is undefined, return undefined.

10.1.9 [[Set]] ( P, V, Receiver )

The [[Set]] internal method of an ordinary object O takes arguments P (a property key), V (an ECMAScript language value), and Receiver (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:


10.1.9.1 OrdinarySet ( O, P, V, Receiver )

The abstract operation OrdinarySet takes arguments O (an Object), P (a property key), V (an ECMAScript language value), and Receiver (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:


10.1.9.2 OrdinarySetWithOwnProperty ( O, P, V, Receiver, ownDesc )

The abstract operation OrdinarySetWithOwnProperty takes arguments O (an Object), P (a property key), V (an ECMAScript language value), Receiver (an ECMAScript language value), and ownDesc (a Property Descriptor or undefined) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If ownDesc is undefined, then
   a. Let parent be ? O.[[GetPrototypeOf]]().
   b. If parent is not null, then
   c. Else,
      i. Set ownDesc to the PropertyDescriptor { [[Value]]: undefined, [[Writable]]: true, [[Enumerable]]: true, [[Configurable]]: true }.
2. If IsDataDescriptor(ownDesc) is true, then
   a. If ownDesc.[[Writable]] is false, return false.
   b. If Receiver is not an Object, return false.
   c. Let existingDescriptor be ? Receiver.[[GetOwnProperty]](P).
   d. If existingDescriptor is not undefined, then
      i. If IsAccessorDescriptor(existingDescriptor) is true, return false.
      ii. If existingDescriptor.[[Writable]] is false, return false.
      iii. Let valueDesc be the PropertyDescriptor { [[Value]]: V }.
   e. Else,
i. Assert: Receiver does not currently have a property \( P \).
ii. Return \(?\ CreateDataProperty(\ Receiver, P, V)\).

3. Assert: IsAccessorDescriptor(ownDesc) is true.
4. Let setter be ownDesc.[[Set]].
5. If setter is undefined, return false.
6. Perform \(?\ Call(setter, Receiver, \[ V \]).
7. Return true.

10.1.10 [[Delete]] ( \( P \) )

The [[Delete]] internal method of an ordinary object \( O \) takes argument \( P \) (a property key) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Return \( ?\ OrdinaryDelete(O, P)\).

10.1.10.1 OrdinaryDelete ( \( O, P \) )

The abstract operation OrdinaryDelete takes arguments \( O \) (an Object) and \( P \) (a property key) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Let desc be \( O.[[GetOwnProperty]](P)\).
2. If desc is undefined, return true.
3. If desc.[[Configurable]] is true, then
   a. Remove the own property with name \( P \) from \( O \).
   b. Return true.
4. Return false.

10.1.11 [[OwnPropertyKeys]] ()

The [[OwnPropertyKeys]] internal method of an ordinary object \( O \) takes no arguments and returns a normal completion containing a List of property keys. It performs the following steps when called:

1. Return OrdinaryOwnPropertyKeys(\( O \)).

10.1.11.1 OrdinaryOwnPropertyKeys ( \( O \) )

The abstract operation OrdinaryOwnPropertyKeys takes argument \( O \) (an Object) and returns a List of property keys. It performs the following steps when called:

1. Let keys be a new empty List.
2. For each own property key \( P \) of \( O \) such that \( P \) is an array index, in ascending numeric index order, do
   a. Append \( P \) to keys.
3. For each own property key \( P \) of \( O \) such that \( P \) is a String and \( P \) is not an array index, in ascending chronological order of property creation, do
   a. Append \( P \) to keys.
4. For each own property key \( P \) of \( O \) such that \( P \) is a Symbol, in ascending chronological order of property creation, do
   a. Append \( P \) to keys.
5. Return keys.

10.1.12 OrdinaryObjectCreate ( \( proto \ [ , additionalInternalSlotsList ] \) )

The abstract operation OrdinaryObjectCreate takes argument \( proto \) (an Object or null) and optional argument additionalInternalSlotsList (a List of names of internal slots) and returns an Object. It is used to specify the runtime creation of new ordinary objects. additionalInternalSlotsList contains the names of additional internal slots.
that must be defined as part of the object, beyond [[Prototype]] and [[Extensible]]. If `additionalInternalSlotsList` is not provided, a new empty `List` is used. It performs the following steps when called:

1. Let `internalSlotsList` be `[[Prototype]], [[Extensible]] ».
2. If `additionalInternalSlotsList` is present, set `internalSlotsList` to the list-concatenation of `internalSlotsList` and `additionalInternalSlotsList`.
3. Let `O` be `MakeBasicObject(`internalSlotsList`)`.
4. Set `O.[[Prototype]]` to `proto`.
5. Return `O`.

**NOTE** Although `OrdinaryObjectCreate` does little more than call `MakeBasicObject`, its use communicates the intention to create an ordinary object, and not an exotic one. Thus, within this specification, it is not called by any algorithm that subsequently modifies the internal methods of the object in ways that would make the result non-ordinary. Operations that create exotic objects invoke `MakeBasicObject` directly.

10.1.13 `OrdinaryCreateFromConstructor ( constructor, intrinsicDefaultProto [, internalSlotsList ] )`

The abstract operation `OrdinaryCreateFromConstructor` takes arguments `constructor` (a constructor) and `intrinsicDefaultProto` (a String) and optional argument `internalSlotsList` (a `List` of names of internal slots) and returns either a normal completion containing an `Object` or a throw completion. It creates an ordinary object whose [[Prototype]] value is retrieved from the `constructor`'s "prototype" property, if it exists. Otherwise the intrinsic named by `intrinsicDefaultProto` is used for [[Prototype]]. `internalSlotsList` contains the names of additional internal slots that must be defined as part of the object. If `internalSlotsList` is not provided, a new empty `List` is used. It performs the following steps when called:

1. **Assert**: `intrinsicDefaultProto` is this specification's name of an intrinsic object. The corresponding object must be an intrinsic that is intended to be used as the [[Prototype]] value of an object.
2. Let `proto` be `? GetPrototypeFromConstructor (constructor, intrinsicDefaultProto)`.  
3. If `internalSlotsList` is present, let `slotsList` be `internalSlotsList`.
4. Else, let `slotsList` be a new empty `List`.
5. Return `OrdinaryObjectCreate (proto, slotsList)`.

10.1.14 `GetPrototypeFromConstructor ( constructor, intrinsicDefaultProto )`

The abstract operation `GetPrototypeFromConstructor` takes arguments `constructor` (a function object) and `intrinsicDefaultProto` (a String) and returns either a normal completion containing an `Object` or a throw completion. It determines the [[Prototype]] value that should be used to create an object corresponding to a specific constructor. The value is retrieved from the `constructor`'s "prototype" property, if it exists. Otherwise the intrinsic named by `intrinsicDefaultProto` is used for [[Prototype]]. It performs the following steps when called:

1. **Assert**: `intrinsicDefaultProto` is this specification's name of an intrinsic object. The corresponding object must be an intrinsic that is intended to be used as the [[Prototype]] value of an object.
2. Let `proto` be `? Get (constructor, "prototype")`.
3. If `proto` is not an `Object`, then
   a. Let `realm` be `? GetFunctionRealm (constructor)`.
   b. Set `proto` to `realm`'s intrinsic object named `intrinsicDefaultProto`.
4. Return `proto`.

**NOTE** If `constructor` does not supply a [[Prototype]] value, the default value that is used is obtained from the `realm` of the `constructor` function rather than from the running execution context.
10.1.15 RequireInternalSlot (O, internalSlot)

The abstract operation RequireInternalSlot takes arguments \( O \) (an ECMAScript language value) and \( \text{internalSlot} \) (an internal slot name) and returns either a normal completion containing \( \text{UNUSED} \) or a throw completion. It throws an exception unless \( O \) is an Object and has the given internal slot. It performs the following steps when called:

1. If \( O \) is not an Object, throw a TypeError exception.
2. If \( O \) does not have an \( \text{internalSlot} \) internal slot, throw a TypeError exception.
3. Return \( \text{UNUSED} \).

10.2 ECMAScript Function Objects

ECMAScript function objects encapsulate parameterized ECMAScript code closed over a lexical environment and support the dynamic evaluation of that code. An ECMAScript function object is an ordinary object and has the same internal slots and the same internal methods as other ordinary objects. The code of an ECMAScript function object may be either strict mode code (11.2.2) or non-strict code. An ECMAScript function object whose code is strict mode code is called a strict function. One whose code is not strict mode code is called a non-strict function.

In addition to [[Extensible]] and [[Prototype]], ECMAScript function objects also have the internal slots listed in Table 30.

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Environment]]</td>
<td>an Environment Record</td>
<td>The Environment Record that the function was closed over. Used as the outer environment when evaluating the code of the function.</td>
</tr>
<tr>
<td>[[PrivateEnvironment]]</td>
<td>a PrivateEnvironment Record or null</td>
<td>The PrivateEnvironment Record for Private Names that the function was closed over. ( \text{null} ) if this function is not syntactically contained within a class. Used as the outer PrivateEnvironment for inner classes when evaluating the code of the function.</td>
</tr>
<tr>
<td>[[FormalParameters]]</td>
<td>a Parse Node</td>
<td>The root parse node of the source text that defines the function's formal parameter list.</td>
</tr>
<tr>
<td>[[ECMAScriptCode]]</td>
<td>a Parse Node</td>
<td>The root parse node of the source text that defines the function's body.</td>
</tr>
<tr>
<td>[[ConstructorKind]]</td>
<td>BASE or DERIVED</td>
<td>Whether or not the function is a derived class constructor.</td>
</tr>
<tr>
<td>[[Realm]]</td>
<td>a Realm Record</td>
<td>The realm in which the function was created and which provides any intrinsic objects that are accessed when evaluating the function.</td>
</tr>
<tr>
<td>[[ScriptOrModule]]</td>
<td>a Script Record or a Module Record</td>
<td>The script or module in which the function was created.</td>
</tr>
<tr>
<td>[[ThisMode]]</td>
<td>LEXICAL, STRICT, or GLOBAL</td>
<td>Defines how this references are interpreted within the formal parameters and code body of the function. LEXICAL means that this refers to the this value of a lexically enclosing function. STRICT means that the this value is used exactly as provided by an invocation of the function. GLOBAL means that a this value of undefined or null is interpreted as a reference to the global object, and any other this value is first passed to ToObject.</td>
</tr>
</tbody>
</table>
### Table 30: Internal Slots of ECMAScript Function Objects (continued)

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Strict]]</td>
<td>a Boolean</td>
<td>true if this is a strict function, false if this is a non-strict function.</td>
</tr>
<tr>
<td>[[HomeObject]]</td>
<td>an Object</td>
<td>If the function uses <code>super</code>, this is the object whose [[GetPrototypeOf]] provides the object where <code>super</code> property lookups begin.</td>
</tr>
<tr>
<td>[[SourceText]]</td>
<td>a sequence of Unicode code points</td>
<td>The source text that defines the function.</td>
</tr>
<tr>
<td>[[Fields]]</td>
<td>a List of ClassFieldDefinitionRecords</td>
<td>If the function is a class, this is a list of Records representing the non-static fields and corresponding initializers of the class.</td>
</tr>
<tr>
<td>[[PrivateMethods]]</td>
<td>a List of PrivateElements</td>
<td>If the function is a class, this is a list representing the non-static private methods and accessors of the class.</td>
</tr>
<tr>
<td>[[ClassFieldInitializerName]]</td>
<td>a String, a Symbol, a Private Name, or EMPTY</td>
<td>If the function is created as the initializer of a class field, the name to use for NamedEvaluation of the field; EMPTY otherwise.</td>
</tr>
<tr>
<td>[[IsClassConstructor]]</td>
<td>a Boolean</td>
<td>Indicates whether the function is a class constructor. (If true, invoking the function's [[Call]] will immediately throw a TypeError exception.)</td>
</tr>
</tbody>
</table>

All ECMAScript function objects have the [[Call]] internal method defined here. ECMAScript functions that are also constructors in addition have the [[Construct]] internal method.

### 10.2.1 [[Call]] (thisArgument, argumentsList)

The [[Call]] internal method of an ECMAScript function object \( F \) takes arguments `thisArgument` (an ECMAScript language value) and `argumentsList` (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let `calleeContext` be the running execution context.
2. Let `calleeContext` be `PrepareForOrdinaryCall(F, undefined)`.
3. Assert: `calleeContext` is now the running execution context.
4. If `F. [[IsClassConstructor]]` is true, then
   a. Let `error` be a newly created TypeError object.
   b. NOTE: `error` is created in `calleeContext` with \( F \)'s associated Realm Record.
   c. Remove `calleeContext` from the execution context stack and restore `calleeContext` as the running execution context.
   d. Return `ThrowCompletion(error)`.
5. Perform `OrdinaryCallBindThis(F, calleeContext, thisArgument)`.
6. Let `result` be `Completion(OrdinaryCallEvaluateBody(F, argumentsList))`.
7. Remove `calleeContext` from the execution context stack and restore `calleeContext` as the running execution context.
8. If `result` is a return completion, return `result. [[Value]]`.
9. Return `IfAbrupt(result)`.
10. Return `undefined`.

**NOTE** When `calleeContext` is removed from the execution context stack in step 7 it must not be destroyed if it is suspended and retained for later resumption by an accessible Generator.
10.2.1.1 PrepareForOrdinaryCall (F, newTarget)

The abstract operation PrepareForOrdinaryCall takes arguments F (an ECMAScript function object) and newTarget (an Object or undefined) and returns an execution context. It performs the following steps when called:

1. Let callerContext be the running execution context.
2. Let calleeContext be a new ECMAScript code execution context.
3. Set the Function of calleeContext to F.
4. Let calleeRealm be F.[[Realm]].
5. Set the Realm of calleeContext to calleeRealm.
6. Set the ScriptOrModule of calleeContext to F.[[ScriptOrModule]].
7. Let localEnv be NewFunctionEnvironment(F, newTarget).
8. Set the LexicalEnvironment of calleeContext to localEnv.
9. Set the VariableEnvironment of calleeContext to localEnv.
10. Let localEnv be NewFunctionEnvironment(F, newTarget).
11. Set the PrivateEnvironment of calleeContext to F.[[PrivateEnvironment]].
12. If callerContext is not already suspended, suspend callerContext.
13. Push calleeContext onto the execution context stack; calleeContext is now the running execution context.
14. NOTE: Any exception objects produced after this point are associated with calleeRealm.
15. Return calleeContext.

10.2.1.2 OrdinaryCallBindThis (F, calleeContext, thisArgument)

The abstract operation OrdinaryCallBindThis takes arguments F (an ECMAScript function object), calleeContext (an execution context), and thisArgument (an ECMAScript language value) and returns UNUSED. It performs the following steps when called:

1. Let thisMode be F.[[ThisMode]].
2. If thisMode is LEXICAL, return UNUSED.
3. Let calleeRealm be F.[[Realm]].
4. Let localEnv be the LexicalEnvironment of calleeContext.
5. If thisMode is STRICT, then
   a. Let thisValue be thisArgument.
6. Else,
   a. If thisArgument is either undefined or null, then
      i. Let globalEnv be calleeRealm.[[GlobalEnv]].
      ii. Assert: globalEnv is a Global Environment Record.
      iii. Let thisValue be globalEnv.[[GlobalThisValue]].
   b. Else,
      i. Let thisValue be ! ToObject(thisArgument).
      ii. NOTE: ToObject produces wrapper objects using calleeRealm.
7. Assert: localEnv is a Function Environment Record.
8. Assert: The next step never returns an abrupt completion because localEnv.[[ThisBindingStatus]] is not INITIALIZED.
9. Perform ! localEnv.BindThisValue(thisValue).
10. Return UNUSED.

10.2.1.3 Runtime Semantics: EvaluateBody

The syntax-directed operation EvaluateBody takes arguments functionObject (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

FunctionBody : FunctionStatementList

ConciseBody : ExpressionBody


AsyncGeneratorBody : FunctionBody

AsyncFunctionBody : FunctionBody

AsyncConciseBody : ExpressionBody

Initializer :
= AssignmentExpression

1. Assert: argumentsList is empty.
2. Assert: functionObject.[[ClassFieldInitializerName]] is not EMPTY.
3. If IsAnonymousFunctionDefinition(AssignmentExpression) is true, then
   a. Let value be ? NamedEvaluation of Initializer with argument functionObject.[[ClassFieldInitializerName]].
4. Else,
   a. Let rhs be ? Evaluation of AssignmentExpression.
   b. Let value be ? GetValue(rhs).
5. Return Completion Record { [[Type]]: RETURN, [[Value]]: value, [[Target]]: EMPTY }.

NOTE Even though field initializers constitute a function boundary, calling FunctionDeclarationInstantiation does not have any observable effect and so is omitted.

ClassStaticBlockBody : ClassStaticBlockStatementList
1. Assert: argumentsList is empty.
2. Return ? EvaluateClassStaticBlockBody of ClassStaticBlockBody with argument functionObject.

10.2.1.4 OrdinaryCallEvaluateBody ( F, argumentsList )

The abstract operation OrdinaryCallEvaluateBody takes arguments F (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:


10.2.2 [[Construct]] ( argumentsList, newTarget )

The [[Construct]] internal method of an ECMAScript function object F takes arguments argumentsList (a List of ECMAScript language values) and newTarget (a constructor) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Let callerContext be the running execution context.
2. Let kind be F.[[ConstructorKind]].
3. If kind is BASE, then
   a. Let thisArgument be ? OrdinaryCreateFromConstructor(newTarget, "%Object.prototype").
4. Let calleeContext be PrepareForOrdinaryCall(F, newTarget).
5. **Assert:** `calleeContext` is now the running execution context.

6. If `kind` is BASE, then
   a. Perform `OrdinaryCallBindThis(F, calleeContext, thisArgument)`.
   b. Let `initializeResult` be `Completion(InitializeInstanceElements(thisArgument, F))`.
   c. If `initializeResult` is an abrupt completion, then
      i. Remove `calleeContext` from the execution context stack and restore `calleeContext` as the running execution context.
      ii. Return `initializeResult`.

7. Let `constructorEnv` be the LexicalEnvironment of `calleeContext`.

8. Let `result` be `Completion(OrdinaryCallEvaluateBody(F, argumentsList))`.

9. Remove `calleeContext` from the execution context stack and restore `calleeContext` as the running execution context.

10. If `result` is a return completion, then
    a. If `result`.[[Value]] is an Object, return `result`.[[Value]].
    b. If `kind` is BASE, return `thisArgument`.
    c. If `result`.[[Value]] is not `undefined`, throw a `TypeError` exception.

11. Else,
    a. `ReturnIfAbrupt(result)`.

12. Let `thisBinding` be `? constructorEnv.GetThisBinding()`.

13. **Assert:** `thisBinding` is an Object.

14. Return `thisBinding`.

10.2.3 **OrdinaryFunctionCreate** ( `functionPrototype, sourceText, ParameterList, Body, thisMode, env, privateEnv` )

The abstract operation OrdinaryFunctionCreate takes arguments `functionPrototype` (an Object), `sourceText` (a sequence of Unicode code points), `ParameterList` (a Parse Node), `Body` (a Parse Node), `thisMode` (LEXICAL-THIS or NON-LEXICAL-THIS), `env` (an Environment Record), and `privateEnv` (a PrivateEnvironment Record or null) and returns an ECMAScript function object. It is used to specify the runtime creation of a new function with a default `[[Call]]` internal method and no `[[Construct]]` internal method (although one may be subsequently added by an operation such as `MakeConstructor`). `sourceText` is the source text of the syntactic definition of the function to be created. It performs the following steps when called:

1. Let `internalSlotsList` be the internal slots listed in Table 30.
2. Let `F` be `OrdinaryObjectCreate(functionPrototype, internalSlotsList)`.
3. Set `F`.[[Call]] to the definition specified in 10.2.1.
4. Set `F`.[[SourceText]] to `sourceText`.
5. Set `F`.[[FormalParameters]] to `ParameterList`.
7. If the `sourceText` matched by `Body` is strict mode code, let `Strict` be `true`; else let `Strict` be `false`.
8. Set `F`.[[[Strict]]] to `Strict`.
9. If `thisMode` is LEXICAL-THIS, set `F`.[[ThisMode]] to LEXICAL.
10. Else if `Strict` is `true`, set `F`.[[ThisMode]] to STRICT.

11. Else, set `F`.[[ThisMode]] to GLOBAL.
12. Set `F`.[[IsClassConstructor]] to `false`.
13. Set `F`.[[Environment]] to `env`.
14. Set `F`.[[PrivateEnvironment]] to `privateEnv`.
15. Set `F`.[[ScriptOrModule]] to `GetActiveScriptOrModule()`.
16. Set `F`.[[Realm]] to the current Realm Record.
17. Set `F`.[[HomeObject]] to `undefined`.
18. Set `F`.[[Fields]] to a new empty `List`.
19. Set `F`.[[PrivateMethods]] to a new empty `List`.
20. Set `F`.[[ClassFieldInitializerName]] to `EMPTY`.
21. Let `len` be the `ExpectedArgumentCount` of `ParameterList`.
22. Perform `SetFunctionLength(F, len)`.
23. Return `F`.
10.2.4 AddRestrictedFunctionProperties (F, realm)

The abstract operation AddRestrictedFunctionProperties takes arguments F (a function object) and realm (a Realm Record) and returns UNUSED. It performs the following steps when called:

1. Assert: realm.[[Intrinsics]].[[%ThrowTypeError%]] exists and has been initialized.
2. Let thrower be realm.[[Intrinsics]].[[%ThrowTypeError%]].
3. Perform ! DefinePropertyOrThrow(F, "caller", PropertyDescriptor { [[Get]]: thrower, [[Set]]: thrower, [[Enumerable]]: false, [[Configurable]]: true }).
4. Perform ! DefinePropertyOrThrow(F, "arguments", PropertyDescriptor { [[Get]]: thrower, [[Set]]: thrower, [[Enumerable]]: false, [[Configurable]]: true }).
5. Return UNUSED.

10.2.4.1 %ThrowTypeError% ( )

This function is the %ThrowTypeError% intrinsic object.

It is an anonymous built-in function object that is defined once for each realm.

It performs the following steps when called:

1. Throw a TypeError exception.

The value of the [[Extensible]] internal slot of this function is false.

The "length" property of this function has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

The "name" property of this function has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

10.2.5 MakeConstructor (F [, writablePrototype [, prototype ]])

The abstract operation MakeConstructor takes argument F (an ECMAScript function object or a built-in function object) and optional arguments writablePrototype (a Boolean) and prototype (an Object) and returns UNUSED. It converts F into a constructor. It performs the following steps when called:

1. If F is an ECMAScript function object, then
   a. Assert: IsConstructor(F) is false.
   b. Assert: F is an extensible object that does not have a "prototype" own property.
   c. Set F.[[Construct]] to the definition specified in 10.2.2.
2. Else, set F.[[ConstructorKind]] to BASE.
3. If writablePrototype is not present, set writablePrototype to true.
4. If prototype is not present, then
   a. Set prototype to OrdinaryObjectCreate(%Object.prototype%).
   b. Perform ! DefinePropertyOrThrow(prototype, "constructor", PropertyDescriptor { [[Value]]: F, [[Writable]]: writablePrototype, [[Enumerable]]: false, [[Configurable]]: true }).
5. Perform ! DefinePropertyOrThrow(F, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: writablePrototype, [[Enumerable]]: false, [[Configurable]]: false }).
6. Return UNUSED.
10.2.6 MakeClassConstructor ( F )

The abstract operation MakeClassConstructor takes argument \( F \) (an ECMAScript function object) and returns UNUSED. It performs the following steps when called:

1. Assert: \( F.[[IsClassConstructor]] \) is false.
2. Set \( F.[[IsClassConstructor]] \) to true.
3. Return UNUSED.

10.2.7 MakeMethod ( F, homeObject )

The abstract operation MakeMethod takes arguments \( F \) (an ECMAScript function object) and \( homeObject \) (an Object) and returns UNUSED. It configures \( F \) as a method. It performs the following steps when called:

1. Set \( F.[[HomeObject]] \) to \( homeObject \).
2. Return UNUSED.

10.2.8 DefineMethodProperty ( homeObject, key, closure, enumerable )

The abstract operation DefineMethodProperty takes arguments \( homeObject \) (an Object), \( key \) (a property key or Private Name), \( closure \) (a function object), and \( enumerable \) (a Boolean) and returns either a normal completion containing either a PrivateElement or UNUSED, or an abrupt completion. It performs the following steps when called:

1. Assert: \( homeObject \) is an ordinary, extensible object.
2. If \( key \) is a Private Name, then
   a. Return PrivateElement { [[Key]]: \( key \), [[Kind]]: METHOD, [[Value]]: \( closure \) }.
3. Else,
   a. Let \( desc \) be the PropertyDescriptor { [[Value]]: \( closure \), [[Writable]]: true, [[Enumerable]]: \( enumerable \), [[Configurable]]: true }.
   b. Perform \( \text{DefinePropertyOrThrow}(homeObject, key, desc) \).
   c. NOTE: \( \text{DefinePropertyOrThrow} \) only returns an abrupt completion when attempting to define a class static method whose \( key \) is "prototype".
   d. Return UNUSED.

10.2.9 SetFunctionName ( F, name [ , prefix ] )

The abstract operation SetFunctionName takes arguments \( F \) (a function object) and \( name \) (a property key or Private Name) and optional argument \( prefix \) (a String) and returns UNUSED. It adds a "name" property to \( F \). It performs the following steps when called:

1. Assert: \( F \) is an extensible object that does not have a "name" own property.
2. If \( name \) is a Symbol, then
   a. Let \( description \) be \( name \)'s [[Description]] value.
   b. If \( description \) is undefined, set \( name \) to the empty String.
   c. Else, set \( name \) to the string-concatenation of "[", \( description \), and "]".
3. Else if \( name \) is a Private Name, then
   a. Set \( name \) to \( name \).[Description].
4. If \( F \) has an [[InitialName]] internal slot, then
   a. Set \( F.[[InitialName]] \) to \( name \).
5. If \( prefix \) is present, then
   a. Set \( name \) to the string-concatenation of \( prefix \), the code unit 0x0020 (SPACE), and \( name \).
   b. If \( F \) has an [[InitialName]] internal slot, then
      i. Optionally, set \( F.[[InitialName]] \) to \( name \).
6. Perform ! \( \text{DefinePropertyOrThrow}(F, "name", PropertyDescriptor { [[Value]]: \( name \), [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }) \).
7. Return UNUSED.
10.2.10 SetFunctionLength ( \( F, \text{length} \) )

The abstract operation `SetFunctionLength` takes arguments `F` (a function object) and `length` (a non-negative integer or +\( \infty \)) and returns `UNUSED`. It adds a "length" property to `F`. It performs the following steps when called:

1. **Assert**: `F` is an extensible object that does not have a "length" own property.
2. **Perform**: ! DefinePropertyOrThrow(`F`, "length", PropertyDescriptor { [[Value]]: F(length), [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }
3. Return `UNUSED`.

10.2.11 FunctionDeclarationInstantiation ( `func`, `argumentsList` )

The abstract operation `FunctionDeclarationInstantiation` takes arguments `func` (an ECMAScript function object) and `argumentsList` (a List of ECMAScript language values) and returns either a normal completion containing `UNUSED` or an abrupt completion. `func` is the function object for which the execution context is being established.

It performs the following steps when called:

1. Let `calleeContext` be the running execution context.
2. Let `code` be `func`.[[ECMAScriptCode]].
3. Let `strict` be `func`.[[Strict]].
4. Let `formals` be `func`.[[FormalParameters]].
5. Let `parameterNames` be the BoundNames of `formals`.
6. If `parameterNames` has any duplicate entries, let `hasDuplicates` be `true`. Otherwise, let `hasDuplicates` be `false`.
7. Let `simpleParameterList` be IsSimpleParameterList of `formals`.
8. Let `hasParameterExpressions` be ContainsExpression of `formals`.
9. Let `varNames` be the VarDeclaredNames of `code`.
10. Let `varDeclarations` be the VarScopedDeclarations of `code`.
11. Let `lexicalNames` be the LexicallyDeclaredNames of `code`.
12. Let `functionNames` be a new empty List.
13. Let `functionsToInitialize` be a new empty List.
14. For each element `d` of `varDeclarations`, in reverse List order, do
   a. If `d` is neither a `VariableDeclaration` nor a `ForBinding` nor a `BindingIdentifier`, then
      i. **Assert**: `d` is either a `FunctionDeclaration`, a `GeneratorDeclaration`, an `AsyncFunctionDeclaration`, or an `AsyncGeneratorDeclaration`.
      ii. Let `fn` be the sole element of the BoundNames of `d`.
      iii. If `functionNames` does not contain `fn`, then
          1. Insert `fn` as the first element of `functionNames`.
          2. NOTE: If there are multiple function declarations for the same name, the last declaration is used.
          3. Insert `d` as the first element of `functionsToInitialize`.
   15. Let `argumentsObjectNeeded` be `true`.
   16. If `func`.[[ThisMode]] is LEXICAL, then
      a. NOTE: Arrow functions never have an arguments object.
      b. Set `argumentsObjectNeeded` to `false`.
   17. Else if `parameterNames` contains "arguments", then
      a. Set `argumentsObjectNeeded` to `false`.

NOTE 1 When an execution context is established for evaluating an ECMAScript function a new Function Environment Record is created and bindings for each formal parameter are instantiated in that Environment Record. Each declaration in the function body is also instantiated. If the function’s formal parameters do not include any default value initializers then the body declarations are instantiated in the same Environment Record as the parameters. If default value parameter initializers exist, a second Environment Record is created for the body declarations. Formal parameters and functions are initialized as part of FunctionDeclarationInstantiation. All other bindings are initialized during evaluation of the function body.
18. Else if hasParameterExpressions is false, then
   a. If functionNames contains "arguments" or lexicalNames contains "arguments", then
      i. Set argumentsObjectNeeded to false.
19. If strict is true or hasParameterExpressions is false, then
   a. NOTE: Only a single Environment Record is needed for the parameters, since calls to eval in strict mode code cannot create new bindings which are visible outside of the eval.
   b. Let env be the LexicalEnvironment of calleeContext.
20. Else,
   a. NOTE: A separate Environment Record is needed to ensure that bindings created by direct eval calls in the formal parameter list are outside the environment where parameters are declared.
   b. Let calleeEnv be the LexicalEnvironment of calleeContext.
   c. Let env be NewDeclarativeEnvironment(calleeEnv).
   d. Assert: The VariableEnvironment of calleeContext is calleeEnv.
   e. Set the LexicalEnvironment of calleeContext to env.
21. For each string paramName of parameterNames, do
   a. Let alreadyDeclared be ! env.HasBinding(paramName).
   b. NOTE: Early errors ensure that duplicate parameter names can only occur in non-strict functions that do not have parameter default values or rest parameters.
   c. If alreadyDeclared is false, then
      i. Perform ! env.CreateMutableBinding(paramName, false).
      ii. If hasDuplicates is true, then
          1. Perform ! env.InitializeBinding(paramName, undefined).
22. If argumentsObjectNeeded is true, then
   a. If strict is true or simpleParameterList is false, then
      i. Let ao be CreateUnmappedArgumentsObject(argumentsList).
   b. Else
      i. NOTE: A mapped argument object is only provided for non-strict functions that don't have a rest parameter, any parameter default value initializers, or any destructured parameters.
      ii. Let ao be CreateMappedArgumentsObject(func, formals, argumentsList, env).
   c. If strict is true, then
      ii. NOTE: In strict mode code early errors prevent attempting to assign to this binding, so its mutability is not observable.
   d. Else
   f. Let parameterBindings be the list-concatenation of parameterNames and « "arguments" ».
23. Else,
   a. Let parameterBindings be parameterNames.
24. Let iteratorRecord be CreateListIteratorRecord(argumentsList).
25. If hasDuplicates is true, then
   a. Perform ? IteratorBindingInitialization of formals with arguments iteratorRecord and undefined.
26. Else,
   a. Perform ? IteratorBindingInitialization of formals with arguments iteratorRecord and env.
27. If hasParameterExpressions is false, then
   a. NOTE: Only a single Environment Record is needed for the parameters and top-level vars.
   b. Let instantiatedVarNames be a copy of the List parameterBindings.
   c. For each element n of varNames, do
      i. If instantiatedVarNames does not contain n, then
         1. Append n to instantiatedVarNames.
   d. Let varEnv be env.
28. Else,
   a. NOTE: A separate Environment Record is needed to ensure that closures created by expressions in the formal parameter list do not have visibility of declarations in the function body.
   b. Let varEnv be NewDeclarativeEnvironment(env).
   c. Set the VariableEnvironment of calleeContext to varEnv.
   d. Let instantiatedVarNames be a new empty List.
   e. For each element n of varNames, do
      i. If instantiatedVarNames does not contain n, then
1. Append \( n \) to \( \text{instantiatedVarNames} \).
2. Perform \( \text{varEnv}.\text{CreateMutableBinding}(n, \text{false}) \).
3. If \( \text{parameterBindings} \) does not contain \( n \), or if \( \text{functionNames} \) contains \( n \), then
   a. Let \( \text{initialValue} \) be \( \text{undefined} \).
4. Else,
   a. Let \( \text{initialValue} \) be \( \text{env}.\text{GetBindingValue}(n, \text{false}) \).
5. Perform \( \text{varEnv}.\text{InitializeBinding}(n, \text{initialValue}) \).
6. NOTE: A var with the same name as a formal parameter initially has the same value as the corresponding initialized parameter.

29. NOTE: Annex B.3.2.1 adds additional steps at this point.
30. If \( \text{strict} \) is \( \text{false} \), then
   a. Let \( \text{lexEnv} \) be \( \text{NewDeclarativeEnvironment}(\text{varEnv}) \).
   b. NOTE: Non-strict functions use a separate Environment Record for top-level lexical declarations so that a direct eval can determine whether any var scoped declarations introduced by the eval code conflict with pre-existing top-level lexically scoped declarations. This is not needed for strict functions because a strict direct eval always places all declarations into a new Environment Record.
31. Else,
   a. Let \( \text{lexEnv} \) be \( \text{varEnv} \).
32. Set the LexicalEnvironment of \( \text{calleeContext} \) to \( \text{lexEnv} \).
33. Let \( \text{lexDeclarations} \) be the LexicallyScopedDeclarations of \( \text{code} \).
34. For each element \( d \) of \( \text{lexDeclarations} \), do
   a. NOTE: A lexically declared name cannot be the same as a function/generator declaration, formal parameter, or a var name. Lexically declared names are only instantiated here but not initialized.
   b. For each element \( dn \) of the BoundNames of \( d \), do
      i. If \( \text{IsConstantDeclaration} \) of \( d \) is \( \text{true} \), then
         1. Perform \( \text{lexEnv}.\text{CreateImmutableBinding}(dn, \text{true}) \).
      ii. Else,
         1. Perform \( \text{lexEnv}.\text{CreateMutableBinding}(dn, \text{false}) \).
35. Let \( \text{privateEnv} \) be the PrivateEnvironment of \( \text{calleeContext} \).
36. For each Parse Node \( f \) of \( \text{functionsToInitialize} \), do
   a. Let \( fn \) be the sole element of the BoundNames of \( f \).
   b. Let \( fo \) be \( \text{InstantiateFunctionObject} \) of \( f \) with arguments \( \text{lexEnv} \) and \( \text{privateEnv} \).
   c. Perform \( \text{varEnv}.\text{SetMutableBinding}(fn, fo, \text{false}) \).
37. Return UNUSED.

NOTE 2 B.3.2 provides an extension to the above algorithm that is necessary for backwards compatibility with web browser implementations of ECMAScript that predate ECMAScript 2015.

10.3 Built-in Function Objects

A built-in function object is an ordinary object; it must satisfy the requirements for ordinary objects set out in 10.1.

In addition to the internal slots required of every ordinary object (see 10.1), a built-in function object must also have the following internal slots:

- \([[\text{Realm}]]\), a Realm Record that represents the realm in which the function was created.
- \([[\text{InitialName}]]\), a String that is the initial name of the function. It is used by 20.2.3.5.

The initial value of a built-in function object's \([[\text{Prototype}]]\) internal slot is \%Function.prototype\%, unless otherwise specified.

A built-in function object must have a [[Call]] internal method that conforms to the definition in 10.3.1.

A built-in function object has a [[Construct]] internal method if and only if it is described as a “constructor”, or some algorithm in this specification explicitly sets its [[Construct]] internal method. Such a [[Construct]] internal method must conform to the definition in 10.3.2.

An implementation may provide additional built-in function objects that are not defined in this specification.
10.3.1 [[Call]] (thisArgument, argumentsList)

The [[Call]] internal method of a built-in function object $F$ takes arguments thisArgument (an ECMAScript language value) and argumentsList (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Return ? BuiltinCallOrConstruct($F$, thisArgument, argumentsList, undefined).

10.3.2 [[Construct]] (argumentsList, newTarget)

The [[Construct]] internal method of a built-in function object $F$ (when the method is present) takes arguments argumentsList (a List of ECMAScript language values) and newTarget (a constructor) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Return ? BuiltinCallOrConstruct($F$, UNINITIALIZED, argumentsList, newTarget).

10.3.3 BuiltinCallOrConstruct ($F$, thisArgument, argumentsList, newTarget)

The abstract operation BuiltinCallOrConstruct takes arguments $F$ (a built-in function object), thisArgument (an ECMAScript language value or UNINITIALIZED), argumentsList (a List of ECMAScript language values), and newTarget (a constructor or undefined) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let callerContext be the running execution context.
2. If callerContext is not already suspended, suspend callerContext.
3. Let calleeContext be a new execution context.
4. Set the Function of calleeContext to $F$.
5. Let calleeRealm be $F$.[[Realm]].
6. Set the Realm of calleeContext to calleeRealm.
7. Set the ScriptOrModule of calleeContext to null.
8. Perform any necessary implementation-defined initialization of calleeContext.
9. Push calleeContext onto the execution context stack; calleeContext is now the running execution context.
10. Let result be the Completion Record that is the result of evaluating $F$ in a manner that conforms to the specification of $F$. If thisArgument is UNINITIALIZED, the this value is uninitialized; otherwise, thisArgument provides the this value. argumentsList provides the named parameters. newTarget provides the NewTarget value.
11. NOTE: If $F$ is defined in this document, “the specification of $F$” is the behaviour specified for it via algorithm steps or other means.
12. Remove calleeContext from the execution context stack and restore callerContext as the running execution context.

10.3.4 CreateBuiltinFunction (behaviour, length, name, additionalInternalSlotsList [, realm [, prototype [, prefix ]]])

The abstract operation CreateBuiltinFunction takes arguments behaviour (an Abstract Closure, a set of algorithm steps, or some other definition of a function’s behaviour provided in this specification), length (a non-negative integer or +∞), name (a property key or a Private Name), and additionalInternalSlotsList (a List of names of internal slots) and optional arguments realm (a Realm Record), prototype (an Object or null), and prefix (a String) and returns a function object. additionalInternalSlotsList contains the names of additional internal slots that must
be defined as part of the object. This operation creates a built-in function object. It performs the following steps when called:

1. If `realm` is not present, set `realm` to the current Realm Record.
2. If `prototype` is not present, set `prototype to realm.([Intrinsics]).[%Function.prototype%].
3. Let `internalSlotsList` be a List containing the names of all the internal slots that 10.3 requires for the built-in function object that is about to be created.
4. Append to `internalSlotsList` the elements of `additionalInternalSlotsList`.
5. Let `func` be a new built-in function object that, when called, performs the action described by `behaviour` using the provided arguments as the values of the corresponding parameters specified by `behaviour`. The new function object has internal slots whose names are the elements of `internalSlotsList`, and an `[[InitialName]]` internal slot.
6. Set `func. [[Prototype]]` to `prototype`.
7. Set `func. [[Extensible]]` to `true`.
8. Set `func. [[Realm]]` to `realm`.
9. Set `func. [[InitialName]]` to `null`.
10. Perform `SetFunctionLength(func, length)`.
11. If `prefix` is not present, then
    a. Perform `SetFunctionName(func, name)`.
12. Else,
    a. Perform `SetFunctionName(func, name, prefix)`.
13. Return `func`.

Each built-in function defined in this specification is created by calling the `CreateBuiltInFunction` abstract operation.

### 10.4 Built-in Exotic Object Internal Methods and Slots

This specification defines several kinds of built-in exotic objects. These objects generally behave similar to ordinary objects except for a few specific situations. The following exotic objects use the ordinary object internal methods except where it is explicitly specified otherwise below:

#### 10.4.1 Bound Function Exotic Objects

A bound function exotic object is an exotic object that wraps another function object. A bound function exotic object is callable (it has a `[[Call]]` internal method and may have a `[[Construct]]` internal method). Calling a bound function exotic object generally results in a call of its wrapped function.

An object is a bound function exotic object if its `[[Call]]` and (if applicable) `[[Construct]]` internal methods use the following implementations, and its other essential internal methods use the definitions found in 10.1. These methods are installed in `BoundFunctionCreate`.

Bound function exotic objects do not have the internal slots of ECMAScript function objects listed in Table 30. Instead, they have the internal slots listed in Table 31, in addition to `[[Prototype]]` and `[[Extensible]]`.

#### Table 31: Internal Slots of Bound Function Exotic Objects

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[BoundTargetFunction]]</code></td>
<td>a callable Object</td>
<td>The wrapped function object.</td>
</tr>
<tr>
<td><code>[[BoundThis]]</code></td>
<td>an ECMAScript language value</td>
<td>The value that is always passed as the this value when calling the wrapped function.</td>
</tr>
<tr>
<td><code>[[BoundArguments]]</code></td>
<td>a List of ECMAScript language values</td>
<td>A list of values whose elements are used as the first arguments to any call to the wrapped function.</td>
</tr>
</tbody>
</table>
10.4.1.1 [[Call]] (thisArgument, argumentsList)

The [[Call]] internal method of a bound function exotic object $F$ takes arguments thisArgument (an ECMAScript language value) and argumentsList (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let $target$ be $F$.[[BoundTargetFunction]].
2. Let $boundThis$ be $F$.[[BoundThis]].
3. Let $boundArgs$ be $F$.[[BoundArguments]].
4. Let $args$ be the list-concatenation of $boundArgs$ and argumentsList.
5. Return ? Call($target$, $boundThis$, $args$).

10.4.1.2 [[Construct]] (argumentsList, newTarget)

The [[Construct]] internal method of a bound function exotic object $F$ takes arguments argumentsList (a List of ECMAScript language values) and newTarget (a constructor) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Let $target$ be $F$.[[BoundTargetFunction]].
2. Assert: IsConstructor($target$) is true.
3. Let $boundArgs$ be $F$.[[BoundArguments]].
4. Let $args$ be the list-concatenation of $boundArgs$ and argumentsList.
5. If SameValue($F$, newTarget) is true, set newTarget to $target$.

10.4.1.3 BoundFunctionCreate (targetFunction, boundThis, boundArgs)

The abstract operation BoundFunctionCreate takes arguments targetFunction (a function object), boundThis (an ECMAScript language value), and boundArgs (a List of ECMAScript language values) and returns either a normal completion containing a function object or a throw completion. It is used to specify the creation of new bound function exotic objects. It performs the following steps when called:

1. Let $proto$ be $targetFunction$.[[GetPrototypeOf]]().
2. Let internalSlotsList be the list-concatenation of « [[Prototype]], [[Extensible]] » and the internal slots listed in Table 31.
3. Let $obj$ be MakeBasicObject(internalSlotsList).
4. Set $obj$.[[Prototype]] to $proto$.
5. Set $obj$.[[Call]] as described in 10.4.1.1.
6. If IsConstructor(targetFunction) is true, then
   a. Set $obj$.[[Construct]] as described in 10.4.1.2.
7. Set $obj$.[[BoundTargetFunction]] to targetFunction.
8. Set $obj$.[[BoundThis]] to boundThis.
9. Set $obj$.[[BoundArguments]] to boundArgs.
10. Return $obj$.

10.4.2 Array Exotic Objects

An Array is an exotic object that gives special treatment to array index property keys (see 6.1.7). A property whose property name is an array index is also called an element. Every Array has a non-configurable "length" property whose value is always a non-negative integral Number whose mathematical value is strictly less than $2^{32}$. The value of the "length" property is numerically greater than the name of every own property whose name is an array index; whenever an own property of an Array is created or changed, other properties are adjusted as necessary to maintain this invariant. Specifically, whenever an own property is added whose name is an array index, the value of the "length" property is changed, if necessary, to be one more than the numeric value of that array index; and whenever the value of the "length" property is changed, every own property whose name is an array index whose value is not smaller than the new length is deleted. This constraint applies only to own
properties of an Array and is unaffected by "length" or array index properties that may be inherited from its prototypes.

An object is an Array exotic object (or simply, an Array) if its [[DefineOwnProperty]] internal method uses the following implementation, and its other essential internal methods use the definitions found in 10.1. These methods are installed in ArrayCreate.

10.4.2.1 [[DefineOwnProperty]] ( P, Desc )

The [[DefineOwnProperty]] internal method of an Array exotic object A takes arguments P (a property key) and Desc (a Property Descriptor) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If P is "length", then
2. Else if P is an array index, then
   a. Let lengthDesc be OrdinaryGetOwnProperty(A, "length").
   b. Assert: IsDataDescriptor(lengthDesc) is true.
   c. Assert: lengthDesc.[[Configurable]] is false.
   d. Let length be lengthDesc.[[Value]].
   e. Assert: length is a non-negative integral Number.
   f. Let index be ! ToUint32(P).
   g. If index ≥ length and lengthDesc.[[Writable]] is false, return false.
   h. Let succeeded be ! OrdinaryDefineOwnProperty(A, P, Desc).
   i. If succeeded is false, return false.
   j. If index ≥ length, then
      i. Set lengthDesc.[[Value]] to index + 1𝔽.
      ii. Set succeeded to ! OrdinaryDefineOwnProperty(A, "length", lengthDesc).
      iii. Assert: succeeded is true.
   k. Return true.

10.4.2.2 ArrayCreate ( length [ , proto ] )

The abstract operation ArrayCreate takes argument length (a non-negative integer) and optional argument proto (an Object) and returns either a normal completion containing an Array exotic object or a throw completion. It is used to specify the creation of new Arrays. It performs the following steps when called:

1. If length > 2^{32} - 1, throw a RangeError exception.
2. If proto is not present, set proto to %Array.prototype%.
3. Let A be MakeBasicObject(" [[Prototype]], [[Extensible]] »).
4. Set A.[[Prototype]] to proto.
5. Set A.[[DefineOwnProperty]] as specified in 10.4.2.1.
6. Perform ! OrdinaryDefineOwnProperty(A, "length", PropertyDescriptor { [[Value]]: F(length), [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).
7. Return A.

10.4.2.3 ArraySpeciesCreate ( originalArray, length )

The abstract operation ArraySpeciesCreate takes arguments originalArray (an Object) and length (a non-negative integer) and returns either a normal completion containing an Object or a throw completion. It is used to specify the creation of a new Array or similar object using a constructor function that is derived from originalArray. It does not enforce that the constructor function returns an Array. It performs the following steps when called:

1. Let isArray be ? IsArray(originalArray).
2. If isArray is false, return ? ArrayCreate(length).
3. Let C be ? Get(originalArray, "constructor").
4. If isConstructor(C) is true, then
   a. Let thisRealm be the current Realm Record.
b. Let \( \text{realmC} \) be ? \( \text{GetFunctionRealm}(C) \).

c. If \( \text{thisRealm} \) and \( \text{realmC} \) are not the same \text{Realm Record}, then
   i. If \( \text{SameValue}(C, \text{realmC}.[[\text{Intrinsics}]].[[\%\text{Array}\%]]) \) is \text{true}, set \( C \) to \text{undefined}.

5. If \( C \) is an Object, then
   a. Set \( C \) to ? \( \text{Get}(C, \text{@@species}) \).
   b. If \( C \) is null, set \( C \) to \text{undefined}.

6. If \( C \) is \text{undefined}, return ? \( \text{ArrayCreate}(\text{length}) \).
7. If \( \text{IsConstructor}(C) \) is \text{false}, throw a \text{TypeError} exception.
8. Return ? \( \text{Construct}(C, \text{«} F(\text{length}) \text{»}) \).

\begin{center}
\text{NOTE}
If \( \text{originalArray} \) was created using the standard built-in Array \text{constructor} for a \text{realm} that is not the \text{realm} of the running \text{execution context}, then a new Array is created using the \text{realm} of the running \text{execution context}. This maintains compatibility with Web browsers that have historically had that behaviour for the \text{Array.prototype} \text{methods} that now are defined using ArraySpeciesCreate.
\end{center}

10.4.2.4 \text{ArraySetLength} (\(A, \text{Desc}\))

The abstract operation \text{ArraySetLength} takes arguments \( A \) (an Array) and \( \text{Desc} \) (a \text{PropertyDescriptor}) and returns either a \text{normal completion} containing a \text{Boolean} or a \text{throw completion}. It performs the following steps when called:

1. If \( \text{Desc} \) does not have a \([\text{Value}]\) field, then
   a. Return ! \text{OrdinaryDefineOwnProperty}(A, \text{"length"}, \text{Desc}).

2. Let \( \text{newLenDesc} \) be a copy of \( \text{Desc} \).

3. Let \( \text{newLen} \) be ? \( \text{ToUint32}(\text{Desc}.[[\text{Value}]].) \).

4. Let \( \text{numberLen} \) be ? \( \text{ToNumber}(\text{Desc}.[[\text{Value}]].) \).

5. If \( \text{SameValueZero}(\text{newLen}, \text{numberLen}) \) is \text{false}, throw a \text{RangeError} exception.

6. Set \( \text{newLenDesc}.[[\text{Value}]] \) to \( \text{newLen} \).

7. Let \( \text{oldLenDesc} \) be \text{OrdinaryGetOwnProperty}(A, \text{"length")}.

8. \text{Assert: \text{IsDataDescriptor}(oldLenDesc) is \text{true}}.

9. \text{Assert: oldLenDesc.}[Configurable]] is \text{false}.

10. Let \( \text{oldLen} \) be \( \text{oldLenDesc}.[[\text{Value}]].

11. If \( \text{newLen} \geq \text{oldLen} \), then
    a. Return ! \text{OrdinaryDefineOwnProperty}(A, \text{"length"}, \text{newLenDesc}).

12. If \( \text{oldLenDesc}.[[\text{Writable}]] \) is \text{false}, return \text{false}.

13. If \( \text{newLenDesc} \) does not have a \([\text{Writable}]\) field or \( \text{newLenDesc}.[[\text{Writable}]] \) is \text{true}, then
    a. Set \( \text{newWritable} \) to \text{true}.

14. Else,
    a. \text{NOTE: Setting the \([\text{Writable}]\) attribute to \text{false} is deferred in case any elements cannot be deleted.}
    b. Let \( \text{newWritable} \) be \text{false}.
    c. Set \( \text{newLenDesc}.[[\text{Writable}]] \) to \text{true}.

15. Let \( \text{succeeded} \) be ! \text{OrdinaryDefineOwnProperty}(A, \text{"length"}, \text{newLenDesc}).

16. If \( \text{succeeded} \) is \text{false}, return \text{false}.

17. For each own \text{property} \text{key} \( P \) of \( A \) such that \( P \) is an \text{array index} and ! \( \text{ToUint32}(P) \geq \text{newLen} \), in descending numeric index order, do
    a. Let \( \text{deleteSucceeded} \) be ! \( A.[[\text{Delete}]](P) \).
    b. If \( \text{deleteSucceeded} \) is \text{false}, then
       i. Set \( \text{newLenDesc}.[[\text{Value}]] \) to ! \( \text{ToUint32}(P) + 1 \).
       ii. If \( \text{newWritable} \) is \text{false}, set \( \text{newLenDesc}.[[\text{Writable}]] \) to \text{false}.
       iii. Perform ! \text{OrdinaryDefineOwnProperty}(A, \text{"length"}, \text{newLenDesc}).
       iv. Return \text{false}.

18. If \( \text{newWritable} \) is \text{false}, then
    a. Set \( \text{succeeded} \) to ! \text{OrdinaryDefineOwnProperty}(A, \text{"length"}, \text{PropertyDescriptor} { [[\text{Writable}]]: \text{false} }).
    b. \text{Assert: succeeded} is \text{true}.

19. Return \text{true}.
10.4.3 String Exotic Objects

A String object is an exotic object that encapsulates a String value and exposes virtual integer-indexed data properties corresponding to the individual code unit elements of the String value. String exotic objects always have a data property named "length" whose value is the length of the encapsulated String value. Both the code unit data properties and the "length" property are non-writable and non-configurable.

An object is a String exotic object (or simply, a String object) if its [[GetOwnProperty]], [[DefineOwnProperty]], and [[OwnPropertyKeys]] internal methods use the following implementations, and its other essential internal methods use the definitions found in 10.1. These methods are installed in StringCreate.

String exotic objects have the same internal slots as ordinary objects. They also have a [[StringData]] internal slot.

10.4.3.1 [[GetOwnProperty]] (P)

The [[GetOwnProperty]] internal method of a String exotic object S takes argument P (a property key) and returns a normal completion containing either a Property Descriptor or undefined. It performs the following steps when called:

1. Let desc be OrdinaryGetOwnProperty(S, P).
2. If desc is not undefined, return desc.
3. Return StringGetOwnProperty(S, P).

10.4.3.2 [[DefineOwnProperty]] (P, Desc)

The [[DefineOwnProperty]] internal method of a String exotic object S takes arguments P (a property key) and Desc (a Property Descriptor) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. Let stringDesc be StringGetOwnProperty(S, P).
2. If stringDesc is not undefined, then
   a. Let extensible be S.[[Extensible]].
   b. Return IsCompatiblePropertyDescriptor(extensible, Desc, stringDesc).
3. Return ! OrdinaryDefineOwnProperty(S, P, Desc).

10.4.3.3 [[OwnPropertyKeys]]()

The [[OwnPropertyKeys]] internal method of a String exotic object O takes no arguments and returns a normal completion containing a List of property keys. It performs the following steps when called:

1. Let keys be a new empty List.
2. Let str be O.[[StringData]].
3. Assert: str is a String.
4. Let len be the length of str.
5. For each integer i such that 0 ≤ i < len, in ascending order, do
   a. Append ! ToString(F(i)) to keys.
6. For each own property key P of O such that P is an array index and ! ToIntegerOrInfinity(P) ≥ len, in ascending numeric index order, do
   a. Append P to keys.
7. For each own property key P of O such that P is a String and P is not an array index, in ascending chronological order of property creation, do
   a. Append P to keys.
For each own property key \( P \) of \( O \) such that \( P \) is a Symbol, in ascending chronological order of property creation, do

a. Append \( P \) to \( keys \).

9. Return \( keys \).

### 10.4.3.4 StringCreate ( \( value, prototype \) )

The abstract operation StringCreate takes arguments \( value \) (a String) and \( prototype \) (an Object) and returns a String exotic object. It is used to specify the creation of new String exotic objects. It performs the following steps when called:

1. Let \( S \) be MakeBasicObject (« [[Prototype]], [[Extensible]], [[StringData]] »).
2. Set \( S.\text{[[Prototype]]} \) to \( prototype \).
3. Set \( S.\text{[[StringData]]} \) to \( value \).
4. Set \( S.\text{[[GetOwnProperty]]} \) as specified in 10.4.3.1.
5. Set \( S.\text{[[DefineOwnProperty]]} \) as specified in 10.4.3.2.
6. Set \( S.\text{[[OwnPropertyKeys]]} \) as specified in 10.4.3.3.
7. Let \( length \) be the length of \( value \).
8. Perform \( ! \text{DefinePropertyOrThrow}(S, \text{"length"}, \text{PropertyDescriptor} \{ \text{[[Value]]}: F(length), \text{[[Writable]]}: false, \text{[[Enumerable]]}: false, \text{[[Configurable]]}: false \}) \).
9. Return \( S \).

### 10.4.3.5 StringGetOwnProperty ( \( S, P \) )

The abstract operation StringGetOwnProperty takes arguments \( S \) (an Object that has a [[StringData]] internal slot) and \( P \) (a property key) and returns a Property Descriptor or undefined. It performs the following steps when called:

1. If \( P \) is not a String, return undefined.
2. Let \( index \) be CanonicalNumericIndexString (\( P \)).
3. If \( index \) is undefined, return undefined.
4. If IsIntegralNumber (\( index \)) is false, return undefined.
5. If \( index \) is -\( \mathbb{F} \), return undefined.
6. Let \( str \) be \( S.\text{[[StringData]]} \).
7. Assert: \( str \) is a String.
8. Let \( len \) be the length of \( str \).
9. If \( ℝ(index) < 0 \) or \( len ≤ ℝ(index) \), return undefined.
10. Let \( resultStr \) be the substring of \( str \) from \( ℝ(index) \) to \( ℝ(index) + 1 \).
11. Return the PropertyDescriptor \{ \text{[[Value]]}: resultStr, \text{[[Writable]]}: false, \text{[[Enumerable]]}: true, \text{[[Configurable]]}: false \}.

### 10.4.4 Arguments Exotic Objects

Most ECMAScript functions make an arguments object available to their code. Depending upon the characteristics of the function definition, its arguments object is either an ordinary object or an arguments exotic object. An arguments exotic object is an exotic object whose array index properties map to the formal parameters bindings of an invocation of its associated ECMAScript function.

An object is an arguments exotic object if its internal methods use the following implementations, with the ones not specified here using those found in 10.1. These methods are installed in CreateMappedArgumentsObject.

**NOTE 1** While CreateUnmappedArgumentsObject is grouped into this clause, it creates an ordinary object, not an arguments exotic object.

Arguments exotic objects have the same internal slots as ordinary objects. They also have a [[ParameterMap]] internal slot. Ordinary arguments objects also have a [[ParameterMap]] internal slot whose value is always undefined. For ordinary argument objects the [[ParameterMap]] internal slot is only used by `Object.prototype.toString` (20.1.3.6) to identify them as such.
NOTE 2 The integer-indexed data properties of an arguments exotic object whose numeric name values are less than the number of formal parameters of the corresponding function object initially share their values with the corresponding argument bindings in the function's execution context. This means that changing the property changes the corresponding value of the argument binding and vice-versa. This correspondence is broken if such a property is deleted and then redefined or if the property is changed into an accessor property. If the arguments object is an ordinary object, the values of its properties are simply a copy of the arguments passed to the function and there is no dynamic linkage between the property values and the formal parameter values.

NOTE 3 The ParameterMap object and its property values are used as a device for specifying the arguments object correspondence to argument bindings. The ParameterMap object and the objects that are the values of its properties are not directly observable from ECMAScript code. An ECMAScript implementation does not need to actually create or use such objects to implement the specified semantics.

NOTE 4 Ordinary arguments objects define a non-configurable accessor property named "callee" which throws a TypeError exception on access. The "callee" property has a more specific meaning for arguments exotic objects, which are created only for some class of non-strict functions. The definition of this property in the ordinary variant exists to ensure that it is not defined in any other manner by conforming ECMAScript implementations.

NOTE 5 ECMAScript implementations of arguments exotic objects have historically contained an accessor property named "caller". Prior to ECMAScript 2017, this specification included the definition of a throwing "caller" property on ordinary arguments objects. Since implementations do not contain this extension any longer, ECMAScript 2017 dropped the requirement for a throwing "caller" accessor.

10.4.4.1 [[GetOwnProperty]] (P)

The [[GetOwnProperty]] internal method of an arguments exotic object args takes argument P (a property key) and returns a normal completion containing either a Property Descriptor or undefined. It performs the following steps when called:

1. Let desc be OrdinaryGetOwnProperty(args, P).
2. If desc is undefined, return undefined.
3. Let map be args.[[ParameterMap]].
4. Let isMapped be ! HasOwnProperty(map, P).
5. If isMapped is true, then
   a. Set desc.[[Value]] to ! Get(map, P).
6. Return desc.

10.4.4.2 [[DefineOwnProperty]] (P, Desc)

The [[DefineOwnProperty]] internal method of an arguments exotic object args takes arguments P (a property key) and Desc (a Property Descriptor) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. Let map be args.[[ParameterMap]].
2. Let isMapped be ! HasOwnProperty(map, P).
3. Let newArgDesc be Desc.
4. If isMapped is true and IsDataDescriptor(Desc) is true, then
   a. If Desc does not have a [[Value]] field, Desc has a [[Writable]] field, and Desc.[[Writable]] is false, then
      i. Set newArgDesc to a copy of Desc.
      ii. Set newArgDesc.[[Value]] to ! Get(map, P).
5. Let allowed be ! OrdinaryDefineOwnProperty(args, P, newArgDesc).
6. If allowed is false, return false.
7. If isMapped is true, then
   a. If IsAccessorDescriptor(Desc) is true, then
      i. Perform ! map.[[Delete]](P).
   b. Else,
      i. If Desc has a [[Value]] field, then
         1. Assert: The following Set will succeed, since formal parameters mapped by arguments objects are always writable.
         2. Perform ! Set(map, P, Desc.[[Value]], false).
      ii. If Desc has a [[Writable]] field and Desc.[[Writable]] is false, then
         1. Perform ! map.#[Delete](P).
8. Return true.

10.4.4.3 [[Get]] (P, Receiver)
The [[Get]] internal method of an arguments exotic object args takes arguments P (a property key) and Receiver (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let map be args.#[ParameterMap]]
2. Let isMapped be ! HasOwnProperty(map, P).
3. If isMapped is false, then
4. Else,
   a. Assert: map contains a formal parameter mapping for P.
   b. Return ! Get(map, P).

10.4.4.4 [[Set]] (P, V, Receiver)
The [[Set]] internal method of an arguments exotic object args takes arguments P (a property key), V (an ECMAScript language value), and Receiver (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If SameValue(args, Receiver) is false, then
   a. Let isMapped be false.
2. Else,
   a. Let map be args.#[ParameterMap]]
   b. Let isMapped be ! HasOwnProperty(map, P).
3. If isMapped is true, then
   a. Assert: The following Set will succeed, since formal parameters mapped by arguments objects are always writable.
   b. Perform ! Set(map, P, V, false).

10.4.4.5 [[Delete]] (P)
The [[Delete]] internal method of an arguments exotic object args takes argument P (a property key) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Let map be args.#[ParameterMap]]
2. Let isMapped be ! HasOwnProperty(map, P).
3. Let result be ? OrdinaryDelete(args, P).
4. If result is true and isMapped is true, then
   a. Perform ! map.#[Delete](P).
5. Return result.
10.4.4.6 CreateUnmappedArgumentsObject (argumentsList)

The abstract operation CreateUnmappedArgumentsObject takes argument argumentsList (a List of ECMAScript language values) and returns an ordinary object. It performs the following steps when called:

1. Let len be the number of elements in argumentsList.
2. Let obj be OrdinaryObjectCreate(%Object.prototype%, « [[ParameterMap]] »).
3. Set obj.[[ParameterMap]] to undefined.
4. Perform ! DefinePropertyOrThrow(obj, "length", PropertyDescriptor { [[Value]]: F(len), [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }).
5. Let index be 0.
6. Repeat, while index < len,
   a. Let val be argumentsList[index].
   b. Perform ! CreateDataPropertyOrThrow(obj, !ToString(F(index)), val).
   c. Set index to index + 1.
7. Perform ! DefinePropertyOrThrow(obj, @@iterator, PropertyDescriptor { [[Value]]: %Array.prototype.values%, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }).
8. Perform ! DefinePropertyOrThrow(obj, "callee", PropertyDescriptor { [[Get]]: %ThrowTypeError%, [[Set]]: %ThrowTypeError%, [[Enumerable]]: false, [[Configurable]]: false }).

10.4.4.7 CreateMappedArgumentsObject (func, formals, argumentsList, env)

The abstract operation CreateMappedArgumentsObject takes arguments func (an Object), formals (a Parse Node), argumentsList (a List of ECMAScript language values), and env (an Environment Record) and returns an arguments exotic object. It performs the following steps when called:

1. Assert: formals does not contain a rest parameter, any binding patterns, or any initializers. It may contain duplicate identifiers.
2. Let len be the number of elements in argumentsList.
3. Let obj be MakeBasicObject(« [[Prototype]], [[Extensible]], [[ParameterMap]] »).
4. Set obj.[[GetOwnProperty]] as specified in 10.4.4.1.
5. Set obj.[[DefineOwnProperty]] as specified in 10.4.4.2.
6. Set obj.[[Get]] as specified in 10.4.4.3.
7. Set obj.[[Set]] as specified in 10.4.4.4.
8. Set obj.[[Delete]] as specified in 10.4.4.5.
9. Set obj.[[Prototype]] to %Object.prototype%.
10. Let map be OrdinaryObjectCreate(null).
11. Set obj.[[ParameterMap]] to map.
12. Let parameterNames be the BoundNames of formals.
13. Let numberOfParameters be the number of elements in parameterNames.
14. Let index be 0.
15. Repeat, while index < len,
   a. Let val be argumentsList[index].
   b. Perform ! CreateDataPropertyOrThrow(obj, !ToString(F(index)), val).
   c. Set index to index + 1.
16. Perform ! DefinePropertyOrThrow(obj, "length", PropertyDescriptor { [[Value]]: F(len), [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }).
17. Let mappedNames be a new empty List.
18. Set index to numberOfParameters - 1.
19. Repeat, while index ≥ 0,
   a. Let name be parameterNames[index].
   b. If mappedNames does not contain name, then
      i. Append name to mappedNames.
      ii. If index < len, then
         1. Let g be MakeArgGetter(name, env).
         2. Let p be MakeArgSetter(name, env).
         3. Perform ! map.[[DefineOwnProperty]](« !ToString(F(index)) », PropertyDescriptor { [[Set]]: p, [[Get]]: g, [[Enumerable]]: false, [[Configurable]]: true }).
   c. Set index to index - 1.
20. Perform `DefinePropertyOrThrow(obj, @@iterator, PropertyDescriptor { [[Value]]: %Array.prototype.values%, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }).
21. Perform `DefinePropertyOrThrow(obj, "callee", PropertyDescriptor { [[Value]]: func, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }).
22. Return `obj.

10.4.4.7.1 MakeArgGetter (name, env)

The abstract operation MakeArgGetter takes arguments `name (a String) and `env (an Environment Record) and returns a function object. It creates a built-in function object that when executed returns the value bound for `name in `env. It performs the following steps when called:

1. Let `getterClosure be a new Abstract Closure with no parameters that captures `name and `env and performs the following steps when called:
2. Let `getter be CreateBuiltinFunction(`getterClosure, 0, "", « »).
3. NOTE: `getter is never directly accessible to ECMAScript code.
4. Return `getter.

10.4.4.7.2 MakeArgSetter (name, env)

The abstract operation MakeArgSetter takes arguments `name (a String) and `env (an Environment Record) and returns a function object. It creates a built-in function object that when executed sets the value bound for `name in `env. It performs the following steps when called:

1. Let `setterClosure be a new Abstract Closure with parameters (`value) that captures `name and `env and performs the following steps when called:
   a. Return `env.SetMutableBinding(`name, `value, false).
2. Let `setter be CreateBuiltinFunction(`setterClosure, 1, "", « »).
3. NOTE: `setter is never directly accessible to ECMAScript code.
4. Return `setter.

10.4.5 TypedArray Exotic Objects

A `TypedArray is an exotic object that performs special handling of integer index property keys.

`TypedArrays have the same internal slots as ordinary objects and additionally `[[ViewedArrayBuffer]], `[[ArrayLength]], `[[ByteOffset]], `[[ContentType]], and `[[TypedArrayName]] internal slots.

An object is a `TypedArray if its `[[GetOwnProperty]], `[[HasProperty]], `[[DefineOwnProperty]], `[[Get]], `[[Set]], `[[Delete]], and `[[OwnPropertyKeys]] internal methods use the definitions in this section, and its other essential internal methods use the definitions found in 10.1. These methods are installed by `TypedArrayCreate.

10.4.5.1 `[[GetOwnProperty]] (P)

The `[[GetOwnProperty]] internal method of a `TypedArray `O takes argument `P (a property key) and returns a normal completion containing either a Property Descriptor or undefined. It performs the following steps when called:

1. If `P is a String, then
   a. Let `numericIndex be CanonicalNumericIndexString(`P).
   b. If `numericIndex is not undefined, then
      i. Let `value be `TypedArrayGetElement(`O, `numericIndex).
      ii. If `value is undefined, return undefined.
      iii. Return the PropertyDescriptor { [[Value]]: `value, [[Writable]]: true, [[Enumerable]]: true, [[Configurable]]: true }.
2. Return `OrdinaryGetOwnProperty(`O, `P).
10.4.5.2 [[HasProperty]] (P)

The [[HasProperty]] internal method of a `TypedArray` `O` takes argument `P` (a property key) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If `P` is a String, then
   a. Let `numericIndex` be `CanonicalNumericIndexString(P)`.
   b. If `numericIndex` is not `undefined`, return `IsValidIntegerIndex(O, numericIndex)`.
2. Return `? OrdinaryHasProperty(O, P)`.

10.4.5.3 [[DefineOwnProperty]] (P, Desc)

The [[DefineOwnProperty]] internal method of a `TypedArray` `O` takes arguments `P` (a property key) and `Desc` (a Property Descriptor) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If `P` is a String, then
   a. Let `numericIndex` be `CanonicalNumericIndexString(P)`.
   b. If `numericIndex` is not `undefined`, then
      i. If `IsValidIntegerIndex(O, numericIndex)` is `false`, return `false`.
      ii. If `Desc` has a [[Configurable]] field and `Desc.[[Configurable]]` is `false`, return `false`.
      iii. If `Desc` has an [[Enumerable]] field and `Desc.[[Enumerable]]` is `false`, return `false`.
      iv. If `IsAccessorDescriptor(Desc)` is `true`, return `false`.
      v. If `Desc` has a [[Writable]] field and `Desc.[[Writable]]` is `false`, return `false`.
     vi. If `Desc` has a [[Value]] field, perform `? TypedArraySetElement(O, numericIndex, Desc.[[Value]])`.
    vii. Return `true`.
2. Return `! OrdinaryDefineOwnProperty(O, P, Desc)`.

10.4.5.4 [[Get]] (P, Receiver)

The [[Get]] internal method of a `TypedArray` `O` takes arguments `P` (a property key) and `Receiver` (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. If `P` is a String, then
   a. Let `numericIndex` be `CanonicalNumericIndexString(P)`.
   b. If `numericIndex` is not `undefined`, then
      i. If `SameValue(O, Receiver)` is `true`, then
         1. Perform `? TypedArrayGetElement(O, numericIndex, V)`.
         2. Return `true`.
      ii. If `IsValidIntegerIndex(O, numericIndex)` is `false`, return `true`.

10.4.5.5 [[Set]] (P, V, Receiver)

The [[Set]] internal method of a `TypedArray` `O` takes arguments `P` (a property key), `V` (an ECMAScript language value), and `Receiver` (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If `P` is a String, then
   a. Let `numericIndex` be `CanonicalNumericIndexString(P)`.
   b. If `numericIndex` is not `undefined`, then
      i. If `SameValue(O, Receiver)` is `true`, then
         1. Perform `? TypedArraySetElement(O, numericIndex, V)`.
         2. Return `true`.
      ii. If `IsValidIntegerIndex(O, numericIndex)` is `false`, return `true`.

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10.4.5.6 [[Delete]] (P)

The [[Delete]] internal method of a TypedArray O takes argument P (a property key) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. If P is a String, then
   a. Let numericIndex be CanonicalNumericIndexString(P).
   b. If numericIndex is not undefined, then
      i. If IsValidIntegerIndex(O, numericIndex) is false, return true; else return false.
2. Return ! OrdinaryDelete(O, P).

10.4.5.7 [[OwnPropertyKeys]] ( )

The [[OwnPropertyKeys]] internal method of a TypedArray O takes no arguments and returns a normal completion containing a List of property keys. It performs the following steps when called:

1. Let taRecord be MakeTypedArrayWithBufferWitnessRecord(O, SEQ-CST).
2. Let keys be a new empty List.
3. If IsTypedArrayOutOfBounds(taRecord) is false, then
   a. Let length be TypedArrayLength(taRecord).
   b. For each integer i such that 0 ≤ i < length, in ascending order, do
      i. Append ! ToString𝔽(i)) to keys.
4. For each own property key P of O such that P is a String and P is not an integer index, in ascending chronological order of property creation, do
   a. Append P to keys.
5. For each own property key P of O such that P is a Symbol, in ascending chronological order of property creation, do
   a. Append P to keys.
6. Return keys.

10.4.5.8 TypedArray With Buffer Witness Records

An TypedArray With Buffer Witness Record is a Record value used to encapsulate a TypedArray along with a cached byte length of the viewed buffer. It is used to help ensure there is a single shared memory read event of the byte length data block when the viewed buffer is a growable SharedArrayBuffer.

TypedArray With Buffer Witness Records have the fields listed in Table 32.

Table 32: TypedArray With Buffer Witness Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Object]]</td>
<td>a TypedArray</td>
<td>The TypedArray whose buffer's byte length is loaded.</td>
</tr>
<tr>
<td>[[CachedBufferByteLength]]</td>
<td>a non-negative integer</td>
<td>The byte length of the object's [[ViewedArrayBuffer]] when</td>
</tr>
<tr>
<td></td>
<td>or DETACHED</td>
<td>the Record was created.</td>
</tr>
</tbody>
</table>

10.4.5.9 MakeTypedArrayWithBufferWitnessRecord (obj, order)

The abstract operation MakeTypedArrayWithBufferWitnessRecord takes arguments obj (a TypedArray) and order (SEQ-CST or UNORDERED) and returns a TypedArray With Buffer Witness Record. It performs the following steps when called:

1. Let buffer be obj.[[ViewedArrayBuffer]].
2. If IsDetachedBuffer(buffer) is true, then
   a. Let byteLength be DETACHED.
10.4.5.10 TypedArrayCreate ( prototype )

The abstract operation TypedArrayCreate takes argument prototype (an Object) and returns a TypedArray. It is used to specify the creation of new TypedArrays. It performs the following steps when called:

1. Let internalSlotsList be « [[Prototype]], [[Extensible]], [[ViewedArrayBuffer]], [[TypedArrayName]], [[ContentType]], [[ByteLength]], [[ByteOffset]], [[ArrayLength]] ».
2. Let A be MakeBasicObject(internalSlotsList).
3. Set A.[[GetOwnProperty]] as specified in 10.4.5.4.
4. Set A.[[HasProperty]] as specified in 10.4.5.2.
5. Set A.[[DefineOwnProperty]] as specified in 10.4.5.3.
6. Set A.[[Get]] as specified in 10.4.5.5.
7. Set A.[[Delete]] as specified in 10.4.5.6.
8. Set A.[[OwnPropertyKeys]] as specified in 10.4.5.7.
9. Set A.[[Prototype]] to prototype.
10. Return A.

10.4.5.11 TypedArrayByteLength ( taRecord )

The abstract operation TypedArrayByteLength takes argument taRecord (a TypedArray With Buffer Witness Record) and returns a non-negative integer. It performs the following steps when called:

1. If IsTypedArrayOutOfBounds(taRecord) is true, return 0.
2. Let length be TypedArrayLength(taRecord).
3. If length = 0, return 0.
4. Let O be taRecord.[[Object]].
5. If O.[[ByteLength]] is not AUTO, return O.[[ByteLength]].
6. Let elementSize be TypedArrayElementSize(O).
7. Return length × elementSize.

10.4.5.12 TypedArrayLength ( taRecord )

The abstract operation TypedArrayLength takes argument taRecord (a TypedArray With Buffer Witness Record) and returns a non-negative integer. It performs the following steps when called:

1. Assert: IsTypedArrayOutOfBounds(taRecord) is false.
2. Let O be taRecord.[[Object]].
3. If O.[[ArrayLength]] is not AUTO, return O.[[ArrayLength]].
4. Assert: IsFixedLengthArrayBuffer(O.[[ViewedArrayBuffer]]) is false.
5. Let byteOffset be O.[[ByteOffset]].
6. Let elementSize be TypedArrayElementSize(O).
7. Let byteLength be taRecord.[[CachedBufferByteLength]].
8. Assert: byteLength is not DETACHED.

10.4.5.13 IsTypedArrayOutOfBounds ( taRecord )

The abstract operation IsTypedArrayOutOfBounds takes argument taRecord (a TypedArray With Buffer Witness Record) and returns a Boolean. It checks if any of the object's numeric properties reference a value at an index not contained within the underlying buffer's bounds. It performs the following steps when called:

1. Let O be taRecord.[[Object]].
2. Let bufferByteLength be taRecord.[[CachedBufferByteLength]].
3. Assert: IsDetachedBuffer(O, [ViewedArrayBuffer]) is true if and only if bufferByteLength is DETACHED.
4. If bufferByteLength is DETACHED, return true.
5. Let byteOffsetStart be O, [ByteOffset].
6. If O, [ArrayLength] is AUTO, then
   a. Let byteOffsetEnd be bufferByteLength.
   b. If byteOffsetStart > bufferByteLength or byteOffsetEnd > bufferByteLength, return true.
   Else,
      a. Let elementSize be TypedArrayElementSize(O).
8. Otherwise, let
      a. IsValidIntegerIndex O, [ViewedArrayBuffer], byteOffsetStart, byteOffsetEnd, elementSize, offset, length.
     If IsValidIntegerIndex is false, return undefined.
   Else,
      a. Return GetValueFromBuffer O, [ViewedArrayBuffer], byteOffsetStart, byteOffsetEnd, elementSize, offset.
   b. Let length be TypedArrayLength taRecord.
   c. If R (index) < 0 or R (index) ≥ length, return false.
   d. Return true.

10.4.5.14 IsValidIntegerIndex (O, index)

The abstract operation IsValidIntegerIndex takes arguments O (a TypedArray) and index (a Number) and returns a Boolean. It performs the following steps when called:

1. If IsDetachedBuffer(O, [ViewedArrayBuffer]) is true, return false.
2. If IsIntegralNumber(index) is false, return false.
3. If index is -0F, return false.
4. Let taRecord be MakeTypedArrayWithBufferWitnessRecord(O, UNORDERED).
5. NOTE: Bounds checking is not a synchronizing operation when O's backing buffer is a growable SharedArrayBuffer.
6. If IsTypedArrayOutOfRangeO)(taRecord) is true, return false.
7. Let length be TypedArrayLength(taRecord).
8. If R (index) < 0 or R (index) ≥ length, return false.
9. Return true.

10.4.5.15 TypedArrayGetElement (O, index)

The abstract operation TypedArrayGetElement takes arguments O (a TypedArray) and index (a Number) and returns a Number, a Bigint, or undefined. It performs the following steps when called:

1. If IsValidIntegerIndex(O, index) is false, return undefined.
2. Let offset be O, [ByteOffset].
3. Let elementSize be TypedArrayElementSize(O).
4. Let byteIndexInBuffer be (R (index) × elementSize) + offset.
5. Let elementType be TypedArrayElementType(O).
6. Return GetValueFromBuffer O, [ViewedArrayBuffer], byteIndexInBuffer, elementType, true, UNORDERED).

10.4.5.16 TypedArraySetElement (O, index, value)

The abstract operation TypedArraySetElement takes arguments O (a TypedArray), index (a Number), and value (an ECMAScript language value) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. If O, [ContentType] is BIGINT, let numValue be ? ToBigInt(value).
2. Otherwise, let numValue be ? ToNumber(value).
3. If IsValidIntegerIndex(O, index) is true, then
   a. Let offset be O, [ByteOffset].
   b. Let elementSize be TypedArrayElementSize(O).
   c. Let byteIndexInBuffer be (R (index) × elementSize) + offset.
   d. Let elementType be TypedArrayElementType(O).
   e. Perform SetValueInBuffer O, [ViewedArrayBuffer], byteIndexInBuffer, elementType, numValue, true, UNORDERED).
4. Return UNUSED.
This operation always appears to succeed, but it has no effect when attempting to write past the end of a `TypedArray` or to a `TypedArray` which is backed by a detached ArrayBuffer.

**10.4.5.17 IsArrayBufferViewOutOfBounds ( O )**

The abstract operation IsArrayBufferViewOutOfBounds takes argument `O` (a `TypedArray` or a `DataView`) and returns a Boolean. It checks if either any of a `TypedArray`'s numeric properties or a `DataView` object's methods can reference a value at an index not contained within the underlying data block's bounds. This abstract operation exists as a convenience for upstream specifications. It performs the following steps when called:

1. If `O` has a `[[DataView]]` internal slot, then
   a. Let `viewRecord` be `MakeDataViewWithBufferWitnessRecord(O, SEQ-CST)`.  
   b. Return `IsViewOutOfBounds(viewRecord)`.
2. Let `taRecord` be `MakeTypedArrayWithBufferWitnessRecord(O, SEQ-CST)`.  
3. Return `IsTypedArrayOutOfBounds(taRecord)`.

**10.4.6 Module Namespace Exotic Objects**

A module namespace exotic object is an exotic object that exposes the bindings exported from an ECMAScript Module (See 16.2.3). There is a one-to-one correspondence between the String-keyed own properties of a module namespace exotic object and the binding names exported by the Module. The exported bindings include any bindings that are indirectly exported using `export *` export items. Each String-valued own property key is the `StringValue` of the corresponding exported binding name. These are the only String-keyed properties of a module namespace exotic object. Each such property has the attributes `{ [[Writable]]: true, [[Enumerable]]: true, [[Configurable]]: false }`. Module namespace exotic objects are not extensible.

An object is a module namespace exotic object if its `[[GetPrototypeOf]]`, `[[SetPrototypeOf]]`, `[[IsExtensible]]`, `[[PreventExtensions]]`, `[[GetProperty]]`, `[[DefineOwnProperty]]`, `[[HasProperty]]`, `[[Get]]`, `[[Set]]`, `[[Delete]]`, and `[[OwnPropertyKeys]]` internal methods use the definitions in this section, and its other essential internal methods use the definitions found in 10.1. These methods are installed by ModuleNamespaceCreate.

Module namespace exotic objects have the internal slots defined in Table 33.

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[Module]]</code></td>
<td>a Module Record</td>
<td>The Module Record whose exports this namespace exposes.</td>
</tr>
<tr>
<td><code>[[Exports]]</code></td>
<td>a List of Strings</td>
<td>A List whose elements are the String values of the exported names exposed as own properties of this object. The list is ordered as if an Array of those String values had been sorted using <code>%Array.prototype.sort% using undefined as comparefn.</code></td>
</tr>
</tbody>
</table>

**10.4.6.1 [[GetPrototypeOf]] ( )**

The `[[GetPrototypeOf]]` internal method of a module namespace exotic object takes no arguments and returns a normal completion containing `null`. It performs the following steps when called:

1. Return `null`. 
10.4.6.2 [[SetPrototypeOf]] ( V )

The [[SetPrototypeOf]] internal method of a module namespace exotic object \( O \) takes argument \( V \) (an Object or null) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. Return \(!\) SetImmutablePrototype\( (O, V)\).

10.4.6.3 [[IsExtensible]] ()

The [[IsExtensible]] internal method of a module namespace exotic object takes no arguments and returns a normal completion containing \( \text{false} \). It performs the following steps when called:

1. Return \( \text{false} \).

10.4.6.4 [[PreventExtensions]] ()

The [[PreventExtensions]] internal method of a module namespace exotic object takes no arguments and returns a normal completion containing \( \text{true} \). It performs the following steps when called:

1. Return \( \text{true} \).

10.4.6.5 [[GetOwnProperty]] ( P )

The [[GetOwnProperty]] internal method of a module namespace exotic object \( O \) takes argument \( P \) (a property key) and returns either a normal completion containing either a Property Descriptor or \( \text{undefined} \), or a throw completion. It performs the following steps when called:

1. If \( P \) is a Symbol, return OrdinaryGetOwnProperty\( (O, P)\).
2. Let \( \text{exports} \) be \( O.\text{[[Exports]]} \).
3. If \( \text{exports} \) does not contain \( P \), return \( \text{undefined} \).
4. Let \( \text{value} \) be \( O.\text{[[Get]]}(P, O) \).
5. Return PropertyDescriptor\( (\{[[\text{Value}}]: \text{value}, [[\text{Writable}}]: \text{true}, [[\text{Enumerable}}]: \text{true}, [[\text{Configurable}}]: \text{false} \}) \).

10.4.6.6 [[DefineOwnProperty]] ( P, Desc )

The [[DefineOwnProperty]] internal method of a module namespace exotic object \( O \) takes arguments \( P \) (a property key) and \( \text{Desc} \) (a Property Descriptor) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If \( P \) is a Symbol, return \(!\) OrdinaryDefineOwnProperty\( (O, P, \text{Desc}) \).
2. Let \( \text{current} \) be \( O.\text{[[GetOwnProperty]]}(P) \).
3. If \( \text{current} \) is \( \text{undefined} \), return \( \text{false} \).
4. If \( \text{Desc} \) has a [[Configurable]] field and \( \text{Desc}.\text{[[Configurable]]} \) is \( \text{true} \), return \( \text{false} \).
5. If \( \text{Desc} \) has an [[Enumerable]] field and \( \text{Desc}.\text{[[Enumerable]]} \) is \( \text{false} \), return \( \text{false} \).
6. If IsAccessorDescriptor\( (\text{Desc}) \) is \( \text{true} \), return \( \text{false} \).
7. If \( \text{Desc} \) has a [[Writable]] field and \( \text{Desc}.\text{[[Writable]]} \) is \( \text{false} \), return \( \text{false} \).
8. If \( \text{Desc} \) has a [[Value]] field, return SameValue\( (\text{Desc}.\text{[[Value]]}, \text{current}.\text{[[Value]]}) \).
9. Return \( \text{true} \).

10.4.6.7 [[HasProperty]] ( P )

The [[HasProperty]] internal method of a module namespace exotic object \( O \) takes argument \( P \) (a property key) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. If \( P \) is a Symbol, return \(!\) OrdinaryHasProperty\( (O, P) \).
2. Let \( \text{exports} \) be \( O.\text{[[Exports]]} \).
3. If \( \text{exports} \) contains \( P \), return \( \text{true} \).
4. Return \( \text{false} \).
10.4.6.8 \([\text{Get}]\) (P, Receiver)

The \([\text{Get}]\) internal method of a module namespace exotic object \(O\) takes arguments \(P\) (a property key) and Receiver (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. If \(P\) is a Symbol, then
   a. Return ! OrdinaryGet\((O, P, \text{Receiver})\).
2. Let exports be \(O.\text{[[Exports]]}\).
3. If exports does not contain \(P\), return undefined.
4. Let \(m\) be \(O.\text{[[Module]]}\).
5. Let binding be \(m.\text{ResolveExport}(P)\).
6. Assert: binding is a ResolvedBinding Record.
7. Let targetModule be binding.\([\text{[[Module]]]}\).
8. Assert: targetModule is not undefined.
9. If binding.\([\text{[[BindingName]]]}\) is NAMESPACE, then
   a. Return GetModuleNamespace\((targetModule)\).
10. Let targetEnv be targetModule.\([\text{[[Environment]]]}\).
11. If targetEnv is EMPTY, throw a ReferenceError exception.
12. Return ? targetEnv.\(\text{GetBindingValue(binding.\([\text{[[BindingName]]]}\), true})\).

**NOTE** ResolveExport is side-effect free. Each time this operation is called with a specific exportName, resolveSet pair as arguments it must return the same result. An implementation might choose to pre-compute or cache the ResolveExport results for the \([\text{Exports]}\) of each module namespace exotic object.

10.4.6.9 \([\text{Set}]\) (P, V, Receiver)

The \([\text{Set}]\) internal method of a module namespace exotic object takes arguments \(P\) (a property key), \(V\) (an ECMAScript language value), and Receiver (an ECMAScript language value) and returns a normal completion containing false. It performs the following steps when called:

1. Return false.

10.4.6.10 \([\text{Delete}]\) (P)

The \([\text{Delete}]\) internal method of a module namespace exotic object \(O\) takes argument \(P\) (a property key) and returns a normal completion containing a Boolean. It performs the following steps when called:

1. If \(P\) is a Symbol, then
   a. Return ! OrdinaryDelete\((O, P)\).
2. Let exports be \(O.\text{[[Exports]]}\).
3. If exports contains \(P\), return false.
4. Return true.

10.4.6.11 \([\text{OwnPropertyKeys}]\) ( )

The \([\text{OwnPropertyKeys}]\) internal method of a module namespace exotic object \(O\) takes no arguments and returns a normal completion containing a List of property keys. It performs the following steps when called:

1. Let exports be \(O.\text{[[Exports]]}\).
2. Let symbolKeys be OrdinaryOwnPropertyKeys\((O)\).
3. Return the list-concatenation of exports and symbolKeys.
10.4.6.12 ModuleNamespaceCreate (module, exports)

The abstract operation ModuleNamespaceCreate takes arguments module (a Module Record) and exports (a List of Strings) and returns a module namespace exotic object. It is used to specify the creation of new module namespace exotic objects. It performs the following steps when called:

1. Assert: module.[[Namespace]] is EMPTY.
2. Let internalSlotsList be the internal slots listed in Table 33.
3. Let M be MakeBasicObject(internalSlotsList).
4. Set M's essential internal methods to the definitions specified in 10.4.6.
5. Set M.[[Module]] to module.
6. Let sortedExports be a List whose elements are the elements of exports ordered as if an Array of the same values had been sorted using %Array.prototype.sort% using undefined as comparefn.
7. Set M.[[Exports]] to sortedExports.
8. Create own properties of M corresponding to the definitions in 28.3.
9. Set module.[[Namespace]] to M.
10. Return M.

10.4.7 Immutable Prototype Exotic Objects

An immutable prototype exotic object is an exotic object that has a [[Prototype]] internal slot that will not change once it is initialized.

An object is an immutable prototype exotic object if its [[SetPrototypeOf]] internal method uses the following implementation. (Its other essential internal methods may use any implementation, depending on the specific immutable prototype exotic object in question.)

NOTE Unlike other exotic objects, there is not a dedicated creation abstract operation provided for immutable prototype exotic objects. This is because they are only used by %Object.prototype% and by host environments, and in host environments, the relevant objects are potentially exotic in other ways and thus need their own dedicated creation operation.

10.4.7.1 [[SetPrototypeOf]] (V)

The [[SetPrototypeOf]] internal method of an immutable prototype exotic object O takes argument V (an Object or null) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:


10.4.7.2 SetImmutablePrototype (O, V)

The abstract operation SetImmutablePrototype takes arguments O (an Object) and V (an Object or null) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Let current be ? O.[[GetPrototypeOf]]().
2. If SameValue(V, current) is true, return true.
3. Return false.

10.5 Proxy Object Internal Methods and Internal Slots

A Proxy object is an exotic object whose essential internal methods are partially implemented using ECMAScript code. Every Proxy object has an internal slot called [[ProxyHandler]]. The value of [[ProxyHandler]] is an object, called the proxy's handler object, or null. Methods (see Table 34) of a handler object may be used to augment the implementation for one or more of the Proxy object's internal methods. Every Proxy object also has an internal
slot called [[ProxyTarget]] whose value is either an object or the null value. This object is called the proxy's target object.

An object is a *Proxy exotic object* if its essential internal methods (including [[Call]] and [[Construct]], if applicable) use the definitions in this section. These internal methods are installed in `ProxyCreate`.

### Table 34: Proxy Handler Methods

<table>
<thead>
<tr>
<th>Internal Method</th>
<th>Handler Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[GetPrototypeOf]]</td>
<td><code>getPrototypeOf</code></td>
</tr>
<tr>
<td>[[SetPrototypeOf]]</td>
<td><code>setPrototypeOf</code></td>
</tr>
<tr>
<td>[[IsExtensible]]</td>
<td><code>isExtensible</code></td>
</tr>
<tr>
<td>[[PreventExtensions]]</td>
<td><code>preventExtensions</code></td>
</tr>
<tr>
<td>[[GetOwnProperty]]</td>
<td><code>getOwnPropertyDescriptor</code></td>
</tr>
<tr>
<td>[[DefineOwnProperty]]</td>
<td><code>defineProperty</code></td>
</tr>
<tr>
<td>[[HasProperty]]</td>
<td><code>has</code></td>
</tr>
<tr>
<td>[[Get]]</td>
<td><code>get</code></td>
</tr>
<tr>
<td>[[Set]]</td>
<td><code>set</code></td>
</tr>
<tr>
<td>[[Delete]]</td>
<td><code>deleteProperty</code></td>
</tr>
<tr>
<td>[[OwnPropertyKeys]]</td>
<td><code>ownKeys</code></td>
</tr>
<tr>
<td>[[Call]]</td>
<td><code>apply</code></td>
</tr>
<tr>
<td>[[Construct]]</td>
<td><code>construct</code></td>
</tr>
</tbody>
</table>

When a handler method is called to provide the implementation of a Proxy object internal method, the handler method is passed the proxy's target object as a parameter. A proxy's handler object does not necessarily have a method corresponding to every essential internal method. Invoking an internal method on the proxy results in the invocation of the corresponding internal method on the proxy's target object if the handler object does not have a method corresponding to the internal trap.

The `[[ProxyHandler]]` and `[[ProxyTarget]]` internal slots of a Proxy object are always initialized when the object is created and typically may not be modified. Some Proxy objects are created in a manner that permits them to be subsequently revoked. When a proxy is revoked, its `[[ProxyHandler]]` and `[[ProxyTarget]]` internal slots are set to null causing subsequent invocations of internal methods on that Proxy object to throw a `TypeError` exception.

Because Proxy objects permit the implementation of internal methods to be provided by arbitrary ECMAScript code, it is possible to define a Proxy object whose handler methods violates the invariants defined in 6.1.7.3. Some of the internal method invariants defined in 6.1.7.3 are essential integrity invariants. These invariants are explicitly enforced by the Proxy object internal methods specified in this section. An ECMAScript implementation must be robust in the presence of all possible invariant violations.

In the following algorithm descriptions, assume `O` is an ECMAScript Proxy object, `P` is a property key value, `V` is any ECMAScript language value and `Desc` is a Property Descriptor record.
10.5.1 [[GetPrototypeOf]] ( )

The [[GetPrototypeOf]] internal method of a Proxy exotic object O takes no arguments and returns either a normal completion containing either an Object or null, or a throw completion. It performs the following steps when called:

1. Perform ? ValidateNonRevokedProxy(O).
2. Let target be O.[[ProxyTarget]].
3. Let handler be O.[[ProxyHandler]].
4. Assert: handler is an Object.
5. Let trap be ? GetMethod(handler, "getPrototypeOf").
6. If trap is undefined, then
   a. Return target.[[GetPrototypeOf]].
7. Let handlerProto be ? Call(trap, handler, « target »).
8. If handlerProto is not an Object and handlerProto is not null, throw a TypeError exception.
10. If extensibleTarget is true, return handlerProto.
11. Let targetProto be ? target.[[GetPrototypeOf]].
12. If SameValue(handlerProto, targetProto) is false, throw a TypeError exception.

NOTE [[GetPrototypeOf]] for Proxy objects enforces the following invariants:

- The result of [[GetPrototypeOf]] must be either an Object or null.
- If the target object is not extensible, [[GetPrototypeOf]] applied to the Proxy object must return the same value as [[GetPrototypeOf]] applied to the Proxy object's target object.

10.5.2 [[SetPrototypeOf]] ( V )

The [[SetPrototypeOf]] internal method of a Proxy exotic object O takes argument V (an Object or null) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Perform ? ValidateNonRevokedProxy(O).
2. Let target be O.[[ProxyTarget]].
3. Let handler be O.[[ProxyHandler]].
4. Assert: handler is an Object.
5. Let trap be ? GetMethod(handler, "setPrototypeOf").
6. If trap is undefined, then
7. Let booleanTrapResult be ToBoolean(? Call(trap, handler, « target, V »)).
8. If booleanTrapResult is false, return false.
10. If extensibleTarget is true, return true.
11. Let targetProto be ? target.[[GetPrototypeOf]].
12. If SameValue(V, targetProto) is false, throw a TypeError exception.
13. Return true.

NOTE [[SetPrototypeOf]] for Proxy objects enforces the following invariants:

- The result of [[SetPrototypeOf]] is a Boolean value.
- If the target object is not extensible, the argument value must be the same as the result of [[GetPrototypeOf]] applied to target object.
10.5.3 `[[IsExtensible]]` ( )

The `[[IsExtensible]]` internal method of a Proxy exotic object `O` takes no arguments and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Perform `? ValidateNonRevokedProxy(O)`. 
2. Let `target` be `O.[[ProxyTarget]]`. 
3. Let `handler` be `O.[[ProxyHandler]]`. 
4. Assert: `handler` is an Object. 
5. Let `trap` be `getMethod(handler, "isExtensible")`. 
6. If `trap` is `undefined`, then
   a. Return `IsExtensible(target)`. 
7. Let `booleanTrapResult` be `ToBoolean(? Call(trap, handler, « target »))`. 
8. Let `targetResult` be `IsExtensible(target)`. 
9. If `booleanTrapResult` is not `targetResult`, throw a TypeError exception. 
10. Return `booleanTrapResult`. 

**NOTE** `[[IsExtensible]]` for Proxy objects enforces the following invariants:

- The result of `[[IsExtensible]]` is a Boolean value.
- `[[IsExtensible]]` applied to the Proxy object must return the same value as `[[IsExtensible]]` applied to the Proxy object's target object with the same argument.

10.5.4 `[[PreventExtensions]]` ( )

The `[[PreventExtensions]]` internal method of a Proxy exotic object `O` takes no arguments and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Perform `? ValidateNonRevokedProxy(O)`. 
2. Let `target` be `O.[[ProxyTarget]]`. 
3. Let `handler` be `O.[[ProxyHandler]]`. 
4. Assert: `handler` is an Object. 
5. Let `trap` be `getMethod(handler, "preventExtensions")`. 
6. If `trap` is `undefined`, then
   a. Return `target.([[PreventExtensions]]())`. 
7. Let `booleanTrapResult` be `ToBoolean(? Call(trap, handler, « target »))`. 
8. If `booleanTrapResult` is `true`, then
   a. Let `extensibleTarget` be `IsExtensible(target)`. 
   b. If `extensibleTarget` is `true`, throw a TypeError exception. 
9. Return `booleanTrapResult`. 

**NOTE** `[[PreventExtensions]]` for Proxy objects enforces the following invariants:

- The result of `[[PreventExtensions]]` is a Boolean value.
- `[[PreventExtensions]]` applied to the Proxy object only returns `true` if `[[IsExtensible]]` applied to the Proxy object's target object is `false`.

10.5.5 `[[GetOwnProperty]]` ( `P` )

The `[[GetOwnProperty]]` internal method of a Proxy exotic object `O` takes argument `P` (a property key) and returns either a normal completion containing either a Property Descriptor or undefined, or a throw completion. It performs the following steps when called:

1. Perform `? ValidateNonRevokedProxy(O)`. 
2. Let `target` be `O.[[ProxyTarget]]`. 

3. Let `handler` be `O.([[ProxyHandler]])`.
4. Assert: `handler` is an Object.
5. Let `trap` be `GetMethod(handler, "getOwnPropertyDescriptor")`.
6. If `trap` is `undefined`, then
   a. Return `target.([[GetOwnProperty]])(P)`.
7. Let `trapResultObj` be `Call(trap, handler, « target, P »)`.
8. If `trapResultObj` is not an Object and `trapResultObj` is not `undefined`, throw a `TypeError` exception.
9. Let `targetDesc` be `target.([[GetOwnProperty]])(P)`.
10. If `trapResultObj` is `undefined`, then
    a. If `targetDesc` is `undefined`, return `undefined`.
    b. If `targetDesc.([[Configurable]])` is `false`, throw a `TypeError` exception.
    c. Let `extensibleTarget` be `IsExtensible(target)`.
    d. If `extensibleTarget` is `false`, throw a `TypeError` exception.
    e. Return `undefined`.
11. Let `extensibleTarget` be `IsExtensible(target)`.
12. Let `resultDesc` be `ToPropertyDescriptor(trapResultObj)`.
13. Perform `CompletePropertyDescriptor(resultDesc)`.
14. Let `valid` be `IsCompatiblePropertyDescriptor(extensibleTarget, resultDesc, targetDesc)`.
15. If `valid` is `false`, throw a `TypeError` exception.
16. If `resultDesc.([[Configurable]])` is `false`, then
    a. If `targetDesc` is `undefined` or `targetDesc.([[Configurable]])` is `true`, then
       i. Throw a `TypeError` exception.
    b. If `resultDesc` has a `[[Writable]]` field and `resultDesc.([[Writable]])` is `false`, then
       i. Assert: `targetDesc` has a `[[Writable]]` field.
       ii. If `targetDesc.([[Writable]])` is `true`, throw a `TypeError` exception.
17. Return `resultDesc`.

NOTE
[[GetOwnProperty]] for Proxy objects enforces the following invariants:

- The result of `[[GetOwnProperty]]` must be either an Object or `undefined`.
- A property cannot be reported as non-existent, if it exists as a non-configurable own property of the target object.
- A property cannot be reported as non-existent, if it exists as an own property of a non-extensible target object.
- A property cannot be reported as existent, if it does not exist as an own property of the target object and the target object is not extensible.
- A property cannot be reported as non-configurable, unless it exists as a non-configurable own property of the target object.
- A property cannot be reported as both non-configurable and non-writable, unless it exists as a non-configurable, non-writable own property of the target object.

10.5.6 [[DefineOwnProperty]] ( P, Desc )

The `[[DefineOwnProperty]]` internal method of a `Proxy exotic object O` takes arguments `P` (a property key) and `Desc` (a `PropertyDescriptor`) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Perform ? `ValidateNonRevokedProxy(O)`.
2. Let `target` be `O.([[ProxyTarget]])`.
3. Let `handler` be `O.([[ProxyHandler]])`.
4. Assert: `handler` is an Object.
5. Let `trap` be `GetMethod(handler, "defineProperty")`.
6. If `trap` is `undefined`, then
   a. Return `target.([[DefineOwnProperty]])(P, Desc)`.
7. Let `descObj` be `FromPropertyDescriptor(Desc)`.
8. Let `booleanTrapResult` be `ToBoolean(Call(trap, handler, « target, P, descObj »))`.
9. If `booleanTrapResult` is `false`, return `false`.
10. Let `targetDesc` be `target.([[GetOwnProperty]])(P)`.
12. If Desc has a [[Configurable]] field and Desc. [[Configurable]] is false, then
   a. Let settingConfigFalse be true.
13. Else,
   a. Let settingConfigFalse be false.
14. If targetDesc is undefined, then
   a. If extensibleTarget is false, throw a TypeError exception.
   b. If settingConfigFalse is true, throw a TypeError exception.
15. Else,
   a. If IsCompatiblePropertyDescriptor(extensibleTarget, Desc, targetDesc) is false, throw a TypeError exception.
   b. If settingConfigFalse is true and targetDesc. [[Configurable]] is true, throw a TypeError exception.
   c. If IsDataDescriptor(targetDesc) is true, targetDesc. [[Configurable]] is false, and targetDesc. [[Writable]] is true, then
      i. If Desc has a [[Writable]] field and Desc. [[Writable]] is false, throw a TypeError exception.
16. Return true.

**NOTE**
[[DefineOwnProperty]] for Proxy objects enforces the following invariants:

- The result of [[DefineOwnProperty]] is a Boolean value.
- A property cannot be added, if the target object is not extensible.
- A property cannot be non-configurable, unless there exists a corresponding non-configurable own property of the target object.
- A non-configurable property cannot be non-writable, unless there exists a corresponding non-configurable, non-writable own property of the target object.
- If a property has a corresponding target object property then applying the Property Descriptor of the property to the target object using [[DefineOwnProperty]] will not throw an exception.

10.5.7 [[HasProperty]](P)

The [[HasProperty]] internal method of a Proxy exotic object O takes argument P (a property key) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Perform ? ValidateNonRevokedProxy(O).
2. Let target be O. [[ProxyTarget]].
3. Let handler be O. [[ProxyHandler]].
4. Assert: handler is an Object.
5. Let trap be ? GetMethod(handler, "has").
6. If trap is undefined, then
7. Let booleanTrapResult be ToBoolean(? Call(trap, handler, « target, P »)).
8. If booleanTrapResult is false, then
   b. If targetDesc is not undefined, then
      i. If targetDesc. [[Configurable]] is false, throw a TypeError exception.
      ii. Let extensibleTarget be ? IsExtensible(target).
      iii. If extensibleTarget is false, throw a TypeError exception.
9. Return booleanTrapResult.
NOTE

[[HasProperty]] for Proxy objects enforces the following invariants:

- The result of [[HasProperty]] is a Boolean value.
- A property cannot be reported as non-existent, if it exists as a non-configurable own property of the target object.
- A property cannot be reported as non-existent, if it exists as an own property of the target object and the target object is not extensible.

10.5.8  [[Get]] (P, Receiver)

The [[Get]] internal method of a Proxy exotic object O takes arguments P (a property key) and Receiver (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Perform ? ValidateNonRevokedProxy(O).
2. Let target be O.[[ProxyTarget]].
3. Let handler be O.[[ProxyHandler]].
4. Assert: handler is an Object.
5. Let trap be ? GetMethod(handler, "get").
6. If trap is undefined, then
7. Let trapResult be ? Call(trap, handler, « target, P, Receiver »).
9. If targetDesc is not undefined and targetDesc.[[Configurable]] is false, then
   a. If IsDataDescriptor(targetDesc) is true and targetDesc.[[Writable]] is false, then
      i. If SameValue(trapResult, targetDesc.[[Value]]) is false, throw a TypeError exception.
   b. If IsAccessorDescriptor(targetDesc) is true and targetDesc.[[Get]] is undefined, then
      i. If trapResult is not undefined, throw a TypeError exception.
10. Return trapResult.

NOTE

[[Get]] for Proxy objects enforces the following invariants:

- The value reported for a property must be the same as the value of the corresponding target object property if the target object property is a non-writable, non-configurable own data property.
- The value reported for a property must be undefined if the corresponding target object property is a non-configurable own accessor property that has undefined as its [[Get]] attribute.

10.5.9  [[Set]] (P, V, Receiver)

The [[Set]] internal method of a Proxy exotic object O takes arguments P (a property key), V (an ECMAScript language value), and Receiver (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. Perform ? ValidateNonRevokedProxy(O).
2. Let target be O.[[ProxyTarget]].
3. Let handler be O.[[ProxyHandler]].
4. Assert: handler is an Object.
5. Let trap be ? GetMethod(handler, "set").
6. If trap is undefined, then
7. Let booleanTrapResult be ToBoolean(? Call(trap, handler, « target, P, V, Receiver »)).
8. If booleanTrapResult is false, return false.
10. If targetDesc is not undefined and targetDesc.[[Configurable]] is false, then
a. If `IsDataDescriptor(targetDesc)` is `true` and `targetDesc.[[Writable]]` is `false`, then
   i. If `SameValue(V, targetDesc.[[Value]])` is `false`, throw a `TypeError` exception.

b. If `IsAccessorDescriptor(targetDesc)` is `true`, then
   i. If `targetDesc.[[Set]]` is `undefined`, throw a `TypeError` exception.

11. Return `true`.

**NOTE**

`[[Set]]` for Proxy objects enforces the following invariants:

- The result of `[[Set]]` is a Boolean value.
- Cannot change the value of a property to be different from the value of the corresponding target object property if the corresponding target object property is a non-writable, non-configurable own data property.
- Cannot set the value of a property if the corresponding target object property is a non-configurable own accessor property that has `undefined` as its `[[Set]]` attribute.

10.5.10 `[[Delete]] ( P )`

The `[[Delete]]` internal method of a `Proxy` exotic object `O` takes argument `P` (a property key) and returns either a normal completion containing a `Boolean` or a throw completion. It performs the following steps when called:

1. Perform `? ValidateNonRevokedProxy(O)`.
2. Let `target` be `O.[[ProxyTarget]]`.
3. Let `handler` be `O.[[ProxyHandler]]`.
4. Assert: `handler` is an `Object`.
5. Let `trap` be `? GetMethod(handler, "deleteProperty")`.
6. If `trap` is `undefined`, then
   a. Return `target.[[Delete]]([P])`.
7. Let `booleanTrapResult` be `ToBoolean(? Call(trap, handler, « target, P »))`.
8. If `booleanTrapResult` is `false`, return `false`.
10. If `targetDesc` is `undefined`, return `true`.
11. If `targetDesc.[[Configurable]]` is `false`, throw a `TypeError` exception.
12. Let `extensibleTarget` be `? IsExtensible(target)`.
13. If `extensibleTarget` is `false`, throw a `TypeError` exception.

**NOTE**

`[[Delete]]` for Proxy objects enforces the following invariants:

- The result of `[[Delete]]` is a `Boolean` value.
- A property cannot be reported as deleted, if it exists as a non-configurable own property of the target object.
- A property cannot be reported as deleted, if it exists as an own property of the target object and the target object is non-extensible.

10.5.11 `[[OwnPropertyKeys]] ( )`

The `[[OwnPropertyKeys]]` internal method of a `Proxy` exotic object `O` takes no arguments and returns either a normal completion containing a List of `property keys` or a throw completion. It performs the following steps when called:

1. Perform `? ValidateNonRevokedProxy(O)`.
2. Let `target` be `O.[[ProxyTarget]]`.
3. Let `handler` be `O.[[ProxyHandler]]`.
4. Assert: `handler` is an `Object`.
5. Let `trap` be `? GetMethod(handler, "ownKeys")`.
6. If `trap` is `undefined`, then
   a. Return ? `target`.[[OwnPropertyKeys]]().
7. Let `trapResultArray` be ? `Call(trap, handler, « target »)`.
8. Let `trapResult` be ? `CreateListFromArrayLike(trapResultArray, « String, Symbol »)`.
9. If `trapResult` contains any duplicate entries, throw a `TypeError` exception.
10. Let `extensibleTarget` be ? `IsExtensible(target)`.
11. Let `targetKeys` be ? `target`.[[OwnPropertyKeys]]().
12. Assert: `targetKeys` is a List of property keys.
14. Let `targetConfigurableKeys` be a new empty List.
15. Let `targetNonconfigurableKeys` be a new empty List.
16. For each element `key` of `targetKeys`, do
   a. Let `desc` be ? `target`.[[GetOwnProperty]](`key`).
   b. If `desc` is not `undefined` and `desc`.[[Configurable]] is `false`, then
      i. Append `key` to `targetNonconfigurableKeys`.
   c. Else,
      i. Append `key` to `targetConfigurableKeys`.
17. If `extensibleTarget` is `true` and `targetNonconfigurableKeys` is empty, then
   a. Return `trapResult`.
18. Let `uncheckedResultKeys` be a List whose elements are the elements of `trapResult`.
19. For each element `key` of `targetNonconfigurableKeys`, do
   a. If `uncheckedResultKeys` does not contain `key`, throw a `TypeError` exception.
   b. Remove `key` from `uncheckedResultKeys`.
20. If `extensibleTarget` is `true`, return `trapResult`.
21. For each element `key` of `targetConfigurableKeys`, do
   a. If `uncheckedResultKeys` does not contain `key`, throw a `TypeError` exception.
   b. Remove `key` from `uncheckedResultKeys`.
22. If `uncheckedResultKeys` is not empty, throw a `TypeError` exception.
23. Return `trapResult`.

NOTE [[OwnPropertyKeys]] for Proxy objects enforces the following invariants:

- The result of [[OwnPropertyKeys]] is a List.
- The returned List contains no duplicate entries.
- The Type of each result List element is either String or Symbol.
- The result List must contain the keys of all non-configurable own properties of the target object.
- If the target object is not extensible, then the result List must contain all the keys of the own properties of the target object and no other values.

10.5.12 [[Call]] ( thisArgument, argumentsList )

The [[Call]] internal method of a Proxy exotic object `O` takes arguments `thisArgument` (an ECMAScript language value) and `argumentsList` (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Perform ? `ValidateNonRevokedProxy(O)`.
2. Let `target` be `O`.[[ProxyTarget]].
3. Let `handler` be `O`.[[ProxyHandler]].
4. Assert: `handler` is an Object.
5. Let `trap` be ? `GetMethod(handler, "apply")`.
6. If `trap` is `undefined`, then
   a. Return ? `Call(target, thisArgument, argumentsList)`.
7. Let `argArray` be `CreateArrayFromList(argumentsList)`.
8. Return ? `Call(trap, handler, ´target, thisArgument, argArray ´)`.

NOTE A Proxy exotic object only has a [[Call]] internal method if the initial value of its [[ProxyTarget]]
internal slot is an object that has a [[Call]] internal method.
10.5.13 [[Construct]] (argumentsList, newTarget)

The [[Construct]] internal method of a Proxy exotic object \( O \) takes arguments \( \text{argumentsList} \) (a List of ECMAScript language values) and \( \text{newTarget} \) (a constructor) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Perform ? ValidateNonRevokedProxy\((O)\).
2. Let \( \text{target} \) be \( O.[[\text{ProxyTarget}]] \).
3. Assert: IsConstructor\((\text{target})\) is true.
4. Let \( \text{handler} \) be \( O.[[\text{ProxyHandler}]] \).
5. Assert: \( \text{handler} \) is an Object.
6. Let \( \text{trap} \) be ? GetMethod\((\text{handler}, \text{"construct"})\).
7. If \( \text{trap} \) is undefined, then
   a. Return ? Construct\((\text{target}, \text{argumentsList}, \text{newTarget})\).
8. Let \( \text{argArray} \) be CreateArrayFromList\((\text{argumentsList})\).
9. Let \( \text{newObj} \) be ? Call\((\text{trap}, \text{handler}, \text{"target, argArray, newTarget"})\).
10. If \( \text{newObj} \) is not an Object, throw a TypeError exception.
11. Return \( \text{newObj} \).

**NOTE 1** A Proxy exotic object only has a [[Construct]] internal method if the initial value of its [[ProxyTarget]] internal slot is an object that has a [[Construct]] internal method.

**NOTE 2** [[Construct]] for Proxy objects enforces the following invariants:

- The result of [[Construct]] must be an Object.

10.5.14 ValidateNonRevokedProxy (proxy)

The abstract operation ValidateNonRevokedProxy takes argument \( proxy \) (a Proxy exotic object) and returns either a normal completion containing UNUSED or a throw completion. It throws a TypeError exception if \( proxy \) has been revoked. It performs the following steps when called:

1. If \( proxy.[[\text{ProxyTarget}]] \) is null, throw a TypeError exception.
2. Assert: \( proxy.[[\text{ProxyHandler}]] \) is not null.
3. Return UNUSED.

10.5.15 ProxyCreate (target, handler)

The abstract operation ProxyCreate takes arguments \( target \) (an ECMAScript language value) and \( handler \) (an ECMAScript language value) and returns either a normal completion containing a Proxy exotic object or a throw completion. It is used to specify the creation of new Proxy objects. It performs the following steps when called:

1. If \( target \) is not an Object, throw a TypeError exception.
2. If \( handler \) is not an Object, throw a TypeError exception.
3. Let \( P \) be MakeBasicObject\(\langle [[\text{ProxyHandler}}], [[\text{ProxyTarget}}] \rangle\).
4. Set \( P \)’s essential internal methods, except for [[Call]] and [[Construct]], to the definitions specified in 10.5.
5. If IsCallable\((target)\) is true, then
   a. Set \( P.[[\text{Call}}] \) as specified in 10.5.12.
   b. If IsConstructor\((target)\) is true, then
      i. Set \( P.[[\text{Construct}}] \) as specified in 10.5.13.
6. Set \( P.[[\text{ProxyTarget}}] \) to \( target \).
7. Set \( P.[[\text{ProxyHandler}}] \) to \( handler \).
8. Return \( P \).
11 ECMAScript Language: Source Text

11.1 Source Text

Syntax

SourceCharacter ::=
  any Unicode code point

ECMAScript source text is a sequence of Unicode code points. All Unicode code point values from U+0000 to U+10FFFF, including surrogate code points, may occur in ECMAScript source text where permitted by the ECMA-Script grammars. The actual encodings used to store and interchange ECMAScript source text is not relevant to this specification. Regardless of the external source text encoding, a conforming ECMAScript implementation processes the source text as if it was an equivalent sequence of SourceCharacter values, each SourceCharacter being a Unicode code point. Conforming ECMAScript implementations are not required to perform any normalization of source text, or behave as though they were performing normalization of source text.

The components of a combining character sequence are treated as individual Unicode code points even though a user might think of the whole sequence as a single character.

NOTE In string literals, regular expression literals, template literals and identifiers, any Unicode code point may also be expressed using Unicode escape sequences that explicitly express a code point's numeric value. Within a comment, such an escape sequence is effectively ignored as part of the comment.

ECMAScript differs from the Java programming language in the behaviour of Unicode escape sequences. In a Java program, if the Unicode escape sequence \u000A, for example, occurs within a single-line comment, it is interpreted as a line terminator (Unicode code point U+000A is LINE FEED (LF)) and therefore the next code point is not part of the comment. Similarly, if the Unicode escape sequence \u000A occurs within a string literal in a Java program, it is likewise interpreted as a line terminator, which is not allowed within a string literal—one must write \n instead of \u000A to cause a LINE FEED (LF) to be part of the String value of a string literal. In an ECMAScript program, a Unicode escape sequence occurring within a comment is never interpreted and therefore cannot contribute to termination of the comment. Similarly, a Unicode escape sequence occurring within a string literal in an ECMAScript program always contributes to the literal and is never interpreted as a line terminator or as a code point that might terminate the string literal.

11.1.1 Static Semantics: UTF16EncodeCodePoint (cp)

The abstract operation UTF16EncodeCodePoint takes argument cp (a Unicode code point) and returns a String. It performs the following steps when called:

1. Assert: 0 ≤ cp ≤ 0x10FFFF.
2. If cp ≤ 0xFFFF, return the String value consisting of the code unit whose numeric value is cp.
3. Let cu₁ be the code unit whose numeric value is floor((cp - 0x10000) / 0x400) + 0xD800.
4. Let cu₂ be the code unit whose numeric value is ((cp - 0x10000) modulo 0x400) + 0xDC00.
5. Return the string-concatenation of cu₁ and cu₂.
11.1.2 Static Semantics: CodePointsToString (text)

The abstract operation CodePointsToString takes argument text (a sequence of Unicode code points) and returns a String. It converts text into a String value, as described in 6.1.4. It performs the following steps when called:

1. Let result be the empty String.
2. For each code point cp of text, do
   a. Set result to the string-concatenation of result and UTF16EncodeCodePoint(cp).
3. Return result.

11.1.3 Static Semantics: UTF16SurrogatePairToCodePoint (lead, trail)

The abstract operation UTF16SurrogatePairToCodePoint takes arguments lead (a code unit) and trail (a code unit) and returns a code point. Two code units that form a UTF-16 surrogate pair are converted to a code point. It performs the following steps when called:

1. Assert: lead is a leading surrogate and trail is a trailing surrogate.
2. Let cp be (lead - 0xD800) × 0x400 + (trail - 0xDC00) + 0x10000.
3. Return the code point cp.

11.1.4 Static Semantics: CodePointAt (string, position)

The abstract operation CodePointAt takes arguments string (a String) and position (a non-negative integer) and returns a Record with fields [[CodePoint]], [[CodeUnitCount]], and [[IsUnpairedSurrogate]] (a Boolean). It interprets string as a sequence of UTF-16 encoded code points, as described in 6.1.4, and reads from it a single code point starting with the code unit at index position. It performs the following steps when called:

1. Let size be the length of string.
2. Assert: position ≥ 0 and position < size.
3. Let first be the code unit at index position within string.
4. Let cp be the code point whose numeric value is the numeric value of first.
5. If first is neither a leading surrogate nor a trailing surrogate, then
   a. Return the Record { [[CodePoint]]: cp, [[CodeUnitCount]]: 1, [[IsUnpairedSurrogate]]: false }
6. If first is a trailing surrogate or position + 1 = size, then
   a. Return the Record { [[CodePoint]]: cp, [[CodeUnitCount]]: 1, [[IsUnpairedSurrogate]]: true }
7. Let second be the code unit at index position + 1 within string.
8. If second is not a trailing surrogate, then
   a. Return the Record { [[CodePoint]]: cp, [[CodeUnitCount]]: 1, [[IsUnpairedSurrogate]]: true }
9. Set cp to UTF16SurrogatePairToCodePoint(first, second).
10. Return the Record { [[CodePoint]]: cp, [[CodeUnitCount]]: 2, [[IsUnpairedSurrogate]]: false }

11.1.5 Static Semantics: StringToCodePoints (string)

The abstract operation StringToCodePoints takes argument string (a String) and returns a List of code points. It returns the sequence of Unicode code points that results from interpreting string as UTF-16 encoded Unicode text as described in 6.1.4. It performs the following steps when called:

1. Let codePoints be a new empty List.
2. Let size be the length of string.
3. Let position be 0.
4. Repeat, while position < size,
   a. Let cp be CodePointAt(string, position).
   b. Append cp,[[CodePoint]] to codePoints.
   c. Set position to position + cp,[[CodeUnitCount]].
5. Return codePoints.
11.1.6 Static Semantics: ParseText (sourceText, goalSymbol)

The abstract operation ParseText takes arguments sourceText (a sequence of Unicode code points) and goalSymbol (a nonterminal in one of the ECMAScript grammars) and returns a Parse Node or a non-empty List of SyntaxError objects. It performs the following steps when called:

1. Attempt to parse sourceText using goalSymbol as the goal symbol, and analyse the parse result for any early error conditions. Parsing and early error detection may be interleaved in an implementation-defined manner.
2. If the parse succeeded and no early errors were found, return the Parse Node (an instance of goalSymbol) at the root of the parse tree resulting from the parse.
3. Otherwise, return a List of one or more SyntaxError objects representing the parsing errors and/or early errors. If more than one parsing error or early error is present, the number and ordering of error objects in the list is implementation-defined, but at least one must be present.

NOTE 1 Consider a text that has an early error at a particular point, and also a syntax error at a later point. An implementation that does a parse pass followed by an early errors pass might report the syntax error and not proceed to the early errors pass. An implementation that interleaves the two activities might report the early error and not proceed to find the syntax error. A third implementation might report both errors. All of these behaviours are conformant.

NOTE 2 See also clause 17.

11.2 Types of Source Code

There are four types of ECMAScript code:

- **Global code** is source text that is treated as an ECMAScript Script. The global code of a particular Script does not include any source text that is parsed as part of a FunctionDeclaration, FunctionExpression, GeneratorDeclaration, GeneratorExpression, AsyncFunctionDeclaration, AsyncFunctionExpression, AsyncGeneratorDeclaration, AsyncGeneratorExpression, MethodDefinition, ArrowFunction, AsyncArrowFunction, ClassDeclaration, or ClassExpression.

- **Eval code** is the source text supplied to the built-in eval function. More precisely, if the parameter to the built-in eval function is a String, it is treated as an ECMAScript Script. The eval code for a particular invocation of eval is the global code portion of that Script.

- **Function code** is source text that is parsed to supply the value of the [[ECMAScriptCode]] and [[FormalParameters]] internal slots (see 10.2) of an ECMAScript function object. The function code of a particular ECMAScript function does not include any source text that is parsed as the function code of a nested FunctionDeclaration, FunctionExpression, GeneratorDeclaration, GeneratorExpression, AsyncFunctionDeclaration, AsyncFunctionExpression, AsyncGeneratorDeclaration, AsyncGeneratorExpression, MethodDefinition, ArrowFunction, AsyncArrowFunction, ClassDeclaration, or ClassExpression.

In addition, if the source text referred to above is parsed as:

- the FormalParameters and FunctionBody of a FunctionDeclaration or FunctionExpression,
- the FormalParameters and GeneratorBody of a GeneratorDeclaration or GeneratorExpression,
- the FormalParameters and AsyncFunctionBody of an AsyncFunctionDeclaration or AsyncFunctionExpression, or
- the FormalParameters and AsyncGeneratorBody of an AsyncGeneratorDeclaration or AsyncGeneratorExpression,

then the source text matched by the BindingIdentifier (if any) of that declaration or expression is also included in the function code of the corresponding function.

- **Module code** is source text that is code that is provided as a ModuleBody. It is the code that is directly evaluated when a module is initialized. The module code of a particular module does not include any source
text that is parsed as part of a nested `FunctionDeclaration`, `FunctionExpression`, `GeneratorDeclaration`, `GeneratorExpression`, `AsyncFunctionDeclaration`, `AsyncFunctionExpression`, `AsyncGeneratorDeclaration`, `AsyncGeneratorExpression`, `MethodDefinition`, `ArrowFunction`, `AsyncArrowFunction`, `ClassDeclaration`, or `ClassExpression`.

**NOTE 1** Function code is generally provided as the bodies of Function Definitions (15.2), Arrow Function Definitions (15.3), Method Definitions (15.4), Generator Function Definitions (15.5), Async Function Definitions (15.8), Async Generator Function Definitions (15.6), and Async Arrow Functions (15.9). Function code is also derived from the arguments to the `Function` constructor (20.2.1.1), the `GeneratorFunction` constructor (27.3.1.1), and the `AsyncFunction` constructor (27.7.1.1).

**NOTE 2** The practical effect of including the `BindingIdentifier` in function code is that the Early Errors for strict mode code are applied to a `BindingIdentifier` that is the name of a function whose body contains a "use strict" directive, even if the surrounding code is not strict mode code.

### 11.2.1 Directive Prologues and the Use Strict Directive

A *Directive Prologue* is the longest sequence of `ExpressionStatements` occurring as the initial `StatementListItems` or `ModuleItems` of a `FunctionBody`, a `ScriptBody`, or a `ModuleBody` and where each `ExpressionStatement` in the sequence consists entirely of a `StringLiteral` token followed by a semicolon. The semicolon may appear explicitly or may be inserted by automatic semicolon insertion (12.10). A *Directive Prologue* may be an empty sequence.

A *Use Strict Directive* is an `ExpressionStatement` in a *Directive Prologue* whose `StringLiteral` is either of the exact code point sequences "use strict" or 'use strict'. A *Use Strict Directive* may not contain an `EscapeSequence` or `LineContinuation`.

A *Directive Prologue* may contain more than one *Use Strict Directive*. However, an implementation may issue a warning if this occurs.

**NOTE** The `ExpressionStatements` of a *Directive Prologue* are evaluated normally during evaluation of the containing production. Implementations may define implementation specific meanings for `ExpressionStatements` which are not a *Use Strict Directive* and which occur in a *Directive Prologue*. If an appropriate notification mechanism exists, an implementation should issue a warning if it encounters in a *Directive Prologue* an `ExpressionStatement` that is not a *Use Strict Directive* and which does not have a meaning defined by the implementation.

### 11.2.2 Strict Mode Code

An ECMAScript syntactic unit may be processed using either unrestricted or strict mode syntax and semantics (4.3.2). Code is interpreted as *strict mode code* in the following situations:

- **Global code** is strict mode code if it begins with a *Directive Prologue* that contains a *Use Strict Directive*.
- **Module code** is always strict mode code.
- All parts of a `ClassDeclaration` or a `ClassExpression` are strict mode code.
- **Eval code** is strict mode code if it begins with a *Directive Prologue* that contains a *Use Strict Directive* or if the call to `eval` is a direct `eval` that is contained in strict mode code.
- **Function code** is strict mode code if the associated `FunctionDeclaration`, `FunctionExpression`, `GeneratorDeclaration`, `GeneratorExpression`, `AsyncFunctionDeclaration`, `AsyncFunctionExpression`, `AsyncGeneratorDeclaration`, `AsyncGeneratorExpression`, `MethodDefinition`, `ArrowFunction`, or `AsyncArrowFunction` is contained in strict mode code or if the code that produces the value of the function's `[[ECMAScriptCode]]` internal slot begins with a *Directive Prologue* that contains a *Use Strict Directive*.
- **Function code** that is supplied as the arguments to the built-in `Function`, `Generator`, `AsyncFunction`, and `AsyncGenerator constructors` is strict mode code if the last argument is a `String` that when processed is a `FunctionBody` that begins with a *Directive Prologue* that contains a *Use Strict Directive*.

ECMAScript code that is not strict mode code is called *non-strict code*. 
An ECMAScript implementation may support the evaluation of function exotic objects whose evaluative behaviour is expressed in some host-defined form of executable code other than ECMAScript source text. Whether a function object is defined within ECMAScript code or is a built-in function is not observable from the perspective of ECMAScript code that calls or is called by such a function object.

12 ECMAScript Language: Lexical Grammar

The source text of an ECMAScript Script or Module is first converted into a sequence of input elements, which are tokens, line terminators, comments, or white space. The source text is scanned from left to right, repeatedly taking the longest possible sequence of code points as the next input element.

There are several situations where the identification of lexical input elements is sensitive to the syntactic grammar context that is consuming the input elements. This requires multiple goal symbols for the lexical grammar. The InputElementHashbangOrRegExp goal is used at the start of a Script or Module. The InputElementRegExpOrTemplateTail goal is used in syntactic grammar contexts where a RegularExpressionLiteral, a TemplateMiddle, or a TemplateTail is permitted. The InputElementRegExp goal symbol is used in all syntactic grammar contexts where a RegularExpressionLiteral is permitted but neither a TemplateMiddle, nor a TemplateTail is permitted. The InputElementTemplateTail goal is used in all syntactic grammar contexts where a TemplateMiddle or a TemplateTail is permitted but a RegularExpressionLiteral is not permitted. In all other contexts, InputElementDiv is used as the lexical goal symbol.

NOTE The use of multiple lexical goals ensures that there are no lexical ambiguities that would affect automatic semicolon insertion. For example, there are no syntactic grammar contexts where both a leading division or division-assignment, and a leading RegularExpressionLiteral are permitted. This is not affected by semicolon insertion (see 12.10); in examples such as the following:

```javascript
a = b /hi/g.exec(c).map(d);
```

where the first non-whitespace, non-comment code point after a LineTerminator is U+002F (SOLIDUS) and the syntactic context allows division or division-assignment, no semicolon is inserted at the LineTerminator. That is, the above example is interpreted in the same way as:

```javascript
a = b / hi / g.exec(c).map(d);
```

Syntax

```
InputElementDiv ::
  Whitespace
  LineTerminator
  Comment
  CommonToken
  DivPunctuator
  RightBracePunctuator

InputElementRegExp ::
  Whitespace
  LineTerminator
  Comment
  CommonToken
  DivPunctuator
  RightBracePunctuator
  RegularExpressionLiteral
```
The Unicode format-control characters (i.e., the characters in category “Cf” in the Unicode Character Database such as LEFT-TO-RIGHT MARK or RIGHT-TO-LEFT MARK) are control codes used to control the formatting of a range of text in the absence of higher-level protocols for this (such as mark-up languages).

It is useful to allow format-control characters in source text to facilitate editing and display. All format control characters may be used within comments, and within string literals, template literals, and regular expression literals.

U+200C (ZERO WIDTH NON-JOINER) and U+200D (ZERO WIDTH JOINER) are format-control characters that are used to make necessary distinctions when forming words or phrases in certain languages. In ECMAScript source text these code points may also be used in an IdentifierName after the first character.

U+FEFF (ZERO WIDTH NO-BREAK SPACE) is a format-control character used primarily at the start of a text to mark it as Unicode and to allow detection of the text's encoding and byte order. <ZWNBSP> characters intended for this purpose can sometimes also appear after the start of a text, for example as a result of concatenating files. In ECMAScript source text <ZWNBSP> code points are treated as white space characters (see 12.2).

The special treatment of certain format-control characters outside of comments, string literals, and regular expression literals is summarized in Table 35.

<table>
<thead>
<tr>
<th>Code Point</th>
<th>Name</th>
<th>Abbreviation</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>U+200C</td>
<td>ZERO WIDTH NON-JOINER</td>
<td>&lt;ZWNJ&gt;</td>
<td>IdentifierPart</td>
</tr>
<tr>
<td>U+200D</td>
<td>ZERO WIDTH JOINER</td>
<td>&lt;ZWJ&gt;</td>
<td>IdentifierPart</td>
</tr>
<tr>
<td>U+FEFF</td>
<td>ZERO WIDTH NO-BREAK SPACE</td>
<td>&lt;ZWNBSP&gt;</td>
<td>WhiteSpace</td>
</tr>
</tbody>
</table>
12.2 White Space

White space code points are used to improve source text readability and to separate tokens (indivisible lexical units) from each other, but are otherwise insignificant. White space code points may occur between any two tokens and at the start or end of input. White space code points may occur within a `StringLiteral`, a `RegularExpressionLiteral`, a `Template`, or a `TemplateSubstitutionTail` where they are considered significant code points forming part of a literal value. They may also occur within a `Comment`, but cannot appear within any other kind of token.

The ECMAScript white space code points are listed in Table 36.

**Table 36: White Space Code Points**

<table>
<thead>
<tr>
<th>Code Points</th>
<th>Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>U+0009</td>
<td>CHARACTER TABULATION</td>
<td>&lt;TAB&gt;</td>
</tr>
<tr>
<td>U+000B</td>
<td>LINE TABULATION</td>
<td>&lt;VT&gt;</td>
</tr>
<tr>
<td>U+000C</td>
<td>FORM FEED (FF)</td>
<td>&lt;FF&gt;</td>
</tr>
<tr>
<td>U+FEFF</td>
<td>ZERO WIDTH NO-BREAK SPACE</td>
<td>&lt;ZWNBSP&gt;</td>
</tr>
<tr>
<td>any code point in general category “Space_Separator”</td>
<td></td>
<td>&lt;USP&gt;</td>
</tr>
</tbody>
</table>

**NOTE 1** U+0020 (SPACE) and U+00A0 (NO-BREAK SPACE) code points are part of <USP>.

**NOTE 2** Other than for the code points listed in Table 36, ECMAScript WhiteSpace intentionally excludes all code points that have the Unicode “White_Space” property but which are not classified in general category “Space_Separator” (“Zs”).

Syntax

```
WhiteSpace  ::=  
                  <TAB>  
                  <VT>  
                  <FF>  
                  <ZWNBSP>  
                  <USP>
```

12.3 Line Terminators

Like white space code points, line terminator code points are used to improve source text readability and to separate tokens (indivisible lexical units) from each other. However, unlike white space code points, line terminators have some influence over the behaviour of the syntactic grammar. In general, line terminators may occur between any two tokens, but there are a few places where they are forbidden by the syntactic grammar. Line terminators also affect the process of automatic semicolon insertion (12.10). A line terminator cannot occur within any token except a `StringLiteral`, `Template`, or `TemplateSubstitutionTail`. `<LF>` and `<CR>` line terminators cannot occur within a `StringLiteral` token except as part of a `LineContinuation`.

A line terminator can occur within a `MultiLineComment` but cannot occur within a `SingleLineComment`.

Line terminators are included in the set of white space code points that are matched by the \s class in regular expressions.
The ECMAScript line terminator code points are listed in Table 37.

### Table 37: Line Terminator Code Points

<table>
<thead>
<tr>
<th>Code Point</th>
<th>Unicode Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>U+000A</td>
<td>LINE FEED (LF)</td>
<td>&lt;LF&gt;</td>
</tr>
<tr>
<td>U+000D</td>
<td>CARRIAGE RETURN (CR)</td>
<td>&lt;CR&gt;</td>
</tr>
<tr>
<td>U+2028</td>
<td>LINE SEPARATOR</td>
<td>&lt;LS&gt;</td>
</tr>
<tr>
<td>U+2029</td>
<td>PARAGRAPH SEPARATOR</td>
<td>&lt;PS&gt;</td>
</tr>
</tbody>
</table>

Only the Unicode code points in Table 37 are treated as line terminators. Other new line or line breaking Unicode code points are not treated as line terminators but are treated as white space if they meet the requirements listed in Table 36. The sequence <CR><LF> is commonly used as a line terminator. It should be considered a single SourceCharacter for the purpose of reporting line numbers.

#### Syntax

**LineTerminator ::**

- <LF>
- <CR>
- <LS>
- <PS>

**LineTerminatorSequence ::**

- <LF>
- <CR> [lookahead ≠ <LF>]
- <LS>
- <PS>
- <CR> <LF>

### 12.4 Comments

Comments can be either single or multi-line. Multi-line comments cannot nest.

Because a single-line comment can contain any Unicode code point except a LineTerminator code point, and because of the general rule that a token is always as long as possible, a single-line comment always consists of all code points from the // marker to the end of the line. However, the LineTerminator at the end of the line is not considered to be part of the single-line comment; it is recognized separately by the lexical grammar and becomes part of the stream of input elements for the syntactic grammar. This point is very important, because it implies that the presence or absence of single-line comments does not affect the process of automatic semicolon insertion (see 12.10).

Comments behave like white space and are discarded except that, if a MultiLineComment contains a line terminator code point, then the entire comment is considered to be a LineTerminator for purposes of parsing by the syntactic grammar.

#### Syntax

**Comment ::**

- MultiLineComment
- SingleLineComment
MultiLineComment ::
   /* MultiLineCommentChars opt */

MultiLineCommentChars ::
   MultiLineNotAsteriskChar MultiLineCommentChars opt
   ★ PostAsteriskCommentChars opt

PostAsteriskCommentChars ::
   MultiLineNotForwardSlashOrAsteriskChar MultiLineCommentChars opt
   ★ PostAsteriskCommentChars opt

MultiLineNotAsteriskChar ::
   SourceCharacter but not ★

MultiLineNotForwardSlashOrAsterisk Char ::
   SourceCharacter but not one of / or ★

SingleLineComment ::
   // SingleLineCommentChars opt

SingleLineCommentChars ::
   SingleLineCommentChar SingleLineCommentChars opt

SingleLineCommentChar ::
   SourceCharacter but not LineTerminator

A number of productions in this section are given alternative definitions in section B.1.1

12.5 Hashbang Comments

Hashbang Comments are location-sensitive and like other types of comments are discarded from the stream of input elements for the syntactic grammar.

Syntax

HashbangComment ::
   #! SingleLineCommentChars opt

12.6 Tokens

Syntax

CommonToken ::
   IdentifierName
   PrivateIdentifier
   Punctuator
   NumericLiteral
   StringLiteral
   Template

NOTE The DivPunctuator, RegularExpressionLiteral, RightBracePunctuator, and TemplateSubstitutionTail productions derive additional tokens that are not included in the CommonToken production.
12.7 Names and Keywords

*IdentifierName* and *ReservedWord* are tokens that are interpreted according to the Default Identifier Syntax given in Unicode Standard Annex #31, Identifier and Pattern Syntax, with some small modifications. *ReservedWord* is an enumerated subset of *IdentifierName*. The syntactic grammar defines *Identifier* as an *IdentifierName* that is not a *ReservedWord*. The Unicode identifier grammar is based on character properties specified by the Unicode Standard. The Unicode code points in the specified categories in the latest version of the Unicode Standard must be treated as in those categories by all conforming ECMAScript implementations. ECMAScript implementations may recognize identifier code points defined in later editions of the Unicode Standard.

**NOTE 1** This standard specifies specific code point additions: U+0024 (DOLLAR SIGN) and U+005F (LOW LINE) are permitted anywhere in an *IdentifierName*, and the code points U+200C (ZERO WIDTH NON-JOINER) and U+200D (ZERO WIDTH JOINER) are permitted anywhere after the first code point of an *IdentifierName*.

**Syntax**

```
PrivateKey :: # IdentifierName

IdentifierName :: IdentifierStart IdentifierName IdentifierPart

IdentifierStart :: IdentifierStartChar UnicodeEscapeSequence

IdentifierPart :: IdentifierPartChar UnicodeEscapeSequence

IdentifierStartChar :: UnicodeIDStart $

IdentifierPartChar :: UnicodeIDContinue $

AsciiLetter :: one of

    a b c d e f g h i j k l m n o p q r s t u v w x y z A B C D E F G H I J K L
    M N O P Q R S T U V W X Y Z

UnicodeIDStart :: any Unicode code point with the Unicode property "ID_Start"

UnicodeIDContinue :: any Unicode code point with the Unicode property "ID_Continue"
```

The definitions of the nonterminal *UnicodeEscapeSequence* is given in 12.9.4.
12.7.1 Identifier Names

Unicode escape sequences are permitted in an IdentifierName, where they contribute a single Unicode code point equal to the IdentifierCodePoint of the UnicodeEscapeSequence. The \ preceding the UnicodeEscapeSequence does not contribute any code points. A UnicodeEscapeSequence cannot be used to contribute a code point to an IdentifierName that would otherwise be invalid. In other words, if a \ UnicodeEscapeSequence sequence were replaced by the SourceCharacter it contributes, the result must still be a valid IdentifierName that has the exact same sequence of SourceCharacter elements as the original IdentifierName. All interpretations of IdentifierName within this specification are based upon their actual code points regardless of whether or not an escape sequence was used to contribute any particular code point.

Two IdentifierNames that are canonically equivalent according to the Unicode Standard are not equal unless, after replacement of each UnicodeEscapeSequence, they are represented by the exact same sequence of code points.

12.7.1.1 Static Semantics: Early Errors

IdentifierStart :: \ UnicodeEscapeSequence

- It is a Syntax Error if IdentifierCodePoint of UnicodeEscapeSequence is not some Unicode code point matched by the IdentifierStartChar lexical grammar production.

IdentifierPart :: \ UnicodeEscapeSequence

- It is a Syntax Error if IdentifierCodePoint of UnicodeEscapeSequence is not some Unicode code point matched by the IdentifierPartChar lexical grammar production.

12.7.1.2 Static Semantics: IdentifierCodePoints

The syntax-directed operation IdentifierCodePoints takes no arguments and returns a List of code points. It is defined piecewise over the following productions:

IdentifierName :: IdentifierStart

1. Let \( cp \) be IdentifierCodePoint of IdentifierStart.
2. Return « \( cp \) ».

IdentifierName :: IdentifierName IdentifierPart

1. Let \( cps \) be IdentifierCodePoints of the derived IdentifierName.
2. Let \( cp \) be IdentifierCodePoint of IdentifierPart.
3. Return the list-concatenation of \( cps \) and « \( cp \) ».

12.7.1.3 Static Semantics: IdentifierCodePoint

The syntax-directed operation IdentifierCodePoint takes no arguments and returns a code point. It is defined piecewise over the following productions:

IdentifierStart :: IdentifierStartChar

1. Return the code point matched by IdentifierStartChar.
1. Return the code point matched by IdentifierPartChar.

UnicodeEscapeSequence :: u Hex4Digits

1. Return the code point whose numeric value is the MV of Hex4Digits.

UnicodeEscapeSequence :: u{ CodePoint }

1. Return the code point whose numeric value is the MV of CodePoint.

12.7.2 Keywords and Reserved Words

A keyword is a token that matches IdentifierName, but also has a syntactic use; that is, it appears literally, in a fixed width font, in some syntactic production. The keywords of ECMAScript include if, while, async, await, and many others.

A reserved word is an IdentifierName that cannot be used as an identifier. Many keywords are reserved words, but some are not, and some are reserved only in certain contexts. if and while are reserved words. await is reserved only inside async functions and modules. async is not reserved; it can be used as a variable name or statement label without restriction.

This specification uses a combination of grammatical productions and early error rules to specify which names are valid identifiers and which are reserved words. All tokens in the ReservedWord list below, except for await and yield, are unconditionally reserved. Exceptions for await and yield are specified in 13.1, using parameterized syntactic productions. Lastly, several early error rules restrict the set of valid identifiers. See 13.1.1, 14.3.1.1, 14.7.5.1, and 15.7.1. In summary, there are five categories of identifier names:

- Those that are always allowed as identifiers, and are not keywords, such as Math, window, toString, and _;
- Those that are never allowed as identifiers, namely the ReservedWords listed below except await and yield;
- Those that are contextually allowed as identifiers, namely await and yield;
- Those that are contextually disallowed as identifiers, in strict mode code: let, static, implements, interface, package, private, protected, and public;
- Those that are always allowed as identifiers, but also appear as keywords within certain syntactic productions, at places where Identifier is not allowed: as, async, from, get, meta, of, set, and target.

The term conditional keyword, or contextual keyword, is sometimes used to refer to the keywords that fall in the last three categories, and thus can be used as identifiers in some contexts and as keywords in others.

Syntax

ReservedWord :: one of
  await break case catch class const continue debugger default delete do else enum export extends false finally for function if import instanceof new null return super switch this throw true try typeof var void while with yield
12.8 Punctuators

Syntax

\[
Punctuator ::=
  OptionalChainingPunctuator
  OtherPunctuator
\]

OptionalChainingPunctuator ::=
  ?. [lookahead ∈ DecimalDigit]

OtherPunctuator :: one of
  { ( ) [ ] . ... ; , < > <= >= != === !== + - * % ** +- -- << >> >>> & | ^ ! ~ && || ?? ? ? :: = += -= *= **= <<= >>= >= &= |== ^= &%= |||== ||= ??= =>

DivPunctuator ::=
  /

RightBracePunctuator ::=
  }

12.9 Literals

12.9.1 Null Literals

Syntax

NullLiteral ::=
  null
12.9.2 Boolean Literals

Syntax

BooleanLiteral ::
  true
  false

12.9.3 Numeric Literals

Syntax

NumericLiteralSeparator ::
  -
NumericLiteral ::
  DecimalLiteral
  DecimalBigIntegerLiteral
  NonDecimalIntegerLiteral[+Sep]
  NonDecimalIntegerLiteral[+Sep] BigIntLiteralSuffix
  LegacyOctalIntegerLiteral

DecimalBigIntegerLiteral ::
  0 BigIntLiteralSuffix
  NonZeroDigit DecimalDigits[+Sep] opt BigIntLiteralSuffix
  NonZeroDigit NumericLiteralSeparator DecimalDigits[+Sep] BigIntLiteralSuffix

NonDecimalIntegerLiteral[Sep] ::
  BinaryIntegerLiteral[?Sep]
  OctalIntegerLiteral[?Sep]
  HexIntegerLiteral[?Sep]

BigIntLiteralSuffix ::
  n

DecimalLiteral ::
  DecimalIntegerLiteral . DecimalDigits[+Sep] opt ExponentPart[+Sep] opt
  . DecimalDigits[+Sep] ExponentPart[+Sep] opt
  DecimalIntegerLiteral ExponentPart[+Sep] opt

DecimalIntegerLiteral ::
  0
  NonZeroDigit
  NonZeroDigit NumericLiteralSeparator opt DecimalDigits[+Sep]
  NonOctalDecimalIntegerLiteral

DecimalDigits[Sep] ::
  DecimalDigit
  DecimalDigits[?Sep] DecimalDigit
  [+Sep] DecimalDigits[+Sep] NumericLiteralSeparator DecimalDigit

DecimalDigit :: one of
  0 1 2 3 4 5 6 7 8 9
NonZeroDigit :: one of 1 2 3 4 5 6 7 8 9

ExponentPart[Sep] ::
  ExponentIndicator SignedInteger[?Sep]

ExponentIndicator :: one of e E

SignedInteger[Sep] ::
  DecimalDigits[?Sep]
  + DecimalDigits[?Sep]
  - DecimalDigits[?Sep]

BinaryIntegerLiteral[Sep] ::
  0b BinaryDigits[?Sep]
  0B BinaryDigits[?Sep]

BinaryDigits[Sep] ::
  BinaryDigit
  BinaryDigits[?Sep] BinaryDigit
  [*Sep] BinaryDigits[+Sep] NumericLiteralSeparator BinaryDigit

BinaryDigit :: one of 0 1

OctalIntegerLiteral[Sep] ::
  0o OctalDigits[?Sep]
  00 OctalDigits[?Sep]

OctalDigits[Sep] ::
  OctalDigit
  OctalDigits[?Sep] OctalDigit
  [*Sep] OctalDigits[+Sep] NumericLiteralSeparator OctalDigit

LegacyOctalIntegerLiteral ::
  0 OctalDigit
  LegacyOctalIntegerLiteral OctalDigit

NonOctalDecimalIntegerLiteral ::
  0 NonOctalDigit
  LegacyOctalLikeDecimalIntegerLiteral NonOctalDigit
  NonOctalDecimalIntegerLiteral DecimalDigit

LegacyOctalLikeDecimalIntegerLiteral ::
  0 OctalDigit
  LegacyOctalLikeDecimalIntegerLiteral OctalDigit

OctalDigit :: one of 0 1 2 3 4 5 6 7

NonOctalDigit :: one of 8 9
HexIntegerLiteral \[\text{Sep}\] ::
  \text{0x HexDigits}[\text{?Sep}]
  \text{0X HexDigits}[\text{?Sep}]

HexDigits \[\text{Sep}\] ::
  HexDigit
  HexDigits[\text{?Sep}] HexDigit
  [+\text{Sep}] HexDigits[+\text{Sep}] NumericLiteralSeparator HexDigit

HexDigit :: one of
  0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F

The SourceCharacter immediately following a NumericLiteral must not be an IdentifierStart or DecimalDigit.

\textbf{NOTE} For example: \texttt{3in} is an error and not the two input elements \texttt{3} and \texttt{in}.

\[12.9.3.1\] Static Semantics: Early Errors

\begin{align*}
\text{NumericLiteral} &:: \text{LegacyOctalIntegerLiteral} \\
\text{DecimalIntegerLiteral} &:: \text{NonOctalDecimalIntegerLiteral}
\end{align*}

- It is a Syntax Error if the source text matched by this production is strict mode code.

\textbf{NOTE} In non-strict code, this syntax is Legacy.

\[12.9.3.2\] Static Semantics: MV

A numeric literal stands for a value of the Number type or the BigInt type.

- The MV of DecimalLiteral :: DecimalIntegerLiteral . DecimalDigits is the MV of DecimalIntegerLiteral plus (the MV of DecimalDigits \(\times 10^n\)), where \(n\) is the number of code points in DecimalDigits, excluding all occurrences of NumericLiteralSeparator.
- The MV of DecimalLiteral :: DecimalIntegerLiteral . ExponentPart is the MV of DecimalIntegerLiteral \(\times 10^e\), where \(e\) is the MV of ExponentPart.
- The MV of DecimalLiteral :: DecimalIntegerLiteral . DecimalDigits ExponentPart is (the MV of DecimalIntegerLiteral plus (the MV of DecimalDigits \(\times 10^{-n}\))) \(\times 10^e\), where \(n\) is the number of code points in DecimalDigits, excluding all occurrences of NumericLiteralSeparator and \(e\) is the MV of ExponentPart.
- The MV of DecimalLiteral :: . DecimalDigits is the MV of DecimalDigits \(\times 10^n\), where \(n\) is the number of code points in DecimalDigits, excluding all occurrences of NumericLiteralSeparator and \(e\) is the MV of ExponentPart.
- The MV of DecimalLiteral :: . DecimalDigits ExponentPart is the MV of DecimalDigits \(\times 10^e\) \(- n\), where \(n\) is the number of code points in DecimalDigits, excluding all occurrences of NumericLiteralSeparator, and \(e\) is the MV of ExponentPart.
- The MV of DecimalLiteral :: DecimalIntegerLiteral ExponentPart is the MV of DecimalIntegerLiteral \(\times 10^e\), where \(e\) is the MV of ExponentPart.
- The MV of DecimalIntegerLiteral :: 0 is 0.
- The MV of DecimalIntegerLiteral :: NonZeroDigit NumericLiteralSeparator opt DecimalDigits is (the MV of NonZeroDigit \(\times 10^n\)) plus the MV of DecimalDigits, where \(n\) is the number of code points in DecimalDigits, excluding all occurrences of NumericLiteralSeparator.
- The MV of DecimalDigits :: DecimalDigits DecimalDigit is (the MV of DecimalDigits \(\times 10\)) plus the MV of DecimalDigit.
- The MV of DecimalDigits :: DecimalDigits NumericLiteralSeparator DecimalDigit is (the MV of DecimalDigits \(\times 10\)) plus the MV of DecimalDigit.
- The MV of ExponentPart :: ExponentIndicator SignedInteger is the MV of SignedInteger.
- The MV of SignedInteger :: - DecimalDigits is the negative of the MV of DecimalDigits.
- The MV of DecimalDigit :: 0 or of HexDigit :: 0 or of OctalDigit :: 0 or of
LegacyOctalEscapeSequence :: 0 or of BinaryDigit :: 0 is 0.

- The MV of DecimalDigit :: 1 or of NonZeroDigit :: 1 or of HexDigit :: 1 or of OctalDigit :: 1 or of BinaryDigit :: 1 is 1.
- The MV of DecimalDigit :: 2 or of NonZeroDigit :: 2 or of HexDigit :: 2 or of OctalDigit :: 2 is 2.
- The MV of DecimalDigit :: 3 or of NonZeroDigit :: 3 or of HexDigit :: 3 or of OctalDigit :: 3 is 3.
- The MV of DecimalDigit :: 4 or of NonZeroDigit :: 4 or of HexDigit :: 4 or of OctalDigit :: 4 is 4.
- The MV of DecimalDigit :: 5 or of NonZeroDigit :: 5 or of HexDigit :: 5 or of OctalDigit :: 5 is 5.
- The MV of DecimalDigit :: 6 or of NonZeroDigit :: 6 or of HexDigit :: 6 or of OctalDigit :: 6 is 6.
- The MV of DecimalDigit :: 7 or of NonZeroDigit :: 7 or of HexDigit :: 7 or of OctalDigit :: 7 is 7.
- The MV of DecimalDigit :: 8 or of NonZeroDigit :: 8 or of NonOctalDigit :: 8 or of HexDigit :: 8 is 8.
- The MV of DecimalDigit :: 9 or of NonZeroDigit :: 9 or of NonOctalDigit :: 9 or of HexDigit :: 9 is 9.
- The MV of HexDigit :: a or of HexDigit :: A is 10.
- The MV of HexDigit :: b or of HexDigit :: B is 11.
- The MV of HexDigit :: c or of HexDigit :: C is 12.
- The MV of HexDigit :: d or of HexDigit :: D is 13.
- The MV of HexDigit :: e or of HexDigit :: E is 14.
- The MV of HexDigit :: f or of HexDigit :: F is 15.
- The MV of BinaryDigits :: BinaryDigits BinaryDigit is (the MV of BinaryDigits × 2) plus the MV of BinaryDigit.
- The MV of BinaryDigits :: BinaryDigits NumericLiteralSeparator BinaryDigit is (the MV of BinaryDigits × 2) plus the MV of BinaryDigit.
- The MV of OctalDigits :: OctalDigits OctalDigit is (the MV of OctalDigits × 8) plus the MV of OctalDigit.
- The MV of OctalDigits :: OctalDigits NumericLiteralSeparator OctalDigit is (the MV of OctalDigits × 8) plus the MV of OctalDigit.
- The MV of LegacyOctalIntegerLiteral :: OctalDigit is (the MV of LegacyOctalIntegerLiteral times 8) plus the MV of OctalDigit.
- The MV of NonOctalDecimalIntegerLiteral :: LegacyOctalLikeDecimalIntegerLiteral NonOctalDigit is (the MV of LegacyOctalLikeDecimalIntegerLiteral times 10) plus the MV of NonOctalDigit.
- The MV of NonOctalDecimalIntegerLiteral :: NonOctalDecimalIntegerLiteral DecimalDigit is (the MV of NonOctalDecimalIntegerLiteral times 10) plus the MV of DecimalDigit.
- The MV of LegacyOctalLikeDecimalIntegerLiteral :: LegacyOctalLikeDecimalIntegerLiteral OctalDigit is (the MV of LegacyOctalLikeDecimalIntegerLiteral times 10) plus the MV of OctalDigit.
- The MV of HexDigits :: HexDigits HexDigit is (the MV of HexDigits × 16) plus the MV of HexDigit.
- The MV of HexDigits :: HexDigits NumericLiteralSeparator HexDigit is (the MV of HexDigits × 16) plus the MV of HexDigit.

12.9.3.3 Static Semantics: NumericValue

The syntax-directed operation NumericValue takes no arguments and returns a Number or a BigInt. It is defined piecewise over the following productions:

NumericLiteral :: DecimalLiteral

1. Return RoundMVResult(MV of DecimalLiteral).

NumericLiteral :: NonDecimalIntegerLiteral

1. Return F(MV of NonDecimalIntegerLiteral).

NumericLiteral :: LegacyOctalIntegerLiteral

1. Return F(MV of LegacyOctalIntegerLiteral).

NumericLiteral :: NonDecimalIntegerLiteral BigIntLiteralSuffix

1. Return the BigInt value for the MV of NonDecimalIntegerLiteral.
DecimalBigIntegerLiteral :: 0 BigIntLiteralSuffix
1. Return 0\(\mathbb{Z}\).

DecimalBigIntegerLiteral :: NonZeroDigit BigIntLiteralSuffix
1. Return the BigInt value for the MV of NonZeroDigit.

DecimalBigIntegerLiteral ::
NonZeroDigit DecimalDigits BigIntLiteralSuffix
NonZeroDigit NumericLiteralSeparator DecimalDigits BigIntLiteralSuffix
1. Let \(n\) be the number of code points in DecimalDigits, excluding all occurrences of NumericLiteralSeparator.
2. Let \(mv\) be (the MV of NonZeroDigit \(\times 10^n\)) plus the MV of DecimalDigits.
3. Return \(\mathbb{Z}(mv)\).

12.9.4 String Literals

NOTE 1 A string literal is 0 or more Unicode code points enclosed in single or double quotes. Unicode code points may also be represented by an escape sequence. All code points may appear literally in a string literal except for the closing quote code points, U+005C (REVERSE SOLIDUS), U+000D (CARRIAGE RETURN), and U+000A (LINE FEED). Any code points may appear in the form of an escape sequence. String literals evaluate to ECMAScript String values. When generating these String values Unicode code points are UTF-16 encoded as defined in 11.1.1. Code points belonging to the Basic Multilingual Plane are encoded as a single code unit element of the string. All other code points are encoded as two code unit elements of the string.

Syntax

StringLiteral ::
  " DoubleStringCharacters opt "
  ' SingleStringCharacters opt '

DoubleStringCharacters ::
  DoubleStringCharacter DoubleStringCharacters opt

SingleStringCharacters ::
  SingleStringCharacter SingleStringCharacters opt

DoubleStringCharacter ::
  SourceCharacter but not one of " or \ or LineTerminator
  <LS>
  <PS>
  \ EscapeSequence
  LineContinuation

SingleStringCharacter ::
  SourceCharacter but not one of ' or \ or LineTerminator
  <LS>
  <PS>
  \ EscapeSequence
  LineContinuation

LineContinuation ::
  \ LineTerminatorSequence
EscapeSequence ::
  CharacterEscapeSequence
  \[ \text{lookahead} \not\in \text{DecimalDigit} \]
  LegacyOctalEscapeSequence
  NonOctalDecimalEscapeSequence
  HexEscapeSequence
  UnicodeEscapeSequence

CharacterEscapeSequence ::
  SingleEscapeCharacter
  NonEscapeCharacter

SingleEscapeCharacter :: one of
  ' " \ b f n r t v

NonEscapeCharacter ::
  SourceCharacter but not one of EscapeCharacter or LineTerminator

EscapeCharacter ::
  SingleEscapeCharacter
  DecimalDigit
  x
  u

LegacyOctalEscapeSequence ::
  \[ \text{lookahead} \in \{ 8, 9 \} \]
  NonZeroOctalDigit \[ \text{lookahead} \not\in \text{OctalDigit} \]
  ZeroToThree OctalDigit \[ \text{lookahead} \not\in \text{OctalDigit} \]
  FourToSeven OctalDigit
  ZeroToThree OctalDigit OctalDigit

NonZeroOctalDigit ::
  OctalDigit but not \theta

ZeroToThree :: one of
  \[ 0 1 2 3 \]

FourToSeven :: one of
  \[ 4 5 6 7 \]

NonOctalDecimalEscapeSequence :: one of
  \[ 8 9 \]

HexEscapeSequence ::
  x HexDigit HexDigit

UnicodeEscapeSequence ::
  u Hex4Digits
  u{ CodePoint }

Hex4Digits ::
  HexDigit HexDigit HexDigit HexDigit

The definition of the nonterminal HexDigit is given in 12.9.3. SourceCharacter is defined in 11.1.
12.9.4.1 Static Semantics: Early Errors

EscapeSequence ::
    LegacyOctalEscapeSequence
    NonOctalDecimalEscapeSequence

- It is a Syntax Error if the source text matched by this production is strict mode code.

12.9.4.2 Static Semantics: SV

The syntax-directed operation SV takes no arguments and returns a String.

A string literal stands for a value of the String type. SV produces String values for string literals through recursive application on the various parts of the string literal. As part of this process, some Unicode code points within the string literal are interpreted as having a mathematical value, as described below or in 12.9.3.

- The SV of StringLiteral :: " " is the empty String.
- The SV of StringLiteral :: " ' ' is the empty String.
- The SV of DoubleStringCharacters :: DoubleStringCharacter DoubleStringCharacters is the string-concatenation of the SV of DoubleStringCharacter and the SV of DoubleStringCharacters.
- The SV of SingleStringCharacters :: SingleStringCharacter SingleStringCharacters is the string-concatenation of the SV of SingleStringCharacter and the SV of SingleStringCharacters.
- The SV of DoubleStringCharacter :: SourceCharacter but not one of " or \ or LineTerminator is the result of performing UTF16EncodeCodePoint on the code point matched by SourceCharacter.
- The SV of DoubleStringCharacter :: <LS> is the String value consisting of the code unit 0x2028 (LINE SEPARATOR).
- The SV of DoubleStringCharacter :: <PS> is the String value consisting of the code unit 0x2029 (PARAGRAPHSeparator).
- The SV of DoubleStringCharacter :: LineContinuation is the empty String.
- The SV of SingleStringCharacter :: SourceCharacter but not one of \ or LineTerminator is the result of performing UTF16EncodeCodePoint on the code point matched by SourceCharacter.
- The SV of SingleStringCharacter :: <LS> is the String value consisting of the code unit 0x2028 (LINE SEPARATOR).
- The SV of SingleStringCharacter :: <PS> is the String value consisting of the code unit 0x2029 (PARAGRAPHSeparator).
- The SV of SingleStringCharacter :: LineContinuation is the empty String.
- The SV of EscapeSequence :: \ is the String value consisting of the code unit 0x0000 (NULL).
- The SV of CharacterEscapeSequence :: SingleEscapeCharacter is the String value consisting of the code unit whose numeric value is determined by the SingleEscapeCharacter according to Table 38.
Table 38: String Single Character Escape Sequences

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Code Unit Value</th>
<th>Unicode Character Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>\b</td>
<td>0x0008</td>
<td>BACKSPACE</td>
<td>&lt;BS&gt;</td>
</tr>
<tr>
<td>\t</td>
<td>0x0009</td>
<td>CHARACTER TABULATION</td>
<td>&lt;HT&gt;</td>
</tr>
<tr>
<td>\n</td>
<td>0x000A</td>
<td>LINE FEED (LF)</td>
<td>&lt;LF&gt;</td>
</tr>
<tr>
<td>\v</td>
<td>0x000B</td>
<td>LINE TABULATION</td>
<td>&lt;VT&gt;</td>
</tr>
<tr>
<td>\f</td>
<td>0x000C</td>
<td>FORM FEED (FF)</td>
<td>&lt;FF&gt;</td>
</tr>
<tr>
<td>\r</td>
<td>0x000D</td>
<td>CARRIAGE RETURN (CR)</td>
<td>&lt;CR&gt;</td>
</tr>
<tr>
<td>&quot;</td>
<td>0x0022</td>
<td>QUOTATION MARK</td>
<td>&quot;</td>
</tr>
<tr>
<td>'</td>
<td>0x0027</td>
<td>APOSTROPHE</td>
<td>'</td>
</tr>
<tr>
<td>\</td>
<td>0x005C</td>
<td>REVERSE SOLIDUS</td>
<td>\</td>
</tr>
</tbody>
</table>

- The SV of `NonEscapeCharacter :: SourceCharacter` but not one of `EscapeCharacter` or `LineTerminator` is the result of performing `UTF16EncodeCodePoint` on the code point matched by `SourceCharacter`.
- The SV of `EscapeSequence :: LegacyOctalEscapeSequence` is the String value consisting of the code unit whose numeric value is the MV of `LegacyOctalEscapeSequence`.
- The SV of `NonOctalDecimalEscapeSequence :: 8` is the String value consisting of the code unit 0x0038 (DIGIT EIGHT).
- The SV of `NonOctalDecimalEscapeSequence :: 9` is the String value consisting of the code unit 0x0039 (DIGIT NINE).
- The SV of `HexEscapeSequence :: x HexDigit HexDigit` is the String value consisting of the code unit whose numeric value is the MV of `HexEscapeSequence`.
- The SV of `Hex4Digits :: HexDigit HexDigit HexDigit HexDigit` is the String value consisting of the code unit whose numeric value is the MV of `Hex4Digits`.
- The SV of `UnicodeEscapeSequence :: u{ CodePoint }` is the result of performing `UTF16EncodeCodePoint` on the MV of `CodePoint`.
- The SV of `TemplateEscapeSequence :: 0` is the String value consisting of the code unit 0x0000 (NULL).

12.9.4.3 Static Semantics: MV

- The MV of `LegacyOctalEscapeSequence :: ZeroToThree OctalDigit` is (8 times the MV of `ZeroToThree`) plus the MV of `OctalDigit`.
- The MV of `LegacyOctalEscapeSequence :: FourToSeven OctalDigit` is (8 times the MV of `FourToSeven`) plus the MV of `OctalDigit`.
- The MV of `LegacyOctalEscapeSequence :: ZeroToThree OctalDigit OctalDigit` is (64 (that is, 8²) times the MV of `ZeroToThree`) plus (8 times the MV of the first `OctalDigit`) plus the MV of the second `OctalDigit`.
- The MV of `ZeroToThree :: 0` is 0.
- The MV of `ZeroToThree :: 1` is 1.
- The MV of `ZeroToThree :: 2` is 2.
- The MV of `ZeroToThree :: 3` is 3.
- The MV of `FourToSeven :: 4` is 4.
- The MV of `FourToSeven :: 5` is 5.
- The MV of `FourToSeven :: 6` is 6.
- The MV of `FourToSeven :: 7` is 7.
- The MV of `HexEscapeSequence :: x HexDigit HexDigit` is (16 times the MV of the first `HexDigit`) plus the MV of the second `HexDigit`.
- The MV of `Hex4Digits :: HexDigit HexDigit HexDigit HexDigit` is (0x1000 × the MV of the first `HexDigit`) plus (0x100 × the MV of the second `HexDigit`) plus (0x10 × the MV of the third `HexDigit`) plus the MV of the fourth `HexDigit`.
12.9.5 Regular Expression Literals

NOTE 1 A regular expression literal is an input element that is converted to a RegExp object (see 22.2) each time the literal is evaluated. Two regular expression literals in a program evaluate to regular expression objects that never compare as === to each other even if the two literals’ contents are identical. A RegExp object may also be created at runtime by new RegExp or calling the RegExp constructor as a function (see 22.2.4).

The productions below describe the syntax for a regular expression literal and are used by the input element scanner to find the end of the regular expression literal. The source text comprising the RegularExpressionBody and the RegularExpressionFlags are subsequently parsed again using the more stringent ECMAScript Regular Expression grammar (22.2.1).

An implementation may extend the ECMAScript Regular Expression grammar defined in 22.2.1, but it must not extend the RegularExpressionBody and RegularExpressionFlags productions defined below or the productions used by these productions.

Syntax

```
RegularExpressionLiteral :: / RegularExpressionBody / RegularExpressionFlags
RegularExpressionBody :: RegularExpressionFirstChar RegularExpressionChars
RegularExpressionChars :: [empty] RegularExpressionChars RegularExpressionChar
RegularExpressionFirstChar :: RegularExpressionNonTerminator but not one of \ or / or [ RegularExpressionBackslashSequence RegularExpressionClass
RegularExpressionChar :: RegularExpressionNonTerminator but not one of \ or / or [ RegularExpressionBackslashSequence RegularExpressionClass
RegularExpressionBackslashSequence :: \ RegularExpressionNonTerminator
RegularExpressionNonTerminator :: SourceCharacter but not LineTerminator
RegularExpressionClass :: [ RegularExpressionClassChars ]
RegularExpressionClassChars :: [empty] RegularExpressionClassChars RegularExpressionClassChar
RegularExpressionClassChar :: RegularExpressionNonTerminator but not one of ] or \ RegularExpressionBackslashSequence
```
**NOTE 2**  Regular expression literals may not be empty; instead of representing an empty regular expression literal, the code unit sequence `//` starts a single-line comment. To specify an empty regular expression, use: `/(?::)/`. 

### 12.9.5.1 Static Semantics: BodyText

The syntax-directed operation BodyText takes no arguments and returns source text. It is defined piecewise over the following productions: 

\[
\text{RegularExpressionLiteral} \::= \ / \ \text{RegularExpressionBody} \ / \ \text{RegularExpressionFlags}
\]

1. Return the source text that was recognized as `RegularExpressionBody`.

### 12.9.5.2 Static Semantics: FlagText

The syntax-directed operation FlagText takes no arguments and returns source text. It is defined piecewise over the following productions: 

\[
\text{RegularExpressionLiteral} \::= \ / \ \text{RegularExpressionBody} \ / \ \text{RegularExpressionFlags}
\]

1. Return the source text that was recognized as `RegularExpressionFlags`.

### 12.9.6 Template Literal Lexical Components

**Syntax**

\[
\text{Template} \::= \\
\quad \text{NoSubstitutionTemplate} \\
\quad \text{TemplateHead}
\]

\[
\text{NoSubstitutionTemplate} \::= \\
\quad ` \ \text{TemplateCharacters}_{}^{\text{opt}} ` \\
\]

\[
\text{TemplateHead} \::= \\
\quad ` \ \text{TemplateCharacters}_{}^{\text{opt}} \ \$\{ \\
\]

\[
\text{TemplateMiddle} \::= \\
\quad \} \ \text{TemplateCharacters}_{}^{\text{opt}} \ \$\{ \\
\]

\[
\text{TemplateTail} \::= \\
\quad \} \ \text{TemplateCharacters}_{}^{\text{opt}} ` \\
\]

\[
\text{TemplateCharacters} \::= \\
\quad \text{TemplateCharacter} \ \text{TemplateCharacters}_{}^{\text{opt}}
\]
TemplateCharacter ::
  $ [lookahead ≠ \]
  \ TemplateEscapeSequence
  \ NotEscapeSequence
LineContinuation
LineTerminatorSequence
SourceCharacter but not one of ` \ $ or LineTerminator

TemplateEscapeSequence ::
CharacterEscapeSequence
0 [lookahead∉DecimalDigit]
HexEscapeSequence
UnicodeEscapeSequence

NotEscapeSequence ::
0 DecimalDigit
DecimalDigit but not 0
x [lookahead∉HexDigit]
x HexDigit [lookahead∉HexDigit]
u [lookahead∉HexDigit] [lookahead ≠ \]
u HexDigit [lookahead∉HexDigit]
u HexDigit HexDigit [lookahead∉HexDigit]
u HexDigit HexDigit HexDigit [lookahead∉HexDigit]
u { [lookahead∉HexDigit]
u { NotCodePoint [lookahead∉HexDigit]
u { CodePoint [lookahead∉HexDigit] [lookahead ≠ \]}

NotCodePoint ::
HexDigits[-Sep] but only if MV of HexDigits > 0x10FFFF

CodePoint ::
HexDigits[-Sep] but only if MV of HexDigits ≤ 0x10FFFF

NOTE TemplateSubstitutionTail is used by the InputElementTemplateTail alternative lexical goal.

12.9.6.1 Static Semantics: TV

The syntax-directed operation TV takes no arguments and returns a String or undefined. A template literal component is interpreted by TV as a value of the String type. TV is used to construct the indexed components of a template object (colloquially, the template values). In TV, escape sequences are replaced by the UTF-16 code unit(s) of the Unicode code point represented by the escape sequence.

- The TV of NoSubstitutionTemplate :: ` ` is the empty String.
- The TV of TemplateHead :: ` $ { is the empty String.
- The TV of TemplateMiddle :: } $ { is the empty String.
- The TV of TemplateTail :: } ` is the empty String.
- The TV of TemplateCharacters :: TemplateCharacter TemplateCharacters is undefined if the TV of TemplateCharacter is undefined or the TV of TemplateCharacters is undefined. Otherwise, it is the string-concatenation of the TV of TemplateCharacter and the TV of TemplateCharacters.
- The TV of TemplateCharacter :: SourceCharacter but not one of ` \ $ or LineTerminator is the result of performing UTF16EncodeCodePoint on the code point matched by SourceCharacter.
- The TV of TemplateCharacter :: $ is the String value consisting of the code unit 0x0024 (DOLLAR SIGN).
- The TV of TemplateCharacter :: \ TemplateEscapeSequence is the SV of TemplateEscapeSequence.
- The TV of TemplateCharacter :: \ NotEscapeSequence is undefined.
- The TV of TemplateCharacter :: LineTerminatorSequence is the TRV of LineTerminatorSequence.
• The TV of `LineContinuation :: \ LineTerminatorSequence` is the empty String.

12.9.6.2 Static Semantics: TRV

The syntax-directed operation TRV takes no arguments and returns a String. A template literal component is interpreted by TRV as a value of the String type. TRV is used to construct the raw components of a template object (colloquially, the template raw values). TRV is similar to TV with the difference being that in TRV, escape sequences are interpreted as they appear in the literal.

- The TRV of `NoSubstitutionTemplate :: ` is the empty String.
- The TRV of `TemplateHead :: ` is the empty String.
- The TRV of `TemplateMiddle :: $` is the empty String.
- The TRV of `TemplateTail :: ` is the empty String.
- The TRV of `TemplateCharacters :: TemplateCharacter TemplateCharacters` is the string-concatenation of the TRV of TemplateCharacter and the TRV of TemplateCharacters.
- The TRV of `TemplateCharacter :: SourceCharacter` but not one of `` or `$` or `LineTerminator` is the result of performing `UTF16EncodeCodePoint` on the code point matched by SourceCharacter.
- The TRV of `TemplateCharacter :: $` is the String value consisting of the code unit `0x0024` (DOLLAR SIGN).
- The TRV of `TemplateCharacter :: \ TemplateEscapeSequence` is the string-concatenation of the code unit `0x005C` (REVERSE SOLIDUS) and the TRV of TemplateEscapeSequence.
- The TRV of `TemplateCharacter :: \ NotEscapeSequence` is the string-concatenation of the code unit `0x005C` (REVERSE SOLIDUS) and the TRV of NotEscapeSequence.
- The TRV of `TemplateEscapeSequence :: ` is the empty String.
- The TRV of `TemplateEscapeSequence :: \ SourceCharacter` but not one of `` or `$` or `LineTerminator` is the result of performing `UTF16EncodeCodePoint` on the code point matched by SourceCharacter.
- The TRV of `TemplateEscapeSequence :: $` is the String value consisting of the code unit `0x0030` (DIGIT ZERO).
- The TRV of `NotEscapeSequence :: \ DecimalDigit` is the string-concatenation of the code unit `0x0030` (DIGIT ZERO) and the TRV of DecimalDigit.
- The TRV of `NotEscapeSequence :: x [lookahead ≠ HexDigit]` is the String value consisting of the code unit `0x007B` (LEFT CURLY BRACKET).
- The TRV of `NotEscapeSequence :: x HexDigit [lookahead ≠ HexDigit]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of HexDigit.
- The TRV of `NotEscapeSequence :: u [lookahead ≠ HexDigit] [lookahead ≠ $]` is the String value consisting of the code unit `0x007B` (LEFT CURLY BRACKET).
- The TRV of `NotEscapeSequence :: u HexDigit [lookahead ≠ HexDigit]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of HexDigit.
- The TRV of `NotEscapeSequence :: u HexDigit HexDigit HexDigit [lookahead ≠ HexDigit]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of HexDigit.
- The TRV of `NotEscapeSequence :: u HexDigit HexDigit HexDigit [lookahead ≠ HexDigit]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of HexDigit.
- The TRV of `NotEscapeSequence :: u { [lookahead ≠ HexDigit]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of HexDigit.
- The TRV of `NotEscapeSequence :: u { [lookahead ≠ HexDigit] [lookahead ≠ $]` is the String value consisting of the code unit `0x007B` (LEFT CURLY BRACKET).
- The TRV of `NotEscapeSequence :: u { NotCodePoint [lookahead ≠ HexDigit]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of NotCodePoint.
- The TRV of `NotEscapeSequence :: u { CodePoint [lookahead ≠ HexDigit] [lookahead ≠ $]` is the String value consisting of the code unit `0x007B` (LEFT CURLY BRACKET).
- The TRV of `NotEscapeSequence :: u { CodePoint [lookahead ≠ HexDigit] [lookahead ≠ $]` is the String value consisting of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of CodePoint.
- The TRV of `DecimalDigit :: one of 0 1 2 3 4 5 6 7 8 9` is the result of performing `UTF16EncodeCodePoint` on the single code point matched by this production.
- The TRV of `CharacterEscapeSequence :: NonEscapeCharacter` is the SV of NonEscapeCharacter.
- The TRV of `SingleEscapeCharacter :: one of "\bfnntv` is the result of performing `UTF16EncodeCodePoint` on the single code point matched by this production.
- The TRV of `HexEscapeSequence :: x HexDigit HexDigit` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of HexDigit.
- The TRV of `UnicodeEscapeSequence :: u Hex4Digits` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of Hex4Digits.
- The TRV of `UnicodeEscapeSequence :: u[ CodePoint ]` is the string-concatenation of the code unit `0x007B` (LEFT CURLY BRACKET) and the TRV of
• The TRV of $\textit{Hex4Digits} :: \textit{HexDigit} \textit{HexDigit} \textit{HexDigit} \textit{HexDigit}$ is the string-concatenation of the TRV of the first $\textit{HexDigit}$, the TRV of the second $\textit{HexDigit}$, the TRV of the third $\textit{HexDigit}$, and the TRV of the fourth $\textit{HexDigit}$.
• The TRV of $\textit{HexDigits} :: \textit{HexDigits} \textit{HexDigit}$ is the string-concatenation of the TRV of $\textit{HexDigits}$ and the TRV of $\textit{HexDigit}$.
• The TRV of $\textit{HexDigit} :: 0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F$ is the result of performing UTF16EncodeCodePoint on the single code point matched by this production.
• The TRV of $\textit{LineContinuation} :: \lineTerminatorSequence$ is the string-concatenation of the code unit 0x005C (REVERSE SOLIDUS) and the TRV of $\textit{LineTerminatorSequence}$.
• The TRV of $\textit{LineTerminatorSequence} :: \texttt{<LF>}$ is the String value consisting of the code unit 0x000A (LINE FEED).
• The TRV of $\textit{LineTerminatorSequence} :: \texttt{<CR>}$ is the String value consisting of the code unit 0x000A (LINE FEED).
• The TRV of $\textit{LineTerminatorSequence} :: \texttt{<LS>}$ is the String value consisting of the code unit 0x2028 (LINE SEPARATOR).
• The TRV of $\textit{LineTerminatorSequence} :: \texttt{<PS>}$ is the String value consisting of the code unit 0x2029 (PARAGRAPH SEPARATOR).
• The TRV of $\textit{LineTerminatorSequence} :: \texttt{<CR><LF>}$ is the String value consisting of the code unit 0x000A (LINE FEED).

**NOTE**

TV excludes the code units of $\textit{LineContinuation}$ while TRV includes them. $\texttt{<CR><LF>}$ and $\texttt{<CR><LF>}$ are normalized to $\texttt{<LF>}$ for both TV and TRV. An explicit $\textit{TemplateEscapeSequence}$ is needed to include a $\texttt{<CR>}$ or $\texttt{<CR><LF>}$ sequence.

# 12.10 Automatic Semicolon Insertion

Most ECMAScript statements and declarations must be terminated with a semicolon. Such semicolons may always appear explicitly in the source text. For convenience, however, such semicolons may be omitted from the source text in certain situations. These situations are described by saying that semicolons are automatically inserted into the source code token stream in those situations.

## 12.10.1 Rules of Automatic Semicolon Insertion

In the following rules, "token" means the actual recognized lexical token determined using the current lexical goal symbol as described in clause 12.

There are three basic rules of semicolon insertion:

1. When, as the source text is parsed from left to right, a token (called the offending token) is encountered that is not allowed by any production of the grammar, then a semicolon is automatically inserted before the offending token if one or more of the following conditions is true:
   - The offending token is separated from the previous token by at least one $\textit{LineTerminator}$.
   - The offending token is }.
   - The previous token is ) and the inserted semicolon would then be parsed as the terminating semicolon of a do-while statement (14.7.2).
2. When, as the source text is parsed from left to right, the end of the input stream of tokens is encountered and the parser is unable to parse the input token stream as a single instance of the goal nonterminal, then a semicolon is automatically inserted at the end of the input stream.
3. When, as the source text is parsed from left to right, a token is encountered that is allowed by some production of the grammar, but the production is a restricted production and the token would be the first token for a terminal or nonterminal immediately following the annotation "[no $\textit{LineTerminator}$ here]" within the restricted production (and therefore such a token is called a restricted token), and the restricted token is separated from the previous token by at least one $\textit{LineTerminator}$, then a semicolon is automatically inserted before the restricted token.
However, there is an additional overriding condition on the preceding rules: a semicolon is never inserted automatically if the semicolon would then be parsed as an empty statement or if that semicolon would become one of the two semicolons in the header of a `for` statement (see 14.7.4).

NOTE

The following are the only restricted productions in the grammar:

- `UpdateExpression[Yield, Await]`:
  - `LeftHandSideExpression[Yield, Await] no LineTerminator here` `++`
  - `LeftHandSideExpression[Yield, Await] no LineTerminator here` `--`

- `ContinueStatement[Yield, Await]`:
  - `continue`;
  - `continue no LineTerminator here` `LabelIdentifier[Yield, Await]`;

- `BreakStatement[Yield, Await]`:
  - `break`;
  - `break no LineTerminator here` `LabelIdentifier[Yield, Await]`;

- `ReturnStatement[Yield, Await]`:
  - `return`;
  - `return no LineTerminator here` `Expression[+In, ?Yield, ?Await]`;

- `ThrowStatement[Yield, Await]`:
  - `throw no LineTerminator here` `Expression[+In, ?Yield, ?Await]`;

- `YieldExpression[In, Await]`:
  - `yield`;
  - `yield no LineTerminator here` `AssignmentExpression[?In, +Yield, ?Await]`;
  - `yield no LineTerminator here` `* AssignmentExpression[?In, +Yield, ?Await]`;

- `ArrowFunction[In, Yield, Await]`:

- `AsyncFunctionDeclaration[Yield, Await, Default]`:
  - `async no LineTerminator here` `function BindingIdentifier[Yield, Await] ( FormalParameters[-Yield, +Await] ) {} AsyncFunctionBody`;
  - `async no LineTerminator here` `function ( FormalParameters[-Yield, +Await] ) {} AsyncFunctionBody`;

- `AsyncFunctionExpression`:
  - `async no LineTerminator here` `function BindingIdentifier[-Yield, +Await] opt ( FormalParameters[-Yield, +Await] ) {} AsyncFunctionBody`;

- `AsyncMethod[Yield, Await]`:
  - `async no LineTerminator here` `ClassElementName[Yield, Await] ( UniqueFormalParameters[-Yield, +Await] ) {} AsyncFunctionBody`;

- `AsyncGeneratorDeclaration[Yield, Await, Default]`:
  - `async no LineTerminator here` `function * BindingIdentifier[Yield, Await] ( FormalParameters[+Yield, +Await] ) {} AsyncGeneratorBody`;
  - `async no LineTerminator here` `function * ( FormalParameters[+Yield, +Await] ) {} AsyncGeneratorBody`;

- `AsyncGeneratorExpression`:

- `AsyncGeneratorMethod[Yield, Await]`:
  - `async no LineTerminator here` `* ClassElementName[Yield, Await] ( UniqueFormalParameters[+Yield, +Await] ) {} AsyncGeneratorBody`;

- `AsyncArrowFunction[In, Yield, Await]`:
  - `CoverCallExpressionAndAsyncArrowHead[Yield, ?Await] no LineTerminator here` `=> AsyncConciseBody[?In]`
AsyncArrowHead :

The practical effect of these restricted productions is as follows:

- When a `++` or `--` token is encountered where the parser would treat it as a postfix operator, and at least one `LineTerminator` occurred between the preceding token and the `++` or `--` token, then a semicolon is automatically inserted before the `++` or `--` token.
- When a `continue`, `break`, `return`, `throw`, or `yield` token is encountered and a `LineTerminator` is encountered before the next token, a semicolon is automatically inserted after the `continue`, `break`, `return`, `throw`, or `yield` token.
- When an `async` token is followed by a `LineTerminator` before a `=>` token, a semicolon is automatically inserted and the punctuator causes a syntax error.
- When an `async` token is followed by a `LineTerminator` before a `*` token, a semicolon is automatically inserted and the punctuator causes a syntax error.

The resulting practical advice to ECMAScript programmers is:

- A postfix `++` or `--` operator should be on the same line as its operand.
- An `Expression` in a `return` or `throw` statement or an `AssignmentExpression` in a `yield` expression should start on the same line as the `return`, `throw`, or `yield` token.
- A `LabelIdentifier` in a `break` or `continue` statement should be on the same line as the `break` or `continue` token.
- The end of an arrow function's parameter(s) and its `=>` should be on the same line.
- The `async` token preceding an asynchronous function or method should be on the same line as the immediately following token.

12.10.2 Examples of Automatic Semicolon Insertion

This section is non-normative.

The source

```
{ 1 2 } 3
```

is not a valid sentence in the ECMAScript grammar, even with the automatic semicolon insertion rules. In contrast, the source

```
{ 1 2 } 3
```

is also not a valid ECMAScript sentence, but is transformed by automatic semicolon insertion into the following:

```
{ 1 ;2 ;} 3;
```

which is a valid ECMAScript sentence.

The source

```
for (a; b)
```

This section is non-normative.
is not a valid ECMAScript sentence and is not altered by automatic semicolon insertion because the semicolon is needed for the header of a `for` statement. Automatic semicolon insertion never inserts one of the two semicolons in the header of a `for` statement.

The source

```
return
a + b
```

is transformed by automatic semicolon insertion into the following:

```
return;
a + b;
```

**NOTE 1** The expression `a + b` is not treated as a value to be returned by the `return` statement, because a `LineTerminator` separates it from the token `return`.

The source

```
a = b
++c
```

is transformed by automatic semicolon insertion into the following:

```
a = b;
++c;
```

**NOTE 2** The token `++` is not treated as a postfix operator applying to the variable `b`, because a `LineTerminator` occurs between `b` and `++`.

The source

```
if (a > b)
else c = d
```

is not a valid ECMAScript sentence and is not altered by automatic semicolon insertion before the `else` token, even though no production of the grammar applies at that point, because an automatically inserted semicolon would then be parsed as an empty statement.

The source

```
a = b + c
(d + e).print()
```

is not transformed by automatic semicolon insertion, because the parenthesized expression that begins the second line can be interpreted as an argument list for a function call:

```
a = b + c(d + e).print()
```

In the circumstance that an assignment statement must begin with a left parenthesis, it is a good idea for the programmer to provide an explicit semicolon at the end of the preceding statement rather than to rely on automatic semicolon insertion.

**12.10.3 Interesting Cases of Automatic Semicolon Insertion**

*This section is non-normative.*
ECMAScript programs can be written in a style with very few semicolons by relying on automatic semicolon insertion. As described above, semicolons are not inserted at every newline, and automatic semicolon insertion can depend on multiple tokens across line terminators.

As new syntactic features are added to ECMAScript, additional grammar productions could be added that cause lines relying on automatic semicolon insertion preceding them to change grammar productions when parsed.

For the purposes of this section, a case of automatic semicolon insertion is considered interesting if it is a place where a semicolon may or may not be inserted, depending on the source text which precedes it. The rest of this section describes a number of interesting cases of automatic semicolon insertion in this version of ECMAScript.

### 12.10.3.1 Interesting Cases of Automatic Semicolon Insertion in Statement Lists

In a `StatementList`, many `StatementListItem`s end in semicolons, which may be omitted using automatic semicolon insertion. As a consequence of the rules above, at the end of a line ending an expression, a semicolon is required if the following line begins with any of the following:

- **An opening parenthesis** (()). Without a semicolon, the two lines together are treated as a `CallExpression`.
- **An opening square bracket** ([]). Without a semicolon, the two lines together are treated as property access, rather than an `ArrayLiteral` or `ArrayAssignmentPattern`.
- **A template literal** (``). Without a semicolon, the two lines together are interpreted as a tagged Template (13.3.11), with the previous expression as the `MemberExpression`.
- **Unary + or -**. Without a semicolon, the two lines together are interpreted as a usage of the corresponding binary operator.
- **A RegExp literal**. Without a semicolon, the two lines together may be parsed instead as the `/` `MultiplicativeOperator`, for example if the RegExp has flags.

### 12.10.3.2 Cases of Automatic Semicolon Insertion and “[no LineTerminator here]”

This section is non-normative.

ECMAScript contains grammar productions which include “[no LineTerminator here]”. These productions are sometimes a means to have optional operands in the grammar. Introducing a `LineTerminator` in these locations would change the grammar production of a source text by using the grammar production without the optional operand.

The rest of this section describes a number of productions using “[no LineTerminator here]” in this version of ECMAScript.

### 12.10.3.2.1 List of Grammar Productions with Optional Operands and “[no LineTerminator here]”

- `UpdateExpression`
- `ContinueStatement`
- `BreakStatement`
- `ReturnStatement`
- `YieldExpression`
- Async Function Definitions (15.8) with relation to Function Definitions (15.2)
13 ECMAScript Language: Expressions

13.1 Identifiers

Syntax

IdentifierReference[Yield, Await] :
  Identifier
  [-Yield] yield
  [-Await] await

BindingIdentifier[Yield, Await] :
  Identifier
  yield
  await

LabelIdentifier[Yield, Await] :
  Identifier
  [-Yield] yield
  [-Await] await

Identifier :
  IdentifierName but not ReservedWord

NOTE  

yield and await are permitted as BindingIdentifier in the grammar, and prohibited with static semantics below, to prohibit automatic semicolon insertion in cases such as

```javascript
let await 0;
```

13.1.1 Static Semantics: Early Errors

BindingIdentifier : Identifier

- It is a Syntax Error if the source text matched by this production is contained in strict mode code and the StringValue of Identifier is either "arguments" or "eval".

IdentifierReference : yield
BindingIdentifier : yield
LabelIdentifier : yield

- It is a Syntax Error if the source text matched by this production is contained in strict mode code.

IdentifierReference : await
BindingIdentifier : await
LabelIdentifier : await

- It is a Syntax Error if the goal symbol of the syntactic grammar is Module.

BindingIdentifier[Yield, Await] : yield

- It is a Syntax Error if this production has a [Yield] parameter.

BindingIdentifier[Yield, Await] : await
It is a Syntax Error if this production has an \([\text{Await}]\) parameter.

\[
\text{IdentifierReference[\text{Yield, Await}]} \ : \ \text{Identifier}
\]

\[
\text{BindingIdentifier[\text{Yield, Await}]} \ : \ \text{Identifier}
\]

\[
\text{LabelIdentifier[\text{Yield, Await}]} \ : \ \text{Identifier}
\]

It is a Syntax Error if this production has a \([\text{Yield}]\) parameter and \text{StringValue} of \text{Identifier} is "\text{yield}".

It is a Syntax Error if this production has an \([\text{Await}]\) parameter and \text{StringValue} of \text{Identifier} is "\text{await}".

\[
\text{Identifier} \ : \ \text{IdentifierName} \ \text{but not ReservedWord}
\]

It is a Syntax Error if this phrase is contained in strict mode code and the \text{StringValue} of \text{IdentifierName} is one of "\text{implements}", "\text{interface}", "\text{let}", "\text{package}", "\text{private}", "\text{protected}", "\text{public}", "\text{static}", or "\text{yield}".

It is a Syntax Error if the \text{goal symbol} of the syntactic grammar is \text{Module} and the \text{StringValue} of \text{IdentifierName} is "\text{await}".

It is a Syntax Error if the \text{StringValue} of \text{IdentifierName} is the \text{StringValue} of any \text{ReservedWord} except for \text{yield} or \text{await}.

\text{NOTE}: \text{StringValue} of \text{IdentifierName} normalizes any Unicode escape sequences in \text{IdentifierName} hence such escapes cannot be used to write an \text{Identifier} whose code point sequence is the same as a \text{ReservedWord}.

### 13.1.2 Static Semantics: StringValue

The \text{syntax-directed operation} \text{StringValue} takes no arguments and returns a String. It is defined piecewise over the following productions:

\[
\text{IdentifierName} ::=
\begin{align*}
& \quad \text{IdentifierStart} \\
& \quad \text{IdentifierName} \ \text{IdentifierPart}
\end{align*}
\]

1. Let \text{idTextUnescaped} be \text{IdentifierCodePoints} of \text{IdentifierName}.
2. Return \text{CodePointsToString(idTextUnescaped)}.

\[
\text{IdentifierReference} : \text{yield}
\]

\[
\text{BindingIdentifier} : \text{yield}
\]

\[
\text{LabelIdentifier} : \text{yield}
\]

1. Return "\text{yield}".

\[
\text{IdentifierReference} : \text{await}
\]

\[
\text{BindingIdentifier} : \text{await}
\]

\[
\text{LabelIdentifier} : \text{await}
\]

1. Return "\text{await}".

\[
\text{Identifier} : \ \text{IdentifierName} \ \text{but not ReservedWord}
\]

1. Return the \text{StringValue} of \text{IdentifierName}.

\[
\text{PrivatelIdentifier} ::=
\begin{align*}
& \quad \# \ \text{IdentifierName} \\
\end{align*}
\]

1. Return the \text{string-concatenation} of 0x0023 (NUMBER SIGN) and the \text{StringValue} of \text{IdentifierName}.

\[
\text{ModuleExportName} : \ \text{StringLiteral}
\]

1. Return the \text{SV} of \text{StringLiteral}. 
13.1.3 Runtime Semantics: Evaluation

`IdentifierReference` : `Identifier`

1. Return `ResolveBinding(StringValue of Identifier)`.

`IdentifierReference` : `yield`

1. Return `ResolveBinding("yield")`.

`IdentifierReference` : `await`

1. Return `ResolveBinding("await")`.

**NOTE 1** The result of evaluating an `IdentifierReference` is always a value of type `Reference`.

**NOTE 2** In non-strict code, the keyword `yield` may be used as an identifier. Evaluating the `IdentifierReference` resolves the binding of `yield` as if it was an `Identifier`. Early Error restriction ensures that such an evaluation only can occur for non-strict code.

### 13.2 Primary Expression

**Syntax**

```
PrimaryExpression[Yield, Await] :
  this
  IdentifierReference[Yield, Await]
  Literal
  ArrayLiteral[Yield, Await]
  ObjectLiteral[Yield, Await]
  FunctionExpression
  ClassExpression[Yield, Await]
  GeneratorExpression
  AsyncFunctionExpression
  AsyncGeneratorExpression
  RegularExpressionLiteral
  TemplateLiteral[Yield, Await, ~Tagged]
  CoverParenthesizedExpressionAndArrowParameterList[Yield, Await]?
```

```
CoverParenthesizedExpressionAndArrowParameterList[Yield, Await] :
  ( Expression[+In, Yield, Await] )
  ( Expression[+In, Yield, Await] , )
  ( )
  ( ... BindingIdentifier[Yield, Await] )
  ( ... BindingPattern[Yield, Await] )
  ( Expression[+In, Yield, Await] , ... BindingIdentifier[Yield, Await] )
  ( Expression[+In, Yield, Await] , ... BindingPattern[Yield, Await] )
```
Supplemental Syntax

When processing an instance of the production

\[
\text{PrimaryExpression} : \text{Yield, Await} \\
\text{CoverParenthesizedExpressionAndArrowParameterList} : \text{Yield, Await}
\]

the interpretation of \text{CoverParenthesizedExpressionAndArrowParameterList} is refined using the following grammar:

\[
\text{ParenthesizedExpression} : \text{Yield, Await} \\
( \text{Expression} + \text{In, Yield, Await} )
\]

13.2.1 The this Keyword

13.2.1.1 Runtime Semantics: Evaluation

\[
\text{PrimaryExpression} : \text{this}
\]

1. Return ? ResolveThisBinding().

13.2.2 Identifier Reference

See 13.1 for IdentifierReference.

13.2.3 Literals

Syntax

\[
\text{Literal} : \\
\text{NullLiteral} \\
\text{BooleanLiteral} \\
\text{NumericLiteral} \\
\text{StringLiteral}
\]

13.2.3.1 Runtime Semantics: Evaluation

\[
\text{Literal} : \text{NullLiteral}
\]

1. Return null.

\[
\text{Literal} : \text{BooleanLiteral}
\]

1. If \text{BooleanLiteral} is the token \text{false}, return \text{false}.
2. If \text{BooleanLiteral} is the token \text{true}, return \text{true}.

\[
\text{Literal} : \text{NumericLiteral}
\]

1. Return the \text{NumericValue} of \text{NumericLiteral} as defined in 12.9.3.

\[
\text{Literal} : \text{StringLiteral}
\]

1. Return the \text{SV} of \text{StringLiteral} as defined in 12.9.4.2.
13.2.4 Array Initializer

**NOTE** An *ArrayLiteral* is an expression describing the initialization of an Array, using a list, of zero or more expressions each of which represents an array element, enclosed in square brackets. The elements need not be literals; they are evaluated each time the array initializer is evaluated.

Array elements may be elided at the beginning, middle or end of the element list. Whenever a comma in the element list is not preceded by an *AssignmentExpression* (i.e., a comma at the beginning or after another comma), the missing array element contributes to the length of the Array and increases the index of subsequent elements. Elided array elements are not defined. If an element is elided at the end of an array, that element does not contribute to the length of the Array.

**Syntax**

```javascript
ArrayLiteral[Yield, Await] :
  [ Elisionopt ]

ElementList[Yield, Await] :
  Elisionopt AssignmentExpression[+In, ?Yield, ?Await]
  Elisionopt SpreadElement[?Yield, ?Await]

Elision :
  ,
  Elision ,

SpreadElement[Yield, Await] :
  ... AssignmentExpression[+In, ?Yield, ?Await]
```

13.2.4.1 Runtime Semantics: ArrayAccumulation

The syntax-directed operation `ArrayAccumulation` takes arguments `array` (an Array) and `nextIndex` (an integer) and returns either a normal completion containing an integer or an abrupt completion. It is defined piecewise over the following productions:

**Elision** :

1. Let `len` be `nextIndex` + 1.
2. Perform `? Set(array, "length", F(len), true).
3. NOTE: The above step throws if `len` exceeds $2^{32} - 1$.
4. Return `len`.

**Elision** : `Elision`

1. Return `? ArrayAccumulation of Elision with arguments array and (nextIndex + 1)`.

**ElementList** : `Elisionopt AssignmentExpression`

1. If `Elision` is present, then
   a. Set `nextIndex` to `? ArrayAccumulation of Elision with arguments array and nextIndex`.
3. Let `initValue` be `? GetValue(initResult)`.
4. Perform `! CreateDataPropertyOrThrow(array, ! ToString(F(nextIndex)), initValue)`.
5. Return `nextIndex` + 1.
ElementList : Elision opt SpreadElement

1. If Elision is present, then
   a. Set nextIndex to \( \text{ArrayAccumulation of Elision with arguments array and nextIndex} \).
2. Return \( \text{ArrayAccumulation of SpreadElement with arguments array and nextIndex} \).

ElementList : ElementList , Elision opt AssignmentExpression

1. Set nextIndex to \( \text{ArrayAccumulation of ElementList with arguments array and nextIndex} \).
2. If Elision is present, then
   a. Set nextIndex to \( \text{ArrayAccumulation of Elision with arguments array and nextIndex} \).
3. Let \( \\text{initResult} \) be \( \text{Evaluation of AssignmentExpression} \).
4. Let \( \\text{initValue} \) be \( \text{GetValue(} \text{initResult} \text{)} \).
5. Perform \( \text{CreateDataPropertyOrThrow(array, ! ToString(F(nextIndex)), initValue)} \).
6. Return nextIndex + 1.

ElementList : ElementList , Elision opt SpreadElement

1. Set nextIndex to \( \text{ArrayAccumulation of ElementList with arguments array and nextIndex} \).
2. If Elision is present, then
   a. Set nextIndex to \( \text{ArrayAccumulation of Elision with arguments array and nextIndex} \).
3. Return \( \text{ArrayAccumulation of SpreadElement with arguments array and nextIndex} \).

SpreadElement : ... AssignmentExpression

1. Let \( \\text{spreadRef} \) be \( \text{Evaluation of AssignmentExpression} \).
2. Let \( \\text{spreadObj} \) be \( \text{GetValue(} \text{spreadRef} \text{)} \).
3. Let \( \\text{iteratorRecord} \) be \( \text{GetIterator(spreadObj, SYNC)} \).
4. Repeat,
   a. Let \( \\text{next} \) be \( \text{IteratorStepValue(} \text{iteratorRecord} \text{)} \).
   b. If \( \\text{next} \) is DONE, return nextIndex.
   c. Perform \( \text{CreateDataPropertyOrThrow(array, ! ToString(F(nextIndex)), next)} \).
   d. Set nextIndex to nextIndex + 1.

NOTE CreateDataPropertyOrThrow is used to ensure that own properties are defined for the array even if the standard built-in Array prototype object has been modified in a manner that would preclude the creation of new own properties using [[Set]].

13.2.4.2 Runtime Semantics: Evaluation

ArrayLiteral : [ Elision opt ]

1. Let \( \\text{array} \) be \( \text{ArrayCreate(} \text{0} \text{)} \).
2. If Elision is present, then
   a. Perform \( \text{ArrayAccumulation of Elision with arguments array and 0} \).
3. Return \( \\text{array} \).

ArrayLiteral : [ ElementList ]

1. Let \( \\text{array} \) be \( \text{ArrayCreate(} \text{0} \text{)} \).
2. Perform \( \text{ArrayAccumulation of ElementList with arguments array and 0} \).
3. Return \( \\text{array} \).

ArrayLiteral : [ ElementList , Elision opt ]

1. Let \( \\text{array} \) be \( \text{ArrayCreate(} \text{0} \text{)} \).
2. Let nextIndex be \( \text{ArrayAccumulation of ElementList with arguments array and 0} \).
3. If Elision is present, then
   a. Perform ? ArrayAccumulation of Elision with arguments array and nextIndex.
4. Return array.

13.2.5 Object Initializer

NOTE 1 An object initializer is an expression describing the initialization of an Object, written in a form resembling a literal. It is a list of zero or more pairs of property keys and associated values, enclosed in curly brackets. The values need not be literals; they are evaluated each time the object initializer is evaluated.

Syntax

```
ObjectLiteral[Yield, Await] :
  { }

PropertyDefinitionList[Yield, Await] :
  PropertyDefinition[?Yield, ?Await]
  PropertyDefinitionList[?Yield, ?Await],

PropertyDefinition[?Yield, ?Await] :
  IdentifierReference[?Yield, ?Await]
  CoverInitializedName[?Yield, ?Await]
  MethodDefinition[?Yield, ?Await]
  ... AssignmentExpression[+In, ?Yield, ?Await]

PropertyName[?Yield, ?Await] :
  LiteralPropertyName
  ComputedPropertyName[?Yield, ?Await]

LiteralPropertyName :
  IdentifierName
  StringLiteral
  NumericLiteral

ComputedPropertyName[?Yield, ?Await] :
  [ AssignmentExpression[+In, ?Yield, ?Await] ]

CoverInitializedName[?Yield, ?Await] :
  IdentifierReference[?Yield, ?Await]Initializer[+In, ?Yield, ?Await]

Initializer[In, Yield, Await] :
  = AssignmentExpression[?In, ?Yield, ?Await]
```

NOTE 2 MethodDefinition is defined in 15.4.
NOTE 3 In certain contexts, `ObjectLiteral` is used as a cover grammar for a more restricted secondary grammar. The `CoverInitializedName` production is necessary to fully cover these secondary grammars. However, use of this production results in an early Syntax Error in normal contexts where an actual `ObjectLiteral` is expected.

13.2.5.1 Static Semantics: Early Errors

PropertyDefinition : MethodDefinition

- It is a Syntax Error if `HasDirectSuper` of `MethodDefinition` is `true`.
- It is a Syntax Error if `PrivateBoundIdentifiers` of `MethodDefinition` is not empty.

In addition to describing an actual object initializer the `ObjectLiteral` productions are also used as a cover grammar for `ObjectAssignmentPattern` and may be recognized as part of a `CoverParenthesizedExpressionAndArrowParameterList`. When `ObjectLiteral` appears in a context where `ObjectAssignmentPattern` is required the following Early Error rules are not applied. In addition, they are not applied when initially parsing a `CoverParenthesizedExpressionAndArrowParameterList` or `CoverCallExpressionAndAsyncArrowHead`.

PropertyDefinition : CoverInitializedName

- It is a Syntax Error if any source text is matched by this production.

NOTE 1 This production exists so that `ObjectLiteral` can serve as a cover grammar for `ObjectAssignmentPattern`. It cannot occur in an actual object initializer.

`ObjectLiteral` :

\[
\{ \text{PropertyDefinitionList} \} \\
\{ \text{PropertyDefinitionList}, \}
\]

- It is a Syntax Error if `PropertyNameList` of `PropertyDefinitionList` contains any duplicate entries for "__proto__" and at least two of those entries were obtained from productions of the form `PropertyName : LiteralPropertyName`. This rule is not applied if this `ObjectLiteral` is contained within a `Script` that is being parsed for JSON.parse (see step 4 of `JSON.parse`).

NOTE 2 The List returned by `PropertyNameList` does not include property names defined using a `ComputedPropertyName`.

13.2.5.2 Static Semantics: IsComputedPropertyKey

The syntax-directed operation `IsComputedPropertyKey` takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

`PropertyName : LiteralPropertyName`

1. Return `false`.

`PropertyName : ComputedPropertyName`

1. Return `true`.
13.2.5.3 Static Semantics: PropertyNameList

The syntax-directed operation PropertyNameList takes no arguments and returns a List of Strings. It is defined piecewise over the following productions:

\[\text{PropertyDefinitionList} : \text{PropertyDefinition} \]

1. Let \( propName \) be \( \text{PropName} \) of \( \text{PropertyDefinition} \).
2. If \( propName \) is EMPTY, return a new empty List.
3. Return « \( propName \) ».

\[\text{PropertyDefinitionList} : \text{PropertyDefinitionList} , \text{PropertyDefinition} \]

1. Let \( list \) be \( \text{PropertyNameList} \) of \( \text{PropertyDefinitionList} \).
2. Let \( propName \) be \( \text{PropName} \) of \( \text{PropertyDefinition} \).
3. If \( propName \) is EMPTY, return \( list \).
4. Return the list-concatenation of \( list \) and « \( propName \) ».

13.2.5.4 Runtime Semantics: Evaluation

\[\text{ObjectLiteral} : \{ \} \]

1. Return \( \text{ OrdinaryObjectCreate}(\%\text{Object.prototype}\%) \).

\[\text{ObjectLiteral} : \{ \text{ PropertyDefinitionList } \} \]

\[\{ \text{ PropertyDefinitionList , } \} \]

1. Let \( obj \) be \( \text{ OrdinaryObjectCreate}(\%\text{Object.prototype}\%) \).
2. Perform ? PropertyDefinitionEvaluation of \( \text{ PropertyDefinitionList } \) with argument \( obj \).
3. Return \( obj \).

\[\text{LiteralPropertyName} : \text{ IdentifierName} \]

1. Return \( \text{ StringValue} \) of \( \text{ IdentifierName} \).

\[\text{LiteralPropertyName} : \text{ StringLiteral} \]

1. Return the \( \text{ SV} \) of \( \text{ StringLiteral} \).

\[\text{LiteralPropertyName} : \text{ NumericLiteral} \]

1. Let \( nbr \) be the \( \text{ NumericValue} \) of \( \text{ NumericLiteral} \).
2. Return ! \( \text{ ToString}(nbr) \).

\[\text{ComputedPropertyName} : [ \text{ AssignmentExpression } ] \]

1. Let \( exprValue \) be ? Evaluation of \( \text{ AssignmentExpression} \).
2. Let \( propName \) be ? GetValue(\( exprValue \)).
3. Return ? ToPropertyKey(\( propName \)).

13.2.5.5 Runtime Semantics: PropertyDefinitionEvaluation

The syntax-directed operation PropertyDefinitionEvaluation takes argument \( object \) (an Object) and returns either a normal completion containing UNUSED or an abrupt completion. It is defined piecewise over the following productions:

\[\text{PropertyDefinitionList} : \text{PropertyDefinitionList} , \text{PropertyDefinition} \]

1. Perform ? PropertyDefinitionEvaluation of \( \text{ PropertyDefinitionList} \) with argument \( object \).
2. Perform ? PropertyDefinitionEvaluation of \( \text{ PropertyDefinition} \) with argument \( object \).
3. Return UNUSED.
PropertyDefinition : ... AssignmentExpression

1. Let exprValue be ? Evaluation of AssignmentExpression.
2. Let fromValue be ? GetValue(exprValue).
3. Let excludedNames be a new empty List.
5. Return UNUSED.

PropertyDefinition : IdentifierReference

1. Let propName be StringValue of IdentifierReference.
3. Let propValue be ? GetValue(exprValue).
4. Assert: object is an ordinary, extensible object with no non-configurable properties.
5. Perform ! CreateDataPropertyOrThrow(object, propName, propValue).
6. Return UNUSED.

PropertyDefinition : PropertyName : AssignmentExpression

1. Let propKey be ? Evaluation of PropertyName.
2. If this PropertyDefinition is contained within a Script that is being evaluated for JSON.parse (see step 7 of JSON.parse), then
   a. Let isProtoSetter be false.
3. Else if propKey is "__proto__" and IsComputedPropertyKey of PropertyName is false, then
   a. Let isProtoSetter be true.
4. Else,
   a. Let isProtoSetter be false.
5. If IsAnonymousFunctionDefinition(AssignmentExpression) is true and isProtoSetter is false, then
   a. Let exprValueRef be ? Evaluation of AssignmentExpression with argument propKey.
6. Else,
   a. Let propValue be ? GetValue(exprValueRef).
7. If isProtoSetter is true, then
   a. If propValue is an Object or propValue is null, then
      i. Perform ! object.[[SetPrototypeOf]](propValue).
   b. Return UNUSED.
8. Assert: object is an ordinary, extensible object with no non-configurable properties.
9. Perform ! CreateDataPropertyOrThrow(object, propKey, propValue).
10. Return UNUSED.

PropertyDefinition : MethodDefinition

2. Return UNUSED.

13.2.6 Function Defining Expressions

See 15.2 for PrimaryExpression : FunctionExpression.
See 15.5 for PrimaryExpression : GeneratorExpression.
See 15.7 for PrimaryExpression : ClassExpression.
See 15.8 for PrimaryExpression : AsyncFunctionExpression.
See 15.6 for PrimaryExpression : AsyncGeneratorExpression.
13.2.7 Regular Expression Literals

Syntax

See 12.9.5.

13.2.7.1 Static Semantics: Early Errors

PrimaryExpression : RegularExpressionLiteral

• It is a Syntax Error if IsValidRegularExpressionLiteral(RegularExpressionLiteral) is false.

13.2.7.2 Static Semantics: IsValidRegularExpressionLiteral ( literal )

The abstract operation IsValidRegularExpressionLiteral takes argument literal (a RegularExpressionLiteral Parse Node) and returns a Boolean. It determines if its argument is a valid regular expression literal. It performs the following steps when called:

1. Let flags be FlagText of literal.
2. If flags contains any code points other than d, g, i, m, s, u, v, or y, or if flags contains any code point more than once, return false.
3. If flags contains u, let u be true; else let u be false.
4. If flags contains v, let v be true; else let v be false.
5. Let patternText be BodyText of literal.
6. If u is false and v is false, then
   a. Let stringValue be CodePointsToString(patternText).
   b. Set patternText to the sequence of code points resulting from interpreting each of the 16-bit elements of stringValue as a Unicode BMP code point. UTF-16 decoding is not applied to the elements.
7. Let parseResult be ParsePattern(patternText, u, v).
8. If parseResult is a Parse Node, return true; else return false.

13.2.7.3 Runtime Semantics: Evaluation

PrimaryExpression : RegularExpressionLiteral

1. Let pattern be CodePointsToString(BodyText of RegularExpressionLiteral).
2. Let flags be CodePointsToString(FlagText of RegularExpressionLiteral).

13.2.8 Template Literals

Syntax

TemplateLiteral[Yield, Await, Tagged] :
  NoSubstitutionTemplate
  SubstitutionTemplate[?Yield, ?Await, ?Tagged]

SubstitutionTemplate[Yield, Await, Tagged] :
  TemplateHead Expression[+In, ?Yield, ?Await]
  TemplateSpans[?Yield, ?Await, ?Tagged]

TemplateSpans[Yield, Await, Tagged] :
  TemplateTail
13.2.8.1 Static Semantics: Early Errors

TemplateLiteral[Yield, Await, Tagged] : NoSubstitutionTemplate

- It is a Syntax Error if the [Tagged] parameter was not set and NoSubstitutionTemplate Contains NotEscapeSequence.


- It is a Syntax Error if the number of elements in the result of TemplateStrings of TemplateLiteral with argument false is greater than or equal to $2^{32}$.

SubstitutionTemplate[Yield, Await, Tagged] : TemplateHead Expression [+In, ?Yield, ?Await]
TemplateSpans[?Yield, ?Await, ?Tagged]

- It is a Syntax Error if the [Tagged] parameter was not set and TemplateHead Contains NotEscapeSequence.

TemplateSpans[Yield, Await, Tagged] : TemplateTail

- It is a Syntax Error if the [Tagged] parameter was not set and TemplateTail Contains NotEscapeSequence.

TemplateMiddleList[Yield, Await, Tagged] :
TemplateMiddle Expression [+In, ?Yield, ?Await]

- It is a Syntax Error if the [Tagged] parameter was not set and TemplateMiddle Contains NotEscapeSequence.

13.2.8.2 Static Semantics: TemplateStrings

The syntax-directed operation TemplateStrings takes argument raw (a Boolean) and returns a List of either Strings or undefined. It is defined piecewise over the following productions:

TemplateLiteral : NoSubstitutionTemplate

1. Return « TemplateString(NoSubstitutionTemplate, raw) ».

SubstitutionTemplate : TemplateHead Expression TemplateSpans

1. Let head be « TemplateString(TemplateHead, raw) ».
2. Let tail be TemplateStrings of TemplateSpans with argument raw.
3. Return the list-concatenation of head and tail.

TemplateSpans : TemplateTail

1. Return « TemplateString(TemplateTail, raw) ».

TemplateSpans : TemplateMiddleList TemplateTail

1. Let middle be TemplateStrings of TemplateMiddleList with argument raw.
2. Let tail be « TemplateString(TemplateTail, raw) ».
3. Return the list-concatenation of middle and tail.
Let \( \text{templateToken} \) be a NoSubstitutionTemplate Parse Node, a TemplateHead Parse Node, a TemplateMiddle Parse Node, or a TemplateTail Parse Node and \( \text{raw} \) (a Boolean) and returns a String or undefined. It performs the following steps when called:

1. If \( \text{raw} \) is true, then
   a. Let \( \text{string} \) be the TRV of \( \text{templateToken} \).
2. Else,
   a. Let \( \text{string} \) be the TV of \( \text{templateToken} \).
3. Return \( \text{string} \).

**NOTE** This operation returns undefined if \( \text{raw} \) is false and \( \text{templateToken} \) contains a NotEscapeSequence. In all other cases, it returns a String.

### 13.2.8.4 GetTemplateObject (templateLiteral)

The abstract operation GetTemplateObject takes argument \( \text{templateLiteral} \) (a Parse Node) and returns an Array. It performs the following steps when called:

1. Let \( \text{realm} \) be the current Realm Record.
2. Let \( \text{templateRegistry} \) be \( \text{realm}.[[\text{TemplateMap}]] \).
3. For each element \( e \) of \( \text{templateRegistry} \), do
   a. If \( e.[[\text{Site}]] \) is the same Parse Node as \( \text{templateLiteral} \), then
      i. Return \( e.[[\text{Array}]] \).
4. Let \( \text{rawStrings} \) be TemplateStrings of \( \text{templateLiteral} \) with argument true.
5. Assert: \( \text{rawStrings} \) is a List of Strings.
6. Let \( \text{cookedStrings} \) be TemplateStrings of \( \text{templateLiteral} \) with argument false.
7. Let \( \text{count} \) be the number of elements in the List \( \text{cookedStrings} \).
8. Assert: \( \text{count} \leq 2^{32} - 1 \).
9. Let \( \text{template} \) be ! ArrayCreate(\( \text{count} \)).
10. Let \( \text{rawObj} \) be ! ArrayCreate(\( \text{count} \)).
11. Let \( \text{index} \) be \( 0 \).
12. Repeat, while \( \text{index} < \text{count} \),
   a. Let \( \text{prop} \) be ! ToString(\( \text{F}([[\text{index}]])) \).
   b. Let \( \text{cookedValue} \) be \( \text{cookedStrings}[[\text{index}]] \).
   c. Perform ! DefinePropertyOrThrow(\( \text{template} \), \( \text{prop} \), PropertyDescriptor { \([[[\text{Value}]]]: \text{cookedValue},\n      [[[\text{Writable}]]]: \text{false}, \text{[[Enumerable]]]: \text{true}, \text{[[Configurable]]]: \text{false}} \)).
   d. Let \( \text{rawValue} \) be the String value \( \text{rawStrings}[[\text{index}]] \).
   e. Perform ! DefinePropertyOrThrow(\( \text{rawObj} \), \( \text{prop} \), PropertyDescriptor { \([[[\text{Value}]]]: \text{rawValue},\n      [[[\text{Writable}]]]: \text{false}, \text{[[Enumerable]]]: \text{true}, \text{[[Configurable]]]: \text{false}} \)).
   f. Set \( \text{index} \) to \( \text{index} + 1 \).
13. Perform ! SetIntegrityLevel(\( \text{rawObj} \), FROZEN).
14. Perform ! DefinePropertyOrThrow(\( \text{template} \), "raw", PropertyDescriptor { \([[[\text{Value}]]]: \text{rawObj},\n      [[[\text{Writable}]]]: \text{false}, \text{[[Enumerable]]]: \text{false}, \text{[[Configurable]]]: \text{false}} \)).
15. Perform ! SetIntegrityLevel(\( \text{template} \), FROZEN).
16. Append the Record { \([[[\text{Site}]]]: \text{templateLiteral}, [[\text{Array}]]: \text{template} \) to \( \text{realm}.[[\text{TemplateMap}]] \).
17. Return \( \text{template} \).
NOTE 1  The creation of a template object cannot result in an abrupt completion.

NOTE 2  Each TemplateLiteral in the program code of a realm is associated with a unique template object that is used in the evaluation of tagged Templates (13.2.8.6). The template objects are frozen and the same template object is used each time a specific tagged Template is evaluated. Whether template objects are created lazily upon first evaluation of the TemplateLiteral or eagerly prior to first evaluation is an implementation choice that is not observable to ECMAScript code.

NOTE 3  Future editions of this specification may define additional non-enumerable properties of template objects.

13.2.8.5  Runtime Semantics: SubstitutionEvaluation

The syntax-directed operation SubstitutionEvaluation takes no arguments and returns either a normal completion containing a List of ECMAScript language values or an abrupt completion. It is defined piecewise over the following productions:

TemplateSpans : TemplateTail

1. Return a new empty List.

TemplateSpans : TemplateMiddleList  TemplateTail

1. Return ? SubstitutionEvaluation of TemplateMiddleList.

TemplateMiddleList : TemplateMiddle  Expression

1. Let subRef be ? Evaluation of Expression.
2. Let sub be ? GetValue(subRef).
3. Return « sub ».

TemplateMiddleList : TemplateMiddleList  TemplateMiddle  Expression

1. Let preceding be ? SubstitutionEvaluation of TemplateMiddleList.
2. Let nextRef be ? Evaluation of Expression.
3. Let next be ? GetValue(nextRef).
4. Return the list-concatenation of preceding and « next ».

13.2.8.6  Runtime Semantics: Evaluation

TemplateLiteral : NoSubstitutionTemplate

1. Return the TV of NoSubstitutionTemplate as defined in 12.9.6.

SubstitutionTemplate : TemplateHead  Expression  TemplateSpans

1. Let head be the TV of TemplateHead as defined in 12.9.6.
2. Let subRef be ? Evaluation of Expression.
3. Let sub be ? GetValue(subRef).
4. Let middle be ? ToString(sub).
5. Let tail be ? Evaluation of TemplateSpans.
6. Return the string-concatenation of head, middle, and tail.

NOTE 1  The string conversion semantics applied to the Expression value are like String.prototype.concat rather than the + operator.
1. Return the TV of TemplateTail as defined in 12.9.6.

TemplateSpans : TemplateMiddleList TemplateTail

1. Let head be ? Evaluation of TemplateMiddleList.
2. Let tail be the TV of TemplateTail as defined in 12.9.6.
3. Return the string-concatenation of head and tail.

TemplateMiddleList : TemplateMiddle Expression

1. Let head be the TV of TemplateMiddle as defined in 12.9.6.
2. Let subRef be ? Evaluation of Expression.
3. Let sub be ? GetValue(subRef).
4. Let middle be ? ToString(sub).
5. Return the string-concatenation of head and middle.

NOTE 2 The string conversion semantics applied to the Expression value are like String.prototype.concat rather than the + operator.

TemplateMiddleList : TemplateMiddleList TemplateMiddle Expression

1. Let rest be ? Evaluation of TemplateMiddleList.
2. Let middle be the TV of TemplateMiddle as defined in 12.9.6.
4. Let sub be ? GetValue(subRef).
5. Let last be ? ToString(sub).
6. Return the string-concatenation of rest, middle, and last.

NOTE 3 The string conversion semantics applied to the Expression value are like String.prototype.concat rather than the + operator.

13.2.9 The Grouping Operator

13.2.9.1 Static Semantics: Early Errors

PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList

• CoverParenthesizedExpressionAndArrowParameterList must cover a ParenthesizedExpression.

13.2.9.2 Runtime Semantics: Evaluation

PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.

ParenthesizedExpression : ( Expression )

1. Return ? Evaluation of Expression. This may be of type Reference.

NOTE This algorithm does not apply GetValue to Evaluation of Expression. The principal motivation for this is so that operators such as delete and typeof may be applied to parenthesized expressions.
13.3 Left-Hand-Side Expressions

Syntax

\[
\begin{align*}
\text{MemberExpression} & \text{[Yield, Await]} : \\
\text{PrimaryExpression} & \text{[?Yield, ?Await]} \\
\text{MemberExpression} & \text{[?Yield, ?Await]} \quad [ \text{Expression}[+\text{In, ?Yield, ?Await}] ] \\
\text{MemberExpression} & \text{[?Yield, ?Await]} \quad . \quad \text{IdentifierName} \\
\text{MemberExpression} & \text{[?Yield, ?Await]} \quad \text{TemplateLiteral}[?Yield, ?Await, +\text{Tagged}] \\
\text{SuperProperty} & \text{[?Yield, ?Await]} \\
\text{MetaProperty} & \text{new MemberExpression} \quad \text{Arguments}[?Yield, ?Await] \\
\text{MemberExpression} & \text{[?Yield, ?Await]} \quad . \quad \text{PrivatIdentifier} \\
\text{SuperProperty} & \text{[Yield, Await]} : \\
\text{super} & \quad [ \text{Expression}[+\text{In, ?Yield, ?Await}] ] \\
\text{super} & \quad . \quad \text{IdentifierName} \\
\text{MetaProperty} : \\
\text{NewTarget} & \quad \text{ImportMeta} \\
\text{NewTarget} : \\
\text{new} & \quad . \quad \text{target} \\
\text{ImportMeta} : \\
\text{import} & \quad . \quad \text{meta} \\
\text{NewExpression} & \text{[Yield, Await]} : \\
\text{MemberExpression} & \text{[?Yield, ?Await]} \\
\text{new} & \quad \text{NewExpression}[?Yield, ?Await] \\
\text{CallExpression} & \text{[Yield, Await]} : \\
\text{CoverCallExpressionAndAsyncArrowHead} & \text{[?Yield, ?Await]} \\
\text{SuperCall} & \text{[?Yield, ?Await]} \\
\text{ImportCall} & \text{[?Yield, ?Await]} \\
\text{CallExpression} & \text{[?Yield, ?Await]} \quad \text{Arguments}[?Yield, ?Await] \\
\text{CallExpression} & \text{[?Yield, ?Await]} \quad [ \text{Expression}[+\text{In, ?Yield, ?Await}] ] \\
\text{CallExpression} & \text{[?Yield, ?Await]} \quad . \quad \text{IdentifierName} \\
\text{CallExpression} & \text{[?Yield, ?Await]} \quad \text{TemplateLiteral}[?Yield, ?Await, +\text{Tagged}] \\
\text{CallExpression} & \text{[?Yield, ?Await]} \quad . \quad \text{PrivatIdentifier} \\
\text{SuperCall} & \text{[Yield, Await]} : \\
\text{super} & \quad \text{Arguments}[?Yield, ?Await] \\
\text{ImportCall} & \text{[Yield, Await]} : \\
\text{import} & \quad ( \text{AssignmentExpression}[+\text{In, ?Yield, ?Await}] ) \\
\text{Arguments} & \text{[Yield, Await]} : \\
( ) & \quad ( \text{ArgumentList}[?Yield, ?Await] ) \\
( ) & \quad ( \text{ArgumentList}[?Yield, ?Await], )
\end{align*}
\]
When processing an instance of the production

\[ \text{CallExpression} : \text{CoverCallExpressionAndAsyncArrowHead} \]

the interpretation of \text{CoverCallExpressionAndAsyncArrowHead} is refined using the following grammar:

\[ \begin{align*}
\text{CallMemberExpression} & : \\
\text{MemberExpression} & : \text{Arguments} \text{[Yield, Await] \ OptionalChain [Yield, Await]}
\end{align*} \]

13.3.1 Static Semantics

13.3.1.1 Static Semantics: Early Errors

OptionalChain :
\[ \begin{align*}
? \cdot & \text{TemplateLiteral} \\
\text{OptionalChain} & \text{ TemplateLiteral} \\
\end{align*} \]

• It is a Syntax Error if any source text is matched by this production.
NOTE This production exists in order to prevent automatic semicolon insertion rules (12.10) from being
applied to the following code:

```
a?.b  
  `c`
```

so that it would be interpreted as two valid statements. The purpose is to maintain consistency with
similar code without optional chaining:

```
a. b  
  `c`
```

which is a valid statement and where automatic semicolon insertion does not apply.

ImportMeta:

```
import . meta
```

- It is a Syntax Error if the syntactic goal symbol is not Module.

13.3.2 Property Accessors

NOTE Properties are accessed by name, using either the dot notation:

- `MemberExpression . IdentifierName`
- `CallExpression . IdentifierName`

or the bracket notation:

- `MemberExpression [ Expression ]`
- `CallExpression [ Expression ]`

The dot notation is explained by the following syntactic conversion:

- `MemberExpression . IdentifierName`
  
is identical in its behaviour to

- `MemberExpression [ <identifier-name-string> ]`
  and similarly

- `CallExpression . IdentifierName`
  
is identical in its behaviour to

- `CallExpression [ <identifier-name-string> ]`
  
where `<identifier-name-string>` is the result of evaluating `StringValue` of `IdentifierName`.

13.3.2.1 Runtime Semantics: Evaluation

```
MemberExpression : MemberExpression [ Expression ]
```

1. Let `baseReference` be ? Evaluation of `MemberExpression`.
2. Let `baseValue` be ? GetValue(`baseReference`).
3. If the source text matched by this `MemberExpression` is strict mode code, let `strict` be `true`; else let `strict` be `false`.
MemberExpression : MemberExpression . IdentifierName

1. Let baseReference be ? Evaluation of MemberExpression.
2. Let baseValue be ? GetValue(baseReference).
3. If the source text matched by this MemberExpression is strict mode code, let strict be true; else let strict be false.
4. Return EvaluatePropertyAccessWithIdentifierKey(baseValue, IdentifierName, strict).

MemberExpression : MemberExpression . PrivateIdentifier

1. Let baseReference be ? Evaluation of MemberExpression.
2. Let baseValue be ? GetValue(baseReference).
3. Let fieldNameString be the StringValue of PrivateIdentifier.
4. Return MakePrivateReference(baseValue, fieldNameString).

CallExpression : CallExpression [ Expression ]

2. Let baseValue be ? GetValue(baseReference).
3. If the source text matched by this CallExpression is strict mode code, let strict be true; else let strict be false.

CallExpression : CallExpression . IdentifierName

2. Let baseValue be ? GetValue(baseReference).
3. If the source text matched by this CallExpression is strict mode code, let strict be true; else let strict be false.
4. Return EvaluatePropertyAccessWithIdentifierKey(baseValue, IdentifierName, strict).

CallExpression : CallExpression . PrivateIdentifier

2. Let baseValue be ? GetValue(baseReference).
3. Let fieldNameString be the StringValue of PrivateIdentifier.
4. Return MakePrivateReference(baseValue, fieldNameString).

13.3.3 EvaluatePropertyAccessWithExpressionKey ( baseValue, expression, strict )

The abstract operation EvaluatePropertyAccessWithExpressionKey takes arguments baseValue (an ECMAScript language value), expression (an Expression Parse Node), and strict (a Boolean) and returns either a normal completion containing a Reference Record or an abrupt completion. It performs the following steps when called:

1. Let propertyNameReference be ? Evaluation of expression.
2. Let propertyNameValue be ? GetValue(propertyNameReference).
3. Let propertyKey be ? ToPropertyKey(propertyNameValue).
4. Return the Reference Record { [[Base]]: baseValue, [[ReferencedName]]: propertyKey, [[Strict]]: strict, [[ThisValue]]: EMPTY }.

13.3.4 EvaluatePropertyAccessWithIdentifierKey ( baseValue, identifierName, strict )

The abstract operation EvaluatePropertyAccessWithIdentifierKey takes arguments baseValue (an ECMAScript language value), identifierName (an IdentifierName Parse Node), and strict (a Boolean) and returns a Reference Record. It performs the following steps when called:

1. Let propertyNameString be StringValue of identifierName.
2. Return the Reference Record { [[Base]]: baseValue, [[ReferencedName]]: propertyNameString, [[Strict]]: strict, [[ThisValue]]: EMPTY }. 
13.3.5 The new Operator

13.3.5.1 Runtime Semantics: Evaluation

NewExpression : new NewExpression


MemberExpression : new MemberExpression Arguments

1. Return ? EvaluateNew(MemberExpression, Arguments).

13.3.5.1.1 EvaluateNew ( constructExpr, arguments )

The abstract operation EvaluateNew takes arguments constructExpr (a NewExpression Parse Node or a MemberExpression Parse Node) and arguments (EMPTY or an Arguments Parse Node) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

2. Let constructor be ? GetValue(ref).
3. If arguments is EMPTY, then
   a. Let argList be a new empty List.
4. Else,
5. If IsConstructor(constructor) is false, throw a TypeError exception.

13.3.6 Function Calls

13.3.6.1 Runtime Semantics: Evaluation

CallExpression : CoverCallExpressionAndAsyncArrowHead

1. Let expr be the CallMemberExpression that is covered by CoverCallExpressionAndAsyncArrowHead.
2. Let memberExpr be the MemberExpression of expr.
3. Let arguments be the Arguments of expr.
5. Let func be ? GetValue(ref).
6. If ref is a Reference Record, IsPropertyReference(ref) is false, and ref.[[ReferencedName]] is "eval", then
   a. If SameValue(func, %eval%) is true, then
      ii. If argList has no elements, return undefined.
      iii. Let evalArg be the first element of argList.
      iv. If the source text matched by this CallExpression is strict mode code, let strictCaller be true.
          Otherwise let strictCaller be false.

7. Let thisCall be this CallExpression.
8. Let tailCall be IsInTailPosition(thisCall).

A CallExpression evaluation that executes step 6.a.v is a direct eval.

CallExpression : CallExpression Arguments

2. Let func be ? GetValue(ref).
3. Let thisCall be this CallExpression.
4. Let tailCall be IsInTailPosition(thisCall).
5. Return ? EvaluateCall(func, ref, Arguments, tailCall).
13.3.6.2 EvaluateCall( func, ref, arguments, tailPosition )

The abstract operation EvaluateCall takes arguments `func` (an ECMAScript language value), `ref` (an ECMAScript language value or a Reference Record), `arguments` (a Parse Node), and `tailPosition` (a Boolean) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. If `ref` is a Reference Record, then
   a. If IsPropertyReference(ref) is true, then
      i. Let `thisValue` be GetThisValue(ref).
   b. Else,
      i. Let `refEnv` be ref.[[Base]].
      ii. Assert: `refEnv` is an Environment Record.
      iii. Let `thisValue` be `refEnv`.WithBaseObject().
2. Else, let `thisValue` be undefined.
4. If `func` is not an Object, throw a TypeError exception.
5. If IsCallable(func) is false, throw a TypeError exception.
6. If `tailPosition` is true, perform PrepareForTailCall().
7. Return ? Call(func, `thisValue`, `argList`).

13.3.7 The super Keyword

13.3.7.1 Runtime Semantics: Evaluation

SuperProperty : super [ Expression ]

1. Let `env` be GetThisEnvironment().
2. Let `actualThis` be ? `env`.GetThisBinding().
4. Let propertyNameValue be ? GetValue(propertyNameReference).
5. Let `propertyKey` be ? ToPropertyKey(propertyNameValue).
6. If the source text matched by this SuperProperty is strict mode code, let `strict` be true; else let `strict` be false.
7. Return ? MakeSuperPropertyReference(actualThis, propertyKey, strict).

SuperProperty : super . IdentifierName

1. Let `env` be GetThisEnvironment().
2. Let `actualThis` be ? `env`.GetThisBinding().
3. Let `propertyKey` be StringValue of IdentifierName.
4. If the source text matched by this SuperProperty is strict mode code, let `strict` be true; else let `strict` be false.
5. Return ? MakeSuperPropertyReference(actualThis, propertyKey, strict).

SuperCall : super Arguments

1. Let `newTarget` be GetNewTarget().
2. Assert: `newTarget` is an Object.
3. Let `func` be GetSuperConstructor().
5. If IsConstructor(func) is false, throw a TypeError exception.
7. Let `thisER` be GetThisEnvironment().
8. Perform ? `thisER`.BindThisValue(result).
9. Let `F` be `thisER`.[[FunctionObject]].
10. Assert: `F` is an ECMAScript function object.
12. Return `result`.
13.3.7.2 GetSuperConstructor ( )

The abstract operation GetSuperConstructor takes no arguments and returns an ECMAScript language value. It performs the following steps when called:

1. Let envRec be GetThisEnvironment().
2. Assert: envRec is a Function Environment Record.
3. Let activeFunction be envRec. [[FunctionObject]].
4. Assert: activeFunction is an ECMAScript function object.
5. Let superConstructor be ! activeFunction. [[GetPrototypeOf]]().
6. Return superConstructor.

13.3.7.3 MakeSuperPropertyReference ( actualThis, propertyKey, strict )

The abstract operation MakeSuperPropertyReference takes arguments actualThis (an ECMAScript language value), propertyKey (a property key), and strict (a Boolean) and returns either a normal completion containing a Super Reference Record or a throw completion. It performs the following steps when called:

1. Let env be GetThisEnvironment().
3. Let baseValue be ? env. GetSuperBase().
4. Return the Reference Record { [[Base]]: baseValue, [[ReferencedName]]: propertyKey, [[Strict]]: strict, [[ThisValue]]: actualThis }.

13.3.8 Argument Lists

NOTE The evaluation of an argument list produces a List of values.

13.3.8.1 Runtime Semantics: ArgumentListEvaluation

The syntax-directed operation ArgumentListEvaluation takes no arguments and returns either a normal completion containing a List of ECMAScript language values or an abrupt completion. It is defined piecewise over the following productions:

Arguments : ( )

1. Return a new empty List.

ArgumentList : AssignmentExpression

2. Let arg be ? GetValue(ref).
3. Return « arg ».

ArgumentList : ... AssignmentExpression

1. Let list be a new empty List.
2. Let spreadRef be ? Evaluation of AssignmentExpression.
3. Let spreadObj be ? GetValue(spreadRef).
4. Let iteratorRecord be ? GetIterator(spreadObj, SYNC).
5. Repeat,
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is DONE, return list.
   c. Append next to list.

ArgumentList : ArgumentList , AssignmentExpression

3. Let \( \text{arg} \) be \( \text{GetValue}(\text{ref}) \).
4. Return the list-concatenation of \( \text{precedingArgs} \) and « \( \text{arg} \) ».

**ArgumentList** : ArgumentList , ... AssignmentExpression

1. Let \( \text{precedingArgs} \) be ? ArgumentListEvaluation of ArgumentList.
2. Let \( \text{spreadRef} \) be ? Evaluation of AssignmentExpression.
3. Let \( \text{iteratorRecord} \) be ? GetIterator(? GetValue(\( \text{spreadRef} \)), SYNC).
4. Repeat,
   a. Let \( \text{next} \) be ? IteratorStepValue(\( \text{iteratorRecord} \)).
   b. If \( \text{next} \) is DONE, return \( \text{precedingArgs} \).
   c. Append \( \text{next} \) to \( \text{precedingArgs} \).

**TemplateLiteral** : NoSubstitutionTemplate

1. Let \( \text{templateLiteral} \) be this TemplateLiteral.
2. Let \( \text{siteObj} \) be GetTemplateObject(\( \text{templateLiteral} \)).
3. Return « \( \text{siteObj} \) ».

**TemplateLiteral** : SubstitutionTemplate

1. Let \( \text{templateLiteral} \) be this TemplateLiteral.
2. Let \( \text{siteObj} \) be GetTemplateObject(\( \text{templateLiteral} \)).
3. Let \( \text{remaining} \) be ? ArgumentListEvaluation of SubstitutionTemplate.
4. Return the list-concatenation of « \( \text{siteObj} \) » and \( \text{remaining} \).

**SubstitutionTemplate** : TemplateHead Expression TemplateSpans

1. Let \( \text{firstSubRef} \) be ? Evaluation of Expression.
2. Let \( \text{firstSub} \) be ? GetValue(\( \text{firstSubRef} \)).
3. Let \( \text{restSub} \) be ? SubstitutionEvaluation of TemplateSpans.
4. Assert: \( \text{restSub} \) is a possibly empty List.
5. Return the list-concatenation of « \( \text{firstSub} \) » and \( \text{restSub} \).

### 13.3.9 Optional Chains

**NOTE** An optional chain is a chain of one or more property accesses and function calls, the first of which begins with the token \?.

### 13.3.9.1 Runtime Semantics: Evaluation

**OptionalExpression** :

MemberExpression OptionalChain

1. Let \( \text{baseReference} \) be ? Evaluation of MemberExpression.
2. Let \( \text{baseValue} \) be ? GetValue(\( \text{baseReference} \)).
3. If \( \text{baseValue} \) is either undefined or null, then
   a. Return undefined.
4. Return ? ChainEvaluation of OptionalChain with arguments \( \text{baseValue} \) and \( \text{baseReference} \).

**OptionalExpression** :

CallExpression OptionalChain

1. Let \( \text{baseReference} \) be ? Evaluation of CallExpression.
2. Let \( \text{baseValue} \) be ? GetValue(\( \text{baseReference} \)).
3. If \( \text{baseValue} \) is either undefined or null, then
   a. Return undefined.
4. Return ? ChainEvaluation of OptionalChain with arguments \( \text{baseValue} \) and \( \text{baseReference} \).
**OptionalExpression**

OptionalExpression OptionalChain

2. Let `baseValue` be ? GetValue(baseReference).
3. If `baseValue` is either undefined or null, then
   a. Return undefined.

### 13.3.9.2 Runtime Semantics: ChainEvaluation

The syntax-directed operation `ChainEvaluation` takes arguments `baseValue` (an ECMAScript language value) and `baseReference` (an ECMAScript language value or a Reference Record) and returns either a normal completion containing either an ECMAScript language value or a Reference Record, or an abrupt completion. It is defined piecewise over the following productions:

**OptionalChain : ?. Arguments**

1. Let `thisChain` be this OptionalChain.
2. Let `tailCall` be IsInTailPosition(thisChain).

**OptionalChain : ?. [ Expression ]**

1. If the source text matched by this OptionalChain is strict mode code, let `strict` be true; else let `strict` be false.

**OptionalChain : ?. IdentifierName**

1. If the source text matched by this OptionalChain is strict mode code, let `strict` be true; else let `strict` be false.
2. Return EvaluatePropertyAccessWithIdentifierKey(baseValue, IdentifierName, strict).

**OptionalChain : ?. PrivateIdentifier**

1. Let `fieldNameString` be the StringValue of PrivateIdentifier.
2. Return MakePrivateReference(baseValue, fieldNameString).

**OptionalChain : OptionalChain Arguments**

1. Let `optionalChain` be OptionalChain.
4. Let `thisChain` be this OptionalChain.
5. Let `tailCall` be IsInTailPosition(thisChain).

**OptionalChain : OptionalChain [ Expression ]**

1. Let `optionalChain` be OptionalChain.
4. If the source text matched by this OptionalChain is strict mode code, let `strict` be true; else let `strict` be false.

**OptionalChain : OptionalChain . IdentifierName**

1. Let `optionalChain` be OptionalChain.
4. If the source text matched by this OptionalChain is strict mode code, let `strict` be true; else let `strict` be false.
5. Return EvaluatePropertyAccessWithIdentifierKey(newValue, IdentifierName, strict).
OptionalChain : OptionalChain , PrivateIdentifier

1. Let optionalChain be OptionalChain.
4. Let fieldNameString be the StringValue of PrivateIdentifier.
5. Return MakePrivateReference(newValue, fieldNameString).

13.3.10 Import Calls

13.3.10.1 Runtime Semantics: Evaluation

ImportCall : import ( AssignmentExpression )

1. Let referrer be GetActiveScriptOrModule().
2. If referrer is null, set referrer to the current Realm Record.
4. Let specifier be ? GetValue(argRef).
5. Let promiseCapability be ! NewPromiseCapability(%Promise%).
6. Let specifierString be Completion(ToString(specifier)).
7. IfAbruptRejectPromise(specifierString, promiseCapability).
8. Perform HostLoadImportedModule(referrer, specifierString, EMPTY, promiseCapability).
9. Return promiseCapability.[]Promise%.

13.3.10.1.1 ContinueDynamicImport ( promiseCapability, moduleCompletion )

The abstract operation ContinueDynamicImport takes arguments promiseCapability (a PromiseCapability Record) and moduleCompletion (either a normal completion containing a Module Record or a throw completion) and returns UNUSED. It completes the process of a dynamic import originally started by an import() call, resolving or rejecting the promise returned by that call as appropriate. It performs the following steps when called:

1. If moduleCompletion is an abrupt completion, then
   a. Perform ! Call(promiseCapability.[]Reject%, undefined, « moduleCompletion.[]Value% »).
   b. Return UNUSED.
2. Let module be moduleCompletion.[]Value%.
3. Let loadPromise be module.LoadRequestedModules().
4. Let rejectedClosure be a new Abstract Closure with parameters (reason) that captures promiseCapability and performs the following steps when called:
   a. Perform ! Call(promiseCapability.[]Reject%, undefined, « reason »).
   b. Return UNUSED.
5. Let onRejected be CreateBuiltInFunction(rejectedClosure, 1, "", " »).
6. Let linkAndEvaluateClosure be a new Abstract Closure with no parameters that captures module, promiseCapability, and onRejected and performs the following steps when called:
   a. Let link be Completion(module.Link()).
   b. If link is an abrupt completion, then
      i. Perform ! Call(promiseCapability.[]Reject%, undefined, « link.[]Value% »).
      ii. Return UNUSED.
   c. Let evaluatePromise be module.Evaluate().
   d. Let fulfilledClosure be a new Abstract Closure with no parameters that captures module and promiseCapability and performs the following steps when called:
      i. Let namespace be GetModuleNameSpace(module).
      ii. Perform ! Call(promiseCapability.[]Resolve%, undefined, « namespace »).
      iii. Return UNUSED.
   e. Let onFulfilled be CreateBuiltInFunction(fulfilledClosure, 0, "", « »).
   f. Perform PerformPromiseThen(evaluatePromise, onFulfilled, onRejected).
   g. Return UNUSED.
7. Let linkAndEvaluate be CreateBuiltInFunction(linkAndEvaluateClosure, 0, "", « »).
8. Perform PerformPromiseThen(loadPromise, linkAndEvaluate, onRejected).
9. Return UNUSED.
13.3.11 Tagged Templates

NOTE A tagged template is a function call where the arguments of the call are derived from a TemplateLiteral (13.2.8). The actual arguments include a template object (13.2.8.4) and the values produced by evaluating the expressions embedded within the TemplateLiteral.

13.3.11.1 Runtime Semantics: Evaluation

MemberExpression : MemberExpression TemplateLiteral

1. Let tagRef be ? Evaluation of MemberExpression.
2. Let tagFunc be ? GetValue(tagRef).
3. Let thisCall be this MemberExpression.
4. Let tailCall be IsInTailPosition(thisCall).
5. Return ? EvaluateCall(tagFunc, tagRef, TemplateLiteral, tailCall).

CallExpression : CallExpression TemplateLiteral

1. Let tagRef be ? Evaluation of CallExpression.
2. Let tagFunc be ? GetValue(tagRef).
3. Let thisCall be this CallExpression.
4. Let tailCall be IsInTailPosition(thisCall).
5. Return ? EvaluateCall(tagFunc, tagRef, TemplateLiteral, tailCall).

13.3.12 Meta Properties

13.3.12.1 Runtime Semantics: Evaluation

NewTarget : new . target

1. Return GetNewTarget().

ImportMeta : import . meta

1. Let module be GetActiveScriptOrModule().
2. Assert: module is a Source Text Module Record.
3. Let importMeta be module.[[ImportMeta]].
4. If importMeta is EMPTY, then
   a. Set importMeta to OrdinaryObjectCreate(null).
   b. Let importMetaValues be HostGetImportMetaProperties(module).
   c. For each Record { [[Key]], [[Value]] } p of importMetaValues, do
      i. Perform ! CreateDataPropertyOrThrow(importMeta, p.[[Key]], p.[[Value]]).
   d. Perform HostFinalizeImportMeta(importMeta, module).
   e. Set module.[[ImportMeta]] to importMeta.
   f. Return importMeta.
5. Else,
   a. Assert: importMeta is an Object.
   b. Return importMeta.

13.3.12.1.1 HostGetImportMetaProperties ( moduleRecord )

The host-defined abstract operation HostGetImportMetaProperties takes argument moduleRecord (a Module Record) and returns a List of Records with fields [[Key]] (a property key) and [[Value]] (an ECMAScript language value). It allows hosts to provide property keys and values for the object returned from import.meta.

The default implementation of HostGetImportMetaProperties is to return a new empty List.
13.3.12.1.2 HostFinalizeImportMeta (importMeta, moduleRecord)

The host-defined abstract operation HostFinalizeImportMeta takes arguments importMeta (an Object) and moduleRecord (a ModuleRecord) and returns UNUSED. It allows hosts to perform any extraordinary operations to prepare the object returned from import.meta.

Most hosts will be able to simply define HostGetImportMetaProperties, and leave HostFinalizeImportMeta with its default behaviour. However, HostFinalizeImportMeta provides an "escape hatch" for hosts which need to directly manipulate the object before it is exposed to ECMAScript code.

The default implementation of HostFinalizeImportMeta is to return UNUSED.

13.4 Update Expressions

Syntax

UpdateExpression[Yield, Await] :
  LeftHandSideExpression[?Yield, ?Await]
  LeftHandSideExpression[?Yield, ?Await] [no LineTerminator here] ++
  LeftHandSideExpression[?Yield, ?Await] [no LineTerminator here] --
    ++ UnaryExpression[?Yield, ?Await]
    -- UnaryExpression[?Yield, ?Await]

13.4.1 Static Semantics: Early Errors

UpdateExpression :
  LeftHandSideExpression ++
  LeftHandSideExpression --

  • It is an early Syntax Error if AssignmentTargetType of LeftHandSideExpression is not SIMPLE.

UpdateExpression :
  ++ UnaryExpression
  -- UnaryExpression

  • It is an early Syntax Error if AssignmentTargetType of UnaryExpression is not SIMPLE.

13.4.2 Postfix Increment Operator

13.4.2.1 Runtime Semantics: Evaluation

UpdateExpression : LeftHandSideExpression ++

2. Let oldValue be ? ToNumeric(? GetValue(lhs)).
3. If oldValue is a Number, then
   a. Let newValue be Number::add(oldValue, 1𝔽).
4. Else,
   a. Assert: oldValue is a BigInt.
   b. Let newValue be BigInt::add(oldValue, 1ℤ).
6. Return oldValue.
13.4.3 Postfix Decrement Operator

13.4.3.1 Runtime Semantics: Evaluation

\[ \text{UpdateExpression} : \text{LeftHandSideExpression} -- \]

1. Let \( \text{lhs} \) be \( ? \text{Evaluation} \) of \( \text{LeftHandSideExpression} \).
2. Let \( \text{oldValue} \) be \( ? \text{ToNumeric}(? \text{GetValue}(\text{lhs})) \).
3. If \( \text{oldValue} \) is a Number, then
   a. Let \( \text{newValue} \) be \( \text{Number::subtract}(\text{oldValue}, 1_F) \).
4. Else,
   a. Assert: \( \text{oldValue} \) is a BigInt.
   b. Let \( \text{newValue} \) be \( \text{BigInt::subtract}(\text{oldValue}, 1_Z) \).
5. Perform \( ? \text{PutValue}(\text{lhs}, \text{newValue}) \).
6. Return \( \text{oldValue} \).

13.4.4 Prefix Increment Operator

13.4.4.1 Runtime Semantics: Evaluation

\[ \text{UpdateExpression} : \text{UnaryExpression} \]

1. Let \( \text{expr} \) be \( ? \text{Evaluation} \) of \( \text{UnaryExpression} \).
2. Let \( \text{oldValue} \) be \( ? \text{ToNumeric}(? \text{GetValue}(\text{expr})) \).
3. If \( \text{oldValue} \) is a Number, then
   a. Let \( \text{newValue} \) be \( \text{Number::add}(\text{oldValue}, 1_F) \).
4. Else,
   a. Assert: \( \text{oldValue} \) is a BigInt.
   b. Let \( \text{newValue} \) be \( \text{BigInt::add}(\text{oldValue}, 1_Z) \).
5. Perform \( ? \text{PutValue}(\text{expr}, \text{newValue}) \).
6. Return \( \text{newValue} \).

13.4.5 Prefix Decrement Operator

13.4.5.1 Runtime Semantics: Evaluation

\[ \text{UpdateExpression} : \text{UnaryExpression} \]

1. Let \( \text{expr} \) be \( ? \text{Evaluation} \) of \( \text{UnaryExpression} \).
2. Let \( \text{oldValue} \) be \( ? \text{ToNumeric}(? \text{GetValue}(\text{expr})) \).
3. If \( \text{oldValue} \) is a Number, then
   a. Let \( \text{newValue} \) be \( \text{Number::subtract}(\text{oldValue}, 1_F) \).
4. Else,
   a. Assert: \( \text{oldValue} \) is a BigInt.
   b. Let \( \text{newValue} \) be \( \text{BigInt::subtract}(\text{oldValue}, 1_Z) \).
5. Perform \( ? \text{PutValue}(\text{expr}, \text{newValue}) \).
6. Return \( \text{newValue} \).
13.5 Unary Operators

Syntax

```
UnaryExpression[Yield, Await] :  
  UpdateExpression[?Yield, ?Await]
  delete UnaryExpression[?Yield, ?Await]
  void UnaryExpression[?Yield, ?Await]
  typeof UnaryExpression[?Yield, ?Await]
  + UnaryExpression[?Yield, ?Await]
  - UnaryExpression[?Yield, ?Await]
  ~ UnaryExpression[?Yield, ?Await]
  ! UnaryExpression[?Yield, ?Await]
  [+Await] AwaitExpression[?Yield]
```

13.5.1 The delete Operator

13.5.1.1 Static Semantics: Early Errors

```
UnaryExpression : delete UnaryExpression
```

- It is a Syntax Error if the `UnaryExpression` is contained in strict mode code and the derived `UnaryExpression` is `PrimaryExpression : IdentifierReference`
  - `MemberExpression : MemberExpression . PrivateIdentifier`

- It is a Syntax Error if the derived `UnaryExpression` is `PrimaryExpression : CoverParenthesizedExpressionAndArrowParameterList` and `CoverParenthesizedExpressionAndArrowParameterList` ultimately derives a phrase that, if used in place of `UnaryExpression`, would produce a Syntax Error according to these rules. This rule is recursively applied.

NOTE The last rule means that expressions such as `delete (((foo)))` produce early errors because of recursive application of the first rule.

13.5.1.2 Runtime Semantics: Evaluation

```
UnaryExpression : delete UnaryExpression
```

1. Let `ref` be `? Evaluation of UnaryExpression`
2. If `ref` is not a `Reference Record`, return `true`.
3. If `IsUnresolvableReference(ref)` is `true`, then
   a. `Assert: ref.[[Strict]] is false`.
   b. Return `true`.
4. If `IsPropertyReference(ref)` is `true`, then
   a. `Assert: IsPrivateReference(ref) is false`.
   b. If `IsSuperReference(ref)` is `true`, throw a `ReferenceError` exception.
   c. Let `baseObj` be `ToObject(ref.[[Base]])`.
   d. Let `deleteStatus` be `baseObj.[[Delete]][ref.[[ReferencedName]]]`.
   e. If `deleteStatus` is `false` and `ref.[[Strict]] is true`, throw a `TypeError` exception.
   f. Return `deleteStatus`.
5. Else,
   a. Let `base` be `ref.[[Base]]`.
   b. `Assert: base` is an `Environment Record`.
   c. Return `? base.DeleteBinding(ref.[[ReferencedName]])`.
NOTE 1 When a delete operator occurs within strict mode code, a SyntaxError exception is thrown if its UnaryExpression is a direct reference to a variable, function argument, or function name. In addition, if a delete operator occurs within strict mode code and the property to be deleted has the attribute { [[Configurable]]: false } (or otherwise cannot be deleted), a TypeError exception is thrown.

NOTE 2 The object that may be created in step 4.c is not accessible outside of the above abstract operation and the ordinary object [[Delete]] internal method. An implementation might choose to avoid the actual creation of that object.

13.5.2 The void Operator

13.5.2.1 Runtime Semantics: Evaluation

UnaryExpression : void UnaryExpression

3. Return undefined.

NOTE GetValue must be called even though its value is not used because it may have observable side-effects.

13.5.3 The typeof Operator

13.5.3.1 Runtime Semantics: Evaluation

UnaryExpression : typeof UnaryExpression

2. If val is a Reference Record, then
   a. If IsUnresolvableReference(val) is true, return "undefined".
4. If val is undefined, return "undefined".
5. If val is null, return "object".
6. If val is a String, return "string".
7. If val is a Symbol, return "symbol".
8. If val is a Boolean, return "boolean".
9. If val is a Number, return "number".
10. If val is a BigInt, return "bigint".
11. Assert: val is an Object.
12. NOTE: This step is replaced in section B.3.6.3.
13. If val has a [[Call]] internal slot, return "function".
14. Return "object".

13.5.4 Unary + Operator

NOTE The unary + operator converts its operand to Number type.
13.5.4.1 Runtime Semantics: Evaluation
UnaryExpression : + UnaryExpression

2. Return ? ToNumber(? GetValue(expr)).

13.5.5 Unary - Operator

NOTE The unary - operator converts its operand to a numeric value and then negates it. Negating +0𝔽 produces -0𝔽, and negating -0𝔽 produces +0𝔽.

13.5.5.1 Runtime Semantics: Evaluation
UnaryExpression : - UnaryExpression

2. Let oldValue be ? ToNumeric(? GetValue(expr)).
3. If oldValue is a Number, then
   a. Return Number::unaryMinus(oldValue).
4. Else,
   a. Assert: oldValue is a BigInt.
   b. Return BigInt::unaryMinus(oldValue).

13.5.6 Bitwise NOT Operator (~)

13.5.6.1 Runtime Semantics: Evaluation
UnaryExpression : ~ UnaryExpression

2. Let oldValue be ? ToNumeric(? GetValue(expr)).
3. If oldValue is a Number, then
   a. Return Number::bitwiseNOT(oldValue).
4. Else,
   a. Assert: oldValue is a BigInt.
   b. Return BigInt::bitwiseNOT(oldValue).

13.5.7 Logical NOT Operator (!)

13.5.7.1 Runtime Semantics: Evaluation
UnaryExpression : ! UnaryExpression

2. Let oldValue be ToBoolean(? GetValue(expr)).
3. If oldValue is true, return false.
4. Return true.

13.6 Exponentiation Operator

Syntax

ExponentiationExpression[Yield, Await] :
  UnaryExpression[Yield, Await]
  UpdateExpression[Yield, Await] ★★ ExponentiationExpression[Yield, Await]
13.6.1 Runtime Semantics: Evaluation

ExponentiationExpression : UpdateExpression ** ExponentiationExpression


13.7 Multiplicative Operators

Syntax

\[
\text{MultiplicativeExpression}[\text{Yield, Await}] : \\
\text{ExponentiationExpression} [?\text{Yield, ?Await}] \\
\text{MultiplicativeExpression} [?\text{Yield, ?Await}] \text{ MultiplicativeOperator} \\
\text{ExponentiationExpression} [?\text{Yield, ?Await}]
\]

MultiplicativeOperator : one of

\[
* / \%
\]

NOTE

- The * operator performs multiplication, producing the product of its operands.
- The / operator performs division, producing the quotient of its operands.
- The % operator yields the remainder of its operands from an implied division.

13.7.1 Runtime Semantics: Evaluation

MultiplicativeExpression : MultiplicativeExpression MultiplicativeOperator ExponentiationExpression

1. Let \(opText\) be the source text matched by \(\text{MultiplicativeOperator}\).

13.8 Additive Operators

Syntax

\[
\text{AdditiveExpression}[\text{Yield, Await}] : \\
\text{MultiplicativeExpression} [?\text{Yield, ?Await}] \\
\text{AdditiveExpression} [?\text{Yield, ?Await}] \text{ AdditiveExpression} [?\text{Yield, ?Await}] \\
\text{AdditiveExpression} [?\text{Yield, ?Await}] \text{ MultiplicativeExpression} [?\text{Yield, ?Await}]
\]

13.8.1 The Addition Operator ( + )

NOTE

The addition operator either performs string concatenation or numeric addition.

13.8.1.1 Runtime Semantics: Evaluation

AdditiveExpression : AdditiveExpression + MultiplicativeExpression

13.8.2 The Subtraction Operator ( - )

**NOTE** The - operator performs subtraction, producing the difference of its operands.

13.8.2.1 Runtime Semantics: Evaluation

\[ \text{AdditiveExpression} : \text{AdditiveExpression} - \text{MultiplicativeExpression} \]

1. Return \( \text{EvaluateStringOrNumericBinaryExpression}(\text{AdditiveExpression}, -, \text{MultiplicativeExpression}) \).

13.9 Bitwise Shift Operators

**Syntax**

\[
\text{ShiftExpression}[\text{Yield, Await}] :
\]

\[
\begin{align*}
\text{AdditiveExpression}[?\text{Yield}, ?\text{Await}] \\
\text{ShiftExpression}[?\text{Yield}, ?\text{Await}] &\ll \text{AdditiveExpression}[?\text{Yield}, ?\text{Await}] \\
\text{ShiftExpression}[?\text{Yield}, ?\text{Await}] &\gg \text{AdditiveExpression}[?\text{Yield}, ?\text{Await}] \\
\text{ShiftExpression}[?\text{Yield}, ?\text{Await}] &\ggg \text{AdditiveExpression}[?\text{Yield}, ?\text{Await}]
\end{align*}
\]

13.9.1 The Left Shift Operator ( << )

**NOTE** Performs a bitwise left shift operation on the left operand by the amount specified by the right operand.

13.9.1.1 Runtime Semantics: Evaluation

\[ \text{ShiftExpression} : \text{ShiftExpression} \ll \text{AdditiveExpression} \]

1. Return \( \text{EvaluateStringOrNumericBinaryExpression}(\text{ShiftExpression}, \ll, \text{AdditiveExpression}) \).

13.9.2 The Signed Right Shift Operator ( >> )

**NOTE** Performs a sign-filling bitwise right shift operation on the left operand by the amount specified by the right operand.

13.9.2.1 Runtime Semantics: Evaluation

\[ \text{ShiftExpression} : \text{ShiftExpression} \gg \text{AdditiveExpression} \]

1. Return \( \text{EvaluateStringOrNumericBinaryExpression}(\text{ShiftExpression}, \gg, \text{AdditiveExpression}) \).

13.9.3 The Unsigned Right Shift Operator ( >>> )

**NOTE** Performs a zero-filling bitwise right shift operation on the left operand by the amount specified by the right operand.
13.9.3.1 Runtime Semantics: Evaluation

**ShiftExpression : ShiftExpression >>> AdditiveExpression**


13.10 Relational Operators

**NOTE 1** The result of evaluating a relational operator is always of type Boolean, reflecting whether the relationship named by the operator holds between its two operands.

**Syntax**

```
RelationalExpression[In, Yield, Await] :
  ShiftExpression[?Yield, ?Await]
[+In] PrivateIdentifier in ShiftExpression[?Yield, ?Await]
```

**NOTE 2** The [+In] grammar parameter is needed to avoid confusing the in operator in a relational expression with the in operator in a for statement.

13.10.1 Runtime Semantics: Evaluation

**RelationalExpression : RelationalExpression < ShiftExpression**

1. Let `lref` be ? **Evaluation** of RelationalExpression.
2. Let `lval` be ? **GetValue**(lref).
5. Let `r` be ? **IsLessThan**(lval, rval, true).
6. If `r` is **undefined**, return **false**. Otherwise, return `r`.

**RelationalExpression : RelationalExpression > ShiftExpression**

1. Let `lref` be ? **Evaluation** of RelationalExpression.
2. Let `lval` be ? **GetValue**(lref).
5. Let `r` be ? **IsLessThan**(rval, lval, false).
6. If `r` is **undefined**, return **false**. Otherwise, return `r`.

**RelationalExpression : RelationalExpression <= ShiftExpression**

1. Let `lref` be ? **Evaluation** of RelationalExpression.
2. Let `lval` be ? **GetValue**(lref).
5. Let `r` be ? **IsLessThan**(rval, lval, false).
6. If `r` is either **true** or **undefined**, return **false**. Otherwise, return **true**.
RelationalExpression : RelationalExpression >= ShiftExpression

1. Let \textit{lref} be ? Evaluation of RelationalExpression.
2. Let \textit{lval} be ? GetValue(\textit{lref}).
4. Let \textit{rval} be ? GetValue(\textit{rref}).
6. If \(\textit{r}\) is either true or undefined, return false. Otherwise, return true.

RelationalExpression : RelationalExpression instanceof ShiftExpression

1. Let \textit{lref} be ? Evaluation of RelationalExpression.
2. Let \textit{lval} be ? GetValue(\textit{lref}).
4. Let \textit{rval} be ? GetValue(\textit{rref}).
5. Return ? InstanceofOperator(\textit{lval}, \textit{rval}).

RelationalExpression : RelationalExpression in ShiftExpression

1. Let \textit{lref} be ? Evaluation of RelationalExpression.
2. Let \textit{lval} be ? GetValue(\textit{lref}).
4. Let \textit{rval} be ? GetValue(\textit{rref}).
5. If \textit{rval} is not an Object, throw a TypeError exception.
6. Return ? HasProperty(\textit{rval}, ? ToPropertyKey(\textit{lval})).

RelationalExpression : PrivateIdentifier in ShiftExpression

1. Let \textit{privateIdentifier} be the StringValue of PrivateIdentifier.
2. Let \textit{rref} be ? Evaluation of ShiftExpression.
3. Let \textit{rval} be ? GetValue(\textit{rref}).
4. If \textit{rval} is not an Object, throw a TypeError exception.
5. Let \textit{privateEnv} be the running execution context’s PrivateEnvironment.
6. Let \textit{privateName} be ResolvePrivateIdentifier(\textit{privateEnv}, \textit{privateIdentifier}).
7. If PrivateElementFind(\textit{rval}, \textit{privateName}) is not EMPTY, return true.
8. Return false.

13.10.2 InstanceofOperator ( \textit{V}, \textit{target} )

The abstract operation InstanceofOperator takes arguments \textit{V} (an ECMAScript language value) and \textit{target} (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It implements the generic algorithm for determining if \textit{V} is an instance of \textit{target} either by consulting \textit{target}'s @@hasInstance method or, if absent, determining whether the value of \textit{target}'s "prototype" property is present in \textit{V}'s prototype chain. It performs the following steps when called:

1. If \textit{target} is not an Object, throw a TypeError exception.
2. Let \textit{instOfHandler} be ? GetMethod(\textit{target}, @@hasInstance).
3. If \textit{instOfHandler} is not undefined, then
   a. Return ToBoolean(? Call(\textit{instOfHandler}, \textit{target}, « \textit{V} »)).
4. If IsCallable(\textit{target}) is false, throw a TypeError exception.
5. Return ? OrdinaryHasInstance(\textit{target}, \textit{V}).

**NOTE** Steps 4 and 5 provide compatibility with previous editions of ECMAScript that did not use a @@hasInstance method to define the instanceof operator semantics. If an object does not define or inherit @@hasInstance it uses the default instanceof semantics.
13.11 Equality Operators

NOTE The result of evaluating an equality operator is always of type Boolean, reflecting whether the relationship named by the operator holds between its two operands.

Syntax

\[
\text{EqualityExpression} \text{[In, Yield, Await]} : \\
\text{RelationalExpression} \text{[?In, ?Yield, ?Await]}
\]

\[
\text{EqualityExpression} \text{[?In, ?Yield, ?Await]} == \text{RelationalExpression} \text{[?In, ?Yield, ?Await]}
\]

\[
\text{EqualityExpression} \text{[?In, ?Yield, ?Await]} != \text{RelationalExpression} \text{[?In, ?Yield, ?Await]}
\]

\[
\text{EqualityExpression} \text{[?In, ?Yield, ?Await]} === \text{RelationalExpression} \text{[?In, ?Yield, ?Await]}
\]

\[
\text{EqualityExpression} \text{[?In, ?Yield, ?Await]} !== \text{RelationalExpression} \text{[?In, ?Yield, ?Await]}
\]

13.11.1 Runtime Semantics: Evaluation

EqualityExpression : EqualityExpression == RelationalExpression

2. Let \textit{lval} be ? GetValue\n63f(lref).
4. Let \textit{rval} be ? GetValue\n63f(rref).

EqualityExpression : EqualityExpression != RelationalExpression

2. Let \textit{lval} be ? GetValue\n63f(lref).
4. Let \textit{rval} be ? GetValue\n63f(rref).
6. If \textit{r} is \textit{true}, return \textit{false}. Otherwise, return \textit{true}.

EqualityExpression : EqualityExpression === RelationalExpression

2. Let \textit{lval} be ? GetValue\n63f(lref).
4. Let \textit{rval} be ? GetValue\n63f(rref).
5. Return IsStrictlyEqual\n63f(rval, lval).

EqualityExpression : EqualityExpression !== RelationalExpression

2. Let \textit{lval} be ? GetValue\n63f(lref).
4. Let \textit{rval} be ? GetValue\n63f(rref).
5. Let \textit{r} be IsStrictlyEqual\n63f(rval, lval).
6. If \textit{r} is \textit{true}, return \textit{false}. Otherwise, return \textit{true}.
NOTE 1  Given the above definition of equality:

- String comparison can be forced by: `{a} == `{b}`.
- Numeric comparison can be forced by: +a == +b.
- Boolean comparison can be forced by: !a == !b.

NOTE 2  The equality operators maintain the following invariants:

- A != B is equivalent to !(A == B).
- A == B is equivalent to B == A, except in the order of evaluation of A and B.

NOTE 3  The equality operator is not always transitive. For example, there might be two distinct String objects, each representing the same String value; each String object would be considered equal to the String value by the == operator, but the two String objects would not be equal to each other. For example:

- new String("a") == "a" and "a" == new String("a") are both true.
- new String("a") == new String("a") is false.

NOTE 4  Comparison of Strings uses a simple equality test on sequences of code unit values. There is no attempt to use the more complex, semantically oriented definitions of character or string equality and collating order defined in the Unicode specification. Therefore Strings values that are canonically equal according to the Unicode Standard could test as unequal. In effect this algorithm assumes that both Strings are already in normalized form.

13.12  Binary Bitwise Operators

Syntax

```
BitwiseANDExpression[In, Yield, Await] :  
  EqualityExpression[?In, ?Yield, ?Await] 
```

```
BitwiseORExpression[In, Yield, Await] :  
  BitwiseANDExpression[?In, ?Yield, ?Await] 
  BitwiseORExpression[?In, ?Yield, ?Await] |  
  BitwiseORExpression[?In, ?Yield, ?Await]
```

```
BitwiseXORExpression[In, Yield, Await] :  
  BitwiseANDExpression[?In, ?Yield, ?Await] 
  BitwiseXORExpression[?In, ?Yield, ?Await] ^  
  BitwiseXORExpression[?In, ?Yield, ?Await]
```

13.12.1  Runtime Semantics: Evaluation

```
BitwiseANDExpression : BitwiseANDExpression & EqualityExpression
```

13.13 Binary Logical Operators

Syntax


NOTE The value produced by a && or || operator is not necessarily of type Boolean. The value produced will always be the value of one of the two operand expressions.

13.13.1 Runtime Semantics: Evaluation

LogicalANDExpression : LogicalANDExpression && BitwiseORExpression

2. Let lval be ? GetValue(lref).
3. Let lbool be ToBoolean(lval).
4. If lbool is false, return lval.

LogicalORExpression : LogicalORExpression || LogicalANDExpression

2. Let lval be ? GetValue(lref).
3. Let lbool be ToBoolean(lval).
4. If lbool is true, return lval.
5. Let rref be ? Evaluation of LogicalANDExpression.
CoalesceExpression : CoalesceExpressionHead ?? BitwiseORExpression

2. Let lval be ? GetValue(lref).
3. If lval is either undefined or null, then
   b. Return ? GetValue(ref).
4. Else,
   a. Return lval.


Syntax

ConditionalExpression[In, Yield, Await] : 
  ShortCircuitExpression[?In, ?Yield, ?Await]
  ShortCircuitExpression[?In, ?Yield, ?Await] ?? 
    AssignmentExpression[+In, ?Yield, ?Await] : 
    AssignmentExpression[?In, ?Yield, ?Await]

NOTE The grammar for a ConditionalExpression in ECMAScript is slightly different from that in C and Java, which each allow the second subexpression to be an Expression but restrict the third expression to be a ConditionalExpression. The motivation for this difference in ECMAScript is to allow an assignment expression to be governed by either arm of a conditional and to eliminate the confusing and fairly useless case of a comma expression as the centre expression.


ConditionalExpression : ShortCircuitExpression ?? AssignmentExpression : AssignmentExpression

2. Let lval be ToBoolean(? GetValue(lref)).
3. If lval is true, then
   a. Let trueRef be ? Evaluation of the first AssignmentExpression.
   b. Return ? GetValue(trueRef).
4. Else,
13.15 Assignment Operators

Syntax

AssignmentExpression \[\text{In, Yield, Await}\] :
  ConditionalExpression[?In, ?Yield, ?Await]
  \([\text{In}]\) YieldExpression[?In, ?Await]
  ArrowFunction[?In, ?Yield, ?Await]
  AsyncArrowFunction[?In, ?Yield, ?Await]
  LeftHandSideExpression[?Yield, ?Await] AssignmentOperator
    AssignmentExpression[?In, ?Yield, ?Await]
  LeftHandSideExpression[?Yield, ?Await] &&=
    AssignmentExpression[?In, ?Yield, ?Await]
  LeftHandSideExpression[?Yield, ?Await] ||=
    AssignmentExpression[?In, ?Yield, ?Await]
  LeftHandSideExpression[?Yield, ?Await] ??=
    AssignmentExpression[?In, ?Yield, ?Await]

  AssignmentOperator : one of
  \(^= /= \%= \+= -= \ll= \gg= \ggg= \&= \|= \^= \***

13.15.1 Static Semantics: Early Errors

AssignmentExpression : LeftHandSideExpression = AssignmentExpression

If LeftHandSideExpression is either an ObjectLiteral or an ArrayLiteral, the following Early Error rules are applied:

- LeftHandSideExpression must cover an AssignmentPattern.

If LeftHandSideExpression is neither an ObjectLiteral nor an ArrayLiteral, the following Early Error rule is applied:

- It is a Syntax Error if AssignmentTargetType of LeftHandSideExpression is not SIMPLE.

AssignmentExpression :
  LeftHandSideExpression AssignmentOperator AssignmentExpression
  LeftHandSideExpression &&= AssignmentExpression
  LeftHandSideExpression ||= AssignmentExpression
  LeftHandSideExpression ??= AssignmentExpression

- It is a Syntax Error if AssignmentTargetType of LeftHandSideExpression is not SIMPLE.

13.15.2 Runtime Semantics: Evaluation

AssignmentExpression : LeftHandSideExpression = AssignmentExpression

1. If LeftHandSideExpression is neither an ObjectLiteral nor an ArrayLiteral, then
   a. Let \(iRef\) be ? Evaluation of LeftHandSideExpression.
   b. If IsAnonymousFunctionDefinition(AssignmentExpression) and IsIdentifierRef of LeftHandSideExpression are both true, then
      i. Let \(rVal\) be ? NamedEvaluation of AssignmentExpression with argument \(iRef.[[ReferencedName]]\).
   c. Else,
      i. Let \(ref\) be ? Evaluation of AssignmentExpression.
      ii. Let \(rVal\) be ? GetValue(\(ref\)).
   d. Perform ? PutValue(\(iRef, rVal\)).
   e. Return \(rVal\).
2. Let assignmentPattern be the AssignmentPattern that is covered by LeftHandSideExpression.
3. Let \( rref \) be ? \text{Evaluation} of AssignmentExpression.
4. Let \( rval \) be ? \text{GetValue}(rref).
5. Perform ? \text{DestructuringAssignmentEvaluation} of assignmentPattern with argument rval.
6. Return rval.

AssignmentExpression : LeftHandSideExpression AssignmentOperator AssignmentExpression

1. Let \( lref \) be ? \text{Evaluation} of LeftHandSideExpression.
2. Let \( lvval \) be ? \text{GetValue}(lref).
3. Let \( rref \) be ? \text{Evaluation} of AssignmentExpression.
4. Let \( rval \) be ? \text{GetValue}(rref).
5. Let assignmentOpText be the source text matched by AssignmentOperator.
6. Let opText be the sequence of Unicode code points associated with assignmentOpText in the following table:

<table>
<thead>
<tr>
<th>assignmentOpText</th>
<th>opText</th>
</tr>
</thead>
<tbody>
<tr>
<td>**=</td>
<td>**</td>
</tr>
<tr>
<td>*=</td>
<td>*</td>
</tr>
<tr>
<td>/=</td>
<td>/</td>
</tr>
<tr>
<td>%=</td>
<td>%</td>
</tr>
<tr>
<td>+=</td>
<td>+</td>
</tr>
<tr>
<td>-=</td>
<td>-</td>
</tr>
<tr>
<td>&lt;&lt;=</td>
<td>&lt;&lt;</td>
</tr>
<tr>
<td>&gt;&gt;=</td>
<td>&gt;&gt;</td>
</tr>
<tr>
<td>&gt;&gt;&gt;=</td>
<td>&gt;&gt;&gt;</td>
</tr>
<tr>
<td>&amp;=</td>
<td>&amp;</td>
</tr>
<tr>
<td>^=</td>
<td>^</td>
</tr>
<tr>
<td></td>
<td>=</td>
</tr>
</tbody>
</table>

7. Let \( r \) be ? \text{ApplyStringOrNumericBinaryOperator}(lvval, opText, rval).
9. Return \( r \).

AssignmentExpression : LeftHandSideExpression &&= AssignmentExpression

1. Let \( lref \) be ? \text{Evaluation} of LeftHandSideExpression.
2. Let \( lvval \) be ? \text{GetValue}(lref).
3. Let \( lbool \) be \text{ToBoolean}(lvval).
4. If \( lbool \) is false, return lvval.
5. If \text{IsAnonymousFunctionDefinition}(AssignmentExpression) is true and \text{IsIdentifierRef} of LeftHandSideExpression is true, then
   a. Let \( rval \) be ? \text{NamedEvaluation} of AssignmentExpression with argument lref.\{[ReferencedName]\].
6. Else,
   a. Let \( rref \) be ? \text{Evaluation} of AssignmentExpression.
   b. Let \( rval \) be ? \text{GetValue}(rref).
8. Return rval.

AssignmentExpression : LeftHandSideExpression ||= AssignmentExpression

1. Let \( lref \) be ? \text{Evaluation} of LeftHandSideExpression.
2. Let \( lvval \) be ? \text{GetValue}(lref).
3. Let \( lbool \) be \text{ToBoolean}(lvval).
4. If \( lbool \) is true, return lvval.
5. If \text{IsAnonymousFunctionDefinition}(AssignmentExpression) is true and \text{IsIdentifierRef} of LeftHandSideExpression is true, then
   a. Let \( rval \) be ? \text{NamedEvaluation} of AssignmentExpression with argument lref.\{[ReferencedName]\].
6. Else,
   a. Let \( rref \) be ? \text{Evaluation} of AssignmentExpression.
   b. Let \( rval \) be ? \text{GetValue}(rref).
Perform ? PutValue(lref, rval).
8. Return rval.

AssignmentExpression : LeftHandSideExpression ??= AssignmentExpression

2. Let lval be ? GetValue(lref).
3. If lval is neither undefined nor null, return lval.
4. If IsAnonymousFunctionDefinition(AssignmentExpression) is true and IsIdentifierRef of LeftHandSideExpression is true, then
   a. Let rval be ? NamedEvaluation of AssignmentExpression with argument lref.??=
5. Else,
   b. Let rval be ? GetValue(rref).
7. Return rval.

NOTE When this expression occurs within strict mode code, it is a runtime error if lref in step 1.d, 2, 2, 2
is an unresolvable reference. If it is, a ReferenceError exception is thrown. Additionally, it is a runtime
error if the lref in step 8, 7, 6 is a reference to a data property with the attribute value {
[[Writable]]: false }, to an accessor property with the attribute value { [[Set]]: undefined }, or to a
non-existent property of an object for which the IsExtensible predicate returns the value false. In
these cases a TypeError exception is thrown.

13.15.3 ApplyStringOrNumericBinaryOperator ( lval, opText, rval )

The abstract operation ApplyStringOrNumericBinaryOperator takes arguments lval (an ECMAScript language
value), opText (**, *, /, %, +, -, <<, >>, >>>, &^, |, }, and rval (an ECMAScript language value) and returns
either a normal completion containing either a String, a BigInt, or a Number, or a throw completion. It performs
the following steps when called:

1. If opText is +, then
   a. Let lprim be ? ToPrimitive(lval).
   b. Let rprim be ? ToPrimitive(rval).
   c. If lprim is a String or rprim is a String, then
      i. Let lstr be ? ToString(lprim).
      ii. Let rstr be ? ToString(rprim).
      iii. Return the string-concatenation of lstr and rstr.
   d. Set lval to lprim.
   e. Set rval to rprim.
2. NOTE: At this point, it must be a numeric operation.
3. Let inum be ? ToNumeric(lval).
4. Let num be ? ToNumeric(rval).
5. If Type(inum) is not Type(num), throw a TypeError exception.
6. If inum is a BigInt, then
   a. If opText is **, return ? BigInt::exponentiate(inum, num).
   b. If opText is /, return ? BigInt::divide(inum, num).
   c. If opText is %, return ? BigInt::remainder(inum, num).
   d. If opText is >>>, return ? BigInt::unsignedRightShift(inum, num).
7. Let operation be the abstract operation associated with opText and Type(inum) in the following table:

<table>
<thead>
<tr>
<th>opText</th>
<th>Type(inum)</th>
<th>operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>**</td>
<td>Number</td>
<td>Number::exponentiate</td>
</tr>
<tr>
<td>*</td>
<td>Number</td>
<td>Number::multiply</td>
</tr>
<tr>
<td>*</td>
<td>BigInt</td>
<td>BigInt::multiply</td>
</tr>
<tr>
<td>/</td>
<td>Number</td>
<td>Number::divide</td>
</tr>
<tr>
<td>%</td>
<td>Number</td>
<td>Number::remainder</td>
</tr>
<tr>
<td>+</td>
<td>Number</td>
<td>Number::add</td>
</tr>
</tbody>
</table>

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8. Return $operation(lnum, rnum)$.

**NOTE 1**  No hint is provided in the calls to $ToPrimitive$ in steps 1.a and 1.b. All standard objects except Dates handle the absence of a hint as if NUMBER were given; Dates handle the absence of a hint as if STRING were given. Exotic objects may handle the absence of a hint in some other manner.

**NOTE 2**  Step 1.c differs from step 3 of the $IsLessThan$ algorithm, by using the logical-or operation instead of the logical-and operation.

### 13.15.4 EvaluateStringOrNumericBinaryExpression ($leftOperand$, $opText$, $rightOperand$)

The abstract operation $EvaluateStringOrNumericBinaryExpression$ takes arguments $leftOperand$ (a Parse Node), $opText$ (a sequence of Unicode code points), and $rightOperand$ (a Parse Node) and returns either a normal completion containing either a String, a BigInt, or a Number, or an abrupt completion. It performs the following steps when called:

1. Let $lref$ be $Evaluation$ of $leftOperand$.
2. Let $lval$ be $GetValue(lref)$.
3. Let $rref$ be $Evaluation$ of $rightOperand$.
4. Let $rval$ be $GetValue(rref)$.
5. Return $ApplyStringOrNumericBinaryOperator(lval, opText, rval)$.

### 13.15.5 Destructuring Assignment

**Supplemental Syntax**

In certain circumstances when processing an instance of the production

$AssignmentExpression : LeftHandSideExpression = AssignmentExpression$

the interpretation of $LeftHandSideExpression$ is refined using the following grammar:

```
AssignmentPattern[Yield, Await] :
    ObjectAssignmentPattern[?Yield, ?Await]
    ArrayAssignmentPattern[?Yield, ?Await]
```
### ObjectAssignmentPattern

```
ObjectAssignmentPattern[Yield, Await] :
  { }
  { AssignmentRestProperty[?Yield, ?Await] }
  { AssignmentPropertyList[?Yield, ?Await] }
```

### ArrayAssignmentPattern

```
ArrayAssignmentPattern[Yield, Await] :
  [ Elision opt AssignmentRestElement[?Yield, ?Await] opt ]
```

### AssignmentRestProperty

```
AssignmentRestProperty[Yield, Await] :
  ... DestructuringAssignmentTarget[?Yield, ?Await]
```

### AssignmentPropertyList

```
AssignmentPropertyList[Yield, Await] :
  AssignmentProperty[?Yield, ?Await]
```

### AssignmentElementList

```
AssignmentElementList[Yield, Await] :
  AssignmentElisionElement[?Yield, ?Await]
```

### AssignmentElisionElement

```
AssignmentElisionElement[Yield, Await] :
  Elision opt AssignmentElement[?Yield, ?Await]
```

### AssignmentProperty

```
AssignmentProperty[Yield, Await] :
```

### AssignmentElement

```
AssignmentElement[Yield, Await] :
  DestructuringAssignmentTarget[?Yield, ?Await] Initializer[+In, ?Yield, ?Await] opt
```

### AssignmentRestElement

```
AssignmentRestElement[Yield, Await] :
  ... DestructuringAssignmentTarget[?Yield, ?Await]
```

### DestructuringAssignmentTarget

```
DestructuringAssignmentTarget[Yield, Await] :
  LeftHandSideExpression[?Yield, ?Await]
```

### 13.15.5.1 Static Semantics: Early Errors

**AssignmentProperty** : IdentifierReference Initializer\_\_opt

- It is a Syntax Error if **AssignmentTargetType** of IdentifierReference is not SIMPLE.

**AssignmentRestProperty** : ... DestructuringAssignmentTarget

- It is a Syntax Error if DestructuringAssignmentTarget is either an ArrayLiteral or an ObjectLiteral.

**DestructuringAssignmentTarget** : LeftHandSideExpression

If LeftHandSideExpression is either an ObjectLiteral or an ArrayLiteral, the following Early Error rules are applied:

- LeftHandSideExpression must cover an AssignmentPattern.

If LeftHandSideExpression is neither an ObjectLiteral nor an ArrayLiteral, the following Early Error rule is applied:
• It is a Syntax Error if `AssignmentTargetType` of `LeftHandSideExpression` is not SIMPLE.

13.15.5.2 Runtime Semantics: DestructuringAssignmentEvaluation

The syntax-directed operation DestructuringAssignmentEvaluation takes argument `value` (an ECMAscript language value) and returns either a normal completion containing UNUSED or an abrupt completion. It is defined piecewise over the following productions:

```
ObjectAssignmentPattern : {  }
  2. Return UNUSED.

ObjectAssignmentPattern : { AssignmentPropertyList  }
  { AssignmentPropertyList , }
  3. Return UNUSED.

ObjectAssignmentPattern : { AssignmentRestProperty }
  2. Let `excludedNames` be a new empty List.

ObjectAssignmentPattern : { AssignmentPropertyList , AssignmentRestProperty }
  2. Let `excludedNames` be ? PropertyDestructuringAssignmentEvaluation of AssignmentPropertyList with argument `value`.

ArrayAssignmentPattern : [  ]
  1. Let `iteratorRecord` be ? GetIterator(value, SYNC).
  2. Return ? IteratorClose(iteratorRecord, NormalCompletion(UNUSED)).

ArrayAssignmentPattern : [ Elision ]
  1. Let `iteratorRecord` be ? GetIterator(value, SYNC).
  2. Let `result` be Completion(IteratorDestructuringAssignmentEvaluation of Elision with argument `iteratorRecord`).
  3. If `iteratorRecord[[Done]]` is `false`, return ? IteratorClose(iteratorRecord, result).
  4. Return `result`.

ArrayAssignmentPattern : [ Elision_opt AssignmentRestElement ]
  1. Let `iteratorRecord` be ? GetIterator(value, SYNC).
  2. If Elision is present, then
     a. Let `status` be Completion(IteratorDestructuringAssignmentEvaluation of Elision with argument `iteratorRecord`).
     b. If `status` is an abrupt completion, then
        i. Assert: `iteratorRecord[[Done]]` is `true`.
        ii. Return `status`.
  3. Let `result` be Completion(IteratorDestructuringAssignmentEvaluation of AssignmentRestElement with argument `iteratorRecord`).
4. If iteratorRecord.[[Done]] is false, return IteratorClose(iteratorRecord, result).
5. Return result.

ArrayAssignmentPattern : [ AssignmentElementList ]

1. Let iteratorRecord be ? GetIterator(value, SYNC).
2. Let result be Completion(IteratorDestructuringAssignmentEvaluation of AssignmentElementList with argument iteratorRecord).
3. If iteratorRecord.[[Done]] is false, return IteratorClose(iteratorRecord, result).
4. Return result.

ArrayAssignmentPattern : [ AssignmentElementList , Elisionopt AssignmentRestElementopt ]

1. Let iteratorRecord be ? GetIterator(value, SYNC).
2. Let status be Completion(IteratorDestructuringAssignmentEvaluation of AssignmentElementList with argument iteratorRecord).
3. If status is an abrupt completion, then
   a. If iteratorRecord.[[Done]] is false, return IteratorClose(iteratorRecord, status).
4. If Elision is present, then
   a. Set status to Completion(IteratorDestructuringAssignmentEvaluation of Elision with argument iteratorRecord).
   b. If status is an abrupt completion, then
      i. Assert: iteratorRecord.[[Done]] is true.
      ii. Return ? status.
5. If AssignmentRestElement is present, then
   a. Set status to Completion(IteratorDestructuringAssignmentEvaluation of AssignmentRestElement with argument iteratorRecord).
6. If iteratorRecord.[[Done]] is false, return IteratorClose(iteratorRecord, status).

13.15.5.3 Runtime Semantics: PropertyDestructuringAssignmentEvaluation

The syntax-directed operation PropertyDestructuringAssignmentEvaluation takes argument value (an ECMA-Script language value) and returns either a normal completion containing a List of property keys or an abrupt completion. It collects a list of all destructured property keys. It is defined piecewise over the following productions:

AssignmentPropertyList : AssignmentPropertyList , AssignmentProperty

1. Let propertyNames be ? PropertyDestructuringAssignmentEvaluation of AssignmentPropertyList with argument value.
2. Let nextNames be ? PropertyDestructuringAssignmentEvaluation of AssignmentProperty with argument value.
3. Return the list-concatenation of propertyNames and nextNames.

AssignmentProperty : IdentifierReference Initializeropt

1. Let P be StringValue of IdentifierReference.
2. Let lref be ? ResolveBinding(P).
3. Let v be ? GetV(value, P).
4. If Initializer is present and v is undefined, then
   a. If IsAnonymousFunctionDefinition(Initializer) is true, then
      i. Set v to ? NamedEvaluation of Initializer with argument P.
   b. Else,
      i. Let defaultValue be ? Evaluation of Initializer.
      ii. Set v to ? GetValue(defaultValue).
6. Return « P ».
AssignmentProperty : PropertyName : AssignmentElement

1. Let name be ? Evaluation of PropertyName.
3. Return « name ».

13.15.5.4 Runtime Semantics: RestDestructuringAssignmentEvaluation

The syntax-directed operation RestDestructuringAssignmentEvaluation takes arguments value (an ECMAScript language value) and excludedNames (a List of property keys) and returns either a normal completion containing UNUSED or an abrupt completion. It is defined piecewise over the following productions:
AssignmentRestProperty : ... DestructuringAssignmentTarget

2. Let restObj be OrdinaryObjectCreate(%Object.prototype%).

13.15.5.5 Runtime Semantics: IteratorDestructuringAssignmentEvaluation

The syntax-directed operation IteratorDestructuringAssignmentEvaluation takes argument iteratorRecord (an Iterator Record) and returns either a normal completion containing UNUSED or an abrupt completion. It is defined piecewise over the following productions:
AssignmentElementList : AssignmentElisionElement

AssignmentElementList : AssignmentElementList , AssignmentElisionElement


AssignmentElisionElement : AssignmentElement

AssignmentElisionElement : Elision AssignmentElement


Elision :

1. If iteratorRecord.[[Done]] is false, then
   a. Let next be Completion(IteratorStep(iteratorRecord)).
   b. If next is an abrupt completion, set iteratorRecord.[[Done]] to true.
   c. ReturnIfAbrupt(next).
   d. If next is false, set iteratorRecord.[[Done]] to true.
2. Return UNUSED.

Elision : Elision

2. If iteratorRecord.[[Done]] is false, then
   a. Let next be Completion(IteratorStep(iteratorRecord)).
   b. If next is an abrupt completion, set iteratorRecord.[[Done]] to true.
AssignmentElement : DestructuringAssignmentTarget Initializer opt

1. If DestructuringAssignmentTarget is neither an ObjectLiteral nor an ArrayLiteral, then
2. Let value be undefined.
3. If iteratorRecord.[[Done]] is false, then
   a. Let next be ? IteratorStepValue(iteratorRecord).
      i. Set value to next.
4. If Initializer is present and value is undefined, then
   a. If IsAnonymousFunctionDefinition(Initializer) is true and IsIdentifierRef of
      DestructuringAssignmentTarget is true, then
      i. Let v be ? NamedEvaluation of Initializer with argument lref.[[ReferencedName]].
   b. Else,
      i. Let defaultValue be ? Evaluation of Initializer.
      ii. Let v be ? GetValue(defaultValue).
5. Else,
   a. Let v be value.
6. If DestructuringAssignmentTarget is either an ObjectLiteral or an ArrayLiteral, then
   a. Let nestedAssignmentPattern be the AssignmentPattern that is covered by
      DestructuringAssignmentTarget.

NOTE Left to right evaluation order is maintained by evaluating a DestructuringAssignmentTarget that is not a destructuring pattern prior to accessing the iterator or evaluating the Initializer.

AssignmentRestElement : ... DestructuringAssignmentTarget

1. If DestructuringAssignmentTarget is neither an ObjectLiteral nor an ArrayLiteral, then
2. Let A be ! ArrayCreate(0).
3. Let n be 0.
4. Repeat, while iteratorRecord.[[Done]] is false,
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is not DONE, then
      i. Perform ! CreateDataPropertyOrThrow(A, ! ToString(F(n)), next).
      ii. Set n to n + 1.
5. If DestructuringAssignmentTarget is neither an ObjectLiteral nor an ArrayLiteral, then
6. Let nestedAssignmentPattern be the AssignmentPattern that is covered by DestructuringAssignmentTarget.
7. Return ? DestructuringAssignmentEvaluation of nestedAssignmentPattern with argument A.

13.15.5.6 Runtime Semantics: KeyedDestructuringAssignmentEvaluation

The syntax-directed operation KeyedDestructuringAssignmentEvaluation takes arguments value (an ECMAScript language value) and propertyName (a property key) and returns either a normal completion containing UNUSED or an abrupt completion. It is defined piecewise over the following productions:

AssignmentElement : DestructuringAssignmentTarget Initializer opt

1. If DestructuringAssignmentTarget is neither an ObjectLiteral nor an ArrayLiteral, then
2. Let v be ? GetV(value, propertyName).
3. If Initializer is present and v is undefined, then
If `IsAnonymousFunctionDefinition(Initializer)` and `IsIdentifierRef` of `DestructuringAssignmentTarget` are both `true`, then
   i. Let `rhsValue` be ? `NamedEvaluation` of `Initializer` with argument `lref`[[ReferencedName]].

b. Else,
   i. Let `defaultValue` be ? `Evaluation` of `Initializer`.
   ii. Let `rhsValue` be ? `GetValue(defaultValue)`.

4. Else,
a. Let `rhsValue` be `v`.

5. If `DestructuringAssignmentTarget` is either an `ObjectLiteral` or an `ArrayLiteral`, then
   a. Let `assignmentPattern` be the `AssignmentPattern` that is `covered` by `DestructuringAssignmentTarget`.


13.16 Comma Operator ( , )

Syntax

```
Expression [In, Yield, Await] :
   AssignmentExpression [?In, ?Yield, ?Await]
```

13.16.1 Runtime Semantics: Evaluation

```
Expression : Expression , AssignmentExpression
```

2. Perform ? `GetValue(lref)`.
4. Return ? `GetValue(rref)`.

**NOTE** `GetValue` must be called even though its value is not used because it may have observable side-effects.

14 ECMAScript Language: Statements and Declarations

Syntax

```
Statement [Yield, Await, Return] :
   BlockStatement [?Yield, ?Await, ?Return]
   VariableStatement [?Yield, ?Await]
   EmptyStatement
   ExpressionStatement [?Yield, ?Await]
   IfStatement [?Yield, ?Await, ?Return]
   ContinueStatement [?Yield, ?Await]
   BreakStatement [?Yield, ?Await]
   [+Return] ReturnStatement [?Yield, ?Await]
   WithStatement [?Yield, ?Await, ?Return]
   LabelledStatement [?Yield, ?Await, ?Return]
   ThrowStatement [?Yield, ?Await]
   TryStatement [?Yield, ?Await, ?Return]
   DebuggerStatement
```
14.1 Statement Semantics

14.1.1 Runtime Semantics: Evaluation

HoistableDeclaration :  
  GeneratorDeclaration  
  AsyncFunctionDeclaration  
  AsyncGeneratorDeclaration

1. Return EMPTY.

HoistableDeclaration : FunctionDeclaration


BreakableStatement :  
  IterationStatement  
  SwitchStatement

1. Let newLabelSet be a new empty List.
2. Return ? LabelledEvaluation of this BreakableStatement with argument newLabelSet.

14.2 Block

Syntax

BlockStatement[Yield, Await, Return] :
  Block[Yield, Await, Return]

Block[Yield, Await, Return] :
  { StatementList[Yield, Await, Return] opt }

StatementList[Yield, Await, Return] :
  StatementListItem[Yield, Await, Return]  
  StatementList[Yield, Await, Return]  
  StatementListItem[Yield, Await, Return]

StatementListItem[Yield, Await, Return] :
  Statement[Yield, Await, Return]  
  Declaration[Yield, Await]
14.2.1 Static Semantics: Early Errors

Block : { StatementList }

- It is a Syntax Error if the LexicallyDeclaredNames of StatementList contains any duplicate entries.
- It is a Syntax Error if any element of the LexicallyDeclaredNames of StatementList also occurs in the VarDeclaredNames of StatementList.

14.2.2 Runtime Semantics: Evaluation

Block : { }

1. Return EMPTY.

Block : { StatementList }

1. Let oldEnv be the running execution context's LexicalEnvironment.
2. Let blockEnv be NewDeclarativeEnvironment(oldEnv).
3. Perform BlockDeclarationInstantiation(StatementList, blockEnv).
4. Set the running execution context's LexicalEnvironment to blockEnv.
5. Let blockValue be Completion(Evaluation of StatementList).
6. Set the running execution context's LexicalEnvironment to oldEnv.

NOTE 1  No matter how control leaves the Block the LexicalEnvironment is always restored to its former state.

StatementList : StatementList StatementList.Item

2. Let s be Completion(Evaluation of StatementList.Item).
3. Return ? UpdateEmpty(s, sl).

NOTE 2  The value of a StatementList is the value of the last value-producing item in the StatementList. For example, the following calls to the eval function all return the value 1:

```
eval("1;;;;;")
eval("1;{")
eval("1;var a;")
```

14.2.3 BlockDeclarationInstantiation (code, env)

The abstract operation BlockDeclarationInstantiation takes arguments code (a Parse Node) and env (a Declarative Environment Record) and returns UNUSED. code is the Parse Node corresponding to the body of the block. env is the Environment Record in which bindings are to be created.

NOTE  When a Block or CaseBlock is evaluated a new Declarative Environment Record is created and bindings for each block scoped variable, constant, function, or class declared in the block are instantiated in the Environment Record.

It performs the following steps when called:

1. Let declarations be the LexicallyScopedDeclarations of code.
2. Let privateEnv be the running execution context's PrivateEnvironment.
3. For each element $d$ of declarations, do
   a. For each element $dn$ of the BoundNames of $d$, do
i. If `IsConstantDeclaration` of `d` is `true`, then
   1. Perform `env.CreateImmutableBinding(dn, true)`.
ii. Else,
   1. Perform `env.CreateMutableBinding(dn, false)`. NOTE: This step is replaced in section B.3.2.6.

b. If `d` is either a `FunctionDeclaration`, a `GeneratorDeclaration`, an `AsyncFunctionDeclaration`, or an `AsyncGeneratorDeclaration`, then
   i. Let `fn` be the sole element of the `BoundNames` of `d`.
   ii. Let `fo` be `InstantiateFunctionObject` of `d` with arguments `env` and `privateEnv`.
   iii. Perform `env.InitializeBinding(fn, fo)`. NOTE: This step is replaced in section B.3.2.6.

4. Return UNUSED.

14.3 Declarations and the Variable Statement

14.3.1 Let and Const Declarations

NOTE `let` and `const` declarations define variables that are scoped to the running execution context’s LexicalEnvironment. The variables are created when their containing Environment Record is instantiated but may not be accessed in any way until the variable’s LexicalBinding is evaluated. A variable defined by a LexicalBinding with an Initializer is assigned the value of its Initializer’s AssignmentExpression when the LexicalBinding is evaluated, not when the variable is created. If a LexicalBinding in a `let` declaration does not have an Initializer the variable is assigned the value `undefined` when the LexicalBinding is evaluated.

Syntax

```
LexicalDeclaration[In, Yield, Await] :
    LetOrConst BindingList[?In, ?Yield, ?Await] ;

LetOrConst :
    let
    const

BindingList[In, Yield, Await] :
    LexicalBinding[?In, ?Yield, ?Await]

LexicalBinding[In, Yield, Await] :
```

14.3.1.1 Static Semantics: Early Errors

`LexicalDeclaration` : `LetOrConst BindingList` ;

- It is a Syntax Error if the `BoundNames` of `BindingList` contains "let".
- It is a Syntax Error if the `BoundNames` of `BindingList` contains any duplicate entries.

`LexicalBinding` : `BindingIdentifier Initializer_opt`

- It is a Syntax Error if `Initializer` is not present and `IsConstantDeclaration` of the `LexicalDeclaration` containing this `LexicalBinding` is `true`. 

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14.3.1.2 Runtime Semantics: Evaluation

**LexicalDeclaration** : LetOrConst BindingList ;

2. Return EMPTY.

**BindingList** : BindingList , LexicalBinding


**LexicalBinding** : BindingIdentifier

1. Let `lhs` be ! ResolveBinding(StringValue of BindingIdentifier).
2. Perform ! InitializeReferencedBinding(`lhs`, `undefined`).
3. Return EMPTY.

**LexicalBinding** : BindingIdentifier Initializer

1. Let `bindingId` be String Value of BindingIdentifier.
2. Let `lhs` be ! ResolveBinding(`bindingId`).
3. If IsAnonymousFunctionDefinition(Initializer) is true, then
   a. Let `value` be ? NamedEvaluation of Initializer with argument `bindingId`.
4. Else,
   a. Let `rhs` be ? Evaluation of Initializer.
   b. Let `value` be ? GetValue(`rhs`).
5. Perform ! InitializeReferencedBinding(`lhs`, `value`).
6. Return EMPTY.

**LexicalBinding** : BindingPattern Initializer

1. Let `rhs` be ? Evaluation of Initializer.
2. Let `value` be ? GetValue(`rhs`).
3. Let `env` be the running execution context's LexicalEnvironment.

14.3.2 Variable Statement

**Syntax**

```
VariableStatement[Yield, Await] :
  var VariableDeclarationList[+In, ?Yield, ?Await] ;
```

VariableDeclaration[?In, ?Yield, ?Await] :

14.3.2.1 Runtime Semantics: Evaluation

VariableStatement : var VariableDeclarationList ;

2. Return EMPTY.

VariableDeclarationList : VariableDeclarationList , VariableDeclaration


VariableDeclaration : BindingIdentifier

1. Return EMPTY.

VariableDeclaration : BindingIdentifier  initializer

1. Let bindingId be StringValue of BindingIdentifier.
2. Let lhs be ? ResolveBinding(bindingId).
3. If IsAnonymousFunctionDefinition(Initializer) is true, then
   a. Let value be ? NamedEvaluation of Initializer with argument bindingId.
4. Else,
   a. Let rhs be ? Evaluation of Initializer.
   b. Let value be ? GetValue(rhs).
6. Return EMPTY.

NOTE If a VariableDeclaration is nested within a with statement and the BindingIdentifier in the VariableDeclaration is the same as a property name of the binding object of the with statement's Object Environment Record, then step 5 will assign value to the property instead of assigning to the VariableEnvironment binding of the Identifier.

VariableDeclaration : BindingPattern  initializer

1. Let rhs be ? Evaluation of Initializer.
2. Let rval be ? GetValue(rhs).

14.3.3 Destructuring Binding Patterns

Syntax

  BindingPattern[?Yield, ?Await] :
    ObjectBindingPattern[?Yield, ?Await]
    ArrayBindingPattern[?Yield, ?Await]
ObjectBindingPattern[Yield, Await] :
  { }
  { BindingRestProperty[?Yield, ?Await] }
  { BindingPropertyList[?Yield, ?Await] }

ArrayBindingPattern[Yield, Await] :
  [ Elision opt BindingRestElement[?Yield, ?Await] opt ]

BindingRestProperty[Yield, Await] :
  ...
  BindingIdentifier[?Yield, ?Await]

BindingPropertyList[Yield, Await] :
  BindingProperty[?Yield, ?Await]

BindingElementList[Yield, Await] :
  BindingElisionElement[?Yield, ?Await]

BindingElisionElement[Yield, Await] :
  Elision opt BindingElement[?Yield, ?Await]

BindingProperty[Yield, Await] :
  SimpleNameBinding[?Yield, ?Await]
  PropertyName[?Yield, ?Await] :
  BindingElement[?Yield, ?Await]

BindingElement[Yield, Await] :
  SimpleNameBinding[?Yield, ?Await]

SimpleNameBinding[Yield, Await] :

BindingRestElement[Yield, Await] :
  ...
  BindingIdentifier[?Yield, ?Await]
  ...
  BindingPattern[?Yield, ?Await]

14.3.3.1 Runtime Semantics: PropertyBindingInitialization

The syntax-directed operation PropertyBindingInitialization takes arguments value (an ECMAScript language value) and environment (an Environment Record or undefined) and returns either a normal completion containing a List of property keys or an abrupt completion. It collects a list of all bound property names. It is defined piecewise over the following productions:

BindingPropertyList : BindingPropertyList , BindingProperty

1. Let boundNames be ? PropertyBindingInitialization of BindingPropertyList with arguments value and environment.
2. Let nextNames be ? PropertyBindingInitialization of BindingProperty with arguments value and environment.
3. Return the list-concatenation of boundNames and nextNames.
BindingProperty : SingleNameBinding

1. Let name be the sole element of the BoundNames of SingleNameBinding.
2. Perform ? KeyedBindingInitialization of SingleNameBinding with arguments value, environment, and name.
3. Return « name ».

BindingProperty : PropertyName : BindingElement

1. Let P be ? Evaluation of PropertyName.
2. Perform ? KeyedBindingInitialization of BindingElement with arguments value, environment, and P.
3. Return « P ».

14.3.3.2 Runtime Semantics: RestBindingInitialization

The syntax-directed operation RestBindingInitialization takes arguments value (an ECMAScript language value), environment (an Environment Record or undefined), and excludedNames (a List of property keys) and returns either a normal completion containing UNUSED or an abrupt completion. It is defined piecewise over the following productions:

BindingRestProperty : ... BindingIdentifier

1. Let lhs be ? ResolveBinding(StringValue of BindingIdentifier, environment).
2. Let restObj be OrdinaryObjectCreate(%Object.prototype%).
4. If environment is undefined, return ? PutValue(lhs, restObj).

14.3.3.3 Runtime Semantics: KeyedBindingInitialization

The syntax-directed operation KeyedBindingInitialization takes arguments value (an ECMAScript language value), environment (an Environment Record or undefined), and propertyName (a property key) and returns either a normal completion containing UNUSED or an abrupt completion.

NOTE When undefined is passed for environment it indicates that a PutValue operation should be used to assign the initialization value. This is the case for formal parameter lists of non-strict functions. In that case the formal parameter bindings are preinitialized in order to deal with the possibility of multiple parameters with the same name.

It is defined piecewise over the following productions:

BindingElement : BindingPattern Initializeropt

1. Let v be ? GetV(value, propertyName).
2. If initializer is present and v is undefined, then
   b. Set v to ? GetValue(defaultValue).

SingleNameBinding : BindingIdentifier Initializeropt

1. Let bindingId be StringValue of BindingIdentifier.
2. Let lhs be ? ResolveBinding(bindingId, environment).
3. Let v be ? GetV(value, propertyName).
4. If initializer is present and v is undefined, then
   a. If IsAnonymousFunctionDefinition(Initializer) is true, then
      i. Set v to ? NamedEvaluation of Initializer with argument bindingId.
   b. Else,
      i. Let defaultValue be ? Evaluation of initializer.
      ii. Set v to ? GetValue(defaultValue).
5. If `environment` is `undefined`, return `? PutValue(lhs, v)`.

### 14.4 Empty Statement

**Syntax**

```
EmptyStatement : ;
```

#### 14.4.1 Runtime Semantics: Evaluation

`EmptyStatement : ;`

1. Return `EMPTY`.

### 14.5 Expression Statement

**Syntax**

```
ExpressionStatement[Yield, Await] :
  [lookahead \[=\} \{, function, async [no LineTerminator here] function, class, let [ ]]
   Expression[+In, ?Yield, ?Await] ;
```

**Note**

An `ExpressionStatement` cannot start with a U+007B (LEFT CURLY BRACKET) because that might make it ambiguous with a `Block`. An `ExpressionStatement` cannot start with the `function` or `class` keywords because that would make it ambiguous with a `FunctionDeclaration`, a `GeneratorDeclaration`, or a `ClassDeclaration`. An `ExpressionStatement` cannot start with `async function` because that would make it ambiguous with an `AsyncFunctionDeclaration` or a `AsyncGeneratorDeclaration`. An `ExpressionStatement` cannot start with the two token sequence `let [ ]` because that would make it ambiguous with a `let LexicalDeclaration` whose first `LexicalBinding` was an `ArrayBindingPattern`.

#### 14.5.1 Runtime Semantics: Evaluation

`ExpressionStatement : Expression ;`

1. Let `exprRef` be `? Evaluation` of `Expression`.
2. Return `? GetValue(exprRef)`.

### 14.6 The `if` Statement

**Syntax**

```
IfStatement[Yield, Await, Return] :
  Statement[?Yield, ?Await, ?Return]
  [lookahead \[=\] else]
```

**Note**

The lookahead-restriction [lookahead \[=\] else] resolves the classic "dangling else" problem in the usual way. That is, when the choice of associated `if` is otherwise ambiguous, the `else` is associated with the nearest (innermost) of the candidate `ifs`
### 14.6.1 Static Semantics: Early Errors

**IfStatement**: `if ( Expression ) Statement else Statement`

- It is a Syntax Error if `IsLabelledFunction` (the first `Statement`) is `true`.
- It is a Syntax Error if `IsLabelledFunction` (the second `Statement`) is `true`.

**IfStatement**: `if ( Expression ) Statement`

- It is a Syntax Error if `IsLabelledFunction` (`Statement`) is `true`.

**NOTE**  
It is only necessary to apply this rule if the extension specified in B.3.1 is implemented.

### 14.6.2 Runtime Semantics: Evaluation

**IfStatement**: `if ( Expression ) Statement else Statement`

1. Let `exprRef` be `? Evaluation` of `Expression`.
2. Let `exprValue` be `ToBoolean(? GetValue(exprRef))`.
3. If `exprValue` is `true`, then
   a. Let `stmtCompletion` be `Completion(Evaluation` of the first `Statement`).
4. Else,
   a. Let `stmtCompletion` be `Completion(Evaluation` of the second `Statement`).
5. Return `? UpdateEmpty(stmtCompletion, undefined)`.

**IfStatement**: `if ( Expression ) Statement`

1. Let `exprRef` be `? Evaluation` of `Expression`.
2. Let `exprValue` be `ToBoolean(? GetValue(exprRef))`.
3. If `exprValue` is `false`, then
   a. Return `undefined`.
4. Else,
   a. Let `stmtCompletion` be `Completion(Evaluation` of `Statement`).
   b. Return `? UpdateEmpty(stmtCompletion, undefined)`.

### 14.7 Iteration Statements

**Syntax**

```
IterationStatement[Yield, Await, Return] :
  DoWhileStatement[Yield, ?Await, ?Return]
  WhileStatement[Yield, ?Await, ?Return]
  ForInOfStatement[Yield, ?Await, ?Return]
```

### 14.7.1 Semantics

#### 14.7.1.1 LoopContinues ( `completion`, `labelSet` )

The abstract operation LoopContinues takes arguments `completion` (a Completion Record) and `labelSet` (a List of Strings) and returns a Boolean. It performs the following steps when called:

1. If `completion` is a normal completion, return `true`.
2. If `completion` is not a continue completion, return `false`.
3. If `completion`.[[Target]] is EMPTY, return `true`. 
4. If \texttt{labelSet} contains \texttt{completion.}[\texttt{[Target]}], return \texttt{true}.  
5. Return \texttt{false}.

\textbf{NOTE} Within the \texttt{Statement} part of an \texttt{IterationStatement} a \texttt{ContinueStatement} may be used to begin a new iteration.

14.7.1.2 Runtime Semantics: LoopEvaluation

The syntax-directed operation \texttt{LoopEvaluation} takes argument \texttt{labelSet} (a \texttt{List} of \texttt{Strings}) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

\begin{itemize}
  \item \texttt{IterationStatement : DoWhileStatement}
  \item \texttt{IterationStatement : WhileStatement}
  \item \texttt{IterationStatement : ForStatement}
  \item \texttt{IterationStatement : ForInOfStatement}
\end{itemize}

14.7.2 The do-while Statement

\textbf{Syntax}

\begin{verbatim}
DoWhileStatement[Yield, Await, Return] :
  do Statement[Yield, Await, Return] while ( Expression[+In, ?Yield, ?Await] ) ;
\end{verbatim}

14.7.2.1 Static Semantics: Early Errors

\texttt{DoWhileStatement : do Statement while ( Expression ) ;}

\begin{itemize}
  \item It is a Syntax Error if \texttt{IsLabelledFunction(Statement)} is \texttt{true}.
\end{itemize}

\textbf{NOTE} It is only necessary to apply this rule if the extension specified in B.3.1 is implemented.

14.7.2.2 Runtime Semantics: DoWhileLoopEvaluation

The syntax-directed operation \texttt{DoWhileLoopEvaluation} takes argument \texttt{labelSet} (a \texttt{List} of \texttt{Strings}) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

\begin{itemize}
  \item \texttt{DoWhileStatement : do Statement while ( Expression ) ;}
\end{itemize}

1. Let \texttt{V} be \texttt{undefined}.
2. Repeat,
   \begin{itemize}
     \item Let \texttt{stmtResult} be \texttt{Completion(Evaluation of Statement)}.
     \item If \texttt{LoopContinues(stmtResult, labelSet)} is \texttt{false}, return ? \texttt{UpdateEmpty(stmtResult, V)}.
     \item If \texttt{stmtResult.}[\texttt{[Value]]} is not \texttt{EMPTY}, set \texttt{V} to \texttt{stmtResult.}[\texttt{[Value]]}.
     \item Let \texttt{exprRef} be ? \texttt{Evaluation of Expression}.
Let `exprValue` be `GetValue(exprRef)`.

If `ToBoolean(exprValue)` is `false`, return `V`.

14.7.3 The while Statement

Syntax

```
WhileStatement[Yield, Await, Return] :
```

14.7.3.1 Static Semantics: Early Errors

```
WhileStatement : while ( Expression ) Statement
```

- It is a Syntax Error if `IsLabelledFunction(Statement)` is `true`.

**NOTE** It is only necessary to apply this rule if the extension specified in B.3.1 is implemented.

14.7.3.2 Runtime Semantics: WhileLoopEvaluation

The syntax-directed operation `WhileLoopEvaluation` takes argument `labelSet` (a List of Strings) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

```
WhileStatement : while ( Expression ) Statement
```

1. Let `V` be `undefined`.
2. Repeat,
   a. Let `exprRef` be `Evaluation` of `Expression`.
   b. Let `exprValue` be `GetValue(exprRef)`.
   c. If `ToBoolean(exprValue)` is `false`, return `V`.
   d. Let `stmtResult` be `Completion(Evaluation of Statement)`.
   e. If `LoopContinues(stmtResult, labelSet)` is `false`, return `UpdateEmpty(stmtResult, V)`.
   f. If `stmtResult.[[Value]]` is not `EMPTY`, set `V` to `stmtResult.[[Value]]`.

14.7.4 The for Statement

Syntax

```
ForStatement[Yield, Await, Return] :
    Statement[?Yield, ?Await, ?Return]
```

```
for ( var VariableDeclarationList[-In, ?Yield, ?Await] ;
  Statement[?Yield, ?Await, ?Return]
```

```
    Expression[+In, ?Yield, ?Await] opt )
  Statement[?Yield, ?Await, ?Return]
```

14.7.4.1 Static Semantics: Early Errors

```
ForStatement :
  for ( Expression opt ; Expression opt ; Expression opt ) Statement
for ( var VariableDeclarationList ; Expression opt ; Expression opt ) Statement
for ( LexicalDeclaration Expression opt ; Expression opt ) Statement
```

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• It is a Syntax Error if IsLabelledFunction(Statement) is true.

NOTE It is only necessary to apply this rule if the extension specified in B.3.1 is implemented.

ForStatement : for ( LexicalDeclaration Expressionopt ; Expressionopt ) Statement
• It is a Syntax Error if any element of the BoundNames of LexicalDeclaration also occurs in the VarDeclaredNames of Statement.

14.7.4.2 Runtime Semantics: ForLoopEvaluation

The syntax-directed operation ForLoopEvaluation takes argument labelSet (a List of Strings) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

ForStatement : for ( Expressionopt ; Expressionopt ; Expressionopt ) Statement

1. If the first Expression is present, then
   a. Let exprRef be ? Evaluation of the first Expression.
   b. Perform ? GetValue(exprRef).
2. If the second Expression is present, let test be the second Expression; otherwise, let test be EMPTY. 
3. If the third Expression is present, let increment be the third Expression; otherwise, let increment be EMPTY. 
4. Return ? ForBodyEvaluation((test, increment, Statement, « », labelSet)).

ForStatement : for ( var VariableDeclarationList ; Expressionopt ; Expressionopt ) Statement

2. If the first Expression is present, let test be the first Expression; otherwise, let test be EMPTY. 
3. If the second Expression is present, let increment be the second Expression; otherwise, let increment be EMPTY. 
4. Return ? ForBodyEvaluation((test, increment, Statement, « », labelSet)).

ForStatement : for ( LexicalDeclaration Expressionopt ; Expressionopt ) Statement

1. Let oldEnv be the running execution context's LexicalEnvironment.
2. Let loopEnv be NewDeclarativeEnvironment(oldEnv).
3. Let isConst be IsConstantDeclaration of LexicalDeclaration.
4. Let boundNames be the BoundNames of LexicalDeclaration.
5. For each element dn of boundNames, do
   a. If isConst is true, then
      i. Perform ! loopEnv.CreateImmutableBinding(dn, true).
   b. Else,
      i. Perform ! loopEnv.CreateMutableBinding(dn, false).
5. Set the running execution context's LexicalEnvironment to loopEnv.
6. Let forDcl be Completion(Evaluation of LexicalDeclaration).
7. If forDcl is an abrupt completion, then
   a. Set the running execution context's LexicalEnvironment to oldEnv.
8. If isConst is false, let perIterationLets be boundNames; otherwise let perIterationLets be a new empty List. 
9. If the first Expression is present, let test be the first Expression; otherwise, let test be EMPTY. 
10. If the second Expression is present, let increment be the second Expression; otherwise, let increment be EMPTY. 
11. Set the running execution context's LexicalEnvironment to oldEnv.
12. Let bodyResult be Completion(ForBodyEvaluation(test, increment, Statement, perIterationLets, labelSet)).
13. Set the running execution context's LexicalEnvironment to oldEnv.
### 14.7.4.3 ForBodyEvaluation (test, increment, stmt, perIterationBindings, labelSet)

The abstract operation ForBodyEvaluation takes arguments test (an Expression Parse Node or EMPT), increment (an Expression Parse Node or EMPT), stmt (a Statement Parse Node), perIterationBindings (a List of Strings), and labelSet (a List of Strings) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. Let V be undefined.
2. Perform ? CreatePerIterationEnvironment(perIterationBindings).
3. Repeat,
   a. If test is not EMPT, then
      i. Let testRef be ? Evaluation of test.
      ii. Let testValue be ? GetValue(testRef).
      iii. If ToBoolean(testValue) is false, return V.
   b. Let result be Completion(Evaluation of stmt).
   c. If LoopContinues(result, labelSet) is false, return ? UpdateEmpty(result, V).
   d. If result.[[Value]] is not EMPT, set V to result.[[Value]].
   e. Perform ? CreatePerIterationEnvironment(perIterationBindings).
   f. If increment is not EMPT, then
      i. Let incRef be ? Evaluation of increment.
      ii. Perform ? GetValue(incRef).

### 14.7.4.4 CreatePerIterationEnvironment (perIterationBindings)

The abstract operation CreatePerIterationEnvironment takes argument perIterationBindings (a List of Strings) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. If perIterationBindings has any elements, then
   a. Let lastIterationEnv be the running execution context’s LexicalEnvironment.
   b. Let outer be lastIterationEnv.[[OuterEnv]].
   c. Assert: outer is not null.
   d. Let thisIterationEnv be NewDeclarativeEnvironment(outer).
   e. For each element bn of perIterationBindings, do
      i. Perform ! thisIterationEnv.CreateMutableBinding(bn, false).
      ii. Let lastValue be ? thisIterationEnv.GetBindingValue(bn, true).
      iii. Perform ! thisIterationEnv.InitializeBinding(bn, lastValue).
   f. Set the running execution context’s LexicalEnvironment to thisIterationEnv.
2. Return UNUSED.
14.7.5 The for-in, for-of, and for-await-of Statements

Syntax

ForInOfStatement[Yield, Await, Return] :


ForDeclaration[Yield, Await] :
   LetOrConst ForBinding[?Yield, ?Await]

ForBinding[Yield, Await] :
   BindingIdentifier[?Yield, ?Await]
   BindingPattern[?Yield, ?Await]

NOTE This section is extended by Annex B.3.5.

14.7.5.1 Static Semantics: Early Errors

ForInOfStatement :
   for ( LeftHandSideExpression in Expression ) Statement
   for ( var ForBinding in Expression ) Statement
   for ( ForDeclaration in Expression ) Statement
   for ( LeftHandSideExpression of AssignmentExpression ) Statement
   for ( var ForBinding of AssignmentExpression ) Statement
   for ( ForDeclaration of AssignmentExpression ) Statement
   for await ( LeftHandSideExpression of AssignmentExpression ) Statement
   for await ( var ForBinding of AssignmentExpression ) Statement
   for await ( ForDeclaration of AssignmentExpression ) Statement

• It is a Syntax Error if IsLabelledFunction(Statement) is true.

NOTE It is only necessary to apply this rule if the extension specified in B.3.1 is implemented.
ForInOfStatement:
    for ( LeftHandSideExpression in Expression ) Statement
    for ( LeftHandSideExpression of AssignmentExpression ) Statement
    for await ( LeftHandSideExpression of AssignmentExpression ) Statement

If LeftHandSideExpression is either an ObjectLiteral or an ArrayLiteral, the following Early Error rules are applied:

- LeftHandSideExpression must cover an AssignmentPattern.

If LeftHandSideExpression is neither an ObjectLiteral nor an ArrayLiteral, the following Early Error rule is applied:

- It is a Syntax Error if AssignmentTargetType of LeftHandSideExpression is not SIMPLE.

ForInOfStatement:
    for ( ForDeclaration in Expression ) Statement
    for ( ForDeclaration of AssignmentExpression ) Statement
    for await ( ForDeclaration of AssignmentExpression ) Statement

- It is a Syntax Error if the BoundNames of ForDeclaration contains "let".
- It is a Syntax Error if any element of the BoundNames of ForDeclaration also occurs in the VarDeclaredNames of Statement.
- It is a Syntax Error if the BoundNames of ForDeclaration contains any duplicate entries.

14.7.5.2 Static Semantics: IsDestructuring

The syntax-directed operation IsDestructuring takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

MemberExpression : PrimaryExpression
  1. If PrimaryExpression is either an ObjectLiteral or an ArrayLiteral, return true.
  2. Return false.

MemberExpression :
  MemberExpression [ Expression ]
  MemberExpression . IdentifierName
  MemberExpression TemplateLiteral
  SuperProperty
  MetaProperty
  new MemberExpression Arguments
  MemberExpression . PrivateIdentifier

NewExpression :
  new NewExpression

LeftHandSideExpression :
  CallExpression
  OptionalExpression

  1. Return false.

ForDeclaration : LetOrConst ForBinding

  1. Return IsDestructuring of ForBinding.

ForBinding : BindingIdentifier

  1. Return false.
ForBinding : BindingPattern

1. Return true.

NOTE This section is extended by Annex B.3.5.

14.7.5.3 Runtime Semantics: ForDeclarationBindingInitialization

The syntax-directed operation ForDeclarationBindingInitialization takes arguments value (an ECMAScript language value) and environment (an Environment Record or undefined) and returns either a normal completion containing UNUSED or an abrupt completion.

NOTE undefined is passed for environment to indicate that a PutValue operation should be used to assign the initialization value. This is the case for var statements and the formal parameter lists of some non-strict functions (see 10.2.11). In those cases a lexical binding is hoisted and preinitialized prior to evaluation of its initializer.

It is defined piecewise over the following productions:

ForDeclaration : LetOrConst ForBinding

1. Return ? BindingInitialization of ForBinding with arguments value and environment.

14.7.5.4 Runtime Semantics: ForDeclarationBindingInstantiation

The syntax-directed operation ForDeclarationBindingInstantiation takes argument environment (a Declarative Environment Record) and returns UNUSED. It is defined piecewise over the following productions:

ForDeclaration : LetOrConst ForBinding

1. For each element name of the BoundNames of ForBinding, do
   a. If IsConstantDeclaration of LetOrConst is true, then
      i. Perform ! environment.CreateImmutableBinding(name, true).
   b. Else,
      i. Perform ! environment.CreateMutableBinding(name, false).
2. Return UNUSED.

14.7.5.5 Runtime Semantics: ForInOfLoopEvaluation

The syntax-directed operation ForInOfLoopEvaluation takes argument labelSet (a List of Strings) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

ForInOfStatement : for ( LeftHandSideExpression in Expression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(« », Expression, ENUMERATE).
2. Return ? ForIn/OfBodyEvaluation(LeftHandSideExpression, Statement, keyResult, ENUMERATE, ASSIGNMENT, labelSet).

ForInOfStatement : for ( var ForBinding in Expression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(« », Expression, ENUMERATE).
2. Return ? ForIn/OfBodyEvaluation(ForBinding, Statement, keyResult, ENUMERATE, VAR-BINDING, labelSet).
ForInOfStatement : for ( ForDeclaration in Expression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(BoundNames of ForDeclaration, Expression, ENUMERATE).
2. Return ? ForIn/OfBodyEvaluation(ForDeclaration, Statement, keyResult, ENUMERATE, LEXICAL-BINDING, labelSet).

ForInOfStatement : for ( LeftHandSideExpression of AssignmentExpression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(« », AssignmentExpression, ITERATE).
2. Return ? ForIn/OfBodyEvaluation(LeftHandSideExpression, Statement, keyResult, ITERATE, ASSIGNMENT, labelSet).

ForInOfStatement : for ( var ForBinding of AssignmentExpression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(« », AssignmentExpression, ITERATE).
2. Return ? ForIn/OfBodyEvaluation(ForBinding, Statement, keyResult, ITERATE, VAR-BINDING, labelSet).

ForInOfStatement : for ( ForDeclaration of AssignmentExpression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(BoundNames of ForDeclaration, AssignmentExpression, ITERATE).
2. Return ? ForIn/OfBodyEvaluation(ForDeclaration, Statement, keyResult, ITERATE, LEXICAL-BINDING, labelSet).

ForInOfStatement : for await ( LeftHandSideExpression of AssignmentExpression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(« », AssignmentExpression, ASYNC-ITERATE).
2. Return ? ForIn/OfBodyEvaluation(LeftHandSideExpression, Statement, keyResult, ITERATE, ASSIGNMENT, labelSet, ASYNC).

ForInOfStatement : for await ( var ForBinding of AssignmentExpression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(« », AssignmentExpression, ASYNC-ITERATE).
2. Return ? ForIn/OfBodyEvaluation(ForBinding, Statement, keyResult, ITERATE, VAR-BINDING, labelSet, ASYNC).

ForInOfStatement : for await ( ForDeclaration of AssignmentExpression ) Statement

1. Let keyResult be ? ForIn/OfHeadEvaluation(BoundNames of ForDeclaration, AssignmentExpression, ASYNC-ITERATE).
2. Return ? ForIn/OfBodyEvaluation(ForDeclaration, Statement, keyResult, ITERATE, LEXICAL-BINDING, labelSet, ASYNC).

NOTE  This section is extended by Annex B.3.5.

14.7.5.6  ForIn/OfHeadEvaluation ( uninitializedBoundNames, expr, iterationKind )

The abstract operation ForIn/OfHeadEvaluation takes arguments uninitializedBoundNames (a List of Strings), expr (an Expression Parse Node or an AssignmentExpression Parse Node), and iterationKind (ENUMERATE, ITERATE, or ASYNC-ITERATE) and returns either a normal completion containing an Iterator Record or an abrupt completion. It performs the following steps when called:

1. Let oldEnv be the running execution context's LexicalEnvironment.
2. If uninitializedBoundNames is not empty, then
   a. Assert: uninitializedBoundNames has no duplicate entries.
   b. Let newEnv be NewDeclarativeEnvironment(oldEnv).
   c. For each String name of uninitializedBoundNames, do
      i. Perform 1 newEnv.CreateMutableBinding(name, false).
   d. Set the running execution context's LexicalEnvironment to newEnv.
Let exprRef be \( \text{Completion} (\text{Evaluation of } expr) \).

Set the running execution context’s LexicalEnvironment to oldEnv.

Let exprValue be ? GetValue(? exprRef).

If iterationKind is ENUMERATE, then

a. If exprValue is either undefined or null, then
   i. Return Completion Record \{ [[Type]]: BREAK, [[Value]]: EMPTY, [[Target]]: EMPTY \}.
   
   b. Let obj be ! ToObject(exprValue).
   
   c. Let iterator be EnumerateObjectProperties(obj).
   
   d. Let nextMethod be ! GetV(iterator, "next").
   
   e. Return the Iterator Record \{ [[Iterator]]: iterator, [[NextMethod]]: nextMethod, [[Done]]: false \}.

Else,

a. Assert: iterationKind is either ITERATE or ASYNC-ITERATE.

b. If iterationKind is ASYNC-ITERATE, let iteratorKind be ASYNC.

c. Else, let iteratorKind be SYNC.


14.7.5.7 ForIn/OfBodyEvaluation ( \( Ihs, stmt, iteratorRecord, iterationKind, IhsKind, labelSet \), IhsKind, iterationKind \) )

The abstract operation ForIn/OfBodyEvaluation takes arguments \( Ihs \) (a Parse Node), \( stmt \) (a Statement Parse Node), \( iteratorRecord \) (an IteratorRecord), \( iterationKind \) (ENUMERATE or ITERATE), \( IhsKind \) (ASSIGNMENT, VAR-BINDING, or LEXICAL-BINDING), and \( labelSet \) (a List of Strings) and optional argument \( iterationKind \) (SYNC or ASYNC) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. If iterationKind is not present, set iterationKind to SYNC.

2. Let oldEnv be the running execution context’s LexicalEnvironment.

3. Let V be undefined.

4. Let destructuring be IsDestructuring of Ihs.

5. If destructuring is true and IhsKind is ASSIGNMENT, then
   
   a. Assert: Ihs is a LeftHandSideExpression.
   
   b. Let assignmentPattern be the AssignmentPattern that is covered by Ihs.

6. Repeat,

   a. Let nextResult be ? Call(iteratorRecord.[[NextMethod]], iteratorRecord.[[Iterator]]).
   
   b. If iterationKind is ASYNC, set nextResult to ? Await(nextResult).
   
   c. If nextResult is not an Object, throw a TypeError exception.
   
   d. Let done be ? IteratorComplete(nextResult).
   
   e. If done is true, return V.
   
   f. Let nextValue be ? IteratorValue(nextResult).

   g. If IhsKind is either ASSIGNMENT or VAR-BINDING, then
      
      i. If destructuring is true, then
         
         1. If IhsKind is ASSIGNMENT, then
            a. Let status be Completion(DestructuringAssignmentEvaluation of assignmentPattern with argument nextValue).
         
         2. Else,
            a. Assert: IhsKind is VAR-BINDING.
            b. Assert: Ihs is a ForBinding.
            c. Let status be Completion(BindingInitialization of Ihs with arguments nextValue and undefined).
      
      ii. Else,
         
         1. Let IhsRef be Completion(Evaluation of Ihs). (It may be evaluated repeatedly.)
         
         2. If IhsRef is an abrupt completion, then
            a. Let status be IhsRef.
         
         3. Else,
            a. Let status be Completion(PutValue(IhsRef.[[Value]], nextValue)).
      
   h. Else,
      
      i. Assert: IhsKind is LEXICAL-BINDING.
      
      ii. Assert: Ihs is a ForDeclaration.
      
      iii. Let iterationEnv be NewDeclarativeEnvironment(oldEnv).
      
      iv. Perform ForDeclarationBindingInstantiation of Ihs with argument iterationEnv.
v. Set the running execution context's LexicalEnvironment to iterationEnv.

vi. If destructuring is true, then
   1. Let status be Completion(ForDeclarationBindingInitialization of lhs with arguments nextValue and iterationEnv).

vii. Else,
   1. Assert: lhs binds a single name.
   2. Let lhsName be the sole element of BoundNames of lhs.
   3. Let lhsRef be ! ResolveBinding(lhsName).
   4. Let status be Completion(InitializeReferencedBinding(lhsRef, nextValue)).

i. If status is an abrupt completion, then
   i. Set the running execution context's LexicalEnvironment to oldEnv.
   ii. If iteratorKind is ASYNC, return ? AsyncIteratorClose(iteratorRecord, status).
   iii. If iterationKind is ENUMERATE, then

iv. Else,
   1. Assert: iterationKind is ITERATE.

j. Let result be Completion(Evaluation of stmt).

k. Set the running execution context's LexicalEnvironment to oldEnv.

l. If LoopContinues(result, labelSet) is false, then
   i. If iterationKind is ENUMERATE, then
   ii. Else,
       1. Assert: iterationKind is ITERATE.
       2. Set status to Completion(UpdateEmpty(result, V)).
       3. If iteratorKind is ASYNC, return ? AsyncIteratorClose(iteratorRecord, status).

m. If result.[[Value]] is not EMPTY, set V to result.[[Value]].

14.7.5.8 Runtime Semantics: Evaluation

BindingIdentifier : Identifier

yield

await

1. Let bindingId be StringValue of BindingIdentifier.
2. Return ? ResolveBinding(bindingId).

14.7.5.9 EnumerateObjectProperties ( O )

The abstract operation EnumerateObjectProperties takes argument O (an Object) and returns an Iterator. It performs the following steps when called:

1. Return an Iterator object (27.1.1.2) whose next method iterates over all the String-valued keys of enumerable properties of O. The iterator object is never directly accessible to ECMAScript code. The mechanics and order of enumerating the properties is not specified but must conform to the rules specified below.

The iterator's throw and return methods are null and are never invoked. The iterator's next method processes object properties to determine whether the property key should be returned as an iterator value. Returned property keys do not include keys that are Symbols. Properties of the target object may be deleted during enumeration. A property that is deleted before it is processed by the iterator's next method is ignored. If new properties are added to the target object during enumeration, the newly added properties are not guaranteed to be processed in the active enumeration. A property name will be returned by the iterator's next method at most once in any enumeration.

Enumerating the properties of the target object includes enumerating properties of its prototype, and the prototype of the prototype, and so on, recursively; but a property of a prototype is not processed if it has the same
name as a property that has already been processed by the iterator's `next` method. The values of `[[Enumerable]]`
attributes are not considered when determining if a property of a prototype object has already been processed.
The enumerable property names of prototype objects must be obtained by invoking `EnumerateObjectProperties`
passing the prototype object as the argument. `EnumerateObjectProperties` must obtain the own property keys
of the target object by calling its `[[OwnPropertyKeys]]` internal method. Property attributes of the target object must
be obtained by calling its `[[GetOwnProperty]]` internal method.

In addition, if neither `O` nor any object in its prototype chain is a `Proxy` exotic object, `TypedArray`, module
name-space exotic object, or implementation provided exotic object, then the iterator must behave as would the iterator
given by `CreateForInIterator(O)` until one of the following occurs:

- the value of the `[[Prototype]]` internal slot of `O` or an object in its prototype chain changes,
- a property is removed from `O` or an object in its prototype chain,
- a property is added to an object in `O`'s prototype chain, or
- the value of the `[[Enumerable]]` attribute of a property of `O` or an object in its prototype chain changes.

NOTE 1 ECMAScript implementations are not required to implement the algorithm in 14.7.5.10.2.1 directly.
They may choose any implementation whose behaviour will not deviate from that algorithm unless
one of the constraints in the previous paragraph is violated.

The following is an informative definition of an ECMAScript generator function that conforms to
these rules:

```javascript
function* EnumerateObjectProperties(obj) {
  const visited = new Set();
  for (const key of Reflect.ownKeys(obj)) {
    if (typeof key === "symbol") continue;
    const desc = Reflect.getOwnPropertyDescriptor(obj, key);
    if (desc) {
      visited.add(key);
      if (desc.enumerable) yield key;
    }
  }
  const proto = Reflect.getPrototypeOf(obj);
  if (proto === null) return;
  for (const protoKey of EnumerateObjectProperties(proto)) {
    if (!visited.has(protoKey)) yield protoKey;
  }
}
```

NOTE 2 The list of exotic objects for which implementations are not required to match `CreateForInIterator`
was chosen because implementations historically differed in behaviour for those cases, and agreed
in all others.

14.7.5.10 For-In Iterator Objects

A For-In Iterator is an object that represents a specific iteration over some specific object. For-In Iterator
objects are never directly accessible to ECMAScript code; they exist solely to illustrate the behaviour of
`EnumerateObjectProperties`.
14.7.5.10.1 CreateForInIterator ( object )

The abstract operation CreateForInIterator takes argument object (an Object) and returns a For-In Iterator. It is used to create a For-In Iterator object which iterates over the own and inherited enumerable string properties of object in a specific order. It performs the following steps when called:

1. Let iterator be OrdinaryObjectCreate(%ForInIteratorPrototype%, « [[Object]], [[ObjectWasVisited]], [[VisitedKeys]], [[RemainingKeys]] »).
2. Set iterator.[[Object]] to object.
3. Set iterator.[[ObjectWasVisited]] to false.
4. Set iterator.[[VisitedKeys]] to a new empty List.
5. Set iterator.[[RemainingKeys]] to a new empty List.
6. Return iterator.

14.7.5.10.2 The %ForInIteratorPrototype% Object

The %ForInIteratorPrototype% object:

• has properties that are inherited by all For-In Iterator Objects.
• is an ordinary object.
• has a [[Prototype]] internal slot whose value is %IteratorPrototype%.
• is never directly accessible to ECMAScript code.
• has the following properties:

14.7.5.10.2.1 %ForInIteratorPrototype%.next ( )

1. Let O be the this value.
2. Assert: O is an Object.
3. Assert: O has all of the internal slots of a For-In Iterator Instance (14.7.5.10.3).
4. Let object be O.[[Object]].
5. Repeat,
   a. If O.[[ObjectWasVisited]] is false, then
      i. Let keys be ? object.[[OwnPropertyKeys]]().
      ii. For each element key of keys, do
          1. If key is a String, then
              a. Append key to O.[[RemainingKeys]].
          iii. Set O.[[ObjectWasVisited]] to true.
      b. Repeat, while O.[[RemainingKeys]] is not empty,
         i. Let r be the first element of O.[[RemainingKeys]].
         ii. Remove the first element from O.[[RemainingKeys]].
         iii. If there does not exist an element v of O.[[VisitedKeys]] such that SameValue(r, v) is true, then
             1. Let desc be ? object.[[GetOwnProperty]](r).
             2. If desc is not undefined, then
                 a. Append r to O.[[VisitedKeys]].
                 b. If desc.[[Enumerable]] is true, return CreateIterResultObject(r, false).
             c. Set object to ? object.[[GetPrototypeOf]]().
             d. Set O.[[Object]] to object.
             e. Set O.[[ObjectWasVisited]] to false.
             f. If object is null, return CreateIterResultObject(undefined, true).
6. Return CreateIterResultObject(undefined, true).

14.7.5.10.3 Properties of For-In Iterator Instances

For-In Iterator instances are ordinary objects that inherit properties from the %ForInIteratorPrototype% intrinsic object. For-In Iterator instances are initially created with the internal slots listed in Table 39.
### Table 39: Internal Slots of For-In Iterator Instances

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Object]]</td>
<td>an Object</td>
<td>The Object value whose properties are being iterated.</td>
</tr>
<tr>
<td>[[ObjectWasVisited]]</td>
<td>a Boolean</td>
<td>true if the iterator has invoked [[OwnPropertyKeys]] on [[Object]], false otherwise.</td>
</tr>
<tr>
<td>[[VisitedKeys]]</td>
<td>a List of Strings</td>
<td>The values that have been emitted by this iterator thus far.</td>
</tr>
<tr>
<td>[[RemainingKeys]]</td>
<td>a List of Strings</td>
<td>The values remaining to be emitted for the current object, before iterating the properties of its prototype (if its prototype is not null).</td>
</tr>
</tbody>
</table>

### 14.8 The continue Statement

**Syntax**

```plaintext
ContinueStatement[Yield, Await] :
  continue ;
```

**14.8.1 Static Semantics: Early Errors**

`ContinueStatement` :

```plaintext
  continue ;
  continue LabelIdentifier ;
```

- It is a Syntax Error if this `ContinueStatement` is not nested, directly or indirectly (but not crossing function or `static` initialization block boundaries), within an `IterationStatement`.

**14.8.2 Runtime Semantics: Evaluation**

`ContinueStatement` : `continue` ;

1. Return Completion Record `{ [[Type]]: CONTINUE, [[Value]]: EMPTY, [[Target]]: EMPTY }`.

   `ContinueStatement` : `continue LabelIdentifier` ;

   1. Let `label` be the `StringValue` of `LabelIdentifier`.
   2. Return Completion Record `{ [[Type]]: CONTINUE, [[Value]]: EMPTY, [[Target]]: `label` }`.

### 14.9 The break Statement

**Syntax**

```plaintext
BreakStatement[Yield, Await] :
  break ;
```

**14.9.1 Static Semantics: Early Errors**

`BreakStatement` : `break` ;
• It is a Syntax Error if this BreakStatement is not nested, directly or indirectly (but not crossing function or static initialization block boundaries), within an IterationStatement or a SwitchStatement.

### 14.9.2 Runtime Semantics: Evaluation

**BreakStatement** : \texttt{break} ;

1. Return Completion Record \{ [[Type]]: BREAK, [[Value]]: EMPTY, [[Target]]: EMPTY \}.

**BreakStatement** : \texttt{break} LabelIdentifier ;

1. Let label be the StringValue of LabelIdentifier.
2. Return Completion Record \{ [[Type]]: BREAK, [[Value]]: EMPTY, [[Target]]: label \}.

### 14.10 The return Statement

#### Syntax

\[
\text{ReturnStatement[Yield, Await]} : \quad \text{return} ; \quad \text{return [no LineTerminator here] Expression[+In, ?Yield, ?Await]} ;
\]

**NOTE** A return statement causes a function to cease execution and, in most cases, returns a value to the caller. If Expression is omitted, the return value is undefined. Otherwise, the return value is the value of Expression. A return statement may not actually return a value to the caller depending on surrounding context. For example, in a try block, a return statement's Completion Record may be replaced with another Completion Record during evaluation of the finally block.

### 14.10.1 Runtime Semantics: Evaluation

**ReturnStatement** : \texttt{return} ;

1. Return Completion Record \{ [[Type]]: RETURN, [[Value]]: undefined, [[Target]]: EMPTY \}.

**ReturnStatement** : \texttt{return} Expression ;

1. Let exprRef be ? Evaluation of Expression.
2. Let exprValue be ? GetValue(exprRef).
3. If GetGeneratorKind() is ASYNC, set exprValue to ? Await(exprValue).
4. Return Completion Record \{ [[Type]]: RETURN, [[Value]]: exprValue, [[Target]]: EMPTY \}.

### 14.11 The with Statement

**NOTE** Use of the Legacy with statement is discouraged in new ECMAScript code. Consider alternatives that are permitted in both strict mode code and non-strict code, such as destructuring assignment.
WithStatement:

```
```

NOTE 2 The `with` statement adds an Object Environment Record for a computed object to the lexical environment of the running execution context. It then executes a statement using this augmented lexical environment. Finally, it restores the original lexical environment.

### 14.11.1 Static Semantics: Early Errors

**WithStatement : with ( Expression ) Statement**

- It is a Syntax Error if the source text matched by this production is contained in strict mode code.
- It is a Syntax Error if `IsLabelledFunction(Statement)` is `true`.

NOTE It is only necessary to apply the second rule if the extension specified in B.3.1 is implemented.

### 14.11.2 Runtime Semantics: Evaluation

**WithStatement : with ( Expression ) Statement**

2. Let `obj` be ? `ToObject(? GetValue(val))`.
3. Let `oldEnv` be the running execution context's `LexicalEnvironment`.
4. Let `newEnv` be `NewObjectEnvironment(obj, true, oldEnv)`.
5. Set the running execution context's `LexicalEnvironment` to `newEnv`.
6. Let `C` be `Completion(Evaluation of Statement)`.
7. Set the running execution context's `LexicalEnvironment` to `oldEnv`.

NOTE No matter how control leaves the embedded Statement, whether normally or by some form of abrupt completion or exception, the `LexicalEnvironment` is always restored to its former state.

### 14.12 The switch Statement

**Syntax**

```
SwitchStatement[Yield, Await, Return] :
```

**CaseBlock[Yield, Await, Return]**

```
{ CaseClauses[?Yield, ?Await, ?Return] opt }
```

**CaseClauses[Yield, Await, Return]**

```
CaseClause[?Yield, ?Await, ?Return]
```
14.12.1 Static Semantics: Early Errors

SwitchStatement : switch ( Expression ) CaseBlock

- It is a Syntax Error if the LexicallyDeclaredNames of CaseBlock contains any duplicate entries.
- It is a Syntax Error if any element of the LexicallyDeclaredNames of CaseBlock also occurs in the VarDeclaredNames of CaseBlock.

14.12.2 Runtime Semantics: CaseBlockEvaluation

The syntax-directed operation CaseBlockEvaluation takes argument input (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

CaseBlock : { }
i. If `foundInB` is `false`, then
   1. Set `foundInB` to ? CaseClauseIsSelected(C, input).

ii. If `foundInB` is `true`, then
   1. Let `R` be Completion(Evaluation of CaseClause C).
   2. If `R`.[[Value]] is not EMPTY, set `V` to `R`.[[Value]].
   3. If `R` is an abrupt completion, return ? UpdateEmpty(R, V).

10. If `foundInB` is `true`, return `V`.
11. Let `defaultR` be Completion(Evaluation of DefaultClause).
12. If `defaultR`.[[Value]] is not EMPTY, set `V` to `defaultR`.[[Value]].
13. If `defaultR` is an abrupt completion, return ? UpdateEmpty(`defaultR`, `V`).
14. NOTE: The following is another complete iteration of the second CaseClauses.
15. For each CaseClause `C` of `B`, do
   a. Let `R` be Completion(Evaluation of CaseClause C).
   b. If `R`.[[Value]] is not EMPTY, set `V` to `R`.[[Value]].
   c. If `R` is an abrupt completion, return ? UpdateEmpty(`R`, `V`).

14.12.3 CaseClausesSelected( C, input )

The abstract operation CaseClausesSelected takes arguments `C` (a CaseClause Parse Node) and `input` (an ECMAScript language value) and returns either a normal completion containing a Boolean or an abrupt completion. It determines whether `C` matches `input`. It performs the following steps when called:

1. Assert: `C` is an instance of the production `CaseClause : case Expression : StatementListopt`.
2. Let `exprRef` be ? Evaluation of the Expression of `C`.
3. Let `clauseSelector` be ? GetValue(`exprRef`).

NOTE This operation does not execute `C`'s StatementList (if any). The CaseBlock algorithm uses its return value to determine which StatementList to start executing.

14.12.4 Runtime Semantics: Evaluation

SwitchStatement : switch ( Expression ) CaseBlock

1. Let `exprRef` be ? Evaluation of Expression.
2. Let `switchValue` be ? GetValue(`exprRef`).
3. Let `oldEnv` be the running execution context's LexicalEnvironment.
4. Let `blockEnv` be NewDeclarativeEnvironment(`oldEnv`).
5. Perform BlockDeclarationInstantiation(CaseBlock, `blockEnv`).
6. Set the running execution context's LexicalEnvironment to `blockEnv`.
7. Let `R` be Completion(CaseBlockEvaluation of CaseBlock with argument `switchValue`).
8. Set the running execution context's LexicalEnvironment to `oldEnv`.

NOTE No matter how control leaves the SwitchStatement the LexicalEnvironment is always restored to its former state.

CaseClause : case Expression :

1. Return EMPTY.

CaseClause : case Expression : StatementList

14.13 Labelled Statements

Syntax

\[
\text{LabelledStatement}[\text{Yield, Await, Return}] : \\
\text{LabelIdentifier}[?\text{Yield, ?Await}] : \text{LabelledItem}[?\text{Yield, ?Await, ?Return}]
\]

\[
\text{LabelledItem}[\text{Yield, Await, Return}] : \\
\text{Statement}[?\text{Yield, ?Await, ?Return}] \\
\text{FunctionDeclaration}[?\text{Yield, ?Await, ~Default}]
\]

**NOTE** A Statement may be prefixed by a label. Labelled statements are only used in conjunction with labelled break and continue statements. ECMAScript has no goto statement. A Statement can be part of a LabelledStatement, which itself can be part of a LabelledStatement, and so on. The labels introduced this way are collectively referred to as the “current label set” when describing the semantics of individual statements.

14.13.1 Static Semantics: Early Errors

**LabelledItem : FunctionDeclaration**

- It is a Syntax Error if any source text is matched by this production.

**NOTE** An alternative definition for this rule is provided in B.3.1.

14.13.2 Static Semantics: IsLabelledFunction ( \textit{stmt} )

The abstract operation IsLabelledFunction takes argument \textit{stmt} (a Statement Parse Node) and returns a Boolean. It performs the following steps when called:

1. If \textit{stmt} is not a LabelledStatement, return \textbf{false}.
2. Let \textit{item} be the LabelledItem of \textit{stmt}.
3. If \textit{item} is LabelledItem : FunctionDeclaration , return \textbf{true}.
4. Let \textit{subStmt} be the Statement of \textit{item}.
5. Return IsLabelledFunction(\textit{subStmt}).

14.13.3 Runtime Semantics: Evaluation

**LabelledStatement : LabelIdentifier : LabelledItem**

1. Return ? LabelledEvaluation of this LabelledStatement with argument « ». 
14.13.4 Runtime Semantics: LabelledEvaluation

The syntax-directed operation LabelledEvaluation takes argument \( \text{labelSet} \) (a List of Strings) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

\[ \text{BreakableStatement} : \text{IterationStatement} \]

1. Let \( \text{stmtResult} \) be \( \text{Completion}(\text{LoopEvaluation of IterationStatement with argument labelSet}) \).
2. If \( \text{stmtResult} \) is a break completion, then
   a. If \( \text{stmtResult}.[[\text{Target}]] \) is EMPTY, then
      i. If \( \text{stmtResult}.[[\text{Value}]] \) is EMPTY, set \( \text{stmtResult} \) to \( \text{NormalCompletion}(\text{undefined}) \).
      ii. Else, set \( \text{stmtResult} \) to \( \text{NormalCompletion}(\text{stmtResult}.[[\text{Value}]]) \).
3. Return \( \text{stmtResult} \).

\[ \text{BreakableStatement} : \text{SwitchStatement} \]

1. Let \( \text{stmtResult} \) be \( \text{Completion}(\text{Evaluation of SwitchStatement}) \).
2. If \( \text{stmtResult} \) is a break completion, then
   a. If \( \text{stmtResult}.[[\text{Target}]] \) is EMPTY, then
      i. If \( \text{stmtResult}.[[\text{Value}]] \) is EMPTY, set \( \text{stmtResult} \) to \( \text{NormalCompletion}(\text{undefined}) \).
      ii. Else, set \( \text{stmtResult} \) to \( \text{NormalCompletion}(\text{stmtResult}.[[\text{Value}]]) \).
3. Return \( \text{stmtResult} \).

\[ \text{NOTE 1} \quad \text{A BreakableStatement is one that can be exited via an unlabelled BreakStatement.} \]

\[ \text{LabelledStatement} : \text{LabelIdentifier} : \text{LabelledItem} \]

1. Let \( \text{label} \) be the StringValue of \( \text{LabelIdentifier} \).
2. Let \( \text{newLabelSet} \) be the list-concatenation of \( \text{labelSet} \) and « \( \text{label} \) ».
3. Let \( \text{stmtResult} \) be \( \text{Completion}(\text{LabelledEvaluation of LabelledItem with argument newLabelSet}) \).
4. If \( \text{stmtResult} \) is a break completion and \( \text{stmtResult}.[[\text{Target}]] \) is \( \text{label} \), then
   a. Set \( \text{stmtResult} \) to \( \text{NormalCompletion}(\text{stmtResult}.[[\text{Value}]]) \).
5. Return \( \text{stmtResult} \).

\[ \text{LabelledItem} : \text{FunctionDeclaration} \]

1. Return \( \text{Evaluation of FunctionDeclaration} \).

\[ \text{Statement} : \text{BlockStatement} \quad \text{VariableStatement} \quad \text{EmptyStatement} \quad \text{ExpressionStatement} \quad \text{IfStatement} \quad \text{ContinueStatement} \quad \text{BreakStatement} \quad \text{ReturnStatement} \quad \text{WithStatement} \quad \text{ThrowStatement} \quad \text{TryStatement} \quad \text{DebuggerStatement} \]

1. Return \( \text{Evaluation of Statement} \).

\[ \text{NOTE 2} \quad \text{The only two productions of Statement which have special semantics for LabelledEvaluation are BreakableStatement and LabelledStatement.} \]
14.14 The throw Statement

Syntax

\[
\text{ThrowStatement}[\text{Yield}, \text{Await}] : \\
\quad \text{throw} \ [\text{no LineTerminator here}] \ \text{Expression}[\text{In}, \text{Yield}, \text{Await}] ;
\]


\(\text{ThrowStatement} : \text{throw} \ \text{Expression} ;\)

1. Let \(\text{exprRef}\) be ? \text{Evaluation} of \text{Expression}.
2. Let \(\text{exprValue}\) be ? \text{GetValue}(\text{exprRef}).
3. Return \text{ThrowCompletion}(\text{exprValue}).

14.15 The try Statement

Syntax

\[
\text{TryStatement}[\text{Yield}, \text{Await}, \text{Return}] : \\
\quad \text{try} \ \text{Block}[\text{Yield}, \text{Await}, \text{Return}] \quad \text{Catch}[\text{Yield}, \text{Await}, \text{Return}] \\
\quad \text{try} \ \text{Block}[\text{Yield}, \text{Await}, \text{Return}] \quad \text{Finally}[\text{Yield}, \text{Await}, \text{Return}] \\
\quad \text{try} \ \text{Block}[\text{Yield}, \text{Await}, \text{Return}] \quad \text{Catch}[\text{Yield}, \text{Await}, \text{Return}] \\
\quad \text{Finally}[\text{Yield}, \text{Await}, \text{Return}]
\]

\(\text{Catch}[\text{Yield}, \text{Await}, \text{Return}] : \\
\quad \text{catch} \ (\ \text{CatchParameter}[\text{Yield}, \text{Await}] \ ) \ \text{Block}[\text{Yield}, \text{Await}, \text{Return}] \quad \text{Catch}[\text{Yield}, \text{Await}, \text{Return}] \\
\quad \text{catch} \ \text{Block}[\text{Yield}, \text{Await}, \text{Return}]
\)

\(\text{Finally}[\text{Yield}, \text{Await}, \text{Return}] : \\
\quad \text{finally} \ \text{Block}[\text{Yield}, \text{Await}, \text{Return}]
\)

\(\text{CatchParameter}[\text{Yield}, \text{Await}] : \\
\quad \text{BindingIdentifier}[\text{Yield}, \text{Await}] \quad \text{BindingPattern}[\text{Yield}, \text{Await}]
\)

| NOTE | The **try** statement encloses a block of code in which an exceptional condition can occur, such as a runtime error or a **throw** statement. The **catch** clause provides the exception-handling code. When a catch clause catches an exception, its **CatchParameter** is bound to that exception. |

14.15.1 Static Semantics: Early Errors

\(\text{Catch} : \text{catch} \ (\ \text{CatchParameter} \ ) \ \text{Block}\)

- It is a Syntax Error if BoundNames of **CatchParameter** contains any duplicate elements.
- It is a Syntax Error if any element of the BoundNames of **CatchParameter** also occurs in the LexicallyDeclaredNames of **Block**.
- It is a Syntax Error if any element of the BoundNames of **CatchParameter** also occurs in the VarDeclaredNames of **Block**.

| NOTE | An alternative static semantics for this production is given in B.3.4. |
14.15.2 Runtime Semantics: CatchClauseEvaluation

The syntax-directed operation CatchClauseEvaluation takes argument thrownValue (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

\[
\text{Catch} : \text{catch} ~ (\text{CatchParameter}) ~ \text{Block}
\]

1. Let oldEnv be the running execution context's LexicalEnvironment.
2. Let catchEnv be NewDeclarativeEnvironment(oldEnv).
3. For each element argName of the BoundNames of CatchParameter, do
   a. Perform ! catchEnv.CreateMutableBinding(argName, false).
4. Set the running execution context's LexicalEnvironment to catchEnv.
5. Let status be Completion(BindingInitialization of CatchParameter with arguments thrownValue and catchEnv).
6. If status is an abrupt completion, then
   a. Set the running execution context's LexicalEnvironment to oldEnv.
7. Let B be Completion(Evaluation of Block).
8. Set the running execution context's LexicalEnvironment to oldEnv.
9. Return ? B.

\[
\text{NOTE} \quad \text{No matter how control leaves the Block the LexicalEnvironment is always restored to its former state.}
\]

14.15.3 Runtime Semantics: Evaluation

\[
\text{TryStatement} : \text{try} ~ \text{Block} ~ \text{Catch}
\]

1. Let B be Completion(Evaluation of Block).
2. If B is a throw completion, let C be Completion(CatchClauseEvaluation of Catch with argument B.[[Value]]).
3. Else, let C be B.

\[
\text{TryStatement} : \text{try} ~ \text{Block} ~ \text{Finally}
\]

1. Let B be Completion(Evaluation of Block).
2. Let F be Completion(Evaluation of Finally).
3. If F is a normal completion, set F to B.

\[
\text{TryStatement} : \text{try} ~ \text{Block} ~ \text{Catch} ~ \text{Finally}
\]

1. Let B be Completion(Evaluation of Block).
2. If B is a throw completion, let C be Completion(CatchClauseEvaluation of Catch with argument B.[[Value]]).
3. Else, let C be B.
4. Let F be Completion(Evaluation of Finally).
5. If F is a normal completion, set F to C.
14.16 The debugger Statement

Syntax

```
DebuggerStatement : 
    debugger ;
```

14.16.1 Runtime Semantics: Evaluation

NOTE Evaluating a DebuggerStatement may allow an implementation to cause a breakpoint when run under a debugger. If a debugger is not present or active this statement has no observable effect.

```
DebuggerStatement : debugger ;
```

1. If an implementation-defined debugging facility is available and enabled, then
   a. Perform an implementation-defined debugging action.
   b. Return a new implementation-defined Completion Record.
2. Else,
   a. Return EMPTY.

15 ECMAScript Language: Functions and Classes

NOTE Various ECMAScript language elements cause the creation of ECMAScript function objects (10.2). Evaluation of such functions starts with the execution of their [[Call]] internal method (10.2.1).

15.1 Parameter Lists

Syntax

```
UniqueFormalParameters[Yield, Await] :
    FormalParameters[?Yield, ?Await]

FormalParameters[Yield, Await] :
    [empty]
    FunctionRestParameter[?Yield, ?Await]
    FormalParameterList[?Yield, ?Await]

FormalParameterList[Yield, Await] :
    FormalParameter[?Yield, ?Await]

FunctionRestParameter[Yield, Await] :
    BindingRestElement[?Yield, ?Await]

FormalParameter[Yield, Await] :
    BindingElement[?Yield, ?Await]
```

15.1.1 Static Semantics: Early Errors

```
UniqueFormalParameters : FormalParameters
```
• It is a Syntax Error if `BoundNames` of `FormalParameters` contains any duplicate elements.

`FormalParameters : FormalParameterList`

• It is a Syntax Error if `IsSimpleParameterList` of `FormalParameterList` is `false` and `BoundNames` of `FormalParameterList` contains any duplicate elements.

**NOTE** Multiple occurrences of the same `BindingIdentifier` in a `FormalParameterList` is only allowed for functions which have simple parameter lists and which are not defined in strict mode code.

### 15.1.2 Static Semantics: ContainsExpression

The **syntax-directed operation** `ContainsExpression` takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

`ObjectBindingPattern :`

1. Return `false`.

`ObjectBindingPattern : { BindingPropertyList , BindingRestProperty }`

1. Return `ContainsExpression` of `BindingPropertyList`.

`ArrayBindingPattern : [ Elisionopt ]`

1. Return `false`.

`ArrayBindingPattern : [ Elisionopt BindingRestElement ]`

1. Return `ContainsExpression` of `BindingRestElement`.

`ArrayBindingPattern : [ BindingElementList , Elisionopt ]`

1. Return `ContainsExpression` of `BindingElementList`.

`ArrayBindingPattern : [ BindingElementList , Elisionopt BindingRestElement ]`

1. Let `has` be `ContainsExpression` of `BindingElementList`.
2. If `has` is `true`, return `true`.
3. Return `ContainsExpression` of `BindingRestElement`.

`BindingPropertyList : BindingPropertyList , BindingProperty`

1. Let `has` be `ContainsExpression` of `BindingPropertyList`.
2. If `has` is `true`, return `true`.
3. Return `ContainsExpression` of `BindingProperty`.

`BindingElementList : BindingElementList , BindingElisionElement`

1. Let `has` be `ContainsExpression` of `BindingElementList`.
2. If `has` is `true`, return `true`.
3. Return `ContainsExpression` of `BindingElisionElement`.

`BindingElisionElement : Elisionopt BindingElement`

1. Return `ContainsExpression` of `BindingElement`. 
BindingProperty : PropertyName : BindingElement

1. Let has be IsComputedPropertyKey of PropertyName.
2. If has is true, return true.
3. Return ContainsExpression of BindingElement.

BindingElement : BindingPattern Initializer

1. Return true.

SingleNameBinding : BindingIdentifier

1. Return false.

SingleNameBinding : BindingIdentifier Initializer

1. Return true.

BindingRestElement : ... BindingIdentifier

1. Return false.

BindingRestElement : ... BindingPattern

1. Return ContainsExpression of BindingPattern.

FormalParameters : [empty]

1. Return false.

FormalParameters : FormalParameterList , FunctionRestParameter

1. If ContainsExpression of FormalParameterList is true, return true.
2. Return ContainsExpression of FunctionRestParameter.

FormalParameterList : FormalParameterList , FormalParameter

1. If ContainsExpression of FormalParameterList is true, return true.
2. Return ContainsExpression of FormalParameter.

ArrowParameters : BindingIdentifier

1. Return false.

ArrowParameters : CoverParenthesizedExpressionAndArrowParameterList

1. Let formals be the ArrowFormalParameters that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return ContainsExpression of formals.

AsyncArrowBindingIdentifier : BindingIdentifier

1. Return false.

15.1.3 Static Semantics: IsSimpleParameterList

The syntax-directed operation IsSimpleParameterList takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

BindingElement : BindingPattern
BindingElement : BindingPattern Initialize

1. Return false.

SingleNameBinding : BindingIdentifier

1. Return true.

SingleNameBinding : BindingIdentifier Initialize

1. Return false.

FormalParameters : [empty]

1. Return true.

FormalParameters : FunctionRestParameter

1. Return false.

FormalParameters : FormalParameterList , FunctionRestParameter

1. Return false.

FormalParameterList : FormalParameterList , FormalParameter

1. If IsSimpleParameterList of FormalParameterList is false, return false.

FormalParameter : BindingElement

1. Return IsSimpleParameterList of BindingElement.

ArrowParameters : BindingIdentifier

1. Return true.

ArrowParameters : CoverParenthesizedExpressionAndArrowParameterList

1. Let formals be the ArrowFormalParameters that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return IsSimpleParameterList of formals.

AsyncArrowBindingIdentifier : BindingIdentifier

1. Return true.

CoverCallExpressionAndAsyncArrowHead : MemberExpression Arguments

1. Let head be the AsyncArrowHead that is covered by CoverCallExpressionAndAsyncArrowHead.
2. Return IsSimpleParameterList of head.

15.1.4 Static Semantics: HasInitializer

The syntax-directed operation HasInitializer takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

BindingElement : BindingPattern

1. Return false.
**BindingElement** : BindingPattern Initializer

1. Return **true**.

**SingleNameBinding** : BindingIdentifier

1. Return **false**.

**SingleNameBinding** : BindingIdentifier Initializer

1. Return **true**.

**FormalParameterList** : FormalParameterList , FormalParameter

1. If HasInitializer of FormalParameterList is **true**, return **true**.
2. Return HasInitializer of FormalParameter.

### 15.1.5 Static Semantics: ExpectedArgumentCount

The syntax-directed operation `ExpectedArgumentCount` takes no arguments and returns an integer. It is defined piecewise over the following productions:

**FormalParameters** :

- [empty]
  - FunctionRestParameter

1. Return 0.

**FormalParameters** : FormalParameterList , FunctionRestParameter

1. Return `ExpectedArgumentCount` of FormalParameterList.

**NOTE** The `ExpectedArgumentCount` of a `FormalParameterList` is the number of `FormalParameters` to the left of either the rest parameter or the first `FormalParameter` with an Initializer. A `FormalParameter` without an initializer is allowed after the first parameter with an initializer but such parameters are considered to be optional with `undefined` as their default value.

**FormalParameterList** : FormalParameter

1. If HasInitializer of FormalParameter is **true**, return 0.
2. Return 1.

**FormalParameterList** : FormalParameterList , FormalParameter

1. Let `count` be `ExpectedArgumentCount` of FormalParameterList.
2. If HasInitializer of FormalParameterList is **true** or HasInitializer of FormalParameter is **true**, return `count`.

**ArrowParameters** : BindingIdentifier

1. Return 1.

**ArrowParameters** : CoverParenthesizedExpressionAndArrowParameterList

1. Let `formals` be the `ArrowFormalParameters` that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return `ExpectedArgumentCount` of `formals`.
PropertySetParameterList : FormalParameter

1. If HasInitializer of FormalParameter is true, return 0.
2. Return 1.

AsyncArrowBindingIdentifier : BindingIdentifier

1. Return 1.

15.2 Function Definitions

Syntax

FunctionDeclaration[Yield, Await, Default] :
   function BindingIdentifier[Yield, Await] ( FormalParameters[Await] ) { FunctionBody[Await] }
   [Default] function ( FormalParameters[Await] ) { FunctionBody[Await] }

FunctionExpression :

FunctionBody[Yield, Await] :
   FunctionStatementList[Yield, Await]

FunctionStatementList[Yield, Await] :
   StatementList[Yield, Await, +Return] opt

15.2.1 Static Semantics: Early Errors

FunctionDeclaration :
   function BindingIdentifier ( FormalParameters ) { FunctionBody }
   function ( FormalParameters ) { FunctionBody }

FunctionExpression :
   function BindingIdentifier opt ( FormalParameters ) { FunctionBody }

• If the source text matched by FormalParameters is strict mode code, the Early Error rules for UniqueFormalParameters : FormalParameters are applied.
• If BindingIdentifier is present and the source text matched by BindingIdentifier is strict mode code, it is a Syntax Error if the StringValue of BindingIdentifier is either "eval" or "arguments".
• It is a Syntax Error if FunctionBodyContainsUseStrict of FunctionBody is true and IsSimpleParameterList of FormalParameters is false.
• It is a Syntax Error if any element of the BoundNames of FormalParameters also occurs in the LexicallyDeclaredNames of FunctionBody.
• It is a Syntax Error if FormalParameters Contains SuperProperty is true.
• It is a Syntax Error if FunctionBody Contains SuperProperty is true.
• It is a Syntax Error if FormalParameters Contains SuperCall is true.
• It is a Syntax Error if FunctionBody Contains SuperCall is true.

NOTE The LexicallyDeclaredNames of a FunctionBody does not include identifiers bound using var or function declarations.

FunctionBody : FunctionStatementList

• It is a Syntax Error if the LexicallyDeclaredNames of FunctionStatementList contains any duplicate entries.
• It is a Syntax Error if any element of the `LexicallyDeclaredNames` of `FunctionStatementList` also occurs in the `VarDeclaredNames` of `FunctionStatementList`.
• It is a Syntax Error if `ContainsDuplicateLabels` of `FunctionStatementList` with argument « » is true.
• It is a Syntax Error if `ContainsUndefinedBreakTarget` of `FunctionStatementList` with argument « » is true.
• It is a Syntax Error if `ContainsUndefinedContinueTarget` of `FunctionStatementList` with arguments « » and « » is true.

15.2.2 Static Semantics: `FunctionBodyContainsUseStrict`

The syntax-directed operation `FunctionBodyContainsUseStrict` takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

```
FunctionBody : FunctionStatementList
```

1. If the `Directive Prologue` of `FunctionBody` contains a `Use Strict Directive`, return true; otherwise, return false.

15.2.3 Runtime Semantics: `EvaluateFunctionBody`

The syntax-directed operation `EvaluateFunctionBody` takes arguments `functionObject` (an ECMAScript function object) and `argumentsList` (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

```
FunctionBody : FunctionStatementList
```

1. Perform `? FunctionDeclarationInstantiation(functionObject, argumentsList)`. 

15.2.4 Runtime Semantics: `InstantiateOrdinaryFunctionObject`

The syntax-directed operation `InstantiateOrdinaryFunctionObject` takes arguments `env` (an Environment Record) and `privateEnv` (a PrivateEnvironment Record or null) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```
FunctionDeclaration : function BindingIdentifier ( FormalParameters ) { FunctionBody }
```

1. Let `name` be `StringValue` of `BindingIdentifier`.
2. Let `sourceText` be the source text matched by `FunctionDeclaration`.
3. Let `F` be `OrdinaryFunctionCreate(%Function.prototype%, sourceText, FormalParameters, FunctionBody, NON-LEXICAL-THIS, env, privateEnv)`.
4. Perform `SetFunctionName(F, name)`.
5. Perform `MakeConstructor(F)`.

```
FunctionDeclaration : function ( FormalParameters ) { FunctionBody }
```

1. Let `sourceText` be the source text matched by `FunctionDeclaration`.
2. Let `F` be `OrdinaryFunctionCreate(%Function.prototype%, sourceText, FormalParameters, FunctionBody, NON-LEXICAL-THIS, env, privateEnv)`.
3. Perform `SetFunctionName(F, "default")`.
4. Perform `MakeConstructor(F)`.
5. Return `F`.

**NOTE** An anonymous `FunctionDeclaration` can only occur as part of an `export default` declaration, and its function code is therefore always strict mode code.
15.2.5 Runtime Semantics: InstantiateOrdinaryFunctionExpression

The syntax-directed operation InstantiateOrdinaryFunctionExpression takes optional argument name (a property key or a Private Name) and returns an ECMAScript function object. It is defined piecewise over the following productions:

FunctionExpression : function ( FormalParameters ) { FunctionBody }

1. If name is not present, set name to "".
2. Let env be the LexicalEnvironment of the running execution context.
3. Let privateEnv be the running execution context's PrivateEnvironment.
4. Let sourceText be the source text matched by FunctionExpression.
5. Let closure be OrdinaryFunctionCreate(%Function.prototype%, sourceText, FormalParameters, FunctionBody, NON-LEXICAL-THIS, env, privateEnv).
6. Perform SetFunctionName(closure, name).
7. Perform MakeConstructor(closure).

FunctionExpression : function BindingIdentifier ( FormalParameters ) { FunctionBody }

1. Assert: name is not present.
2. Set name to StringValue of BindingIdentifier.
3. Let outerEnv be the running execution context's LexicalEnvironment.
4. Let funcEnv be NewDeclarativeEnvironment(outerEnv).
5. Perform ! funcEnv.CreateImmutableBinding(name, false).
6. Let privateEnv be the running execution context's PrivateEnvironment.
7. Let sourceText be the source text matched by FunctionExpression.
8. Let closure be OrdinaryFunctionCreate(%Function.prototype%, sourceText, FormalParameters, FunctionBody, NON-LEXICAL-THIS, funcEnv, privateEnv).
9. Perform SetFunctionName(closure, name).
10. Perform MakeConstructor(closure).
11. Perform ! funcEnv.InitializeBinding(name, closure).
12. Return closure.

NOTE The BindingIdentifier in a FunctionExpression can be referenced from inside the FunctionExpression's FunctionBody to allow the function to call itself recursively. However, unlike in a FunctionDeclaration, the BindingIdentifier in a FunctionExpression cannot be referenced from and does not affect the scope enclosing the FunctionExpression.

15.2.6 Runtime Semantics: Evaluation

FunctionDeclaration : function BindingIdentifier ( FormalParameters ) { FunctionBody }

1. Return EMPTY.

NOTE 1 An alternative semantics is provided in B.3.2.

FunctionDeclaration : function ( FormalParameters ) { FunctionBody }

1. Return EMPTY.

FunctionExpression : function BindingIdentifier opt ( FormalParameters ) { FunctionBody }


NOTE 2 A "prototype" property is automatically created for every function defined using a FunctionDeclaration or FunctionExpression, to allow for the possibility that the function will be used as a constructor.
15.3 Arrow Function Definitions

Syntax

\[
\text{ArrowFunction}[	ext{In, Yield, Await}] : \text{ArrowParameters}[	ext{?Yield, ?Await}] \ [\text{no LineTerminator here}] \Rightarrow \text{ConciseBody}[	ext{?In}]
\]

\[
\text{ArrowParameters}[	ext{Yield, Await}] : \text{BindingIdentifier}[	ext{?Yield, ?Await}] \text{CoverParenthesizedExpressionAndArrowParameterList}[	ext{?Yield, ?Await}]
\]

\[
\text{ConciseBody}[	ext{In}] : \{ \text{ExpressionBody}[	ext{?In, ~Await}] \}
\]

Supplemental Syntax

When processing an instance of the production 
\[
\text{ArrowParameters}[	ext{Yield, Await}] : \text{CoverParenthesizedExpressionAndArrowParameterList}[	ext{?Yield, ?Await}]
\]

the interpretation of \text{CoverParenthesizedExpressionAndArrowParameterList} is refined using the following grammar:

\[
\text{ArrowFormalParameters}[	ext{Yield, Await}] : ( \text{UniqueFormalParameters}[	ext{?Yield, ?Await}] )
\]

15.3.1 Static Semantics: Early Errors

\[\text{ArrowFunction} : \text{ArrowParameters} \Rightarrow \text{ConciseBody}\]

- It is a Syntax Error if \text{ArrowParameters} Contains \text{YieldExpression} is \text{true}.
- It is a Syntax Error if \text{ArrowParameters} Contains \text{AwaitExpression} is \text{true}.
- It is a Syntax Error if \text{ConciseBodyContainsUseStrict} of \text{ConciseBody} is \text{true} and \text{IsSimpleParameterList} of \text{ArrowParameters} is \text{false}.
- It is a Syntax Error if any element of the \text{BoundNames} of \text{ArrowParameters} also occurs in the \text{LexicallyDeclaredNames} of \text{ConciseBody}.

\[\text{ArrowParameters} : \text{CoverParenthesizedExpressionAndArrowParameterList}\]

- \text{CoverParenthesizedExpressionAndArrowParameterList} must cover an \text{ArrowFormalParameters}.

15.3.2 Static Semantics: \text{ConciseBodyContainsUseStrict}

The syntax-directed operation \text{ConciseBodyContainsUseStrict} takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

\[\text{ConciseBody} : \text{ExpressionBody}\]

1. Return \text{false}.
ConciseBody : { FunctionBody }

1. Return FunctionBodyContainsUseStrict of FunctionBody.

15.3.3 Runtime Semantics: EvaluateConciseBody

The syntax-directed operation EvaluateConciseBody takes arguments functionObject (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

ConciseBody : ExpressionBody


15.3.4 Runtime Semantics: InstantiateArrowFunctionExpression

The syntax-directed operation InstantiateArrowFunctionExpression takes optional argument name (a property key or a Private Name) and returns an ECMAScript function object. It is defined piecewise over the following productions:

ArrowFunction : ArrowParameters => ConciseBody

1. If name is not present, set name to "".
2. Let env be the LexicalEnvironment of the running execution context.
3. Let privateEnv be the running execution context's PrivateEnvironment.
4. Let sourceText be the source text matched by ArrowFunction.
5. Let closure be OrdinaryFunctionCreate(%Function.prototype%, sourceText, ArrowParameters, ConciseBody, LEXICAL-THIS, env, privateEnv).
6. Perform SetFunctionName(closure, name).
7. Return closure.

NOTE An ArrowFunction does not define local bindings for arguments, super, this, or new.target. Any reference to arguments, super, this, or new.target within an ArrowFunction must resolve to a binding in a lexically enclosing environment. Typically this will be the Function Environment of an immediately enclosing function. Even though an ArrowFunction may contain references to super, the function object created in step 5 is not made into a method by performing MakeMethod. An ArrowFunction that references super is always contained within a non-ArrowFunction and the necessary state to implement super is accessible via the env that is captured by the function object of the ArrowFunction.

15.3.5 Runtime Semantics: Evaluation

ArrowFunction : ArrowParameters => ConciseBody


ExpressionBody : AssignmentExpression

1. Let exprRef be ? Evaluation of AssignmentExpression.
2. Let exprValue be ? GetValue(exprRef).
3. Return Completion Record { [[Type]]: RETURN, [[Value]]: exprValue, [[Target]]: EMPTY }.
15.4 Method Definitions

Syntax

MethodDefinition[?Yield, ?Await] :
ClassElementName[?Yield, ?Await] ( UniqueFormalParameters[~Yield, ~Await] ) {
  FunctionBody[~Yield, ~Await] }
GeneratorMethod[?Yield, ?Await]
AsyncMethod[?Yield, ?Await]
AsyncGeneratorMethod[?Yield, ?Await]
  get ClassElementName[?Yield, ?Await] ( ) { FunctionBody[~Yield, ~Await] }
  set ClassElementName[?Yield, ?Await] ( PropertySetParameterList ) {
    FunctionBody[~Yield, ~Await] }

PropertySetParameterList :
  FormalParameter[~Yield, ~Await]

15.4.1 Static Semantics: Early Errors

MethodDefinition : ClassElementName ( UniqueFormalParameters ) { FunctionBody }

• It is a Syntax Error if `FunctionBodyContainsUseStrict` of `FunctionBody` is `true` and `IsSimpleParameterList` of `UniqueFormalParameters` is `false`.
• It is a Syntax Error if any element of the `BoundNames` of `UniqueFormalParameters` also occurs in the `LexicallyDeclaredNames` of `FunctionBody`.

MethodDefinition : set ClassElementName ( PropertySetParameterList ) { FunctionBody }

• It is a Syntax Error if `BoundNames` of `PropertySetParameterList` contains any duplicate elements.
• It is a Syntax Error if `FunctionBodyContainsUseStrict` of `FunctionBody` is `true` and `IsSimpleParameterList` of `PropertySetParameterList` is `false`.
• It is a Syntax Error if any element of the `BoundNames` of `PropertySetParameterList` also occurs in the `LexicallyDeclaredNames` of `FunctionBody`.

15.4.2 Static Semantics: HasDirectSuper

The syntax-directed operation `HasDirectSuper` takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

MethodDefinition : ClassElementName ( UniqueFormalParameters ) { FunctionBody }

1. If `UniqueFormalParameters Contains SuperCall` is `true`, return `true`.
2. Return `FunctionBody Contains SuperCall`.

MethodDefinition : get ClassElementName ( ) { FunctionBody }

1. Return `FunctionBody Contains SuperCall`.

MethodDefinition : set ClassElementName ( PropertySetParameterList ) { FunctionBody }

1. If `PropertySetParameterList Contains SuperCall` is `true`, return `true`.
2. Return `FunctionBody Contains SuperCall`.

GeneratorMethod : ★ ClassElementName ( UniqueFormalParameters ) { GeneratorBody }

1. If `UniqueFormalParameters Contains SuperCall` is `true`, return `true`.
2. Return `GeneratorBody Contains SuperCall`. 
AsyncGeneratorMethod : async ★ ClassElementName ( UniqueFormalParameters ) { AsyncGeneratorBody }

1. If UniqueFormalParameters Contains SuperCall is true, return true.
2. Return AsyncGeneratorBody Contains SuperCall.

AsyncMethod : async ClassElementName ( UniqueFormalParameters ) { AsyncFunctionBody }

1. If UniqueFormalParameters Contains SuperCall is true, return true.
2. Return AsyncFunctionBody Contains SuperCall.

15.4.3 Static Semantics: SpecialMethod

The syntax-directed operation SpecialMethod takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

MethodDefinition : ClassElementName ( UniqueFormalParameters ) { FunctionBody }

1. Return false.

MethodDefinition :
  GeneratorMethod
  AsyncMethod
  AsyncGeneratorMethod
    get ClassElementName ( ) { FunctionBody }
    set ClassElementName ( PropertySetParameterList ) { FunctionBody }

1. Return true.

15.4.4 Runtime Semantics: DefineMethod

The syntax-directed operation DefineMethod takes argument object (an Object) and optional argument functionPrototype (an Object) and returns either a normal completion containing a Record with fields [[Key]] (a property key) and [[Closure]] (an ECMAScript function object) or an abrupt completion. It is defined piecewise over the following productions:

MethodDefinition : ClassElementName ( UniqueFormalParameters ) { FunctionBody }

1. Let propName be ? Evaluation of ClassElementName.
2. Let env be the running execution context's LexicalEnvironment.
3. Let privateEnv be the running execution context's PrivateEnvironment.
4. If functionPrototype is present, then
   a. Let prototype be functionPrototype.
5. Else,
   a. Let prototype be %Function.prototype%.
6. Let sourceText be the source text matched by MethodDefinition.
7. Let closure be OrdinaryFunctionCreate(prototype, sourceText, UniqueFormalParameters, FunctionBody, NON-LEXICAL-THIS, env, privateEnv).
9. Return the Record { [[Key]]: propName, [[Closure]]: closure }. 
15.4.5 Runtime Semantics: MethodDefinitionEvaluation

The syntax-directed operation MethodDefinitionEvaluation takes arguments object (an Object) and enumerable (a Boolean) and returns either a normal completion containing either a PrivateElement or UNUSED, or an abrupt completion. It is defined piecewise over the following productions:

MethodDefinition : ClassElementName ( UniqueFormalParameters ) { FunctionBody }

1. Let methodDef be ? DefineMethod of MethodDefinition with argument object.
2. Perform SetFunctionName(methodDef,[[Closure]], methodDef,[[Key]]).

MethodDefinition : get ClassElementName ( ) { FunctionBody }

1. Let propKey be ? Evaluation of ClassElementName.
2. Let env be the running execution context's LexicalEnvironment.
3. Let privateEnv be the running execution context's PrivateEnvironment.
4. Let sourceText be the source text matched by MethodDefinition.
5. Let formalParameterList be an instance of the production FormalParameters : [empty] .
7. Perform MakeMethod(closure, object).
8. Perform SetFunctionName(closure, propKey, "get").
9. If propKey is a Private Name, then
   a. Return PrivateElement { [[Key]]: propKey, [[Kind]]: ACCESSOR, [[Get]]: closure, [[Set]]: undefined }.
10. Else, then
    a. Let desc be the PropertyDescriptor { [[Get]]: closure, [[Enumerable]]: enumerable, [[Configurable]]: true }.
    b. Perform ? DefinePropertyOrThrow(object, propKey, desc).
    c. Return UNUSED.

MethodDefinition : set ClassElementName ( PropertySetParameterList ) { FunctionBody }

1. Let propKey be ? Evaluation of ClassElementName.
2. Let env be the running execution context's LexicalEnvironment.
3. Let privateEnv be the running execution context's PrivateEnvironment.
4. Let sourceText be the source text matched by MethodDefinition.
5. Let closure be OrdinaryFunctionCreate(%Function.prototype%, sourceText, PropertySetParameterList, FunctionBody, NON-LEXICAL-THIS, env, privateEnv).
7. Perform SetFunctionName(closure, propKey, "set").
8. If propKey is a Private Name, then
   a. Return PrivateElement { [[Key]]: propKey, [[Kind]]: ACCESSOR, [[Get]]: undefined, [[Set]]: closure }.
9. Else, then
   a. Let desc be the PropertyDescriptor { [[Set]]: closure, [[Enumerable]]: enumerable, [[Configurable]]: true }.
   b. Perform ? DefinePropertyOrThrow(object, propKey, desc).
   c. Return UNUSED.

GeneratorMethod : ★ ClassElementName ( UniqueFormalParameters ) { GeneratorBody }

1. Let propKey be ? Evaluation of ClassElementName.
2. Let env be the running execution context's LexicalEnvironment.
3. Let privateEnv be the running execution context's PrivateEnvironment.
4. Let sourceText be the source text matched by GeneratorMethod.
5. Let closure be OrdinaryFunctionCreate(%GeneratorFunction.prototype%, sourceText, UniqueFormalParameters, GeneratorBody, NON-LEXICAL-THIS, env, privateEnv).
7. Perform SetFunctionName(closure, propKey).
8. Let prototype be OrdinaryObjectCreate(%GeneratorFunction.prototype.prototype%).
9. Perform `DefinePropertyOrThrow(closure, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).
10. Return `DefineMethodProperty(object, propKey, closure, enumerable).

AsyncGeneratorMethod : async ★ ClassElementName ( UniqueFormalParameters ) { AsyncGeneratorBody }

1. Let `propKey` be ? Evaluation of ClassElementName.
2. Let `env` be the running execution context’s LexicalEnvironment.
3. Let `privateEnv` be the running execution context’s PrivateEnvironment.
4. Let `sourceText` be the source text matched by AsyncGeneratorMethod.
5. Let `closure` be OrdinaryFunctionCreate(%AsyncGeneratorFunction.prototype.prototype%, sourceText, UniqueFormalParameters, AsyncGeneratorBody, NON-LEXICAL-THIS, env, privateEnv).
7. Perform SetFunctionName(closure, propKey).
8. Let `prototype` be OrdinaryObjectCreate(%AsyncGeneratorFunction.prototype.prototype%).
9. Perform ! DefinePropertyOrThrow(closure, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).

AsyncMethod : async ClassElementName ( UniqueFormalParameters ) { AsyncFunctionBody }

1. Let `propKey` be ? Evaluation of ClassElementName.
2. Let `env` be the LexicalEnvironment of the running execution context.
3. Let `privateEnv` be the running execution context’s PrivateEnvironment.
4. Let `sourceText` be the source text matched by AsyncMethod.
5. Let `closure` be OrdinaryFunctionCreate(%AsyncFunction.prototype.prototype%, sourceText, UniqueFormalParameters, AsyncFunctionBody, NON-LEXICAL-THIS, env, privateEnv).
7. Perform SetFunctionName(closure, propKey).

15.5 Generator Function Definitions

Syntax

GeneratorDeclaration[Yield, Await, Default] :
  function ★ BindingIdentifier?[?Yield, ?Await] ( FormalParameters[+Yield, ~Await] ) { GeneratorBody }
  [+Default] function ★ ( FormalParameters[+Yield, ~Await] ) { GeneratorBody }

GeneratorExpression :
  function ★ BindingIdentifier[+Yield, ~Await] opt ( FormalParameters[+Yield, ~Await] ) { GeneratorBody }

GeneratorMethod[Yield, Await] :
  ★ ClassElementName?[?Yield, ?Await] ( UniqueFormalParameters[+Yield, ~Await] ) { GeneratorBody }

GeneratorBody :
  FunctionBody[+Yield, ~Await]

YieldExpression[In, Await] :
  yield
    yield [no LineTerminator here] AssignmentExpression?[?In, +Yield, ?Await]
  yield [no LineTerminator here] ★ AssignmentExpression?[?In, +Yield, ?Await]
NOTE 1 The syntactic context immediately following yield requires use of theInputElementRegExpOrTemplateTail lexical goal.

NOTE 2 YieldExpression cannot be used within the FormaParameters of a generator function because any expressions that are part of FormaParameters are evaluated before the resulting Generator is in a resumable state.

NOTE 3 Abstract operations relating to Generators are defined in 27.5.3.

15.5.1 Static Semantics: Early Errors

GeneratorMethod : ★ ClassElementName ( UniqueFormaParameters ) { GeneratorBody }

- It is a Syntax Error if HasDirectSuper of GeneratorMethod is true.
- It is a Syntax Error if UniqueFormalParameters Contains YieldExpression is true.
- It is a Syntax Error if FunctionBodyContainsUseStrict of GeneratorBody is true and IsSimpleParameterList of UniqueFormalParameters is false.
- It is a Syntax Error if any element of the BoundNames of UniqueFormalParameters also occurs in the LexicallyDeclaredNames of GeneratorBody.

GeneratorDeclaration :

    function ★ BindingIdentifier ( FormalParameters ) { GeneratorBody }
    function ★ ( FormalParameters ) { GeneratorBody }

GeneratorExpression :

    function ★ BindingIdentifieropt ( FormalParameters ) { GeneratorBody }

- If the source text matched by FormalParameters is strict mode code, the Early Error rules for UniqueFormalParameters are applied.
- If BindingIdentifier is present and the source text matched by BindingIdentifier is strict mode code, it is a Syntax Error if the StringValue of BindingIdentifier is either "eval" or "arguments".
- It is a Syntax Error if FunctionBodyContainsUseStrict of GeneratorBody is true and IsSimpleParameterList of FormalParameters is false.
- It is a Syntax Error if any element of the BoundNames of FormalParameters also occurs in the LexicallyDeclaredNames of GeneratorBody.
- It is a Syntax Error if FormalParameters Contains YieldExpression is true.
- It is a Syntax Error if FormalParameters Contains SuperProperty is true.
- It is a Syntax Error if GeneratorBody Contains SuperProperty is true.
- It is a Syntax Error if FormalParameters Contains SuperCall is true.
- It is a Syntax Error if GeneratorBody Contains SuperCall is true.

15.5.2 Runtime Semantics: EvaluateGeneratorBody

The syntax-directed operation EvaluateGeneratorBody takes arguments functionObject (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns a throw completion or a return completion. It is defined piecewise over the following productions:

GeneratorBody : FunctionBody

2. Let G be ? OrdinaryCreateFromConstructor(functionObject, "%GeneratorFunction.prototype.prototype%", « [[GeneratorState]], [[GeneratorContext]], [[GeneratorBrand]] »).
3. Set G.[[GeneratorBrand]] to EMPTY.
5. Return Completion Record { [[Type]]: RETURN, [[Value]]: G, [[Target]]: EMPTY }.
15.5.3 Runtime Semantics: InstantiateGeneratorFunctionObject

The syntax-directed operation `InstantiateGeneratorFunctionObject` takes arguments `env` (an `EnvironmentRecord`) and `privateEnv` (a `PrivateEnvironmentRecord` or null) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```
GeneratorDeclaration : function * BindingIdentifier ( FormalParameters ) { GeneratorBody }
```

1. Let `name` be `StringValue` of `BindingIdentifier`.
2. Let `sourceText` be the source text matched by `GeneratorDeclaration`.
3. Let `F` be `OrdinaryFunctionCreate('%GeneratorFunction.prototype%', sourceText, FormalParameters, GeneratorBody, NON-LEXICAL-THIS, env, privateEnv)`.  
   4. Perform `SetFunctionName(F, "name")`.
5. Let `prototype` be `OrdinaryObjectCreate('%GeneratorFunction.prototype.prototype%')`.
6. Perform `DefinePropertyOrThrow(F, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false })`.
7. Return `F`.

**NOTE** An anonymous `GeneratorDeclaration` can only occur as part of an `export default` declaration, and its function code is therefore always strict mode code.

15.5.4 Runtime Semantics: InstantiateGeneratorFunctionExpression

The syntax-directed operation `InstantiateGeneratorFunctionExpression` takes optional argument `name` (a property key or a `Private Name`) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```
GeneratorExpression : function * ( FormalParameters ) { GeneratorBody }
```

1. If `name` is not present, set `name` to "".
2. Let `env` be the LexicalEnvironment of the running execution context.
3. Let `privateEnv` be the running execution context’s PrivateEnvironment.
4. Let `sourceText` be the source text matched by `GeneratorExpression`.
5. Let `closure` be `OrdinaryFunctionCreate('%GeneratorFunction.prototype%', sourceText, FormalParameters, GeneratorBody, NON-LEXICAL-THIS, env, privateEnv)`.  
   6. Perform `SetFunctionName(closure, name)`.
7. Let `prototype` be `OrdinaryObjectCreate('%GeneratorFunction.prototype.prototype%')`.
8. Perform `DefinePropertyOrThrow(closure, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false })`.

```
GeneratorExpression : function * BindingIdentifier ( FormalParameters ) { GeneratorBody }
```

1. Assert: `name` is not present.
2. Set `name` to `StringValue` of `BindingIdentifier`.
3. Let `outerEnv` be the running execution context’s LexicalEnvironment.
4. Let `funcEnv` be `NewDeclarativeEnvironment(outerEnv)`.
5. Perform `funcEnv.CreateImmutableBinding(name, false)`.
6. Let `privateEnv` be the running execution context’s PrivateEnvironment.
7. Let `sourceText` be the source text matched by `GeneratorExpression`.  

---

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8. Let closure be OrdinaryFunctionCreate(%GeneratorFunction.prototype%, sourceText, FormalParameters, GeneratorBody, NON-LEXICAL-THIS, funcEnv, privateEnv).
9. Perform SetFunctionName(closure, name).
10. Let prototype be OrdinaryObjectCreate(%GeneratorFunction.prototype.prototype%).
11. Perform ! DefinePropertyOrThrow(closure, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).
12. Perform ! funcEnv.InitializeBinding(name, closure).

NOTE The BindingIdentifier in a GeneratorExpression can be referenced from inside the GeneratorExpression’s FunctionBody to allow the generator code to call itself recursively. However, unlike in a GeneratorDeclaration, the BindingIdentifier in a GeneratorExpression cannot be referenced from and does not affect the scope enclosing the GeneratorExpression.

15.5.5 Runtime Semantics: Evaluation

GeneratorExpression : function * BindingIdentifieropt ( FormalParameters ) { GeneratorBody }

1. Return InstantiateGeneratorFunctionExpression of GeneratorExpression.

YieldExpression : yield


YieldExpression : yield AssignmentExpression

1. Let exprRef be ? Evaluation of AssignmentExpression.
2. Let value be ? GetValue(exprRef).

YieldExpression : yield * AssignmentExpression

1. Let generatorKind be GetGeneratorKind().
2. Let exprRef be ? Evaluation of AssignmentExpression.
3. Let value be ? GetValue(exprRef).
4. Let iteratorRecord be ? GetIterator(value, generatorKind).
5. Let iterator be iteratorRecord.[[Iterator]].
6. Let received be NormalCompletion(undefined).
7. Repeat,
   a. If received is a normal completion, then
      i. Let innerResult be ? Call(iteratorRecord.[[NextMethod]], iteratorRecord.[[Iterator]], « received.[[Value]] »).
      ii. If generatorKind is ASYNC, set innerResult to ? Await(innerResult).
      iii. If innerResult is not an Object, throw a TypeError exception.
      iv. Let done be ? IteratorComplete(innerResult).
      v. If done is true, then
      vi. If generatorKind is ASYNC, set received to Completion(AsyncGeneratorYield(?
         IteratorValue(innerResult))).
      vii. Else, set received to Completion(GeneratorYield(innerResult)).
   b. Else if received is a throw completion, then
      i. Let throw be ? GetMethod(iterator, "throw").
      ii. If throw is not undefined, then
         1. Let innerResult be ? Call(throw, iterator, « received.[[Value]] »).
         2. If generatorKind is ASYNC, set innerResult to ? Await(innerResult).
         3. NOTE: Exceptions from the inner iterator throw method are propagated. Normal completions from an inner throw method are processed similarly to an inner next.
         4. If innerResult is not an Object, throw a TypeError exception.
         5. Let done be ? IteratorComplete(innerResult).
6. If \( \text{done} \) is \( \text{true} \), then
   a. Return \( \text{IteratorValue(innerResult)} \).
7. If \( \text{generatorKind} \) is \( \text{ASYNC} \), set \( \text{received} \) to \( \text{Completion(AsyncGeneratorYield(\text{IteratorValue(innerResult)}))} \).
8. Else, set \( \text{received} \) to \( \text{Completion(GeneratorYield(innerResult))} \).

   iii. Else,
      1. NOTE: If \( \text{iterator} \) does not have a \( \text{throw} \) method, this throw is going to terminate the \( \text{yield}\star \) loop. But first we need to give \( \text{iterator} \) a chance to clean up.
      2. Let \( \text{closeCompletion} \) be \( \text{Completion Record} \{ [[\text{Type}}]: \text{NORMAL}, [[\text{Value}}]: \text{EMPTY}, [[\text{Target}}]: \text{EMPTY} \} \).
      3. If \( \text{generatorKind} \) is \( \text{ASYNC} \), perform \( \text{? AsyncIteratorClose(iteratorRecord, closeCompletion)} \).
      4. Else, perform \( \text{? IteratorClose(iteratorRecord, closeCompletion)} \).
      5. NOTE: The next step throws a \( \text{TypeError} \) to indicate that there was a \( \text{yield}\star \) protocol violation: \( \text{iterator} \) does not have a \( \text{throw} \) method.
      6. Throw a \( \text{TypeError} \) exception.
   c. Else,
      i. Assert: \( \text{received} \) is a \( \text{return completion} \).
      ii. Let \( \text{return} \) be \( \text{? GetMethod(iterator, "return")} \).
      iii. If \( \text{return} \) is \( \text{undefined} \), then
          1. Set \( \text{value} \) to \( \text{received}[[\text{Value}}] \).
          2. If \( \text{generatorKind} \) is \( \text{ASYNC} \), then
             a. Set \( \text{value} \) to \( \text{? Await(value)} \).
             3. Return \( \text{Completion Record} \{ [[\text{Type}}]: \text{RETURN}, [[\text{Value}}]: \text{value}, [[\text{Target}}]: \text{EMPTY} \} \).
      iv. Let \( \text{innerReturnResult} \) be \( \text{? Call(return, iterator, \"received\"\[\text{Value}}]} \).
      v. If \( \text{generatorKind} \) is \( \text{ASYNC} \), set \( \text{innerReturnResult} \) to \( \text{? Await(innerReturnResult)} \).
      vi. If \( \text{innerReturnResult} \) is not an \( \text{Object} \), throw a \( \text{TypeError} \) exception.
      vii. Let \( \text{done} \) be \( \text{? IteratorComplete(innerReturnResult)} \).
      viii. If \( \text{done} \) is \( \text{true} \), then
           1. Set \( \text{value} \) to \( \text{? IteratorValue(innerReturnResult)} \).
           2. Return \( \text{Completion Record} \{ [[\text{Type}}]: \text{RETURN}, [[\text{Value}}]: \text{value}, [[\text{Target}}]: \text{EMPTY} \} \).
      ix. If \( \text{generatorKind} \) is \( \text{ASYNC} \), set \( \text{received} \) to \( \text{Completion(AsyncGeneratorYield(\text{IteratorValue(innerReturnResult)})]} \).
      x. Else, set \( \text{received} \) to \( \text{Completion(GeneratorYield(innerReturnResult))} \).

### 15.6 Async Generator Function Definitions

**Syntax**

AsyncGeneratorDeclaration[Yield, Await, Default] :

\[
\text{async [no Line Terminator here] function * BindingIdentifier[?Yield, ?Await] ( FormalParameters[+Yield, +Await] ) \{} \text{AsyncGeneratorBody} \}\]


AsyncGeneratorExpression :

\[
\text{async [no Line Terminator here] function * BindingIdentifier[+Yield, +Await] opt ( FormalParameters[+Yield, +Await] ) \{} \text{AsyncGeneratorBody} \}\]

AsyncGeneratorMethod[Yield, Await] :

\[
\text{async [no Line Terminator here] * ClassElementName[?Yield, ?Await] ( UniqueFormalParameters[+Yield, +Await] ) \{} \text{AsyncGeneratorBody} \}\]

AsyncGeneratorBody :

\[
\text{FunctionBody[+Yield, +Await]} \]

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NOTE 1  YieldExpression and AwaitExpression cannot be used within the FormalParameters of an async generator function because any expressions that are part of FormalParameters are evaluated before the resulting AsyncGenerator is in a resumable state.

NOTE 2  Abstract operations relating to AsyncGenerators are defined in 27.6.3.

15.6.1 Static Semantics: Early Errors

AsyncGeneratorMethod : async * ClassElementName ( UniqueFormalParameters ) {
AsyncGeneratorBody }

- It is a Syntax Error if HasDirectSuper of AsyncGeneratorMethod is true.
- It is a Syntax Error if UniqueFormalParameters Contains YieldExpression is true.
- It is a Syntax Error if UniqueFormalParameters Contains AwaitExpression is true.
- It is a Syntax Error if FunctionBodyContainsUseStrict of AsyncGeneratorBody is true and IsSimpleParameterList of UniqueFormalParameters is false.
- It is a Syntax Error if any element of the BoundNames of UniqueFormalParameters also occurs in the LexicallyDeclaredNames of AsyncGeneratorBody.

AsyncGeneratorDeclaration :
async function * BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }
async function * ( FormalParameters ) { AsyncGeneratorBody }

- If the source text matched by FormalParameters is strict mode code, the Early Error rules for UniqueFormalParameters: FormalParameters are applied.
- If BindingIdentifier is present and the source text matched by BindingIdentifier is strict mode code, it is a Syntax Error if the StringValue of BindingIdentifier is either "eval" or "arguments".
- It is a Syntax Error if FunctionBodyContainsUseStrict of AsyncGeneratorBody is true and IsSimpleParameterList of FormalParameters is false.
- It is a Syntax Error if any element of the BoundNames of FormalParameters also occurs in the LexicallyDeclaredNames of AsyncGeneratorBody.
- It is a Syntax Error if FormalParameters Contains YieldExpression is true.
- It is a Syntax Error if FormalParameters Contains AwaitExpression is true.
- It is a Syntax Error if FormalParameters Contains SuperProperty is true.
- It is a Syntax Error if AsyncGeneratorBody Contains SuperProperty is true.
- It is a Syntax Error if FormalParameters Contains SuperCall is true.
- It is a Syntax Error if AsyncGeneratorBody Contains SuperCall is true.

15.6.2 Runtime Semantics: EvaluateAsyncGeneratorBody

The syntax-directed operation EvaluateAsyncGeneratorBody takes arguments functionObject (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns a throw completion or a return completion. It is defined piecewise over the following productions:

AsyncGeneratorBody : FunctionBody

2. Let generator be ? OrdinaryCreateFromConstructor(functionObject, "%AsyncGeneratorFunction.prototype.prototype%", [[AsyncGeneratorState]], [[AsyncGeneratorContext]], [[AsyncGeneratorQueue]], [[GeneratorBrand]]).
3. Set generator.[[GeneratorBrand]] to EMPTY.
5. Return Completion Record { [[Type]]: RETURN, [[Value]]: generator, [[Target]]: EMPTY }. 

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15.6.3 Runtime Semantics: InstantiateAsyncGeneratorFunctionObject

The syntax-directed operation `InstantiateAsyncGeneratorFunctionObject` takes arguments `env` (an Environment Record) and `privateEnv` (a PrivateEnvironment Record or null) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```javascript
AsyncGeneratorDeclaration : async function * BindingIdentifier ( FormalParameters ) {
  AsyncGeneratorBody
}
```

1. Let `name` be `StringValue` of BindingIdentifier.
2. Let `sourceText` be the source text matched by AsyncGeneratorDeclaration.
3. Let `F` be OrdinaryFunctionCreate(%AsyncGeneratorFunction.prototype%, `sourceText`, FormalParameters, AsyncGeneratorBody, NON-LEXICAL-THIS, `env`, `privateEnv`).
4. Perform SetFunctionName(`F`, `name`).
5. Let `prototype` be OrdinaryObjectCreate(%AsyncGeneratorFunction.prototype.prototype%).
6. Perform `I DefinePropertyOrThrow(F, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).
7. Return `F`.

**NOTE** An anonymous AsyncGeneratorDeclaration can only occur as part of an `export default` declaration.

15.6.4 Runtime Semantics: InstantiateAsyncGeneratorFunctionExpression

The syntax-directed operation `InstantiateAsyncGeneratorFunctionExpression` takes optional argument `name` (a property key or a Private Name) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```javascript
AsyncGeneratorExpression : async function * ( FormalParameters ) { AsyncGeneratorBody }
```

1. If `name` is not present, set `name` to "".
2. Let `env` be the LexicalEnvironment of the running execution context.
3. Let `privateEnv` be the running execution context's PrivateEnvironment.
4. Let `sourceText` be the source text matched by AsyncGeneratorExpression.
5. Let `closure` be OrdinaryFunctionCreate(%AsyncGeneratorFunction.prototype.prototype%, `sourceText`, FormalParameters, AsyncGeneratorBody, NON-LEXICAL-THIS, `env`, `privateEnv`).
6. Perform SetFunctionName(`closure`, `name`).
7. Let `prototype` be OrdinaryObjectCreate(%AsyncGeneratorFunction.prototype.prototype%).
8. Perform `I DefinePropertyOrThrow(closure, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).

```javascript
AsyncGeneratorExpression : async function * BindingIdentifier ( FormalParameters ) {
  AsyncGeneratorBody
}
```

1. Assert: `name` is not present.
2. Set `name` to `StringValue` of BindingIdentifier.
3. Let `outerEnv` be the running execution context's LexicalEnvironment.
4. Let `funcEnv` be NewDeclarativeEnvironment(`outerEnv`).
5. Perform `I funcEnv.CreateImmutableBinding(name, false).`
6. Let `privateEnv` be the running execution context's PrivateEnvironment.

7. Let `sourceText` be the source text matched by `AsyncGeneratorExpression`.

8. Let `closure` be `OrdinaryFunctionCreate(%AsyncGeneratorFunction.prototype%, sourceText, FormalParameters, AsyncGeneratorBody, NON-LEXICAL-THIS, `funcEnv`, `privateEnv`).`

9. Perform `SetFunctionName(closure, name)`.

10. Let `prototype` be `OrdinaryObjectCreate(%AsyncGeneratorFunction.prototype.prototype%)`.

11. Perform `DefinePropertyOrThrow(closure, "prototype", PropertyDescriptor { [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false })`.

12. Perform `funcEnv.InitializeBinding(name, closure)`.


**NOTE** The `BindingIdentifier` in an `AsyncGeneratorExpression` can be referenced from inside the `AsyncGeneratorExpression`'s `AsyncGeneratorBody` to allow the generator code to call itself recursively. However, unlike in an `AsyncGeneratorDeclaration`, the `BindingIdentifier` in an `AsyncGeneratorExpression` cannot be referenced from and does not affect the scope enclosing the `AsyncGeneratorExpression`.

### 15.6.5 Runtime Semantics: Evaluation

`AsyncGeneratorExpression` : `async function * BindingIdentifier_opt ( FormalParameters ) { AsyncGeneratorBody }`

1. Return `InstantiateAsyncGeneratorFunctionExpression` of `AsyncGeneratorExpression`.

### 15.7 Class Definitions

**Syntax**

```
ClassDeclaration[Yield, Await, Default] :
    class BindingIdentifier[Yield, Await]  ClassTail[Yield, Await]
    [+Default] class ClassTail[Yield, Await]

ClassExpression[Yield, Await] :
    class BindingIdentifier[Yield, Await] opt  ClassTail[Yield, Await]

ClassTail[Yield, Await] :
    ClassHeritage[Yield, Await] opt  { ClassBody[Yield, Await] opt }

ClassHeritage[Yield, Await] :
    extends LeftHandSideExpression[Yield, Await]

ClassBody[Yield, Await] :
    ClassElementList[Yield, Await]

ClassElementList[Yield, Await] :
    ClassElement[Yield, Await]
    ClassElement[Yield, Await]
    ClassElementList[Yield, Await]  ClassElement[Yield, Await]

ClassElement[Yield, Await] :
    MethodDefinition[Yield, Await]
    static MethodDefinition[Yield, Await]
    FieldDefinition[Yield, Await];
    static FieldDefinition[Yield, Await];
    ClassStaticBlock
```

15.7.1 Static Semantics: Early Errors

ClassTail : ClassHeritageopt { ClassBody }

- It is a Syntax Error if ClassHeritage is not present and the following algorithm returns true:
  1. Let constructor be ConstructorMethod of ClassBody.
  2. If constructor is EMPTY, return false.
  3. Return HasDirectSuper of constructor.

ClassBody : ClassElementList

- It is a Syntax Error if PrototypePropertyNameList of ClassElementList contains more than one occurrence of "constructor".
- It is a Syntax Error if PrivateBoundIdentifiers of ClassElementList contains any duplicate entries, unless the name is used once for a getter and once for a setter and in no other entries, and the getter and setter are either both static or both non-static.

ClassElement : MethodDefinition

- It is a Syntax Error if PropName of MethodDefinition is not "constructor" and HasDirectSuper of MethodDefinition is true.
- It is a Syntax Error if PropName of MethodDefinition is "constructor" and SpecialMethod of MethodDefinition is true.

ClassElement : static MethodDefinition

- It is a Syntax Error if HasDirectSuper of MethodDefinition is true.
- It is a Syntax Error if PropName of MethodDefinition is "prototype".

ClassElement : FieldDefinition ;

- It is a Syntax Error if PropName of FieldDefinition is "constructor".

ClassElement : static FieldDefinition ;

- It is a Syntax Error if PropName of FieldDefinition is either "prototype" or "constructor".

FieldDefinition :
  ClassElementName Initializeropt

- It is a Syntax Error if Initializer is present and ContainsArguments of Initializer is true.
• It is a Syntax Error if `Initializer` is present and `Initializer Contains SuperCall` is true.

`ClassElementName` : `PrivateIdentifier`

• It is a Syntax Error if `StringValue` of `PrivateIdentifier` is "#constructor".

`ClassStaticBlockBody` : `ClassStaticBlockStatementList`

• It is a Syntax Error if the `LexicallyDeclaredNames` of `ClassStaticBlockStatementList` contains any duplicate entries.
• It is a Syntax Error if any element of the `LexicallyDeclaredNames` of `ClassStaticBlockStatementList` also occurs in the `VarDeclaredNames` of `ClassStaticBlockStatementList`.
• It is a Syntax Error if `ContainsDuplicateLabels` of `ClassStaticBlockStatementList` with argument « » is true.
• It is a Syntax Error if `ContainsUndefinedBreakTarget` of `ClassStaticBlockStatementList` with argument « » is true.
• It is a Syntax Error if `ContainsUndefinedContinueTarget` of `ClassStaticBlockStatementList` with arguments « » and « » is true.
• It is a Syntax Error if `ContainsArguments` of `ClassStaticBlockStatementList` is true.
• It is a Syntax Error if `ClassStaticBlockStatementList Contains SuperCall` is true.
• It is a Syntax Error if `ClassStaticBlockStatementList Contains await` is true.

15.7.2 Static Semantics: `ClassElementKind`

The syntax-directed operation `ClassElementKind` takes no arguments and returns `CONSTRUCTOR-METHOD`, `NON-CONSTRUCTOR-METHOD`, or `EMPTY`. It is defined piecewise over the following productions:

`ClassElement` : `MethodDefinition`

1. If `PropName` of `MethodDefinition` is "constructor", return `CONSTRUCTOR-METHOD`.
2. Return `NON-CONSTRUCTOR-METHOD`.

`ClassElement` :

    `static` `MethodDefinition`
    `FieldDefinition` ;
    `static` `FieldDefinition` ;

1. Return `NON-CONSTRUCTOR-METHOD`.

`ClassElement` : `ClassStaticBlock`

1. Return `NON-CONSTRUCTOR-METHOD`.

`ClassElement` :`

1. Return `EMPTY`.

15.7.3 Static Semantics: `ConstructorMethod`

The syntax-directed operation `ConstructorMethod` takes no arguments and returns a `ClassElement Parse Node` or `EMPTY`. It is defined piecewise over the following productions:

`ClassElementList` : `ClassElement`

1. If `ClassElementKind` of `ClassElement` is `CONSTRUCTOR-METHOD`, return `ClassElement`.
2. Return `EMPTY`.

`ClassElementList` : `ClassElementList` `ClassElement`

1. Let `head` be `ConstructorMethod` of `ClassElementList`.
2. If `head` is not `EMPTY`, return `head`.

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3. If `ClassElementKind` of `ClassElement` is CONSTRUCTOR-METHOD, return `ClassElement`.
4. Return EMPTY.

NOTE Early Error rules ensure that there is only one method definition named "constructor" and that it is not an accessor property or generator definition.

15.7.4 Static Semantics: `IsStatic`

The syntax-directed operation `IsStatic` takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

```
ClassElement : MethodDefinition
1. Return false.
```

```
ClassElement : static MethodDefinition
1. Return true.
```

```
ClassElement : FieldDefinition ;
1. Return false.
```

```
ClassElement : static FieldDefinition ;
1. Return true.
```

```
ClassElement : ClassStaticBlock
1. Return true.
```

```
ClassElement : ;
1. Return false.
```

15.7.5 Static Semantics: `NonConstructorElements`

The syntax-directed operation `NonConstructorElements` takes no arguments and returns a List of `ClassElement Parse Nodes`. It is defined piecewise over the following productions:

```
ClassElementList : ClassElement
1. If `ClassElementKind` of `ClassElement` is NON-CONSTRUCTOR-METHOD, then
   a. Return « `ClassElement` ».
2. Return a new empty List.
```

```
ClassElementList : ClassElementList ClassElement
1. Let `list` be `NonConstructorElements` of `ClassElementList`.
2. If `ClassElementKind` of `ClassElement` is NON-CONSTRUCTOR-METHOD, then
   a. Append `ClassElement` to the end of `list`.
3. Return `list`.
15.7.6 Static Semantics: PrototypePropertyNameList

The syntax-directed operation PrototypePropertyNameList takes no arguments and returns a List of property keys. It is defined piecewise over the following productions:

\[ \text{ClassElementList} : \text{ClassElement} \]

1. Let \( \text{propName} \) be \( \text{PropName} \) of \( \text{ClassElement} \).
2. If \( \text{propName} \) is EMPTY, return a new empty List.
3. If \( \text{IsStatic} \) of \( \text{ClassElement} \) is true, return a new empty List.
4. Return \( \text{propName} \).

\[ \text{ClassElementList} : \text{ClassElementList} \text{ ClassElement} \]

1. Let \( \text{list} \) be \( \text{PrototypePropertyNameList} \) of \( \text{ClassElementList} \).
2. Let \( \text{propName} \) be \( \text{PropName} \) of \( \text{ClassElement} \).
3. If \( \text{propName} \) is EMPTY, return \( \text{list} \).
4. If \( \text{IsStatic} \) of \( \text{ClassElement} \) is true, return \( \text{list} \).
5. Return the list-concatenation of \( \text{list} \) and \( \text{propName} \).

15.7.7 Static Semantics: AllPrivateIdentifiersValid

The syntax-directed operation AllPrivateIdentifiersValid takes argument \( \text{names} \) (a List of Strings) and returns a Boolean.

Every grammar production alternative in this specification which is not listed below implicitly has the following default definition of AllPrivateIdentifiersValid:

1. For each child node \( \text{child} \) of this Parse Node, do
   a. If \( \text{child} \) is an instance of a nonterminal, then
      i. If \( \text{AllPrivateIdentifiersValid} \) of \( \text{child} \) with argument \( \text{names} \) is false, return false.
   2. Return true.

\[ \text{MemberExpression} : \text{MemberExpression} \text{. Privatidentifier} \]

1. If \( \text{names} \) contains the StringValue of Privatidentifier, then
   a. Return \( \text{AllPrivateIdentifiersValid} \) of \( \text{MemberExpression} \) with argument \( \text{names} \).
2. Return false.

\[ \text{CallExpression} : \text{CallExpression} \text{. Privatidentifier} \]

1. If \( \text{names} \) contains the StringValue of Privatidentifier, then
   a. Return \( \text{AllPrivateIdentifiersValid} \) of \( \text{CallExpression} \) with argument \( \text{names} \).
2. Return false.

\[ \text{OptionalChain} : ? \text{. Privatidentifier} \]

1. If \( \text{names} \) contains the StringValue of Privatidentifier, return true.
2. Return false.

\[ \text{OptionalChain} : \text{OptionalChain} \text{. Privatidentifier} \]

1. If \( \text{names} \) contains the StringValue of Privatidentifier, then
   a. Return \( \text{AllPrivateIdentifiersValid} \) of \( \text{OptionalChain} \) with argument \( \text{names} \).
2. Return false.

\[ \text{ClassBody} : \text{ClassElementList} \]

1. Let \( \text{newNames} \) be the list-concatenation of \( \text{names} \) and PrivatBoundIdentifiers of \( \text{ClassBody} \).
2. Return \( \text{AllPrivateIdentifiersValid} \) of \( \text{ClassElementList} \) with argument \( \text{newNames} \).
RelationalExpression : PrivateIdentifier in ShiftExpression

1. If names contains the StringValue of PrivateIdentifier, then
   a. Return AllPrivateIdentifiersValid of ShiftExpression with argument names.
2. Return false.

15.7.8 Static Semantics: PrivateBoundIdentifiers

The syntax-directed operation PrivateBoundIdentifiers takes no arguments and returns a List of Strings. It is defined piecewise over the following productions:
FieldDefinition : ClassElementName Initializeopt

1. Return PrivateBoundIdentifiers of ClassElementName.

ClassElementName : PrivateIdentifier

1. Return a List whose sole element is the StringValue of PrivateIdentifier.

ClassElementName :
    PropertyName
ClassElement :
    ClassStaticBlock
    ;

1. Return a new empty List.

ClassElementList : ClassElementList ClassElement

1. Let names1 be PrivateBoundIdentifiers of ClassElementList.
2. Let names2 be PrivateBoundIdentifiers of ClassElement.
3. Return the list-concatenation of names1 and names2.

MethodDefinition :
    ClassElementName ( UniqueFormalParameters ) { FunctionBody }
    get ClassElementName ( ) { FunctionBody }
    set ClassElementName ( PropertySetParameterList ) { FunctionBody }
GeneratorMethod :
    ★ ClassElementName ( UniqueFormalParameters ) { GeneratorBody }
AsyncMethod :
    async ClassElementName ( UniqueFormalParameters ) { AsyncFunctionBody }
AsyncGeneratorMethod :
    async ★ ClassElementName ( UniqueFormalParameters ) { AsyncGeneratorBody }

1. Return PrivateBoundIdentifiers of ClassElementName.

15.7.9 Static Semantics: ContainsArguments

The syntax-directed operation ContainsArguments takes no arguments and returns a Boolean.

Every grammar production alternative in this specification which is not listed below implicitly has the following default definition of ContainsArguments:

1. For each child node child of this Parse Node, do
   a. If child is an instance of a nonterminal, then
      i. If ContainsArguments of child is true, return true.
2. Return false.
1. If the `StringValue` of `Identifier` is "arguments", return `true`.
2. Return `false`.

FunctionDeclaration:

```javascript
function BindingIdentifier ( FormalParameters ) { FunctionBody }
function ( FormalParameters ) { FunctionBody }
```

FunctionExpression:

```javascript
function BindingIdentifieropt ( FormalParameters ) { FunctionBody }
```

GeneratorDeclaration:

```javascript
function * BindingIdentifier ( FormalParameters ) { GeneratorBody }
n function * ( FormalParameters ) { GeneratorBody }
```

GeneratorExpression:

```javascript
function * BindingIdentifieropt ( FormalParameters ) { GeneratorBody }
```

AsyncGeneratorDeclaration:

```javascript
async function * BindingIdentifier ( FormalParameters ) { AsyncGeneratorBody }
async function * ( FormalParameters ) { AsyncGeneratorBody }
```

AsyncGeneratorExpression:

```javascript
async function * BindingIdentifieropt ( FormalParameters ) { AsyncGeneratorBody }
```

AsyncFunctionDeclaration:

```javascript
async function BindingIdentifier ( FormalParameters ) { AsyncFunctionBody }
async function ( FormalParameters ) { AsyncFunctionBody }
```

AsyncFunctionExpression:

```javascript
async function BindingIdentifieropt ( FormalParameters ) { AsyncFunctionBody }
```

1. Return `false`.

MethodDefinition:

```javascript
ClassElementName ( UniqueFormalParameters ) { FunctionBody }
get ClassElementName ( ) { FunctionBody }
set ClassElementName ( PropertySetParameterList ) { FunctionBody }
```

GeneratorMethod:

```javascript
* ClassElementName ( UniqueFormalParameters ) { GeneratorBody }
```

AsyncGeneratorMethod:

```javascript
async * ClassElementName ( UniqueFormalParameters ) { AsyncGeneratorBody }
```

AsyncMethod:

```javascript
async ClassElementName ( UniqueFormalParameters ) { AsyncFunctionBody }
```

1. Return `ContainsArguments` of `ClassName`.

15.7.10 Runtime Semantics: ClassFieldDefinitionEvaluation

The syntax-directed operation `ClassFieldDefinitionEvaluation` takes argument `homeObject` (an Object) and returns either a normal completion containing a `ClassFieldDefinition Record` or an abrupt completion. It is defined piecewise over the following productions:

```
FieldDefinition : ClassElementName Initializeropt
```

1. Let `name` be ? `Evaluation` of `ClassName`.
2. If `Initializer` is present, then
   a. Let `formalParameterList` be an instance of the production `FormalParameters : [empty]`.
   b. Let `env` be the LexicalEnvironment of the running execution context.
   c. Let `privateEnv` be the running execution context's PrivateEnvironment.
   d. Let `sourceText` be the empty sequence of Unicode code points.
   e. Let `initializer` be `OrdinaryFunctionCreate(%Function.prototype%, sourceText, formalParameterList, Initializer, NON-LEXICAL-THIS, env, privateEnv)`.

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f. Perform `MakeMethod(initializer, homeObject)`.

g. Set `initializer.[[ClassFieldInitializerName]]` to `name`.

3. Else,
   a. Let `initializer` be EMPTY.

4. Return the `ClassFieldDefinition` Record `{ [[Name]]: name, [[Initializer]]: initializer }`.

**NOTE** The function created for `initializer` is never directly accessible to ECMAScript code.

### 15.7.11 Runtime Semantics: `ClassStaticBlockDefinitionEvaluation`  
The syntax-directed operation `ClassStaticBlockDefinitionEvaluation` takes argument `homeObject` (an Object) and returns a `ClassStaticBlockDefinition` Record. It is defined piecewise over the following productions:

```plaintext
ClassStaticBlock : static { ClassStaticBlockBody }
```

1. Let `lex` be the running execution context’s LexicalEnvironment.
2. Let `privateEnv` be the running execution context’s PrivateEnvironment.
3. Let `sourceText` be the empty sequence of Unicode code points.
4. Let `formalParameters` be an instance of the production `FormalParameters` : [empty].
5. Let `bodyFunction` be `OrdinaryFunctionCreate(%Function.prototype%, sourceText, formalParameters, ClassStaticBlockBody, NON-LEXICAL-THIS, lex, privateEnv).
6. Perform `MakeMethod(bodyFunction, homeObject)`.
7. Return the `ClassStaticBlockDefinition` Record `{ [[BodyFunction]]: bodyFunction }`.

**NOTE** The function `bodyFunction` is never directly accessible to ECMAScript code.

### 15.7.12 Runtime Semantics: `EvaluateClassStaticBlockBody`  
The syntax-directed operation `EvaluateClassStaticBlockBody` takes argument `functionObject` (an ECMAScript function object) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It is defined piecewise over the following productions:

```plaintext
ClassStaticBlockBody : ClassStaticBlockStatementList
```

1. `Assert: functionObject` is a synthetic function created by `ClassStaticBlockDefinitionEvaluation` step 5.

### 15.7.13 Runtime Semantics: `ClassElementEvaluation`  
The syntax-directed operation `ClassElementEvaluation` takes argument `object` (an Object) and returns either a normal completion containing either a `ClassFieldDefinition` Record, a `ClassStaticBlockDefinition` Record, a `PrivateElement`, or UNUSED, or an abrupt completion. It is defined piecewise over the following productions:

```plaintext
ClassElement : FieldDefinition ;
static FieldDefinition ;
```

1. Return `? ClassFieldDefinitionEvaluation of FieldDefinition` with argument `object`.

```plaintext
ClassElement : MethodDefinition
static MethodDefinition
```


```plaintext
ClassElement : ClassStaticBlock
```

1. Return `ClassStaticBlockDefinitionEvaluation of ClassStaticBlock` with argument `object`.
1. Return UNUSED.

### 15.7.14 Runtime Semantics: ClassDefinitionEvaluation

The syntax-directed operation `ClassDefinitionEvaluation` takes arguments `classBinding` (a String or `undefined`) and `className` (a property key or a Private Name) and returns either a normal completion containing a function object or an abrupt completion.

**NOTE**

For ease of specification, private methods and accessors are included alongside private fields in the `[[PrivateElements]]` slot of class instances. However, any given object has either all or none of the private methods and accessors defined by a given class. This feature has been designed so that implementations may choose to implement private methods and accessors using a strategy which does not require tracking each method or accessor individually. For example, an implementation could directly associate instance private methods with their corresponding Private Name and track, for each object, which class constructors have run with that object as their `this` value. Looking up an instance private method on an object then consists of checking that the class constructor which defines the method has been used to initialize the object, then returning the method associated with the Private Name.

This differs from private fields: because field initializers can throw during class instantiation, an individual object may have some proper subset of the private fields of a given class, and so private fields must in general be tracked individually.

It is defined piecewise over the following productions:

```
ClassTail : ClassHeritage opt { ClassBody opt }
```

1. Let `env` be the LexicalEnvironment of the running execution context.
2. Let `classEnv` be `NewDeclarativeEnvironment(env)`.
3. If `classBinding` is not `undefined`, then
   a. Perform `classEnv.CreateImmutableBinding(classBinding, true)`.
4. Let `outerPrivateEnvironment` be the running execution context's PrivateEnvironment.
5. Let `classPrivateEnvironment` be `NewPrivateEnvironment(outerPrivateEnvironment)`.
6. If `ClassBody` is present, then
   a. For each String `dn` of the `PrivateBoundIdentifiers` of `ClassBody`, do
      i. If `classPrivateEnvironment.\[\[Names\]\]` contains a Private Name `pn` such that `pn.\[\[Description\]\]` is `dn`, then
         1. **Assert**: This is only possible for getter/setter pairs.
      ii. Else,
         1. Let `name` be a new Private Name whose `\[\[Description\]\]` is `dn`.
         2. Append `name` to `classPrivateEnvironment.\[\[Names\]\]`.
7. If `ClassHeritage` is not present, then
   a. Let `protoParent` be `%Object.prototype%`.
   b. Let `constructorParent` be `%Function.prototype%`.
8. Else,
   a. Set the running execution context's LexicalEnvironment to `classEnv`.
   b. **NOTE**: The running execution context's PrivateEnvironment is `outerPrivateEnvironment` when evaluating `ClassHeritage`.
   c. Let `superclassRef` be `Completion(Evaluation of ClassHeritage)`.
   d. Set the running execution context's LexicalEnvironment to `env`.
   e. Let `superclass` be `? GetValue(\? superclassRef)`.
   f. If `superclass` is `null`, then
      i. Let `protoParent` be `null`.
      ii. Let `constructorParent` be `%Function.prototype%`.
g. Else if IsConstructor(superclass) is false, then
   i. Throw a TypeError exception.

h. Else,
   i. Let protoParent be ? Get(superclass, "prototype").
   ii. If protoParent is not an Object and protoParent is not null, throw a TypeError exception.
   iii. Let constructorParent be superclass.

9. Let proto be OrdinaryObjectCreate(protoParent).

10. If ClassBody is not present, let constructor be EMPTY.
11. Else, let constructor be ConstructorMethod of ClassBody.

12. Set the running execution context's LexicalEnvironment to classEnv.
13. Set the running execution context's PrivateEnvironment to classPrivateEnvironment.
14. If constructor is EMPTY, then
   a. Let defaultConstructor be a new Abstract Closure with no parameters that captures nothing and performs the following steps when called:
      i. Let args be the List of arguments that was passed to this function by [[Call]] or [[Construct]].
      ii. If NewTarget is undefined, throw a TypeError exception.
      iii. Let F be the active function object.
      iv. If F.[[ConstructorKind]] is DERIVED, then
          1. NOTE: This branch behaves similarly to constructor(...args) { super(...args); }. The most notable distinction is that while the aforementioned ECMAScript source text observably calls the @@iterator method on %Array.prototype%, this function does not.
          2. Let func be ! F.[[GetPrototypeOf]]().
          3. If IsConstructor(func) is false, throw a TypeError exception.
          v. Else, 
             1. NOTE: This branch behaves similarly to constructor() {}.
             2. Let result be ? OrdinaryCreateFromConstructor(NewTarget, "%Object.prototype").
             vii. Return result.
    b. Let F be CreateBuiltInFunction(defaultConstructor, 0, className, « [[ConstructorKind]], [[SourceText]] », the current Realm Record, constructorParent).

15. Else,
    a. Let constructorInfo be ! DefineMethod of constructor with arguments proto and constructorParent.
    b. Let F be constructorInfo.[[Closure]].
    c. Perform MakeClassConstructor(F).
    d. Perform SetFunctionName(F, className).

16. Perform MakeConstructor(F, false, proto).
17. If ClassHeritage is present, set F.[[ConstructorKind]] to DERIVED.
19. If ClassBody is not present, let elements be a new empty List.
20. Else, let elements be NonConstructorElements of ClassBody.
21. Let instancePrivateMethods be a new empty List.
22. Let staticPrivateMethods be a new empty List.
23. Let instanceFields be a new empty List.
24. Let staticElements be a new empty List.
25. For each ClassElement e of elements, do
   a. If IsStatic of e is false, then
      i. Let element be Completion(ClassElementEvaluation of e with argument proto).
   b. Else,
      i. Let element be Completion(ClassElementEvaluation of e with argument F).
   c. If element is an abrupt completion, then
      i. Set the running execution context's LexicalEnvironment to env.
      ii. Set the running execution context's PrivateEnvironment to outerPrivateEnvironment.
      iii. Return ? element.
   d. Set element to ! element.
   e. If element is a PrivateElement, then
      i. Assert: element.[[Kind]] is either METHOD or ACCESSOR.
      ii. If IsStatic of e is false, let container be instancePrivateMethods.
      iii. Else, let container be staticPrivateMethods.
      iv. If container contains a PrivateElement pe such that pe.[[Key]] is element.[[Key]], then
1. Assert: `element`.[[Kind]] and `pe`.[[Kind]] are both ACCESSOR.

2. If `element`.[[Get]] is undefined, then
   a. Let `combined` be `PrivateElement` { `element`.[[Key]], `element`.[[Kind]]: ACCESSOR, `[Get]`:
      `pe`.[[Get]], `[Set]`: `element`.[[Set]]).

3. Else,
   a. Let `combined` be `PrivateElement` { `element`.[[Key]], `element`.[[Kind]]: ACCESSOR, `[Get]`:
      `element`.[[Get]], `[Set]`: `pe`.[[Set]]).

4. Replace `pe` in `container` with `combined`.

   v. Else,
   1. Append `element` to `container`.
   f. Else if `element` is a `ClassFieldDefinitionRecord`, then
      i. If `IsStatic` of `e` is false, append `element` to `instanceFields`.
      ii. Else, append `element` to `staticElements`.
   g. Else if `element` is a `ClassStaticBlockDefinitionRecord`, then
      i. Append `element` to `staticElements`.

26. Set the running execution context's LexicalEnvironment to `env`.

27. If `classBinding` is not undefined, then
   a. Perform `!classEnv.InitailzeBinding(classBinding, F)`.


29. Set `F`.[[Fields]] to `instanceFields`.

30. For each `PrivateElement` of `staticPrivateMethods`, do
    a. Perform `!PrivateMethodOrAccessorAdd(F, method)`.

31. For each `elementRecord` of `staticElements`, do
    a. If `elementRecord` is a `ClassFieldDefinitionRecord`, then
       i. Let `result` be `Completion(DefineField(F, elementRecord))`.
    b. Else,
       i. Assert `elementRecord` is a `ClassStaticBlockDefinitionRecord`.
       ii. Let `result` be `Completion(Call(elementRecord.[[BodyFunction]], F))`.
    c. If `result` is an abrupt completion, then
       i. Set the running execution context's PrivateEnvironment to `outerPrivateEnvironment`.
       ii. Return `result`.

32. Set the running execution context's PrivateEnvironment to `outerPrivateEnvironment`.

33. Return `F`.

15.7.15 Runtime Semantics: BindingClassDeclarationEvaluation

The syntax-directed operation `BindingClassDeclarationEvaluation` takes no arguments and returns either a normal completion containing a function object or an abrupt completion. It is defined piecewise over the following productions:

```
ClassDeclaration : class BindingIdentifier ClassTail
```

1. Let `className` be `StringValue` of `BindingIdentifier`.
2. Let `value` be `?ClassDefinitionEvaluation` of `ClassTail` with arguments `className` and `className`.
3. Set `value.[[SourceText]]` to the source text matched by `ClassDeclaration`.
4. Let `env` be the running execution context's LexicalEnvironment.
5. Perform `!InitializeBoundName(className, value, env)`.
6. Return `value`.

```
ClassDeclaration : class ClassTail
```

1. Let `value` be `?ClassDefinitionEvaluation` of `ClassTail` with arguments `undefined` and "default".
2. Set `value.[[SourceText]]` to the source text matched by `ClassDeclaration`.
3. Return `value`.

NOTE ClassDeclaration : class ClassTail only occurs as part of an ExportDeclaration and establishing its binding is handled as part of the evaluation action for that production. See 16.2.3.7.
15.7.16 Runtime Semantics: Evaluation

ClassDeclaration : class BindingIdentifier ClassTail

1. Perform ? BindingClassDeclarationEvaluation of this ClassDeclaration.
2. Return EMPTY.

NOTE ClassDeclaration : class ClassTail only occurs as part of an ExportDeclaration and is never directly evaluated.

ClassExpression : class ClassTail

1. Let value be ? ClassDefinitionEvaluation of ClassTail with arguments undefined and "".
2. Set value.[[SourceText]] to the source text matched by ClassExpression.
3. Return value.

ClassExpression : class BindingIdentifier ClassTail

1. Let className be StringValue of BindingIdentifier.
2. Let value be ? ClassDefinitionEvaluation of ClassTail with arguments className and className.
3. Set value.[[SourceText]] to the source text matched by ClassExpression.
4. Return value.

ClassElementName : PrivateIdentifier

1. Let privateIdentifier be StringValue of PrivateIdentifier.
2. Let privateEnvRec be the running execution context's PrivateEnvironment.
3. Let names be privateEnvRec.[[Names]].
4. Assert: Exactly one element of names is a Private Name whose [[Description]] is privateIdentifier.
5. Let privateName be the Private Name in names whose [[Description]] is privateIdentifier.
6. Return privateName.

ClassStaticBlockStatementList : [empty]

1. Return undefined.

15.8 Async Function Definitions

Syntax

AsyncFunctionDeclaration[Yield, Await, Default] :

AsyncFunctionDeclaration[+Default] :

AsyncFunctionExpression :

AsyncMethod[Yield, Await] :

AsyncFunctionBody :
  FunctionBody[~Yield, +Await]
AwaitExpression: \[\text{Yield}\] :
\[\text{await}\ \text{UnaryExpression}[^{?\text{Yield}, +\text{Await}}]\]

**NOTE 1**

*await* is parsed as a *keyword* of an *AwaitExpression* when the [*Await*] parameter is present. The [*Await*] parameter is present in the top level of the following contexts, although the parameter may be absent in some contexts depending on the nonterminals, such as *FunctionBody*:

- In an *AsyncFunctionBody*.
- In the *FormalParameters* of an *AsyncFunctionDeclaration*, *AsyncFunctionExpression*, *AsyncGeneratorDeclaration*, or *AsyncGeneratorExpression*. *AwaitExpression* in this position is a Syntax error via static semantics.
- In a *Module*.

When *Script* is the syntactic *goal symbol*, *await* may be parsed as an identifier when the [*Await*] parameter is absent. This includes the following contexts:

- Anywhere outside of an *AsyncFunctionBody* or *FormalParameters* of an *AsyncFunctionDeclaration*, *AsyncFunctionExpression*, *AsyncGeneratorDeclaration*, or *AsyncGeneratorExpression*.
- In the *BindingIdentifier* of a *FunctionExpression*, *GeneratorExpression*, or *AsyncGeneratorExpression*.

**NOTE 2**

Unlike *YieldExpression*, it is a Syntax Error to omit the operand of an *AwaitExpression*. You must await something.

### 15.8.1 Static Semantics: Early Errors

**AsyncMethod** :
\[\text{async}\ \text{ClassElementName}\ (\ \text{UniqueFormalParameters}\ )\ \{\ \text{AsyncFunctionBody}\ \}\]

- It is a Syntax Error if *FunctionBodyContainsUseStrict* of *AsyncFunctionBody* is *true* and *IsSimpleParameterList* of *UniqueFormalParameters* is *false*.
- It is a Syntax Error if *HasDirectSuper* of *AsyncMethod* is *true*.
- It is a Syntax Error if *UniqueFormalParameters* contain *AwaitExpression* is *true*.
- It is a Syntax Error if any element of the *BoundNames* of *UniqueFormalParameters* also occurs in the *LexicallyDeclaredNames* of *AsyncFunctionBody*.

**AsyncFunctionDeclaration** :

\[\text{async}\ \text{function}\ BindingIdentifier\ (\ \text{FormalParameters}\ )\ \{\ \text{AsyncFunctionBody}\ \}\]

**AsyncFunctionExpression** :

\[\text{async}\ \text{function}\ BindingIdentifier_{\text{opt}}\ (\ \text{FormalParameters}\ )\ \{\ \text{AsyncFunctionBody}\ \}\]

- It is a Syntax Error if *FunctionBodyContainsUseStrict* of *AsyncFunctionBody* is *true* and *IsSimpleParameterList* of *FormalParameters* is *false*.
- It is a Syntax Error if *FormalParameters* contain *AwaitExpression* is *true*.
- If the source text matched by *FormalParameters* is strict mode code, the Early Error rules for *UniqueFormalParameters*: *FormalParameters* are applied.
- If *BindingIdentifier* is present and the source text matched by *BindingIdentifier* is strict mode code, it is a Syntax Error if the *StringValue* of *BindingIdentifier* is either "eval" or "arguments".
- It is a Syntax Error if any element of the *BoundNames* of *FormalParameters* also occurs in the *LexicallyDeclaredNames* of *AsyncFunctionBody*.
- It is a Syntax Error if *FormalParameters* contain *SuperProperty* is *true*.
- It is a Syntax Error if *AsyncFunctionBody* contains *SuperProperty* is *true*.
- It is a Syntax Error if *FormalParameters* contain *SuperCall* is *true*.
- It is a Syntax Error if *AsyncFunctionBody* contains *SuperCall* is *true*. 
15.8.2 Runtime Semantics: InstantiateAsyncFunctionObject

The syntax-directed operation `InstantiateAsyncFunctionObject` takes arguments `env` (an Environment Record) and `privateEnv` (a PrivateEnvironment Record or null) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```plaintext
AsyncFunctionDeclaration : async function BindingIdentifier ( FormalParameters ) {
  AsyncFunctionBody }

1. Let `name` be `StringValue` of `BindingIdentifier`.
2. Let `sourceText` be the source text matched by `AsyncFunctionDeclaration`.
3. Let `F` be `OrdinaryFunctionCreate`(%AsyncFunction.prototype%, `sourceText`, `FormalParameters`, `AsyncFunctionBody`, NON-LEXICAL-THIS, `env`, `privateEnv`).
4. Perform `SetFunctionName`(F, `name`).
5. Return `F`.
```

```plaintext
AsyncFunctionDeclaration : async function ( FormalParameters ) {
  AsyncFunctionBody }
```

1. Let `sourceText` be the source text matched by `AsyncFunctionDeclaration`.
2. Let `F` be `OrdinaryFunctionCreate`(%AsyncFunction.prototype%, `sourceText`, `FormalParameters`, `AsyncFunctionBody`, NON-LEXICAL-THIS, `env`, `privateEnv`).
3. Perform `SetFunctionName`(F, "default").
4. Return `F`.

15.8.3 Runtime Semantics: InstantiateAsyncFunctionExpression

The syntax-directed operation `InstantiateAsyncFunctionExpression` takes optional argument `name` (a property key or a Private Name) and returns an ECMAScript function object. It is defined piecewise over the following productions:

```plaintext
AsyncFunctionExpression : async function ( FormalParameters ) {
  AsyncFunctionBody }
```

1. If `name` is not present, set `name` to "".
2. Let `env` be the LexicalEnvironment of the running execution context.
3. Let `privateEnv` be the running execution context's PrivateEnvironment.
4. Let `sourceText` be the source text matched by `AsyncFunctionExpression`.
5. Let `closure` be `OrdinaryFunctionCreate`(%AsyncFunction.prototype%, `sourceText`, `FormalParameters`, `AsyncFunctionBody`, NON-LEXICAL-THIS, `env`, `privateEnv`).
6. Perform `SetFunctionName`(closure, `name`).
7. Return `closure`.

```plaintext
AsyncFunctionExpression : async function BindingIdentifier ( FormalParameters ) {
  AsyncFunctionBody }
```

1. Assert: `name` is not present.
2. Set `name` to `StringValue` of `BindingIdentifier`.
3. Let `outerEnv` be the LexicalEnvironment of the running execution context.
4. Let `funcEnv` be `NewDeclarativeEnvironment`(outerEnv).
5. Perform `funcEnv.CreateImmutableBinding`(`name`, false).
6. Let `privateEnv` be the running execution context's PrivateEnvironment.
7. Let `sourceText` be the source text matched by `AsyncFunctionExpression`.
8. Let `closure` be `OrdinaryFunctionCreate`(%AsyncFunction.prototype%, `sourceText`, `FormalParameters`, `AsyncFunctionBody`, NON-LEXICAL-THIS, `funcEnv`, `privateEnv`).
9. Perform `SetFunctionName`(closure, `name`).
10. Perform `funcEnv.InitializeBinding`(`name`, closure).

**NOTE**

The `BindingIdentifier` in an `AsyncFunctionExpression` can be referenced from inside the `AsyncFunctionExpression`'s `AsyncFunctionBody` to allow the function to call itself recursively. However, unlike in a `FunctionDeclaration`, the `BindingIdentifier` in a `AsyncFunctionExpression` cannot be referenced from and does not affect the scope enclosing the `AsyncFunctionExpression`.
15.8.4 Runtime Semantics: EvaluateAsyncFunctionBody

The syntax-directed operation EvaluateAsyncFunctionBody takes arguments functionObject (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns a return completion. It is defined piecewise over the following productions:

\[
\text{AsyncFunctionBody} : \text{FunctionBody}
\]

1. Let promiseCapability be ! NewPromiseCapability(%Promise%).
2. Let declResult be Completion(FunctionDeclarationInstantiation(functionObject, argumentsList)).
3. If declResult is an abrupt completion, then
   a. Perform ! Call(promiseCapability.[[Reject]], undefined, « declResult.[[Value]] »).
5. Return Completion Record { [[Type]]: RETURN, [[Value]]: promiseCapability.[[Promise]], [[Target]]: EMPTY }.

15.8.5 Runtime Semantics: Evaluation

AsyncFunctionExpression :

\[
\text{async } \text{BindingIdentifieropt ( FormalParameters )} \{ \text{AsyncFunctionBody} \}
\]


AwaitExpression : await UnaryExpression

1. Let exprRef be ? Evaluation of UnaryExpression.
2. Let value be ? GetValue(exprRef).

15.9 Async Arrow Function Definitions

Syntax

AsyncArrowFunction\[ In, Yield, Await \] :

\[
\text{async } \{ \text{no LineTerminator here} \} \text{AsyncArrowBindingIdentifier[?Yield] [no LineTerminator here]} \Rightarrow \text{AsyncConciseBody[?In]}
\]

CoverCallExpressionAndAsyncArrowHead[?Yield, ?Await] [no LineTerminator here] => AsyncConciseBody[?In]

AsyncConciseBody[In] :

\[
[\text{lookahead } \neq \{ \} ] \text{ExpressionBody[?In, +Await]}\]
\{ AsyncFunctionBody \}

AsyncArrowBindingIdentifier[Yield] :

\[
\text{BindingIdentifier[?Yield, +Await]}
\]

CoverCallExpressionAndAsyncArrowHead[Yield, Await] :

\[
\text{MemberExpression[?Yield, ?Await] Arguments[?Yield, ?Await]}
\]

Supplemental Syntax

When processing an instance of the production

\[
\text{AsyncArrowFunction : CoverCallExpressionAndAsyncArrowHead } \Rightarrow \text{AsyncConciseBody}
\]

the interpretation of CoverCallExpressionAndAsyncArrowHead is refined using the following grammar:

AsyncArrowHead :

\[
\text{async } \{ \text{no LineTerminator here} \} \text{ArrowFormalParameters[~Yield, +Await]}
\]
15.9.1 Static Semantics: Early Errors

AsyncArrowFunction : async AsyncArrowBindingIdentifier => AsyncConciseBody

• It is a Syntax Error if any element of the BoundNames of AsyncArrowBindingIdentifier also occurs in the LexicallyDeclaredNames of AsyncConciseBody.

AsyncArrowFunction : CoverCallExpressionAndAsyncArrowHead => AsyncConciseBody

• CoverCallExpressionAndAsyncArrowHead must cover an AsyncArrowHead.
• It is a Syntax Error if CoverCallExpressionAndAsyncArrowHead Contains YieldExpression is true.
• It is a Syntax Error if CoverCallExpressionAndAsyncArrowHead Contains AwaitExpression is true.
• It is a Syntax Error if any element of the BoundNames of CoverCallExpressionAndAsyncArrowHead also occurs in the LexicallyDeclaredNames of AsyncConciseBody.
• It is a Syntax Error if AsyncConciseBodyContainsUseStrict of AsyncConciseBody is true and IsSimpleParameterList of CoverCallExpressionAndAsyncArrowHead is false.

15.9.2 Static Semantics: AsyncConciseBodyContainsUseStrict

The syntax-directed operation AsyncConciseBodyContainsUseStrict takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

AsyncConciseBody : ExpressionBody
1. Return false.

AsyncConciseBody : { AsyncFunctionBody }

15.9.3 Runtime Semantics: EvaluateAsyncConciseBody

The syntax-directed operation EvaluateAsyncConciseBody takes arguments functionObject (an ECMAScript function object) and argumentsList (a List of ECMAScript language values) and returns a return completion. It is defined piecewise over the following productions:

AsyncConciseBody : ExpressionBody
1. Let promiseCapability be ! NewPromiseCapability(%Promise%).
2. Let declResult be Completion(FunctionDeclarationInstantiation(functionObject, argumentsList)).
3. If declResult is an abrupt completion, then
   a. Perform ! Call(promiseCapability, [[Reject]], undefined, « declResult. [[Value]] »).
4. Else,
5. Return Completion Record { [[Type]]: RETURN, [[Value]]: promiseCapability. [[Promise]], [[Target]]: EMPTY }.

15.9.4 Runtime Semantics: InstantiateAsyncArrowFunctionExpression

The syntax-directed operation InstantiateAsyncArrowFunctionExpression takes optional argument name (a property key or a Private Name) and returns an ECMAScript function object. It is defined piecewise over the following productions:

AsyncArrowFunction : async AsyncArrowBindingIdentifier => AsyncConciseBody
1. If name is not present, set name to "".
2. Let env be the LexicalEnvironment of the running execution context.
3. Let privateEnv be the running execution context’s PrivateEnvironment.
4. Let sourceText be the source text matched by AsyncArrowFunction.
5. Let parameters be AsyncArrowBindingIdentifier.
7. Perform SetFunctionName(closure, name).
AsyncArrowFunction: CoverCallExpressionAndAsyncArrowHead => AsyncConciseBody

1. If `name` is not present, set `name` to "".
2. Let `env` be the LexicalEnvironment of the running execution context.
3. Let `privateEnv` be the running execution context's PrivateEnvironment.
4. Let `sourceText` be the source text matched by `AsyncArrowFunction`.
5. Let `head` be the `AsyncArrowHead` that is covered by CoverCallExpressionAndAsyncArrowHead.
6. Let `parameters` be the ArrowFormalParameters of `head`.
7. Let `closure` be OrdinaryFunctionCreate(%AsyncFunction.prototype%, `sourceText`, `parameters`, AsyncConciseBody, LEXICAL-THIS, `env`, `privateEnv`).
8. Perform SetFunctionName(`closure`, `name`).

15.9.5 Runtime Semantics: Evaluation

AsyncArrowFunction:

```javascript
async AsyncArrowBindingIdentifier => AsyncConciseBody
CoverCallExpressionAndAsyncArrowHead => AsyncConciseBody
```


15.10 Tail Position Calls

15.10.1 Static Semantics: IsInTailPosition (call)

The abstract operation IsInTailPosition takes argument `call` (a CallExpression Parse Node, a MemberExpression Parse Node, or an OptionalChain Parse Node) and returns a Boolean. It performs the following steps when called:

1. If the source text matched by `call` is non-strict code, return false.
2. If `call` is not contained within a FunctionBody, a ConciseBody, or an AsyncConciseBody, return false.
3. Let `body` be the FunctionBody, ConciseBody, or AsyncConciseBody that most closely contains `call`.
4. If `body` is the FunctionBody of a GeneratorBody, return false.
5. If `body` is the FunctionBody of an AsyncFunctionBody, return false.
6. If `body` is the FunctionBody of an AsyncGeneratorBody, return false.
7. If `body` is an AsyncConciseBody, return false.
8. Return the result of HasCallInTailPosition of `body` with argument `call`.

**NOTE** Tail Position calls are only defined in strict mode code because of a common non-standard language extension (see 10.2.4) that enables observation of the chain of caller contexts.

15.10.2 Static Semantics: HasCallInTailPosition

The syntax-directed operation HasCallInTailPosition takes argument `call` (a CallExpression Parse Node, a MemberExpression Parse Node, or an OptionalChain Parse Node) and returns a Boolean.

**NOTE 1** `call` is a Parse Node that represents a specific range of source text. When the following algorithms compare `call` to another Parse Node, it is a test of whether they represent the same source text.

**NOTE 2** A potential tail position call that is immediately followed by return GetValue of the call result is also a possible tail position call. A function call cannot return a Reference Record, so such a GetValue operation will always return the same value as the actual function call result.
It is defined piecewise over the following productions:

StatementList : StatementList StatementListItem

1. Let has be HasCallInTailPosition of StatementList with argument call.
2. If has is true, return true.
3. Return HasCallInTailPosition of StatementListItem with argument call.

FunctionStatementList :
[empty]
StatementListItem :
Declaration
Statement :
VariableStatement
EmptyStatement
ExpressionStatement
ContinueStatement
BreakStatement
ThrowStatement
DebuggerStatement
Block :
{ }
ReturnStatement :
return ;
LabelledItem :
FunctionDeclaration
ForInOfStatement :
for ( LeftHandSideExpression of AssignmentExpression ) Statement
for ( var ForBinding of AssignmentExpression ) Statement
for ( ForDeclaration of AssignmentExpression ) Statement
CaseBlock :
{ }
1. Return false.

IfStatement : if ( Expression ) Statement else Statement

1. Let has be HasCallInTailPosition of the first Statement with argument call.
2. If has is true, return true.
3. Return HasCallInTailPosition of the second Statement with argument call.

IfStatement :
if ( Expression ) Statement
DoWhileStatement :
do Statement while ( Expression ) ;
WhileStatement :
while ( Expression ) Statement
ForStatement :
for ( Expressionopt ; Expressionopt ; Expressionopt ) Statement
for ( var VariableDeclarationList ; Expressionopt ; Expressionopt ) Statement
for ( LexicalDeclaration Expressionopt ; Expressionopt ) Statement
ForInOfStatement :
for ( LeftHandSideExpression in Expression ) Statement
for ( var ForBinding in Expression ) Statement
for ( ForDeclaration in Expression ) Statement
WithStatement:
    with (Expression) Statement

1. Return HasCallInTailPosition of Statement with argument call.

LabelledStatement:
    LabelIdentifier : LabelledItem

1. Return HasCallInTailPosition of LabelledItem with argument call.

ReturnStatement: return Expression;

1. Return HasCallInTailPosition of Expression with argument call.

SwitchStatement: switch (Expression) CaseBlock

1. Return HasCallInTailPosition of CaseBlock with argument call.

CaseBlock: { CaseClausesopt DefaultClause CaseClausesopt }

1. Let has be false.
2. If the first CaseClauses is present, set has to HasCallInTailPosition of the first CaseClauses with argument call.
3. If has is true, return true.
4. Set has to HasCallInTailPosition of DefaultClause with argument call.
5. If has is true, return true.
6. If the second CaseClauses is present, set has to HasCallInTailPosition of the second CaseClauses with argument call.
7. Return has.

CaseClauses: CaseClauses CaseClause

1. Let has be HasCallInTailPosition of CaseClauses with argument call.
2. If has is true, return true.
3. Return HasCallInTailPosition of CaseClause with argument call.

CaseClause: case Expression : StatementListopt
DefaultClause: default : StatementListopt

1. If StatementList is present, return HasCallInTailPosition of StatementList with argument call.
2. Return false.

TryStatement: try Block Catch

1. Return HasCallInTailPosition of Catch with argument call.

TryStatement:
    try Block Finally
    try Block Catch Finally

1. Return HasCallInTailPosition of Finally with argument call.

Catch: catch (CatchParameter) Block

1. Return HasCallInTailPosition of Block with argument call.
AssignmentExpression :
    YieldExpression
    ArrowFunction
    AsyncArrowFunction
    LeftHandSideExpression = AssignmentExpression
    LeftHandSideExpression AssignmentOperator AssignmentExpression
    LeftHandSideExpression &-= AssignmentExpression
    LeftHandSideExpression ||= AssignmentExpression
    LeftHandSideExpression ??= AssignmentExpression

BitwiseANDExpression :
    BitwiseANDExpression & EqualityExpression

BitwiseXORExpression :
    BitwiseXORExpression ^ BitwiseANDExpression

BitwiseORExpression :
    BitwiseORExpression | BitwiseXORExpression

EqualityExpression :
    EqualityExpression == RelationalExpression
    EqualityExpression != RelationalExpression
    EqualityExpression === RelationalExpression
    EqualityExpression !== RelationalExpression

RelationalExpression :
    RelationalExpression < ShiftExpression
    RelationalExpression > ShiftExpression
    RelationalExpression <= ShiftExpression
    RelationalExpression >= ShiftExpression
    RelationalExpression instanceof ShiftExpression
    RelationalExpression in ShiftExpression

PrivateIdentifier in ShiftExpression

ShiftExpression :
    ShiftExpression << AdditiveExpression
    ShiftExpression >> AdditiveExpression
    ShiftExpression >>> AdditiveExpression

AdditiveExpression :
    AdditiveExpression + MultiplicativeExpression
    AdditiveExpression - MultiplicativeExpression

MultiplicativeExpression :
    MultiplicativeExpression MultiplicativeOperator ExponentiationExpression

ExponentiationExpression :
    UpdateExpression ** ExponentiationExpression

UpdateExpression :
    LeftHandSideExpression ++
    LeftHandSideExpression --
    ++ UnaryExpression
    -- UnaryExpression

UnaryExpression :
    delete UnaryExpression
    void UnaryExpression
typeof UnaryExpression
    + UnaryExpression
    - UnaryExpression
    ~ UnaryExpression
    ! UnaryExpression
    AwaitExpression
1. Return `false`.

Expression:

1. Return `HasCallInTailPosition` of `AssignmentExpression` with argument `call`.

ConditionalExpression:

1. Let `has` be `HasCallInTailPosition` of the first `AssignmentExpression` with argument `call`.
2. If `has` is `true`, return `true`.
3. Return `HasCallInTailPosition` of the second `AssignmentExpression` with argument `call`.

LogicalANDExpression:

1. Return `HasCallInTailPosition` of `BitwiseORExpression` with argument `call`.

LogicalORExpression:

1. Return `HasCallInTailPosition` of `LogicalANDExpression` with argument `call`.

CoalesceExpression:

1. Return `HasCallInTailPosition` of `BitwiseORExpression` with argument `call`.
CallExpression:
  CoverCallExpressionAndAsyncArrowHead
  CallExpression Arguments
  CallExpression TemplateLiteral

1. If this CallExpression is call, return true.
2. Return false.

OptionalExpression:
  MemberExpression OptionalChain
  CallExpression OptionalChain
  OptionalExpression OptionalChain

1. Return HasCallInTailPosition of OptionalChain with argument call.

OptionalChain:
  ?. [ Expression ]
  ?. IdentifierName
  ?. PrivateIdentifier
  OptionalChain [ Expression ]
  OptionalChain . IdentifierName
  OptionalChain . PrivateIdentifier

1. Return false.

OptionalChain:
  ?. Arguments
  OptionalChain Arguments

1. If this OptionalChain is call, return true.
2. Return false.

MemberExpression:
  MemberExpression TemplateLiteral

1. If this MemberExpression is call, return true.
2. Return false.

PrimaryExpression: CoverParenthesizedExpressionAndArrowParameterList

1. Let expr be the ParenthesizedExpression that is covered by CoverParenthesizedExpressionAndArrowParameterList.
2. Return HasCallInTailPosition of expr with argument call.

ParenthesizedExpression:
  ( Expression )

1. Return HasCallInTailPosition of Expression with argument call.
15.10.3 PrepareForTailCall ( )

The abstract operation PrepareForTailCall takes no arguments and returns UNUSED. It performs the following steps when called:

1. **Assert**: The current execution context will not subsequently be used for the evaluation of any ECMAScript code or built-in functions. The invocation of Call subsequent to the invocation of this abstract operation will create and push a new execution context before performing any such evaluation.
2. Discard all resources associated with the current execution context.
3. Return UNUSED.

A tail position call must either release any transient internal resources associated with the currently executing function execution context before invoking the target function or reuse those resources in support of the target function.

**NOTE** For example, a tail position call should only grow an implementation's activation record stack by the amount that the size of the target function's activation record exceeds the size of the calling function's activation record. If the target function's activation record is smaller, then the total size of the stack should decrease.

16 ECMAScript Language: Scripts and Modules

16.1 Scripts

Syntax

\[
\text{Script} : \quad \text{ScriptBody}^{\text{opt}}
\]

\[
\text{ScriptBody} : \quad \text{StatementList}[^{\text{~Yield, ~Await, ~Return}}]
\]

16.1.1 Static Semantics: Early Errors

**Script** : **ScriptBody**

- It is a Syntax Error if the LexicallyDeclaredNames of ScriptBody contains any duplicate entries.
- It is a Syntax Error if any element of the LexicallyDeclaredNames of ScriptBody also occurs in the VarDeclaredNames of ScriptBody.

**ScriptBody** : **StatementList**

- It is a Syntax Error if StatementList Contains super unless the source text containing super is eval code that is being processed by a direct eval. Additional early error rules for super within direct eval are defined in 19.2.1.1.
- It is a Syntax Error if StatementList Contains NewTarget unless the source text containing NewTarget is eval code that is being processed by a direct eval. Additional early error rules for NewTarget in direct eval are defined in 19.2.1.1.
- It is a Syntax Error if ContainsDuplicateLabels of StatementList with argument « » is true.
- It is a Syntax Error if ContainsUndefinedBreakTarget of StatementList with argument « » is true.
- It is a Syntax Error if ContainsUndefinedContinueTarget of StatementList with arguments « » and « » is true.
- It is a Syntax Error if AllPrivateIdentifiersValid of StatementList with argument « » is false unless the source text containing ScriptBody is eval code that is being processed by a direct eval.
16.1.2 Static Semantics: IsStrict

The syntax-directed operation IsStrict takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

\[ \text{Script} : \text{ScriptBody}_{\text{opt}} \]

1. If ScriptBody is present and the Directive Prologue of ScriptBody contains a Use Strict Directive, return true; otherwise, return false.

16.1.3 Runtime Semantics: Evaluation

\[ \text{Script} : [\text{empty}] \]

1. Return undefined.

16.1.4 Script Records

A Script Record encapsulates information about a script being evaluated. Each script record contains the fields listed in Table 40.

Table 40: Script Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Realm]]</td>
<td>a Realm Record or undefined</td>
<td>The realm within which this script was created. undefined if not yet assigned.</td>
</tr>
<tr>
<td>[[ECMAScriptCode]]</td>
<td>a Script Parse Node</td>
<td>The result of parsing the source text of this script.</td>
</tr>
<tr>
<td>[[LoadedModules]]</td>
<td>a List of Records with fields</td>
<td>A map from the specifier strings imported by this script to the resolved Module Record. The list does not contain two different Records with the same [[Specifier]].</td>
</tr>
<tr>
<td></td>
<td>[[Specifier]] (a String) and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[[Module]] (a Module Record)</td>
<td></td>
</tr>
<tr>
<td>[[HostDefined]]</td>
<td>anything (default value is EMPTY)</td>
<td>Field reserved for use by host environments that need to associate additional information with a script.</td>
</tr>
</tbody>
</table>

16.1.5 ParseScript (sourceText, realm, hostDefined)

The abstract operation ParseScript takes arguments sourceText (ECMAScript source text), realm (a Realm Record or undefined), and hostDefined (anything) and returns a Script Record or a non-empty List of Syntax-Error objects. It creates a Script Record based upon the result of parsing sourceText as a Script. It performs the following steps when called:

1. Let script be ParseText(sourceText, Script).
2. If script is a List of errors, return script.

NOTE An implementation may parse script source text and analyse it for Early Error conditions prior to evaluation of ParseScript for that script source text. However, the reporting of any errors must be deferred until the point where this specification actually performs ParseScript upon that source text.
16.1.6 ScriptEvaluation (scriptRecord)

The abstract operation ScriptEvaluation takes argument scriptRecord (a Script Record) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. Let globalEnv be scriptRecord.[[Realm]].[[GlobalEnv]].
2. Let scriptContext be a new ECMAScript code execution context.
3. Set the Function of scriptContext to null.
4. Set the Realm of scriptContext to scriptRecord.[[Realm]].
5. Set the ScriptOrModule of scriptContext to scriptRecord.
6. Set the VariableEnvironment of scriptContext to globalEnv.
7. Set the LexicalEnvironment of scriptContext to globalEnv.
8. Set the PrivateEnvironment of scriptContext to null.
9. Suspend the running execution context.
10. Push scriptContext onto the execution context stack; scriptContext is now the running execution context.
11. Let script be scriptRecord.[[ECMAScriptCode]].
12. Let result be Completion(GlobalDeclarationInstantiation(script, globalEnv)).
13. If result is a normal completion, then
   a. Set result to Completion(Evaluation of script).
   b. If result is a normal completion and result.[[Value]] is EMPTY, then
      i. Set result to NormalCompletion(undefined).
14. Suspend scriptContext and remove it from the execution context stack.
15. Assert: The execution context stack is not empty.
16. Resume the context that is now on the top of the execution context stack as the running execution context.
17. Return ? result.

16.1.7 GlobalDeclarationInstantiation (script, env)

The abstract operation GlobalDeclarationInstantiation takes arguments script (a Script Parse Node) and env (a Global Environment Record) and returns either a normal completion containing UNUSED or a throw completion. script is the Script for which the execution context is being established. env is the global environment in which bindings are to be created.

NOTE 1 When an execution context is established for evaluating scripts, declarations are instantiated in the current global environment. Each global binding declared in the code is instantiated.

It performs the following steps when called:

1. Let lexNames be the LexicallyDeclaredNames of script.
2. Let varNames be the VarDeclaredNames of script.
3. For each element name of lexNames, do
   a. If env.HasVarDeclaration(name) is true, throw a SyntaxError exception.
   b. If env.HasLexicalDeclaration(name) is true, throw a SyntaxError exception.
   c. Let hasRestrictedGlobal be ? env.HasRestrictedGlobalProperty(name).
   d. If hasRestrictedGlobal is true, throw a SyntaxError exception.
4. For each element name of varNames, do
   a. If env.HasLexicalDeclaration(name) is true, throw a SyntaxError exception.
5. Let varDeclarations be the VarScopedDeclarations of script.
6. Let functionsToInitialize be a new empty List.
7. Let declaredFunctionNames be a new empty List.
8. For each element d of varDeclarations, in reverse List order, do
   a. If d is not either a VariableDeclaration, a ForBinding, or a BindingIdentifier, then
      i. Assert: d is either a FunctionDeclaration, a GeneratorDeclaration, an AsyncFunctionDeclaration, or an AsyncGeneratorDeclaration.
      ii. NOTE: If there are multiple function declarations for the same name, the last declaration is used.
      iii. Let fn be the sole element of the BoundNames of d.
      iv. If declaredFunctionNames does not contain fn, then
2. If `fnDefinable` is `false`, throw a `TypeError` exception.
3. Append `fn` to `declaredFunctionNames`.
4. Insert `d` as the first element of `functionsToInitialize`.

9. Let `declaredVarNames` be a new empty `List`.
10. For each element `d` of `varDeclarations`, do
    a. If `d` is either a `VariableDeclaration`, a `ForBinding`, or a `BindingIdentifier`, then
       i. For each String `vn` of the `BoundNames` of `d`, do
          1. If `declaredFunctionNames` does not contain `vn`, then
             a. Let `vnDefinable` be `false`.
             b. If `vnDefinable` is `false`, throw a `TypeError` exception.
          i. If `declaredVarNames` does not contain `vn`, then
             i. Append `vn` to `declaredVarNames`.

11. NOTE: No abnormal terminations occur after this algorithm step if the global object is an ordinary object. However, if the global object is a Proxy exotic object it may exhibit behaviours that cause abnormal terminations in some of the following steps.
12. NOTE: Annex B.3.2.2 adds additional steps at this point.
13. Let `lexDeclarations` be the `LexicallyScopedDeclarations` of `script`.
14. Let `privateEnv` be null.
15. For each element `d` of `lexDeclarations`, do
    a. NOTE: Lexically declared names are only instantiated here but not initialized.
    b. For each element `dn` of the `BoundNames` of `d`, do
       i. If `IsConstantDeclaration` of `d` is `true`, then
          1. Perform `env.CreateImmutableBinding(dn, true)`.
          ii. Else, 
              1. Perform `env.CreateMutableBinding(dn, false)`.
16. For each Parse Node `f` of `functionsToInitialize`, do
    a. Let `fn` be the sole element of the `BoundNames` of `f`.
    b. Let `fo` be `InstantiateFunctionObject` of `f` with arguments `env` and `privateEnv`.
17. For each String `vn` of `declaredVarNames`, do
18. Return UNUSED.

NOTE 2 Early errors specified in 16.1.1 prevent name conflicts between function/var declarations and let/const/class declarations as well as redeclaration of let/const/class bindings for declaration contained within a single `Script`. However, such conflicts and redeclarations that span more than one `Script` are detected as runtime errors during GlobalDeclarationInstantiation. If any such errors are detected, no bindings are instantiated for the script. However, if the global object is defined using Proxy exotic objects then the runtime tests for conflicting declarations may be unreliable resulting in an abrupt completion and some global declarations not being instantiated. If this occurs, the code for the `Script` is not evaluated.

Unlike explicit var or function declarations, properties that are directly created on the global object result in global bindings that may be shadowed by let/const/class declarations.

16.2 Modules

Syntax

```plaintext
Module : ModuleBodyopt

ModuleBody : ModuleItemList

ModuleItemList : ModuleItem ModuleItemList ModuleItem
```
ModuleItem:
  ImportDeclaration
  ExportDeclaration
  StatementListItem[^Yield, +Await, ~Return]

ModuleExportName:
  IdentifierName
  StringLiteral

16.2.1 Module Semantics

16.2.1.1 Static Semantics: Early Errors

ModuleBody: ModuleItemList

- It is a Syntax Error if the LexicallyDeclaredNames of ModuleItemList contains any duplicate entries.
- It is a Syntax Error if any element of the LexicallyDeclaredNames of ModuleItemList also occurs in the VarDeclaredNames of ModuleItemList.
- It is a Syntax Error if the ExportedNames of ModuleItemList contains any duplicate entries.
- It is a Syntax Error if any element of the ExportedBindings of ModuleItemList does not also occur in either the VarDeclaredNames of ModuleItemList, or the LexicallyDeclaredNames of ModuleItemList.
- It is a Syntax Error if ModuleItemList Contains super.
- It is a Syntax Error if ModuleItemList Contains NewTarget.
- It is a Syntax Error if ContainsDuplicateLabels of ModuleItemList with argument « » is true.
- It is a Syntax Error if ContainsUndefinedBreakTarget of ModuleItemList with argument « » is true.
- It is a Syntax Error if ContainsUndefinedContinueTarget of ModuleItemList with arguments « » and « » is true.
- It is a Syntax Error if AllPrivateIdentifiersValid of ModuleItemList with argument « » is false.

NOTE The duplicate ExportedNames rule implies that multiple export default ExportDeclaration items within a ModuleBody is a Syntax Error. Additional error conditions relating to conflicting or duplicate declarations are checked during module linking prior to evaluation of a Module. If any such errors are detected the Module is not evaluated.

ModuleExportName: StringLiteral

- It is a Syntax Error if IsStringWellFormedUnicode(the SV of StringLiteral) is false.

16.2.1.2 Static Semantics: ImportedLocalNames (importEntries)

The abstract operation ImportedLocalNames takes argument importEntries (a List of ImportEntry Records) and returns a List of Strings. It creates a List of all of the local name bindings defined by importEntries. It performs the following steps when called:

1. Let localNames be a new empty List.
2. For each ImportEntry Record i of importEntries, do
   a. Append i.[[LocalName]] to localNames.
3. Return localNames.

16.2.1.3 Static Semantics: ModuleRequests

The syntax-directed operation ModuleRequests takes no arguments and returns a List of Strings. It is defined piecewise over the following productions:

Module: [empty]

1. Return a new empty List.
ModuleItemList : ModuleItem

1. Return ModuleRequests of ModuleItem.

ModuleItemList : ModuleItemList ModuleItem

1. Let moduleNames be ModuleRequests of ModuleItemList.
2. Let additionalNames be ModuleRequests of ModuleItem.
3. For each String name of additionalNames, do
   a. If moduleNames does not contain name, then
      i. Append name to moduleNames.
4. Return moduleNames.

ModuleItem : StatementListItem

1. Return a new empty List.

ImportDeclaration : import ImportClause FromClause ;

1. Return ModuleRequests of FromClause.

ModuleSpecifier : StringLiteral

1. Return a List whose sole element is the SV of StringLiteral.

ExportDeclaration : export ExportFromClause FromClause ;

1. Return the ModuleRequests of FromClause.

ExportDeclaration :
   export NamedExports ;
   export VariableStatement
   export Declaration
   export default HoistableDeclaration
   export default ClassDeclaration
   export default AssignmentExpression ;

1. Return a new empty List.

16.2.1.4 Abstract Module Records

A Module Record encapsulates structural information about the imports and exports of a single module. This information is used to link the imports and exports of sets of connected modules. A Module Record includes four fields that are only used when evaluating a module.

For specification purposes Module Record values are values of the Record specification type and can be thought of as existing in a simple object-oriented hierarchy where Module Record is an abstract class with both abstract and concrete subclasses. This specification defines the abstract subclass named Cyclic Module Record and its concrete subclass named Source Text Module Record. Other specifications and implementations may define additional Module Record subclasses corresponding to alternative module definition facilities that they defined.

Module Record defines the fields listed in Table 41. All Module Definition subclasses include at least those fields. Module Record also defines the abstract method list in Table 42. All Module definition subclasses must provide concrete implementations of these abstract methods.
Table 41: Module Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Realm]]</td>
<td>a Realm Record</td>
<td>The Realm within which this module was created.</td>
</tr>
<tr>
<td>[[Environment]]</td>
<td>a Module Environment Record or EMPTY</td>
<td>The Environment Record containing the top level bindings for this module. This field is set when the module is linked.</td>
</tr>
<tr>
<td>[[Namespace]]</td>
<td>an Object or EMPTY</td>
<td>The Module Namespace Object (28.3) if one has been created for this module.</td>
</tr>
<tr>
<td>[[HostDefined]]</td>
<td>anything (default value is undefined)</td>
<td>Field reserved for use by host environments that need to associate additional information with a module.</td>
</tr>
</tbody>
</table>

Table 42: Abstract Methods of Module Records

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>LoadRequestedModules( [ hostDefined ] )</td>
<td>Prepares the module for linking by recursively loading all its dependencies, and returns a promise.</td>
</tr>
<tr>
<td>GetExportedNames([exportStarSet])</td>
<td>Return a list of all names that are either directly or indirectly exported from this module.</td>
</tr>
<tr>
<td></td>
<td>LoadRequestedModules must have completed successfully prior to invoking this method.</td>
</tr>
<tr>
<td>ResolveExport(exportName [, resolveSet])</td>
<td>Return the binding of a name exported by this module. Bindings are represented by a ResolvedBinding Record, of the form { [[Module]]: Module Record, [[BindingName]]: String</td>
</tr>
<tr>
<td></td>
<td>Each time this operation is called with a specific exportName, resolveSet pair as arguments it must return the same result.</td>
</tr>
<tr>
<td></td>
<td>LoadRequestedModules must have completed successfully prior to invoking this method.</td>
</tr>
<tr>
<td>Link()</td>
<td>Prepare the module for evaluation by transitively resolving all module dependencies and creating a Module Environment Record.</td>
</tr>
<tr>
<td></td>
<td>LoadRequestedModules must have completed successfully prior to invoking this method.</td>
</tr>
<tr>
<td>Evaluate()</td>
<td>Returns a promise for the evaluation of this module and its dependencies, resolving on successful evaluation or if it has already been evaluated successfully, and rejecting for an evaluation error or if it has already been evaluated unsuccessfully. If the promise is rejected, hosts are expected to handle the promise rejection and rethrow the evaluation error.</td>
</tr>
<tr>
<td></td>
<td>Link must have completed successfully prior to invoking this method.</td>
</tr>
</tbody>
</table>
### 16.2.1.5 Cyclic Module Records

A **Cyclic Module Record** is used to represent information about a module that can participate in dependency cycles with other modules that are subclasses of the **Cyclic Module Record** type. **Module Records** that are not subclasses of the **Cyclic Module Record** type must not participate in dependency cycles with **Source Text Module Records**.

In addition to the fields defined in Table 41 **Cyclic Module Records** have the additional fields listed in Table 43.

#### Table 43: Additional Fields of **Cyclic Module Records**

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Status]]</td>
<td>NEW, UNLINKED, LINKING, LINKED, EVALUATING, EVALUATING-ASYNC, or EVALUATED</td>
<td>Initially NEW. Transitions to UNLINKED, LINKING, LINKED, EVALUATING, possibly EVALUATING-ASYNC, EVALUATED (in that order) as the module progresses throughout its lifecycle. EVALUATING-ASYNC indicates this module is queued to execute on completion of its asynchronous dependencies or it is a module whose [[HasTLA]] field is true that has been executed and is pending top-level completion.</td>
</tr>
<tr>
<td>[[EvaluationError]]</td>
<td>a throw completion or EMPTY</td>
<td>A throw completion representing the exception that occurred during evaluation. undefined if no exception occurred or if [[Status]] is not EVALUATED.</td>
</tr>
<tr>
<td>[[DFSIndex]]</td>
<td>an integer or EMPTY</td>
<td>Auxiliary field used during Link and Evaluate only. If [[Status]] is either LINKING or EVALUATING, this non-negative number records the point at which the module was first visited during the depth-first traversal of the dependency graph.</td>
</tr>
<tr>
<td>[[DFSAncestorIndex]]</td>
<td>an integer or EMPTY</td>
<td>Auxiliary field used during Link and Evaluate only. If [[Status]] is either LINKING or EVALUATING, this is either the module’s own [[DFSIndex]] or that of an “earlier” module in the same strongly connected component.</td>
</tr>
<tr>
<td>[[RequestedModules]]</td>
<td>a List of Strings</td>
<td>A List of all the ModuleSpecifier strings used by the module represented by this record to request the importation of a module. The List is in source text occurrence order.</td>
</tr>
<tr>
<td>[[LoadedModules]]</td>
<td>a List of Records with fields [[Specifier]] (a String) and [[Module]] (a Module Record)</td>
<td>A map from the specifier strings used by the module represented by this record to request the importation of a module to the resolved Module Record. The list does not contain two different Records with the same [[Specifier]].</td>
</tr>
<tr>
<td>[[CycleRoot]]</td>
<td>a Cyclic Module Record or EMPTY</td>
<td>The first visited module of the cycle, the root DFS ancestor of the strongly connected component. For a module not in a cycle, this would be the module itself. Once Evaluate has completed, a module’s [[DFSAncestorIndex]] is the [[DFSIndex]] of its [[CycleRoot]].</td>
</tr>
</tbody>
</table>
Table 43: Additional Fields of Cyclic Module Records (continued)

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[HasTLA]]</td>
<td>a Boolean</td>
<td>Whether this module is individually asynchronous (for example, if it's a Source Text Module Record containing a top-level await). Having an asynchronous dependency does not mean this field is true. This field must not change after the module is parsed.</td>
</tr>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>a Boolean</td>
<td>Whether this module is either itself asynchronous or has an asynchronous dependency. Note: The order in which this field is set is used to order queued executions, see 16.2.1.5.3.4.</td>
</tr>
<tr>
<td>[[TopLevelCapability]]</td>
<td>a PromiseCapability Record or EMPTY</td>
<td>If this module is the [[CycleRoot]] of some cycle, and Evaluate() was called on some module in that cycle, this field contains the PromiseCapability Record for that entire evaluation. It is used to settle the Promise object that is returned from the Evaluate() abstract method. This field will be EMPTY for any dependencies of that module, unless a top-level Evaluate() has been initiated for some of those dependencies.</td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>a List of Cyclic Module Records</td>
<td>If this module or a dependency has [[HasTLA]] true, and execution is in progress, this tracks the parent importers of this module for the top-level execution job. These parent modules will not start executing before this module has successfully completed execution.</td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>an integer or EMPTY</td>
<td>If this module has any asynchronous dependencies, this tracks the number of asynchronous dependency modules remaining to execute for this module. A module with asynchronous dependencies will be executed when this field reaches 0 and there are no execution errors.</td>
</tr>
</tbody>
</table>

In addition to the methods defined in Table 42 Cyclic Module Records have the additional methods listed in Table 44

Table 44: Additional Abstract Methods of Cyclic Module Records

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>InitializeEnvironment()</td>
<td>Initialize the Environment Record of the module, including resolving all imported bindings, and create the module's execution context.</td>
</tr>
<tr>
<td>ExecuteModule( [promiseCapability ] )</td>
<td>Evaluate the module's code within its execution context. If this module has true in [[HasTLA]], then a PromiseCapability Record is passed as an argument, and the method is expected to resolve or reject the given capability. In this case, the method must not throw an exception, but instead reject the PromiseCapability Record if necessary.</td>
</tr>
</tbody>
</table>

A GraphLoadingState Record is a Record that contains information about the loading process of a module graph. It’s used to continue loading after a call to HostLoadImportedModule. Each GraphLoadingState Record has the fields defined in Table 45:
Table 45: **GraphLoadingState Record** Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[PromiseCapability]]</td>
<td>a PromiseCapability Record</td>
<td>The promise to resolve when the loading process finishes.</td>
</tr>
<tr>
<td>[[IsLoading]]</td>
<td>a Boolean</td>
<td>It is true if the loading process has not finished yet, neither successfully nor with an error.</td>
</tr>
<tr>
<td>[[PendingModulesCount]]</td>
<td>a non-negative integer</td>
<td>It tracks the number of pending HostLoadImportedModule calls.</td>
</tr>
<tr>
<td>[[Visited]]</td>
<td>a List of Cyclic Module Records</td>
<td>It is a list of the Cyclic Module Records that have been already loaded by the current loading process, to avoid infinite loops with circular dependencies.</td>
</tr>
<tr>
<td>[[HostDefined]]</td>
<td>anything (default value is EMPTY)</td>
<td>It contains host-defined data to pass from the LoadRequestedModules caller to HostLoadImportedModule.</td>
</tr>
</tbody>
</table>

16.2.1.5.1 **LoadRequestedModules** ( [ hostDefined ] )

The LoadRequestedModules concrete method of a Cyclic Module Record module takes optional argument hostDefined (anything) and returns a Promise. It populates the [[LoadedModules]] of all the Module Records in the dependency graph of module (most of the work is done by the auxiliary function InnerModuleLoading). It takes an optional hostDefined parameter that is passed to the HostLoadImportedModule hook. It performs the following steps when called:

1. If hostDefined is not present, let hostDefined be EMPTY.
2. Let pc be ! NewPromiseCapability(%Promise%).
3. Let state be the GraphLoadingState Record { [[IsLoading]]: true, [[PendingModulesCount]]: 1, [[Visited]]: « », [[PromiseCapability]]: pc, [[HostDefined]]: hostDefined }.
4. Perform InnerModuleLoading(state, module).
5. Return pc.\[Promise].

**NOTE** The hostDefined parameter can be used to pass additional information necessary to fetch the imported modules. It is used, for example, by HTML to set the correct fetch destination for <link rel="preload" as="..."> tags. import() expressions never set the hostDefined parameter.

16.2.1.5.1.1 **InnerModuleLoading** ( state, module )

The abstract operation InnerModuleLoading takes arguments state (a GraphLoadingStateRecord) and module (a ModuleRecord) and returns UNUSED. It is used by LoadRequestedModules to recursively perform the actual loading process for module's dependency graph. It performs the following steps when called:

1. Assert: state.\[[IsLoading]] is true.
2. If module is a Cyclic Module Record, module.\[[Status]] is NEW, and state.\[[Visited]] does not contain module, then
   a. Append module to state.\[[Visited]].
   b. Let requestedModulesCount be the number of elements in module.\[[RequestedModules]].
   c. Set state.\[[PendingModulesCount]] to state.\[[PendingModulesCount]] + requestedModulesCount.
   d. For each String required of module.\[[RequestedModules]], do
      i. If module.\[[LoadedModules]] contains a Record whose \[[Specifier]] is required, then
         1. Let record be that Record.
         2. Perform InnerModuleLoading(state, record.\[[Module]])..
      ii. Else,
1. Perform `HostLoadImportedModule(module, required, state.[[HostDefined]], state).
2. NOTE: `HostLoadImportedModule` will call `FinishLoadingImportedModule`, which re-enters the graph loading process through `ContinueModuleLoading`.
   iii. If `state.[[IsLoading]]` is `false`, return UNUSED.
3. Assert: `state.[[PendingModulesCount]]` ≥ 1.
4. Set `state.[[PendingModulesCount]]` to `state.[[PendingModulesCount]]` - 1.
5. If `state.[[PendingModulesCount]]` = 0, then
   a. Set `state.[[IsLoading]]` to `false`.
   b. For each Cyclic Module Record `loaded` of `state.[[Visited]]`, do
      i. If `loaded.[[Status]]` is NEW, set `loaded.[[Status]]` to UNLINKED.
   c. Perform `Call(state.[[PromiseCapability]].[[Resolve]], undefined, « moduleCompletion »)`.
6. Return UNUSED.

### 16.2.1.5.1.2 ContinueModuleLoading (state, moduleCompletion)

The abstract operation `ContinueModuleLoading` takes arguments `state` (a `GraphLoadingState` Record) and `moduleCompletion` (either a normal completion containing a `Module` Record or a throw completion) and returns UNUSED. It is used to re-enter the loading process after a call to `HostLoadImportedModule`. It performs the following steps when called:

1. If `state.[[IsLoading]]` is `false`, return UNUSED.
2. If `moduleCompletion` is a normal completion, then
   a. Perform `InnerModuleLoading(state, moduleCompletion.[[Value]])`.
3. Else,
   a. Set `state.[[IsLoading]]` to `false`.
   b. Perform `Call(state.[[PromiseCapability]].[[Reject]], undefined, « moduleCompletion.[[Value]] »)`.
4. Return UNUSED.

### 16.2.1.5.2 Link ()

The `Link` concrete method of a Cyclic Module Record `module` takes no arguments and returns either a normal completion containing UNUSED or a throw completion. On success, `Link` transitions this module's `[[Status]]` from UNLINKED to LINKED. On failure, an exception is thrown and this module's `[[Status]]` remains UNLINKED. (Most of the work is done by the auxiliary function `InnerModuleLinking`.) It performs the following steps when called:

1. Assert: `module.[[Status]]` is one of UNLINKED, LINKED, EVALUATING-ASYNC, or EVALUATED.
2. Let `stack` be a new empty List.
3. Let `result` be `Completion(InnerModuleLinking(module, stack, 0))`.
4. If `result` is an abrupt completion, then
   a. For each Cyclic Module Record `m` of `stack`, do
      i. Assert: `m.[[Status]]` is LINKING.
      ii. Set `m.[[Status]]` to UNLINKED.
   b. Assert: `module.[[Status]]` is UNLINKED.
   c. Return `result`.
5. Assert: `module.[[Status]]` is one of LINKED, EVALUATING-ASYNC, or EVALUATED.
6. Assert: `stack` is empty.
7. Return UNUSED.

### 16.2.1.5.2.1 InnerModuleLinking (module, stack, index)

The abstract operation `InnerModuleLinking` takes arguments `module` (a `Module` Record), `stack` (a List of Cyclic Module Records), and `index` (a non-negative integer) and returns either a normal completion containing a non-negative integer or a throw completion. It is used by `Link` to perform the actual linking process for `module`, as well as recursively on all other modules in the dependency graph. The `stack` and `index` parameters, as well as a module's `[[DFSIndex]]` and `[[DFSAncestorIndex]]` fields, keep track of the depth-first search (DFS) traversal.
In particular, [[DFSAncestorIndex]] is used to discover strongly connected components (SCCs), such that all modules in an SCC transition to LINKED together. It performs the following steps when called:

1. If `module` is not a Cyclic Module Record, then
   a. Perform `module`.Link().
   b. Return `index`.
2. If `module`.[[Status]] is one of LINKING, LINKED, EVALUATING-ASYNC, or EVALUATED, then
   a. Return `index`.
3. Assert: `module`.[[Status]] is UNLINKED.
4. Set `module`.[[Status]] to LINKING.
5. Set `module`.[[DFSIndex]] to `index`.
6. Set `module`.[[DFSAncestorIndex]] to `index`.
7. Set `index` to `index` + 1.
8. Append `module` to `stack`.
9. For each String `required` of `module`.[[RequestedModules]], do
   a. Let `requiredModule` be GetImportedModule(`module`, `required`).
   b. Set `index` to ? InnerModuleLinking(`requiredModule`, `stack`, `index`).
   c. If `requiredModule` is a Cyclic Module Record, then
      i. Assert: `requiredModule`.[[Status]] is one of LINKING, LINKED, EVALUATING-ASYNC, or EVALUATED.
      ii. Assert: `requiredModule`.[[Status]] is LINKING if and only if `stack` contains `requiredModule`.
      iii. If `requiredModule`.[[Status]] is LINKING, then
          1. Set `module`.[[DFSAncestorIndex]] to `min(module`.[[DFSAncestorIndex]],
             `requiredModule`.[[DFSAncestorIndex]])
10. Perform `module`.InitializeEnvironment().
11. Assert: `module` occurs exactly once in `stack`.
12. Assert: `module`.[[DFSAncestorIndex]] ≤ `module`.[[DFSIndex]].
13. If `module`.[[DFSAncestorIndex]] = `module`.[[DFSIndex]], then
    a. Let `done` be `false`.
    b. Repeat, while `done` is `false`,
       i. Let `requiredModule` be the last element of `stack`.
       ii. Remove the last element of `stack`.
       iii. Assert: `requiredModule` is a Cyclic Module Record.
       iv. Set `requiredModule`.[[Status]] to LINKED.
    v. If `requiredModule` and `module` are the same Module Record, set `done` to `true`.

### 16.2.1.5.3 Evaluate()

The Evaluate concrete method of a Cyclic Module Record `module` takes no arguments and returns a Promise. Evaluate transitions this module's [[Status]] from LINKED to either EVALUATING-ASYNC or EVALUATED. The first time it is called on a module in a given strongly connected component, Evaluate creates and returns a Promise which resolves when the module has finished evaluating. This Promise is stored in the [[TopLevelCapability]] field of the [[CycleRoot]] for the component. Future invocations of Evaluate on any module in the component return the same Promise. (Most of the work is done by the auxiliary function InnerModuleEvaluation.) It performs the following steps when called:

1. Assert: This call to Evaluate is not happening at the same time as another call to Evaluate within the surrounding agent.
2. Assert: `module`.[[Status]] is one of LINKED, EVALUATING-ASYNC, or EVALUATED.
3. If `module`.[[Status]] is either EVALUATING-ASYNC or EVALUATED, set `module` to `module`.[[CycleRoot]]
4. If `module`.[[TopLevelCapability]] is not EMPTY, then
   a. Return `module`.[[TopLevelCapability]].[[Promise]].
5. Let `stack` be a new empty List.
6. Let `capability` be ! NewPromiseCapability(%Promise%).
7. Set `module`.[[TopLevelCapability]] to `capability`.
8. Let `result` be Completion(InnerModuleEvaluation(`module`, `stack`, 0)).
9. If `result` is an abrupt completion, then
   a. For each Cyclic Module Record `m` of `stack`, do
      i. Assert: `m`.[[Status]] is EVALUATING.
ii. Set \(m.([\text{Status}])\) to EVALUATED.

iii. Set \(m.([\text{EvaluationError}]\) to \(\text{result}\).

b. Assert: \(m.([\text{Status}]\) is EVALUATED.

c. Assert: \(m.([\text{EvaluationError}]\) is \(\text{result}\).

d. Perform \(\text{Call}(\text{capability}.[[\text{Reject}]], \text{undefined}, \leftarrow \text{result}.[[\text{Value}]]\})\).

10. Else,

a. Assert: \(m.([\text{Status}]\) is either EVALUATING-ASYNC or EVALUATED.

b. Assert: \(m.([\text{EvaluationError}]\) is EMPTY.

c. If \(m.([\text{AsyncEvaluation}]\) is false, then

i. Assert: \(m.([\text{Status}]\) is EVALUATED.

ii. Perform \(\text{Call}(\text{capability}.[[\text{Resolve}]], \text{undefined}, \leftarrow \text{undefined} \rightarrow )\).

d. Assert: \(\text{stack}\) is empty.

11. Return \(\text{capability}.[[\text{Promise}]]\).

16.2.1.5.3.1 InnerModuleEvaluation (\(\text{module}, \text{stack}, \text{index}\) )

The abstract operation InnerModuleEvaluation takes arguments \(\text{module}\) (a Module Record), \(\text{stack}\) (a List of Cyclic Module Records), and \(\text{index}\) (a non-negative integer) and returns either a normal completion containing a non-negative integer or a throw completion. It is used by Evaluate to perform the actual evaluation process for \(\text{module}\), as well as recursively on all other modules in the dependency graph. The \(\text{stack}\) and \(\text{index}\) parameters, as well as \(\text{module}\)’s [[DFSIndex]] and [[DFSAncestorIndex]] fields, are used the same way as in InnerModuleLinking.

It performs the following steps when called:

1. If \(\text{module}\) is not a Cyclic Module Record, then

   a. Let \(\text{promise}\) be \(\text{module}.\text{Evaluate}()\).

   b. Assert: \(\text{promise}.[[\text{PromiseState}]\) is not PENDING.

   c. If \(\text{promise}.[[\text{PromiseState}]\) is REJECTED, then

      i. Return \(\text{ThrowCompletion}(\text{promise}.[[\text{PromiseResult}]]\).

   d. Return \(\text{index}\).

2. If \(\text{module}.[[\text{Status}]\) is either EVALUATING-ASYNC or EVALUATED, then

   a. If \(\text{module}.[[\text{EvaluationError}]\) is EMPTY, return \(\text{index}\).

   b. Otherwise, return \(\text{module}.[[\text{EvaluationError}]\).

3. If \(\text{module}.[[\text{Status}]\) is EVALUATING, return \(\text{index}\).

4. Assert: \(\text{module}.[[\text{Status}]\) is LINKED.

5. Set \(\text{module}.[[\text{Status}]\) to EVALUATING.

6. Set \(\text{module}.[[\text{DFSIndex}]\) to \(\text{index}\).

7. Set \(\text{module}.[[\text{DFSAncestorIndex}]\) to \(\text{index}\).

8. Set \(\text{module}.[[\text{PendingAsyncDependencies}]\) to \(\emptyset\).

9. Set \(\text{index}\) to \(\text{index} + 1\).

10. Append \(\text{module}\) to \(\text{stack}\).

11. For each String \(\text{required}\) of \(\text{module}.[[\text{RequestedModules}]\), do

   a. Let \(\text{requiredModule}\) be \(\text{GetImportedModule}(<\text{module}, \text{required}>\).

   b. Set \(\text{index}\) to ? InnerModuleEvaluation(<\text{requiredModule}, \text{stack}, \text{index}>).

   c. If \(\text{requiredModule}\) is a Cyclic Module Record, then

      i. Assert: \(\text{requiredModule}.[[\text{Status}]\) is one of EVALUATING, EVALUATING-ASYNC, or EVALUATED.

      ii. Assert: \(\text{requiredModule}.[[\text{Status}]\) is EVALUATING if and only if \(\text{stack}\) contains \(\text{requiredModule}\).

      iii. If \(\text{requiredModule}.[[\text{Status}]\) is EVALUATING, then

         1. Set \(\text{module}.[[\text{DFSAncestorIndex}]\) to \(\text{min}(\text{module}.[[\text{DFSAncestorIndex}], \text{requiredModule}.[[\text{DFSAncestorIndex}]])\).

      iv. Else,

         1. Set \(\text{requiredModule}\) to \(\text{requiredModule}.[[\text{CycleRoot}]\).

         2. Assert: \(\text{requiredModule}.[[\text{Status}]\) is either EVALUATING-ASYNC or EVALUATED.

         3. If \(\text{requiredModule}.[[\text{EvaluationError}]\) is not EMPTY, return \(\text{false}\).

         v. If \(\text{requiredModule}.[[\text{AsyncEvaluation}]\) is true, then

            1. Set \(\text{module}.[[\text{PendingAsyncDependencies}]\) to \(\text{module}.[[\text{PendingAsyncDependencies}]\) + 1.

            2. Append module to \(\text{requiredModule}.[[\text{AsyncParentModules}]\).

12. If \(\text{module}.[[\text{PendingAsyncDependencies}]\) > \(\emptyset\) or \(\text{module}.[[\text{HasTLA}]\) is true, then

   a. Assert: \(\text{module}.[[\text{AsyncEvaluation}]\) is \(\text{false}\) and was never previously set to true.

   b. Set \(\text{module}.[[\text{AsyncEvaluation}]\) to true.
NOTE: The order in which module records have their [[AsyncEvaluation]] fields transition to true is significant. (See 16.2.1.5.3.4.)

d. If module.[[PendingAsyncDependencies]] = 0, perform ExecuteAsyncModule(module).

13. Else,
   a. Perform ? module.ExecuteModule().
   b. Repeat, while done is false,
      i. Let requiredModule be the last element of stack.
      ii. Remove the last element of stack.
      iii. Assert: requiredModule is a Cyclic Module Record.
      iv. If requiredModule.[[AsyncEvaluation]] is false, set requiredModule.[[Status]] to EVALUATED.
      v. Otherwise, set requiredModule.[[Status]] to EVALUATING-ASYNC.
      vi. If requiredModule and module are the same Module Record, set done to true.
      vii. Set requiredModule.[[CycleRoot]] to module.

17. Return index.

NOTE 1 A module is EVALUATING while it is being traversed by InnerModuleEvaluation. A module is EVALUATED on execution completion or EVALUATING-ASYNC during execution if its [[HasTLA]] field is true or if it has asynchronous dependencies.

NOTE 2 Any modules depending on a module of an asynchronous cycle when that cycle is not EVALUATING will instead depend on the execution of the root of the cycle via [[CycleRoot]]. This ensures that the cycle state can be treated as a single strongly connected component through its root module state.

16.2.1.5.3.2 ExecuteAsyncModule ( module )

The abstract operation ExecuteAsyncModule takes argument module (a Cyclic Module Record) and returns UNUSED. It performs the following steps when called:

1. Assert: module.[[Status]] is either EVALUATING or EVALUATING-ASYNC.
2. Assert: module.[[HasTLA]] is true.
3. Let capability be ! NewPromiseCapability(%Promise%).
4. Let fulfilledClosure be a new Abstract Closure with no parameters that captures module and performs the following steps when called:
   a. Perform AsyncModuleExecutionFulfilled(module).
   b. Return undefined.
5. Let onFulfilled be CreateBuiltInFunction(fulfilledClosure, 0, "", « »).
6. Let rejectedClosure be a new Abstract Closure with parameters (error) that captures module and performs the following steps when called:
   a. Perform AsyncModuleExecutionRejected(module, error).
   b. Return undefined.
7. Let onRejected be CreateBuiltInFunction(rejectedClosure, 0, "", « »).
8. Perform PerformPromiseThen(capability.[[Promise]], onFulfilled, onRejected).
10. Return UNUSED.

16.2.1.5.3.3 GatherAvailableAncestors ( module, execList )

The abstract operation GatherAvailableAncestors takes arguments module (a Cyclic Module Record) and execList (a List of Cyclic Module Records) and returns UNUSED. It performs the following steps when called:

1. For each Cyclic Module Record m of module.[[AsyncParentModules]], do
   a. If execList does not contain m and m.[[CycleRoot]].[[EvaluationError]] is EMPTY, then
      i. Assert: m.[[Status]] is EVALUATING-ASYNC.
NOTE When an asynchronous execution for a root module is fulfilled, this function determines the list of modules which are able to synchronously execute together on this completion, populating them in execList.

16.2.1.5.3.4 AsyncModuleExecutionFulfilled (module)

The abstract operation AsyncModuleExecutionFulfilled takes argument module (a Cyclic Module Record) and returns Unused. It performs the following steps when called:

1. If module.[[Status]] is EVALUATED, then
   a. Assert: module.[[EvaluationError]] is not EMPTY.
   b. Return Unused.
2. Assert: module.[[Status]] is EVALUATING-ASYNC.
3. Assert: module.[[AsyncEvaluation]] is true.
4. Assert: module.[[EvaluationError]] is EMPTY.
5. Set module.[[AsyncEvaluation]] to false.
6. Set module.[[Status]] to EVALUATED.
7. If module.[[TopLevelCapability]] is not EMPTY, then
   a. Assert: module.[[CycleRoot]] is module.
   b. Perform !Call(module.[[TopLevelCapability]].[[Resolve]], undefined, « undefined »).
8. Let execList be a new empty List.
10. Let sortedExecList be a List whose elements are the elements of execList, in the order in which they had their [[AsyncEvaluation]] fields set to true in InnerModuleEvaluation.
11. Assert: All elements of sortedExecList have their [[AsyncEvaluation]] field set to true, [[PendingAsyncDependencies]] field set to 0, and [[EvaluationError]] field set to EMPTY.
12. For each Cyclic Module Record m of sortedExecList, do
   a. If m.[[Status]] is EVALUATED, then
      i. Assert: m.[[EvaluationError]] is not EMPTY.
   b. Else if m.[[HasTLA]] is true, then
      i. Perform ExecuteAsyncModule(m).
   c. Else,
      i. Let result be m.ExecuteModule().
      ii. If result is an abrupt completion, then
          1. Perform AsyncModuleExecutionRejected(m, result.[[Value]]).
      iii. Else,
          1. Set m.[[Status]] to EVALUATED.
          2. If m.[[TopLevelCapability]] is not EMPTY, then
             a. Assert: m.[[CycleRoot]] is m.
             b. Perform !Call(m.[[TopLevelCapability]].[[Resolve]], undefined, « undefined »).
13. Return Unused.

16.2.1.5.3.5 AsyncModuleExecutionRejected (module, error)

The abstract operation AsyncModuleExecutionRejected takes arguments module (a Cyclic Module Record) and error (an ECMAScript language value) and returns Unused. It performs the following steps when called:

1. If module.[[Status]] is EVALUATED, then
a. **Assert**: `module.[[EvaluationError]]` is not EMPTY.
b. Return UNUSED.

2. **Assert**: `module.[[Status]]` is EVALUATING-ASYNC.

3. **Assert**: `module.[[AsyncEvaluation]]` is true.

4. Set `module.[[EvaluationError]]` to `ThrowCompletion(error)`.

5. Set `module.[[Status]]` to EVALUATED.

6. For each Cyclic Module Record `m` of `module.[[AsyncParentModules]]`, do
   a. Perform `AsyncModuleExecutionRejected(m, error)`.

7. If `module.[[TopLevelCapability]]` is not EMPTY, then
   a. **Assert**: `module.[[CycleRoot]]` is `module`.
   b. Perform `! Call(module.[[TopLevelCapability]].[[Reject]], undefined, « error »)`.

8. Return UNUSED.

### 16.2.1.5.4 Example Cyclic Module Record Graphs

This non-normative section gives a series of examples of the linking and evaluation of a few common module graphs, with a specific focus on how errors can occur.

First consider the following simple module graph:

![Figure 2: A simple module graph]

Let’s first assume that there are no error conditions. When a host first calls `A.LoadRequestedModules()`, this will complete successfully by assumption, and recursively load the dependencies of `B` and `C` as well (respectively, `C` and none), and then set `A.[[Status]] = B.[[Status]] = C.[[Status]] = UNLINKED`. Then, when the host calls `A.Link()`, it will complete successfully (again by assumption) such that `A.[[Status]] = B.[[Status]] = C.[[Status]]` = linked. These preparatory steps can be performed at any time. Later, when the host is ready to incur any possible side effects of the modules, it can call `A.Evaluate()`, which will complete successfully, returning a Promise resolving to `undefined` (again by assumption), recursively having evaluated first `C` and then `B`. Each module’s `[[Status]]` at this point will be EVALUATED.

Consider then cases involving linking errors, after a successful call to `A.LoadRequestedModules()`. If `InnerModuleLinking` of `C` succeeds but, thereafter, fails for `B`, for example because it imports something that `C` does not provide, then the original `A.Link()` will fail, and both `A` and `B’s` `[[Status]]` remain UNLINKED. `C’s` `[[Status]]` has become LINKED, though.

Finally, consider a case involving evaluation errors after a successful call to `Link()`. If `InnerModuleEvaluation` of `C` succeeds but, thereafter, fails for `B`, for example because `B` contains code that throws an exception, then the original `A.Evaluate()` will fail, returning a rejected Promise. The resulting exception will be recorded in both `A` and `B’s` `[[EvaluationError]]` fields, and their `[[Status]]` will become EVALUATED. `C` will also become EVALUATED but, in contrast to `A` and `B`, will remain without an `[[EvaluationError]]`, as it successfully completed evaluation. Storing the exception ensures that any time a host tries to reuse `A` or `B` by calling their `Evaluate()` method, it will encounter the same exception. (Hosts are not required to reuse Cyclic Module Records; similarly, hosts are not required to expose the exception objects thrown by these methods. However, the specification enables such uses.)

Now consider a different type of error condition:
In this scenario, module A declares a dependency on some other module, but no Module Record exists for that module, i.e. HostLoadImportedModule calls FinishLoadingImportedModule with an exception when asked for it. This could occur for a variety of reasons, such as the corresponding resource not existing, or the resource existing but ParseModule returning some errors when trying to parse the resulting source text. Hosts can choose to expose the cause of failure via the completion they pass to FinishLoadingImportedModule. In any case, this exception causes a loading failure, which results in A’s [[Status]] remaining NEW.

The difference here between loading, linking and evaluation errors is due to the following characteristic:

- Evaluation must be only performed once, as it can cause side effects; it is thus important to remember whether evaluation has already been performed, even if unsuccessfully. (In the error case, it makes sense to also remember the exception because otherwise subsequent Evaluate() calls would have to synthesize a new one.)
- Linking, on the other hand, is side-effect-free, and thus even if it fails, it can be retried at a later time with no issues.
- Loading closely interacts with the host, and it may be desiderable for some of them to allow users to retry failed loads (for example, if the failure is caused by temporarily bad network conditions).

Now, consider a module graph with a cycle:

Here we assume that the entry point is module A, so that the host proceeds by calling A.LoadRequestedModules(), which performs InnerModuleLoading on A. This in turn calls InnerModuleLoading on B and C. Because of the cycle, this again triggers InnerModuleLoading on A, but at this point it is a no-op since A’s dependencies loading has already been triggered during this LoadRequestedModules process. When all the modules in the graph have been successfully loaded, their [[Status]] transitions from NEW to UNLINKED at the same time.

Then the host proceeds by calling A.Link(), which performs InnerModuleLinking on A. This in turn calls InnerModuleLinking on B. Because of the cycle, this again triggers InnerModuleLinking on A, but at this point it is a no-op since A.[[Status]] is already LINKING. B.[[Status]] itself remains LINKING when control gets back to A and InnerModuleLinking is triggered on C. After this returns with C.[[Status]] being LINKED, both A and B transition from LINKING to LINKED together; this is by design, since they form a strongly connected component. It’s possible to transition the status of modules in the same SCC at the same time because during this phase the module graph is traversed with a depth-first search.

An analogous story occurs for the evaluation phase of a cyclic module graph, in the success case.

Now consider a case where A has a linking error; for example, it tries to import a binding from C that does not exist. In that case, the above steps still occur, including the early return from the second call to InnerModuleLinking on A. However, once we unwind back to the original InnerModuleLinking on A, it fails during InitializeEnvironment, namely right after C.ResolveExport(). The thrown SyntaxError exception propagates up to A.Link, which resets all modules that are currently on its stack (these are always exactly the modules that are still LINKING). Hence both A and B become UNLINKED. Note that C is left as LINKED.
Alternatively, consider a case where \( A \) has an evaluation error; for example, its source code throws an exception. In that case, the evaluation-time analog of the above steps still occurs, including the early return from the second call to `InnerModuleEvaluation` on \( A \). However, once we unwind back to the original `InnerModuleEvaluation` on \( A \), it fails by assumption. The exception thrown propagates up to `A.Evaluate()`, which records the error in all modules that are currently on its stack (i.e., the modules that are still EVALUATING) as well as via `AsyncParentModules`, which form a chain for modules which contain or depend on top-level `await` through the whole dependency graph through the `AsyncModuleExecutionRejected` algorithm. Hence both \( A \) and \( B \) become EVALUATED and the exception is recorded in both \( A \) and \( B \)'s `EvaluationError` fields, while \( C \) is left as EVALUATED with no `EvaluationError`.

Lastly, consider a module graph with a cycle, where all modules complete asynchronously:

![Figure 5: An asynchronous cyclic module graph](image)

Loading and linking happen as before, and all modules end up with `[[Status]]` set to LINKED.

Calling `A.Evaluate()` calls `InnerModuleEvaluation` on \( A \), \( B \), and \( D \), which all transition to EVALUATING. Then `InnerModuleEvaluation` is called on \( A \) again, which is a no-op because it is already EVALUATING. At this point, \( D.\text{[[PendingAsyncDependencies]]} \) is 0, so `ExecuteAsyncModule(D)` is called and we call `D.ExecuteModule` with a new PromiseCapability tracking the asynchronous execution of \( D \). We unwind back to the `InnerModuleEvaluation` on \( B \), setting \( B.\text{[[PendingAsyncDependencies]]} \) to 1 and \( B.\text{[[AsyncEvaluation]]} \) to `true`. We unwind back to the original `InnerModuleEvaluation` on \( A \), setting \( A.\text{[[PendingAsyncDependencies]]} \) to 1. In the next iteration of the loop over \( A \)'s dependencies, we call `InnerModuleEvaluation` on \( C \) and thus on \( D \) (again a no-op) and \( E \). As \( E \) has no dependencies and is not part of a cycle, we call `ExecuteAsyncModule(E)` in the same manner as \( D \) and \( E \) is immediately removed from the stack. We unwind once more to the original `InnerModuleEvaluation` on \( A \), setting \( C.\text{[[AsyncEvaluation]]} \) to `true`. Now we finish the loop over \( A \)'s dependencies, set \( A.\text{[[AsyncEvaluation]]} \) to `true`, and remove the entire strongly connected component from the stack, transitioning all of the modules to EVALUATING-ASYNC at once. At this point, the fields of the modules are as given in Table 46.

### Table 46: Module fields after the initial Evaluate() call

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[DFSIndex]]</code></td>
<td>A: 0</td>
</tr>
<tr>
<td><code>[[DFSAncestorIndex]]</code></td>
<td>A: 0</td>
</tr>
<tr>
<td><code>[[Status]]</code></td>
<td>EVALUATING-ASYNC</td>
</tr>
<tr>
<td><code>[[AsyncEvaluation]]</code></td>
<td><code>true</code></td>
</tr>
<tr>
<td><code>[[PendingAsyncDependencies]]</code></td>
<td>2 (( B ) and ( C ))</td>
</tr>
</tbody>
</table>
Let us assume that \( E \) finishes executing first. When that happens, \( \text{AsyncModuleExecutionFulfilled} \) is called, \( E.[[\text{Status}]] \) is set to EVALUATED and \( C.[[\text{PendingAsyncDependencies}]] \) is decremented to become 1. The fields of the updated modules are as given in Table 47.

Table 47: Module fields after module \( E \) finishes executing

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>([\text{DFSIndex}])</td>
<td>(C) 4</td>
</tr>
<tr>
<td>([\text{DFSAncestorIndex}])</td>
<td>0 4</td>
</tr>
<tr>
<td>([\text{Status}])</td>
<td>EVALUATING-ASYNC</td>
</tr>
<tr>
<td>([\text{AsyncEvaluation}])</td>
<td>true</td>
</tr>
<tr>
<td>([\text{AsyncParentModules}])</td>
<td>« (A) »</td>
</tr>
<tr>
<td>([\text{PendingAsyncDependencies}])</td>
<td>1 ((D))</td>
</tr>
</tbody>
</table>

\(D\) is next to finish (as it was the only module that was still executing). When that happens, \( \text{AsyncModuleExecutionFulfilled} \) is called again and \( D.[[\text{Status}]] \) is set to EVALUATED. Then \( B.[[\text{PendingAsyncDependencies}]] \) is decremented to become 0, \( \text{ExecuteAsyncModule} \) is called on \( B \), and it starts executing. \( C.[[\text{PendingAsyncDependencies}]] \) is also decremented to become 0, and \( C \) starts executing (potentially in parallel to \( B \) if \( B \) contains an \textit{await}). The fields of the updated modules are as given in Table 48.

Table 48: Module fields after module \( D \) finishes executing

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>([\text{DFSIndex}])</td>
<td>(B) 2</td>
</tr>
<tr>
<td>([\text{DFSAncestorIndex}])</td>
<td>0 (C)</td>
</tr>
<tr>
<td>([\text{Status}])</td>
<td>EVALUATING-ASYNC</td>
</tr>
<tr>
<td>([\text{AsyncEvaluation}])</td>
<td>true</td>
</tr>
<tr>
<td>([\text{AsyncParentModules}])</td>
<td>« (A) »</td>
</tr>
<tr>
<td>([\text{PendingAsyncDependencies}])</td>
<td>0</td>
</tr>
</tbody>
</table>

Let us assume that \( C \) finishes executing next. When that happens, \( \text{AsyncModuleExecutionFulfilled} \) is called again, \( C.[[\text{Status}]] \) is set to EVALUATED and \( A.[[\text{PendingAsyncDependencies}]] \) is decremented to become 1. The fields of the updated modules are as given in Table 49.

Table 49: Module fields after module \( C \) finishes executing

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>([\text{DFSIndex}])</td>
<td>(A) 2</td>
</tr>
<tr>
<td>([\text{DFSAncestorIndex}])</td>
<td>0 (C)</td>
</tr>
<tr>
<td>([\text{Status}])</td>
<td>EVALUATING-ASYNC</td>
</tr>
</tbody>
</table>
Table 49: Module fields after module C finishes executing
(continued)

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>true</td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>« »</td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>1 (B)</td>
</tr>
</tbody>
</table>

Then, B finishes executing. When that happens, AsyncModuleExecutionFulfilled is called again and B.[[Status]] is set to EVALUATED. A.[[PendingAsyncDependencies]] is decremented to become 0, so ExecuteAsyncModule is called and it starts executing. The fields of the updated modules are as given in Table 50.

Table 50: Module fields after module B finishes executing

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>[[DFSIndex]]</td>
<td>0</td>
</tr>
<tr>
<td>[[DFSAncestorIndex]]</td>
<td>0</td>
</tr>
<tr>
<td>[[Status]]</td>
<td>EVALUATING-ASYNC</td>
</tr>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>true</td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>« »</td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>0</td>
</tr>
</tbody>
</table>

Finally, A finishes executing. When that happens, AsyncModuleExecutionFulfilled is called again and A.[[Status]] is set to EVALUATED. At this point, the Promise in A.[[TopLevelCapability]] (which was returned from A.Evaluate()) is resolved, and this concludes the handling of this module graph. The fields of the updated module are as given in Table 51.

Table 51: Module fields after module A finishes executing

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>[[DFSIndex]]</td>
<td>0</td>
</tr>
<tr>
<td>[[DFSAncestorIndex]]</td>
<td>0</td>
</tr>
<tr>
<td>[[Status]]</td>
<td>EVALUATED</td>
</tr>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>true</td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>« »</td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>0</td>
</tr>
</tbody>
</table>

Alternatively, consider a failure case where C fails execution and returns an error before B has finished executing. When that happens, AsyncModuleExecutionRejected is called, which sets C.[[Status]] to EVALUATED and
C.[[EvaluationError]] to the error. It then propagates this error to all of the AsyncParentModules by performing AsyncModuleExecutionRejected on each of them. The fields of the updated modules are as given in Table 52.

Table 52: Module fields after module C finishes with an error

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[DFSIndex]]</td>
<td>A</td>
</tr>
<tr>
<td>[[DFSAncestorIndex]]</td>
<td>0</td>
</tr>
<tr>
<td>[[Status]]</td>
<td>EVALUATED</td>
</tr>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>true</td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>« »</td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>1 (B)</td>
</tr>
<tr>
<td>[[EvaluationError]]</td>
<td>EMPTY</td>
</tr>
</tbody>
</table>

A will be rejected with the same error as C since C will call AsyncModuleExecutionRejected on A with C's error. A.[[Status]] is set to EVALUATED. At this point the Promise in A.[[TopLevelCapability]] (which was returned from A.Evaluate()) is rejected. The fields of the updated module are as given in Table 53.

Table 53: Module fields after module A is rejected

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[DFSIndex]]</td>
<td>A</td>
</tr>
<tr>
<td>[[DFSAncestorIndex]]</td>
<td>0</td>
</tr>
<tr>
<td>[[Status]]</td>
<td>EVALUATED</td>
</tr>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>true</td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>« »</td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>0</td>
</tr>
<tr>
<td>[[EvaluationError]]</td>
<td>C's Evaluation Error</td>
</tr>
</tbody>
</table>

Then, B finishes executing without an error. When that happens, AsyncModuleExecutionFulfilled is called again and B.[[Status]] is set to EVALUATED. GatherAvailableAncestors is called on B. However, A.[[CycleRoot]] is A which has an evaluation error, so it will not be added to the returned sortedExecList and AsyncModuleExecutionFulfilled will return without further processing. Any future importer of B will resolve the rejection of B.[[CycleRoot]].[[EvaluationError]] from the evaluation error from C that was set on the cycle root A. The fields of the updated modules are as given in Table 54.
Table 54: Module fields after module B finishes executing in an erroring graph

<table>
<thead>
<tr>
<th>Fields</th>
<th>Modules</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[[DFSIndex]]</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>[[DFSAncestorIndex]]</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>[[Status]]</td>
<td>EVALUATED</td>
<td>EVALUATED</td>
<td></td>
</tr>
<tr>
<td>[[AsyncEvaluation]]</td>
<td>true</td>
<td>true</td>
<td></td>
</tr>
<tr>
<td>[[AsyncParentModules]]</td>
<td>« »</td>
<td>« A »</td>
<td></td>
</tr>
<tr>
<td>[[PendingAsyncDependencies]]</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>[[EvaluationError]]</td>
<td>C's Evaluation Error</td>
<td>EMPTY</td>
<td></td>
</tr>
</tbody>
</table>

16.2.1.6 Source Text Module Records

A Source Text Module Record is used to represent information about a module that was defined from ECMAScript source text (11) that was parsed using the goal symbol Module. Its fields contain digested information about the names that are imported and exported by the module, and its concrete methods use these digests to link and evaluate the module.

A Source Text Module Record can exist in a module graph with other subclasses of the abstract Module Record type, and can participate in cycles with other subclasses of the Cyclic Module Record type.

In addition to the fields defined in Table 43, Source Text Module Records have the additional fields listed in Table 55. Each of these fields is initially set in ParseModule.

Table 55: Additional Fields of Source Text Module Records

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[ECMAScriptCode]]</td>
<td>a Parse Node</td>
<td>The result of parsing the source text of this module using Module as the goal symbol.</td>
</tr>
<tr>
<td>[[Context]]</td>
<td>an ECMAScript code execution context or EMPTY</td>
<td>The execution context associated with this module. It is EMPTY until the module's environment has been initialized.</td>
</tr>
<tr>
<td>[[ImportMeta]]</td>
<td>an Object or EMPTY</td>
<td>An object exposed through the import.meta meta property. It is EMPTY until it is accessed by ECMAScript code.</td>
</tr>
<tr>
<td>[[ImportEntries]]</td>
<td>a List of ImportEntry Records</td>
<td>A List of ImportEntry records derived from the code of this module.</td>
</tr>
<tr>
<td>[[LocalExportEntries]]</td>
<td>a List of ExportEntry Records</td>
<td>A List of ExportEntry records derived from the code of this module that correspond to declarations that occur within the module.</td>
</tr>
<tr>
<td>[[IndirectExportEntries]]</td>
<td>a List of ExportEntry Records</td>
<td>A List of ExportEntry records derived from the code of this module that correspond to reexported imports that occur within the module or exports from export * as namespace declarations.</td>
</tr>
</tbody>
</table>
Table 55: Additional Fields of Source Text Module Records (continued)

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[StarExportEntries]]</td>
<td>a List of ExportEntry Records</td>
<td>A List of ExportEntry records derived from the code of this module that correspond to export * declarations that occur within the module, not including export * as namespace declarations.</td>
</tr>
</tbody>
</table>

An ImportEntry Record is a Record that digests information about a single declarative import. Each ImportEntry Record has the fields defined in Table 56:

Table 56: ImportEntry Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[ModuleRequest]]</td>
<td>a String</td>
<td>String value of the ModuleSpecifier of the ImportDeclaration.</td>
</tr>
<tr>
<td>[[ImportName]]</td>
<td>a String or NAMESPACE-OBJECT</td>
<td>The name under which the desired binding is exported by the module identified by [[ModuleRequest]]. The value NAMESPACE-OBJECT indicates that the import request is for the target module's namespace object.</td>
</tr>
<tr>
<td>[[LocalName]]</td>
<td>a String</td>
<td>The name that is used to locally access the imported value from within the importing module.</td>
</tr>
</tbody>
</table>

NOTE 1 Table 57 gives examples of ImportEntry records fields used to represent the syntactic import forms:

Table 57 (Informative): Import Forms Mappings to ImportEntry Records

<table>
<thead>
<tr>
<th>Import Statement Form</th>
<th>[[ModuleRequest]]</th>
<th>[[ImportName]]</th>
<th>[[LocalName]]</th>
</tr>
</thead>
<tbody>
<tr>
<td>import v from &quot;mod&quot;;</td>
<td>&quot;mod&quot;</td>
<td>&quot;default&quot;</td>
<td>&quot;v&quot;</td>
</tr>
<tr>
<td>import * as ns from &quot;mod&quot;;</td>
<td>&quot;mod&quot;</td>
<td>NAMESPACE-OBJECT</td>
<td>&quot;ns&quot;</td>
</tr>
<tr>
<td>import {x} from &quot;mod&quot;;</td>
<td>&quot;mod&quot;</td>
<td>&quot;x&quot;</td>
<td>&quot;x&quot;</td>
</tr>
<tr>
<td>import {x as v} from &quot;mod&quot;;</td>
<td>&quot;mod&quot;</td>
<td>&quot;x&quot;</td>
<td>&quot;v&quot;</td>
</tr>
<tr>
<td>import &quot;mod&quot;;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An ExportEntry Record is a Record that digests information about a single declarative export. Each ExportEntry Record has the fields defined in Table 58:
Table 58: **ExportEntry Record** Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[ExportName]]</td>
<td>a String or null</td>
<td>The name used to export this binding by this module.</td>
</tr>
<tr>
<td>[[ModuleRequest]]</td>
<td>a String or null</td>
<td>The String value of the <code>ModuleSpecifier</code> of the <code>ExportDeclaration</code>. null if the <code>ExportDeclaration</code> does not have a <code>ModuleSpecifier</code>.</td>
</tr>
<tr>
<td>[[ImportName]]</td>
<td>a String, null, ALL, or ALL-BUT-DEFAULT</td>
<td>The name under which the desired binding is exported by the module identified by <code>[[ModuleRequest]]</code>. null if the <code>ExportDeclaration</code> does not have a <code>ModuleSpecifier</code>. ALL is used for <code>export * as ns from &quot;mod&quot;</code> declarations. ALL-BUT-DEFAULT is used for <code>export * from &quot;mod&quot;</code> declarations.</td>
</tr>
<tr>
<td>[[LocalName]]</td>
<td>a String or null</td>
<td>The name that is used to locally access the exported value from within the importing module. null if the exported value is not locally accessible from within the module.</td>
</tr>
</tbody>
</table>

**NOTE 2** Table 59 gives examples of the ExportEntry record fields used to represent the syntactic export forms:

Table 59 (Informative): Export Forms Mappings to **ExportEntry Records**

<table>
<thead>
<tr>
<th>Export Statement Form</th>
<th>[[ExportName]]</th>
<th>[[ModuleRequest]]</th>
<th>[[ImportName]]</th>
<th>[[LocalName]]</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>export var v;</code></td>
<td>&quot;v&quot;</td>
<td>null</td>
<td>null</td>
<td>&quot;v&quot;</td>
</tr>
<tr>
<td><code>export default function f() {}</code></td>
<td>&quot;default&quot;</td>
<td>null</td>
<td>null</td>
<td>&quot;f&quot;</td>
</tr>
<tr>
<td><code>export default function () {}</code></td>
<td>&quot;default&quot;</td>
<td>null</td>
<td>null</td>
<td>&quot;<em>default</em>&quot;</td>
</tr>
<tr>
<td><code>export default 42;</code></td>
<td>&quot;default&quot;</td>
<td>null</td>
<td>null</td>
<td>&quot;<em>default</em>&quot;</td>
</tr>
<tr>
<td><code>export {x};</code></td>
<td>&quot;x&quot;</td>
<td>null</td>
<td>null</td>
<td>&quot;x&quot;</td>
</tr>
<tr>
<td><code>export {v as x};</code></td>
<td>&quot;x&quot;</td>
<td>null</td>
<td>null</td>
<td>&quot;v&quot;</td>
</tr>
<tr>
<td><code>export {x} from &quot;mod&quot;;</code></td>
<td>&quot;x&quot;</td>
<td>&quot;mod&quot;</td>
<td>&quot;x&quot;</td>
<td>null</td>
</tr>
<tr>
<td><code>export {v as x} from &quot;mod&quot;;</code></td>
<td>&quot;x&quot;</td>
<td>&quot;mod&quot;</td>
<td>&quot;v&quot;</td>
<td>null</td>
</tr>
<tr>
<td><code>export * from &quot;mod&quot;;</code></td>
<td>null</td>
<td>&quot;mod&quot;</td>
<td>ALL-BUT-DEFAULT</td>
<td>null</td>
</tr>
<tr>
<td><code>export * as ns from &quot;mod&quot;;</code></td>
<td>&quot;ns&quot;</td>
<td>&quot;mod&quot;</td>
<td>ALL</td>
<td>null</td>
</tr>
</tbody>
</table>

The following definitions specify the required concrete methods and other abstract operations for Source Text Module Records.
16.2.1.6.1 ParseModule (sourceText, realm, hostDefined)

The abstract operation ParseModule takes arguments sourceText (ECMAScript source text), realm (a Realm Record), and hostDefined (anything) and returns a Source Text Module Record or a non-empty List of Syntax-Error objects. It creates a Source Text Module Record based upon the result of parsing sourceText as a Module.

It performs the following steps when called:

1. Let body be ParseText(sourceText, Module).
2. If body is a List of errors, return body.
3. Let requestedModules be the ModuleRequests of body.
4. Let importEntries be ImportEntries of body.
5. Let importedBoundNames be ImportedLocalNames(importEntries).
6. Let indirectExportEntries be a new empty List.
7. Let localExportEntries be a new empty List.
8. Let starExportEntries be a new empty List.
9. Let exportEntries be ExportEntries of body.
10. For each ExportEntry Record ee of exportEntries, do
    a. If ee.[[ModuleRequest]] is null, then
        i. If importedBoundNames does not contain ee.[[LocalName]], then
            1. Append ee to localExportEntries.
        ii. Else,
            1. Let ie be the element of importEntries whose [[LocalName]] is ee.[[LocalName]].
            2. If ie.[[ImportName]] is NAMESPACE-OBJECT, then
                a. NOTE: This is a re-export of an imported module namespace object.
                b. Append ee to localExportEntries.
            3. Else,
                a. NOTE: This is a re-export of a single name.
                b. Append the ExportEntry Record { [[ModuleRequest]]: ie.[[ModuleRequest]],
                    [[ImportName]]: ie.[[ImportName]], [[LocalName]]: null, [[ExportName]]: ee.[[ExportName]] } to indirectExportEntries.
    b. Else if ee.[[ImportName]] is ALL-BUT-DEFAULT, then
        i. Assert: ee.[[ExportName]] is null.
        ii. Append ee to starExportEntries.
    c. Else,
        i. Append ee to indirectExportEntries.
11. Let async be body.Contains(awaIt).

NOTE An implementation may parse module source text and analyse it for Early Error conditions prior to the evaluation of ParseModule for that module source text. However, the reporting of any errors must be deferred until the point where this specification actually performs ParseModule upon that source text.

16.2.1.6.2 GetExportedNames ([exportStarSet])

The GetExportedNames concrete method of a Source Text Module Record module takes optional argument exportStarSet (a List of Source Text Module Records) and returns a List of Strings. It performs the following steps when called:

1. Assert: module.[[Status]] is not NEW.
2. If exportStarSet is not present, set exportStarSet to a new empty List.
3. If exportStarSet contains module, then
a. **Assert**: We've reached the starting point of an export ★ circularity.
   b. Return a new empty List.
4. Append `module` to `exportStarSet`.
5. Let `exportedNames` be a new empty List.
6. For each `ExportEntry Record` `e` of `module`.
   a. **Assert**: `module` provides the direct binding for this export.
   b. **Assert**: `e`.[[ExportName]] is not null.
   c. Append `e`.[[ExportName]] to `exportedNames`.
7. For each `ExportEntry Record` `e` of `module`.
   a. **Assert**: `module` imports a specific binding for this export.
   b. **Assert**: `e`.[[ExportName]] is not null.
   c. Append `e`.[[ExportName]] to `exportedNames`.
8. For each `ExportEntry Record` `e` of `module`.
   a. **Assert**: `e`.[[ModuleRequest]] is not null.
   b. Let `requestedModule` be `GetImportedModule(module, e`.[[ModuleRequest]])).
   c. Let `starNames` be `requestedModule`.GetExportedNames(`exportStarSet`).
   d. For each element `n` of `starNames`, do
      i. If `SameValue(n, "default")` is **false**, then
         1. If `exportedNames` does not contain `n`, then
            a. Append `n` to `exportedNames`.
9. Return `exportedNames`.

**NOTE**
GetExportedNames does not filter out or throw an exception for names that have ambiguous star export bindings.

### 16.2.1.6.3 ResolveExport ( `exportName` [, `resolveSet` ] )

The `ResolveExport` concrete method of a `Source Text Module Record` `module` takes argument `exportName` (a String) and optional argument `resolveSet` (a List of Records with fields `[[Module]]` (a Module Record) and `[[ExportName]]` (a String)) and returns a `ResolvedBinding Record`, `null`, or `AMBIGUOUS`.

`ResolveExport` attempts to resolve an imported binding to the actual defining module and local binding name. The defining module may be the module represented by the `Module Record` this method was invoked on or some other module that is imported by that module. The parameter `resolveSet` is used to detect unresolved circular import/export paths. If a pair consisting of specific `Module Record` and `exportName` is reached that is already in `resolveSet`, an import circularity has been encountered. Before recursively calling ResolveExport, a pair consisting of `module` and `exportName` is added to `resolveSet`.

If a defining module is found, a `ResolvedBinding Record` `{ [[Module]], [[BindingName]] }` is returned. This record identifies the resolved binding of the originally requested export, unless this is the export of a namespace with no local binding. In this case, `[[BindingName]]` will be set to `NAMESPACE`. If no definition was found or the request is found to be circular, `null` is returned. If the request is found to be ambiguous, `AMBIGUOUS` is returned.

It performs the following steps when called:

1. **Assert**: `module`.[[Status]] is not NEW.
2. If `resolveSet` is not present, set `resolveSet` to a new empty List.
3. For each `Record` `{ [[Module]], [[ExportName]] }` `r` of `resolveSet`, do
   a. If `module` and `r`.[[Module]] are the same `Module Record` and `SameValue(exportName, r`.[[ExportName]])
      is **true**, then
      i. **Assert**: This is a circular import request.
      ii. **Return** `null`.
4. Append the `Record` `{ [[Module]]: `module`, [[ExportName]]: `exportName` } to `resolveSet`.
5. For each `ExportEntry Record` `e` of `module`.[[LocalExportEntries]], do
   a. If `SameValue(exportName, e`.[[ExportName]]) is **true**, then
      i. **Assert**: `module` provides the direct binding for this export.
      ii. **Return** `ResolvedBinding Record` `{ [[Module]]: `module`, [[BindingName]]: `e`.[[LocalName]] }`.
6. For each `ExportEntry Record` `e` of `module`.[[IndirectExportEntries]], do
   a. If `SameValue(exportName, e`.[[ExportName]]) is **true**, then
16.2.1.6.4 InitializeEnvironment ( )

The InitializeEnvironment concrete method of a Source Text Module Record module takes no arguments and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. For each ExportEntry Record \( e \) of module.[[StarExportEntries]], do
   a. Assert: \( e.[[ModuleRequest]] \) is not null.
   b. Let \( importedModule \) be GetImportedModule(module, e.[[ModuleRequest]]).
   c. Let \( resolution \) be importedModule.ResolveExport(e.[[ModuleName]], resolveSet).
   d. If \( resolution \) is AMBIGUOUS, return AMBIGUOUS.
   e. If \( resolution \) is null, then
      i. Assert: \( resolution \) is a ResolvedBinding Record.
      ii. If \( starResolution \) is null, then
           1. Set \( starResolution \) to \( resolution \).
           iii. Else,
                1. Assert: There is more than one \( * \) import that includes the requested name.
                2. If \( resolution.[[Module]] \) and \( starResolution.[[Module]] \) are not the same Module Record, return AMBIGUOUS.
      3. If \( resolution.[[BindingName]] \) is not \( starResolution.[[BindingName]] \) and either
         \( resolution.[[BindingName]] \) or \( starResolution.[[BindingName]] \) is NAMESPACE, return AMBIGUOUS.
   4. If \( resolution.[[BindingName]] \) is a String, \( starResolution.[[BindingName]] \) is a String, and
      SameValue(resolution.[[BindingName]], starResolution.[[BindingName]]) is false, return AMBIGUOUS.
10. Return \( starResolution \).

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If

If

If

If

If

If

If

If

If

If

Let

Else,

Return

Perform !

For each element

For each element

Push

Set the ScriptOrModule of

normalcompletioncontaining

Set the

Let

Let

Perform !

Let

Let

Assert

Let

Perform !

Let

Set the VariableEnvironment of

Perform !

Set the Function of

Append

Else,

SourceTextModuleRecord

Set the Function of

For each element

throwcompletion

Set the PrivateEnvironment of

Set the VariableEnvironment of

Perform !

Set the LexicalEnvironment of

Perform !

Suspend the

Let

Set the LexicalEnvironment of

Perform !

Determine the execution context stack

Resolve

Push moduleContext onto the execution context stack; moduleContext is now the running execution context

Let code be module.[[ECMAScriptCode]].

Let varDeclarations be the VarScopedDeclarations of code.

Let declaredVarNames be a new empty List.

For each element d of varDeclarations, do

a. For each element dn of the BoundNames of d, do

i. If declaredVarNames does not contain dn, then


3. Append dn to declaredVarNames.

b. For each element d of lexDeclarations, do

a. For each element dn of the BoundNames of d, do

i. If IsConstantDeclaration of d is true, then


ii. Else,


iii. If d is either a FunctionDeclaration, a GeneratorDeclaration, an AsyncFunctionDeclaration, or an AsyncGeneratorDeclaration, then

1. Let fo be InstantiateFunctionObject of d with arguments env and privateEnv.


b. For each element d of lexDeclarations, do

25. Remove moduleContext from the execution context stack.

26. Return UNUSED.

16.2.1.6.5 ExecuteModule ( [ capability ] )

The ExecuteModule concrete method of a Source Text Module Record module takes optional argument capability (a PromiseCapability Record) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let moduleContext be a new ECMAScript code execution context.

2. Set the Function of moduleContext to null.

3. Set the Realm of moduleContext to module.[[Realm]].

4. Set the ScriptOrModule of moduleContext to module.

5. Assert: module has been linked and declarations in its module environment have been instantiated.

6. Set the VariableEnvironment of moduleContext to module.[[Environment]].

7. Set the LexicalEnvironment of moduleContext to module.[[Environment]].

8. Suspend the running execution context.

9. If module.[[HasTLA]] is false, then

a. Assert: capability is not present.

b. Push moduleContext onto the execution context stack; moduleContext is now the running execution context.

c. Let result be Completion(Evaluation of module.[[ECMAScriptCode]]).
d. Suspend moduleContext and remove it from the execution context stack.
e. Resume the context that is now on the top of the execution context stack as the running execution context.
f. If result is an abrupt completion, then
   i. Return ? result.
10. Else,
   a. Assert: capability is a PromiseCapability Record.
   b. Perform AsyncBlockStart(capability, module.[[ECMAScriptCode]], moduleContext).
11. Return UNUSED.

16.2.1.7 GetImportedModule (referrer, specifier)

The abstract operation GetImportedModule takes arguments referrer (a Cyclic Module Record) and specifier (a String) and returns a Module Record. It performs the following steps when called:

1. Assert: Exactly one element of referrer.[[LoadedModules]] is a Record whose [[Specifier]] is specifier, since LoadRequestedModules has completed successfully on referrer prior to invoking this abstract operation.
2. Let record be the Record in referrer.[[LoadedModules]] whose [[Specifier]] is specifier.
3. Return record.[[Module]].

16.2.1.8 HostLoadImportedModule (referrer, specifier, hostDefined, payload)

The host-defined abstract operation HostLoadImportedModule takes arguments referrer (a Script Record, a Cyclic Module Record, or a Realm Record), specifier (a String), hostDefined (anything), and payload (a GraphLoadingState Record or a PromiseCapability Record) and returns UNUSED.

An example of when referrer can be a Realm Record is in a web browser host. There, if a user clicks on a control given by

```html
<button type="button" onclick="import('./foo.mjs')">Click me</button>
```

there will be no active script or module at the time the import() expression runs. More generally, this can happen in any situation where the host pushes execution contexts with null ScriptOrModule components onto the execution context stack.

An implementation of HostLoadImportedModule must conform to the following requirements:

- The host environment must perform FinishLoadingImportedModule(referrer, specifier, payload, result), where result is either a normal completion containing the loaded Module Record or a throw completion, either synchronously or asynchronously.
- If this operation is called multiple times with the same (referrer, specifier) pair and it performs FinishLoadingImportedModule(referrer, specifier, payload, result) where result is a normal completion, then it must perform FinishLoadingImportedModule(referrer, specifier, payload, result) with the same result each time.
- The operation must treat payload as an opaque value to be passed through to FinishLoadingImportedModule.

The actual process performed is host-defined, but typically consists of performing whatever I/O operations are necessary to load the appropriate Module Record. Multiple different (referrer, specifier) pairs may map to the same Module Record instance. The actual mapping semantics is host-defined but typically a normalization process is applied to specifier as part of the mapping process. A typical normalization process would include actions such as expansion of relative and abbreviated path specifiers.
16.2.1.9 FinishLoadingImportedModule (referrer, specifier, payload, result)

The abstract operation FinishLoadingImportedModule takes arguments referrer (a ScriptRecord, a Cyclic Module Record, or a Realm Record), specifier (a String), payload (a GraphLoadingState Record or a PromiseCapability Record), and result (either a normal completion containing a ModuleRecord or a throw completion) and returns UNUSED. It performs the following steps when called:

1. If result is a normal completion, then
   a. If referrer.[[LoadedModules]] contains a Record whose [[Specifier]] is specifier, then
      i. Assert: That Record's [[Module]] is result.[[Value]].
   b. Else,
      i. Append the Record {[[Specifier]]: specifier, [[Module]]: result.[[Value]]} to referrer.[[LoadedModules]].
2. If payload is a GraphLoadingState Record, then
   a. Perform ContinueModuleLoading(payload, result).
3. Else,
   a. Perform ContinueDynamicImport(payload, result).
4. Return UNUSED.

16.2.1.10 GetModuleNamespace (module)

The abstract operation GetModuleNamespace takes argument module (an instance of a concrete subclass of ModuleRecord) and returns a ModuleNamespaceObject or EMPTY. It retrieves the Module Namespace Object representing module's exports, lazily creating it the first time it was requested, and storing it in module.[[Name-space]] for future retrieval. It performs the following steps when called:

1. Assert: If module is a Cyclic Module Record, then module.[[Status]] is not NEW or UNLINKED.
2. Let namespace be module.[[Namespace]].
3. If namespace is EMPTY, then
   a. Let exportedNames be module.GetExportedNames().
   b. Let unambiguousNames be a new empty List.
   c. For each element name of exportedNames, do
      i. Let resolution be module.ResolveExport(name).
      ii. If resolution is a ResolvedBinding Record, append name to unambiguousNames.
   d. Set namespace to ModuleNamespaceCreate(module, unambiguousNames).
4. Return namespace.

NOTE GetModuleNamespace never throws. Instead, unresolvable names are simply excluded from the namespace at this point. They will lead to a real linking error later unless they are all ambiguous star exports that are not explicitly requested anywhere.

16.2.1.11 Runtime Semantics: Evaluation

Module : [empty]

1. Return undefined.

ModuleBody : ModuleItemList

1. Let result be Completion(Evaluation of ModuleItemList).
2. If result is a normal completion and result.[[Value]] is EMPTY, then
   a. Return undefined.

ModuleItemList : ModuleItemList ModuleItem

1. Let sl be ? Evaluation of ModuleItemList.
2. Let s be Completion(Evaluation of ModuleItem).
3. Return ? UpdateEmpty(s, sl).
NOTE The value of a ModuleItemList is the value of the last value-producing item in the ModuleItemList.

ModuleItem : ImportDeclaration

1. Return EMPTY.

16.2.2 Imports

Syntax

ImportDeclaration :
import ImportClause FromClause ;
import ModuleSpecifier ;

ImportClause :
ImportedDefaultBinding
NameSpaceImport
NamedImports
ImportedDefaultBinding , NameSpaceImport
ImportedDefaultBinding , NamedImports

ImportedDefaultBinding :
ImportedBinding

NameSpaceImport :
* as ImportedBinding

NamedImports :
{}{}
{ ImportsList }{}
{ ImportsList , }{}

FromClause :
from ModuleSpecifier

ImportsList :
ImportSpecifier
ImportsList , ImportSpecifier

ImportSpecifier :
ImportedBinding
ModuleExportName as ImportedBinding

ModuleSpecifier :
StringLiteral

ImportedBinding :
BindingIdentifier[-Yield, +Await]

16.2.2.1 Static Semantics: Early Errors

ModuleItem : ImportDeclaration

• It is a Syntax Error if the BoundNames of ImportDeclaration contains any duplicate entries.
16.2.2.2 Static Semantics: ImportEntries

The syntax-directed operation ImportEntries takes no arguments and returns a List of ImportEntry Records. It is defined piecewise over the following productions:

_module_ : [empty]

1. Return a new empty List.

_ModuleItemList_ : ModuleItemList ModuleItem

1. Let _entries1_ be ImportEntries of ModuleItemList.
2. Let _entries2_ be ImportEntries of ModuleItem.
3. Return the list-concatenation of _entries1_ and _entries2_.

_module_:
  ExportDeclaration
  StatementListItem

1. Return a new empty List.

_ImportDeclaration_ : import ImportClause FromClause ;

1. Let _module_ be the sole element of ModuleRequests of FromClause.
2. Return ImportEntriesForModule of ImportClause with argument _module_.

_ImportDeclaration_ : import ModuleSpecifier ;

1. Return a new empty List.

16.2.2.3 Static Semantics: ImportEntriesForModule

The syntax-directed operation ImportEntriesForModule takes argument _module_ (a String) and returns a List of ImportEntry Records. It is defined piecewise over the following productions:

_ImportClause_ : ImportedDefaultBinding , NamespaceImport

1. Let _entries1_ be ImportEntriesForModule of ImportedDefaultBinding with argument _module_.
2. Let _entries2_ be ImportEntriesForModule of NamespaceImport with argument _module_.
3. Return the list-concatenation of _entries1_ and _entries2_.

_ImportClause_ : ImportedDefaultBinding , NamedImports

1. Let _entries1_ be ImportEntriesForModule of ImportedDefaultBinding with argument _module_.
2. Let _entries2_ be ImportEntriesForModule of NamedImports with argument _module_.
3. Return the list-concatenation of _entries1_ and _entries2_.

_ImportedDefaultBinding_ : ImportedBinding

1. Let _localName_ be the sole element of BoundNames of ImportedBinding.
2. Let _defaultEntry_ be the ImportEntry Record { [[ModuleRequest]]: _module_, [[ImportName]]: "default", [[LocalName]]: _localName_ }.
3. Return « _defaultEntry_ ».

_NamespaceImport_ : * as ImportedBinding

1. Let _localName_ be the StringValue of ImportedBinding.
2. Let _entry_ be the ImportEntry Record { [[ModuleRequest]]: _module_, [[ImportName]]: NAMESPACE-OBJECT, [[LocalName]]: _localName_ }.
3. Return « _entry_ ».
1. Return a new empty List.

ImportsList : ImportsList , ImportSpecifier

1. Let \( \text{specs1} \) be the ImportEntriesForModule of \( \text{ImportsList} \) with argument \( \text{module} \).
2. Let \( \text{specs2} \) be the ImportEntriesForModule of \( \text{ImportSpecifier} \) with argument \( \text{module} \).
3. Return the list-concatenation of \( \text{specs1} \) and \( \text{specs2} \).

ImportSpecifier : ImportedBinding

1. Let \( \text{localName} \) be the sole element of BoundNames of \( \text{ImportedBinding} \).
2. Let \( \text{entry} \) be the ImportEntry Record \{ [[[ModuleRequest]]]: \( \text{module} \), [[[ImportName]]]: \( \text{localName} \), [[[LocalName]]]: \( \text{localName} \) \}.
3. Return « \( \text{entry} \) ».

ImportSpecifier : ModuleExportName as ImportedBinding

1. Let \( \text{importName} \) be the StringValue of \( \text{ModuleExportName} \).
2. Let \( \text{localName} \) be the StringValue of \( \text{ImportedBinding} \).
3. Let \( \text{entry} \) be the ImportEntry Record \{ [[[ModuleRequest]]]: \( \text{module} \), [[[ImportName]]]: \( \text{importName} \), [[[LocalName]]]: \( \text{localName} \) \}.
4. Return « \( \text{entry} \) ».

16.2.3 Exports

Syntax

ExportDeclaration :

\textbf{export} ExportFromClause FromClause ;
\textbf{export} NamedExports ;
\textbf{export} VariableStatement[~Yield, +Await]
\textbf{export} Declaration[~Yield, +Await]
\textbf{export default} HoistableDeclaration[~Yield, +Await, +Default]
\textbf{export default} ClassDeclaration[~Yield, +Await, +Default]
\textbf{export default} \{ lookahead \( \notin \{ \text{function}, \text{async} \) [no LineTerminator here] \text{function}, \text{class} \} \} AssignmentExpression[+In, ~Yield, +Await] ;

ExportFromClause :

\star
\star \textbf{as} \text{ModuleExportName}
NamedExports

NamedExports :

\{ \}
\{ \text{ExportsList} \}
\{ \text{ExportsList} , \}

ExportsList :

ExportSpecifier
ExportsList , ExportSpecifier

ExportSpecifier :

\text{ModuleExportName}
\text{ModuleExportName} \textbf{as} \text{ModuleExportName}
16.2.3.1 Static Semantics: Early Errors

ExportDeclaration : export NamedExports ;

- It is a Syntax Error if ReferencedBindings of NamedExports contains any StringLiterals.
- For each IdentifierName n in ReferencedBindings of NamedExports: It is a Syntax Error if StringValue of n is a ReservedWord or the StringValue of n is one of "implements", "interface", "let", "package", "private", "protected", "public", or "static".

NOTE The above rule means that each ReferencedBindings of NamedExports is treated as an IdentifierReference.

16.2.3.2 Static Semantics: ExportedBindings

The syntax-directed operation ExportedBindings takes no arguments and returns a List of Strings.

NOTE ExportedBindings are the locally bound names that are explicitly associated with a Module's ExportedNames.

It is defined piecewise over the following productions:

ModuleItemList : ModuleItemList ModuleItem

1. Let names1 be ExportedBindings of ModuleItemList.
2. Let names2 be ExportedBindings of ModuleItem.
3. Return the list-concatenation of names1 and names2.

ModuleItem : ImportDeclaration
StatementListItem

1. Return a new empty List.

ExportDeclaration :
    export ExportFromClause FromClause ;

1. Return a new empty List.

ExportDeclaration : export NamedExports ;

1. Return the ExportedBindings of NamedExports.

ExportDeclaration : export VariableStatement

1. Return the BoundNames of VariableStatement.

ExportDeclaration : export Declaration

1. Return the BoundNames of Declaration.

ExportDeclaration :
    export default HoistableDeclaration
    export default ClassDeclaration
    export default AssignmentExpression ;

1. Return the BoundNames of this ExportDeclaration.
NamedExports : { }

1. Return a new empty List.

ExportsList : ExportsList , ExportSpecifier

1. Let names1 be the ExportedBindings of ExportsList.
2. Let names2 be the ExportedBindings of ExportSpecifier.
3. Return the list-concatenation of names1 and names2.

ExportSpecifier : ModuleExportName

1. Return a List whose sole element is the StringValue of ModuleExportName.

ExportSpecifier : ModuleExportName as ModuleExportName

1. Return a List whose sole element is the StringValue of the first ModuleExportName.

16.2.3.3 Static Semantics: ExportedNames

The syntax-directed operation ExportedNames takes no arguments and returns a List of Strings.

NOTE ExportedNames are the externally visible names that a Module explicitly maps to one of its local name bindings.

It is defined piecewise over the following productions:

ModuleItemList : ModuleItemList ModuleItem

1. Let names1 be ExportedNames of ModuleItemList.
2. Let names2 be ExportedNames of ModuleItem.
3. Return the list-concatenation of names1 and names2.

ModuleItem : ExportDeclaration

1. Return the ExportedNames of ExportDeclaration.

ModuleItem : ImportDeclaration
StatementList.Item

1. Return a new empty List.

ExportDeclaration : export ExportFromClause FromClause ;

1. Return the ExportedNames of ExportFromClause.

ExportFromClause : *

1. Return a new empty List.

ExportFromClause : * as ModuleExportName

1. Return a List whose sole element is the StringValue of ModuleExportName.

ExportFromClause : NamedExports

1. Return the ExportedNames of NamedExports.
ExportDeclaration : export VariableStatement
1. Return the BoundNames of VariableStatement.

ExportDeclaration : export Declaration
1. Return the BoundNames of Declaration.

ExportDeclaration : export default HoistableDeclaration
export default ClassDeclaration
export default AssignmentExpression ;
1. Return « "default" ».

NamedExports : { }
1. Return a new empty List.

ExportsList : ExportsList , ExportSpecifier
1. Let names1 be the ExportedNames of ExportsList.
2. Let names2 be the ExportedNames of ExportSpecifier.
3. Return the list-concatenation of names1 and names2.

ExportSpecifier : ModuleExportName
1. Return a List whose sole element is the StringValue of ModuleExportName.

ExportSpecifier : ModuleExportName as ModuleExportName
1. Return a List whose sole element is the StringValue of the second ModuleExportName.

16.2.3.4 Static Semantics: ExportEntries

The syntax-directed operation ExportEntries takes no arguments and returns a List of ExportEntry Records. It is defined piecewise over the following productions:

Module : [empty]
1. Return a new empty List.

ModuleItemList : ModuleItemList ModuleItem
1. Let entries1 be ExportEntries of ModuleItemList.
2. Let entries2 be ExportEntries of ModuleItem.
3. Return the list-concatenation of entries1 and entries2.

ModuleItem :
  ImportDeclaration
  StatementListItem
1. Return a new empty List.

ExportDeclaration : export ExportFromClause FromClause ;
1. Let module be the sole element of ModuleRequests of FromClause.
2. Return ExportEntriesForModule of ExportFromClause with argument module.
ExportDeclaration : export NamedExports ;

1. Return ExportEntriesForModule of NamedExports with argument null.

ExportDeclaration : export VariableStatement

1. Let entries be a new empty List.
2. Let names be the BoundNames of VariableStatement.
3. For each element name of names, do
   a. Append the ExportEntry Record { [[ModuleRequest]]: null, [[ImportName]]: null, [[LocalName]]: name, [[ExportName]]: name } to entries.
4. Return entries.

ExportDeclaration : export Declaration

1. Let entries be a new empty List.
2. Let names be the BoundNames of Declaration.
3. For each element name of names, do
   a. Append the ExportEntry Record { [[ModuleRequest]]: null, [[ImportName]]: null, [[LocalName]]: name, [[ExportName]]: name } to entries.
4. Return entries.

ExportDeclaration : export default HoistableDeclaration

1. Let names be BoundNames of HoistableDeclaration.
2. Let localName be the sole element of names.
3. Return a List whose sole element is a new ExportEntry Record { [[ModuleRequest]]: null, [[ImportName]]: null, [[LocalName]]: localName, [[ExportName]]: "default" }.

ExportDeclaration : export default ClassDeclaration

1. Let names be BoundNames of ClassDeclaration.
2. Let localName be the sole element of names.
3. Return a List whose sole element is a new ExportEntry Record { [[ModuleRequest]]: null, [[ImportName]]: null, [[LocalName]]: localName, [[ExportName]]: "default" }.

ExportDeclaration : export default AssignmentExpression ;

1. Let entry be the ExportEntry Record { [[ModuleRequest]]: null, [[ImportName]]: null, [[LocalName]]: "default", [[ExportName]]: "default" }.
2. Return « entry ».

NOTE "default" is used within this specification as a synthetic name for anonymous default export values. See this note for more details.

16.2.3.5 Static Semantics: ExportEntriesForModule

The syntax-directed operation ExportEntriesForModule takes argument module (a String or null) and returns a List of ExportEntry Records. It is defined piecewise over the following productions:

ExportFromClause : *

1. Let entry be the ExportEntry Record { [[ModuleRequest]]: module, [[ImportName]]: ALL-BUT-DEFAULT, [[LocalName]]: null, [[ExportName]]: null }.
2. Return « entry ».
ExportFromClause : ★ as ModuleExportName

1. Let exportName be the StringValue of ModuleExportName.
2. Let entry be the ExportEntry Record { [[ModuleRequest]]: module, [[ImportName]]: ALL, [[LocalName]]: null, [[ExportName]]: exportName }.
3. Return « entry ».

NamedExports : { }

1. Return a new empty List.

ExportsList : ExportsList , ExportSpecifier

1. Let specs1 be the ExportEntriesForModule of ExportsList with argument module.
2. Let specs2 be the ExportEntriesForModule of ExportSpecifier with argument module.
3. Return the list-concatenation of specs1 and specs2.

ExportSpecifier : ModuleExportName

1. Let sourceName be the StringValue of ModuleExportName.
2. If module is null, then
   a. Let localName be sourceName.
   b. Let importName be null.
3. Else,
   a. Let localName be null.
   b. Let importName be sourceName.
4. Return a List whose sole element is a new ExportEntry Record { [[ModuleRequest]]: module, [[ImportName]]: importName, [[LocalName]]: localName, [[ExportName]]: sourceName }.

ExportSpecifier : ModuleExportName as ModuleExportName

1. Let sourceName be the StringValue of the first ModuleExportName.
2. Let exportName be the StringValue of the second ModuleExportName.
3. If module is null, then
   a. Let localName be sourceName.
   b. Let importName be null.
4. Else,
   a. Let localName be null.
   b. Let importName be sourceName.
5. Return a List whose sole element is a new ExportEntry Record { [[ModuleRequest]]: module, [[ImportName]]: importName, [[LocalName]]: localName, [[ExportName]]: exportName }.

16.2.3.6 Static Semantics: ReferencedBindings

The syntax-directed operation ReferencedBindings takes no arguments and returns a List of Parse Nodes. It is defined piecewise over the following productions:

NamedExports : { }

1. Return a new empty List.

ExportsList : ExportsList , ExportSpecifier

1. Let names1 be the ReferencedBindings of ExportsList.
2. Let names2 be the ReferencedBindings of ExportSpecifier.
3. Return the list-concatenation of names1 and names2.

ExportSpecifier : ModuleExportName as ModuleExportName

1. Return the ReferencedBindings of the first ModuleExportName.
ModuleExportName : IdentifierName

1. Return a List whose sole element is the IdentifierName.

ModuleExportName : StringLiteral

1. Return a List whose sole element is the StringLiteral.

### 16.2.3.7 Runtime Semantics: Evaluation

**ExportDeclaration**:

1. Return EMPTYS.

**ExportDeclaration** : \texttt{export} VariableStatement


**ExportDeclaration** : \texttt{export} Declaration


**ExportDeclaration** : \texttt{export default} HoistableDeclaration


**ExportDeclaration** : \texttt{export default} ClassDeclaration

1. Let \texttt{value} be ? BindingClassDeclarationEvaluation of ClassDeclaration.
2. Let \texttt{className} be the sole element of BoundNames of ClassDeclaration.
3. If \texttt{className} is \texttt{"default"}, then
   a. Let \texttt{env} be the running execution context's LexicalEnvironment.
   b. Perform ? InitializeBoundName\texttt{("default", value, env)}.
4. Return EMPTYS.

**ExportDeclaration** : \texttt{export default} AssignmentExpression

1. If \texttt{isAnonymousFunctionDefinition(AssignmentExpression)} is \texttt{true}, then
   a. Let \texttt{value} be ? NamedEvaluation of AssignmentExpression with argument \texttt{"default"}.
2. Else,
   a. Let \texttt{rhs} be ? Evaluation of AssignmentExpression.
   b. Let \texttt{value} be ? GetValue(rhs).
3. Let \texttt{env} be the running execution context's LexicalEnvironment.
4. Perform ? InitializeBoundName\texttt{("default", value, env)}.
5. Return EMPTYS.

### 17 Error Handling and Language Extensions

An implementation must report most errors at the time the relevant ECMAScript language construct is evaluated. An \textit{early error} is an error that can be detected and reported prior to the evaluation of any construct in the \textit{Script} containing the error. The presence of an \textit{early error} prevents the evaluation of the construct. An implementation must report \textit{early errors} in a \textit{Script} as part of parsing that \textit{Script} in \textit{ParseScript}. \textit{Early errors} in a \textit{Module} are reported at the point when the \textit{Module} would be evaluated and the \textit{Module} is never initialized. \textit{Early errors} in
**eval** code are reported at the time **eval** is called and prevent evaluation of the **eval** code. All errors that are not early errors are runtime errors.

An implementation must report as an early error any occurrence of a condition that is listed in a “Static Semantics: Early Errors” subclause of this specification.

An implementation shall not treat other kinds of errors as early errors even if the compiler can prove that a construct cannot execute without error under any circumstances. An implementation may issue an early warning in such a case, but it should not report the error until the relevant construct is actually executed.

An implementation shall report all errors as specified, except for the following:

- Except as restricted in 17.1, a host or implementation may extend **Script** syntax, **Module** syntax, and regular expression pattern or flag syntax. To permit this, all operations (such as calling **eval**, using a regular expression literal, or using the Function or **RegExp** constructor) that are allowed to throw **SyntaxError** are permitted to exhibit host-defined behaviour instead of throwing **SyntaxError** when they encounter a host-defined extension to the script syntax or regular expression pattern or flag syntax.
- Except as restricted in 17.1, a host or implementation may provide additional types, values, objects, properties, and functions beyond those described in this specification. This may cause constructs (such as looking up a variable in the global scope) to have host-defined behaviour instead of throwing an error (such as **ReferenceError**).

### 17.1 Forbidden Extensions

An implementation must not extend this specification in the following ways:

- ECMAScript function objects defined using syntactic constructors in strict mode code must not be created with own properties named "**caller**" or "**arguments**". Such own properties also must not be created for function objects defined using an **ArrowFunction**, **MethodDefinition**, **GeneratorDeclaration**, **GeneratorExpression**, **AsyncGeneratorDeclaration**, **AsyncGeneratorExpression**, **ClassDeclaration**, **ClassExpression**, **AsyncFunctionDeclaration**, **AsyncFunctionExpression**, or **AsyncArrowFunction** regardless of whether the definition is contained in strict mode code. Built-in functions, strict functions created using the Function constructor, generator functions created using the Generator constructor, async functions created using the AsyncFunction constructor, and functions created using the **bind** method also must not be created with such own properties.
- If an implementation extends any function object with an own property named "**caller**" the value of that property, as observed using [[Get]] or [[GetOwnProperty]], must not be a strict function object. If it is an accessor property, the function that is the value of the property's [[Get]] attribute must never return a strict function when called.
- Neither mapped nor unmapped arguments objects may be created with an own property named "**caller**".
- The behaviour of built-in methods which are specified in ECMA-402, such as those named **toLocaleString**, must not be extended except as specified in ECMA-402.
- The **RegExp** pattern grammars in 22.2.1 and B.1.2 must not be extended to recognize any of the source characters A-Z or a-z as **IdentityEscape**[UnicodeMode] when the [UnicodeMode] grammar parameter is present.
- The Syntactic Grammar must not be extended in any manner that allows the token : to immediately follow source text that is matched by the **BindingIdentifier** nonterminal symbol.
- When processing strict mode code, an implementation must not relax the early error rules of 12.9.3.1.
- **TemplateEscapeSequence** must not be extended to include **LegacyOctalEscapeSequence** or **NonOctalDecimalEscapeSequence** as defined in 12.9.4.
- When processing strict mode code, the extensions defined in B.3.1, B.3.2, B.3.3, and B.3.5 must not be supported.
- When parsing for the **Module goal symbol**, the lexical grammar extensions defined in B.1.1 must not be supported.
- **ImportCall** must not be extended.
18 ECMAScript Standard Built-in Objects

There are certain built-in objects available whenever an ECMAScript Script or Module begins execution. One, the global object, is part of the global environment of the executing program. Others are accessible as initial properties of the global object or indirectly as properties of accessible built-in objects.

Unless specified otherwise, a built-in object that is callable as a function is a built-in function object with the characteristics described in 10.3. Unless specified otherwise, the [[Extensible]] internal slot of a built-in object initially has the value true. Every built-in function object has a [[Realm]] internal slot whose value is the Realm Record of the realm for which the object was initially created.

Many built-in objects are functions: they can be invoked with arguments. Some of them furthermore are constructors: they are functions intended for use with the new operator. For each built-in function, this specification describes the arguments required by that function and the properties of that function object. For each built-in constructor, this specification furthermore describes properties of the prototype object of that constructor and properties of specific object instances returned by a new expression that invokes that constructor.

Unless otherwise specified in the description of a particular function, if a built-in function or constructor is given fewer arguments than the function is specified to require, the function or constructor shall behave exactly as if it had been given sufficient additional arguments, each such argument being the undefined value. Such missing arguments are considered to be "not present" and may be identified in that manner by specification algorithms. In the description of a particular function, the terms "this" value and "NewTarget" have the meanings given in 10.3.

Unless otherwise specified in the description of a particular function, if a built-in function or constructor described is given more arguments than the function is specified to allow, the extra arguments are evaluated by the call and then ignored by the function. However, an implementation may define implementation specific behaviour relating to such arguments as long as the behaviour is not the throwing of a TypeError exception that is predicated simply on the presence of an extra argument.

NOTE 1 Implementations that add additional capabilities to the set of built-in functions are encouraged to do so by adding new functions rather than adding new parameters to existing functions.

Unless otherwise specified every built-in function and every built-in constructor has the Function prototype object, which is the initial value of the expression Function.prototype (20.2.3), as the value of its [[Prototype]] internal slot.

Unless otherwise specified every built-in prototype object has the Object prototype object, which is the initial value of the expression Object.prototype (20.1.3), as the value of its [[Prototype]] internal slot, except the Object prototype object itself.

If this specification defines a built-in constructor’s behaviour via algorithm steps, then that is its behaviour for the purposes of both [[Call]] and [[Construct]]. If such an algorithm needs to distinguish the two cases, it checks whether NewTarget is undefined, which indicates a [[Call]] invocation.

Built-in function objects that are not identified as constructors do not implement the [[Construct]] internal method unless otherwise specified in the description of a particular function.

Built-in function objects that are not constructors do not have a "prototype" property unless otherwise specified in the description of a particular function.

Each built-in function defined in this specification is created by calling the CreateBuiltinFunction abstract operation (10.3.4). The values of the length and name parameters are the initial values of the "length" and "name" properties as discussed below. The values of the prefix parameter are similarly discussed below.

Every built-in function object, including constructors, has a "length" property whose value is a non-negative integral Number. Unless otherwise specified, this value is the number of required parameters shown in the subclause heading for the function description. Optional parameters and rest parameters are not included in the parameter count.
NOTE 2  For example, the function object that is the initial value of the "map" property of the Array prototype object is described under the subclause heading «Array.prototype.map (callbackFm [ , thisArg])» which shows the two named arguments callbackFm and thisArg, the latter being optional; therefore the value of the "length" property of that function object is 1.

Unless otherwise specified, the "length" property of a built-in function object has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

Every built-in function object, including constructors, has a "name" property whose value is a String. Unless otherwise specified, this value is the name that is given to the function in this specification. Functions that are identified as anonymous functions use the empty String as the value of the "name" property. For functions that are specified as properties of objects, the name value is the property name string used to access the function. Functions that are specified as get or set accessor functions of built-in properties have "get" or "set" (respectively) passed to the prefix parameter when calling CreateBuiltinFunction.

The value of the "name" property is explicitly specified for each built-in functions whose property key is a Symbol value. If such an explicitly specified value starts with the prefix "get " or "set " and the function for which it is specified is a get or set accessor function of a built-in property, the value without the prefix is passed to the name parameter, and the value "get" or "set" (respectively) is passed to the prefix parameter when calling CreateBuiltinFunction.

Unless otherwise specified, the "name" property of a built-in function object has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

Every other data property described in clauses 19 through 28 and in Annex B.2 has the attributes { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true } unless otherwise specified.

Every accessor property described in clauses 19 through 28 and in Annex B.2 has the attributes { [[Enumerable]]: false, [[Configurable]]: true } unless otherwise specified. If only a get accessor function is described, the set accessor function is the default value, undefined. If only a set accessor is described the get accessor is the default value, undefined.

19 The Global Object

The global object:

- is created before control enters any execution context.
- does not have a [[Construct]] internal method; it cannot be used as a constructor with the new operator.
- does not have a [[Call]] internal method; it cannot be invoked as a function.
- has a [[Prototype]] internal slot whose value is host-defined.
- may have host-defined properties in addition to the properties defined in this specification. This may include a property whose value is the global object itself.

19.1 Value Properties of the Global Object

19.1.1 globalThis

The initial value of the "globalThis" property of the global object in a Realm Record realm is realm.[[Global-Env]].[[GlobalThisValue]].

This property has the attributes { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: true }.

19.1.2 Infinity

The value of Infinity is +∞ (see 6.1.6.1). This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }. 
19.1.3 NaN

The value of NaN is NaN (see 6.1.6.1). This property has the attributes \{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false \}.

19.1.4 undefined

The value of undefined is undefined (see 6.1.1). This property has the attributes \{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false \}.

19.2 Function Properties of the Global Object

19.2.1 eval (x)

This function is the %eval% intrinsic object.

It performs the following steps when called:
1. Return ? PerformEval(x, false, false).

19.2.1.1 PerformEval (x, strictCaller, direct)

The abstract operation PerformEval takes arguments x (an ECMAScript language value), strictCaller (a Boolean), and direct (a Boolean) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Assert: If direct is false, then strictCaller is also false.
2. If x is not a String, return x.
3. Let evalRealm be the current Realm Record.
4. NOTE: In the case of a direct eval, evalRealm is the realm of both the caller of eval and of the eval function itself.
6. Let inFunction be false.
7. Let inMethod be false.
8. Let inDerivedConstructor be false.
9. Let inClassFieldInitializer be false.
10. If direct is true, then
    a. Let thisEnvRec be GetThisEnvironment().
    b. If thisEnvRec is a Function Environment Record, then
       i. Let F be thisEnvRec.[[FunctionObject]].
       ii. Set inFunction to true.
       iii. Set inMethod to thisEnvRec.HasSuperBinding().
       iv. If F.[[ConstructorKind]] is DERIVED, set inDerivedConstructor to true.
       v. Let classFieldInitializerName be F.[[ClassFieldInitializerName]].
       vi. If classFieldInitializerName is not EMPTY, set inClassFieldInitializer to true.
11. Perform the following substeps in an implementation-defined order, possibly interleaving parsing and error detection:
    a. Let script be ParseText(StringToCodePoints(x), Script).
    b. If script is a List of errors, throw a SyntaxError exception.
    c. If script Contains ScriptBody is false, return undefined.
    d. Let body be the ScriptBody of script.
    e. If inFunction is false and body Contains NewTarget, throw a SyntaxError exception.
    f. If inMethod is false and body Contains SuperProperty, throw a SyntaxError exception.
    g. If inDerivedConstructor is false and body Contains SuperCall, throw a SyntaxError exception.
    h. If inClassFieldInitializer is true and ContainesArguments of body is true, throw a SyntaxError exception.
12. If strictCaller is true, let strictEval be true.
13. Else, let strictEval be IsStrict of script.
14. Let runningContext be the running execution context.
NOTE: If \textit{direct} is \textit{true}, \textit{runningContext} will be the execution context that performed the direct eval. If \textit{direct} is \textit{false}, \textit{runningContext} will be the execution context for the invocation of the \texttt{eval} function.

If \textit{direct} is \textit{true}, then

\begin{itemize}
    \item Let \textit{lexEnv} be \texttt{NewDeclarativeEnvironment(runningContext's LexicalEnvironment)}.
    \item Let \textit{varEnv} be \texttt{runningContext's VariableEnvironment}.
    \item Let \textit{privateEnv} be \texttt{runningContext's PrivateEnvironment}.
\end{itemize}

Else,

\begin{itemize}
    \item Let \textit{lexEnv} be \texttt{NewDeclarativeEnvironment(evalRealm.\[[\text{GlobalEnv}]\])}.
    \item Let \textit{varEnv} be \texttt{evalRealm.\[[\text{GlobalEnv}]\]}.
    \item Let \textit{privateEnv} be \texttt{null}.
\end{itemize}

If \textit{strictEval} is \textit{true}, set \textit{varEnv} to \textit{lexEnv}.

If \textit{runningContext} is not already suspended, suspend \textit{runningContext}.

Let \textit{evalContext} be a new ECMAScript code execution context.

Set \textit{evalContext}'s Function to \texttt{null}.

Set \textit{evalContext}'s Realm to \textit{evalRealm}.

Set \textit{evalContext}'s ScriptOrModule to \textit{runningContext}'s ScriptOrModule.

Set \textit{evalContext}'s VariableEnvironment to \textit{varEnv}.

Set \textit{evalContext}'s LexicalEnvironment to \textit{lexEnv}.

Set \textit{evalContext}'s PrivateEnvironment to \textit{privateEnv}.

Push \textit{evalContext} onto the execution context stack; \textit{evalContext} is now the running execution context.

Let \textit{result} be \texttt{Completion(EvalDeclarationInstantiation(body, varEnv, lexEnv, privateEnv, strictEval))}.

If \textit{result} is a normal completion, then

\begin{itemize}
    \item Set \textit{result} to \texttt{Completion(\texttt{Evaluation of body})}.
\end{itemize}

If \textit{result} is a normal completion and \textit{result}.\[[\text{Value}]\] is \texttt{EMPTY}, then

\begin{itemize}
    \item Set \textit{result} to \texttt{NormalCompletion(\texttt{undefined})}.
\end{itemize}

Suspend \textit{evalContext} and remove it from the execution context stack.

Resume the context that is now on the top of the execution context stack as the running execution context.

Return \texttt{? result}.

\begin{itemize}
    \item The eval code cannot instantiate variable or function bindings in the variable environment of the calling context that invoked the eval if either the code of the calling context or the eval code is \texttt{strict mode code}. Instead such bindings are instantiated in a new VariableEnvironment that is only accessible to the eval code. Bindings introduced by \texttt{let}, \texttt{const}, or \texttt{class} declarations are always instantiated in a new LexicalEnvironment.
\end{itemize}

\subsection{19.2.1.2 HostEnsureCanCompileStrings (calleeRealm, parameterStrings, bodyString, direct)}

The host-defined abstract operation \texttt{HostEnsureCanCompileStrings} takes arguments \texttt{calleeRealm} (a \texttt{Realm Record}), \texttt{parameterStrings} (a \texttt{List} of \texttt{Strings}), \texttt{bodyString} (a \texttt{String}), and \texttt{direct} (a \texttt{Boolean}) and returns either a normal completion containing \texttt{UNUSED} or a throw completion. It allows host environments to block certain ECMAScript functions which allow developers to interpret and evaluate strings as ECMAScript code.

\texttt{parameterStrings} represents the strings that, when using one of the function constructors, will be concatenated together to build the parameters list. \texttt{bodyString} represents the function body or the string passed to an \texttt{eval} call. \texttt{direct} signifies whether the evaluation is a direct eval.

The default implementation of \texttt{HostEnsureCanCompileStrings} is to return \texttt{NormalCompletion(UNUSED)}.

\subsection{19.2.1.3 EvalDeclarationInstantiation (body, varEnv, lexEnv, privateEnv, strict)}

The abstract operation \texttt{EvalDeclarationInstantiation} takes arguments \texttt{body} (a \texttt{ScriptBody Parse Node}), \texttt{varEnv} (an \texttt{Environment Record}), \texttt{lexEnv} (a \texttt{Declarative Environment Record}), \texttt{privateEnv} (a \texttt{PrivateEnvironment Record} or \texttt{null}), and \texttt{strict} (a \texttt{Boolean}) and returns either a normal completion containing \texttt{UNUSED} or a throw completion. It performs the following steps when called:

\begin{enumerate}
    \item Let \textit{varNames} be the \texttt{VarDeclaredNames} of \texttt{body}.
    \item Let \textit{varDeclarations} be the \texttt{VarScopedDeclarations} of \texttt{body}.
    \item If \textit{strict} is \textit{false}, then
a. If `varEnv` is a Global Environment Record, then
   i. For each element name of varNames, do
      1. If `varEnv.HasLexicalDeclaration(name)` is true, throw a SyntaxError exception.
      2. NOTE: eval will not create a global var declaration that would be shadowed by a global lexical declaration.

b. Let `thisEnv` be lexEnv.

c. Assert: The following loop will terminate.

d. Repeat, while `thisEnv` is not `varEnv`,
   i. If `thisEnv` is not an Object Environment Record, then
      1. NOTE: The environment of with statements cannot contain any lexical declaration so it doesn’t need to be checked for var/let hoisting conflicts.
      2. For each element name of varNames, do
         a. If `thisEnv.HasBinding(name)` is true, then
            i. Throw a SyntaxError exception.
            ii. NOTE: Annex B.3.4 defines alternate semantics for the above step.
         b. NOTE: A direct eval will not hoist var declaration over a like-named lexical declaration.
   ii. Set `thisEnv` to `thisEnv`.[[OuterEnv]].

4. Let privateIdentifiers be a new empty List.
5. Let pointer be privateEnv.
6. Repeat, while pointer is not null,
   a. For each Private Name binding of pointer.[[Names]], do
      i. If `privateIdentifiers` does not contain binding.[[Description]], append binding.[[Description]] to privateIdentifiers.
      b. Set pointer to pointer.[[OuterPrivateEnvironment]].
7. If AllPrivateIdentifiersValid of body with argument privateIdentifiers is false, throw a SyntaxError exception.
8. Let functionsToInitialize be a new empty List.
9. Let declaredFunctionNames be a new empty List.
10. For each element d of varDeclarations, in reverse List order, do
   a. If d is not either a VariableDeclaration, a ForBinding, or a BindingIdentifier, then
      i. Assert: d is either a FunctionDeclaration, a GeneratorDeclaration, an AsyncFunctionDeclaration, or an AsyncGeneratorDeclaration.
      ii. NOTE: If there are multiple function declarations for the same name, the last declaration is used.
      iii. Let fn be the sole element of the BoundNames of d.
      iv. If `declaredFunctionNames` does not contain fn, then
         1. If `varEnv` is a Global Environment Record, then
            a. Let `fnDefinable` be `varEnv.CanDeclareGlobalFunction(fn)`.
            b. If `fnDefinable` is false, throw a TypeError exception.
         2. Append fn to `declaredFunctionNames`.
         3. Insert d as the first element of functionsToInitialize.
   b. If d is either a VariableDeclaration, a ForBinding, or a BindingIdentifier, then
      i. For each String vn of the BoundNames of d, do
         1. If `declaredFunctionNames` does not contain vn, then
            a. If `varEnv` is a Global Environment Record, then
               i. Let `vnDefinable` be `varEnv.CanDeclareGlobalVar(vn)`.
               ii. If `vnDefinable` is false, throw a TypeError exception.
            b. If `declaredVarNames` does not contain vn, then
               i. Append vn to `declaredVarNames`.
11. Let declaredVarNames be a new empty List.
12. For each element d of varDeclarations, do
   a. If d is either a VariableDeclaration, a ForBinding, or a BindingIdentifier, then
      i. For each String vn of the BoundNames of d, do
         1. If `IsConstantDeclaration of d` is true, then
            1. Perform `lexEnv.CreateImmutableBinding(dn, true)`.
         2. Else,
            1. Perform `lexEnv.CreateMutableBinding(dn, false)`.
13. NOTE: Annex B.3.2.3 adds additional steps at this point.
14. NOTE: No abnormal terminations occur after this algorithm step unless `varEnv` is a Global Environment Record and the global object is a Proxy exotic object.
15. Let lexDeclarations be the LexicallyScopedDeclarations of body.
16. For each element d of lexDeclarations, do
   a. NOTE: Lexically declared names are only instantiated here but not initialized.
   b. For each element dn of the BoundNames of d, do
      i. If `IsConstantDeclaration of d` is true, then
         1. Perform `lexEnv.CreateImmutableBinding(dn, true)`.
      ii. Else,
         1. Perform `lexEnv.CreateMutableBinding(dn, false)`.
17. For each Parse Node f of functionsToInitialize, do
Let $fn$ be the sole element of the `BoundNames` of $f$.

Let $fo$ be `InstantiateFunctionObject` of $f$ with arguments `lexEnv` and `privateEnv`.

If `varEnv` is a `Global Environment Record`, then
  1. Perform `? varEnv.CreateGlobalFunctionBinding($fn$, $fo$, true)`.

Else,
  1. Let `bindingExists` be `true`.
  2. If `bindingExists` is `false`, then
     1. NOTE: The following invocation cannot return an abrupt completion because of the validation preceding step 14.
     2. Perform `? varEnv.SetMutableBinding($fn$, $fo$)`.
     3. Perform `? varEnv.InitializeBinding($fn$, $fo$)`.
  3. Else,
     1. For each String $vn$ of `declaredVarNames`, do
        a. If `varEnv` is a `Global Environment Record`, then
           i. Perform `? varEnv.CreateGlobalVarBinding($vn$, true)`.
        b. Else,
           i. Let `bindingExists` be `true`.
           ii. If `bindingExists` is `false`, then
                1. NOTE: The following invocation cannot return an abrupt completion because of the validation preceding step 14.
                2. Perform ! `varEnv.CreateMutableBinding($vn$, true)`.
                3. Perform ! `varEnv.InitializeBinding($vn$, undefined)`.

Return `UNUSED`.

NOTE An alternative version of this algorithm is described in B.3.4.

19.2.2 `isFinite ( number )`

This function is the `%isFinite% intrinsic object.

It performs the following steps when called:

1. Let `num` be `? ToNumber(number)`.
2. If `num` is not finite, return `false`.
3. Otherwise, return `true`.

19.2.3 `isNaN ( number )`

This function is the `%isNaN% intrinsic object.

It performs the following steps when called:

1. Let `num` be `? ToNumber(number)`.
2. If `num` is `NaN`, return `true`.
3. Otherwise, return `false`.

NOTE A reliable way for ECMAScript code to test if a value $X$ is `NaN` is an expression of the form $X !== X$. The result will be `true` if and only if $X$ is `NaN`.

19.2.4 `parseFloat ( string )`

This function produces a Number value dictated by interpretation of the contents of the `string` argument as a decimal literal.

It is the `%parseFloat% intrinsic object.
It performs the following steps when called:

1. Let `inputString` be `ToString(string)`.  
2. Let `trimmedString` be `TrimString(inputString, START)`.  
3. Let `trimmed` be `StringToCodePoints(trimmedString)`.  
4. Let `trimmedPrefix` be the longest prefix of `trimmed` that satisfies the syntax of a `StrDecimalLiteral`, which might be `trimmed` itself. If there is no such prefix, return `NaN`.  
5. Let `parsedNumber` be `ParseText(trimmedPrefix, StrDecimalLiteral)`.  
6. Assert: `parsedNumber` is a `Parse Node`.  
7. Return `StringNumericValue` of `parsedNumber`.

NOTE This function may interpret only a leading portion of `string` as a Number value; it ignores any code units that cannot be interpreted as part of the notation of a decimal literal, and no indication is given that any such code units were ignored.

19.2.5 `parseInt` ( `string`, `radix` )

This function produces an integral `Number` dictated by interpretation of the contents of `string` according to the specified `radix`. Leading white space in `string` is ignored. If `radix` coerces to 0 (such as when it is `undefined`), it is assumed to be 10 except when the number representation begins with "0x" or "0X", in which case it is assumed to be 16. If `radix` is 16, the number representation may optionally begin with "0x" or "0X".

It is the `%parseInt% intrinsic object.

It performs the following steps when called:

1. Let `inputString` be `ToString(string)`.  
2. Let `S` be `TrimString(inputString, START)`.  
3. Let `sign` be 1.  
4. If `S` is not empty and the first code unit of `S` is the code unit 0x002D (HYPHEN-MINUS), set `sign` to -1.  
5. If `S` is not empty and the first code unit of `S` is either the code unit 0x002B (PLUS SIGN) or the code unit 0x002D (HYPHEN-MINUS), set `S` to the substring of `S` from index 1.  
6. Let `R` be `R(? ToInt32(radix))`.  
7. Let `stripPrefix` be true.  
8. If `R ≠ 0`, then  
   a. If `R < 2` or `R > 36`, return `NaN`.  
   b. If `R ≠ 16`, set `stripPrefix` to false.  
9. Else,  
   a. Set `R` to 10.  
10. If `stripPrefix` is true, then  
   a. If the length of `S` is at least 2 and the first two code units of `S` are either "0x" or "0X", then  
      i. Set `S` to the substring of `S` from index 2.  
      ii. Set `R` to 16.  
11. If `S` contains a code unit that is not a radix-`R` digit, let `end` be the index within `S` of the first such code unit; otherwise, let `end` be the length of `S`.  
12. Let `Z` be the substring of `S` from 0 to `end`.  
13. If `Z` is empty, return `NaN`.  
14. Let `mathInt` be the integer value that is represented by `Z` in radix-`R` notation, using the letters A through Z and a through z for digits with values 10 through 35. (However, if `R = 10` and `Z` contains more than 20 significant digits, every significant digit after the 20th may be replaced by a 0 digit, at the option of the implementation; and if `R` is not one of 2, 4, 8, 10, 16, or 32, then `mathInt` may be an implementation-approximated integer representing the integer value denoted by `Z` in radix-`R` notation.)  
15. If `mathInt` = 0, then  
   a. If `sign` = -1, return `-0F`.  
   b. Return `+0F`.  

19.2.6 `parseFloat` ( `string` )

This function produces a number represented as a floating-point `Number` according to the `radix` specified by the contents of the `string`. Leading white space in `string` is ignored. If `radix` coerces to 0 (such as when it is `undefined`), it is assumed to be 10 except when the number representation begins with "0x" or "0X", in which case it is assumed to be 16. If `radix` is 16, the number representation may optionally begin with "0x" or "0X".

19.2.6.1 When `radix` is 10

It performs the following steps when called:

1. Let `inputString` be `ToString(string)`.  
2. Let `convertedString` be `TrimString(inputString, START)`.  
3. Let `trimmedString` be `StringLengthToCodePoints(convertedString)`.  
4. Let `trimmed` be the longest prefix of `trimmedString` that satisfies the syntax of a `StrDecimalLiteral`, which might be `trimmedString` itself. If there is no such prefix, return `NaN`.  
5. Let `parsedNumber` be `ParseText(trimmed, StrDecimalLiteral)`.  
6. Assert: `parsedNumber` is a `Parse Node`.  
7. Return `NumberNumericValue` of `parsedNumber`.
NOTE This function may interpret only a leading portion of string as an integer value; it ignores any code units that cannot be interpreted as part of the notation of an integer, and no indication is given that any such code units were ignored.

19.2.6 URI Handling Functions

Uniform Resource Identifiers, or URIs, are Strings that identify resources (e.g. web pages or files) and transport protocols by which to access them (e.g. HTTP or FTP) on the Internet. The ECMAScript language itself does not provide any support for using URIs except for functions that encode and decode URIs as described in this section. encodeURI and decodeURI are intended to work with complete URIs; they assume that any reserved characters are intended to have special meaning (e.g., as delimiters) and so are not encoded. encodeURIComponent and decodeURIComponent are intended to work with the individual components of a URI; they assume that any reserved characters represent text and must be encoded to avoid special meaning when the component is part of a complete URI.

NOTE 1 The set of reserved characters is based upon RFC 2396 and does not reflect changes introduced by the more recent RFC 3986.

NOTE 2 Many implementations of ECMAScript provide additional functions and methods that manipulate web pages; these functions are beyond the scope of this standard.

19.2.6.1 decodeURI (encodedURI)

This function computes a new version of a URI in which each escape sequence and UTF-8 encoding of the sort that might be introduced by the encodeURI function is replaced with the UTF-16 encoding of the code point that it represents. Escape sequences that could not have been introduced by encodeURI are not replaced.

It is the %decodeURI% intrinsic object.

It performs the following steps when called:

1. Let uriString be ? ToString(encodedURI).
2. Let preserveEscapeSet be ";/:@&=+$,#".

19.2.6.2 decodeURIComponent (encodedURIComponent)

This function computes a new version of a URI in which each escape sequence and UTF-8 encoding of the sort that might be introduced by the encodeURIComponent function is replaced with the UTF-16 encoding of the code point that it represents.

It is the %decodeURIComponent% intrinsic object.

It performs the following steps when called:

1. Let componentString be ? ToString(encodedURIComponent).
2. Let preserveEscapeSet be the empty String.
19.2.6.3 encodeURI ( uri )

This function computes a new version of a UTF-16 encoded (6.1.4) URI in which each instance of certain code points is replaced by one, two, three, or four escape sequences representing the UTF-8 encoding of the code point.

It is the %encodeURI% intrinsic object.

It performs the following steps when called:

1. Let uriString be ? ToString(uri).
2. Let extraUnescaped be ";/@&=+$,#".

19.2.6.4 encodeURIComponent ( uriComponent )

This function computes a new version of a UTF-16 encoded (6.1.4) URI in which each instance of certain code points is replaced by one, two, three, or four escape sequences representing the UTF-8 encoding of the code point.

It is the %encodeURIComponent% intrinsic object.

It performs the following steps when called:

1. Let componentString be ? ToString(uriComponent).
2. Let extraUnescaped be the empty String.

19.2.6.5 Encode ( string, extraUnescaped )

The abstract operation Encode takes arguments string (a String) and extraUnescaped (a String) and returns either a normal completion containing a String or a throw completion. It performs URI encoding and escaping, interpreting string as a sequence of UTF-16 encoded code points as described in 6.1.4. If a character is identified as unreserved in RFC 2396 or appears in extraUnescaped, it is not escaped. It performs the following steps when called:

1. Let len be the length of string.
2. Let R be the empty String.
3. Let alwaysUnescaped be the string-concatenation of the ASCII word characters and ".-!~*'()".
4. Let unescapedSet be the string-concatenation of alwaysUnescaped and extraUnescaped.
5. Let k be 0.
6. Repeat, while k < len,
   a. Let C be the code unit at index k within string.
   b. If unescapedSet contains C, then
      i. Set k to k + 1.
      ii. Set R to the string-concatenation of R and C.
   c. Else,
      i. Let cp be CodePointAt(string, k).
      ii. If cp.[[IsUnpairedSurrogate]] is true, throw a URIError exception.
      iii. Set k to k + cp.[[CodeUnitCount]].
      iv. Let Octets be the List of octets resulting by applying the UTF-8 transformation to cp.[[CodePoint]].
      v. For each element octet of Octets, do
         1. Let hex be the String representation of octet, formatted as an uppercase hexadecimal number.
         2. Set R to the string-concatenation of R, "%", and StringPad(hex, 2, "0", START).
   7. Return R.

NOTE Because percent-encoding is used to represent individual octets, a single code point may be expressed as multiple consecutive escape sequences (one for each of its 8-bit UTF-8 code units).
19.2.6.6 Decode (string, preserveEscapeSet)

The abstract operation Decode takes arguments string (a String) and preserveEscapeSet (a String) and returns either a normal completion containing a String or a throw completion. It performs URI unescaping and decoding, preserving any escape sequences that correspond to Basic Latin characters in preserveEscapeSet. It performs the following steps when called:

1. Let len be the length of string.
2. Let R be the empty String.
3. Let k be 0.
4. Repeat, while k < len,
   a. Let C be the code unit at index k within string.
   b. Let S be C.
   c. If C is the code unit 0x0025 (PERCENT SIGN), then
      i. If k + 3 > len, throw a URIError exception.
      ii. Let escape be the substring of string from k to k + 3.
      iii. Let B be ParseHexOctet(string, k + 1).
      iv. If B is not an integer, throw a URIError exception.
      v. Set k to k + 2.
      vi. Let n be the number of leading 1 bits in B.
      vii. If n = 0, then
           1. Let asciiChar be the code unit whose numeric value is B.
           2. If preserveEscapeSet contains asciiChar, set S to escape. Otherwise, set S to asciiChar.
      viii. Else,
           1. If n = 1 or n > 4, throw a URIError exception.
           2. Let Octets be « B ».
           3. Let j be 1.
           4. Repeat, while j < n,
              a. Set k to k + 1.
              b. If k + 3 > len, throw a URIError exception.
              c. If the code unit at index k within string is not the code unit 0x0025 (PERCENT SIGN), throw a URIError exception.
              d. Let continuationByte be ParseHexOctet(string, k + 1).
              e. If continuationByte is not an integer, throw a URIError exception.
              f. Append continuationByte to Octets.
              g. Set k to k + 2.
              h. Set j to j + 1.
      5. Assert: The length of Octets is n.
      6. If Octets does not contain a valid UTF-8 encoding of a Unicode code point, throw a URIError exception.
      7. Let V be the code point obtained by applying the UTF-8 transformation to Octets, that is, from a List of octets into a 21-bit value.
      8. Set S to UTF16EncodeCodePoint(V).
   d. Set R to the string-concatenation of R and S.
   e. Set k to k + 1.
5. Return R.

NOTE RFC 3629 prohibits the decoding of invalid UTF-8 octet sequences. For example, the invalid sequence 0xC0 0x80 must not decode into the code unit 0x0000. Implementations of the Decode algorithm are required to throw a URIError when encountering such invalid sequences.
19.2.6.7 ParseHexOctet \( (\text{string}, \text{position}) \)

The abstract operation ParseHexOctet takes arguments \text{string} (a String) and \text{position} (a non-negative integer) and returns either a non-negative integer or a non-empty List of SyntaxError objects. It parses a sequence of two hexadecimal characters at the specified \text{position} in \text{string} into an unsigned 8-bit integer. It performs the following steps when called:

1. Let \( \text{len} \) be the length of \text{string}.
2. \textbf{Assert:} \( \text{position} + 2 \leq \text{len} \).
3. Let \( \text{hexDigits} \) be the substring of \text{string} from \text{position} to \text{position} + 2.
4. Let \( \text{parseResult} \) be ParseText(StringToCodePoints(\text{hexDigits}), HexDigits[^Sep]).
5. If \( \text{parseResult} \) is not a Parse Node, return \( \text{parseResult} \).
6. Let \( n \) be the MV of \( \text{parseResult} \).
7. \textbf{Assert:} \( n \) is in the inclusive interval from 0 to 255.
8. Return \( n \).

19.3 Constructor Properties of the Global Object

19.3.1 AggregateError ( . . . )

See 20.5.7.1.

19.3.2 Array ( . . . )

See 23.1.1.

19.3.3 ArrayBuffer ( . . . )

See 25.1.4.

19.3.4 BigInt ( . . . )

See 21.2.1.

19.3.5 BigUint64Array ( . . . )

See 23.2.5.

19.3.6 BigUint64Array ( . . . )

See 23.2.5.

19.3.7 Boolean ( . . . )

See 20.3.1.

19.3.8 DataView ( . . . )

See 25.3.2.

19.3.9 Date ( . . . )

See 21.4.2.
19.3.10 Error ( . . )
See 20.5.1.

19.3.11 EvalError ( . . )
See 20.5.5.1.

19.3.12 FinalizationRegistry ( . . )
See 26.2.1.

19.3.13 Float32Array ( . . )
See 23.2.5.

19.3.14 Float64Array ( . . )
See 23.2.5.

19.3.15 Function ( . . )
See 20.2.1.

19.3.16 Int8Array ( . . )
See 23.2.5.

19.3.17 Int16Array ( . . )
See 23.2.5.

19.3.18 Int32Array ( . . )
See 23.2.5.

19.3.19 Map ( . . )
See 24.1.1.

19.3.20 Number ( . . )
See 21.1.1.

19.3.21 Object ( . . )
See 20.1.1.

19.3.22 Promise ( . . )
See 27.2.3.
19.3.23  Proxy ( . . . )

See 28.2.1.

19.3.24  RangeError ( . . . )

See 20.5.5.2.

19.3.25  ReferenceError ( . . . )

See 20.5.5.3.

19.3.26  RegExp ( . . . )

See 22.2.4.

19.3.27  Set ( . . . )

See 24.2.1.

19.3.28  SharedArrayBuffer ( . . . )

See 25.2.3.

19.3.29  String ( . . . )

See 22.1.1.

19.3.30  Symbol ( . . . )

See 20.4.1.

19.3.31  SyntaxError ( . . . )

See 20.5.5.4.

19.3.32  TypeError ( . . . )

See 20.5.5.5.

19.3.33  Uint8Array ( . . . )

See 23.2.5.

19.3.34  Uint8ClampedArray ( . . . )

See 23.2.5.

19.3.35  Uint16Array ( . . . )

See 23.2.5.
The Object constructor:

- is `%Object%`.
- is the initial value of the "Object" property of the global object.
- creates a new ordinary object when called as a constructor.
- performs a type conversion when called as a function rather than as a constructor.
- may be used as the value of an `extends` clause of a class definition.
This function performs the following steps when called:

1. If NewTarget is neither **undefined** nor the active function object, then
   a. Return ? OrdinaryCreateFromConstructor(NewTarget, "%Object.prototype%").
2. If value is either **undefined** or null, return OrdinaryObjectCreate(%Object.prototype%).
3. Return ! ToObject(value).

20.1.2 Properties of the Object Constructor

The Object constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has a "length" property whose value is 1𝔽.
- has the following additional properties:

20.1.2.1 Object.assign ( target, ...sources )

This function copies the values of all of the enumerable own properties from one or more source objects to a target object.

It performs the following steps when called:

1. Let to be ? ToObject(target).
2. If only one argument was passed, return to.
3. For each element nextSource of sources, do
   a. If nextSource is neither **undefined** nor null, then
      i. Let from be ! ToObject(nextSource).
      ii. Let keys be ? from.[[OwnPropertyKeys]]().
      iii. For each element nextKey of keys, do
           1. Let desc be ? from.[[GetOwnProperty]](nextKey).
           2. If desc is not **undefined** and desc.[[Enumerable]] is true, then
              a. Let propValue be ? Get(from, nextKey).
              b. Perform ? Set(to, nextKey, propValue, true).
4. Return to.

The "length" property of this function is 2𝔽.

20.1.2.2 Object.create ( O, Properties )

This function creates a new object with a specified prototype.

It performs the following steps when called:

1. If O is not an Object and O is not null, throw a TypeError exception.
2. Let obj be OrdinaryObjectCreate(O).
3. If Properties is not **undefined**, then
4. Return obj.

20.1.2.3 Object.defineProperty ( O, Properties )

This function adds own properties and/or updates the attributes of existing own properties of an object.

It performs the following steps when called:
1. If \( O \) is not an Object, throw a **TypeError** exception.
2. Return ? \( \text{ObjectDefineProperties}(O, \text{Properties}) \).

### 20.1.2.3.1 ObjectDefineProperties ( \( O, \text{Properties} \) )

The abstract operation `ObjectDefineProperties` takes arguments \( O \) (an Object) and `Properties` (an ECMAScript language value) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Let `props` be `? ToObject(Properties)`.
2. Let `keys` be `? props.[[OwnPropertyKeys]]()`.
3. Let `descriptors` be a new empty List.
4. For each element `nextKey` of `keys`, do
   a. Let `propDesc` be `? props.[[GetOwnProperty]](nextKey)`.
   b. If `propDesc` is not undefined and `propDesc.[[Enumerable]]` is true, then
      i. Let `descObj` be `Get(props, nextKey)`.
      ii. Let `desc` be `ToPropertyDescriptor(descObj)`.
      iii. Append the `Record` (`[[Key]]: nextKey, [[Descriptor]]: desc`) to `descriptors`.
5. For each element `property` of `descriptors`, do
   a. Perform `? DefinePropertyOrThrow(O, property.[[Key]], property.[[Descriptor]])`.
6. Return `O`.

### 20.1.2.4 Object.defineProperty ( \( O, P, \text{Attributes} \) )

This function adds an own property and/or updates the attributes of an existing own property of an object.

It performs the following steps when called:

1. If \( O \) is not an Object, throw a **TypeError** exception.
2. Let `key` be `? ToPropertyKey(P)`.
3. Let `desc` be `? ToPropertyDescriptor(Attributes)`.
4. Perform `? DefinePropertyOrThrow(O, key, desc)`.
5. Return `O`.

### 20.1.2.5 Object.entries ( \( O \) )

This function performs the following steps when called:

1. Let `obj` be `? ToObject(O)`.
2. Let `entryList` be `? EnumerableOwnProperties(obj, KEY+VALUE)`.
3. Return `CreateArrayFromList(entryList)`.

### 20.1.2.6 Object.freeze ( \( O \) )

This function performs the following steps when called:

1. If \( O \) is not an Object, return `O`.
2. Let `status` be `? SetIntegrityLevel(O, FROZEN)`.
3. If `status` is false, throw a **TypeError** exception.
4. Return `O`.

### 20.1.2.7 Object.fromEntries ( iterable )

This function performs the following steps when called:

1. Perform `? RequireObjectCoercible(iterable)`.
2. Let `obj` be `OrdinaryObjectCreate(%Object.prototype%)`.
3. Assert: `obj` is an extensible ordinary object with no own properties.
4. Let closure be a new Abstract Closure with parameters (key, value) that captures obj and performs the following steps when called:
   a. Let propertyKey be ? ToPropertyKey(key).
   b. Perform ! CreateDataPropertyOrThrow(obj, propertyKey, value).
   c. Return undefined.
5. Let adder be CreateBuiltInFunction(closure, 2, "", " »).

NOTE The function created for adder is never directly accessible to ECMAScript code.

20.1.2.8 Object.getOwnPropertyDescriptor (O, P)
This function performs the following steps when called:
1. Let obj be ? ToObject(O).
2. Let key be ? ToPropertyKey(P).
3. Let desc be ? obj.[[GetOwnProperty]](key).
4. Return FromPropertyDescriptor(desc).

20.1.2.9 Object.getOwnPropertyDescriptors (O)
This function performs the following steps when called:
1. Let obj be ? ToObject(O).
2. Let ownKeys be ? obj.[[OwnPropertyKeys]]().
3. Let descriptors be OrdinaryObjectCreate(%Object.prototype%).
4. For each element key of ownKeys, do
   a. Let desc be ? obj.[[GetOwnProperty]](key).
   b. Let descriptor be FromPropertyDescriptor(desc).
   c. If descriptor is not undefined, perform ! CreateDataPropertyOrThrow(descriptors, key, descriptor).
5. Return descriptors.

20.1.2.10 Object.getOwnPropertyNames (O)
This function performs the following steps when called:
1. Return CreateArrayFromList(? GetOwnPropertyKeys(O, STRING)).

20.1.2.11 Object.getOwnPropertySymbols (O)
This function performs the following steps when called:
1. Return CreateArrayFromList(? GetOwnPropertyKeys(O, SYMBOL)).

20.1.2.11.1 GetOwnPropertyKeys (O, type)
The abstract operation GetOwnPropertyKeys takes arguments O (an ECMAScript language value) and type (STRING or Symbol) and returns either a normal completion containing a List of property keys or a throw completion. It performs the following steps when called:
1. Let obj be ? ToObject(O).
2. Let keys be ? obj.[[OwnPropertyKeys]]().
3. Let nameList be a new empty List.
4. For each element nextKey of keys, do
   a. If nextKey is a Symbol and type is Symbol, or if nextKey is a String and type is STRING, then
      i. Append nextKey to nameList.
5. Return nameList.
20.1.2.12 Object.getPrototypeOf (O)

This function performs the following steps when called:

1. Let obj be ? ToObject(O).
2. Return ? obj.[[GetPrototypeOf]].

20.1.2.13 Object.groupBy (items, callbackfn)

NOTE callbackfn should be a function that accepts two arguments. groupBy calls callbackfn once for each element in items, in ascending order, and constructs a new object. Each value returned by callbackfn is coerced to a property key. For each such property key, the result object has a property whose key is that property key and whose value is an array containing all the elements for which the callbackfn return value coerced to that key.

callbackfn is called with two arguments: the value of the element and the index of the element.

The return value of groupBy is an object that does not inherit from %Object.prototype%.

This function performs the following steps when called:

1. Let groups be ? GroupBy(items, callbackfn, PROPERTY).
2. Let obj be OrdinaryObjectCreate(null).
3. For each Record { [[Key]], [[Elements]] } g of groups, do
   a. Let elements be CreateArrayFromList(g.[[Elements]]).
   b. Perform ! CreateDataPropertyOrThrow(obj, g.[[Key]], elements).
4. Return obj.

20.1.2.14 Object.hasOwn (O, P)

This function performs the following steps when called:

1. Let obj be ? ToObject(O).
2. Let key be ? ToPropertyKey(P).
3. Return ? HasOwnProperty(obj, key).

20.1.2.15 Object.is (value1, value2)

This function performs the following steps when called:

1. Return SameValue(value1, value2).

20.1.2.16 Object.isExtensible (O)

This function performs the following steps when called:

1. If O is not an Object, return false.

20.1.2.17 Object.isFrozen (O)

This function performs the following steps when called:

1. If O is not an Object, return true.
2. Return ? TestIntegrityLevel(O, FROZEN).
20.1.2.18 Object.isSealed (O)

This function performs the following steps when called:
1. If O is not an Object, return true.
2. Return ? TestIntegrityLevel(O, SEALED).

20.1.2.19 Object.keys (O)

This function performs the following steps when called:
1. Let obj be ? ToObject(O).
2. Let keyList be ? EnumerableOwnProperties(obj, KEY).
3. Return CreateArrayFromList(keyList).

20.1.2.20 Object.preventExtensions (O)

This function performs the following steps when called:
1. If O is not an Object, return O.
2. Let status be ? O. [[PreventExtensions]]().
3. If status is false, throw a TypeError exception.
4. Return O.

20.1.2.21 Object.prototype

The initial value of object.prototype is the Object prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.1.2.22 Object.seal (O)

This function performs the following steps when called:
1. If O is not an Object, return O.
2. Let status be ? SetIntegrityLevel(O, SEALED).
3. If status is false, throw a TypeError exception.
4. Return O.

20.1.2.23 Object.setPrototypeOf (O, proto)

This function performs the following steps when called:
1. Set O to ? RequireObjectCoercible(O).
2. If proto is not an Object and proto is not null, throw a TypeError exception.
3. If O is not an Object, return O.
5. If status is false, throw a TypeError exception.
6. Return O.

20.1.2.24 Object.values (O)

This function performs the following steps when called:
1. Let obj be ? ToObject(O).
2. Let valueList be ? EnumerableOwnProperties(obj, VALUE).
3. Return CreateArrayFromList(valueList).
20.1.3 Properties of the Object Prototype Object

The Object prototype object:

- is %Object.prototype%.
- has an [[Extensible]] internal slot whose value is true.
- has the internal methods defined for ordinary objects, except for the [[SetPrototypeOf]] method, which is as defined in 10.4.7.1. (Thus, it is an immutable prototype exotic object.)
- has a [[Prototype]] internal slot whose value is null.

20.1.3.1 Object.prototype.constructor

The initial value of Object.prototype.constructor is %Object%.

20.1.3.2 Object.prototype.hasOwnProperty (V)

This method performs the following steps when called:

1. Let P be ? ToPropertyKey(V).
2. Let O be ? ToObject(this value).
3. Return ? HasOwnProperty(O, P).

NOTE The ordering of steps 1 and 2 is chosen to ensure that any exception that would have been thrown by step 1 in previous editions of this specification will continue to be thrown even if the this value is undefined or null.

20.1.3.3 Object.prototype.isPrototypeOf (V)

This method performs the following steps when called:

1. If V is not an Object, return false.
2. Let O be ? ToObject(this value).
3. Repeat,
   a. Set V to ? V.[[GetPrototypeOf]]().
   b. If V is null, return false.
   c. If SameValue(O, V) is true, return true.

NOTE The ordering of steps 1 and 2 preserves the behaviour specified by previous editions of this specification for the case where V is not an object and the this value is undefined or null.

20.1.3.4 Object.prototype.propertyIsEnumerable (V)

This method performs the following steps when called:

1. Let P be ? ToPropertyKey(V).
2. Let O be ? ToObject(this value).
4. If desc is undefined, return false.
5. Return desc.[[Enumerable]].

NOTE 1 This method does not consider objects in the prototype chain.
NOTE 2  The ordering of steps 1 and 2 is chosen to ensure that any exception that would have been thrown by step 1 in previous editions of this specification will continue to be thrown even if the `this` value is `undefined` or `null`.

20.1.3.5 Object.prototype.toLocaleString ([ `reserved1` [, `reserved2` ] ])

This method performs the following steps when called:

1. Let `O` be the `this` value.
2. Return `Invoke(O, "toString")`.

The optional parameters to this method are not used but are intended to correspond to the parameter pattern used by ECMA-402 `toLocaleString` methods. Implementations that do not include ECMA-402 support must not use those parameter positions for other purposes.

NOTE 1  This method provides a generic `toLocaleString` implementation for objects that have no locale-sensitive `toString` behaviour. Array, Number, Date, and `%TypedArray%` provide their own locale-sensitive `toLocaleString` methods.

NOTE 2  ECMA-402 intentionally does not provide an alternative to this default implementation.

20.1.3.6 Object.prototype.toString ()

This method performs the following steps when called:

1. If the `this` value is `undefined`, return "'[object Undefined]'".
2. If the `this` value is `null`, return "'[object Null]'".
3. Let `O` be `ToObject(this value)`.
4. Let `isArray` be `IsArray(O)`.
5. If `isArray` is `true`, let `builtinTag` be "Array".
6. Else if `O` has a `[[ParameterMap]]` internal slot, let `builtinTag` be "Arguments".
7. Else if `O` has a `[[Call]]` internal method, let `builtinTag` be "Function".
8. Else if `O` has an `[[ErrorData]]` internal slot, let `builtinTag` be "Error".
9. Else if `O` has a `[[BooleanData]]` internal slot, let `builtinTag` be "Boolean".
10. Else if `O` has a `[[NumberData]]` internal slot, let `builtinTag` be "Number".
11. Else if `O` has a `[[StringData]]` internal slot, let `builtinTag` be "String".
12. Else if `O` has a `[[DateValue]]` internal slot, let `builtinTag` be "Date".
13. Else if `O` has a `[[RegExpMatcher]]` internal slot, let `builtinTag` be "RegExp".
14. Else, let `builtinTag` be "Object".
15. Let `tag` be `Get(O, @@toStringTag)`.
16. If `tag` is not a String, set `tag` to `builtinTag`.
17. Return the string-concatenation of "'[object ', tag, and ']']".

NOTE  Historically, this method was occasionally used to access the String value of the `[[Class]]` internal slot that was used in previous editions of this specification as a nominal type tag for various built-in objects. The above definition of `toString` preserves compatibility for legacy code that uses `toString` as a test for those specific kinds of built-in objects. It does not provide a reliable type testing mechanism for other kinds of built-in or program defined objects. In addition, programs can use `@@toStringTag` in ways that will invalidate the reliability of such legacy type tests.
20.1.3.7 Object.prototype.valueOf( )

This method performs the following steps when called:

1. Return ? ToObject(this value).

NORMATIVE OPTIONAL, LEGACY

20.1.3.8 Object.prototype.__proto__

Object.prototype.__proto__ is an accessor property with attributes { [[Enumerable]]: false, [[Configurable]]: true }. The [[Get]] and [[Set]] attributes are defined as follows:

20.1.3.8.1 get Object.prototype.__proto__

The value of the [[Get]] attribute is a built-in function that requires no arguments. It performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Return ? O.[[GetPrototypeOf]]().

20.1.3.8.2 set Object.prototype.__proto__

The value of the [[Set]] attribute is a built-in function that takes an argument proto. It performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. If proto is not an Object and proto is not null, return undefined.
3. If O is not an Object, return undefined.
5. If status is false, throw a TypeError exception.
6. Return undefined.

NORMATIVE OPTIONAL, LEGACY

20.1.3.9 Legacy Object.prototype Accessor Methods

20.1.3.9.1 Object.prototype.__defineGetter__ ( P, getter )

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. If IsCallable(getter) is false, throw a TypeError exception.
3. Let desc be PropertyDescriptor { [[Get]]: getter, [[Enumerable]]: true, [[Configurable]]: true }.
4. Let key be ? ToPropertyKey(P).
5. Perform ? DefinePropertyOrThrow(O, key, desc).
6. Return undefined.
20.1.3.9.2 Object.prototype.__defineSetter__(P, setter)

This method performs the following steps when called:

1. Let O be ?ToObject(this value).
2. If IsCallable(setter) is false, throw a TypeError exception.
3. Let desc be PropertyDescriptor { [[Set]]: setter, [[Enumerable]]: true, [[Configurable]]: true }.
4. Let key be ?ToPropertyKey(P).
5. Perform ?DefinePropertyOrThrow(O, key, desc).
6. Return undefined.

20.1.3.9.3 Object.prototype.__lookupGetter__(P)

This method performs the following steps when called:

1. Let O be ?ToObject(this value).
2. Let key be ?ToPropertyKey(P).
3. Repeat,
   a. Let desc be ?O.[[GetOwnProperty]](key).
   b. If desc is not undefined, then
      i. If IsAccessorDescriptor(desc) is true, return desc.[[Get]].
      ii. Return undefined.
   c. Set O to ?O.[[GetPrototypeOf]]().
   d. If O is null, return undefined.

20.1.3.9.4 Object.prototype.__lookupSetter__(P)

This method performs the following steps when called:

1. Let O be ?ToObject(this value).
2. Let key be ?ToPropertyKey(P).
3. Repeat,
   a. Let desc be ?O.[[GetOwnProperty]](key).
   b. If desc is not undefined, then
      i. If IsAccessorDescriptor(desc) is true, return desc.[[Set]].
      ii. Return undefined.
   c. Set O to ?O.[[GetPrototypeOf]]().
   d. If O is null, return undefined.

20.1.4 Properties of Object Instances

Object instances have no special properties beyond those inherited from the Object prototype object.

20.2 Function Objects

20.2.1 The Function Constructor

The Function constructor:

- is %Function%.
- is the initial value of the "Function" property of the global object.
- creates and initializes a new function object when called as a function rather than as a constructor. Thus the function call Function(…) is equivalent to the object creation expression new Function(…) with the same arguments.
• may be used as the value of an `extends` clause of a class definition. Subclass constructors that intend to inherit the specified Function behaviour must include a `super` call to the Function constructor to create and initialize a subclass instance with the internal slots necessary for built-in function behaviour. All ECMAScript syntactic forms for defining function objects create instances of Function. There is no syntactic means to create instances of Function subclasses except for the built-in GeneratorFunction, AsyncFunction, and AsyncGeneratorFunction subclasses.

### 20.2.1 Function ( ...parameterArgs, bodyArg )

The last argument (if any) specifies the body (executable code) of a function; any preceding arguments specify formal parameters.

This function performs the following steps when called:

1. Let `C` be the active function object.
2. If `bodyArg` is not present, set `bodyArg` to the empty String.

---

**NOTE**

It is permissible but not necessary to have one argument for each formal parameter to be specified. For example, all three of the following expressions produce the same result:

```
new Function("a", "b", "c", "return a+b+c")
new Function("a, b, c", "return a+b+c")
new Function("a,b", "c", "return a+b+c")
```

### 20.2.1.1 CreateDynamicFunction ( constructor, newTarget, kind, parameterArgs, bodyArg )

The abstract operation CreateDynamicFunction takes arguments `constructor` (a constructor), `newTarget` (a constructor), `kind` (NORMAL, GENERATOR, ASYNC, or ASYNC-GENERATOR), `parameterArgs` (a List of ECMAScript language values), and `bodyArg` (an ECMAScript language value) and returns either a normal completion containing an ECMA-Script function object or a throw completion. `constructor` is the constructor function that is performing this action. `newTarget` is the constructor that `new` was initially applied to. `parameterArgs` and `bodyArg` reflect the argument values that were passed to `constructor`. It performs the following steps when called:

1. If `newTarget` is `undefined`, set `newTarget` to `constructor`.
2. If `kind` is NORMAL, then
   a. Let `prefix` be "function".
   b. Let `exprSym` be the grammar symbol `FunctionExpression`.
   c. Let `bodySym` be the grammar symbol `FunctionBody`[~Yield, ~Await] .
   d. Let `parameterSym` be the grammar symbol `FormalParameters`[~Yield, ~Await] .
   e. Let `fallbackProto` be ":%Function.prototype%".
3. Else if `kind` is GENERATOR, then
   a. Let `prefix` be "function".
   b. Let `exprSym` be the grammar symbol `GeneratorExpression`.
   c. Let `bodySym` be the grammar symbol `GeneratorBody`.
   d. Let `parameterSym` be the grammar symbol `FormalParameters`[+Yield, ~Await] .
   e. Let `fallbackProto` be ":%GeneratorFunction.prototype%".
4. Else if `kind` is ASYNC, then
   a. Let `prefix` be "async function".
   b. Let `exprSym` be the grammar symbol `AsyncFunctionExpression`.
   c. Let `bodySym` be the grammar symbol `AsyncFunctionBody`.
   d. Let `parameterSym` be the grammar symbol `FormalParameters`[~Yield, +Await] .
   e. Let `fallbackProto` be ":%AsyncFunction.prototype%".
5. Else,
   a. Assert: `kind` is ASYNC-GENERATOR.
   b. Let `prefix` be "async function".
   c. Let `exprSym` be the grammar symbol `AsyncGeneratorExpression`.

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d. Let `bodySym` be the grammar symbol `AsyncGeneratorBody`.
e. Let `parameterSym` be the grammar symbol `FormalParameters[+Yield, +Await]`.
f. Let `fallbackProto` be `%AsyncGeneratorFunction.prototype%`.

6. Let `argCount` be the number of elements in `parameterArgs`.
7. Let `parameterStrings` be a new empty List.
8. For each element `arg` of `parameterArgs`, do
   a. Append `?` `ToString(arg)` to `parameterStrings`.
9. Let `bodyString` be `?` `ToString(bodyArg)`.
10. Let `currentRealm` be the current Realm Record.
11. Perform ? `HostEnsureCanCompileStrings(currentRealm, parameterStrings, bodyString, false)`.
12. Let `P` be the empty String.
13. If `argCount` > 0, then
   a. Set `P` to `parameterStrings[0]`.
   b. Let `k` be 1.
   c. Repeat, while `k < argCount`,
      i. Let `nextArgString` be `parameterStrings[k]`.
      ii. Set `P` to the string-concatenation of `P`, `,` (a comma), and `nextArgString`.
      iii. Set `k` to `k + 1`.
14. Let `bodyParseString` be the string-concatenation of `0x000A` (LINE FEED), `bodyString`, and `0x000A` (LINE FEED).
15. Let `sourceString` be the string-concatenation of `prefix`, `, anonymous("", `P`, `0x000A` (LINE FEED), ") {}", `bodyParseString`, and ",")`.
16. Let `sourceText` be `StringToCodePoints(sourceString)`.
17. Let `parameters` be `ParseText(StringToCodePoints(P), parameterSym)`.
18. If `parameters` is a List of errors, throw a `SyntaxError` exception.
19. Let `body` be `ParseText(StringToCodePoints(bodyParseString), bodySym)`.
20. If `body` is a List of errors, throw a `SyntaxError` exception.

NOTE: The parameters and body are parsed separately to ensure that each is valid alone. For example, `new Function("/*", "anonymous([, P, 0x000A (LINE FEED), ") {}", bodyParseString, and ",")")` does not evaluate to a function.

NOTE: If this step is reached, `sourceText` must have the syntax of `exprSym` (although the reverse implication does not hold). The purpose of the next two steps is to enforce any Early Error rules which apply to `exprSym` directly.

23. Let `expr` be `ParseText(sourceText, exprSym)`.
24. If `expr` is a List of errors, throw a `SyntaxError` exception.
25. Let `proto` be `? GetPrototypeFromConstructor(newTarget, fallbackProto)`.
26. Let `env` be `currentRealm.[[GlobalEnv]]`.
27. Let `privateEnv` be `null`.
28. Let `F` be `OrdinaryFunctionCreate(proto, sourceText, parameters, body, NON-LEXICAL-THIS, env, privateEnv)`.
29. Perform `SetFunctionName(F, "anonymous")`.
30. If `kind` is GENERATOR, then
   a. Let `prototype` be ` OrdinaryObjectCreate(%GeneratorFunction.prototype.prototype.prototype%)`.
   b. Perform `! DefinePropertyOrThrow(F, "prototype", PropertyDescriptor ( [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false )).`
31. Else if `kind` is SYNC-GENERATOR, then
   a. Let `prototype` be ` OrdinaryObjectCreate(%AsyncGeneratorFunction.prototype.prototype.prototype%)`.
   b. Perform `! DefinePropertyOrThrow(F, "prototype", PropertyDescriptor ( [[Value]]: prototype, [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false )).`
32. Else if `kind` is NORMAL, then
   a. Perform `MakeConstructor(F)`.
33. NOTE: Functions whose `kind` is ASYNC are not constructible and do not have a [[Construct]] internal method or a "property" property.
34. Return `F`.

NOTE: `CreateDynamicFunction` defines a "property" property on any function it creates whose `kind` is not ASYNC to provide for the possibility that the function will be used as a `constructor`. 
20.2.2 Properties of the Function Constructor

The Function constructor:

- is itself a built-in function object.
- has a \[[Prototype]\] internal slot whose value is %Function.prototype%.
- has a "length" property whose value is 1ₚ.
- has the following properties:

20.2.2.1 Function.prototype

The value of Function.prototype is the Function prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.2.3 Properties of the Function Prototype Object

The Function prototype object:

- is %Function.prototype%.
- is itself a built-in function object.
- accepts any arguments and returns undefined when invoked.
- does not have a [[Construct]] internal method; it cannot be used as a constructor with the new operator.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- does not have a "prototype" property.
- has a "length" property whose value is +0ₚ.
- has a "name" property whose value is the empty String.

NOTE The Function prototype object is specified to be a function object to ensure compatibility with ECMAScript code that was created prior to the ECMAScript 2015 specification.

20.2.3.1 Function.prototype.apply ( thisArg, argArray )

This method performs the following steps when called:

1. Let func be the this value.
2. If IsCallable(func) is false, throw a TypeError exception.
3. If argArray is either undefined or null, then
   a. Perform PrepareForTailCall().
   b. Return ? Call(func, thisArg).
4. Let argList be ? CreateListFromArrayLike(argArray).
5. Perform PrepareForTailCall().

NOTE 1 The thisArg value is passed without modification as the this value. This is a change from Edition 3, where an undefined or null thisArg is replaced with the global object and ToObject is applied to all other values and that result is passed as the this value. Even though the thisArg is passed without modification, non-strict functions still perform these transformations upon entry to the function.

NOTE 2 If func is either an arrow function or a bound function exotic object, then the thisArg will be ignored by the function [[Call]] in step 6.
20.2.3.2 Function.prototype.bind (thisArg, ...args)

This method performs the following steps when called:

1. Let Target be the this value.
2. If IsCallable(Target) is false, throw a TypeError exception.
3. Let F be BoundFunctionCreate(Target, thisArg, args).
4. Let L be 0.
5. Let targetHasLength be ? HasOwnProperty(Target, "length").
6. If targetHasLength is true, then
   a. Let targetLen be ? Get(Target, "length").
   b. If targetLen is a Number, then
      i. If targetLen is +∞𝔽, then
         1. Set L to +∞.
      ii. Else if targetLen is -∞𝔽, then
          1. Set L to 0.
   iii. Else,
      1. Let targetLenAsInt be ! ToIntegerOrInfinity(targetLen).
      2. Assert: targetLenAsInt is finite.
      3. Let argCount be the number of elements in args.
      4. Set L to max(targetLenAsInt - argCount, 0).
7. Perform SetFunctionLength(F, L).
8. Let targetName be ? Get(Target, "name").
9. If targetName is not a String, set targetName to the empty String.
10. Perform SetFunctionName(F, targetName, "bound").
11. Return F.

NOTE 1 Function objects created using Function.prototype.bind are exotic objects. They also do not have a "prototype" property.

NOTE 2 If Target is either an arrow function or a bound function exotic object, then the thisArg passed to this method will not be used by subsequent calls to F.

20.2.3.3 Function.prototype.call (thisArg, ...args)

This method performs the following steps when called:

1. Let func be the this value.
2. If IsCallable(func) is false, throw a TypeError exception.
3. Perform PrepareForTailCall().
4. Return ? Call(func, thisArg, args).

NOTE 1 The thisArg value is passed without modification as the this value. This is a change from Edition 3, where an undefined or null thisArg is replaced with the global object and ToObject is applied to all other values and that result is passed as the this value. Even though the thisArg is passed without modification, non-strict functions still perform these transformations upon entry to the function.

NOTE 2 If func is either an arrow function or a bound function exotic object, then the thisArg will be ignored by the function [[Call]] in step 4.

20.2.3.4 Function.prototype.constructor

The initial value of Function.prototype.constructor is %Function%. 
20.2.3.5 Function.prototype.toString ( )

This method performs the following steps when called:

1. Let `func` be the `this` value.
2. If `func` is an Object, `func` has a `[[SourceText]]` internal slot, `func.[[SourceText]]` is a sequence of Unicode code points, and `HostHasSourceTextAvailable(func)` is true, then
3. If `func` is a built-in function object, return an implementation-defined String source code representation of `func`. The representation must have the syntax of a `NativeFunction`. Additionally, if `func` has an `[[InitialName]]` internal slot and `func.[[InitialName]]` is a String, the portion of the returned String that would be matched by `NativeFunctionAccessor$_PropertyName$[-Yield, ~Await]` must be the value of `func.[[InitialName]]`.
4. If `func` is an Object and `IsCallable(func)` is true, return an implementation-defined String source code representation of `func`. The representation must have the syntax of a `NativeFunction`.
5. Throw a `TypeError` exception.

```
NativeFunction : 
    function NativeFunctionAccessor_opt PropertyName[-Yield, ~Await] opt ( 
        FormalParameters[-Yield, ~Await]  ) { [ native code ] }

NativeFunctionAccessor : 
    get 
    set
```

20.2.3.6 Function.prototype [ @@hasInstance ] ( V )

This method performs the following steps when called:

1. Let `F` be the `this` value.
2. Return ? `OrdinaryHasInstance(F, V)`.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

```
NOTE
This is the default implementation of @@hasInstance that most functions inherit. @@hasInstance is called by the instanceof operator to determine whether a value is an instance of a specific constructor. An expression such as

v instanceof F

evaluates as

F[@@hasInstance](v)

A constructor function can control which objects are recognized as its instances by instanceof by exposing a different @@hasInstance method on the function.
```

This property is non-writable and non-configurable to prevent tampering that could be used to globally expose the target function of a bound function.

The value of the "name" property of this method is "[Symbol.hasInstance]".

20.2.4 Function Instances

Every Function instance is an ECMAScript function object and has the internal slots listed in Table 30. Function objects created using the Function.prototype.bind method (20.2.3.2) have the internal slots listed in Table 31.

Function instances have the following properties:
20.2.4.1 length

The value of the "length" property is an integral Number that indicates the typical number of arguments expected by the function. However, the language permits the function to be invoked with some other number of arguments. The behaviour of a function when invoked on a number of arguments other than the number specified by its "length" property depends on the function. This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

20.2.4.2 name

The value of the "name" property is a String that is descriptive of the function. The name has no semantic significance but is typically a variable or property name that is used to refer to the function at its point of definition in ECMAScript source text. This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

Anonymous functions objects that do not have a contextual name associated with them by this specification use the empty String as the value of the "name" property.

20.2.4.3 prototype

Function instances that can be used as a constructor have a "prototype" property. Whenever such a Function instance is created another ordinary object is also created and is the initial value of the function's "prototype" property. Unless otherwise specified, the value of the "prototype" property is used to initialize the [[Prototype]] internal slot of the object created when that function is invoked as a constructor.

This property has the attributes { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }.

NOTE Function objects created using Function.prototype.bind, or by evaluating a MethodDefinition (that is not a GeneratorMethod or AsyncGeneratorMethod) or an ArrowFunction do not have a "prototype" property.

20.2.5 HostHasSourceTextAvailable ( func )

The host-defined abstract operation HostHasSourceTextAvailable takes argument func (a function object) and returns a Boolean. It allows host environments to prevent the source text from being provided for func.

An implementation of HostHasSourceTextAvailable must conform to the following requirements:

• It must be deterministic with respect to its parameters. Each time it is called with a specific func as its argument, it must return the same result.

The default implementation of HostHasSourceTextAvailable is to return true.

20.3 Boolean Objects

20.3.1 The Boolean Constructor

The Boolean constructor:

• is %Boolean%.
• is the initial value of the "Boolean" property of the global object.
• creates and initializes a new Boolean object when called as a constructor.
• performs a type conversion when called as a function rather than as a constructor.
• may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified Boolean behaviour must include a super call to the Boolean constructor to create and initialize the subclass instance with a [[BooleanData]] internal slot.
20.3.1.1 Boolean (value)

This function performs the following steps when called:

1. Let \( b \) be \( \text{ToBoolean}(\text{value}) \).
2. If \( \text{NewTarget} \) is \( \text{undefined} \), return \( b \).
3. Let \( O \) be \( ? \text{OrdinaryCreateFromConstructor}(\text{NewTarget}, "%\text{Boolean.prototype}%", \text{« [[BooleanData]] »}) \).
4. Set \( O.\text{[[BooleanData]]} \) to \( b \).
5. Return \( O \).

20.3.2 Properties of the Boolean Constructor

The Boolean constructor:

- has a [[Prototype]] internal slot whose value is \%Function.prototype\%.
- has the following properties:

20.3.2.1 Boolean.prototype

The initial value of Boolean.prototype is the Boolean prototype object.

This property has the attributes \{ [[Writable]]: \text{false}, [[Enumerable]]: \text{false}, [[Configurable]]: \text{false} \}.

20.3.3 Properties of the Boolean Prototype Object

The Boolean prototype object:

- is \%Boolean.prototype\%.
- is an ordinary object.
- is itself a Boolean object; it has a [[BooleanData]] internal slot with the value \text{false}.
- has a [[Prototype]] internal slot whose value is \%Object.prototype\%.

20.3.3.1 Boolean.prototype.constructor

The initial value of Boolean.prototype.constructor is \%Boolean\%.

20.3.3.2 Boolean.prototype.toString ()

This method performs the following steps when called:

1. Let \( b \) be \( ? \text{ThisBooleanValue}(\text{this value}) \).
2. If \( b \) is \text{true}, return "true"; else return "false".

20.3.3.3 Boolean.prototype.valueOf ()

This method performs the following steps when called:

1. Return \( ? \text{ThisBooleanValue}(\text{this value}) \).

20.3.3.3.1 ThisBooleanValue (value)

The abstract operation ThisBooleanValue takes argument value (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If value is a Boolean, return value.
2. If value is an Object and value has a [[BooleanData]] internal slot, then
a. Let \( b \) be value.\([[\text{BooleanData}]\].

b. Assert: \( b \) is a Boolean.

c. Return \( b \).

3. Throw a \textbf{TypeError} exception.

### 20.3.4 Properties of Boolean Instances

Boolean instances are ordinary objects that inherit properties from the \texttt{Boolean prototype object}. Boolean instances have a \([[\text{BooleanData}]\] internal slot. The \([[\text{BooleanData}]\] internal slot is the Boolean value represented by this Boolean object.

### 20.4 Symbol Objects

#### 20.4.1 The Symbol Constructor

The Symbol constructor:

- is \%\texttt{Symbol}\%.
- is the initial value of the "Symbol" property of the \texttt{global object}.
- returns a new Symbol value when called as a function.
- is not intended to be used with the \texttt{new} operator.
- is not intended to be subclassed.
- may be used as the value of an \texttt{extends} clause of a class definition but a \texttt{super} call to it will cause an exception.

#### 20.4.1.1 Symbol ([ \texttt{description} ]) 

This function performs the following steps when called:

1. If NewTarget is not \texttt{undefined}, throw a \textbf{TypeError} exception.
2. If \texttt{description} is \texttt{undefined}, let \texttt{descString} be \texttt{undefined}.
3. Else, let \texttt{descString} be ? \texttt{ToString}(\texttt{description}).
4. Return a new Symbol whose [[Description]] is \texttt{descString}.

#### 20.4.2 Properties of the Symbol Constructor

The Symbol constructor:

- has a [[Prototype]] internal slot whose value is \%\texttt{Function.prototype}\%.
- has the following properties:

#### 20.4.2.1 Symbol.\texttt{asyncIterator}

The initial value of \texttt{Symbol.\texttt{asyncIterator}} is the well known symbol \%\texttt{@@asyncIterator}\% (Table 1).

This property has the attributes { [[Writable]]: \texttt{false}, [[Enumerable]]: \texttt{false}, [[Configurable]]: \texttt{false} }.

#### 20.4.2.2 Symbol.\texttt{for} ( \texttt{key} ) 

This function performs the following steps when called:

1. Let \texttt{strByKey} be ? \texttt{ToString}(\texttt{key}).
2. For each element \( e \) of the GlobalSymbolRegistry List, do
   a. If SameValue(e.[[Key]], \texttt{strByKey}) is \texttt{true}, return \( e.[[\text{Symbol}]] \).
3. Assert: GlobalSymbolRegistry does not currently contain an entry for \texttt{strByKey}.
4. Let \texttt{newSymbol} be a new Symbol whose [[Description]] is \texttt{strByKey}.
5. Append the Record `{ [[Key]]: stringKey, [[Symbol]]: newSymbol }` to the GlobalSymbolRegistry List.

The GlobalSymbolRegistry is an append-only List that is globally available. It is shared by all realms. Prior to the evaluation of any ECMAScript code, it is initialized as a new empty List. Elements of the GlobalSymbolRegistry are Records with the structure defined in Table 60.

Table 60: GlobalSymbolRegistry Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Key]]</td>
<td>a String</td>
<td>A string key used to globally identify a Symbol.</td>
</tr>
<tr>
<td>[[Symbol]]</td>
<td>a Symbol</td>
<td>A symbol that can be retrieved from any realm.</td>
</tr>
</tbody>
</table>

20.4.2.3 Symbol.hasInstance

The initial value of `Symbol.hasInstance` is the well-known symbol `@@hasInstance` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.4 Symbol.isConcatSpreadable

The initial value of `Symbol.isConcatSpreadable` is the well-known symbol `@@isConcatSpreadable` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.5 Symbol.iterator

The initial value of `Symbol.iterator` is the well-known symbol `@@iterator` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.6 Symbol.keyFor (sym)

This function performs the following steps when called:

1. If `sym` is not a Symbol, throw a TypeError exception.
2. Return `KeyForSymbol(sym)`.

20.4.2.7 Symbol.match

The initial value of `Symbol.match` is the well-known symbol `@@match` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.8 Symbol.matchAll

The initial value of `Symbol.matchAll` is the well-known symbol `@@matchAll` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.
20.4.2.9 Symbol.prototype

The initial value of `Symbol.prototype` is the `Symbol prototype object`.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.10 Symbol.replace

The initial value of `Symbol.replace` is the well-known symbol `@@replace` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.11 Symbol.search

The initial value of `Symbol.search` is the well-known symbol `@@search` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.12 Symbol.species

The initial value of `Symbol.species` is the well-known symbol `@@species` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.13 Symbol.split

The initial value of `Symbol.split` is the well-known symbol `@@split` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.14 Symbol.toPrimitive

The initial value of `Symbol.toPrimitive` is the well-known symbol `@@toPrimitive` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.15 Symbol.toStringTag

The initial value of `Symbol.toStringTag` is the well-known symbol `@@toStringTag` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.2.16 Symbol.unscopables

The initial value of `Symbol.unscopables` is the well-known symbol `@@unscopables` (Table 1).

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.4.3 Properties of the Symbol Prototype Object

The `Symbol prototype object`:

- is `%Symbol.prototype%`.
- is an `ordinary object`.
- is not a `Symbol` instance and does not have a `[[SymbolData]]` internal slot.
- has a `[[Prototype]]` internal slot whose value is `%Object.prototype%`. 
20.4.3.1 Symbol.prototype.constructor

The initial value of `Symbol.prototype.constructor` is `%Symbol%`.

20.4.3.2 get Symbol.prototype.description

`Symbol.prototype.description` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `s` be the this value.
2. Let `sym` be `? ThisSymbolValue(s)`.
3. Return `sym.[[Description]]`.

20.4.3.3 Symbol.prototype.toString ()

This method performs the following steps when called:

1. Let `sym` be `? ThisSymbolValue(this value)`.
2. Return `SymbolDescriptiveString(sym)`.

20.4.3.3.1 SymbolDescriptiveString (sym)

The abstract operation `SymbolDescriptiveString` takes argument `sym` (a Symbol) and returns a String. It performs the following steps when called:

1. Let `desc` be `sym`'s `[[Description]]` value.
2. If `desc` is `undefined`, set `desc` to the empty String.
3. Assert: `desc` is a String.
4. Return the string-concatenation of "Symbol(" , `desc` , and ")".

20.4.3.4 Symbol.prototype.valueOf ()

This method performs the following steps when called:

1. Return `? ThisSymbolValue(this value)`.

20.4.3.4.1 ThisSymbolValue (value)

The abstract operation `ThisSymbolValue` takes argument `value` (an ECMAScript language value) and returns either a normal completion containing a Symbol or a throw completion. It performs the following steps when called:

1. If `value` is a Symbol, return `value`.
2. If `value` is an Object and `value` has a `[[SymbolData]]` internal slot, then
   a. Let `s` be `value.[[SymbolData]]`.
   b. Assert: `s` is a Symbol.
   c. Return `s`.
3. Throw a `TypeError` exception.

20.4.3.5 Symbol.prototype [ @@toPrimitive ] (hint)

This method is called by ECMAScript language operators to convert a Symbol object to a primitive value.

It performs the following steps when called:

1. Return `? ThisSymbolValue(this value)`.
NOTE  The argument is ignored.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

The value of the "name" property of this method is "[Symbol.toPrimitive]".

20.4.3.6 Symbol.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "Symbol".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

20.4.4 Properties of Symbol Instances

Symbol instances are ordinary objects that inherit properties from the Symbol prototype object. Symbol instances have a [[SymbolData]] internal slot. The [[SymbolData]] internal slot is the Symbol value represented by this Symbol object.

20.4.5 Abstract Operations for Symbols

20.4.5.1 KeyForSymbol ( sym )

The abstract operation KeyForSymbol takes argument sym (a Symbol) and returns a String or undefined. If sym is in the GlobalSymbolRegistry (see 20.4.2.2) the String used to register sym will be returned. It performs the following steps when called:

1. For each element e of the GlobalSymbolRegistry List, do
   a. If SAMEVALUE(e.[[Symbol]], sym) is true, return e.[[Key]].
2. Assert: GlobalSymbolRegistry does not currently contain an entry for sym.
3. Return undefined.

20.5 Error Objects

Instances of Error objects are thrown as exceptions when runtime errors occur. The Error objects may also serve as base objects for user-defined exception classes.

When an ECMAScript implementation detects a runtime error, it throws a new instance of one of the NativeError objects defined in 20.5.5 or a new instance of AggregateError object defined in 20.5.7. Each of these objects has the structure described below, differing only in the name used as the constructor name instead of NativeError, in the "name" property of the prototype object, in the implementation-defined "message" property of the prototype object, and in the presence of the %AggregateError%-specific "errors" property.

20.5.1 The Error Constructor

The Error constructor:

• is %Error%.
• is the initial value of the "Error" property of the global object.
• creates and initializes a new Error object when called as a function rather than as a constructor. Thus the function call Error(...) is equivalent to the object creation expression new Error(...) with the same arguments.
• may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified Error behaviour must include a super call to the Error constructor to create and initialize subclass instances with an [[ErrorData]] internal slot.
20.5.1.1 Error (message [, options ])

This function performs the following steps when called:

1. If NewTarget is undefined, let newTarget be the active function object; else let newTarget be NewTarget.
2. Let O be ? OrdinaryCreateFromConstructor(newTarget, "%Error.prototype%", « [[ErrorData]] »).
3. If message is not undefined, then
   a. Let msg be ? ToString(message).
   b. Perform CreateNonEnumerableDataPropertyOrThrow(O, "message", msg).
5. Return O.

20.5.2 Properties of the Error Constructor

The Error constructor:

• has a [[Prototype]] internal slot whose value is %Function.prototype%.
• has the following properties:

20.5.2.1 Error.prototype

The initial value of Error.prototype is the Error prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.5.3 Properties of the Error Prototype Object

The Error prototype object:

• is %Error.prototype%.
• is an ordinary object.
• is not an Error instance and does not have an [[ErrorData]] internal slot.
• has a [[Prototype]] internal slot whose value is %Object.prototype%.

20.5.3.1 Error.prototype.constructor

The initial value of Error.prototype.constructor is %Error%.

20.5.3.2 Error.prototype.message

The initial value of Error.prototype.message is the empty String.

20.5.3.3 Error.prototype.name

The initial value of Error.prototype.name is “Error”.

20.5.3.4 Error.prototype.toString ()

This method performs the following steps when called:

1. Let O be the this value.
2. If O is not an Object, throw a TypeError exception.
3. Let name be ? Get(O, "name").
4. If name is undefined, set name to "Error"; otherwise set name to ? ToString(name).
5. Let msg be ? Get(O, "message").
6. If msg is undefined, set msg to the empty String; otherwise set msg to ? ToString(msg).
7. If name is the empty String, return msg.
8. If `msg` is the empty String, return `name`.
9. Return the string-concatenation of `name`, the code unit 0x003A (COLON), the code unit 0x0020 (SPACE), and `msg`.

20.5.4 Properties of Error Instances

Error instances are ordinary objects that inherit properties from the Error prototype object and have an [[ErrorData]] internal slot whose value is undefined. The only specified uses of [[ErrorData]] is to identify Error, AggregateError, and NativeError instances as Error objects within `Object.prototype.toString`.

20.5.5 Native Error Types Used in This Standard

A new instance of one of the NativeError objects below or of the AggregateError object is thrown when a runtime error is detected. All NativeError objects share the same structure, as described in 20.5.6.

20.5.5.1 EvalError

The EvalError constructor is `%EvalError%`. This exception is not currently used within this specification. This object remains for compatibility with previous editions of this specification.

20.5.5.2 RangeError

The RangeError constructor is `%RangeError%`. Indicates a value that is not in the set or range of allowable values.

20.5.5.3 ReferenceError

The ReferenceError constructor is `%ReferenceError%`. Indicate that an invalid reference has been detected.

20.5.5.4 SyntaxError

The SyntaxError constructor is `%SyntaxError%`. Indicates that a parsing error has occurred.

20.5.5.5 TypeError

The TypeError constructor is `%TypeError%`. TypeError is used to indicate an unsuccessful operation when none of the other NativeError objects are an appropriate indication of the failure cause.

20.5.5.6 URIError

The URIError constructor is `%URIError%`. Indicates that one of the global URI handling functions was used in a way that is incompatible with its definition.
20.5.6  

NativeError Object Structure

When an ECMAScript implementation detects a runtime error, it throws a new instance of one of the NativeError objects defined in 20.5.5. Each of these objects has the structure described below, differing only in the name used as the constructor name instead of NativeError, in the "name" property of the prototype object, and in the implementation-defined "message" property of the prototype object.

For each error object, references to NativeError in the definition should be replaced with the appropriate error object name from 20.5.5.

20.5.6.1  
The NativeError Constructors

Each NativeError constructor:

- creates and initializes a new NativeError object when called as a function rather than as a constructor. A call of the object as a function is equivalent to calling it as a constructor with the same arguments. Thus the function call NativeError(...) is equivalent to the object creation expression new NativeError(...) with the same arguments.
- may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified NativeError behaviour must include a super call to the NativeError constructor to create and initialize subclass instances with an [[ErrorData]] internal slot.

20.5.6.1.1  

NativeError ( message [, options ] )

Each NativeError function performs the following steps when called:

1. If NewTarget is undefined, let newTarget be the active function object; else let newTarget be NewTarget.
2. Let O be ? OrdinaryCreateFromConstructor(newTarget, "%NativeError.prototype%", « [[ErrorData]] »).
3. If message is not undefined, then
   a. Let msg be ? ToString(message).
   b. Perform CreateNonEnumerableDataPropertyOrThrow(O, "message", msg).
5. Return O.

The actual value of the string passed in step 2 is either "%EvalError.prototype%", "%RangeError.prototype%", "%ReferenceError.prototype%", "%SyntaxError.prototype%", "%TypeError.prototype%", or "%URLError.prototype%" corresponding to which NativeError constructor is being defined.

20.5.6.2  
Properties of the NativeError Constructors

Each NativeError constructor:

- has a [[Prototype]] internal slot whose value is %Error%.
- has a "name" property whose value is the String value "NativeError".
- has the following properties:

20.5.6.2.1  

NativeError.prototype

The initial value of NativeError.prototype is a NativeError prototype object (20.5.6.3). Each NativeError constructor has a distinct prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.5.6.3  
Properties of the NativeError Prototype Objects

Each NativeError prototype object:
• is an ordinary object.
• is not an Error instance and does not have an [[ErrorData]] internal slot.
• has a [[Prototype]] internal slot whose value is %Error.prototype%.

20.5.6.3.1 **NativeError.prototype.constructor**

The initial value of the "constructor" property of the prototype for a given NativeError constructor is the constructor itself.

20.5.6.3.2 **NativeError.prototype.message**

The initial value of the "message" property of the prototype for a given NativeError constructor is the empty String.

20.5.6.3.3 **NativeError.prototype.name**

The initial value of the "name" property of the prototype for a given NativeError constructor is the String value consisting of the name of the constructor (the name used instead of NativeError).

20.5.6.4 **Properties of NativeError Instances**

NativeError instances are ordinary objects that inherit properties from their NativeError prototype object and have an [[ErrorData]] internal slot whose value is undefined. The only specified use of [[ErrorData]] is by Object.prototype.toString (20.1.3.6) to identify Error, AggregateError, or NativeError instances.

20.5.7 **AggregateError Objects**

20.5.7.1 **The AggregateError Constructor**

The AggregateError constructor:

• is %AggregateError%.
• is the initial value of the "AggregateError" property of the global object.
• creates and initializes a new AggregateError object when called as a function rather than as a constructor. Thus the function call AggregateError(…) is equivalent to the object creation expression new AggregateError(…) with the same arguments.
• may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified AggregateError behaviour must include a super call to the AggregateError constructor to create and initialize subclass instances with an [[ErrorData]] internal slot.

20.5.7.1.1 **AggregateError ( errors, message [ , options ] )**

This function performs the following steps when called:

1. If NewTarget is undefined, let newTarget be the active function object; else let newTarget be NewTarget.
2. Let O be ? OrdinaryCreateFromConstructor(newTarget, "%AggregateError.prototype%", « [[ErrorData]] »).
3. If message is not undefined, then
   a. Let msg be ? ToString(message).
   b. Perform CreateNonEnumerableDataPropertyOrThrow(O, "message", msg).
5. Let errorsList be ? IteratorToList(? GetIterator(errors, SYNC)).
6. Perform ! DefinePropertyOrThrow(O, "errors", PropertyDescriptor { [[Configurable]]: true, [[Enumerable]]: false, [[Writable]]: true, [[Value]]: CreateArrayFromList(errorsList) }).
7. Return O.
20.5.7.2 Properties of the AggregateError Constructor

The AggregateError constructor:

• has a [[Prototype]] internal slot whose value is %Error%.
• has the following properties:

20.5.7.2.1 AggregateError.prototype

The initial value of AggregateError.prototype is %AggregateError.prototype%.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

20.5.7.3 Properties of the AggregateError Prototype Object

The AggregateError prototype object:

• is %AggregateError.prototype%.
• is an ordinary object.
• is not an Error instance or an AggregateError instance and does not have an [[ErrorData]] internal slot.
• has a [[Prototype]] internal slot whose value is %Error.prototype%.

20.5.7.3.1 AggregateError.prototype.constructor

The initial value of AggregateError.prototype.constructor is %AggregateError%.

20.5.7.3.2 AggregateError.prototype.message

The initial value of AggregateError.prototype.message is the empty String.

20.5.7.3.3 AggregateError.prototype.name

The initial value of AggregateError.prototype.name is "AggregateError".

20.5.7.4 Properties of AggregateError Instances

AggregateError instances are ordinary objects that inherit properties from their AggregateError prototype object and have an [[ErrorData]] internal slot whose value is undefined. The only specified use of [[ErrorData]] is by Object.prototype.toString (20.1.3.6) to identify Error, AggregateError, or NativeError instances.

20.5.8 Abstract Operations for Error Objects

20.5.8.1 InstallErrorCause ( O, options )

The abstract operation InstallErrorCause takes arguments O (an Object) and options (an ECMAScript language value) and returns either a normal completion containing UNUSED or a throw completion. It is used to create a "cause" property on O when a "cause" property is present on options. It performs the following steps when called:

1. If options is an Object and ? HasProperty(options, "cause") is true, then
   a. Let cause be ? Get(options, "cause").
   b. Perform CreateNonEnumerableDataPropertyOrThrow(O, "cause", cause).
2. Return UNUSED.
21 Numbers and Dates

21.1 Number Objects

21.1.1 The Number Constructor

The Number constructor:

• is %Number%.
• is the initial value of the "Number" property of the global object.
• creates and initializes a new Number object when called as a constructor.
• performs a type conversion when called as a function rather than as a constructor.
• may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified Number behaviour must include a super call to the Number constructor to create and initialize the subclass instance with a [[NumberData]] internal slot.

21.1.1.1 Number ( value )

This function performs the following steps when called:

1. If value is present, then
   a. Let prim be ? ToNumeric(value).
   b. If prim is a BigInt, let n be 𝕆(𝔽(ℝ(prim))).
   c. Otherwise, let n be prim.
2. Else,
   a. Let n be +𝔽.
3. If NewTarget is undefined, return n.
4. Let O be ? OrdinaryCreateFromConstructor(NewTarget, "%Number.prototype!", « [[NumberData]] »).
5. Set O.[[NumberData]] to n.
6. Return O.

21.1.2 Properties of the Number Constructor

The Number constructor:

• has a [[Prototype]] internal slot whose value is %Function.prototype%.
• has the following properties:

21.1.2.1 Number.EPSILON

The value of Number.EPSILON is the Number value for the magnitude of the difference between 1 and the smallest value greater than 1 that is representable as a Number value, which is approximately 2.220446049250310808472633361816 × 10⁻¹⁶.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.2 Number.isFinite ( number )

This function performs the following steps when called:

1. If number is not a Number, return false.
2. If number is not finite, return false.
3. Otherwise, return true.
21.1.2.3 Number.isInteger (number)

This function performs the following steps when called:
1. Return IsIntegralNumber(number).

21.1.2.4 Number.isNaN (number)

This function performs the following steps when called:
1. If number is not a Number, return false.
2. If number is NaN, return true.
3. Otherwise, return false.

**NOTE** This function differs from the global isNaN function (19.2.3) in that it does not convert its argument to a Number before determining whether it is NaN.

21.1.2.5 Number.isSafeInteger (number)

**NOTE** An integer n is a "safe integer" if and only if the Number value for n is not the Number value for any other integer.

This function performs the following steps when called:
1. If IsIntegralNumber(number) is true, then
   a. If abs(R(number)) ≤ 2^{53} - 1, return true.
2. Return false.

21.1.2.6 Number.MAX_SAFE_INTEGER

**NOTE** Due to rounding behaviour necessitated by precision limitations of IEEE 754-2019, the Number value for every integer greater than Number.MAX_SAFE_INTEGER is shared with at least one other integer. Such large-magnitude integers are therefore not safe, and are not guaranteed to be exactly representable as Number values or even to be distinguishable from each other. For example, both 9007199254740992 and 9007199254740993 evaluate to the Number value 9007199254740992𝔽. The value of Number.MAX_SAFE_INTEGER is 9007199254740991_F (F(2^{53} - 1)).

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.7 Number.MAX_VALUE

The value of Number.MAX_VALUE is the largest positive finite value of the Number type, which is approximately 1.7976931348623157 × 10^{308}.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }. © Ecma International 2024
21.1.2.8 `Number.MIN_SAFE_INTEGER`

Due to rounding behaviour necessitated by precision limitations of IEEE 754-2019, the `Number` value for every integer less than `Number.MIN_SAFE_INTEGER` is shared with at least one other integer. Such large-magnitude integers are therefore not safe, and are not guaranteed to be exactly representable as `Number` values or even to be distinguishable from each other. For example, both `-9007199254740992` and `-9007199254740993` evaluate to the `Number` value `-9007199254740992𝔽`. The value of `Number.MIN_SAFE_INTEGER` is `-9007199254740991𝔽` ($2^{53} - 1$)).

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.9 `Number.MIN_VALUE`

The value of `Number.MIN_VALUE` is the smallest positive value of the `Number` type, which is approximately $5 \times 10^{-324}$. In the IEEE 754-2019 double precision binary representation, the smallest possible value is a denormalized number. If an implementation does not support denormalized values, the value of `Number.MIN_Value` must be the smallest non-zero positive value that can actually be represented by the implementation.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.10 `Number.NaN`

The value of `Number.NaN` is `NaN`.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.11 `Number.NEGATIVE_INFINITY`

The value of `Number.NEGATIVE_INFINITY` is $-∞𝔽$. This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.12 `Number.parseFloat` (string)

The initial value of the "parseFloat" property is `%parseFloat%`.

21.1.2.13 `Number.parseInt` (string, radix)

The initial value of the "parseInt" property is `%parseInt%`.

21.1.2.14 `Number.POSITIVE_INFINITY`

The value of `Number.POSITIVE_INFINITY` is $+∞𝔽$. This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.1.2.15 `Number.prototype`

The initial value of `Number.prototype` is the `Number` prototype object. This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.
21.1.3 Properties of the Number Prototype Object

The *Number prototype object*:

- is `%Number.prototype%`.
- is an *ordinary object*.
- is itself a *Number object*: it has a `[[NumberData]]` internal slot with the value `+0𝔽`.
- has a `[[Prototype]]` internal slot whose value is `%Object.prototype%`.

Unless explicitly stated otherwise, the methods of the Number prototype object defined below are not generic and the *this* value passed to them must be either a Number value or an object that has a `[[NumberData]]` internal slot that has been initialized to a Number value.

The phrase "this Number value" within the specification of a method refers to the result returned by calling the abstract operation `ThisNumberValue` with the *this* value of the method invocation passed as the argument.

21.1.3.1 Number.prototype.constructor

The initial value of `Number.prototype.constructor` is `%Number%`.

21.1.3.2 Number.prototype.toExponential ( `fractionDigits` )

This method returns a String containing this Number value represented in decimal exponential notation with one digit before the significand's decimal point and `fractionDigits` digits after the significand's decimal point. If `fractionDigits` is `undefined`, it includes as many significand digits as necessary to uniquely specify the Number (just like in `ToString` except that in this case the Number is always output in exponential notation).

It performs the following steps when called:

1. Let `x` be `ThisNumberValue(this value)`.
2. Let `f` be `ToIntegerOrInfinity(fractionDigits)`.
3. Assert: If `fractionDigits` is `undefined`, then `f` is 0.
4. If `x` is not *finite*, return `Number::toString(x, 10)`.
5. If `f < 0` or `f > 100`, throw a `RangeError` exception.
6. Set `x` to `ℝ(x)`.
7. Let `s` be the empty String.
8. If `x < 0`, then
   a. Set `s` to "-".
   b. Set `x` to `-x`.
9. If `x = 0`, then
   a. Let `m` be the String value consisting of `f + 1` occurrences of the code unit `0x0030` (DIGIT ZERO).
   b. Let `e` be 0.
10. Else,
    a. If `fractionDigits` is not `undefined`, then
      i. Let `e` and `n` be integers such that `10^e ≤ n < 10^{e+1}` and for which `n × 10^e · x` is as close to zero as possible. If there are two such sets of `e` and `n`, pick the `e` and `n` for which `n × 10^e · x` is larger.
    b. Else,
      i. Let `e`, `n`, and `ff` be integers such that `ff ≥ 0`, `10^{ff} ≤ n < 10^{ff+1}`, `𝔽(n × 10^e · ff)` is `𝔽(x)`, and `ff` is as small as possible. Note that the decimal representation of `n` has `ff + 1` digits, `n` is not divisible by 10, and the least significant digit of `n` is not necessarily uniquely determined by these criteria.
      ii. Set `f` to `ff`.
    c. Let `m` be the String value consisting of the digits of the decimal representation of `n` (in order, with no leading zeroes).
11. If `f ≠ 0`, then
    a. Let `a` be the first code unit of `m`.
    b. Let `b` be the other `f` code units of `m`.
    c. Set `m` to the string-concatenation of `a`, "," , and `b`.
12. If `e = 0`, then
a. Let \( c \) be "+".
b. Let \( d \) be "0".

13. Else,
a. If \( e > 0 \), then
   i. Let \( c \) be "+".
b. Else,
   i. Assert: \( e < 0 \).
   ii. Let \( c \) be "-".
   iii. Set \( e \) to \(-e\).
c. Let \( d \) be the String value consisting of the digits of the decimal representation of \( e \) (in order, with no leading zeroes).

14. Set \( m \) to the string-concatenation of \( m \), "e", \( c \), and \( d \).
15. Return the string-concatenation of \( s \) and \( m \).

NOTE For implementations that provide more accurate conversions than required by the rules above, it is recommended that the following alternative version of step 10.b.i be used as a guideline:

i. Let \( e \), \( n \), and \( f \) be integers such that \( f \geq 0 \), \( 10^f \leq n < 10^{f+1} \), \( \mathbb{F}(n \times 10^{f} - f) \) is \( \mathbb{F}(x) \), and \( f \) is as small as possible. If there are multiple possibilities for \( n \), choose the value of \( n \) for which \( \mathbb{F}(n \times 10^{f} - f) \) is closest in value to \( \mathbb{F}(x) \). If there are two such possible values of \( n \), choose the one that is even.

21.1.3.3 Number.prototype.toFixed ( \( fractionDigits \) )

NOTE 1 This method returns a String containing this Number value represented in decimal fixed-point notation with \( fractionDigits \) digits after the decimal point. If \( fractionDigits \) is undefined, \( \emptyset \) is assumed.

It performs the following steps when called:

1. Let \( x \) be \( \text{ThisNumberValue}(\text{this value}) \).
2. Let \( f \) be \( \text{ToIntegerOrInfinity}(fractionDigits) \).
3. Assert: If \( fractionDigits \) is undefined, then \( f = 0 \).
4. If \( f \) is not finite, throw a RangeError exception.
5. If \( f < 0 \) or \( f > 100 \), throw a RangeError exception.
6. If \( x \) is not finite, return Number::toString \( (x, 10) \).
7. Set \( x \) to \( \mathbb{R}(x) \).
8. Let \( s \) be the empty String.
9. If \( x < 0 \), then
   a. Set \( s \) to "+".
   b. Set \( x \) to \(-x\).
10. If \( x \geq 10^{21} \), then
   a. Let \( m \) be \( \text{ToString}(\mathbb{F}(x)) \).
11. Else,
a. Let \( n \) be an integer for which \( n \cdot 10^f - x \) is as close to zero as possible. If there are two such \( n \), pick the larger \( n \).
b. If \( n = 0 \), let \( m \) be "0". Otherwise, let \( m \) be the String value consisting of the digits of the decimal representation of \( n \) (in order, with no leading zeroes).
c. If \( f \neq 0 \), then
   i. Let \( k \) be the length of \( m \).
   ii. If \( k \leq f \), then
      1. Let \( z \) be the String value consisting of \( f + 1 - k \) occurrences of the code unit \( 0x0030 \) (DIGIT ZERO).
      2. Set \( m \) to the string-concatenation of \( z \) and \( m \).
      3. Set \( k \) to \( f + 1 \).
   iii. Let \( a \) be the first \( k - f \) code units of \( m \).
iv. Let \( b \) be the other \( f \) code units of \( m \).
v. Set \( m \) to the string-concatenation of \( a \), ",", and \( b \).

12. Return the string-concatenation of \( s \) and \( m \).

NOTE 2 The output of \( \texttt{toFixed} \) may be more precise than \( \texttt{toString} \) for some values because \( \texttt{toString} \) only prints enough significant digits to distinguish the number from adjacent Number values. For example,

\[
(1000000000000000128).\texttt{toString}() \text{ returns } "1000000000000000100", \text{ while } (1000000000000000128).\texttt{toFixed}(0) \text{ returns } "1000000000000000128".
\]

21.1.3.4 \( \text{Number.prototype.toLocaleString} \) ([reserved1 [, reserved2 ]])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method produces a String value that represents this Number value formatted according to the conventions of the host environment’s current locale. This method is implementation-defined, and it is permissible, but not encouraged, for it to return the same thing as \( \texttt{toString} \).

The meanings of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

21.1.3.5 \( \text{Number.prototype.toPrecision} \) ( \( \text{precision} \) )

This method returns a String containing this Number value represented either in decimal exponential notation with one digit before the significand’s decimal point and \( \text{precision} - 1 \) digits after the significand’s decimal point or in decimal fixed notation with \( \text{precision} \) significant digits. If \( \text{precision} \) is \( \text{undefined} \), it calls \( \text{ToString} \) instead.

It performs the following steps when called:

1. Let \( x \) be ? \( \text{ThisNumberValue}(\text{this} \text{ value}) \).
2. If \( \text{precision} \) is \( \text{undefined} \), return ! \( \text{ToString}(x) \).
3. Let \( p \) be ? \( \text{ToIntegerOrInfinity}(\text{precision}) \).
4. If \( x \) is not \( \text{finite} \), return \( \text{Number::toString}(x, 10) \).
5. If \( p < 1 \) or \( p > 100 \), throw a \( \text{RangeError} \) exception.
6. Set \( x \) to \( \mathbb{R}(x) \).
7. Let \( s \) be the empty String.
8. If \( x = 0 \), then
   a. Set \( s \) to the code unit \( 0x002D \) (HYPHEN-MINUS).
   b. Set \( s \) to \( -x \).
9. If \( x = 0 \), then
   a. Let \( m \) be the String value consisting of \( p \) occurrences of the code unit \( 0x0030 \) (DIGIT ZERO).
   b. Let \( e \) be \( 0 \).
10. Else,
   a. Let \( e \) and \( n \) be integers such that \( 10^p - 1 \leq n < 10^p \) and for which \( n \times 10^p + 1 - x \) is as close to zero as possible. If there are two such sets of \( e \) and \( n \), pick the \( e \) and \( n \) for which \( n \times 10^p + 1 \) is larger.
   b. Let \( m \) be the String value consisting of the digits of the decimal representation of \( n \) (in order, with no leading zeroes).
   c. If \( e < -6 \) or \( e \geq p \), then
      i. Assert: \( e \neq 0 \).
      ii. If \( p \neq 1 \), then
         1. Let \( a \) be the first code unit of \( m \).
         2. Let \( b \) be the other \( p - 1 \) code units of \( m \).
         3. Set \( m \) to the string-concatenation of \( a \), ",", and \( b \).
      iii. If \( e > 0 \), then
          1. Let \( c \) be the code unit \( 0x002B \) (PLUS SIGN).
iv. Else,
   1. Assert: $e < 0$.
   2. Let $c$ be the code unit 0x002D (HYPHEN-MINUS).
   3. Set $e$ to -$e$.

v. Return the string-concatenation of $s$, $m$, the code unit 0x0065 (LATIN SMALL LETTER E), $c$, and $d$.

vi. Let $d$ be the String value consisting of the digits of the decimal representation of $e$ (in order, with no leading zeroes).

11. If $e = p - 1$, return the string-concatenation of $s$ and $m$.

12. If $e \geq 0$, then
   a. Set $m$ to the string-concatenation of the first $e + 1$ code units of $m$, the code unit 0x002E (FULL STOP), and the remaining $p - (e + 1)$ code units of $m$.

13. Else,
   a. Set $m$ to the string-concatenation of the code unit 0x0030 (DIGIT ZERO), the code unit 0x002E (FULL STOP), -(e + 1) occurrences of the code unit 0x0030 (DIGIT ZERO), and the String $m$.

14. Return the string-concatenation of $s$ and $m$.

21.1.3.6 Number.prototype.toString ( [ radix ] )

NOTE  The optional radix should be an integral Number value in the inclusive interval from 2𝔽 to 36𝔽. If radix is undefined then 10𝔽 is used as the value of radix.

This method performs the following steps when called:

1. Let x be ? ThisNumberValue(this value).
2. If radix is undefined, let radixMV be 10𝔽.
3. Else, let radixMV be ? ToIntegerOrInfinity(radix).
4. If radixMV is not in the inclusive interval from 2𝔽 to 36𝔽, throw a RangeError exception.
5. Return Number::toString(x, radixMV).

This method is not generic; it throws a TypeError exception if its this value is not a Number or a Number object. Therefore, it cannot be transferred to other kinds of objects for use as a method.

The "length" property of this method is $1𝔽$.

21.1.3.7 Number.prototype.valueOf ( )

1. Return ? ThisNumberValue(this value).

21.1.3.7.1 ThisNumberValue ( value )

The abstract operation ThisNumberValue takes argument value (an ECMAScript language value) and returns either a normal completion containing a Number or a throw completion. It performs the following steps when called:

1. If value is a Number, return value.
2. If value is an Object and value has a [[NumberData]] internal slot, then
   a. Let n be value.[[NumberData]].
   b. Assert: n is a Number.
   c. Return n.
3. Throw a TypeError exception.

21.1.4 Properties of Number Instances

Number instances are ordinary objects that inherit properties from the Number prototype object. Number instances also have a [[NumberData]] internal slot. The [[NumberData]] internal slot is the Number value represented by this Number object.
21.2 BigInt Objects

21.2.1 The BigInt Constructor

The BigInt constructor:

• is %BigInt%.
• is the initial value of the "BigInt" property of the global object.
• performs a type conversion when called as a function rather than as a constructor.
• is not intended to be used with the new operator or to be subclassed. It may be used as the value of an extends clause of a class definition but a super call to the BigInt constructor will cause an exception.

21.2.1.1 BigInt ( value )

This function performs the following steps when called:

1. If NewTarget is not undefined, throw a TypeError exception.
2. Let prim be ? ToPrimitive(value, NUMBER).
3. If prim is a Number, return ? NumberToBigInt(prim).
4. Otherwise, return ? ToBigInt(prim).

21.2.1.1.1 NumberToBigInt ( number )

The abstract operation NumberToBigInt takes argument number (a Number) and returns either a normal completion containing a BigInt or a throw completion. It performs the following steps when called:

1. If IsIntegralNumber(number) is false, throw a RangeError exception.
2. Return ℤ(ℝ(number)).

21.2.2 Properties of the BigInt Constructor

The BigInt constructor:

• has a [[Prototype]] internal slot whose value is %Function.prototype%.
• has the following properties:

21.2.2.1 BigInt.asIntN ( bits, bigint )

This function performs the following steps when called:

1. Set bits to ? ToIndex(bits).
2. Set bigint to ? ToBigInt(bigint).
3. Let mod be ℝ(bigint) modulo 2<sup>bits</sup>.
4. If mod ≥ 2<sup>bits - 1</sup>, return ℤ(mod - 2<sup>bits</sup>); otherwise, return ℤ(mod).

21.2.2.2 BigInt.asUintN ( bits, bigint )

This function performs the following steps when called:

1. Set bits to ? ToIndex(bits).
2. Set bigint to ? ToBigInt(bigint).
3. Return ℤ(ℝ(bigint) modulo 2<sup>bits</sup>).
21.2.2.3 BigInt.prototype

The initial value of `BigInt.prototype` is the BigInt prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.2.3 Properties of the BigInt Prototype Object

The `BigInt prototype object`:

- is `%BigInt.prototype%`.
- is an ordinary object.
- is not a BigInt object; it does not have a [[BigIntData]] internal slot.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.

The phrase “this BigInt value” within the specification of a method refers to the result returned by calling the abstract operation `ThisBigIntValue` with the this value of the method invocation passed as the argument.

21.2.3.1 BigInt.prototype.constructor

The initial value of `BigInt.prototype.constructor` is `%BigInt%`.

21.2.3.2 BigInt.prototype.toLocaleString ([reserved1, reserved2])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method produces a String value that represents this BigInt value formatted according to the conventions of the host environment's current locale. This method is implementation-defined, and it is permissible, but not encouraged, for it to return the same thing as `toString`.

The meanings of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

21.2.3.3 BigInt.prototype.toString ([radix])

This method performs the following steps when called:

1. Let x be ? `ThisBigIntValue(this value)`.
2. If `radix` is undefined, let `radixMV` be 10.
3. Else, let `radixMV` be `ToIntegerOrInfinity(radix)`.
4. If `radixMV` is not in the inclusive interval from 2 to 36, throw a `RangeError` exception.
5. Return `BigInt::toString(x, radixMV)`.

This method is not generic; it throws a `TypeError` exception if its this value is not a BigInt or a BigInt object. Therefore, it cannot be transferred to other kinds of objects for use as a method.

21.2.3.4 BigInt.prototype.valueOf ()

1. Return ? `ThisBigIntValue(this value)`.
21.2.3.4.1 ThisBigIntValue ( value )

The abstract operation ThisBigIntValue takes argument value (an ECMAScript language value) and returns either a normal completion containing a BigInt or a throw completion. It performs the following steps when called:

1. If value is a BigInt, return value.
2. If value is an Object and value has a [[BigIntData]] internal slot, then
   a. Assert: value.[[BigIntData]] is a BigInt.
   b. Return value.[[BigIntData]].
3. Throw a TypeError exception.

21.2.3.5 BigInt.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "BigInt".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

21.2.4 Properties of BigInt Instances

BigInt instances are ordinary objects that inherit properties from the BigInt prototype object. BigInt instances also have a [[BigIntData]] internal slot. The [[BigIntData]] internal slot is the BigInt value represented by this BigInt object.

21.3 The Math Object

The Math object:

- is %Math%.
- is the initial value of the "Math" property of the global object.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is not a function object.
- does not have a [[Construct]] internal method; it cannot be used as a constructor with the new operator.
- does not have a [[Call]] internal method; it cannot be invoked as a function.

NOTE In this specification, the phrase “the Number value for x” has a technical meaning defined in 6.1.6.1.

21.3.1 Value Properties of the Math Object

21.3.1.1 Math.E

The Number value for e, the base of the natural logarithms, which is approximately 2.7182818284590452354.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.3.1.2 Math.LN10

The Number value for the natural logarithm of 10, which is approximately 2.302585092994046.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }. 

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21.3.1.3 Math.LN2

The Number value for the natural logarithm of 2, which is approximately 0.6931471805599453.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.3.1.4 Math.LOG10E

The Number value for the base-10 logarithm of e, the base of the natural logarithms; this value is approximately 0.4342944819032518.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

NOTE The value of Math.LOG10E is approximately the reciprocal of the value of Math.LN10.

21.3.1.5 Math.LOG2E

The Number value for the base-2 logarithm of e, the base of the natural logarithms; this value is approximately 1.4426950408889634.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

NOTE The value of Math.LOG2E is approximately the reciprocal of the value of Math.LN2.

21.3.1.6 Math.PI

The Number value for π, the ratio of the circumference of a circle to its diameter, which is approximately 3.1415926535897932.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.3.1.7 Math.SQRT1_2

The Number value for the square root of ½, which is approximately 0.7071067811865476.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

NOTE The value of Math.SQRT1_2 is approximately the reciprocal of the value of Math.SQRT2.

21.3.1.8 Math.SQRT2

The Number value for the square root of 2, which is approximately 1.4142135623730951.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.3.1.9 Math [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "Math".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.
21.3.2 Function Properties of the Math Object

NOTE  The behaviour of the functions $\text{acos}$, $\text{acosh}$, $\text{asin}$, $\text{asinh}$, $\text{atan}$, $\text{atanh}$, $\text{atan2}$, $\text{cbrt}$, $\text{cos}$, $\text{cosh}$, $\text{exp}$, $\text{expm1}$, $\text{hypot}$, $\text{log}$, $\text{log1p}$, $\text{log2}$, $\text{log10}$, $\text{pow}$, $\text{random}$, $\text{sin}$, $\text{sinh}$, $\text{sqrt}$, $\text{tan}$, and $\text{tanh}$ is not precisely specified here except to require specific results for certain argument values that represent boundary cases of interest. For other argument values, these functions are intended to compute approximations to the results of familiar mathematical functions, but some latitude is allowed in the choice of approximation algorithms. The general intent is that an implementer should be able to use the same mathematical library for ECMAScript on a given hardware platform that is available to C programmers on that platform.

Although the choice of algorithms is left to the implementation, it is recommended (but not specified by this standard) that implementations use the approximation algorithms for IEEE 754-2019 arithmetic contained in \texttt{fdlibm}, the freely distributable mathematical library from Sun Microsystems (http://www.netlib.org/fdlibm).

21.3.2.1 Math.abs ( $x$ )

This function returns the absolute value of $x$; the result has the same magnitude as $x$ but has positive sign.

It performs the following steps when called:

1. Let $n$ be $\text{ToNumber}(x)$.
2. If $n$ is $\text{NaN}$, return $\text{NaN}$.
3. If $n$ is $-\text{0F}$, return $+\text{0F}$.
4. If $n$ is $-\infty\text{F}$, return $+\infty\text{F}$.
5. If $n < -\text{0F}$, return $-n$.
6. Return $n$.

21.3.2.2 Math.acos ( $x$ )

This function returns the inverse cosine of $x$. The result is expressed in radians and is in the inclusive interval from $+\text{0F}$ to $\text{F}(\pi)$.

It performs the following steps when called:

1. Let $n$ be $\text{ToNumber}(x)$.
2. If $n$ is $\text{NaN}$, $n > 1\text{F}$, or $n < -1\text{F}$, return $\text{NaN}$.
3. If $n$ is $1\text{F}$, return $+\text{0F}$.
4. Return an implementation-approximated $\text{Number}$ value representing the result of the inverse cosine of $\mathbb{R}(n)$.

21.3.2.3 Math.acosh ( $x$ )

This function returns the inverse hyperbolic cosine of $x$.

It performs the following steps when called:

1. Let $n$ be $\text{ToNumber}(x)$.
2. If $n$ is either $\text{NaN}$ or $+\infty\text{F}$, return $n$.
3. If $n$ is $1\text{F}$, return $+\text{0F}$.
4. If $n < 1\text{F}$, return $\text{NaN}$.
5. Return an implementation-approximated $\text{Number}$ value representing the result of the inverse hyperbolic cosine of $\mathbb{R}(n)$.
21.3.2.4 Math.asin (x)

This function returns the inverse sine of x. The result is expressed in radians and is in the inclusive interval from \( \mathbb{F}(-\pi / 2) \) to \( \mathbb{F}(\pi / 2) \).

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(x).
2. If \( n \) is one of NaN, +\( \mathbb{F} \), or -\( \mathbb{F} \), return \( n \).
3. If \( n > 1 \mathbb{F} \) or \( n < -1 \mathbb{F} \), return NaN.
4. Return an implementation-approximated Number value representing the result of the inverse sine of \( \mathbb{R}(n) \).

21.3.2.5 Math.asinh (x)

This function returns the inverse hyperbolic sine of x.

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(x).
2. If \( n \) is not finite or \( n \) is either +\( \mathbb{F} \) or -\( \mathbb{F} \), return \( n \).
3. Return an implementation-approximated Number value representing the result of the inverse hyperbolic sine of \( \mathbb{R}(n) \).

21.3.2.6 Math.atan (x)

This function returns the inverse tangent of x. The result is expressed in radians and is in the inclusive interval from \( \mathbb{F}(-\pi / 2) \) to \( \mathbb{F}(\pi / 2) \).

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(x).
2. If \( n \) is one of NaN, +\( \mathbb{F} \), or -\( \mathbb{F} \), return \( n \).
3. If \( n \) is positive infinity, return an implementation-approximated Number value representing \( \pi / 2 \).
4. If \( n \) is negative infinity, return an implementation-approximated Number value representing \(-\pi / 2 \).
5. Return an implementation-approximated Number value representing the result of the inverse tangent of \( \mathbb{R}(n) \).

21.3.2.7 Math.atanh (x)

This function returns the inverse hyperbolic tangent of x.

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(x).
2. If \( n \) is one of NaN, +\( \mathbb{F} \), or -\( \mathbb{F} \), return \( n \).
3. If \( n > 1 \mathbb{F} \) or \( n < -1 \mathbb{F} \), return NaN.
4. If \( n \) is positive infinity, return positive infinity.
5. If \( n \) is negative infinity, return negative infinity.
6. Return an implementation-approximated Number value representing the result of the inverse hyperbolic tangent of \( \mathbb{R}(n) \).
21.3.2.8 Math.atan2 ( y, x )

This function returns the inverse tangent of the quotient \( y / x \) of the arguments \( y \) and \( x \), where the signs of \( y \) and \( x \) are used to determine the quadrant of the result. Note that it is intentional and traditional for the two-argument inverse tangent function that the argument named \( y \) be first and the argument named \( x \) be second. The result is expressed in radians and is in the inclusive interval from -\( \pi \) to +\( \pi \).

It performs the following steps when called:

1. Let \( ny \) be ? ToNumber(y).
2. Let \( nx \) be ? ToNumber(x).
3. If \( ny \) is NaN or \( nx \) is NaN, return NaN.
4. If \( ny \) is +\( \infty \), then
   a. If \( nx \) is +\( \infty \), return an implementation-approximated Number value representing \( \pi / 4 \).
   b. If \( nx \) is -\( \infty \), return an implementation-approximated Number value representing 3\( \pi / 4 \).
   c. Return an implementation-approximated Number value representing \( \pi / 2 \).
5. If \( ny \) is -\( \infty \), then
   a. If \( nx \) is +\( \infty \), return an implementation-approximated Number value representing -3\( \pi / 4 \).
   b. If \( nx \) is -\( \infty \), return an implementation-approximated Number value representing \( -\pi / 2 \).
   c. Return an implementation-approximated Number value representing -\( \pi / 2 \).
6. If \( ny \) is +0, then
   a. If \( nx \) is +0 or \( nx \) is +0, return +0.
   b. Return an implementation-approximated Number value representing \( \pi \).
7. If \( ny \) is -0, then
   a. If \( nx \) is +0 or \( nx \) is +0, return -0.
   b. Return an implementation-approximated Number value representing -\( \pi \).
8. Assert: \( ny \) is finite and is neither +0 nor -0.
9. If \( ny \) > +0, then
   a. If \( nx \) is +\( \infty \), return +0.
   b. If \( nx \) is -\( \infty \), return an implementation-approximated Number value representing \( \pi \).
   c. If \( nx \) is either +0 or -0, return an implementation-approximated Number value representing \( \pi / 2 \).
10. If \( ny \) < -0, then
    a. If \( nx \) is +\( \infty \), return -0.
    b. If \( nx \) is -\( \infty \), return an implementation-approximated Number value representing -\( \pi \).
    c. If \( nx \) is either +0 or -0, return an implementation-approximated Number value representing -\( \pi / 2 \).
11. Assert: \( nx \) is finite and is neither +0 nor -0.
12. Let \( r \) be the inverse tangent of abs(\( R(ny) / R(nx) \)).
13. If \( nx \) < -0, then
    a. If \( ny \) > +0, set \( r \) to \( \pi - r \).
    b. Else, set \( r \) to -\( \pi + r \).
14. Else,
    a. If \( ny \) < -0, set \( r \) to -r.
15. Return an implementation-approximated Number value representing \( r \).

21.3.2.9 Math.cbrt ( x )

This function returns the cube root of \( x \).

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(x).
2. If \( n \) is not finite or \( n \) is either +0 or -0, return \( n \).
3. Return an implementation-approximated Number value representing the result of the cube root of \( R(n) \).
21.3.2.10 Math.ceil (x)

This function returns the smallest (closest to -∞) integral Number value that is not less than x. If x is already an integral Number, the result is x.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is not finite or n is either +0_F or -0_F, return n.
3. If n < -0_F and n > -1_F, return -0_F.
4. If n is an integral Number, return n.
5. Return the smallest (closest to -∞) integral Number value that is not less than n.

NOTE The value of Math.ceil(x) is the same as the value of -Math.floor(-x).

21.3.2.11 Math.clz32 (x)

This function performs the following steps when called:

1. Let n be ? ToUint32(x).
2. Let p be the number of leading zero bits in the unsigned 32-bit binary representation of n.
3. Return ᵈ(p).

NOTE If n is either +0_F or -0_F, this method returns 32_F. If the most significant bit of the 32-bit binary encoding of n is 1, this method returns +0_F.

21.3.2.12 Math.cos (x)

This function returns the cosine of x. The argument is expressed in radians.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is not finite, return NaN.
3. If n is either +0_F or -0_F, return 1_F.
4. Return an implementation-approximated Number value representing the result of the cosine of ℝ(n).

21.3.2.13 Math.cosh (x)

This function returns the hyperbolic cosine of x.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is NaN, return NaN.
3. If n is either +∞_F or -∞_F, return +∞_F.
4. If n is either +0_F or -0_F, return 1_F.
5. Return an implementation-approximated Number value representing the result of the hyperbolic cosine of ℝ(n).

NOTE The value of Math.cosh(x) is the same as the value of (Math.exp(x) + Math.exp(-x)) / 2.
21.3.2.14 Math.exp (x)

This function returns the exponential function of \( x \) (\( e \) raised to the power of \( x \), where \( e \) is the base of the natural logarithms).

It performs the following steps when called:

1. Let \( n \) be \( \text{ToNumber}(x) \).
2. If \( n \) is either \( \text{NaN} \) or \( +\infty \), return \( n \).
3. If \( n \) is either \( +0 \) or \( -0 \), return \( 1 \).
4. If \( n \) is \( -\infty \), return \( +0 \).
5. Return an implementation-approximated Number value representing the result of the exponential function of \( \mathbb{R} (n) \).

21.3.2.15 Math.expm1 (x)

This function returns the result of subtracting 1 from the exponential function of \( x \) (\( e \) raised to the power of \( x \), where \( e \) is the base of the natural logarithms). The result is computed in a way that is accurate even when the value of \( x \) is close to 0.

It performs the following steps when called:

1. Let \( n \) be \( \text{ToNumber}(x) \).
2. If \( n \) is one of \( \text{NaN} \), \( +0 \), \( -0 \), or \( +\infty \), return \( n \).
3. If \( n \) is \( -\infty \), return \( -1 \).
4. Return an implementation-approximated Number value representing the result of subtracting 1 from the exponential function of \( \mathbb{R} (n) \).

21.3.2.16 Math.floor (x)

This function returns the greatest (closest to \( +\infty \)) integral Number value that is not greater than \( x \). If \( x \) is already an integral Number, the result is \( x \).

It performs the following steps when called:

1. Let \( n \) be \( \text{ToNumber}(x) \).
2. If \( n \) is not finite or \( n \) is either \( +0 \) or \( -0 \), return \( n \).
3. If \( n < 1 \) and \( n > +0 \), return +0.
4. If \( n \) is an integral Number, return \( n \).
5. Return the greatest (closest to \( +\infty \)) integral Number value that is not greater than \( n \).

NOTE The value of Math.floor(x) is the same as the value of -Math.ceil(-x).

21.3.2.17 Math.fround (x)

This function performs the following steps when called:

1. Let \( n \) be \( \text{ToNumber}(x) \).
2. If \( n \) is \( \text{NaN} \), return \( \text{NaN} \).
3. If \( n \) is one of \( +0 \), \( -0 \), \( +\infty \), or \( -\infty \), return \( n \).
4. Let \( n_{32} \) be the result of converting \( n \) to IEEE 754-2019 binary32 format using roundTiesToEven mode.
5. Let \( n_{64} \) be the result of converting \( n_{32} \) to IEEE 754-2019 binary64 format.
6. Return the ECMAScript Number value corresponding to \( n_{64} \).
21.3.2.18 Math.hypot (...args)

Given zero or more arguments, this function returns the square root of the sum of squares of its arguments.

It performs the following steps when called:

1. Let coerced be a new empty List.
2. For each element arg of args, do
   a. Let n be ?ToNumber(arg).
   b. Append n to coerced.
3. For each element number of coerced, do
   a. If number is either +∞𝔽 or -∞𝔽, return +∞𝔽.
4. Let onlyZero be true.
5. For each element number of coerced, do
   a. If number is NaN, return NaN.
   b. If number is neither +0𝔽 nor -0𝔽, set onlyZero to false.
6. If onlyZero is true, return +0𝔽.
7. Return an implementation-approximated Number value representing the square root of the sum of squares of the mathematical values of the elements of coerced.

The "length" property of this function is 2𝔽.

NOTE Implementations should take care to avoid the loss of precision from overflows and underflows that are prone to occur in naive implementations when this function is called with two or more arguments.

21.3.2.19 Math.imul (x, y)

This function performs the following steps when called:

1. Let a be ℝ(?ToUint32(x)).
2. Let b be ℝ(?ToUint32(y)).
3. Let product be (a × b) modulo 2^{32}.
4. If product ≥ 2^{31}, return F(product - 2^{32}); otherwise return F(product).

21.3.2.20 Math.log (x)

This function returns the natural logarithm of x.

It performs the following steps when called:

1. Let n be ?ToNumber(x).
2. If n is either NaN or +∞𝔽, return n.
3. If n is 1𝔽, return +0𝔽.
4. If n is either +0𝔽 or -0𝔽, return -∞𝔽.
5. If n < -0𝔽, return NaN.
6. Return an implementation-approximated Number value representing the result of the natural logarithm of ℝ(n).

21.3.2.21 Math.log1p (x)

This function returns the natural logarithm of 1 + x. The result is computed in a way that is accurate even when the value of x is close to zero.

It performs the following steps when called:
1. Let \( n \) be ? ToNumber(\( x \)).
2. If \( n \) is one of NaN, +\( \infty \), -\( \infty \) or \( +\infty \), return \( n \).
3. If \( n \) is -1\( \infty \), return \( -\infty \).
4. If \( n < -1 \), return NaN.
5. Return an implementation-approximated Number value representing the result of the natural logarithm of \( 1 + R(n) \).

21.3.2.22 Math.log10 ( \( x \) )

This function returns the base 10 logarithm of \( x \).

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(\( x \)).
2. If \( n \) is either NaN or \( +\infty \), return \( n \).
3. If \( n \) is 1\( \infty \), return \( +\infty \).
4. If \( n \) is either \( +\infty \) or -\( \infty \), return \( -\infty \).
5. If \( n < -\infty \), return NaN.
6. Return an implementation-approximated Number value representing the result of the base 10 logarithm of \( R(n) \).

21.3.2.23 Math.log2 ( \( x \) )

This function returns the base 2 logarithm of \( x \).

It performs the following steps when called:

1. Let \( n \) be ? ToNumber(\( x \)).
2. If \( n \) is either NaN or \( +\infty \), return \( n \).
3. If \( n \) is 1\( \infty \), return \( +\infty \).
4. If \( n \) is either \( +\infty \) or -\( \infty \), return \( -\infty \).
5. If \( n < -\infty \), return NaN.
6. Return an implementation-approximated Number value representing the result of the base 2 logarithm of \( R(n) \).

21.3.2.24 Math.max ( ...args )

Given zero or more arguments, this function calls ToNumber on each of the arguments and returns the largest of the resulting values.

It performs the following steps when called:

1. Let coerced be a new empty List.
2. For each element arg of args, do
   a. Let \( n \) be ? ToNumber(\( arg \)).
   b. Append \( n \) to coerced.
3. Let highest be \( -\infty \).
4. For each element number of coerced, do
   a. If number is NaN, return NaN.
   b. If number is \( +\infty \) and highest is \( -\infty \), set highest to \( +\infty \).
   c. If number > highest, set highest to number.
5. Return highest.

NOTE The comparison of values to determine the largest value is done using the IsLessThan algorithm except that \( +\infty \) is considered to be larger than \( -\infty \).

The "length" property of this function is \( 2 \infty \).
21.3.2.25 Math.min ( ...args )

Given zero or more arguments, this function calls ToNumber on each of the arguments and returns the smallest of the resulting values.

It performs the following steps when called:

1. Let coerced be a new empty List.
2. For each element arg of args, do
   a. Let n be ? ToNumber(arg).
   b. Append n to coerced.
3. Let lowest be +∞𝔽.
4. For each element number of coerced, do
   a. If number is NaN, return NaN.
   b. If number is -0𝔽 and lowest is +0𝔽, set lowest to -0𝔽.
   c. If number < lowest, set lowest to number.
5. Return lowest.

NOTE The comparison of values to determine the largest value is done using the IsLessThan algorithm except that +0𝔽 is considered to be larger than -0𝔽.

The "length" property of this function is 2𝔽.

21.3.2.26 Math.pow ( base, exponent )

This function performs the following steps when called:

1. Set base to ? ToNumber(base).
2. Set exponent to ? ToNumber(exponent).
3. Return Number::exponentiate(base, exponent).

21.3.2.27 Math.random ( )

This function returns a Number value with positive sign, greater than or equal to +0𝔽 but strictly less than 1𝔽, chosen randomly or pseudo randomly with approximately uniform distribution over that range, using an implementation-defined algorithm or strategy.

Each Math.random function created for distinct realms must produce a distinct sequence of values from successive calls.

21.3.2.28 Math.round ( x )

This function returns the Number value that is closest to x and is integral. If two integral Numbers are equally close to x, then the result is the Number value that is closer to +∞. If x is already integral, the result is x.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is not finite or n is an integral Number, return n.
3. If n < 0.5𝔽 and n > +0𝔽, return +0𝔽.
4. If n < -0.5𝔽 and n ≥ -0.5𝔽, return -0𝔽.
5. Return the integral Number closest to n, preferring the Number closer to +∞ in the case of a tie.

NOTE 1 Math.round(3.5) returns 4, but Math.round(-3.5) returns -3.
21.3.2.29 Math.sign (x)

This function returns the sign of x, indicating whether x is positive, negative, or zero.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is one of NaN, +0F, or -0F, return n.
3. If n < -0F, return -1F.
4. Return 1F.

21.3.2.30 Math.sin (x)

This function returns the sine of x. The argument is expressed in radians.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is one of NaN, +0F, or -0F, return n.
3. If n is either +∞F or -∞F, return NaN.
4. Return an implementation-approximated Number value representing the result of the sine of ℝ(n).

21.3.2.31 Math.sinh (x)

This function returns the hyperbolic sine of x.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is not finite or n is either +0F or -0F, return n.
3. Return an implementation-approximated Number value representing the result of the hyperbolic sine of ℝ(n).

NOTE 2 The value of Math.round(x) is not always the same as the value of Math.floor(x + 0.5).
When x is -0F or x is less than +0F but greater than or equal to -0.5F, Math.round(x) returns -0F, but Math.floor(x + 0.5) returns +0F. Math.round(x) may also differ from the value of Math.floor(x + 0.5) because of internal rounding when computing x + 0.5.

NOTE The value of Math.sinh(x) is the same as the value of (Math.exp(x) - Math.exp(-x)) / 2.

21.3.2.32 Math.sqrt (x)

This function returns the square root of x.

It performs the following steps when called:

1. Let n be ? ToNumber(x).
2. If n is one of NaN, +0F, -0F, or +∞F, return n.
3. If n < -0F, return NaN.
4. Return an implementation-approximated Number value representing the result of the square root of ℝ(n).
21.3.2.33 Math.tan (x)

This function returns the tangent of x. The argument is expressed in radians.

It performs the following steps when called:

1. Let n be ToNumber(x).
2. If n is one of NaN, +0\_F, or -0\_F, return n.
3. If n is either +\infty\_F or -\infty\_F, return NaN.
4. Return an implementation-approximated Number value representing the result of the tangent of \( R(n) \).

21.3.2.34 Math.tanh (x)

This function returns the hyperbolic tangent of x.

It performs the following steps when called:

1. Let n be ToNumber(x).
2. If n is one of NaN, +0\_F, or -0\_F, return n.
3. If n is +\infty\_F, return 1\_F.
4. If n is -\infty\_F, return -1\_F.
5. Return an implementation-approximated Number value representing the result of the hyperbolic tangent of \( R(n) \).

**NOTE**
The value of Math.tanh(x) is the same as the value of \( (\text{Math.exp}(x) - \text{Math.exp}(-x)) / (\text{Math.exp}(x) + \text{Math.exp}(-x)) \).

21.3.2.35 Math.trunc (x)

This function returns the integral part of the number x, removing any fractional digits. If x is already integral, the result is x.

It performs the following steps when called:

1. Let n be ToNumber(x).
2. If n is not finite or n is either +0\_F or -0\_F, return n.
3. If n < 1\_F and n > +0\_F, return +0\_F.
4. If n < -0\_F and n > -1\_F, return -0\_F.
5. Return the integral Number nearest n in the direction of +0\_F.

21.4 Date Objects

21.4.1 Overview of Date Objects and Definitions of Abstract Operations

The following abstract operations operate on time values (defined in 21.4.1.1). Note that, in every case, if any argument to one of these functions is NaN, the result will be NaN.

21.4.1.1 Time Values and Time Range

Time measurement in ECMAScript is analogous to time measurement in POSIX, in particular sharing definition in terms of the proleptic Gregorian calendar, an epoch of midnight at the beginning of 1 January 1970 UTC, and an accounting of every day as comprising exactly 86,400 seconds (each of which is 1000 milliseconds long).

An ECMAScript time value is a Number, either a finite integral Number representing an instant in time to millisecond precision or NaN representing no specific instant. A time value that is a multiple of 24 \times 60 \times 60 \times 1000 = 86,400,000 (i.e., is 86,400,000 \times d for some integer d) represents the instant at the start of the UTC day that
follows the epoch by \( d \) whole UTC days (preceding the epoch for negative \( d \)). Every other finite time value \( t \) is defined relative to the greatest preceding time value \( s \) that is such a multiple, and represents the instant that occurs within the same UTC day as \( s \) but follows it by \((t - s)\) milliseconds.

Time values do not account for UTC leap seconds—there are no time values representing instants within positive leap seconds, and there are time values representing instants removed from the UTC timeline by negative leap seconds. However, the definition of time values nonetheless yields piecewise alignment with UTC, with discontinuities only at leap second boundaries and zero difference outside of leap seconds.

A Number can exactly represent all integers from \(-9,007,199,254,740,992\) to \(9,007,199,254,740,992\) (21.1.2.8 and 21.1.2.6). A time value supports a slightly smaller range of \(-8,640,000,000,000,000\) to \(8,640,000,000,000,000\) milliseconds. This yields a supported time value range of exactly \(-100,000,000\) days to \(100,000,000\) days relative to midnight at the beginning of 1 January 1970 UTC.

The exact moment of midnight at the beginning of 1 January 1970 UTC is represented by the time value \( +\theta_F \).

**NOTE**

In the proleptic Gregorian calendar, leap years are precisely those which are both divisible by 4 and either divisible by 400 or not divisible by 100.

The 400 year cycle of the proleptic Gregorian calendar contains 97 leap years. This yields an average of 365.2425 days per year, which is 31,556,952 milliseconds. Therefore, the maximum range a Number could represent exactly with millisecond precision is approximately \(-285,426\) to \(285,426\) years relative to 1970. The smaller range supported by a time value as specified in this section is approximately \(-273,790\) to \(273,790\) years relative to 1970.

### 21.4.1.2 Time-related Constants

These constants are referenced by algorithms in the following sections.

- \( \text{HoursPerDay} = 24 \)
- \( \text{MinutesPerHour} = 60 \)
- \( \text{SecondsPerMinute} = 60 \)
- \( \text{msPerSecond} = 1000_F \)
- \( \text{msPerMinute} = 6000000_F = \text{msPerSecond} \times \text{SecondsPerMinute} \)
- \( \text{msPerHour} = 36000000_F = \text{msPerMinute} \times \text{MinutesPerHour} \)
- \( \text{msPerDay} = 864000000_F = \text{msPerHour} \times \text{HoursPerDay} \)

### 21.4.1.3 Day (\( t \))

The abstract operation \( \text{Day} \) takes argument \( t \) (a finite time value) and returns an integral Number. It returns the day number of the day in which \( t \) falls. It performs the following steps when called:

1. \( \text{Return } F(\text{floor}(R.(t / \text{msPerDay}))) \).

### 21.4.1.4 TimeWithinDay (\( t \))

The abstract operation \( \text{TimeWithinDay} \) takes argument \( t \) (a finite time value) and returns an integral Number in the interval from \( +\theta_F \) (inclusive) to \( \text{msPerDay} \) (exclusive). It returns the number of milliseconds since the start of the day in which \( t \) falls. It performs the following steps when called:

1. \( \text{Return } F(R.(t \text{ modulo } R.(\text{msPerDay}))) \).
21.4.1.5 DaysInYear ( y )

The abstract operation DaysInYear takes argument \( y \) (an integral Number) and returns \( 365 \) or \( 366 \). It returns the number of days in year \( y \). Leap years have 366 days; all other years have 365. It performs the following steps when called:

1. Let \( ry \) be \( \mathbb{R}(y) \).
2. If \((ry \mod 400) = 0\), return \( 366 \).
3. If \((ry \mod 100) = 0\), return \( 365 \).
4. If \((ry \mod 4) = 0\), return \( 366 \).
5. Return \( 365 \).

21.4.1.6 DayFromYear ( y )

The abstract operation DayFromYear takes argument \( y \) (an integral Number) and returns an integral Number. It returns the day number of the first day of year \( y \). It performs the following steps when called:

1. Let \( ry \) be \( \mathbb{R}(y) \).
2. NOTE: In the following steps, \( numYears1 \), \( numYears4 \), \( numYears100 \), and \( numYears400 \) represent the number of years divisible by 1, 4, 100, and 400, respectively, that occur between the epoch and the start of year \( y \). The number is negative if \( y \) is before the epoch.
3. Let \( numYears1 \) be \( (ry - 1970) \).
4. Let \( numYears4 \) be \( \text{floor}((ry - 1969) / 4) \).
5. Let \( numYears100 \) be \( \text{floor}((ry - 1901) / 100) \).
6. Let \( numYears400 \) be \( \text{floor}((ry - 1601) / 400) \).
7. Return \( \mathbb{F}(365 \times numYears1 + numYears4 - numYears100 + numYears400) \).

21.4.1.7 TimeFromYear ( y )

The abstract operation TimeFromYear takes argument \( y \) (an integral Number) and returns a time value. It returns the time value of the start of year \( y \). It performs the following steps when called:

1. Return \( \text{msPerDay} \times \text{DayFromYear}(y) \).

21.4.1.8 YearFromTime ( t )

The abstract operation YearFromTime takes argument \( t \) (a finite time value) and returns an integral Number. It returns the year in which \( t \) falls. It performs the following steps when called:

1. Return the largest integral Number \( y \) (closest to \( +\infty \)) such that \( \text{TimeFromYear}(y) \leq t \).

21.4.1.9 DayWithinYear ( t )

The abstract operation DayWithinYear takes argument \( t \) (a finite time value) and returns an integral Number in the inclusive interval from \( +0 \) to \( 365 \). It performs the following steps when called:

1. Return \( \text{Day}(t) - \text{DayFromYear}(\text{YearFromTime}(t)) \).

21.4.1.10 InLeapYear ( t )

The abstract operation InLeapYear takes argument \( t \) (a finite time value) and returns \( +0 \) or \( 1 \). It returns \( 1 \) if \( t \) is within a leap year and \( +0 \) otherwise. It performs the following steps when called:

1. If \( \text{DaysInYear}(\text{YearFromTime}(t)) \) is \( 366 \), return \( 1 \); else return \( +0 \).
21.4.1.11 MonthFromTime ( t )

The abstract operation MonthFromTime takes argument \( t \) (a finite time value) and returns an integral Number in the inclusive interval from \(+0_\mathbb{F}\) to \(11_\mathbb{F}\). It returns a Number identifying the month in which \( t \) falls. A month value of \(+0_\mathbb{F}\) specifies January; \(1_\mathbb{F}\) specifies February; \(2_\mathbb{F}\) specifies March; \(3_\mathbb{F}\) specifies April; \(4_\mathbb{F}\) specifies May; \(5_\mathbb{F}\) specifies June; \(6_\mathbb{F}\) specifies July; \(7_\mathbb{F}\) specifies August; \(8_\mathbb{F}\) specifies September; \(9_\mathbb{F}\) specifies October; \(10_\mathbb{F}\) specifies November; and \(11_\mathbb{F}\) specifies December. Note that MonthFromTime(\(+0_\mathbb{F}\)) = \(+0_\mathbb{F}\), corresponding to Thursday, 1 January 1970. It performs the following steps when called:

1. Let \( \text{inLeapYear} \) be \( \text{InLeapYear}(t) \).
2. Let \( \text{dayWithinYear} \) be \( \text{DayWithinYear}(t) \).
3. If \( \text{dayWithinYear} < 31_\mathbb{F} \), return \(+0_\mathbb{F}\).
4. If \( \text{dayWithinYear} < 59_\mathbb{F} + \text{inLeapYear} \), return \(1_\mathbb{F}\).
5. If \( \text{dayWithinYear} < 90_\mathbb{F} + \text{inLeapYear} \), return \(2_\mathbb{F}\).
6. If \( \text{dayWithinYear} < 120_\mathbb{F} + \text{inLeapYear} \), return \(3_\mathbb{F}\).
7. If \( \text{dayWithinYear} < 151_\mathbb{F} + \text{inLeapYear} \), return \(4_\mathbb{F}\).
8. If \( \text{dayWithinYear} < 181_\mathbb{F} + \text{inLeapYear} \), return \(5_\mathbb{F}\).
9. If \( \text{dayWithinYear} < 212_\mathbb{F} + \text{inLeapYear} \), return \(6_\mathbb{F}\).
10. If \( \text{dayWithinYear} < 243_\mathbb{F} + \text{inLeapYear} \), return \(7_\mathbb{F}\).
11. If \( \text{dayWithinYear} < 273_\mathbb{F} + \text{inLeapYear} \), return \(8_\mathbb{F}\).
12. If \( \text{dayWithinYear} < 304_\mathbb{F} + \text{inLeapYear} \), return \(9_\mathbb{F}\).
13. If \( \text{dayWithinYear} < 334_\mathbb{F} + \text{inLeapYear} \), return \(10_\mathbb{F}\).
14. Assert: \( \text{dayWithinYear} < 365_\mathbb{F} + \text{inLeapYear} \).
15. Return \(11_\mathbb{F}\).

21.4.1.12 DateFromTime ( t )

The abstract operation DateFromTime takes argument \( t \) (a finite time value) and returns an integral Number in the inclusive interval from \(1_\mathbb{F}\) to \(31_\mathbb{F}\). It returns the day of the month in which \( t \) falls. It performs the following steps when called:

1. Let \( \text{inLeapYear} \) be \( \text{InLeapYear}(t) \).
2. Let \( \text{dayWithinYear} \) be \( \text{DayWithinYear}(t) \).
3. Let \( \text{month} \) be \( \text{MonthFromTime}(t) \).
4. If \( \text{month} \) is \(+0_\mathbb{F}\), return \( \text{dayWithinYear} + 1_\mathbb{F} \).
5. If \( \text{month} \) is \(1_\mathbb{F}\), return \( \text{dayWithinYear} - 30_\mathbb{F} \).
6. If \( \text{month} \) is \(2_\mathbb{F}\), return \( \text{dayWithinYear} - 58_\mathbb{F} - \text{inLeapYear} \).
7. If \( \text{month} \) is \(3_\mathbb{F}\), return \( \text{dayWithinYear} - 89_\mathbb{F} - \text{inLeapYear} \).
8. If \( \text{month} \) is \(4_\mathbb{F}\), return \( \text{dayWithinYear} - 119_\mathbb{F} - \text{inLeapYear} \).
9. If \( \text{month} \) is \(5_\mathbb{F}\), return \( \text{dayWithinYear} - 150_\mathbb{F} - \text{inLeapYear} \).
10. If \( \text{month} \) is \(6_\mathbb{F}\), return \( \text{dayWithinYear} - 180_\mathbb{F} - \text{inLeapYear} \).
11. If \( \text{month} \) is \(7_\mathbb{F}\), return \( \text{dayWithinYear} - 211_\mathbb{F} - \text{inLeapYear} \).
12. If \( \text{month} \) is \(8_\mathbb{F}\), return \( \text{dayWithinYear} - 242_\mathbb{F} - \text{inLeapYear} \).
13. If \( \text{month} \) is \(9_\mathbb{F}\), return \( \text{dayWithinYear} - 272_\mathbb{F} - \text{inLeapYear} \).
14. If \( \text{month} \) is \(10_\mathbb{F}\), return \( \text{dayWithinYear} - 303_\mathbb{F} - \text{inLeapYear} \).
15. Assert: \( \text{month} \) is \(11_\mathbb{F}\).
16. Return \( \text{dayWithinYear} - 333_\mathbb{F} - \text{inLeapYear} \).

21.4.1.13 WeekDay ( t )

The abstract operation WeekDay takes argument \( t \) (a finite time value) and returns an integral Number in the inclusive interval from \(+0_\mathbb{F}\) to \(6_\mathbb{F}\). It returns a Number identifying the day of the week in which \( t \) falls. A weekday value of \(+0_\mathbb{F}\) specifies Sunday; \(1_\mathbb{F}\) specifies Monday; \(2_\mathbb{F}\) specifies Tuesday; \(3_\mathbb{F}\) specifies Wednesday; \(4_\mathbb{F}\) specifies Thursday; \(5_\mathbb{F}\) specifies Friday; and \(6_\mathbb{F}\) specifies Saturday. Note that WeekDay(\(+0_\mathbb{F}\)) = \(4_\mathbb{F}\), corresponding to Thursday, 1 January 1970. It performs the following steps when called:

1. Return \( F(\mathbb{R}(\text{Day}(t) + 4_\mathbb{F}) \text{ modulo } 7) \).
21.4.1.14 HourFromTime ( t )

The abstract operation HourFromTime takes argument t (a finite time value) and returns an integral Number in the inclusive interval from 0 to 23. It returns the hour of the day in which t falls. It performs the following steps when called:

1. Return \( \mathbb{F}(\text{floor}(\mathbb{R}(t / \text{msPerHour})) \mod \text{HoursPerDay}) \).

21.4.1.15 MinFromTime ( t )

The abstract operation MinFromTime takes argument t (a finite time value) and returns an integral Number in the inclusive interval from 0 to 59. It returns the minute of the hour in which t falls. It performs the following steps when called:

1. Return \( \mathbb{F}(\text{floor}(\mathbb{R}(t / \text{msPerMinute})) \mod \text{MinutesPerHour}) \).

21.4.1.16 SecFromTime ( t )

The abstract operation SecFromTime takes argument t (a finite time value) and returns an integral Number in the inclusive interval from 0 to 59. It returns the second of the minute in which t falls. It performs the following steps when called:

1. Return \( \mathbb{F}(\text{floor}(\mathbb{R}(t / \text{msPerSecond})) \mod \text{SecondsPerMinute}) \).

21.4.1.17 msFromTime ( t )

The abstract operation msFromTime takes argument t (a finite time value) and returns an integral Number in the inclusive interval from 0 to 999. It returns the millisecond of the second in which t falls. It performs the following steps when called:

1. Return \( \mathbb{F}(\mathbb{R}(t) \mod \mathbb{R}(\text{msPerSecond})) \).

21.4.1.18 GetUTCEpochNanoseconds ( year, month, day, hour, minute, second, millisecond, microsecond, nanosecond )

The abstract operation GetUTCEpochNanoseconds takes arguments year (an integer), month (an integer in the inclusive interval from 1 to 12), day (an integer in the inclusive interval from 1 to 31), hour (an integer in the inclusive interval from 0 to 23), minute (an integer in the inclusive interval from 0 to 59), second (an integer in the inclusive interval from 0 to 59), millisecond (an integer in the inclusive interval from 0 to 999), microsecond (an integer in the inclusive interval from 0 to 999), and nanosecond (an integer in the inclusive interval from 0 to 999) and returns a BigInt. The returned value represents a number of nanoseconds since the epoch that corresponds to the given ISO 8601 calendar date and wall-clock time in UTC. It performs the following steps when called:

1. Let date be MakeDay(\( \mathbb{F}(\text{year}) \), \( \mathbb{F}(\text{month} - 1) \), \( \mathbb{F}(\text{day}) \)).
2. Let time be MakeTime(\( \mathbb{F}(\text{hour}) \), \( \mathbb{F}(\text{minute}) \), \( \mathbb{F}(\text{second}) \), \( \mathbb{F}(\text{millisecond}) \)).
3. Let ms be MakeDate(date, time).
4. Assert: ms is an integral Number.
5. Return \( \mathbb{Z}(\mathbb{R}(\text{ms}) \times 10^6 + \text{microsecond} \times 10^3 + \text{nanosecond}) \).

21.4.1.19 Time Zone Identifiers

Time zones in ECMAScript are represented by time zone identifiers, which are Strings composed entirely of code units in the inclusive interval from 0x0000 to 0x007F. Time zones supported by an ECMAScript implementation may be available named time zones, represented by the [[Identifier]] field of the Time Zone Identifier Records.
A primary time zone identifier is the preferred identifier for an available named time zone. A non-primary time zone identifier is an identifier for an available named time zone that is not a primary time zone identifier. An available named time zone identifier is either a primary time zone identifier or a non-primary time zone identifier. Each available named time zone identifier is associated with exactly one available named time zone. Each available named time zone is associated with exactly one primary time zone identifier and zero or more non-primary time zone identifiers.

ECMAScript implementations must support an available named time zone with the identifier "UTC", which must be the primary time zone identifier for the UTC time zone. In addition, implementations may support any number of other available named time zones. Implementations that follow the requirements for time zones as described in the ECMA-402 Internationalization API specification are called time zone aware. Time zone aware implementations must support available named time zones corresponding to the Zone and Link names of the IANA Time Zone Database, and only such names. In time zone aware implementations, a primary time zone identifier is a Zone name, and a non-primary time zone identifier is a Link name, respectively, in the IANA Time Zone Database except as specifically overridden by AvailableNamedTimeZoneIdentifiers as specified in the ECMA-402 specification. Implementations that do not support the entire IANA Time Zone Database are still recommended to use IANA Time Zone Database names as identifiers to represent time zones.

21.4.1.20 GetNamedTimeZoneEpochNanoseconds ( timeZoneIdentifier, year, month, day, hour, minute, second, millisecond, microsecond, nanosecond )

The implementation-defined abstract operation GetNamedTimeZoneEpochNanoseconds takes arguments timeZoneIdentifier (a String), year (an integer), month (an integer in the inclusive interval from 1 to 12), day (an integer in the inclusive interval from 1 to 31), hour (an integer in the inclusive interval from 0 to 23), minute (an integer in the inclusive interval from 0 to 59), second (an integer in the inclusive interval from 0 to 59), millisecond (an integer in the inclusive interval from 0 to 999), microsecond (an integer in the inclusive interval from 0 to 999), and nanosecond (an integer in the inclusive interval from 0 to 999) and returns a List of BigInts. Each value in the returned List represents a number of nanoseconds since the epoch that corresponds to the given ISO 8601 calendar date and wall-clock time in the named time zone identified by timeZoneIdentifier.

When the input represents a local time occurring more than once because of a negative time zone transition (e.g. when daylight saving time ends or the time zone offset is decreased due to a time zone rule change), the returned List will have more than one element and will be sorted by ascending numerical value. When the input represents a local time skipped because of a positive time zone transition (e.g. when daylight saving time begins or the time zone offset is increased due to a time zone rule change), the returned List will be empty. Otherwise, the returned List will have one element.

The default implementation of GetNamedTimeZoneEpochNanoseconds, to be used for ECMAScript implementations that do not include local political rules for any time zones, performs the following steps when called:

1. Assert: timeZoneIdentifier is "UTC".
2. Let epochNanoseconds be GetUTCEpochNanoseconds(year, month, day, hour, minute, second, millisecond, microsecond, nanosecond).
3. Return « epochNanoseconds ».
NOTE It is required for time zone aware implementations (and recommended for all others) to use the time zone information of the IANA Time Zone Database https://www.iana.org/time-zones.

1:30 AM on 5 November 2017 in America/New_York is repeated twice, so GetNamedTimeZoneEpochNanoseconds("America/New_York", 2017, 11, 5, 1, 30, 0, 0, 0, 0) would return a List of length 2 in which the first element represents 05:30 UTC (corresponding with 01:30 US Eastern Daylight Time at UTC offset -04:00) and the second element represents 06:30 UTC (corresponding with 01:30 US Eastern Standard Time at UTC offset -05:00).

2:30 AM on 12 March 2017 in America/New_York does not exist, so GetNamedTimeZoneEpochNanoseconds("America/New_York", 2017, 3, 12, 2, 30, 0, 0, 0, 0) would return an empty List.

21.4.1.21 GetNamedTimeZoneOffsetNanoseconds ( timeZoneIdentifier, epochNanoseconds )

The implementation-defined abstract operation GetNamedTimeZoneOffsetNanoseconds takes arguments timeZoneIdentifier (a String) and epochNanoseconds (a BigInt) and returns an integer.

The returned integer represents the offset from UTC of the named time zone identified by timeZoneIdentifier, at the instant corresponding with epochNanoseconds relative to the epoch, both in nanoseconds.

The default implementation of GetNamedTimeZoneOffsetNanoseconds, to be used for ECMAScript implementations that do not include local political rules for any time zones, performs the following steps when called:

1. Assert: timeZoneIdentifier is "UTC".
2. Return 0.

NOTE Time zone offset values may be positive or negative.

21.4.1.22 Time Zone Identifier Record

A Time Zone Identifier Record is a Record used to describe an available named time zone identifier and its corresponding primary time zone identifier.

Time Zone Identifier Records have the fields listed in Table 61.

Table 61: Time Zone Identifier Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Identifier]]</td>
<td>a String</td>
<td>An available named time zone identifier that is supported by the implementation.</td>
</tr>
<tr>
<td>[[PrimaryIdentifier]]</td>
<td>a String</td>
<td>The primary time zone identifier that [[Identifier]] resolves to.</td>
</tr>
</tbody>
</table>

NOTE If [[Identifier]] is a primary time zone identifier, then [[Identifier]] is [[PrimaryIdentifier]].
21.4.1.23 AvailableNamedTimeZoneIdentifiers ( )

The implementation-defined abstract operation AvailableNamedTimeZoneIdentifiers takes no arguments and returns a List of Time Zone Identifier Records. Its result describes all available named time zone identifiers in this implementation, as well as the primary time zone identifier corresponding to each available named time zone identifier. The List is ordered according to the [[Identifier]] field of each Time Zone Identifier Record.

Time zone aware implementations, including all implementations that implement the ECMA-402 Internationalization API, must implement the AvailableNamedTimeZoneIdentifiers abstract operation as specified in the ECMA-402 specification. For implementations that are not time zone aware, AvailableNamedTimeZoneIdentifiers performs the following steps when called:

1. If the implementation does not include local political rules for any time zones, then
   a. Return « the Time Zone Identifier Record { [[Identifier]]: "UTC", [[PrimaryIdentifier]]: "UTC" } ».
2. Let identifiers be the List of unique available named time zone identifiers.
3. Sort identifiers into the same order as if an Array of the same values had been sorted using %Array.prototype.sort% with undefined as comparefn.
4. Let result be a new empty List.
5. For each element identifier of identifiers, do
   a. Let primary be identifier.
   b. If identifier is a non-primary time zone identifier in this implementation and identifier is not "UTC", then
      i. Set primary to the primary time zone identifier associated with identifier.
      ii. NOTE: An implementation may need to resolve identifier iteratively to obtain the primary time zone identifier.
   c. Let record be the Time Zone Identifier Record { [[Identifier]]: identifier, [[PrimaryIdentifier]]: primary }.
   d. Append record to result.
6. Assert: result contains a Time Zone Identifier Record r such that r.[[Identifier]] is "UTC" and r.[[PrimaryIdentifier]] is "UTC".
7. Return result.

21.4.1.24 SystemTimeZoneIdentifier ( )

The implementation-defined abstract operation SystemTimeZoneIdentifier takes no arguments and returns a String. It returns a String representing the host environment's current time zone, which is either a String representing a UTC offset for which IsTimeZoneOffsetString returns true, or a primary time zone identifier. It performs the following steps when called:

1. If the implementation only supports the UTC time zone, return "UTC".
2. Let systemTimeZoneString be the String representing the host environment's current time zone, either a primary time zone identifier or an offset time zone identifier.
3. Return systemTimeZoneString.

NOTE To ensure the level of functionality that implementations commonly provide in the methods of the Date object, it is recommended that SystemTimeZoneIdentifier return an IANA time zone name corresponding to the host environment's time zone setting, if such a thing exists. GetNamedTimeZoneEpochNanoseconds and GetNamedTimeZoneOffsetNanoseconds must reflect the local political rules for standard time and daylight saving time in that time zone, if such rules exist.

For example, if the host environment is a browser on a system where the user has chosen US Eastern Time as their time zone, SystemTimeZoneIdentifier returns "America/New_York".
21.4.1.25 LocalTime ( t )

The abstract operation LocalTime takes argument t (a finite time value) and returns an integral Number. It converts t from UTC to local time. The local political rules for standard time and daylight saving time in effect at t should be used to determine the result in the way specified in this section. It performs the following steps when called:

1. Let systemTimeZoneIdentifier be SystemTimeZoneIdentifier().
2. If IsTimeZoneOffsetString(systemTimeZoneIdentifier) is true, then
   a. Let offsetNs be ParseTimeZoneOffsetString(systemTimeZoneIdentifier).
3. Else,
   a. Let offsetNs be GetNamedTimeZoneOffsetNanoseconds(systemTimeZoneIdentifier, Z(ℝ( t × 10⁶))).
4. Let offsetMs be truncate(offsetNs / 10⁶).
5. Return t + F(offsetMs).

NOTE 1 If political rules for the local time t are not available within the implementation, the result is t because SystemTimeZoneIdentifier returns "UTC" and GetNamedTimeZoneOffsetNanoseconds returns 0.

NOTE 2 It is required for time zone aware implementations (and recommended for all others) to use the time zone information of the IANA Time Zone Database https://www.iana.org/time-zones/.

NOTE 3 Two different input time values tUTC are converted to the same local time tlocal at a negative time zone transition when there are repeated times (e.g. the daylight saving time ends or the time zone adjustment is decreased.).

LocalTime(tUTC(tlocal)) is not necessarily always equal to tlocal. Correspondingly, UTC(LocalTime(tUTC)) is not necessarily always equal to tUTC.

21.4.1.26 UTC ( t )

The abstract operation UTC takes argument t (a Number) and returns a time value. It converts t from local time to a UTC time value. The local political rules for standard time and daylight saving time in effect at t should be used to determine the result in the way specified in this section. It performs the following steps when called:

1. If t is not finite, return NaN.
2. Let systemTimeZoneIdentifier be SystemTimeZoneIdentifier().
3. If IsTimeZoneOffsetString(systemTimeZoneIdentifier) is true, then
   a. Let offsetNs be ParseTimeZoneOffsetString(systemTimeZoneIdentifier).
4. Else,
   a. Let possibleInstants be GetNamedTimeZoneEpochNanoseconds(systemTimeZoneIdentifier, ℝ(YearFromTime(t)), ℝ(MonthFromTime(t)) + 1, ℝ(DateFromTime(t)), ℝ(HourFromTime(t)), ℝ(MinFromTime(t)), ℝ(SecFromTime(t)), ℝ(msFromTime(t)), 0, 0).
   b. NOTE: The following steps ensure that when t represents local time repeating multiple times at a negative time zone transition (e.g. when the daylight saving time ends or the time zone offset is decreased due to a time zone rule change) or skipped local time at a positive time zone transition (e.g. when the daylight saving time starts or the time zone offset is increased due to a time zone rule change), t is interpreted using the time zone offset before the transition.
   c. If possibleInstants is not empty, then
      i. Let disambiguatedInstant be possibleInstants[0].
   d. Else,
      i. NOTE: t represents a local time skipped at a positive time zone transition (e.g. due to daylight saving time starting or a time zone rule change increasing the UTC offset).
      ii. Let possibleInstantsBefore be GetNamedTimeZoneEpochNanoseconds(systemTimeZoneIdentifier, ℝ(YearFromTime(tBefore)), ℝ(MonthFromTime(tBefore)) + 1, ℝ(DateFromTime(tBefore)), ℝ(HourFromTime(tBefore)), ℝ(MinFromTime(tBefore)), ℝ(SecFromTime(tBefore)), ℝ(msFromTime(tBefore)), 0, 0), where tBefore is the largest integral Number < t for which...
possibleInstantsBefore is not empty (i.e., $t_{\text{Before}}$ represents the last local time before the transition).

iii. Let $\text{disambiguatedInstant}$ be the last element of possibleInstantsBefore.

Let $\text{offsetNs}$ be $\text{GetNamedTimeZoneOffsetNanoseconds}(\text{systemTimeZoneIdentifier, disambiguatedInstant})$.

5. Let $\text{offsetMs}$ be $\text{truncate}(\text{offsetNs} / 10^6)$.

6. Return $t - F(\text{offsetMs})$.

Input $t$ is nominally a time value but may be any Number value. The algorithm must not limit $t$ to the time value range, so that inputs corresponding with a boundary of the time value range can be supported regardless of local UTC offset. For example, the maximum time value is $8.64 \times 10^{15}$, corresponding with "+275760-09-13T00:00:00Z". In an environment where the local time zone offset is ahead of UTC by 1 hour at that instant, it is represented by the larger input of $8.64 \times 10^{15} + 3.6 \times 10^6$, corresponding with "+275760-09-13T01:00:00+01:00".

If political rules for the local time $t$ are not available within the implementation, the result is $t$ because SystemTimeZoneIdentifier returns "UTC" and GetNamedTimeZoneOffsetNanoseconds returns 0.

Note 1: It is required for time zone aware implementations (and recommended for all others) to use the time zone information of the IANA Time Zone Database https://www.iana.org/time-zones/.

1:30 AM on 5 November 2017 in America/New_York is repeated twice (fall backward), but it must be interpreted as 1:30 AM UTC-05 instead of 1:30 AM UTC-05. In UTC(TimeClip(MakeDate(MakeDay(2017, 10, 5), MakeTime(1, 30, 0, 0)))), the value of $\text{offsetMs}$ is $-4 \times \text{msPerHour}$.

2:30 AM on 12 March 2017 in America/New_York does not exist, but it must be interpreted as 2:30 AM UTC-05 (equivalent to 3:30 AM UTC-04). In UTC(TimeClip(MakeDate(MakeDay(2017, 2, 12), MakeTime(2, 30, 0, 0)))), the value of $\text{offsetMs}$ is $-5 \times \text{msPerHour}$.

Note 2: UTC(LocalTime($t_{\text{UTC}}$)) is not necessarily always equal to $t_{\text{UTC}}$. Correspondingly, LocalTime(UTC($t_{\text{local}}$)) is not necessarily always equal to $t_{\text{local}}$.

21.4.1.27 MakeTime ( hour, min, sec, ms )

The abstract operation MakeTime takes arguments hour (a Number), min (a Number), sec (a Number), and ms (a Number) and returns a Number. It calculates a number of milliseconds. It performs the following steps when called:

1. If hour is not finite, min is not finite, sec is not finite, or ms is not finite, return NaN.
2. Let $h$ be $F(!\text{TolIntegerOrInfinity}(\text{hour}))$.
3. Let $m$ be $F(!\text{TolIntegerOrInfinity}(\text{min}))$.
4. Let $s$ be $F(!\text{TolIntegerOrInfinity}(\text{sec}))$.
5. Let $\text{milli}$ be $F(!\text{TolIntegerOrInfinity}(\text{ms}))$.
6. Return $((h \times \text{msPerHour} + m \times \text{msPerMinute} + s \times \text{msPerSecond}) + \text{milli})$.

Note: The arithmetic in MakeTime is floating-point arithmetic, which is not associative, so the operations must be performed in the correct order.

21.4.1.28 MakeDay ( year, month, date )

The abstract operation MakeDay takes arguments year (a Number), month (a Number), and date (a Number) and returns a Number. It calculates a number of days. It performs the following steps when called:

1. If year is not finite, month is not finite, or date is not finite, return NaN.
2. Let $y$ be $F(!\text{TolIntegerOrInfinity}(\text{year}))$. 
3. Let \( m \) be \( \mathbb{F}(\text{ToIntIntegerOrInfinity}(\text{month})) \).
4. Let \( dt \) be \( \mathbb{F}(\text{ToIntIntegerOrInfinity}(\text{date})) \).
5. Let \( ym \) be \( y + \mathbb{F}(\text{floor}(\mathbb{R}(m) / 12)) \).
6. If \( ym \) is not \( \text{finite} \), return \( \text{NaN} \).
7. Let \( mn \) be \( \mathbb{F}(\mathbb{R}(m) \mod 12) \).
8. Find a finite time value \( t \) such that \( \text{YearFromTime}(t) \) is \( ym \), \( \text{MonthFromTime}(t) \) is \( mn \), and \( \text{DateFromTime}(t) \) is \( 1 \); but if this is not possible (because some argument is out of range), return \( \text{NaN} \).
9. Return \( \text{Day}(t) + dt - 1 \mathbb{F} \).

### 21.4.1.29 MakeDate ( \( \text{day}, \text{time} \) )

The abstract operation MakeDate takes arguments \( \text{day} \) (a Number) and \( \text{time} \) (a Number) and returns a Number. It calculates a number of milliseconds. It performs the following steps when called:

1. If \( \text{day} \) is not \( \text{finite} \) or \( \text{time} \) is not \( \text{finite} \), return \( \text{NaN} \).
2. Let \( tv \) be \( \text{day} \times \text{msPerDay} + \text{time} \).
3. If \( tv \) is not \( \text{finite} \), return \( \text{NaN} \).
4. Return \( tv \).

### 21.4.1.30 MakeFullYear ( \( \text{year} \) )

The abstract operation MakeFullYear takes argument \( \text{year} \) (a Number) and returns an integral Number or \( \text{NaN} \). It returns the full year associated with the integer part of \( \text{year} \), interpreting any value in the inclusive interval from 0 to 99 as a count of years since the start of 1900. For alignment with the proleptic Gregorian calendar, "full year" is defined as the signed count of complete years since the start of year 0 (1 B.C.). It performs the following steps when called:

1. If \( \text{year} \) is \( \text{NaN} \), return \( \text{NaN} \).
2. Let \( \text{truncated} \) be \( !\text{ToIntIntegerOrInfinity}(\text{year}) \).
3. If \( \text{truncated} \) is in the inclusive interval from 0 to 99, return \( 1900 \mathbb{F} + \mathbb{F}(\text{truncated}) \).
4. Return \( \mathbb{F}(\text{truncated}) \).

### 21.4.1.31 TimeClip ( \( \text{time} \) )

The abstract operation TimeClip takes argument \( \text{time} \) (a Number) and returns a Number. It calculates a number of milliseconds. It performs the following steps when called:

1. If \( \text{time} \) is not \( \text{finite} \), return \( \text{NaN} \).
2. If \( \text{abs}(\mathbb{R}(\text{time})) > 8.64 \times 10^{15} \), return \( \text{NaN} \).
3. Return \( \mathbb{F}(!\text{ToIntIntegerOrInfinity}(\text{time})) \).

### 21.4.1.32 Date Time String Format

ECMAScript defines a string interchange format for date-times based upon a simplification of the ISO 8601 calendar date extended format. The format is as follows: \( \text{YYYY-MM-DDTHH:mm:ss.sssZ} \)

Where the elements are as follows:

- \( \text{YYYY} \) is the year in the proleptic Gregorian calendar as four decimal digits from 0000 to 9999, or as an expanded year of "+" or "-" followed by six decimal digits.
- \( \text{MM} \) is the month of the year as two decimal digits from 01 (January) to 12 (December).
- \( \text{DD} \) is the day of the month as two decimal digits from 01 to 31.
- \( \text{T} \) "T" appears literally in the string, to indicate the beginning of the time element.
- \( \text{HH} \) is the number of complete hours that have passed since midnight as two decimal digits from 00 to 24.
- \( \text{mm} \) is the number of complete minutes since the start of the hour as two decimal digits from 00 to 59.
- \( : \) "." (colon) appears literally twice in the string.
ss is the number of complete seconds since the start of the minute as two decimal digits from 00 to 59.
.
"." (dot) appears literally in the string.

sss is the number of complete milliseconds since the start of the second as three decimal digits.

Z is the UTC offset representation specified as "Z" (for UTC with no offset) or as either "+" or "-" followed by a time expression HH:mm (a subset of the time zone offset string format for indicating local time ahead of or behind UTC, respectively).

This format includes date-only forms:

YYYY
YYYY-MM
YYYY-MM-DD

It also includes “date-time” forms that consist of one of the above date-only forms immediately followed by one of the following time forms with an optional UTC offset representation appended:

THH:mm
THH:mm:ss
THH:mm:ss.sss

A string containing out-of-bounds or nonconforming elements is not a valid instance of this format.

NOTE 1 As every day both starts and ends with midnight, the two notations 00:00 and 24:00 are available to distinguish the two midnights that can be associated with one date. This means that the following two notations refer to exactly the same point in time: 1995-02-04T24:00 and 1995-02-05T00:00. This interpretation of the latter form as “end of a calendar day” is consistent with ISO 8601, even though that specification reserves it for describing time intervals and does not permit it within representations of single points in time.

NOTE 2 There exists no international standard that specifies abbreviations for civil time zones like CET, EST, etc. and sometimes the same abbreviation is even used for two very different time zones. For this reason, both ISO 8601 and this format specify numeric representations of time zone offsets.

21.4.1.32.1 Expanded Years

Covering the full time value range of approximately 273,790 years forward or backward from 1 January 1970 (21.4.1.1) requires representing years before 0 or after 9999. ISO 8601 permits expansion of the year representation, but only by mutual agreement of the partners in information interchange. In the simplified ECMAScript format, such an expanded year representation shall have 6 digits and is always prefixed with a + or - sign. The year 0 is considered positive and must be prefixed with a + sign. The representation of the year 0 as -000000 is invalid. Strings matching the Date Time String Format with expanded years representing instants in time outside the range of a time value are treated as unrecognizable by Date.parse and cause that function to return NaN without falling back to implementation-specific behaviour or heuristics.
NOTE Examples of date-time values with expanded years:

-271821-04-20T00:00:00Z 271822 B.C.
-000001-01-01T00:00:00Z 2 B.C.
+000000-01-01T00:00:00Z 1 B.C.
+000001-01-01T00:00:00Z 1 A.D.
+001970-01-01T00:00:00Z 1970 A.D.
+002009-12-15T00:00:00Z 2009 A.D.
+275760-09-13T00:00:00Z 275760 A.D.

21.4.1.33 Time Zone Offset String Format

ECMAScript defines a string interchange format for UTC offsets, derived from ISO 8601. The format is described by the following grammar. The usage of Unicode code points in this grammar is listed in Table 62.

Table 62: Time Zone Offset String Code Points

<table>
<thead>
<tr>
<th>Code Point</th>
<th>Unicode Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>U+2212</td>
<td>MINUS SIGN</td>
<td>&lt;MINUS&gt;</td>
</tr>
</tbody>
</table>

Syntax

```
UTCOffset ::=
TemporalSign Hour
TemporalSign Hour HourSubcomponents[+Extended]
TemporalSign Hour HourSubcomponents[-Extended]

TemporalSign ::= ASCIISign
<MINUS>

ASCIISign ::= one of
+ -

Hour ::= 0 DecimalDigit
1 DecimalDigit
20
21
22
23

HourSubcomponents[Extended] ::= TimeSeparator[?Extended] MinuteSecond
TemporalDecimalFraction opt

TimeSeparator[Extended] ::= [+Extended] :
[-Extended] [empty]
```
21.4.133.1 IsTimeZoneOffsetString (offsetString)

The abstract operation IsTimeZoneOffsetString takes argument offsetString (a String) and returns a Boolean. The return value indicates whether offsetString conforms to the grammar given by UTCOffset. It performs the following steps when called:

1. Let parseResult be ParseText(StringToCodePoints(offsetString), UTCOffset).
2. If parseResult is a List of errors, return false.
3. Return true.

21.4.133.2 ParseTimeZoneOffsetString (offsetString)

The abstract operation ParseTimeZoneOffsetString takes argument offsetString (a String) and returns an integer. The return value is the UTC offset, as a number of nanoseconds, that corresponds to the String offsetString. It performs the following steps when called:

1. Let parseResult be ParseText(StringToCodePoints(offsetString), UTCOffset).
2. Assert: parseResult is not a List of errors.
4. Let parsedSign be the source text matched by the TemporalSign Parse Node contained within parseResult.
5. If parsedSign is the single code point U+002D (HYPHEN-MINUS) or U+2212 (MINUS SIGN), then
   a. Let sign be -1.
6. Else,
   a. Let sign be 1.
7. NOTE: Applications of StringToNumber below do not lose precision, since each of the parsed values is guaranteed to be a sufficiently short string of decimal digits.
9. Let parsedHours be the source text matched by the Hour Parse Node contained within parseResult.
10. Let hours be ℝ(StringToNumber(CodePointsToString(parsedHours))).
11. If parseResult does not contain a MinuteSecond Parse Node, then
   a. Let minutes be 0.
12. Else,
   a. Let \( \text{parsedMinutes} \) be the source text matched by the first \( \text{MinuteSecond} \) Parse Node contained within \( \text{parseResult} \).
   b. Let \( \text{minutes} \) be \( \mathbb{R} \left( \text{StringToNumber(\text{CodePointsToString(parsedMinutes)})} \right) \).
13. If \( \text{parseResult} \) does not contain two \( \text{MinuteSecond} \) Parse Nodes, then
   a. Let \( \text{seconds} \) be 0.
14. Else,
   a. Let \( \text{parsedSeconds} \) be the source text matched by the second \( \text{MinuteSecond} \) Parse Node contained within \( \text{parseResult} \).
   b. Let \( \text{seconds} \) be \( \mathbb{R} \left( \text{StringToNumber(\text{CodePointsToString(parsedSeconds)})} \right) \).
15. If \( \text{parseResult} \) does not contain a \( \text{TemporalDecimalFraction} \) Parse Node, then
   a. Let \( \text{nanoseconds} \) be 0.
16. Else,
   a. Let \( \text{parsedFraction} \) be the source text matched by the \( \text{TemporalDecimalFraction} \) Parse Node contained within \( \text{parseResult} \).
   b. Let \( \text{fraction} \) be the string-concatenation of \( \text{CodePointsToString(parsedFraction)} \) and "000000000".
   c. Let \( \text{nanosecondsString} \) be the substring of \( \text{fraction} \) from 1 to 10.
   d. Let \( \text{nanoseconds} \) be \( \mathbb{R} \left( \text{StringToNumber(nanosecondsString)} \right) \).
17. Return \( \text{sign} \times ((\text{hours} \times 60 + \text{minutes}) \times 60 + \text{seconds}) \times 10^9 + \text{nanoseconds}) \).

21.4.2 The Date Constructor

The Date constructor:

- is \%Date\%.
- is the initial value of the "Date" property of the global object.
- creates and initializes a new Date when called as a constructor.
- returns a String representing the current time (UTC) when called as a function rather than as a constructor.
- is a function whose behaviour differs based upon the number and types of its arguments.
- may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified Date behaviour must include a super call to the Date constructor to create and initialize the subclass instance with a [[DateValue]] internal slot.

21.4.2.1 Date ( ...values )

This function performs the following steps when called:

1. If NewTarget is undefined, then
   a. Let \( \text{now} \) be the time value (UTC) identifying the current time.
   b. Return ToDateString(\( \text{now} \)).
2. Let numberOfArgs be the number of elements in \( \text{values} \).
3. If numberOfArgs = 0, then
   a. Let \( \text{dv} \) be the time value (UTC) identifying the current time.
4. Else if numberOfArgs = 1, then
   a. Let \( \text{value} \) be \( \text{values}[0] \).
   b. If \( \text{value} \) is an Object and \( \text{value} \) has a [[DateValue]] internal slot, then
      i. Let \( \text{tv} \) be \( \text{value}.[[\text{DateValue}]] \).
   c. Else,
      i. Let \( \text{v} \) be ? ToPrimitive(\( \text{value} \)).
      ii. If \( \text{v} \) is a String, then
          1. Assert: The next step never returns an abrupt completion because \( \text{v} \) is a String.
          2. Let \( \text{tv} \) be the result of parsing \( \text{v} \) as a date, in exactly the same manner as for the parse method (21.4.3.2).
      iii. Else,
          1. Let \( \text{tv} \) be ? ToNumber(\( \text{v} \)).
   d. Let \( \text{dv} \) be TimeClip(\( \text{tv} \)).
5. Else,
   a. Assert: numberOfArgs \( \geq \) 2.
   b. Let \( \text{y} \) be ? ToNumber(\( \text{values}[0] \)).
c. Let \( m \) be \( \text{ToNumber(values[1])} \).
d. If \( \text{numberOfArgs} > 2 \), let \( dt \) be \( \text{ToNumber(values[2])} \); else let \( dt \) be \( 1 \).  
e. If \( \text{numberOfArgs} > 3 \), let \( h \) be \( \text{ToNumber(values[3])} \); else let \( h \) be \( +0 \).  
f. If \( \text{numberOfArgs} > 4 \), let \( \text{min} \) be \( \text{ToNumber(values[4])} \); else let \( \text{min} \) be \( +0 \).  
g. If \( \text{numberOfArgs} > 5 \), let \( s \) be \( \text{ToNumber(values[5])} \); else let \( s \) be \( +0 \).  
h. If \( \text{numberOfArgs} > 6 \), let \( \text{milli} \) be \( \text{ToNumber(values[6])} \); else let \( \text{milli} \) be \( +0 \).  
i. Let \( y \) be \( \text{MakeFullYear(y)} \).  
j. Let \( \text{finalDate} \) be \( \text{MakeDate(MakeDay(y, m, dt), MakeTime(h, min, s, milli))} \).  
k. Let \( dv \) be \( \text{TimeClip(UTC(finalDate))} \).  

6. Let \( O \) be \( \text{OrdinaryCreateFromConstructor(NewTarget, "%Date.prototype%", [[DateValue]])} \).  
7. Set \( O.[[DateValue]] \) to \( dv \).  
8. Return \( O \).

21.4.3 Properties of the Date Constructor

The Date constructor:

- has a [[Prototype]] internal slot whose value is \%Function.prototype%.
- has a "length" property whose value is \( 7 \).  
- has the following properties:

21.4.3.1 Date.now ()

This function returns the time value designating the UTC date and time of the occurrence of the call to it.

21.4.3.2 Date.parse ( string )

This function applies the ToString operator to its argument. If ToString results in an abrupt completion the Completion Record is immediately returned. Otherwise, this function interprets the resulting String as a date and time; it returns a Number, the UTC time value corresponding to the date and time. The String may be interpreted as a local time, a UTC time, or a time in some other time zone, depending on the contents of the String. The function first attempts to parse the String according to the format described in Date Time String Format (21.4.1.32), including expanded years. If the String does not conform to that format the function may fall back to any implementation-specific heuristics or implementation-specific date formats. Strings that are unrecognizable or contain out-of-bounds format element values shall cause this function to return NaN.

If the String conforms to the Date Time String Format, substitute values take the place of absent format elements. When the MM or DD elements are absent, "01" is used. When the HH, mm, or ss elements are absent, "00" is used. When the sss element is absent, "000" is used. When the UTC offset representation is absent, date-only forms are interpreted as a UTC year and date-time forms are interpreted as a local time.

If \( x \) is any Date whose milliseconds amount is zero within a particular implementation of ECMAScript, then all of the following expressions should produce the same numeric value in that implementation, if all the properties referenced have their initial values:

\[
\begin{align*}
x.\text{valueOf}() \\
\text{Date.parse(x.toString())} \\
\text{Date.parse(x.toUTCString())} \\
\text{Date.parse(x.toISOString())}
\end{align*}
\]

However, the expression

\[
\text{Date.parse(x.toLocaleString())}
\]

is not required to produce the same Number value as the preceding three expressions and, in general, the value produced by this function is implementation-defined when given any String value that does not conform to the Date Time String Format (21.4.1.32) and that could not be produced in that implementation by the toString or toUTCString method.
21.4.3.3 Date.prototype

The initial value of `Date.prototype` is the Date prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

21.4.3.4 Date.UTC ( `year` [, `month` [, `date` [, `hours` [, `minutes` [, `seconds` [, `ms` ]]]]]])

This function performs the following steps when called:

1. Let `y` be `ToNumber(year)`.
2. If `month` is present, let `m` be `ToNumber(month)`; else let `m` be `+0𝔽`.
3. If `date` is present, let `dt` be `ToNumber(date)`; else let `dt` be `1𝔽`.
4. If `hours` is present, let `h` be `ToNumber(hours)`; else let `h` be `+0𝔽`.
5. If `minutes` is present, let `min` be `ToNumber(minutes)`; else let `min` be `+0𝔽`.
6. If `seconds` is present, let `s` be `ToNumber(seconds)`; else let `s` be `+0𝔽`.
7. If `ms` is present, let `milli` be `ToNumber(ms)`; else let `milli` be `+0𝔽`.
8. Let `yr` be `MakeFullYear(y)`.
9. Return `TimeClip(MakeDate(MakeDay(yr, m, dt), MakeTime(h, min, s, milli)))`.

The "length" property of this function is `7𝔽`.

NOTE This function differs from the Date constructor in two ways: it returns a time value as a Number, rather than creating a Date, and it interprets the arguments in UTC rather than as local time.

21.4.4 Properties of the Date Prototype Object

The Date prototype object:

- is `%Date.prototype%`.
- is itself an ordinary object.
- is not a Date instance and does not have a [[DateValue]] internal slot.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.

Unless explicitly defined otherwise, the methods of the Date prototype object defined below are not generic and the this value passed to them must be an object that has a [[DateValue]] internal slot that has been initialized to a time value.

21.4.4.1 Date.prototype.constructor

The initial value of `Date.prototype.constructor` is `%Date%`.

21.4.4.2 Date.prototype.getDate ( )

This method performs the following steps when called:

1. Let `dateObject` be the this value.
2. Perform `RequireInternalSlot(dateObject, [[DateValue]])`.
3. Let `t` be `dateObject.[[DateValue]]`.
4. If `t` is `NaN`, return `NaN`.
5. Return `DateFromTime(LocalTime(t))`. 
21.4.4.3 Date.prototype.getDay ( )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, return NaN.
5. Return WeekDay(LocalTime(t)).

21.4.4.4 Date.prototype.getFullYear ( )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, return NaN.
5. Return YearFromTime(LocalTime(t)).

21.4.4.5 Date.prototype.getHours ( )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, return NaN.
5. Return HourFromTime(LocalTime(t)).

21.4.4.6 Date.prototype.getMilliseconds ( )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, return NaN.
5. Return msFromTime(LocalTime(t)).

21.4.4.7 Date.prototype.getMinutes ( )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, return NaN.
5. Return MinFromTime(LocalTime(t)).

21.4.4.8 Date.prototype.getMonth ( )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If \( t \) is NaN, return NaN.
5. Return \( \text{MonthFromTime} (\text{LocalTime}(t)) \).

21.4.4.9 \( \text{Date.prototype.getSeconds}() \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \text{RequireInternalSlot} (\text{dateObject}, [[\text{DateValue}]]) \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{SecFromTime} (\text{LocalTime}(t)) \).

21.4.4.10 \( \text{Date.prototype.getTime}() \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \text{RequireInternalSlot} (\text{dateObject}, [[\text{DateValue}]]) \).
3. Return \( \text{dateObject}.[[\text{DateValue}]] \).

21.4.4.11 \( \text{Date.prototype.getTimezoneOffset}() \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \text{RequireInternalSlot} (\text{dateObject}, [[\text{DateValue}]]) \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. If \( t \) is NaN, return NaN.
5. Return \( (t - \text{LocalTime}(t)) / \text{msPerMinute} \).

21.4.4.12 \( \text{Date.prototype.getUTCDate}() \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \text{RequireInternalSlot} (\text{dateObject}, [[\text{DateValue}]]) \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{DateFromTime}(t) \).

21.4.4.13 \( \text{Date.prototype.getUTCDay}() \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \text{RequireInternalSlot} (\text{dateObject}, [[\text{DateValue}]]) \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{WeekDay}(t) \).

21.4.4.14 \( \text{Date.prototype.getUTCFullYear}() \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \text{RequireInternalSlot} (\text{dateObject}, [[\text{DateValue}]]) \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{YearFromTime}(t) \).

21.4.4.15 Date.prototype.getUTCHours ( )

This method performs the following steps when called:

1. Let \( dateObject \) be the this value.
2. Perform \( \text{RequireInternalSlot}(dateObject, [[DateValue]]) \).
3. Let \( t \) be \( dateObject.\text{[[DateValue]]} \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{HourFromTime}(t) \).

21.4.4.16 Date.prototype.getUTCMilliseconds ( )

This method performs the following steps when called:

1. Let \( dateObject \) be the this value.
2. Perform \( \text{RequireInternalSlot}(dateObject, [[DateValue]]) \).
3. Let \( t \) be \( dateObject.\text{[[DateValue]]} \).
4. If \( t \) is NaN, return NaN.
5. Return \( msFromTime(t) \).

21.4.4.17 Date.prototype.getUTCMinutes ( )

This method performs the following steps when called:

1. Let \( dateObject \) be the this value.
2. Perform \( \text{RequireInternalSlot}(dateObject, [[DateValue]]) \).
3. Let \( t \) be \( dateObject.\text{[[DateValue]]} \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{MinFromTime}(t) \).

21.4.4.18 Date.prototype.getUTCMonth ( )

This method performs the following steps when called:

1. Let \( dateObject \) be the this value.
2. Perform \( \text{RequireInternalSlot}(dateObject, [[DateValue]]) \).
3. Let \( t \) be \( dateObject.\text{[[DateValue]]} \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{MonthFromTime}(t) \).

21.4.4.19 Date.prototype.getUTCSeconds ( )

This method performs the following steps when called:

1. Let \( dateObject \) be the this value.
2. Perform \( \text{RequireInternalSlot}(dateObject, [[DateValue]]) \).
3. Let \( t \) be \( dateObject.\text{[[DateValue]]} \).
4. If \( t \) is NaN, return NaN.
5. Return \( \text{SecFromTime}(t) \).
21.4.4.20 Date.prototype.setDate ( date )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let dt be ? ToNumber(date).
5. If t is NaN, return NaN.
6. Set t to LocalTime(t).
7. Let newDate be MakeDate(MakeDay(YearFromTime(t), MonthFromTime(t), dt), TimeWithinDay(t)).
8. Let u be TimeClip(UTC(newDate)).
9. Set dateObject.[[DateValue]] to u.
10. Return u.

The "length" property of this method is 3𝔽.

NOTE If month is not present, this method behaves as if month was present with the value getMonth(). If date is not present, it behaves as if date was present with the value getDate().

21.4.4.21 Date.prototype.setFullYear ( year [ , month [ , date ] ] )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let y be ? ToNumber(year).
5. If t is NaN, set t to +0𝔽; otherwise, set t to LocalTime(t).
6. If month is not present, let m be MonthFromTime(t); otherwise, let m be ? ToNumber(month).
7. If date is not present, let dt be DateFromTime(t); otherwise, let dt be ? ToNumber(date).
8. Let newDate be MakeDate(MakeDay(y, m, dt), TimeWithinDay(t)).
9. Let u be TimeClip(UTC(newDate)).
10. Set dateObject.[[DateValue]] to u.
11. Return u.

The "length" property of this method is 4𝔽.

21.4.4.22 Date.prototype.setHours ( hour [ , min [ , sec [ , ms ] ] ] )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let h be ? ToNumber(hour).
5. If min is present, let m be ? ToNumber(min).
6. If sec is present, let s be ? ToNumber(sec).
7. If ms is present, let milli be ? ToNumber(ms).
8. If t is NaN, return NaN.
9. Set t to LocalTime(t).
10. If min is not present, let m be MinFromTime(t).
11. If sec is not present, let s be SecFromTime(t).
12. If ms is not present, let milli be msFromTime(t).
13. Let date be MakeDate(Day(t), MakeTime(h, m, s, milli)).
14. Let u be TimeClip(UTC(date)).
15. Set dateObject.[[DateValue]] to u.
16. Return u.

The "length" property of this method is 4𝔽.
21.4.4.23 Date.prototype.setMilliseconds (ms)

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Set ms to ? ToNumber(ms).
5. If t is NaN, return NaN.
6. Set t to LocalTime(t).
7. Let time be MakeTime(HourFromTime(t), MinFromTime(t), SecFromTime(t), ms).
8. Let u be TimeClip(UTC(MakeDate(Day(t), time))).
9. Set dateObject.[[DateValue]] to u.
10. Return u.

The "length" property of this method is 3𝔽.

21.4.4.24 Date.prototype.setMinutes (min[, sec[, ms]])

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let m be ? ToNumber(min).
5. If sec is present, let s be ? ToNumber(sec).
6. If ms is present, let milli be ? ToNumber(ms).
7. If t is NaN, return NaN.
8. Set t to LocalTime(t).
9. If sec is not present, return SecFromTime(t).
10. If ms is not present, return msFromTime(t).
11. Let date be MakeDate(Day(t), MakeTime(HourFromTime(t), m, s, milli)).
12. Let u be TimeClip(UTC(date)).
13. Set dateObject.[[DateValue]] to u.

The "length" property of this method is 3𝔽.

21.4.4.25 Date.prototype.setMonth (month[, date])

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let m be ? ToNumber(month).
5. If date is present, let dt be ? ToNumber(date).
6. If t is NaN, return NaN.
7. Set t to LocalTime(t).
8. If date is not present, let dt be DateFromTime(t).
9. Let newDate be MakeDate(MakeDay(YearFromTime(t), m, dt), TimeWithinDay(t)).
10. Let \( u \) be \( \text{TimeClip}(\text{UTC}(\text{newDate})) \).
11. Set \( \text{dateObject.}[\text{[DateValue]}] \) to \( u \).
12. Return \( u \).

The "length" property of this method is \( 2^\infty \).

**NOTE** If \( \text{date} \) is not present, this method behaves as if \( \text{date} \) was present with the value \( \text{getDateTime()} \).

**21.4.4.26** \( \text{Date.prototype.setSeconds (} \text{sec} \ [\ , \ \text{ms}] \) \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the \( \text{this} \) value.
2. Perform \( \text{RequireInternalSlot}(\text{dateObject.}[\text{[DateValue]}]) \).
3. Let \( t \) be \( \text{dateObject.}[\text{[DateValue]}] \).
4. Let \( s \) be \( \text{ToNumber}(\text{sec}) \).
5. If \( \text{ms} \) is present, let \( \text{milli} \) be \( \text{ToNumber}(\text{ms}) \).
6. If \( t \) is \( \text{NaN} \), return \( \text{NaN} \).
7. Set \( t \) to \( \text{LocalTime}(t) \).
8. If \( \text{ms} \) is not present, let \( \text{milli} \) be \( \text{msFromTime}(t) \).
9. Let \( \text{date} \) be \( \text{MakeDate}(\text{Day}(t), \text{MakeTime}(\text{HourFromTime}(t), \text{MinFromTime}(t), s, \text{milli})) \).
10. Let \( u \) be \( \text{TimeClip}(\text{UTC}(\text{date})) \).
11. Set \( \text{dateObject.}[\text{[DateValue]}] \) to \( u \).
12. Return \( u \).

The "length" property of this method is \( 2^\infty \).

**NOTE** If \( \text{ms} \) is not present, this method behaves as if \( \text{ms} \) was present with the value \( \text{getMilliseconds()} \).

**21.4.4.27** \( \text{Date.prototype.setTime (} \text{time} \) \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the \( \text{this} \) value.
2. Perform \( \text{RequireInternalSlot}(\text{dateObject.}[\text{[DateValue]}]) \).
3. Let \( t \) be \( \text{ToNumber}(\text{time}) \).
4. Let \( v \) be \( \text{TimeClip}(t) \).
5. Set \( \text{dateObject.}[\text{[DateValue]}] \) to \( v \).
6. Return \( v \).

**21.4.4.28** \( \text{Date.prototype.setUTCDate (} \text{date} \) \)

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the \( \text{this} \) value.
2. Perform \( \text{RequireInternalSlot}(\text{dateObject.}[\text{[DateValue]}]) \).
3. Let \( t \) be \( \text{dateObject.}[\text{[DateValue]}] \).
4. Let \( \text{dt} \) be \( \text{ToNumber}(\text{date}) \).
5. If \( t \) is \( \text{NaN} \), return \( \text{NaN} \).
6. Let \( \text{newDate} \) be \( \text{MakeDate}(\text{MakeDay}(\text{YearFromTime}(t), \text{MonthFromTime}(t), dt), \text{TimeWithinDay}(t)) \).
7. Let \( v \) be \( \text{TimeClip}(\text{newDate}) \).
8. Set \( \text{dateObject.}[\text{[DateValue]}] \) to \( v \).
9. Return \( v \).
21.4.4.29  Date.prototype.setUTCFullYear ( year [, month [, date ]] )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, set t to +0𝔽.
5. Let y be ? ToNumber(year).
6. If month is not present, let m be MonthFromTime(t); otherwise, let m be ? ToNumber(month).
7. If date is not present, let dt be DateFromTime(t); otherwise, let dt be ? ToNumber(date).
8. Let newDate be MakeDate(MakeDay(y, m, dt), TimeWithinDay(t)).
9. Let v be TimeClip(newDate).
10. Set dateObject.[[DateValue]] to v.
11. Return v.

The "length" property of this method is 3𝔽.

NOTE  If month is not present, this method behaves as if month was present with the value getUTCMonth(). If date is not present, it behaves as if date was present with the value getUTCDate().

21.4.4.30  Date.prototype.setUTCHours ( hour [, min [, sec [, ms ]] ] )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let h be ? ToNumber(hour).
5. If min is present, let m be ? ToNumber(min).
6. If sec is present, let s be ? ToNumber(sec).
7. If ms is present, let milli be ? ToNumber(ms).
8. If t is NaN, return NaN.
9. If min is not present, let m be MinFromTime(t).
10. If sec is not present, let s be SecFromTime(t).
11. If ms is not present, let milli be msFromTime(t).
12. Let date be MakeDate(Day(t), MakeTime(h, m, s, milli)).
13. Let v be TimeClip(date).
14. Set dateObject.[[DateValue]] to v.
15. Return v.

The "length" property of this method is 4𝔽.

NOTE  If min is not present, this method behaves as if min was present with the value getUTCMinutes(). If sec is not present, it behaves as if sec was present with the value getUTCSeconds(). If ms is not present, it behaves as if ms was present with the value getUTCMilliseconds().

21.4.4.31  Date.prototype.setUTCMilliseconds ( ms )

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Set ms to ? ToNumber(ms).
5. If t is NaN, return NaN.
6. Let time be \( \text{MakeTime}(\text{HourFromTime}(t), \text{MinFromTime}(t), \text{SecFromTime}(t), ms) \).
7. Let \( v \) be \( \text{TimeClip}(\text{MakeDate}(\text{Day}(t), \text{time})) \).
8. Set \( \text{dateObject}.[[\text{DateValue}]] \) to \( v \).
9. Return \( v \).

21.4.4.32 \textbf{Date.prototype.setUTCMinutes} ( \( \text{min} \), sec, ms) )

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \ \text{RequireInternalSlot}(\text{dateObject}, [[\text{DateValue}])] \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. Let \( m \) be \( \text{ToNumber}(\text{min}) \).
5. If sec is present, let \( s \) be \( \text{ToNumber}(\text{sec}) \).
6. If ms is present, let \( \text{milli} \) be \( \text{ToNumber}(\text{ms}) \).
7. If \( t \) is NaN, return NaN.
8. If sec is not present, let \( s \) be \( \text{SecFromTime}(t) \).
9. If ms is not present, let \( \text{milli} \) be \( \text{msFromTime}(t) \).
10. Let \( date \) be \( \text{MakeDate}(\text{Day}(t), \text{MakeTime}(\text{HourFromTime}(t), m, s, \text{milli})) \).
11. Let \( v \) be \( \text{TimeClip}(date) \).
12. Set \( \text{dateObject}.[[\text{DateValue}]] \) to \( v \).
13. Return \( v \).

The "length" property of this method is 3.

\begin{preformatted}
\textbf{NOTE} \hspace{1em} If \( \text{sec} \) is not present, this method behaves as if \( \text{sec} \) was present with the value \( \text{getUTCSeconds()} \).
If \( \text{ms} \) is not present, it behaves as if \( \text{ms} \) was present with the value return by \( \text{getUTCMilliseconds()} \).
\end{preformatted}

21.4.4.33 \textbf{Date.prototype.setUTCMonth} ( \( \text{month} \), date) )

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \ \text{RequireInternalSlot}(\text{dateObject}, [[\text{DateValue}])] \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. Let \( s \) be \( \text{ToNumber}(\text{sec}) \).
5. If date is present, let \( dt \) be \( \text{ToNumber}(\text{date}) \).
6. If \( t \) is NaN, return NaN.
7. If date is not present, let \( dt \) be \( \text{DateFromTime}(t) \).
8. Let \( \text{newDate} \) be \( \text{MakeDate}(\text{MakeDay}(\text{YearFromTime}(t), m, dt), \text{TimeWithinDay}(t)) \).
9. Let \( v \) be \( \text{TimeClip}(\text{newDate}) \).
10. Set \( \text{dateObject}.[[\text{DateValue}]] \) to \( v \).
11. Return \( v \).

The "length" property of this method is 2.

\begin{preformatted}
\textbf{NOTE} \hspace{1em} If \( \text{date} \) is not present, this method behaves as if \( \text{date} \) was present with the value \( \text{getUTCDate()} \).
\end{preformatted}

21.4.4.34 \textbf{Date.prototype.setUTCSeconds} ( \( \text{sec} \), ms) )

This method performs the following steps when called:

1. Let \( \text{dateObject} \) be the this value.
2. Perform \( ? \ \text{RequireInternalSlot}(\text{dateObject}, [[\text{DateValue}])] \).
3. Let \( t \) be \( \text{dateObject}.[[\text{DateValue}]] \).
4. Let \( s \) be \( \text{ToNumber}(\text{sec}) \).
5. If \( ms \) is present, let \( milli \) be \( \text{ToNumber}(ms) \).
6. If \( t \) is \( NaN \), return \( NaN \).
7. If \( ms \) is not present, let \( milli \) be \( \text{msFromTime}(t) \).
8. Let \( date \) be \( \text{MakeDate}(\text{Day}(t), \text{MakeTime}(\text{HourFromTime}(t), \text{MinFromTime}(t), s, milli)) \).
9. Let \( v \) be \( \text{TimeClip}(date) \).
10. Set \( dateObject.\[\[\text{DateValue}\]\] \) to \( v \).
11. Return \( v \).

The "length" property of this method is \( 2^\mathbb{F} \).

**NOTE** If \( ms \) is not present, this method behaves as if \( ms \) was present with the value \( \text{getUTCMilliseconds()} \).

### 21.4.4.35 Date.prototype.toDateString ()

This method performs the following steps when called:

1. Let \( dateObject \) be the \( \text{this} \) value.
2. Perform \( \text{? RequireInternalSlot}(dateObject, \[\[\text{DateValue}\]\]) \).
3. Let \( tv \) be \( dateObject.\[\[\text{DateValue}\]\] \).
4. If \( tv \) is \( NaN \), return "Invalid Date".
5. Let \( t \) be \( \text{LocalTime}(tv) \).
6. Return \( \text{DateString}(t) \).

### 21.4.4.36 Date.prototype.toISOString ()

This method performs the following steps when called:

1. Let \( dateObject \) be the \( \text{this} \) value.
2. Perform \( \text{? RequireInternalSlot}(dateObject, \[\[\text{DateValue}\]\]) \).
3. Let \( tv \) be \( dateObject.\[\[\text{DateValue}\]\] \).
4. If \( tv \) is not \( \text{finite} \), throw a \( \text{RangeError} \) exception.
5. If \( tv \) corresponds with a year that cannot be represented in the \text{Date Time String Format}, throw a \( \text{RangeError} \) exception.
6. Return a String representation of \( tv \) in the \text{Date Time String Format} on the UTC time scale, including all format elements and the UTC offset representation "Z".

### 21.4.4.37 Date.prototype.toJSON ( \( key \) )

This method provides a String representation of a Date for use by \( \text{JSON.stringify}(25.5.2) \).

It performs the following steps when called:

1. Let \( O \) be \( \text{ToObject}(\text{this} \text{ value}) \).
2. Let \( tv \) be \( \text{ToPrimitive}(O, \text{NUMBER}) \).
3. If \( tv \) is a Number and \( tv \) is not \( \text{finite} \), return \( \text{null} \).
4. Return \( \text{Invoke}(O, \text{"toISOString"}) \).

**NOTE 1** The argument is ignored.

**NOTE 2** This method is intentionally generic; it does not require that its \( \text{this} \) value be a Date. Therefore, it can be transferred to other kinds of objects for use as a method. However, it does require that any such object have a \( \text{toISOString} \) method.
21.4.38 Date.prototype.toLocaleDateString ([reserved1[, reserved2]])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method returns a String value. The contents of the String are implementation-defined, but are intended to represent the “date” portion of the Date in the current time zone in a convenient, human-readable form that corresponds to the conventions of the host environment’s current locale.

The meaning of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

21.4.39 Date.prototype.toLocaleString ([reserved1[, reserved2]])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method returns a String value. The contents of the String are implementation-defined, but are intended to represent the Date in the current time zone in a convenient, human-readable form that corresponds to the conventions of the host environment’s current locale.

The meaning of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

21.4.40 Date.prototype.toLocaleTimeString ([reserved1[, reserved2]])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method returns a String value. The contents of the String are implementation-defined, but are intended to represent the “time” portion of the Date in the current time zone in a convenient, human-readable form that corresponds to the conventions of the host environment’s current locale.

The meaning of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

21.4.41 Date.prototype.toString ()

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let tv be dateObject.[[DateValue]].
4. Return ToDateString(tv).

NOTE 1 For any Date d such that d.[[DateValue]] is evenly divisible by 1000, the result of Date.parse(d.toString()) = d.valueOf(). See 21.4.3.2.

NOTE 2 This method is not generic; it throws a TypeError exception if its this value is not a Date. Therefore, it cannot be transferred to other kinds of objects for use as a method.
21.4.4.1.1 `TimeString (tv)`

The abstract operation `TimeString` takes argument `tv` (a Number, but not `NaN`) and returns a String. It performs the following steps when called:

1. Let `hour` be `ToZeroPaddedDecimalString(ℝ(HourFromTime(tv)), 2)`.
2. Let `minute` be `ToZeroPaddedDecimalString(ℝ(MinFromTime(tv)), 2)`.
3. Let `second` be `ToZeroPaddedDecimalString(ℝ(SecFromTime(tv)), 2)`.
4. Return the string-concatenation of `hour`, ",:``, `minute`, ",:``, `second`, the code unit 0x0020 (SPACE), and "GMT".

21.4.4.1.2 `DateString (tv)`

The abstract operation `DateString` takes argument `tv` (a Number, but not `NaN`) and returns a String. It performs the following steps when called:

1. Let `weekday` be the Name of the entry in Table 63 with the Number `WeekDay(tv)`.
2. Let `month` be the Name of the entry in Table 64 with the Number `MonthFromTime(tv)`.
3. Let `day` be `ToZeroPaddedDecimalString(ℝ(DateFromTime(tv)), 2)`.
4. Let `yv` be `YearFromTime(tv)`.
5. If `yv` is `+0𝔽` or `yv > +0𝔽`, let `yearSign` be the empty String; otherwise, let `yearSign` be ",-".
6. Let `paddedYear` be `ToZeroPaddedDecimalString(abs(ℝ(yv)), 4)`.
7. Return the string-concatenation of `weekday`, the code unit 0x0020 (SPACE), `month`, the code unit 0x0020 (SPACE), `day`, the code unit 0x0020 (SPACE), `yearSign`, and `paddedYear`.

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0𝔽</td>
<td>&quot;Sun&quot;</td>
</tr>
<tr>
<td>1𝔽</td>
<td>&quot;Mon&quot;</td>
</tr>
<tr>
<td>2𝔽</td>
<td>&quot;Tue&quot;</td>
</tr>
<tr>
<td>3𝔽</td>
<td>&quot;Wed&quot;</td>
</tr>
<tr>
<td>4𝔽</td>
<td>&quot;Thu&quot;</td>
</tr>
<tr>
<td>5𝔽</td>
<td>&quot;Fri&quot;</td>
</tr>
<tr>
<td>6𝔽</td>
<td>&quot;Sat&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0𝔽</td>
<td>&quot;Jan&quot;</td>
</tr>
<tr>
<td>1𝔽</td>
<td>&quot;Feb&quot;</td>
</tr>
<tr>
<td>2𝔽</td>
<td>&quot;Mar&quot;</td>
</tr>
<tr>
<td>3𝔽</td>
<td>&quot;Apr&quot;</td>
</tr>
<tr>
<td>4𝔽</td>
<td>&quot;May&quot;</td>
</tr>
<tr>
<td>5𝔽</td>
<td>&quot;Jun&quot;</td>
</tr>
<tr>
<td>6𝔽</td>
<td>&quot;Jul&quot;</td>
</tr>
</tbody>
</table>
Table 64: Names of months of the year (continued)

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>7(_F)</td>
<td>&quot;Aug&quot;</td>
</tr>
<tr>
<td>8(_F)</td>
<td>&quot;Sep&quot;</td>
</tr>
<tr>
<td>9(_F)</td>
<td>&quot;Oct&quot;</td>
</tr>
<tr>
<td>10(_F)</td>
<td>&quot;Nov&quot;</td>
</tr>
<tr>
<td>11(_F)</td>
<td>&quot;Dec&quot;</td>
</tr>
</tbody>
</table>

21.4.4.41.3 TimeZoneString ( tv )

The abstract operation TimeZoneString takes argument tv (an integral Number) and returns a String. It performs the following steps when called:

1. Let systemTimeZoneIdentifier be SystemTimeZoneIdentifier().
2. If isTimeZoneOffsetString(systemTimeZoneIdentifier) is true, then
   a. Let offsetNs be ParseTimeZoneOffsetString(systemTimeZoneIdentifier).
3. Else,
   a. Let offsetNs be GetNamedTimeZoneOffsetNanoseconds(systemTimeZoneIdentifier, \( \mathbb{Z}(R(tv) \times 10^6) \)).
4. Let offset be \( \mathbb{F}(\text{truncate}(\text{offsetNs}/10^6)) \).
5. If offset is +0\(_F\) or offset > +0\(_F\), then
   a. Let offsetSign be "+".
   b. Let absOffset be offset.
6. Else,
   a. Let offsetSign be "-".
   b. Let absOffset be -offset.
7. Let offsetMin be ToZeroPaddedDecimalString(\( R(\text{MinFromTime}(\text{absOffset})) \)), 2).
8. Let offsetHour be ToZeroPaddedDecimalString(\( R(\text{HourFromTime}(\text{absOffset})) \)), 2).
9. Let tzName be an implementation-defined string that is either the empty String or the string-concatenation of the code unit 0x0020 (SPACE), the code unit 0x0028 (LEFT PARENTHESES), an implementation-defined timezone name, and the code unit 0x0029 (RIGHT PARENTHESES).
10. Return the string-concatenation of offsetSign, offsetHour, offsetMin, and tzName.

21.4.4.41.4 ToDateString ( tv )

The abstract operation ToDateString takes argument tv (an integral Number or NaN) and returns a String. It performs the following steps when called:

1. If tv is NaN, return "Invalid Date".
2. Let t be LocalTime(tv).
3. Return the string-concatenation of TimeString(t), the code unit 0x0020 (SPACE), TimeZoneString(tv), and Date.prototype.toTimeString().
This method returns a String value representing the instant in time corresponding to the this value. The format of the String is based upon "HTTP-date" from RFC 7231, generalized to support the full range of times supported by ECMAScript Dates.

It performs the following steps when called:

1. Let `dateObject` be the this value.
2. Perform ? RequireInternalSlot(`dateObject`, [[DateValue]]).
3. Let `tv` be `dateObject`.[[DateValue]].
4. If `tv` is NaN, return "Invalid Date".
5. Let `weekday` be the Name of the entry in Table 63 with the Number WeekDay(`tv`).
6. Let `month` be the Name of the entry in Table 64 with the Number MonthFromTime(`tv`).
7. Let `day` be ToZeroPaddedDecimalString(ℝ(DateFromTime(`tv`)), 2).
8. Let `yv` be YearFromTime(`tv`).
9. If `yv` is +0𝔽 or `yv` > +0𝔽, let `yearSign` be the empty String; otherwise, let `yearSign` be ".-".
10. Let `paddedYear` be ToZeroPaddedDecimalString(abs(R(ℝ(DateFromTime(`tv`))), 4)).
11. Return the string-concatenation of `weekday`, ",", the code unit 0x0020 (SPACE), `day`, the code unit 0x0020 (SPACE), `month`, the code unit 0x0020 (SPACE), `yearSign`, `paddedYear`, the code unit 0x0020 (SPACE), and TimeString(`tv`).

This method performs the following steps when called:

1. Let `dateObject` be the this value.
2. Perform ? RequireInternalSlot(`dateObject`, [[DateValue]]).
3. Return `dateObject`.[[DateValue]].

This method is called by ECMAScript language operators to convert a Date to a primitive value. The allowed values for `hint` are "default", "number", and "string". Dates are unique among built-in ECMAScript object in that they treat "default" as being equivalent to "string", All other built-in ECMAScript objects treat "default" as being equivalent to "number".

It performs the following steps when called:

1. Let `O` be the this value.
2. If `O` is not an Object, throw a TypeError exception.
3. If `hint` is either "string" or "default", then
   a. Let `tryFirst` be STRING.
4. Else if `hint` is "number", then
   a. Let `tryFirst` be NUMBER.
5. Else,
   a. Throw a TypeError exception.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

The value of the "name" property of this method is "[Symbol.toPrimitive]".

Date instances are ordinary objects that inherit properties from the Date prototype object. Date instances also have a [[DateValue]] internal slot. The [[DateValue]] internal slot is the time value represented by this Date.
22 Text Processing

22.1 String Objects

22.1.1 The String Constructor

The String constructor:

- is %String%.
- is the initial value of the "String" property of the global object.
- creates and initializes a new String object when called as a constructor.
- performs a type conversion when called as a function rather than as a constructor.
- may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified String behaviour must include a super call to the String constructor to create and initialize the subclass instance with a [[StringData]] internal slot.

22.1.1.1 String ( value )

This function performs the following steps when called:

1. If value is not present, then
   a. Let s be the empty String.
2. Else,
   a. If NewTarget is undefined and value is a Symbol, return SymbolDescriptiveString(value).
   b. Let s be ? ToString(value).
3. If NewTarget is undefined, return s.
4. Return StringCreate(s, ? GetPrototypeFromConstructor(NewTarget, "%String.prototype%"))

22.1.2 Properties of the String Constructor

The String constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has the following properties:

22.1.2.1 String.fromCharCode ( ...codeUnits )

This function may be called with any number of arguments which form the rest parameter codeUnits.

It performs the following steps when called:

1. Let result be the empty String.
2. For each element next of codeUnits, do
   a. Let nextCU be the code unit whose numeric value is ℝ(ʔ ToUint16(next)).
   b. Set result to the string-concatenation of result and nextCU.
3. Return result.

The "length" property of this function is 1𝔽.

22.1.2.2 String.fromCodePoint ( ...codePoints )

This function may be called with any number of arguments which form the rest parameter codePoints.

It performs the following steps when called:

1. Let result be the empty String.
2. For each element next of codePoints, do
a. Let `nextCP` be `? ToNumber(next)`.
b. If `IsIntegralNumber(nextCP)` is `false`, throw a `RangeError` exception.
c. If \( R(nextCP) < 0 \) or \( R(nextCP) > 0x10FFFF \), throw a `RangeError` exception.
d. Set `result` to the string-concatenation of `result` and `UTF16EncodeCodePoint(R(nextCP))`.

3. Assert: If `codePoints` is empty, then `result` is the empty String.
4. Return `result`.

The "length" property of this function is \( 1_F \).

22.1.2.3 String.prototype

The initial value of `String.prototype` is the String prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

22.1.2.4 String.raw ( `template`, ...`substitutions` )

This function may be called with a variable number of arguments. The first argument is `template` and the remainder of the arguments form the List `substitutions`.

It performs the following steps when called:

1. Let `substitutionCount` be the number of elements in `substitutions`.
2. Let `cooked` be `? ToObject(template)`.
3. Let `literals` be `? ToObject(? Get(cooked, "raw"))`.
4. Let `literalCount` be `? LengthOfArrayLike(literals)`.
5. If `literalCount ≤ 0`, return the empty String.
6. Let `R` be the empty String.
7. Let `nextIndex` be 0.
8. Repeat,
   a. Let `nextLiteralVal` be `? Get(literals, ! ToString(F(nextIndex)))`.
   b. Let `nextLiteral` be `? ToString(nextLiteralVal)`.
   c. Set `R` to the string-concatenation of `R` and `nextLiteral`.
   d. If `nextIndex + 1 = literalCount`, return `R`.
   e. If `nextIndex < substitutionCount`, then
      i. Let `nextSubVal` be `substitutions[nextIndex]`.
      ii. Let `nextSub` be `? ToString(nextSubVal)`.
      iii. Set `R` to the string-concatenation of `R` and `nextSub`.
   f. Set `nextIndex` to `nextIndex + 1`.

NOTE This function is intended for use as a tag function of a Tagged Template (13.3.11). When called as such, the first argument will be a well formed template object and the rest parameter will contain the substitution values.

22.1.3 Properties of the String Prototype Object

The `String.prototype object`:

- is `%String.prototype%`.
- is a String exotic object and has the internal methods specified for such objects.
- has a [[StringData]] internal slot whose value is the empty String.
- has a "length" property whose initial value is \( +0_F \) and whose attributes are `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.

Unless explicitly stated otherwise, the methods of the String prototype object defined below are not generic and the `this` value passed to them must be either a String value or an object that has a [[StringData]] internal slot that has been initialized to a String value.
22.1.3.1 String.prototype.at (index)

1. Let \( O \) be \( \text{RequireObjectCoercible}(\text{this value}) \).
2. Let \( S \) be \( \text{ToString}(O) \).
3. Let \( \text{len} \) be the length of \( S \).
4. Let \( \text{relativeIndex} \) be \( \text{ToIntegerOrInfinity}(\text{index}) \).
5. If \( \text{relativeIndex} \geq 0 \), then
   a. Let \( k \) be \( \text{relativeIndex} \).
6. Else,
   a. Let \( k \) be \( \text{len} + \text{relativeIndex} \).
7. If \( k < 0 \) or \( k \geq \text{len} \), return undefined.
8. Return the substring of \( S \) from \( k \) to \( k + 1 \).

22.1.3.2 String.prototype.charAt (pos)

NOTE 1 This method returns a single element String containing the code unit at index \( \text{pos} \) within the String value resulting from converting this object to a String. If there is no element at that index, the result is the empty String. The result is a String value, not a String object.

If \( \text{pos} \) is an integral Number, then the result of \( \text{x.charAt(pos)} \) is equivalent to the result of \( \text{x.substring(pos, pos + 1)} \).

This method performs the following steps when called:

1. Let \( O \) be \( \text{RequireObjectCoercible}(\text{this value}) \).
2. Let \( S \) be \( \text{ToString}(O) \).
3. Let \( \text{position} \) be \( \text{ToIntegerOrInfinity}(\text{pos}) \).
4. Let \( \text{size} \) be the length of \( S \).
5. If \( \text{position} < 0 \) or \( \text{position} \geq \text{size} \), return the empty String.
6. Return the substring of \( S \) from \( \text{position} \) to \( \text{position} + 1 \).

NOTE 2 This method is intentionally generic; it does not require that its \( \text{this} \) value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.3 String.prototype.charCodeAt (pos)

NOTE 1 This method returns a Number (a non-negative integral Number less than \( 2^{16} \)) that is the numeric value of the code unit at index \( \text{pos} \) within the String resulting from converting this object to a String. If there is no element at that index, the result is NaN.

This method performs the following steps when called:

1. Let \( O \) be \( \text{RequireObjectCoercible}(\text{this value}) \).
2. Let \( S \) be \( \text{ToString}(O) \).
3. Let \( \text{position} \) be \( \text{ToIntegerOrInfinity}(\text{pos}) \).
4. Let \( \text{size} \) be the length of \( S \).
5. If \( \text{position} < 0 \) or \( \text{position} \geq \text{size} \), return NaN.
6. Return the Number value for the numeric value of the code unit at index \( \text{position} \) within the String \( S \).

NOTE 2 This method is intentionally generic; it does not require that its \( \text{this} \) value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.4 String.prototype.codePointAt (pos)

**NOTE 1** This method returns a non-negative integral Number less than or equal to $0x10FFFF F$ that is the numeric value of the UTF-16 encoded code point (6.1.4) starting at the string element at index pos within the String resulting from converting this object to a String. If there is no element at that index, the result is undefined. If a valid UTF-16 surrogate pair does not begin at pos, the result is the code unit at pos.

This method performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. Let S be ? ToString(O).
3. Let position be ? ToIntegerOrInfinity(pos).
4. Let size be the length of S.
5. If position < 0 or position ≥ size, return undefined.
6. Let cp be CodePointAt(S, position).
7. Return $F(cp.[[CodePoint]])$.

**NOTE 2** This method is intentionally generic; it does not require that its this value be a String object. Therefore it can be transferred to other kinds of objects for use as a method.

22.1.3.5 String.prototype.concat (...args)

**NOTE 1** When this method is called it returns the String value consisting of the code units of the this value (converted to a String) followed by the code units of each of the arguments converted to a String. The result is a String value, not a String object.

This method performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. Let S be ? ToString(O).
3. Let R be S.
4. For each element next of args, do
   a. Let nextString be ? ToString(next).
   b. Set R to the string-concatenation of R and nextString.
5. Return R.

The “length” property of this method is $1 F$.

**NOTE 2** This method is intentionally generic; it does not require that its this value be a String object. Therefore it can be transferred to other kinds of objects for use as a method.

22.1.3.6 String.prototype.constructor

The initial value of String.prototype.constructor is %String%.

22.1.3.7 String.prototype.endsWith (searchString [, endPosition])

This method performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. Let S be ? ToString(O).
4. If isRegExp is true, throw a TypeError exception.
5. Let `searchStr` be `ToString(searchString)`.
6. Let `len` be the length of `S`.
7. If `endPosition` is `undefined`, let `pos` be `len`; else let `pos` be `ToIntegerOrInfinity(endPosition)`.
8. Let `end` be the result of clamping `pos` between `0` and `len`.
9. Let `searchLength` be the length of `searchStr`.
10. If `searchLength` = `0`, return `true`.
11. Let `start` be `end - searchLength`.
12. If `start` < `0`, return `false`.
13. Let `substring` be the substring of `S` from `start` to `end`.
14. If `substring` is `searchStr`, return `true`.
15. Return `false`.

NOTE 1 This method returns `true` if the sequence of code units of `searchString` converted to a String is the same as the corresponding code units of this object (converted to a String) starting at `endPosition - length(this)`. Otherwise it returns `false`.

NOTE 2 Throwing an exception if the first argument is a RegExp is specified in order to allow future editions to define extensions that allow such argument values.

NOTE 3 This method is intentionally generic; it does not require that its `this` value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.8 `String.prototype.includes( searchString [, position ] )`

This method performs the following steps when called:

1. Let `O` be `RequireObjectCoercible(this value)`.
2. Let `S` be `ToString(O)`.
3. Let `isRegExp` be `IsRegExp(searchString)`.
4. If `isRegExp` is `true`, throw a `TypeError` exception.
5. Let `searchStr` be `ToString(searchString)`.
6. Let `pos` be `ToIntegerOrInfinity(position)`.
7. Assert: If `position` is `undefined`, then `pos` is `0`.
8. Let `len` be the length of `S`.
9. Let `start` be the result of clamping `pos` between `0` and `len`.
10. Let `index` be `StringIndexOf(S, searchStr, start)`.
11. If `index` ≠ `-1`, return `true`.
12. Return `false`.

NOTE 1 If `searchString` appears as a substring of the result of converting this object to a String, at one or more indices that are greater than or equal to `position`, this function returns `true`; otherwise, it returns `false`. If `position` is `undefined`, `0` is assumed, so as to search all of the String.

NOTE 2 Throwing an exception if the first argument is a RegExp is specified in order to allow future editions to define extensions that allow such argument values.

NOTE 3 This method is intentionally generic; it does not require that its `this` value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.9  String.prototype.indexOf ( searchString [ , position ] )

NOTE 1  If searchString appears as a substring of the result of converting this object to a String, at one or more indices that are greater than or equal to position, then the smallest such index is returned; otherwise, \(-1\) is returned. If position is undefined, \(+0\) is assumed, so as to search all of the String.

This method performs the following steps when called:

1. Let \(O\) be ? RequireObjectCoercible(this value).
2. Let \(S\) be ? ToString(O).
3. Let \(searchStr\) be ? ToString(searchString).
4. Let \(pos\) be ? ToIntegerOrInfinity(position).
5. Assert: If position is undefined, then \(pos\) is \(0\).
6. Let \(len\) be the length of \(S\).
7. Let \(start\) be the result of clamping \(pos\) between \(0\) and \(len\).
8. Return \(\text{𝔽(StringIndexOf}(S, searchStr, start))\).

NOTE 2  This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.10  String.prototype.isWellFormed ( )

This method performs the following steps when called:

1. Let \(O\) be ? RequireObjectCoercible(this value).
2. Let \(S\) be ? ToString(O).
3. Return IsStringWellFormedUnicode(S).

22.1.3.11  String.prototype.lastIndexOf ( searchString [ , position ] )

NOTE 1  If searchString appears as a substring of the result of converting this object to a String at one or more indices that are smaller than or equal to position, then the greatest such index is returned; otherwise, \(-1\) is returned. If position is undefined, the length of the String value is assumed, so as to search all of the String.

This method performs the following steps when called:

1. Let \(O\) be ? RequireObjectCoercible(this value).
2. Let \(S\) be ? ToString(O).
3. Let \(searchStr\) be ? ToString(searchString).
4. Let \(numPos\) be ? ToNumber(position).
5. Assert: If position is undefined, then \(numPos\) is \(\text{NaN}\).
6. If \(numPos\) is \(\text{NaN}\), let \(pos\) be \(+\infty\); otherwise, let \(pos\) be \(\text{ToIntOrInfinity}(numPos)\).
7. Let \(len\) be the length of \(S\).
8. Let \(searchLen\) be the length of \(searchStr\).
9. Let \(start\) be the result of clamping \(pos\) between \(0\) and \(len - searchLen\).
10. If \(searchStr\) is the empty String, return \(\text{𝔽}(start)\).
11. For each integer \(i\) such that \(0 \leq i \leq start\), in descending order, do
    a. Let \(candidate\) be the substring of \(S\) from \(i\) to \(i + searchLen\).
    b. If \(candidate\) is \(searchStr\), return \(\text{𝔽}(i)\).
12. Return \(-1\).

NOTE 2  This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.12 String.prototype.localeCompare (that [, reserved1 [, reserved2 ]])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method returns a Number other than NaN representing the result of an implementation-defined locale-sensitive String comparison of the this value (converted to a String S) with that (converted to a String thatValue). The result is intended to correspond with a sort order of String values according to conventions of the host environment’s current locale, and will be negative when S is ordered before thatValue, positive when S is ordered after thatValue, and zero in all other cases (representing no relative ordering between S and thatValue).

Before performing the comparisons, this method performs the following steps to prepare the Strings:

1. Let O be ? RequireObjectCoercible(this value).
2. Let S be ? ToString(O).
3. Let thatValue be ? ToString(that).

The meaning of the optional second and third parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not assign any other interpretation to those parameter positions.

The actual return values are implementation-defined to permit encoding additional information in them, but this method, when considered as a method of two arguments, is required to be a consistent comparator defining a total ordering on the set of all Strings. This method is also required to recognize and honour canonical equivalence according to the Unicode Standard, including returning +0HTTPRequest when comparing distinguishable Strings that are canonically equivalent.

NOTE 1 This method itself is not directly suitable as an argument to Array.prototype.sort because the latter requires a function of two arguments.
NOTE 2 This method may rely on whatever language- and/or locale-sensitive comparison functionality is available to the ECMAScript environment from the host environment, and is intended to compare according to the conventions of the host environment's current locale. However, regardless of comparison capabilities, this method must recognize and honour canonical equivalence according to the Unicode Standard—for example, the following comparisons must all return +0𝔽:

// Å ANGSTROM SIGN vs. // A' LATIN CAPITAL LETTER A + COMBINING RING ABOVE "\u212B".localeCompare("A\u030A")

// Ω OHM SIGN vs. // Ω GREEK CAPITAL LETTER OMEGA "\u2126".localeCompare("\u03A9")

// ṡ LATIN SMALL LETTER S WITH DOT BELOW AND DOT ABOVE vs. // ₩ LATIN SMALL LETTER S + COMBINING DOT ABOVE + COMBINING DOT BELOW "\u1E69".localeCompare("s\u0307\u0323")

// ḍ LATIN SMALL LETTER D WITH DOT ABOVE + COMBINING DOT BELOW vs. // ḍ LATIN SMALL LETTER D WITH DOT BELOW + COMBINING DOT ABOVE "\u1E0B\u0307\u0323".localeCompare("\u1E0D\u0307")

// 가 HANGUL CHOSEONG KIYEOK + HANGUL JUNGSEONG A vs. // 가 HANGUL SYLLABLE GA "\u1100\u1161".localeCompare("\uAC00")


It is recommended that this method should not honour Unicode compatibility equivalents or compatibility decompositions as defined in the Unicode Standard, chapter 3, section 3.7.

NOTE 3 This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.13 String.prototype.match (regexp)

This method performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. If regexp is neither undefined nor null, then
   a. Let matcher be ? GetMethod(regexp, @@match).
   b. If matcher is not undefined, then
      i. Return ? Call(matcher, regexp, « O »).
3. Let S be ? ToString(O).
4. Let rx be ? RegExpCreate(regexp, undefined).
5. Return ? Invoke(rx, @@match, « S »).

NOTE This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.14 String.prototype.matchAll (regexp)

This method performs a regular expression match of the String representing the `this` value against `regexp` and returns an iterator. Each iteration result’s value is an Array containing the results of the match, or `null` if the String did not match.

It performs the following steps when called:

1. Let `O` be `RequireObjectCoercible(this value).`
2. If `regexp` is neither `undefined` nor `null`, then
   a. Let `isRegExp` be `IsRegExp(regexp).`
   b. If `isRegExp` is `true`, then
      i. Let `flags` be `Get(regexp, "flags").`
      ii. Perform `RequireObjectCoercible(flags).`
      iii. If `flags` does not contain "g", throw a `TypeError` exception.
   c. Let `matcher` be `GetMethod(regexp, @@matchAll).`
   d. If `matcher` is not `undefined`, then
      i. Return `Call(matcher, regexp, «O»).`
3. Let `S` be `ToString(O).`
4. Let `rx` be `RegExpCreate(regexp, "g").`
5. Return `Invoke(rx, @@matchAll, «S»).

NOTE 1 This method is intentionally generic, it does not require that its `this` value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

NOTE 2 Similarly to String.prototype.split, String.prototype.matchAll is designed to typically act without mutating its inputs.

22.1.3.15 String.prototype.normalize ([form])

This method performs the following steps when called:

1. Let `O` be `RequireObjectCoercible(this value).`
2. Let `S` be `ToString(O).`
3. If `form` is `undefined`, let `f` be "NFC".
4. Else, let `f` be `ToString(form).`
5. If `f` is not one of "NFC", "NFD", "NFKC", or "NFKD", throw a `RangeError` exception.
6. Let `ns` be the String value that is the result of normalizing `S` into the normalization form named by `f` as specified in the latest Unicode Standard, Normalization Forms <https://www.unicode.org/versions/latest/ch03.pdf>.
7. Return `ns`.

NOTE This method is intentionally generic; it does not require that its `this` value be a String object. Therefore it can be transferred to other kinds of objects for use as a method.

22.1.3.16 String.prototype.padEnd (maxLength [, fillString])

This method performs the following steps when called:

1. Let `O` be `RequireObjectCoercible(this value).`
2. Return `StringPaddingBuiltinsImpl(O, maxLength, fillString, END).`
22.1.3.17 \texttt{String.prototype.padStart (} \texttt{maxLength [ , fillString ] )}

This method performs the following steps when called:

1. Let \( O \) be ? \texttt{RequireObjectCoercible} (this value).
2. Return ? \texttt{StringPaddingBuiltinsImpl} (\( O \), \texttt{maxLength}, \texttt{fillString}, \texttt{START}).

22.1.3.17.1 \texttt{StringPaddingBuiltinsImpl (} \( O \), \texttt{maxLength, fillString, placement } \)

The abstract operation \texttt{StringPaddingBuiltinsImpl} takes arguments \( O \) (an ECMAScript language value), \texttt{maxLength} (an ECMAScript language value), \texttt{fillString} (an ECMAScript language value), and \texttt{placement} (START or END) and returns either a normal completion containing a String or a throw completion. It performs the following steps when called:

1. Let \( S \) be ? \texttt{ToString} (\( O \)).
2. Let \( \texttt{intMaxLength} \) be \( \mathbb{R} \) (\( \texttt{ToLength} (\texttt{maxLength}) \)).
3. Let \( \texttt{stringLength} \) be the length of \( S \).
4. If \( \texttt{intMaxLength} \leq \texttt{stringLength} \), return \( S \).
5. If \( \texttt{fillString} \) is undefined, set \( \texttt{fillString} \) to the String value consisting solely of the code unit \( 0x0020 \) (SPACE).
6. Else, set \( \texttt{fillString} \) to ? \texttt{ToString} (\( \texttt{fillString} \)).
7. Return \texttt{StringPad} (\( S \), \texttt{intMaxLength}, \texttt{fillString}, \texttt{placement}).

22.1.3.17.2 \texttt{StringPad (} \( S \), \texttt{maxLength, fillString, placement } \)

The abstract operation \texttt{StringPad} takes arguments \( S \) (a String), \texttt{maxLength} (a non-negative integer), \texttt{fillString} (a String), and \texttt{placement} (START or END) and returns a String. It performs the following steps when called:

1. Let \( \texttt{stringLength} \) be the length of \( S \).
2. If \( \texttt{maxLength} \leq \texttt{stringLength} \), return \( S \).
3. If \( \texttt{fillString} \) is the empty String, return \( S \).
4. Let \( \texttt{fillLen} \) be \( \texttt{maxLength} - \texttt{stringLength} \).
5. Let \( \texttt{truncatedStringFiller} \) be the String value consisting of repeated concatenations of \( \texttt{fillString} \) truncated to length \( \texttt{fillLen} \).
6. If \( \texttt{placement} \) is START, return the string-concatenation of \( \texttt{truncatedStringFiller} \) and \( S \).
7. Else, return the string-concatenation of \( S \) and \( \texttt{truncatedStringFiller} \).

\textbf{NOTE 1} The argument \texttt{maxLength} will be clamped such that it can be no smaller than the length of \( S \).

\textbf{NOTE 2} The argument \texttt{fillString} defaults to " " (the String value consisting of the code unit \( 0x0020 \) SPACE).

22.1.3.17.3 \texttt{ToZeroPaddedDecimalString (} \( n \), \texttt{minLength } \)

The abstract operation \texttt{ToZeroPaddedDecimalString} takes arguments \( n \) (a non-negative integer) and \texttt{minLength} (a non-negative integer) and returns a String. It performs the following steps when called:

1. Let \( S \) be the String representation of \( n \), formatted as a decimal number.
2. Return \texttt{StringPad} (\( S \), \texttt{minLength}, "0", \texttt{START}).

22.1.3.18 \texttt{String.prototype.repeat (} \texttt{count } \)

This method performs the following steps when called:

1. Let \( O \) be ? \texttt{RequireObjectCoercible} (this value).
2. Let \( S \) be ? \texttt{ToString} (\( O \)).
3. Let \( n \) be ? \texttt{ToIntegerOrInfinity} (\( \texttt{count} \)).
4. If \( n < 0 \) or \( n = +\infty \), throw a \texttt{RangeError} exception.
5. If \( n = 0 \), return the empty String.
6. Return the String value that is made from \( n \) copies of \( S \) appended together.

**NOTE 1** This method creates the String value consisting of the code units of the this value (converted to String) repeated \( count \) times.

**NOTE 2** This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

### 22.1.3.19 String.prototype.replace (searchValue, replaceValue)

This method performs the following steps when called:

1. Let \( O \) be ? RequireObjectCoercible(this value).
2. If \( searchValue \) is neither undefined nor null, then
   a. Let \( replacer \) be ? GetMethod(searchValue, @@replace).
   b. If \( replacer \) is not undefined, then
      i. Return ? Call(replacer, searchValue, « \( O \), replaceValue »).
3. Let \( string \) be ? ToString(O).
4. Let \( searchString \) be ? ToString(searchValue).
5. Let \( functionalReplace \) be IsCallable(replaceValue).
6. If \( functionalReplace \) is false, then
   a. Set \( replaceValue \) to ? ToString(? Call(replaceValue, undefined, « searchString, \( \_ \), string »)).
7. Let \( searchLength \) be the length of \( searchString \).
8. Let \( position \) be StringIndexOf(string, searchString, 0).
9. If \( position \) = -1, return \( string \).
10. Let \( preceding \) be the substring of \( string \) from 0 to \( position \).
11. Let \( following \) be the substring of \( string \) from \( position + searchLength \).
12. If \( functionalReplace \) is true, then
    a. Let \( replacement \) be ? ToString(? Call(replaceValue, undefined, « searchString, \( \_ \), string »)).
13. Else,
    a. Assert: replaceValue is a String.
    b. Let \( captures \) be a new empty List.
    c. Let \( replacement \) be ! GetSubstitution(searchString, string, position, captures, undefined, replaceValue).
14. Return the string-concatenation of preceding, replacement, and following.

**NOTE** This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

### 22.1.3.19.1 GetSubstitution (matched, str, position, captures, namedCaptures, replacementTemplate)

The abstract operation GetSubstitution takes arguments matched (a String), str (a String), position (a non-negative integer), captures (a List of either Strings or undefined), namedCaptures (an Object or undefined), and replacementTemplate (a String) and returns either a normal completion containing a String or a throw completion. For the purposes of this abstract operation, a decimal digit is a code unit in the inclusive interval from 0x0030 (DIGIT ZERO) to 0x0039 (DIGIT NINE). It performs the following steps when called:

1. Let \( stringLength \) be the length of \( str \).
2. Assert: position \( \leq stringLength \).
3. Let \( result \) be the empty String.
4. Let \( templateRemainder \) be replacementTemplate.
5. Repeat, while \( templateRemainder \) is not the empty String,
   a. NOTE: The following steps isolate ref (a prefix of \( templateRemainder \)), determine refReplacement (its replacement), and then append that replacement to \( result \).
   b. If \( templateRemainder \) starts with "$$", then
i. Let `ref` be "$$".
ii. Let `refReplacement` be "$".

C. Else if `templateRemainder` starts with "$", then
   i. Let `ref` be "$".
   ii. Let `refReplacement` be the substring of `str` from 0 to `position`.

D. Else if `templateRemainder` starts with "$\&\&", then
   i. Let `ref` be "$\&\&".
   ii. Let `refReplacement` be matched.

E. Else if `templateRemainder` starts with "$\" (0x0024 (DOLLAR SIGN) followed by 0x0027 (APPOSTROPHE)), then
   i. Let `ref` be "$\".
   ii. Let `matchLength` be the length of `matched`.
   iii. Let `tailPos` be `position + matchLength`.
   iv. Let `refReplacement` be the substring of `str` from `min(tailPos, stringLength)`.
   v. NOTE: `tailPos` can exceed `stringLength` only if this abstract operation was invoked by a call to the intrinsic `@@replace` method of `%RegExp.prototype% exec% on an object whose "exec" property is not the intrinsic %RegExp.prototype.exec%.

F. Else if `templateRemainder` starts with "$\" followed by 1 or more decimal digits, then
   i. If `templateRemainder` starts with "$\" followed by 2 or more decimal digits, let `digitCount` be 2.
      Otherwise, let `digitCount` be 1.
   ii. Let `digits` be the substring of `templateRemainder` from 1 to 1 + `digitCount`.
   iii. Let `index` be `ℝ(StringToNumber(digits))`.
   iv. Assert: `0 ≤ index ≤ 99`.
   v. Let `captureLen` be the number of elements in `captures`.
   vi. If `index > captureLen` and `digitCount = 2`, then
      1. NOTE: When a two-digit replacement pattern specifies an index exceeding the count of capturing groups, it is treated as a one-digit replacement pattern followed by a literal digit.
      2. Set `digitCount` to 1.
      3. Set `digits` to the substring of `digits` from 0 to 1.
      4. Set `index` to ` ℝ(StringToNumber(digits))`.
   vii. Let `ref` be the substring of `templateRemainder` from 0 to 1 + `digitCount`.
   viii. If `1 ≤ index ≤ captureLen`, then
        1. Let `capture` be `captures[index - 1]`.
        2. If `capture` is `undefined`, then
           a. Let `refReplacement` be the empty String.
        3. Else,
           a. Let `refReplacement` be `capture`.
   ix. Else,
      1. Let `refReplacement` be `ref`.

G. Else if `templateRemainder` starts with "$<\", then
   i. Let `gtPos` be `StringIndexOf(templateRemainder, ">", 0)`.
   ii. If `gtPos = -1` or `namedCaptures` is `undefined`, then
      1. Let `ref` be "$<\".
      2. Let `refReplacement` be `ref`.
   iii. Else,
      1. Let `ref` be the substring of `templateRemainder` from 0 to `gtPos + 1`.
      2. Let `groupName` be the substring of `templateRemainder` from 2 to `gtPos`.
      3. Assert: `namedCaptures` is an Object.
      4. Let `capture` be `? Get(namedCaptures, groupName)`.
      5. If `capture` is `undefined`, then
         a. Let `refReplacement` be the empty String.
      6. Else,
         a. Let `refReplacement` be `? ToString(capture)`.
   h. Else,
      1. Let `ref` be the substring of `templateRemainder` from 0 to 1.
      2. Let `refReplacement` be `ref`.
   i. Let `refLength` be the length of `ref`.
   j. Set `templateRemainder` to the substring of `templateRemainder` from `refLength`.
   k. Set `result` to the string-concatenation of `result` and `refReplacement`.

6. Return `result`. 
22.1.3.20  String.prototype.replaceAll ( searchValue, replaceValue )

This method performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. If searchValue is neither undefined nor null, then
   b. If isRegExp is true, then
      i. Let flags be ? Get(searchValue, "flags").
      iii. If ? ToString(flags) does not contain "g", throw a TypeError exception.
   c. Let replacer be ? GetMethod(searchValue, @@replace).
   d. If replacer is not undefined, then
      i. Return ? Call(replacer, searchValue, « O, replaceValue »).
3. Let string be ? ToString(O).
5. Let functionalReplace be IsCallable(replaceValue).
6. If functionalReplace is false, then
   a. Set replaceValue to ? ToString(replaceValue).
7. Let searchLength be the length of searchString.
8. Let advanceBy be max(1, searchLength).
9. Let matchPositions be a new empty List.
10. Let position be StringIndexOf(string, searchString, 0).
11. Repeat, while position ≠ -1,
    a. Append position to matchPositions.
    b. Set position to StringIndexOf(string, searchString, position + advanceBy).
12. Let endOfLastMatch be 0.
13. Let result be the empty String.
14. For each element p of matchPositions, do
    a. Let preserved be the substring of string from endOfLastMatch to p.
    b. If functionalReplace is true, then
       i. Let replacement be ? ToString(? Call(replaceValue, undefined, « searchString, F(p), string »)).
    c. Else,
       i. Assert: replaceValue is a String.
       ii. Let captures be a new empty List.
       iii. Let replacement be ! GetSubstitution(searchString, string, p, captures, undefined, replaceValue).
    d. Set result to the string-concatenation of result, preserved, and replacement.
    e. Set endOfLastMatch to p + searchLength.
15. If endOfLastMatch < the length of string, then
    a. Set result to the string-concatenation of result and the substring of string from endOfLastMatch.
16. Return result.

22.1.3.21  String.prototype.search ( regexp )

This method performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. If regexp is neither undefined nor null, then
   b. If searcher is not undefined, then
      i. Return ? Call(searcher, regexp, « O »).
3. Let string be ? ToString(O).
4. Let rx be ? RegExpCreate(regexp, undefined).
5. Return ? Invoke(rx, @@search, « string »).

NOTE  This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.22 String.prototype.slice ( \( start \), \( end \) )

This method returns a substring of the result of converting this object to a String, starting from index \( start \) and running to, but not including, index \( end \) (or through the end of the String if \( end \) is \text{undefined}). If \( start \) is negative, it is treated as \( sourceLength + start \) where \( sourceLength \) is the length of the String. If \( end \) is negative, it is treated as \( sourceLength + end \) where \( sourceLength \) is the length of the String. The result is a String value, not a String object.

It performs the following steps when called:

1. Let \( O \) be ? \text{RequireObjectCoercible}(this value).
2. Let \( S \) be ? \text{ToString}(O).
3. Let \( len \) be the length of \( S \).
4. Let \( intStart \) be ? \text{ToIntegerOrInfinity}(start).
5. If \( intStart = -\infty \), let \( from \) be \( 0 \).
6. Else if \( intStart < 0 \), let \( from \) be \( \max(len + intStart, 0) \).
7. Else, let \( from \) be \( \min(intStart, len) \).
8. If \( end \) is \text{undefined}, let \( intEnd \) be \( len \); else let \( intEnd \) be ? \text{ToIntegerOrInfinity}(end).
9. If \( intEnd = -\infty \), let \( to \) be \( 0 \).
10. Else if \( intEnd < 0 \), let \( to \) be \( \max(len + intEnd, 0) \).
11. Else, let \( to \) be \( \min(intEnd, len) \).
12. If \( from \geq to \), return the empty String.
13. Return the substring of \( S \) from \( from \) to \( to \).

\textbf{NOTE}  
This method is intentionally generic; it does not require that its this value be a String object. Therefore it can be transferred to other kinds of objects for use as a method.

22.1.3.23 String.prototype.split ( \( separator \), \( limit \) )

This method returns an Array into which substrings of the result of converting this object to a String have been stored. The substrings are determined by searching from left to right for occurrences of \( separator \); these occurrences are not part of any String in the returned array, but serve to divide up the String value. The value of \( separator \) may be a String of any length or it may be an object, such as a RegExp, that has a @@split method.

It performs the following steps when called:

1. Let \( O \) be ? \text{RequireObjectCoercible}(this value).
2. If \( separator \) is neither \text{undefined} nor \text{null}, then
   a. Let \( splitter \) be ? \text{GetMethod}(separator, @@split).
   b. If \( splitter \) is not \text{undefined}, then
      i. Return ? \text{Call}(splitter, separator, « O, limit »).
3. Let \( S \) be ? \text{ToString}(O).
4. If \( limit \) is \text{undefined}, let \( lim \) be \( 2^{32} - 1 \); else let \( lim \) be \( R \) (? \text{ToUint32}(limit)).
5. Let \( R \) be ? \text{ToString}(separator).
6. If \( lim = 0 \), then
   a. Return CreateArrayFromList(« »).
7. If \( separator \) is \text{undefined}, then
   a. Return CreateArrayFromList(« S »).
8. Let \( separatorLength \) be the length of \( R \).
9. If \( separatorLength = 0 \), then
   a. Let \( head \) be the substring of \( S \) from \( 0 \) to \( lim \).
   b. Let \( codeUnits \) be a List consisting of the sequence of code units that are the elements of \( head \).
   c. Return CreateArrayFromList(codeUnits).
10. If \( S \) is the empty String, return CreateArrayFromList(« S »).
11. Let \( substrings \) be a new empty List.
12. Let \( i \) be \( 0 \).
13. Let \( j \) be \text{StringIndexOf}(S, R, 0).
14. Repeat, while \( j \neq -1 \),
   a. Let \( T \) be the substring of \( S \) from \( i \) to \( j \).

b. Append $T$ to $substrings$.

c. If the number of elements in $substrings$ is $lim$, return $\text{CreateArrayFromList}(substrings)$.

d. Set $i$ to $j + \text{separatorLength}$.

e. Set $j$ to $\text{StringIndexOf}(S, R, i)$.

15. Let $T$ be the substring of $S$ from $i$.

16. Append $T$ to $substrings$.

17. Return $\text{CreateArrayFromList}(substrings)$.

NOTE 1 The value of $\text{separator}$ may be an empty String. In this case, $\text{separator}$ does not match the empty substring at the beginning or end of the input String, nor does it match the empty substring at the end of the previous separator match. If $\text{separator}$ is the empty String, the String is split up into individual code unit elements; the length of the result array equals the length of the String, and each substring contains one code unit.

If the $\text{this}$ value is (or converts to) the empty String, the result depends on whether $\text{separator}$ can match the empty String. If it can, the result array contains no elements. Otherwise, the result array contains one element, which is the empty String.

If $\text{separator}$ is $\text{undefined}$, then the result array contains just one String, which is the $\text{this}$ value (converted to a String). If $\text{limit}$ is not $\text{undefined}$, then the output array is truncated so that it contains no more than $\text{limit}$ elements.

NOTE 2 This method is intentionally generic; it does not require that its $\text{this}$ value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.24 String.prototype.startsWith ( searchString [ , position ] )

This method performs the following steps when called:

1. Let $O$ be $\text{RequireObjectCoercible}(\text{this value})$.
2. Let $S$ be $\text{ToString}(O)$.
3. Let $\text{isRegExp}$ be $\text{IsRegExp}(\text{searchString})$.
4. If $\text{isRegExp}$ is $\text{true}$, throw a $\text{TypeError}$ exception.
5. Let $\text{searchStr}$ be $\text{ToString}(\text{searchString})$.
6. Let $\text{len}$ be the length of $S$.
7. If $\text{position}$ is $\text{undefined}$, let $\text{pos}$ be 0; else let $\text{pos}$ be $\text{ToIntegerOrInfinity}(\text{position})$.
8. Let $\text{start}$ be the result of clamping $\text{pos}$ between 0 and $\text{len}$.
9. Let $\text{searchLength}$ be the length of $\text{searchStr}$.
10. If $\text{searchLength} = 0$, return $\text{true}$.
11. Let $\text{end}$ be $\text{start} + \text{searchLength}$.
12. If $\text{end} > \text{len}$, return $\text{false}$.
13. Let $\text{substring}$ be the substring of $S$ from $\text{start}$ to $\text{end}$.
14. If $\text{substring}$ is $\text{searchStr}$, return $\text{true}$.
15. Return $\text{false}$.

NOTE 1 This method returns $\text{true}$ if the sequence of code units of $\text{searchString}$ converted to a String is the same as the corresponding code units of this object (converted to a String) starting at index $\text{position}$. Otherwise it returns $\text{false}$.

NOTE 2 Throwing an exception if the first argument is a RegExp is specified in order to allow future editions to define extensions that allow such argument values.

NOTE 3 This method is intentionally generic; it does not require that its $\text{this}$ value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.25 String.prototype.substring (start, end)

This method returns a substring of the result of converting this object to a String, starting from index start and running to, but not including, index end of the String (or through the end of the String if end is undefined). The result is a String value, not a String object.

If either argument is NaN or negative, it is replaced with zero; if either argument is strictly greater than the length of the String, it is replaced with the length of the String.

If start is strictly greater than end, they are swapped.

It performs the following steps when called:

1. Let O be ? RequireObjectCoercible(this value).
2. Let S be ? ToString(O).
3. Let len be the length of S.
4. Let intStart be ? ToIntegerOrInfinity(start).
5. If end is undefined, let intEnd be len; else let intEnd be ? ToIntegerOrInfinity(end).
6. Let finalStart be the result of clamping intStart between 0 and len.
7. Let finalEnd be the result of clamping intEnd between 0 and len.
8. Let from be min(finalStart, finalEnd).
9. Let to be max(finalStart, finalEnd).
10. Return the substring of S from from to to.

NOTE This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.26 String.prototype.toLocaleLowerCase (reserved1[, reserved2])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It works exactly the same as toLowerCase except that it is intended to yield a locale-sensitive result corresponding with conventions of the host environment’s current locale. There will only be a difference in the few cases (such as Turkish) where the rules for that language conflict with the regular Unicode case mappings.

The meaning of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

NOTE This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.27 String.prototype.toLocaleUpperCase (reserved1[, reserved2])

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used:

This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It works exactly the same as toUpperCase except that it is intended to yield a locale-sensitive result corresponding with conventions of the host environment’s current locale. There will only be a difference in the few cases (such as Turkish) where the rules for that language conflict with the regular Unicode case mappings.
The meaning of the optional parameters to this method are defined in the ECMA-402 specification; implementations that do not include ECMA-402 support must not use those parameter positions for anything else.

NOTE  This method is intentionally generic; it does not require that its `this` value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

### 22.1.3.28 `String.prototype.toLowerCase()`

This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It performs the following steps when called:

1. Let `O` be `RequireObjectCoercible(this value)`.
2. Let `S` be `ToString(O)`.
3. Let `sText` be `StringToCodePoints(S)`.
4. Let `lowerText` be the result of `toLowercase(sText)`, according to the Unicode Default Case Conversion algorithm.
5. Let `L` be `CodePointsToString(lowerText)`.
6. Return `L`.

The result must be derived according to the locale-insensitive case mappings in the Unicode Character Database (this explicitly includes not only the file `UnicodeData.txt` <https://unicode.org/Public/UCD/latest/ucd/UnicodeData.txt>, but also all locale-insensitive mappings in the file `SpecialCasing.txt` <https://unicode.org/Public/UCD/latest/ucd/SpecialCasing.txt> that accompanies it).

**NOTE 1** The case mapping of some code points may produce multiple code points. In this case the result string may not be the same length as the source String. Because both `toUpperCase` and `toLowerCase` have context-sensitive behaviour, the methods are not symmetrical. In other words, `s.toUpperCase().toLowerCase()` is not necessarily equal to `s.toLowercase()`.

**NOTE 2** This method is intentionally generic; it does not require that its `this` value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

### 22.1.3.29 `String.prototype.toString()`

This method performs the following steps when called:

1. Return `ThisStringValue(this value)`.

**NOTE** For a String object, this method happens to return the same thing as the `valueOf` method.

### 22.1.3.30 `String.prototype.toUpperCase()`

This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It behaves in exactly the same way as `String.prototype.toLowerCase()`, except that the String is mapped using the `toUpperCase` algorithm of the Unicode Default Case Conversion.

**NOTE** This method is intentionally generic; it does not require that its `this` value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.
22.1.3.31 String.prototype.toWellFormed ( )

This method returns a String representation of this object with all leading surrogates and trailing surrogates that are not part of a surrogate pair replaced with U+FFFD (REPLACEMENT CHARACTER).

It performs the following steps when called:

1. Let \( O \) be ? RequireObjectCoercible(this value).
2. Let \( S \) be ? ToString(O).
3. Let \( \text{strLen} \) be the length of \( S \).
4. Let \( k \) be \( 0 \).
5. Let \( \text{result} \) be the empty String.
6. Repeat, while \( k < \text{strLen} \),
   a. Let \( cp \) be CodePointAt(\( S \), \( k \)).
   b. If \( \text{cp} [[\text{IsUnpairedSurrogate}]] \) is true, then
      i. Set \( \text{result} \) to the string-concatenation of \( \text{result} \) and \( \text{0xFFFD} \) (REPLACEMENT CHARACTER).
   c. Else,
      i. Set \( \text{result} \) to the string-concatenation of \( \text{result} \) and UTF16EncodeCodePoint(\( \text{cp} [[\text{CodePoint}]] \)).
   d. Set \( k \) to \( k + \text{cp} [[\text{CodeUnitCount}]] \).
7. Return \( \text{result} \).

22.1.3.32 String.prototype.trim ( )

This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It performs the following steps when called:

1. Let \( S \) be the this value.
2. Return ? TrimString(\( S \), START+END).

NOTE This method is intentionally generic; it does not require that its this value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

22.1.3.32.1 TrimString ( string, where )

The abstract operation TrimString takes arguments \( \text{string} \) (an ECMAScript language value) and \( \text{where} \) (START, END, or START+END) and returns either a normal completion containing a String or a throw completion. It interprets \( \text{string} \) as a sequence of UTF-16 encoded code points, as described in 6.1.4. It performs the following steps when called:

1. Let \( \text{str} \) be ? RequireObjectCoercible(\( \text{string} \)).
2. Let \( S \) be ? ToString(\( \text{str} \)).
3. If \( \text{where} \) is START, then
   a. Let \( T \) be the String value that is a copy of \( S \) with leading white space removed.
4. Else if \( \text{where} \) is END, then
   a. Let \( T \) be the String value that is a copy of \( S \) with trailing white space removed.
5. Else,
   a. \textbf{Assert:} \( \text{where} \) is START+END.
   b. Let \( T \) be the String value that is a copy of \( S \) with both leading and trailing white space removed.
6. Return \( T \).

The definition of white space is the union of \text{WhiteSpace} and \text{LineTerminator}. When determining whether a Unicode code point is in Unicode general category “Space_Separator” (“Zs”), code unit sequences are interpreted as UTF-16 encoded code point sequences as specified in 6.1.4.
This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It performs the following steps when called:

1. Let \( S \) be the \texttt{this} value.
2. Return \texttt{TrimString}(S, END).

**NOTE** This method is intentionally generic; it does not require that its \texttt{this} value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

This method interprets a String value as a sequence of UTF-16 encoded code points, as described in 6.1.4.

It performs the following steps when called:

1. Let \( S \) be the \texttt{this} value.
2. Return \texttt{TrimString}(S, START).

**NOTE** This method is intentionally generic; it does not require that its \texttt{this} value be a String object. Therefore, it can be transferred to other kinds of objects for use as a method.

This method performs the following steps when called:

1. Return \texttt{ThisStringValue}(	exttt{this} value).

**22.1.3.35.1** \texttt{ThisStringValue} ( \texttt{value} )

The abstract operation \texttt{ThisStringValue} takes argument \texttt{value} (an ECMAScript language value) and returns either a normal completion containing a String or a throw completion. It performs the following steps when called:

1. If \texttt{value} is a String, return \texttt{value}.
2. If \texttt{value} is an Object and \texttt{value} has a [[StringData]] internal slot, then
   a. Let \( s \) be \texttt{value}.[[StringData]].
   b. Assert: \( s \) is a String.
   c. Return \( s \).
3. Throw a \texttt{TypeError} exception.

This method returns an Iterator object (27.1.1.2) that iterates over the code points of a String value, returning each code point as a String value.

It performs the following steps when called:

1. Let \( O \) be \texttt{RequireObjectCoercible}(	exttt{this} value).
2. Let \( s \) be \texttt{ToString}(O).
3. Let \texttt{closure} be a new Abstract Closure with no parameters that captures \( s \) and performs the following steps when called:
   a. Let \( len \) be the length of \( s \).
   b. Let \texttt{position} be 0.
   c. Repeat, while \texttt{position} < \( len \),
i. Let \( cp \) be `CodePointAt(s, position)`.
ii. Let `nextIndex` be `position + cp[[CodeUnitCount]]`.
iii. Let `resultString` be the substring of `s` from `position` to `nextIndex`.
iv. Set `position` to `nextIndex`.
v. Perform \( \text{GeneratorYield(CreateIterResultObject(resultString, false))} \).

d. Return `undefined`.

4. Return `CreateIteratorFromClosure(closure, "%StringIteratorPrototype", %StringIteratorPrototype%)`.

The value of the "name" property of this method is "[Symbol.iterator]".

22.1.4 Properties of String Instances

String instances are String exotic objects and have the internal methods specified for such objects. String instances inherit properties from the String prototype object. String instances also have a `[[StringData]]` internal slot. The `[[StringData]]` internal slot is the String value represented by this String object.

String instances have a "length" property, and a set of enumerable properties with integer-indexed names.

22.1.4.1 length

The number of elements in the String value represented by this String object.

Once a String object is initialized, this property is unchanging. It has the attributes { [[Writable]]: `false`, [[Enumerable]]: `false`, [[Configurable]]: `false` }.

22.1.5 String Iterator Objects

A String Iterator is an object, that represents a specific iteration over some specific String instance object. There is not a named constructor for String Iterator objects. Instead, String iterator objects are created by calling certain methods of String instance objects.

22.1.5.1 The `%StringIteratorPrototype% Object

The `%StringIteratorPrototype% object:

- has properties that are inherited by all String Iterator Objects.
- is an ordinary object.
- has a `[[Prototype]]` internal slot whose value is `%IteratorPrototype%`.
- has the following properties:

22.1.5.1.1 `%StringIteratorPrototype%.next ( )

1. Return `? GeneratorResume(this value, EMPTY, "%StringIteratorPrototype%")`.

22.1.5.1.2 `%StringIteratorPrototype% [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "String Iterator".

This property has the attributes { [[Writable]]: `false`, [[Enumerable]]: `false`, [[Configurable]]: `true` }.

22.2 RegExp (Regular Expression) Objects

A RegExp object contains a regular expression and the associated flags.
NOTE The form and functionality of regular expressions is modelled after the regular expression facility in the Perl 5 programming language.

22.2.1 Patterns

The RegExp constructor applies the following grammar to the input pattern String. An error occurs if the grammar cannot interpret the String as an expansion of Pattern.

Syntax

\[\text{Pattern} [\text{UnicodeMode, UnicodeSetsMode, NamedCaptureGroups}] :: \]
  \[\text{Disjunction} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \]

\[\text{Disjunction} [\text{UnicodeMode, UnicodeSetsMode, NamedCaptureGroups}] :: \]
  \[\text{Alternative} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \]
  \[\text{Alternative} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] | \text{Disjunction} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \]

\[\text{Alternative} [\text{UnicodeMode, UnicodeSetsMode, NamedCaptureGroups}] :: \]
  \[\text{empty} \]
  \[\text{Term} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \]

\[\text{Term} [\text{UnicodeMode, UnicodeSetsMode, NamedCaptureGroups}] :: \]
  \[\text{Assertion} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \]
  \[\text{Atom} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \]
  \[\text{Atom} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] \text{ Quantifier} \]

\[\text{Assertion} [\text{UnicodeMode, UnicodeSetsMode, NamedCaptureGroups}] :: \]
  \[^ \]
  \[$ \]
  \[\backslash b \]
  \[\backslash B \]
  \[(?= \text{Disjunction} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] ) \]
  \[(?! \text{Disjunction} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] ) \]
  \[(?<= \text{Disjunction} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] ) \]
  \[(?<! \text{Disjunction} [?\text{UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups}] ) \]

Quantifier ::
  \text{QuantifierPrefix} 
  \text{QuantifierPrefix} ?

QuantifierPrefix ::
  *
  +
  ?
  \{ DecimalDigits [-Sep] \}
  \{ DecimalDigits [-Sep], \}
  \{ DecimalDigits [-Sep] , DecimalDigits [-Sep] \}
Atom[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] ::
  PatternCharacter
  \AtomEscape[?UnicodeMode, ?NamedCaptureGroups]
CharacterClass[?UnicodeMode, ?UnicodeSetsMode]
  ( GroupSpecifier[?UnicodeMode] opt

SyntaxCharacter :: one of
  ^ $ \ . * + ? ( ) [ ] { } |

PatternCharacter ::
  SourceCharacter but not SyntaxCharacter

AtomEscape[UnicodeMode, NamedCaptureGroups] ::
  DecimalEscape
  CharacterClassEscape[?UnicodeMode]
  CharacterEscape[?UnicodeMode]
  [+NamedCaptureGroups] k GroupName[?UnicodeMode]

CharacterEscape[UnicodeMode] ::
  ControlEscape
    c AsciiLetter
    \ [lookahead ∈ DecimalDigit]
  HexEscapeSequence
  RegExpUnicodeEscapeSequence[?UnicodeMode]
  IdentityEscape[?UnicodeMode]

ControlEscape :: one of
  \n \r \t \v

GroupSpecifier[UnicodeMode] ::
  ? GroupName[?UnicodeMode]

GroupName[UnicodeMode] ::
  < RegExpIdentifierName[?UnicodeMode] >

RegExpIdentifierName[UnicodeMode] ::
  RegExpIdentifierStart[?UnicodeMode]
  RegExpIdentifierName[?UnicodeMode] RegExpIdentifierPart[?UnicodeMode]

RegExpIdentifierStart[UnicodeMode] ::
  IdentifierStartChar
  \ RegExpUnicodeEscapeSequence[+UnicodeMode]
  [-UnicodeMode] UnicodeLeadSurrogate UnicodeTrailSurrogate

RegExpIdentifierPart[UnicodeMode] ::
  IdentifierPartChar
  \ RegExpUnicodeEscapeSequence[+UnicodeMode]
  [-UnicodeMode] UnicodeLeadSurrogate UnicodeTrailSurrogate
RegExpUnicodeEscapeSequence[UnicodeMode]  ::= 
  [+UnicodeMode]  u  HexLeadSurrogate \u  HexTrailSurrogate 
  [+UnicodeMode]  u  HexLeadSurrogate 
  [+UnicodeMode]  u  HexTrailSurrogate 
  [+UnicodeMode]  u  HexNonSurrogate 
  [-UnicodeMode]  u  Hex4Digits 
  [+UnicodeMode]  u{  CodePoint  }

UnicodeLeadSurrogate  ::= 
  any Unicode code point in the inclusive interval from U+D800 to U+DBFF

UnicodeTrailSurrogate  ::= 
  any Unicode code point in the inclusive interval from U+DC00 to U+DFFF

Each \u HexTrailSurrogate for which the choice of associated u HexLeadSurrogate is ambiguous shall be associated with the nearest possible u HexLeadSurrogate that would otherwise have no corresponding \u HexTrailSurrogate.

HexLeadSurrogate  ::= 
  Hex4Digits  but only if the MV of Hex4Digits is in the inclusive interval from 0xD800 to 0xDBFF

HexTrailSurrogate  ::= 
  Hex4Digits  but only if the MV of Hex4Digits is in the inclusive interval from 0xDC00 to 0xDFFF

HexNonSurrogate  ::= 
  Hex4Digits  but only if the MV of Hex4Digits is not in the inclusive interval from 0xD800 to 0xDFFF

IdentityEscape[UnicodeMode]  ::= 
  [+UnicodeMode]  SyntaxCharacter 
  [+UnicodeMode]  / 
  [-UnicodeMode]  SourceCharacter  but not UnicodeIDContinue

DecimalEscape  ::= 
  NonZeroDigit  DecimalDigits[~Sep]  opt  [lookahead $\notin$ DecimalDigit]

CharacterClassEscape[UnicodeMode]  ::= 
  d 
  D 
  s 
  S 
  w 
  W 
  [+UnicodeMode]  p{  UnicodePropertyValueExpression  }
  [+UnicodeMode]  P{  UnicodePropertyValueExpression  }

UnicodePropertyValueExpression  ::= 
  UnicodePropertyName  =  UnicodePropertyValue 
  LoneUnicodePropertyNameOrValue

UnicodePropertyName  ::= 
  UnicodePropertyNameCharacters

UnicodePropertyNameCharacters  ::= 
  UnicodePropertyNameCharacter  UnicodePropertyNameCharactersopt
UnicodePropertyValue ::
    UnicodePropertyValueCharacters

LoneUnicodePropertyNameOrValue ::
    UnicodePropertyValueCharacters

UnicodePropertyValueCharacters ::
    UnicodePropertyValueCharacter UnicodePropertyValueCharactersopt

UnicodePropertyValueCharacter ::
    UnicodePropertyNameCharacter
    DecimalDigit

UnicodePropertyNameCharacter ::
    AsciiLetter
    -

CharacterClass[UnicodeMode, UnicodeSetsMode] ::
    [ [lookahead ≠ \] ClassContents[?UnicodeMode, ?UnicodeSetsMode] ]
    [ ClassContents[?UnicodeMode, ?UnicodeSetsMode] ]

ClassContents[UnicodeMode, UnicodeSetsMode] ::
    [empty]
    [-~UnicodeSetsMode] NonemptyClassRanges[?UnicodeMode]
    [+UnicodeSetsMode] ClassSetExpression

NonemptyClassRanges[UnicodeMode] ::
    ClassAtom[?UnicodeMode]
    ClassAtom[?UnicodeMode] NonemptyClassRangesNoDash[?UnicodeMode]
    ClassAtom[?UnicodeMode] - ClassAtom[?UnicodeMode]
    ClassContents[?UnicodeMode, ~UnicodeSetsMode]

NonemptyClassRangesNoDash[UnicodeMode] ::
    ClassAtom[?UnicodeMode]
    ClassAtomNoDash[?UnicodeMode] NonemptyClassRangesNoDash[?UnicodeMode]
    ClassAtomNoDash[?UnicodeMode] - ClassAtom[?UnicodeMode]
    ClassContents[?UnicodeMode, ~UnicodeSetsMode]

ClassAtom[UnicodeMode] ::
    -
    ClassAtomNoDash[?UnicodeMode]

ClassAtomNoDash[UnicodeMode] ::
    SourceCharacter but not one of \ or ] or -
    \ ClassEscape[?UnicodeMode]

ClassEscape[UnicodeMode] ::
    b
    [+UnicodeMode] -
    CharacterClassEscape[?UnicodeMode]
    CharacterEscape[?UnicodeMode]

ClassSetExpression ::
    ClassUnion
    ClassIntersection
    ClassSubtraction
ClassUnion ::
    ClassSetRange ClassUnion opt
    ClassSetOperand ClassUnion opt

ClassIntersection ::
    ClassSetOperand && [lookahead \neq &] ClassSetOperand
    ClassIntersection && [lookahead \neq &] ClassSetOperand

ClassSubtraction ::
    ClassSetOperand -- ClassSetOperand
    ClassSubtraction -- ClassSetOperand

ClassSetRange ::
    ClassSetCharacter - ClassSetCharacter

ClassSetOperand ::
    NestedClass
    ClassStringDisjunction
    ClassSetCharacter

NestedClass ::
    [ [lookahead \neq ^] ClassContents[+UnicodeMode, +UnicodeSetsMode] ]
    [^ ClassContents[+UnicodeMode, +UnicodeSetsMode] ]
    \ CharacterClassEscape[+UnicodeMode]

NOTE 1  The first two lines here are equivalent to CharacterClass.

ClassStringDisjunction ::
    \{ ClassStringDisjunctionContents \}

ClassStringDisjunctionContents ::
    ClassString
    ClassString | ClassStringDisjunctionContents

ClassString ::
    [empty]
    NonEmptyClassString

NonEmptyClassString ::
    ClassSetCharacter NonEmptyClassString opt

ClassSetCharacter ::
    [lookahead \neq ClassSetReservedDoublePunctuator] SourceCharacter but not
    ClassSetSyntaxCharacter
    \ CharacterEscape[+UnicodeMode]
    \ ClassSetReservedPunctuator
    b

ClassSetReservedDoublePunctuator :: one of
    && !! ### $$ %%% ** ++ , .. :: :: ; ; < <= >> ?? @@ ^^ ` ` ~

ClassSetSyntaxCharacter :: one of
    ( ) [ ] { } / - \ |
NOTE 2  A number of productions in this section are given alternative definitions in section B.1.2.

22.2.1.1 Static Semantics: Early Errors

NOTE  This section is amended in B.1.2.

Pattern :: Disjunction

- It is a Syntax Error if CountLeftCapturingParensWithin(Pattern) ≥ 2^{32} - 1.
- It is a Syntax Error if Pattern contains two or more GroupSpecifiers for which CapturingGroupName of GroupSpecifier is the same.

QuantifierPrefix :: { DecimalDigits , DecimalDigits }

- It is a Syntax Error if the MV of the first DecimalDigits is strictly greater than the MV of the second DecimalDigits.

AtomEscape :: k GroupName

- It is a Syntax Error if GroupSpecifiersThatMatch(GroupName) is empty.

AtomEscape :: DecimalEscape

- It is a Syntax Error if the CapturingGroupNumber of DecimalEscape is strictly greater than CountLeftCapturingParensWithin(the Pattern containing AtomEscape).

NonemptyClassRanges :: ClassAtom - ClassAtom ClassContents

- It is a Syntax Error if IsCharacterClass of the first ClassAtom is true or IsCharacterClass of the second ClassAtom is true.
- It is a Syntax Error if IsCharacterClass of the first ClassAtom is false, IsCharacterClass of the second ClassAtom is false, and the CharacterValue of the first ClassAtom is strictly greater than the CharacterValue of the second ClassAtom.

NonemptyClassRangesNoDash :: ClassAtomNoDash - ClassAtom ClassContents

- It is a Syntax Error if IsCharacterClass of ClassAtomNoDash is true or IsCharacterClass of ClassAtom is true.
- It is a Syntax Error if IsCharacterClass of ClassAtomNoDash is false, IsCharacterClass of ClassAtom is false, and the CharacterValue of ClassAtomNoDash is strictly greater than the CharacterValue of ClassAtom.

RegExpIdentifierStart :: \ RegExpUnicodeEscapeSequence

- It is a Syntax Error if the CharacterValue of RegExpUnicodeEscapeSequence is not the numeric value of some code point matched by the IdentifierStartChar lexical grammar production.

RegExpIdentifierStart :: UnicodeLeadSurrogate UnicodeTrailSurrogate

- It is a Syntax Error if RegExpIdentifierCodePoint of RegExpIdentifierStart is not matched by the UnicodeIDStart lexical grammar production.

RegExpIdentifierPart :: \ RegExpUnicodeEscapeSequence

- It is a Syntax Error if the CharacterValue of RegExpUnicodeEscapeSequence is not the numeric value of some code point matched by the IdentifierPartChar lexical grammar production.

RegExpIdentifierPart :: UnicodeLeadSurrogate UnicodeTrailSurrogate
It is a Syntax Error if `RegExpIdentifierCodePoint` of `RegExpIdentifierPart` is not matched by the `UnicodeIDContinue` lexical grammar production.

UnicodePropertyValueExpression :: UnicodePropertyName = UnicodePropertyValue

- It is a Syntax Error if the source text matched by `UnicodePropertyName` is not a Unicode property name or property alias listed in the "Property name and aliases" column of Table 67.
- It is a Syntax Error if the source text matched by `UnicodePropertyValue` is not a property value or property value alias for the Unicode property or property alias given by the source text matched by `UnicodePropertyName` listed in `PropertyValueAliases.txt` <https://unicode.org/Public/UCD/latest/ucd/PropertyValueAliases.txt>.

UnicodePropertyValueExpression :: LoneUnicodePropertyNameOrValue

- It is a Syntax Error if the source text matched by `LoneUnicodePropertyNameOrValue` is not a Unicode property value or property value alias for the General_Category (gc) property listed in `PropertyValueAliases.txt` <https://unicode.org/Public/UCD/latest/ucd/PropertyValueAliases.txt>, nor a binary property or binary property alias listed in the "Property name and aliases" column of Table 68, nor a binary property of strings listed in the "Property name" column of Table 69.

CharacterClassEscape :: P{ UnicodePropertyValueExpression }

- It is a Syntax Error if `MayContainStrings` of the `UnicodePropertyValueExpression` is `true`.

CharacterClass :: [^ ClassContents ]

- It is a Syntax Error if `MayContainStrings` of the `ClassContents` is `true`.

NestedClass :: [^ ClassContents ]

- It is a Syntax Error if `MayContainStrings` of the `ClassContents` is `true`.

ClassSetRange :: ClassSetCharacter - ClassSetCharacter

- It is a Syntax Error if the CharacterValue of the first `ClassSetCharacter` is strictly greater than the CharacterValue of the second `ClassSetCharacter`.

22.2.1.2 Static Semantics: CountLeftCapturingParensWithin (node)

The abstract operation `CountLeftCapturingParensWithin` takes argument `node` (a Parse Node) and returns a non-negative integer. It returns the number of left-capturing parentheses in `node`. A left-capturing parenthesis is any ( pattern character that is matched by the ( terminal of the `Atom :: ( GroupSpecifier opt Disjunction )` production.

NOTE: This section is amended in B.1.2.2.

It performs the following steps when called:

1. Assert: `node` is an instance of a production in the RegExp Pattern grammar.
2. Return the number of `Atom :: ( GroupSpecifier opt Disjunction )` Parse Nodes contained within `node`.

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22.2.1.3 Static Semantics: CountLeftCapturingParensBefore (node)

The abstract operation CountLeftCapturingParensBefore takes argument node (a Parse Node) and returns a non-negative integer. It returns the number of left-capturing parentheses within the enclosing pattern that occur to the left of node.

NOTE   This section is amended in B.1.2.2.

It performs the following steps when called:

1. Assert: node is an instance of a production in the RegExp Pattern grammar.
2. Let pattern be the Pattern containing node.
3. Return the number of Atom :: ( GroupSpecifieropt Disjunction ) Parse Nodes contained within pattern that either occur before node or contain node.

22.2.1.4 Static Semantics: CapturingGroupNumber

The syntax-directed operation CapturingGroupNumber takes no arguments and returns a positive integer.

NOTE   This section is amended in B.1.2.1.

It is defined piecewise over the following productions:

DecimalEscape :: NonZeroDigit
1. Return the MV of NonZeroDigit.

DecimalEscape :: NonZeroDigit DecimalDigits
1. Let n be the number of code points in DecimalDigits.
2. Return (the MV of NonZeroDigit × 10^n plus the MV of DecimalDigits).

The definitions of “the MV of NonZeroDigit” and “the MV of DecimalDigits” are in 12.9.3.

22.2.1.5 Static Semantics: IsCharacterClass

The syntax-directed operation IsCharacterClass takes no arguments and returns a Boolean.

NOTE   This section is amended in B.1.2.3.

It is defined piecewise over the following productions:

ClassAtom ::
- ClassAtomNoDash ::
    SourceCharacter but not one of \ or ] or -
ClassEscape ::
    b
    - CharacterEscape

1. Return false.
22.2.1.6 Static Semantics: CharacterValue

The syntax-directed operation CharacterValue takes no arguments and returns a non-negative integer.

NOTE 1  This section is amended in B.1.2.4.

It is defined piecewise over the following productions:

ClassAtom :: -
1. Return the numeric value of \u201cHYPHEN-MINUS\u201d.

ClassAtomNoDash :: SourceCharacter but not one of \ or ] or -
1. Let \textit{ch} be the code point matched by SourceCharacter.
2. Return the numeric value of \textit{ch}.

ClassEscape :: b
1. Return the numeric value of \u201cBACKSPACE\u201d.

ClassEscape :: -
1. Return the numeric value of \u201cHYPHEN-MINUS\u201d.

CharacterEscape :: ControlEscape
1. Return the numeric value according to Table 65.

<table>
<thead>
<tr>
<th>ControlEscape</th>
<th>Numeric Value</th>
<th>Code Point</th>
<th>Unicode Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>9</td>
<td>\u0009</td>
<td>CHARACTER TABULATION</td>
<td>&lt;HT&gt;</td>
</tr>
<tr>
<td>n</td>
<td>10</td>
<td>\u000A</td>
<td>LINE FEED (LF)</td>
<td>&lt;LF&gt;</td>
</tr>
<tr>
<td>v</td>
<td>11</td>
<td>\u000B</td>
<td>LINE TABULATION</td>
<td>&lt;VT&gt;</td>
</tr>
<tr>
<td>f</td>
<td>12</td>
<td>\u000C</td>
<td>FORM FEED (FF)</td>
<td>&lt;FF&gt;</td>
</tr>
<tr>
<td>r</td>
<td>13</td>
<td>\u000D</td>
<td>CARRIAGE RETURN (CR)</td>
<td>&lt;CR&gt;</td>
</tr>
</tbody>
</table>

CharacterEscape :: c AsciiLetter
1. Let \textit{ch} be the code point matched by AsciiLetter.
2. Let \(i\) be the numeric value of \textit{ch}.
3. Return the remainder of dividing \(i\) by 32.

CharacterEscape :: \(\theta\) [lookahead \(\notin\) DecimalDigit]
1. Return the numeric value of \u201cNULL\u201d.

NOTE 2  \\(\theta\) represents the <NUL> character and cannot be followed by a decimal digit.
CharacterEscape :: HexEscapeSequence

1. Return the MV of HexEscapeSequence.

RegExpUnicodeEscapeSequence :: \u HexLeadSurrogate \u HexTrailSurrogate

1. Let lead be the CharacterValue of HexLeadSurrogate.
2. Let trail be the CharacterValue of HexTrailSurrogate.
3. Let cp be UTF16SurrogatePairToCodePoint(lead, trail).
4. Return the numeric value of cp.

RegExpUnicodeEscapeSequence :: u Hex4Digits

1. Return the MV of Hex4Digits.

RegExpUnicodeEscapeSequence :: u{ CodePoint }

1. Return the MV of CodePoint.

HexLeadSurrogate :: Hex4Digits
HexTrailSurrogate :: Hex4Digits
HexNonSurrogate :: Hex4Digits

1. Return the MV of Hex4Digits.

CharacterEscape :: IdentityEscape

1. Let ch be the code point matched by IdentityEscape.
2. Return the numeric value of ch.

ClassSetCharacter :: SourceCharacter but not ClassSetSyntaxCharacter

1. Let ch be the code point matched by SourceCharacter.
2. Return the numeric value of ch.

ClassSetCharacter :: \ ClassSetReservedPunctuator

1. Let ch be the code point matched by ClassSetReservedPunctuator.
2. Return the numeric value of ch.

ClassSetCharacter :: \b

1. Return the numeric value of U+0008 (BACKSPACE).

22.2.1.7 Static Semantics: MayContainStrings

The syntax-directed operation MayContainStrings takes no arguments and returns a Boolean. It is defined piecewise over the following productions:

CharacterClassEscape ::

d
D
s
S
w
W
P{ UnicodePropertyValueExpression }

UnicodePropertyValueExpression ::

UnicodePropertyName = UnicodePropertyValue
NestedClass ::
  [^ ClassContents ]
ClassContents ::
  [empty]
NonemptyClassRanges
ClassSetOperand ::
  ClassSetCharacter

1. Return false.

UnicodePropertyValueExpression :: LoneUnicodePropertyNameOrValue

1. If the source text matched by LoneUnicodePropertyNameOrValue is a binary property of strings listed in the “Property name” column of Table 69, return true.
2. Return false.

ClassUnion :: ClassSetRange ClassUnionept

1. If the ClassUnion is present, return MayContainStrings of the ClassUnion.
2. Return false.

ClassUnion :: ClassSetOperand ClassUnionept

1. If MayContainStrings of the ClassSetOperand is true, return true.
2. If ClassUnion is present, return MayContainStrings of the ClassUnion.
3. Return false.

ClassIntersection :: ClassSetOperand && ClassSetOperand

1. If MayContainStrings of the first ClassSetOperand is false, return false.
2. If MayContainStrings of the second ClassSetOperand is false, return false.
3. Return true.

ClassIntersection :: ClassIntersection && ClassSetOperand

1. If MayContainStrings of the ClassIntersection is false, return false.
2. If MayContainStrings of the ClassSetOperand is false, return false.
3. Return true.

ClassSubtraction :: ClassSetOperand -- ClassSetOperand

1. Return MayContainStrings of the first ClassSetOperand.

ClassSubtraction :: ClassSubtraction -- ClassSetOperand

1. Return MayContainStrings of the ClassSubtraction.

ClassStringDisjunctionContents :: ClassString | ClassStringDisjunctionContents

1. If MayContainStrings of the ClassString is true, return true.
2. Return MayContainStrings of the ClassStringDisjunctionContents.

ClassString :: [empty]

1. Return true.

ClassString :: NonEmptyClassString

1. Return MayContainStrings of the NonEmptyClassString.
NonEmptyClassString :: ClassSetCharacter NonEmptyClassStringopt

1. If NonEmptyClassString is present, return true.
2. Return false.

22.2.1.8 Static Semantics: GroupSpecifiersThatMatch (thisGroupName)

The abstract operation GroupSpecifiersThatMatch takes argument thisGroupName (a GroupName Parse Node) and returns a List of GroupSpecifier Parse Nodes. It performs the following steps when called:

1. Let name be the CapturingGroupName of thisGroupName.
2. Let pattern be the Pattern containing thisGroupName.
3. Let result be a new empty List.
4. For each GroupSpecifier gs that pattern contains, do
   a. If the CapturingGroupName of gs is name, then
      i. Append gs to result.
5. Return result.

22.2.1.9 Static Semantics: CapturingGroupName

The syntax-directed operation CapturingGroupName takes no arguments and returns a String. It is defined piecewise over the following productions:

GroupName :: < RegExpIdentifierName >

1. Let idTextUnescaped be RegExpIdentifierCodePoints of RegExpIdentifierName.
2. Return CodePointsToString(idTextUnescaped).

22.2.1.10 Static Semantics: RegExpIdentifierCodePoints

The syntax-directed operation RegExpIdentifierCodePoints takes no arguments and returns a List of code points. It is defined piecewise over the following productions:

RegExpIdentifierName :: RegExpIdentifierStart

1. Let cp be RegExpIdentifierCodePoint of RegExpIdentifierStart.
2. Return « cp ».

RegExpIdentifierName :: RegExpIdentifierName RegExpIdentifierPart

1. Let cps be RegExpIdentifierCodePoints of the derived RegExpIdentifierName.
2. Let cp be RegExpIdentifierCodePoint of RegExpIdentifierPart.
3. Return the list-concatenation of cps and « cp ».

22.2.1.11 Static Semantics: RegExpIdentifierCodePoint

The syntax-directed operation RegExpIdentifierCodePoint takes no arguments and returns a code point. It is defined piecewise over the following productions:

RegExpIdentifierStart :: IdentifierStartChar

1. Return the code point matched by IdentifierStartChar.

RegExpIdentifierPart :: IdentifierPartChar

1. Return the code point matched by IdentifierPartChar.

RegExpIdentifierStart :: \ RegExpUnicodeEscapeSequence
RegExpIdentifierPart :: \ RegExpUnicodeEscapeSequence

1. Return the code point whose numeric value is the CharacterValue of RegExpUnicodeEscapeSequence.
1. Let \textit{lead} be the code unit whose numeric value is the numeric value of the code point matched by \textit{UnicodeLeadSurrogate}.

2. Let \textit{trail} be the code unit whose numeric value is the numeric value of the code point matched by \textit{UnicodeTrailSurrogate}.

3. Return \texttt{UTF16SurrogatePairToCodePoint(lead, trail)}.

### 22.2.2 Pattern Semantics

A regular expression pattern is converted into an \texttt{Abstract Closure} using the process described below. An implementation is encouraged to use more efficient algorithms than the ones listed below, as long as the results are the same. The \texttt{Abstract Closure} is used as the value of a RegExp object's [[RegExpMatcher]] internal slot.

A \textit{Pattern} is a BMP pattern if its associated flags contain neither a \texttt{u} nor a \texttt{v}. Otherwise, it is a Unicode pattern. A BMP pattern matches against a String interpreted as consisting of a sequence of 16-bit values that are Unicode code points in the range of the Basic Multilingual Plane. A Unicode pattern matches against a String interpreted as consisting of Unicode code points encoded using UTF-16. In the context of describing the behaviour of a BMP pattern “character” means a single 16-bit Unicode BMP code point. In the context of describing the behaviour of a Unicode pattern “character” means a UTF-16 encoded code point (6.1.4). In either context, “character value” means the numeric value of the corresponding non-encoded code point.

The syntax and semantics of \textit{Pattern} is defined as if the source text for the \textit{Pattern} was a List of SourceCharacter values where each SourceCharacter corresponds to a Unicode code point. If a BMP pattern contains a non-BMP SourceCharacter the entire pattern is encoded using UTF-16 and the individual code units of that encoding are used as the elements of the List.

**NOTE** For example, consider a pattern expressed in source text as the single non-BMP character U+1D11E (MUSICAL SYMBOL G CLEF). Interpreted as a Unicode pattern, it would be a single element (character) List consisting of the single code point U+1D11E. However, interpreted as a BMP pattern, it is first UTF-16 encoded to produce a two element List consisting of the code units 0xD834 and 0xDD1E.

Patterns are passed to the RegExp constructor as ECMAScript String values in which non-BMP characters are UTF-16 encoded. For example, the single character MUSICAL SYMBOL G CLEF pattern, expressed as a String value, is a String of length 2 whose elements were the code units 0xD834 and 0xDD1E. So no further translation of the string would be necessary to process it as a BMP pattern consisting of two pattern characters. However, to process it as a Unicode pattern \texttt{UTF16SurrogatePairToCodePoint} must be used in producing a List whose sole element is a single pattern character, the code point U+1D11E.

An implementation may not actually perform such translations to or from UTF-16, but the semantics of this specification requires that the result of pattern matching be as if such translations were performed.

### 22.2.2.1 Notation

The descriptions below use the following internal data structures:

- A \texttt{CharSetElement} is one of the two following entities:
  - If \texttt{rer.[[UnicodeSets]]} is \texttt{false}, then a CharSetElement is a character in the sense of the Pattern Semantics above.
  - If \texttt{rer.[[UnicodeSets]]} is \texttt{true}, then a CharSetElement is a sequence whose elements are characters in the sense of the Pattern Semantics above. This includes the empty sequence, sequences of one character, and sequences of more than one character. For convenience, when working with CharSetElements of this kind, an individual character is treated interchangeably with a sequence of one character.

- A \texttt{CharSet} is a mathematical set of CharSetElements.
• A **CaptureRange** is a Record \{[[StartIndex]], [[EndIndex]]\} that represents the range of characters included in a capture, where [[StartIndex]] is an integer representing the start index (inclusive) of the range within Input, and [[EndIndex]] is an integer representing the end index (exclusive) of the range within Input. For any CaptureRange, these indices must satisfy the invariant that [[StartIndex]] ≤ [[EndIndex]].

• A **MatchState** is a Record \{[[Input]], [[EndIndex]], [[Captures]]\} where [[Input]] is a List of characters representing the String being matched, [[EndIndex]] is an integer, and [[Captures]] is a List of values, one for each left-capturing parenthesis in the pattern. States are used to represent partial match states in the regular expression matching algorithms. The [[EndIndex]] is one plus the index of the last input character matched so far by the pattern, while [[Captures]] holds the results of capturing parentheses. The \(n\)th element of [[Captures]] is either a CaptureRange representing the range of characters captured by the \(n\)th set of capturing parentheses, or undefined if the \(n\)th set of capturing parentheses hasn't been reached yet. Due to backtracking, many States may be in use at any time during the matching process.

• A **MatchResult** is either a MatchState or the special token FAILURE that indicates that the match failed.

• A **MatcherContinuation** is an Abstract Closure that takes one MatchState argument and returns a MatchResult result. The MatcherContinuation attempts to match the remaining portion (specified by the closure's captured values) of the pattern against Input, starting at the intermediate state given by its MatchState argument. If the match succeeds, the MatcherContinuation returns the final MatchState that it reached; if the match fails, the MatcherContinuation returns FAILURE.

• A **Matcher** is an Abstract Closure that takes two arguments—a MatchState and a MatcherContinuation—and returns a MatchResult result. A Matcher attempts to match a middle subpattern (specified by the closure's captured values) of the pattern against the MatchState's [[Input]], starting at the intermediate state given by its MatchState argument. The MatcherContinuation argument should be a closure that matches the rest of the pattern. After matching the subpattern of a pattern to obtain a new MatchState, the Matcher then calls MatcherContinuation on that new MatchState to test if the rest of the pattern can match as well. If it can, the Matcher returns the MatchState returned by MatcherContinuation; if not, the Matcher may try different choices at its choice points, repeatedly calling MatcherContinuation until it either succeeds or all possibilities have been exhausted.

### 22.2.2.1 RegExp Records

A **RegExp Record** is a Record value used to store information about a RegExp that is needed during compilation and possibly during matching.

It has the following fields:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[IgnoreCase]]</td>
<td>a Boolean</td>
<td>indicates whether &quot;i&quot; appears in the RegExp's flags</td>
</tr>
<tr>
<td>[[Multiline]]</td>
<td>a Boolean</td>
<td>indicates whether &quot;m&quot; appears in the RegExp's flags</td>
</tr>
<tr>
<td>[[DotAll]]</td>
<td>a Boolean</td>
<td>indicates whether &quot;s&quot; appears in the RegExp's flags</td>
</tr>
<tr>
<td>[[Unicode]]</td>
<td>a Boolean</td>
<td>indicates whether &quot;u&quot; appears in the RegExp's flags</td>
</tr>
<tr>
<td>[[UnicodeSets]]</td>
<td>a Boolean</td>
<td>indicates whether &quot;v&quot; appears in the RegExp's flags</td>
</tr>
<tr>
<td>[[CapturingGroupsCount]]</td>
<td>a non-negative integer</td>
<td>the number of left-capturing parentheses in the RegExp's pattern</td>
</tr>
</tbody>
</table>

22.2.2.1.1 RegExp Records

A **RegExp Record** is a Record value used to store information about a RegExp that is needed during compilation and possibly during matching.

It has the following fields:
22.2.2.2 Runtime Semantics: CompilePattern

The syntax-directed operation CompilePattern takes argument \( rer \) (a RegExp Record) and returns an Abstract Closure that takes a List of characters and a non-negative integer and returns a MatchResult. It is defined piecewise over the following productions:

\[
\text{Pattern} :: \ Disjunction
\]

1. Let \( m \) be CompileSubpattern of Disjunction with arguments \( rer \) and FORWARD.
2. Return a new Abstract Closure with parameters \((\text{Input, index})\) that captures \( rer \) and \( m \) and performs the following steps when called:
   a. Assert: \( \text{Input} \) is a List of characters.
   b. Assert: \( 0 \leq \text{index} \leq \) the number of elements in \( \text{Input} \).
   c. Let \( c \) be a new MatcherContinuation with parameters \((y)\) that captures nothing and performs the following steps when called:
      i. Assert: \( y \) is a MatchState.
      ii. Return \( y \).
   d. Let \( \text{cap} \) be a List of \( rer.[]\) values, indexed 1 through \( rer.[]\) values.
   e. Let \( x \) be the MatchState \{ \{\text{Input}\}: \text{Input}, \{\text{EndIndex}\}: \text{index}, \{\text{Captures}\}: \text{cap} \}.
   f. Return \( m(x, c) \).

NOTE A Pattern compiles to an Abstract Closure value. RegExpBuiltinExec can then apply this procedure to a List of characters and an offset within that List to determine whether the pattern would match starting at exactly that offset within the List, and, if it does match, what the values of the capturing parentheses would be. The algorithms in 22.2.2 are designed so that compiling a pattern may throw a SyntaxError exception; on the other hand, once the pattern is successfully compiled, applying the resulting Abstract Closure to find a match in a List of characters cannot throw an exception (except for any implementation-defined exceptions that can occur anywhere such as out-of-memory).

22.2.2.3 Runtime Semantics: CompileSubpattern

The syntax-directed operation CompileSubpattern takes arguments \( rer \) (a RegExp Record) and \( \text{direction} \) (FORWARD or BACKWARD) and returns a Matcher.

NOTE 1 This section is amended in B.1.2.5.

It is defined piecewise over the following productions:

\[
\text{Disjunction} :: \ Alternative \mid Disjunction
\]

1. Let \( m1 \) be CompileSubpattern of Alternative with arguments \( rer \) and \( \text{direction} \).
2. Let \( m2 \) be CompileSubpattern of Disjunction with arguments \( rer \) and \( \text{direction} \).
3. Return MatchTwoAlternatives\((m1, m2)\).
NOTE 2

The `|` regular expression operator separates two alternatives. The pattern first tries to match the left `Alternative` (followed by the sequel of the regular expression); if it fails, it tries to match the right `Disjunction` (followed by the sequel of the regular expression). If the left `Alternative`, the right `Disjunction`, and the sequel all have choice points, all choices in the sequel are tried before moving on to the next choice in the left `Alternative`. If choices in the left `Alternative` are exhausted, the right `Disjunction` is tried instead of the left `Alternative`. Any capturing parentheses inside a portion of the pattern skipped by `|` produce `undefined` values instead of Strings. Thus, for example,

```
/ab|ab/.exec("abc")
```

returns the result "a" and not "ab". Moreover,

```
/((a)|(ab))((c)|(bc))/exec("abc")
```

returns the array

```
["abc", "a", "a", undefined, "bc", undefined, "bc"]
```

and not

```
["abc", "ab", undefined, "ab", "c", "c", undefined]
```

The order in which the two alternatives are tried is independent of the value of `direction`.

```
Alternative :: [empty]
1. Return EmptyMatcher().
```

```
Alternative :: Alternative Term
1. Let `m1` be CompileSubpattern of `Alternative` with arguments `rer` and `direction`.
2. Let `m2` be CompileSubpattern of `Term` with arguments `rer` and `direction`.
3. Return MatchSequence(`m1`, `m2`, `direction`).
```

NOTE 3

Consecutive `Term`s try to simultaneously match consecutive portions of `Input`. When `direction` is `FORWARD`, if the left `Alternative`, the right `Term`, and the sequel of the regular expression all have choice points, all choices in the sequel are tried before moving on to the next choice in the right `Term`, and all choices in the right `Term` are tried before moving on to the next choice in the left `Alternative`. When `direction` is `BACKWARD`, the evaluation order of `Alternative` and `Term` are reversed.

```
Term :: Assertion
1. Return CompileAssertion of `Assertion` with argument `rer`.
```

NOTE 4

The resulting `Matcher` is independent of `direction`.

```
Term :: Atom
1. Return CompileAtom of `Atom` with arguments `rer` and `direction`.
```

```
Term :: Atom Quantifier
1. Let `m` be CompileAtom of `Atom` with arguments `rer` and `direction`.
2. Let `q` be CompileQuantifier of `Quantifier`.
3. Assert: `q.([Min]) ≤ q.([Max])`.
4. Let `parenIndex` be CountLeftCapturingParensBefore(`Term`).
```
5. Let parenCount be CountLeftCapturingParensWithin(Atom).
6. Return a new Matcher with parameters \((x, c)\) that captures \(m, q, parenIndex,\) and \(parenCount\) and performs the following steps when called:
   a. Assert: \(x\) is a MatchState.
   b. Assert: \(c\) is a MatcherContinuation.
   c. Return RepeatMatcher\((m, q, [\llbracket \text{Min} \rrbracket], q, [\llbracket \text{Max} \rrbracket], q, [\llbracket \text{Greedy} \rrbracket], x, c, parenIndex, parenCount)\).

### 22.2.2.3.1 RepeatMatcher

The abstract operation RepeatMatcher takes arguments \(m\) (a Matcher), \(min\) (a non-negative integer), \(max\) (a non-negative integer or +\(\infty\)), \(greedy\) (a Boolean), \(x\) (a MatchState), \(c\) (a MatcherContinuation), \(parenIndex\) (a non-negative integer), and \(parenCount\) (a non-negative integer) and returns a MatchResult. It performs the following steps when called:

1. If \(max = 0\), return \(c(x)\).
2. Let \(d\) be a new MatcherContinuation with parameters \((y)\) that captures \(m, min, max, greedy, x, c, parenIndex,\) and \(parenCount\) and performs the following steps when called:
   a. Assert: \(y\) is a MatchState.
   b. If \(min = 0\) and \(y.\llbracket \text{EndIndex} \rrbracket = x.\llbracket \text{EndIndex} \rrbracket\), return FAILURE.
   c. If \(min = 0\), let \(min2\) be \(0\); otherwise let \(min2\) be \(min - 1\).
   d. If \(max = +\infty\), let \(max2\) be \(+\infty\); otherwise let \(max2\) be \(max - 1\).
   e. Return RepeatMatcher\((m, min2, max2, greedy, y, c, parenIndex, parenCount)\).
3. Let \(cap\) be a copy of \(x.\llbracket \text{Captures} \rrbracket\).
4. For each integer \(k\) in the inclusive interval from \(parenIndex + 1\) to \(parenIndex + parenCount\), set \(cap[k]\) to undefined.
5. Let Input be \(x.\llbracket \text{Input} \rrbracket\).
6. Let e be \(x.\llbracket \text{EndIndex} \rrbracket\).
7. Let xr be the MatchState \(\{ \llbracket \text{Input} \rrbracket: \text{Input}, \llbracket \text{EndIndex} \rrbracket: e, \llbracket \text{Captures} \rrbracket: \text{cap} \}\).
8. If \(min \neq 0\), return \(m(xr, d)\).
9. If \(greedy\) is \(false\), then
   a. Let \(z\) be \(c(x)\).
   b. If \(z\) is not FAILURE, return \(z\).
   c. Return \(m(xr, d)\).
10. Let \(z\) be \(m(xr, d)\).
11. If \(z\) is not FAILURE, return \(z\).
12. Return \(c(x)\).

**NOTE** 1 An Atom followed by a Quantifier is repeated the number of times specified by the Quantifier. A Quantifier can be non-greedy, in which case the Atom pattern is repeated as few times as possible while still matching the sequel, or it can be greedy, in which case the Atom pattern is repeated as many times as possible while still matching the sequel. The Atom pattern is repeated rather than the input character sequence that it matches, so different repetitions of the Atom can match different input substrings.
NOTE 2 If the Atom and the sequel of the regular expression all have choice points, the Atom is first matched as many (or as few, if non-greedy) times as possible. All choices in the sequel are tried before moving on to the next choice in the last repetition of Atom. All choices in the last (nth) repetition of Atom are tried before moving on to the next choice in the next-to-last (n-1)st repetition of Atom; at which point it may turn out that more or fewer repetitions of Atom are now possible; these are exhausted (again, starting with either as few or as many as possible) before moving on to the next choice in the (n-1)st repetition of Atom and so on.

Compare

/a[a-zA-Z]{2,4}\/.exec("abcdefghi")

which returns "abcdefde" with

/a[a-zA-Z]{2,4}\?/.exec("abcdefghi")

which returns "abc".

Consider also

/(aa|aabaac|ba|b|c)*/.exec("aabaac")

which, by the choice point ordering above, returns the array

["aaba", "ba"]

and not any of:

["aabaac", "aabaac"]
["aabaac", "c"]

The above ordering of choice points can be used to write a regular expression that calculates the greatest common divisor of two numbers (represented in unary notation). The following example calculates the gcd of 10 and 15:

"aaaaaaaaaa,aaaaaaaaaaaaaaa".replace(/^(a+)(\1*,\1+$/, "$1")

which returns the gcd in unary notation "aaaaa".

NOTE 3 Step 4 of the RepeatMatcher clears Atom's captures each time Atom is repeated. We can see its behaviour in the regular expression

/(z)((a+)?(b+)?(c))*/.exec("zaacbbbcac")

which returns the array

["zaacbbbcac", "z", "ac", "a", undefined, "c"]

and not

["zaacbbbcac", "z", "ac", "a", "bbb", "c"]

because each iteration of the outermost \* clears all captured Strings contained in the quantified Atom, which in this case includes capture Strings numbered 2, 3, 4, and 5.
NOTE 4  Step 2.b of the RepeatMatcher states that once the minimum number of repetitions has been satisfied, any more expansions of \textit{Atom} that match the empty character sequence are not considered for further repetitions. This prevents the regular expression engine from falling into an infinite loop on patterns such as:

\begin{verbatim}
/(a*)*/.exec("b")
\end{verbatim}

or the slightly more complicated:

\begin{verbatim}
/(a*)b\1+.exec("baaaac")
\end{verbatim}

which returns the array

\begin{verbatim}
["b", ""]
\end{verbatim}

22.2.2.3.2 \textbf{EmptyMatcher ()}

The abstract operation \textit{EmptyMatcher} takes no arguments and returns a \textit{Matcher}. It performs the following steps when called:

1. Return a new Matcher with parameters \((x, c)\) that captures nothing and performs the following steps when called:
   a. \textbf{Assert}: \(x\) is a MatchState.
   b. \textbf{Assert}: \(c\) is a MatcherContinuation.
   c. Return \(c(x)\).

22.2.2.3.3 \textbf{MatchTwoAlternatives ( \(m1, m2\) )}

The abstract operation \textit{MatchTwoAlternatives} takes arguments \(m1\) (a Matcher) and \(m2\) (a Matcher) and returns a Matcher. It performs the following steps when called:

1. Return a new Matcher with parameters \((x, c)\) that captures \(m1\) and \(m2\) and performs the following steps when called:
   a. \textbf{Assert}: \(x\) is a MatchState.
   b. \textbf{Assert}: \(c\) is a MatcherContinuation.
   c. Let \(r\) be \(m1(x, c)\).
   d. If \(r\) is not FAILURE, return \(r\).
   e. Return \(m2(x, c)\).

22.2.2.3.4 \textbf{MatchSequence ( \(m1, m2, direction\) )}

The abstract operation \textit{MatchSequence} takes arguments \(m1\) (a Matcher), \(m2\) (a Matcher), and \textit{direction} (FORWARD or BACKWARD) and returns a Matcher. It performs the following steps when called:

1. If \textit{direction} is FORWARD, then
   a. Return a new Matcher with parameters \((x, c)\) that captures \(m1\) and \(m2\) and performs the following steps when called:
      i. \textbf{Assert}: \(x\) is a MatchState.
      ii. \textbf{Assert}: \(c\) is a MatcherContinuation.
      iii. Let \(d\) be a new MatcherContinuation with parameters \((y)\) that captures \(c\) and \(m2\) and performs the following steps when called:
          1. \textbf{Assert}: \(y\) is a MatchState.
          2. Return \(m2(y, c)\).
      iv. Return \(m1(x, d)\).
2. Else,
22.2.2.4 Runtime Semantics: CompileAssertion

The syntax-directed operation CompileAssertion takes argument rer (a RegExp Record) and returns a Matcher.

NOTE 1 This section is amended in B.1.2.6.

It is defined piecewise over the following productions:

Assertion :: ^

1. Return a new Matcher with parameters \((x, c)\) that captures rer and performs the following steps when called:
   a. Assert: \(x\) is a MatchState.
   b. Assert: \(c\) is a MatcherContinuation.
   c. Let \(Input\) be \(x\.[[Input]]\).
   d. Let \(e\) be \(x\.[[EndIndex]]\).
   e. If \(e = 0\), or if rer.[[Multiline]] is true and the character \(Input[e - 1]\) is matched by LineTerminator, then
      i. Return \(c(x)\).
   f. Return FAILURE.

NOTE 2 Even when the \(y\) flag is used with a pattern, ^ always matches only at the beginning of \(Input\), or (if rer.[[Multiline]] is true) at the beginning of a line.

Assertion :: $

1. Return a new Matcher with parameters \((x, c)\) that captures rer and performs the following steps when called:
   a. Assert: \(x\) is a MatchState.
   b. Assert: \(c\) is a MatcherContinuation.
   c. Let \(Input\) be \(x\.[[Input]]\).
   d. Let \(e\) be \(x\.[[EndIndex]]\).
   e. Let \(InputLength\) be the number of elements in \(Input\).
   f. If \(e = InputLength\), or if rer.[[Multiline]] is true and the character \(Input[e]\) is matched by LineTerminator, then
      i. Return \(c(x)\).
   g. Return FAILURE.

Assertion :: \b

1. Return a new Matcher with parameters \((x, c)\) that captures rer and performs the following steps when called:
   a. Assert: \(x\) is a MatchState.
   b. Assert: \(c\) is a MatcherContinuation.
   c. Let \(Input\) be \(x\.[[Input]]\).
   d. Let \(e\) be \(x\.[[EndIndex]]\).
   e. Let \(a\) be IsWordChar(rer, Input, e - 1).
   f. Let \(b\) be IsWordChar(rer, Input, e).
   g. If \(a\) is true and \(b\) is false, or if \(a\) is false and \(b\) is true, return \(c(x)\).
   h. Return FAILURE.
Assertion :: \B

1. Return a new Matcher with parameters \((x, c)\) that captures \(rer\) and performs the following steps when called:
   a. **Assert**: \(x\) is a MatchState.
   b. **Assert**: \(c\) is a MatcherContinuation.
   c. Let \(Input\) be \(x.([\text{Input}])\).
   d. Let \(e\) be \(x.([\text{EndIndex}])\).
   e. Let \(a\) be \(\text{IsWordChar}(rer, Input, e - 1)\).
   f. Let \(b\) be \(\text{IsWordChar}(rer, Input, e)\).
   g. If \(a\) is true and \(b\) is true, or if \(a\) is false and \(b\) is false, return \(c(x)\).
   h. Return FAILURE.

Assertion :: (?= Disjunction )

1. Let \(m\) be CompileSubpattern of Disjunction with arguments \(rer\) and FORWARD.
2. Return a new Matcher with parameters \((x, c)\) that captures \(m\) and performs the following steps when called:
   a. **Assert**: \(x\) is a MatchState.
   b. **Assert**: \(c\) is a MatcherContinuation.
   c. Let \(d\) be a new MatcherContinuation with parameters \((y)\) that captures nothing and performs the following steps when called:
      i. **Assert**: \(y\) is a MatchState.
      ii. Return \(y\).
   d. Let \(r\) be \(m(x, d)\).
   e. If \(r\) is FAILURE, return FAILURE.
   f. **Assert**: \(r\) is a MatchState.
   g. Let \(cap\) be \(r.([\text{Captures}])\).
   h. Let \(Input\) be \(x.([\text{Input}])\).
   i. Let \(xe\) be \(x.([\text{EndIndex}])\).
   j. Let \(z\) be the MatchState \(
      \{\text{[Input]}: Input, [\text{EndIndex}]: xe, [\text{Captures}]: cap \}\).
   k. Return \(c(z)\).

**NOTE 3** The form (?= Disjunction ) specifies a zero-width positive lookahead. In order for it to succeed, the pattern inside Disjunction must match at the current position, but the current position is not advanced before matching the sequel. If Disjunction can match at the current position in several ways, only the first one is tried. Unlike other regular expression operators, there is no backtracking into a (?= form (this unusual behaviour is inherited from Perl). This only matters when the Disjunction contains capturing parentheses and the sequel of the pattern contains backreferences to those captures.

For example,

\[
/(?=(a+))/ .exec("baaabac")
\]

matches the empty String immediately after the first b and therefore returns the array:

\[
["", "aaa"]
\]

To illustrate the lack of backtracking into the lookahead, consider:

\[
/(?=(a+))a*b\1/.exec("baaabac")
\]

This expression returns

\[
["aba", "a"]
\]

and not:

\[
["aaaba", "a"]
\]
Assertion :: (?) Disjunction

1. Let \( m \) be CompileSubpattern of \( \text{Disjunction} \) with arguments \( rer \) and FORWARD.
2. Return a new Matcher with parameters \( (x, c) \) that captures \( m \) and performs the following steps when called:
   a. Assert: \( x \) is a MatchState.
   b. Assert: \( c \) is a MatcherContinuation.
   c. Let \( d \) be a new MatcherContinuation with parameters \( (y) \) that captures nothing and performs the following steps when called:
      i. Assert: \( y \) is a MatchState.
      ii. Return \( y \).
   d. Let \( r \) be \( m(x, d) \).
   e. If \( r \) is not FAILURE, return FAILURE.
   f. Return \( c(x) \).

NOTE 4

The form \( (?) \text{Disjunction} \) specifies a zero-width negative lookahead. In order for it to succeed, the pattern inside \( \text{Disjunction} \) must fail to match at the current position. The current position is not advanced before matching the sequel. \( \text{Disjunction} \) can contain capturing parentheses, but backreferences to them only make sense from within \( \text{Disjunction} \) itself. Backreferences to these capturing parentheses from elsewhere in the pattern always return undefined because the negative lookahead must fail for the pattern to succeed. For example,

\[
/(.*?)a(?!\1)b\2c)\2(.*)/.exec("baaabac")
\]

looks for an \( a \) not immediately followed by some positive number \( n \) of \( a \)'s, a \( b \), another \( n \) \( a \)'s (specified by the first \( \2 \) and a \( c \). The second \( \2 \) is outside the negative lookahead, so it matches against undefined and therefore always succeeds. The whole expression returns the array:

\[
["baaabac", "ba", undefined, "abaac"]
\]

Assertion :: (?<= Disjunction

1. Let \( m \) be CompileSubpattern of \( \text{Disjunction} \) with arguments \( rer \) and BACKWARD.
2. Return a new Matcher with parameters \( (x, c) \) that captures \( m \) and performs the following steps when called:
   a. Assert: \( x \) is a MatchState.
   b. Assert: \( c \) is a MatcherContinuation.
   c. Let \( d \) be a new MatcherContinuation with parameters \( (y) \) that captures nothing and performs the following steps when called:
      i. Assert: \( y \) is a MatchState.
      ii. Return \( y \).
   d. Let \( r \) be \( m(x, d) \).
   e. If \( r \) is FAILURE, return FAILURE.
   f. Assert: \( r \) is a MatchState.
   g. Let \( cap \) be \( r[\text{Captures}] \).
   h. Let \( input \) be \( x[\text{Input}] \).
   i. Let \( xe \) be \( x[\text{EndIndex}] \).
   j. Let \( z \) be the MatchState \{ [[Input]]: \( input \), [[EndIndex]]: \( xe \), [[Captures]]: \( cap \) \}.
   k. Return \( c(z) \).

Assertion :: (?<! Disjunction

1. Let \( m \) be CompileSubpattern of \( \text{Disjunction} \) with arguments \( rer \) and BACKWARD.
2. Return a new Matcher with parameters \( (x, c) \) that captures \( m \) and performs the following steps when called:
   a. Assert: \( x \) is a MatchState.
   b. Assert: \( c \) is a MatcherContinuation.
   c. Let \( d \) be a new MatcherContinuation with parameters \( (y) \) that captures nothing and performs the following steps when called:
      i. Assert: \( y \) is a MatchState.
      ii. Return \( y \).
   d. Let \( r \) be \( m(x, d) \).
22.2.2.4.1 IsWordChar (rer, Input, e)

The abstract operation IsWordChar takes arguments rer (a RegExp Record), Input (a List of characters), and e (an integer) and returns a Boolean. It performs the following steps when called:

1. Let InputLength be the number of elements in Input.
2. If $e = -1$ or $e = InputLength$, return false.
3. Let $c$ be the character $Input[e]$.
4. If WordCharacters(rer) contains $c$, return true.
5. Return false.

22.2.2.5 Runtime Semantics: CompileQuantifier

The syntax-directed operation CompileQuantifier takes no arguments and returns a Record with fields [[Min]] (a non-negative integer), [[Max]] (a non-negative integer or $\infty$), and [[Greedy]] (a Boolean). It is defined piecewise over the following productions:

Quantifier :: QuantifierPrefix

1. Let qp be CompileQuantifierPrefix of QuantifierPrefix.
2. Return the Record { [[Min]]: qp.[[Min]], [[Max]]: qp.[[Max]], [[Greedy]]: true }.

Quantifier :: QuantifierPrefix ?

1. Let qp be CompileQuantifierPrefix of QuantifierPrefix.
2. Return the Record { [[Min]]: qp.[[Min]], [[Max]]: qp.[[Max]], [[Greedy]]: false }.

22.2.2.6 Runtime Semantics: CompileQuantifierPrefix

The syntax-directed operation CompileQuantifierPrefix takes no arguments and returns a Record with fields [[Min]] (a non-negative integer) and [[Max]] (a non-negative integer or $\infty$). It is defined piecewise over the following productions:

QuantifierPrefix :: *

1. Return the Record { [[Min]]: 0, [[Max]]: $\infty$ }.

QuantifierPrefix :: +

1. Return the Record { [[Min]]: 1, [[Max]]: $\infty$ }.

QuantifierPrefix :: ?

1. Return the Record { [[Min]]: 0, [[Max]]: 1 }.

QuantifierPrefix :: { DecimalDigits }

1. Let $i$ be the MV of DecimalDigits (see 12.9.3).
2. Return the Record { [[Min]]: $i$, [[Max]]: $i$ }.

QuantifierPrefix :: { DecimalDigits ,}

1. Let $i$ be the MV of DecimalDigits.
2. Return the Record { [[Min]]: $i$, [[Max]]: $\infty$ }.
QuantifierPrefix :: \{ DecimalDigits , DecimalDigits \}

1. Let \( i \) be the MV of the first \( \text{DecimalDigits} \).
2. Let \( j \) be the MV of the second \( \text{DecimalDigits} \).
3. Return the Record \{ [[Min]]: \( i \), [[Max]]: \( j \) \}.

22.2.2.7 Runtime Semantics: CompileAtom

The syntax-directed operation CompileAtom takes arguments \( rer \) (a RegExp Record) and \( direction \) (FORWARD or BACKWARD) and returns a Matcher.

NOTE 1 This section is amended in B.1.2.7.

It is defined piecewise over the following productions:

Atom :: PatternCharacter

1. Let \( ch \) be the character matched by \( \text{PatternCharacter} \).
2. Let \( A \) be a one-element \( \text{CharSet} \) containing the character \( ch \).
3. Return \( \text{CharacterSetMatcher}(rer, A, false, direction) \).

Atom :: .

1. Let \( A \) be \( \text{AllCharacters}(rer) \).
2. If \( rer.([\text{DotAll}]) \) is not true, then
   a. Remove from \( A \) all characters corresponding to a code point on the right-hand side of the \( \text{LineTerminator} \) production.
3. Return \( \text{CharacterSetMatcher}(rer, A, false, direction) \).

Atom :: CharacterClass

1. Let \( cc \) be \( \text{CompileCharacterClass} \) of \( \text{CharacterClass} \) with argument \( rer \).
2. Let \( cs \) be \( cc.([\text{ CharSet}] ) \).
3. If \( rer.([\text{UnicodeSets}]) \) is false, or if every \( \text{CharSetElement} \) of \( cs \) consists of a single character (including if \( cs \) is empty), return \( \text{CharacterSetMatcher}(rer, cs, cc.([\text{ Invert}]), direction) \).
4. Assert: \( cc.([\text{Invert}]) \) is false.
5. Let \( lm \) be an empty List of Matchers.
6. For each \( \text{CharSetElement} \) \( s \) in \( cs \) containing more than 1 character, iterating in descending order of length, do
   a. Let \( cs2 \) be a one-element \( \text{CharSet} \) containing the last code point of \( s \).
   b. Let \( m2 \) be \( \text{CharacterSetMatcher}(rer, cs2, false, direction) \).
   c. For each code point \( c1 \) in \( s \), iterating backwards from its second-to-last code point, do
      i. Let \( cs1 \) be a one-element \( \text{CharSet} \) containing \( c1 \).
      ii. Let \( m1 \) be \( \text{CharacterSetMatcher}(rer, cs1, false, direction) \).
      iii. Set \( m2 \) to \( \text{MatchSequence}(m1, m2) \).
   d. Append \( m2 \) to \( lm \).
7. Let \( singles \) be the \( \text{CharSet} \) containing every \( \text{CharSetElement} \) of \( cs \) that consists of a single character.
8. Append \( \text{CharacterSetMatcher}(rer, singles, false, direction) \) to \( lm \).
9. If \( cs \) contains the empty sequence of characters, append \( \text{EmptyMatcher}() \) to \( lm \).
10. Let \( m2 \) be the last Matcher in \( lm \).
11. For each Matcher \( m1 \) of \( lm \), iterating backwards from its second-to-last element, do
       a. Set \( m2 \) to \( \text{MatchTwoAlternatives}(m1, m2) \).
12. Return \( m2 \).
Atom :: ( GroupSpecifier \opt Disjunction )

1. Let m be CompileSubpattern of Disjunction with arguments rer and direction.
2. Let parenIndex be CountLeftCapturingParensBefore(Atom).
3. Return a new Matcher with parameters (x, c) that captures direction, m, and parenIndex and performs the following steps when called:
   a. Assert: x is a MatchState.
   b. Assert: c is a MatcherContinuation.
   c. Let d be a new MatcherContinuation with parameters (y) that captures x, c, direction, and parenIndex and performs the following steps when called:
      i. Assert: y is a MatchState.
      ii. Let cap be a copy of y.[Captures].
      iii. Let Input be x.[Input].
      iv. Let xe be x.[EndIndex].
      v. Let ye be y.[EndIndex].
      vi. If direction is FORWARD, then
         2. Let r be the CaptureRange { [[StartIndex]]: xe, [[EndIndex]]: ye }.
      vii. Else,
         1. Assert: direction is BACKWARD.
         3. Let r be the CaptureRange { [[StartIndex]]: ye, [[EndIndex]]: xe }.
     viii. Set cap[parenIndex + 1] to r.
   ix. Let z be the MatchState { [[Input]]: Input, [[EndIndex]]: ye, [[Captures]]: cap }.
   x. Return c(z).
   d. Return m(x, d).

NOTE 2 Parentheses of the form ( Disjunction ) serve both to group the components of the Disjunction pattern together and to save the result of the match. The result can be used either in a backreference (\ followed by a non-zero decimal number), referenced in a replace String, or returned as part of an array from the regular expression matching Abstract Closure. To inhibit the capturing behaviour of parentheses, use the form (?: Disjunction ) instead.

Atom ::= (?: Disjunction )

1. Return CompileSubpattern of Disjunction with arguments rer and direction.

AtomEscape :: DecimalEscape

1. Let n be the CapturingGroupNumber of DecimalEscape.
2. Assert: n ≤ rer.[CapturingGroupsCount].
3. Return BackreferenceMatcher(rer, n, direction).

NOTE 3 An escape sequence of the form \ followed by a non-zero decimal number n matches the result of the n\textsuperscript{th} set of capturing parentheses (22.2.2.1). It is an error if the regular expression has fewer than n capturing parentheses. If the regular expression has n or more capturing parentheses but the n\textsuperscript{th} one is undefined because it has not captured anything, then the backreference always succeeds.

AtomEscape :: CharacterEscape

1. Let cv be the CharacterValue of CharacterEscape.
2. Let ch be the character whose character value is cv.
3. Let A be a one-element CharSet containing the character ch.
AtomEscape :: CharacterClassEscape

1. Let \( cs \) be CompileToCharSet of CharacterClassEscape with argument \( rer \).
2. If \( rer.\{[\text{UnicodeSets}]\} \) is false, or if every CharSetElement of \( cs \) consists of a single character (including if \( cs \) is empty), return CharSetMatcher(\( rer, cs, false, direction \)).
3. Let \( lm \) be an empty List of Matchers.
4. For each CharSetElement \( s \) in \( cs \) containing more than 1 character, iterating in descending order of length, do
   a. Let \( cs2 \) be a one-element CharSet containing the last code point of \( s \).
   b. Let \( m2 \) be CharSetMatcher(\( rer, cs2, false, direction \)).
   c. For each code point \( c1 \) in \( s \), iterating backwards from its second-to-last code point, do
      i. Let \( cs1 \) be a one-element CharSet containing \( c1 \).
      ii. Let \( m1 \) be CharSetMatcher(\( rer, cs1, false, direction \)).
      iii. Set \( m2 \) to MatchSequence(\( m1, m2, direction \)).
   d. Append \( m2 \) to \( lm \).
5. Let \( singles \) be the CharSet containing every CharSetElement of \( cs \) that consists of a single character.
6. Append CharSetMatcher(\( rer, singles, false, direction \)) to \( lm \).
7. If \( cs \) contains the empty sequence of characters, append EmptyMatcher() to \( lm \).
8. Let \( m2 \) be the last Matcher in \( lm \).
9. For each Matcher \( m1 \) of \( lm \), iterating backwards from its second-to-last element, do
   a. Set \( m2 \) to MatchTwoAlternatives(\( m1, m2 \)).
10. Return \( m2 \).

AtomEscape :: k GroupName

1. Let matchingGroupSpecifiers be GroupSpecifiersThatMatch(GroupName).
3. Let groupSpecifier be the sole element of matchingGroupSpecifiers.
4. Let parenIndex be CountLeftCapturingParensBefore(groupSpecifier).
5. Return BackreferenceMatcher(\( rer, parenIndex, direction \)).

22.2.2.7.1 CharacterSetMatcher ( \( rer, A, invert, direction \) )

The abstract operation CharacterSetMatcher takes arguments \( rer \) (a RegExp Record), \( A \) (a CharSet), \( invert \) (a Boolean), and \( direction \) (FORWARD or BACKWARD) and returns a Matcher. It performs the following steps when called:

1. If \( rer.\{[\text{UnicodeSets}]\} \) is true, then
   a. Assert: \( invert \) is false.
   b. Assert: Every CharSetElement of \( A \) consists of a single character.
2. Return a new Matcher with parameters \( (x, c) \) that captures \( rer, A, invert \), and \( direction \) and performs the following steps when called:
   a. Assert: \( x \) is a MatchState.
   b. Assert: \( c \) is a MatcherContinuation.
   c. Let \( Input \) be \( x.\{[Input]\} \).
   d. Let \( e \) be \( x.\{[EndIndex]\} \).
   e. If \( direction \) is FORWARD, let \( f \) be \( e + 1 \).
   f. Else, let \( f \) be \( e - 1 \).
   g. Let \( InputLength \) be the number of elements in \( Input \).
   h. If \( f < 0 \) or \( f > InputLength \), return FAILURE.
   i. Let \( index \) be \( min(e, f) \).
   j. Let \( ch \) be the character \( Input[index] \).
   k. Let \( cc \) be Canonicalize(\( rer, ch \)).
   l. If there exists a CharSetElement in \( A \) containing exactly one character \( a \) such that Canonicalize(\( rer, a \)) is \( cc \), let \( found \) be \( true \). Otherwise, let \( found \) be \( false \).
   m. If \( invert \) is \( false \) and \( found \) is \( false \), return FAILURE.
   n. If \( invert \) is \( true \) and \( found \) is \( true \), return FAILURE.
   o. Let \( cap \) be \( x.\{[Captures]\} \).
   p. Let \( y \) be the MatchState \( \{[Input] \}: Input, [EndIndex]: f, [Captures]: cap \).
   q. Return \( c(y) \).
The abstract operation BackreferenceMatcher takes arguments \( rer \) (a RegExp Record), \( n \) (a positive integer), and \( direction \) (FORWARD or BACKWARD) and returns a Matcher. It performs the following steps when called:

1. **Assert:** \( n \geq 1 \).
2. Return a new Matcher with parameters \( (x, c) \) that captures \( rer, n \), and \( direction \) and performs the following steps when called:
   a. **Assert:** \( x \) is a MatchState.
   b. **Assert:** \( c \) is a MatcherContinuation.
   c. Let \( Input \) be \( x.\[\text{[Input]}\] \).
   d. Let \( cap \) be \( x.\[\text{Captures}\] \).
   e. Let \( r \) be \( cap^{n} \).
   f. If \( r \) is undefined, return \( c(x) \).
   g. Let \( e \) be \( x.\[\text{EndIndex}\] \).
   h. Let \( rs \) be \( r.\[\text{StartIndex}\] \).
   i. Let \( re \) be \( r.\[\text{EndIndex}\] \).
   j. Let \( len \) be \( re - rs \).
   k. If \( direction \) is FORWARD, let \( f = e + len \).
   l. Else, let \( f = e - len \).
   m. Let \( InputLength \) be the number of elements in \( Input \).
   n. If \( f < 0 \) or \( f > InputLength \), return FAILURE.
   o. Let \( g \) be \( \min(e, f) \).
   p. If there exists an integer \( i \) in the interval from \( 0 \) (inclusive) to \( len \) (exclusive) such that \( \text{Canonicalize}(rer, Input[rs + i]) \) is not \( \text{Canonicalize}(rer, Input[g + i]) \), return FAILURE.
   q. Let \( y \) be the MatchState \( \{\[\text{Input}\]: \[\text{Input} \], \[\text{EndIndex}\]: \[\text{EndIndex}\], \[\text{Captures}\]: \[\text{Captures}\] \} \).
   r. Return \( c(y) \).

The abstract operation Canonicalize takes arguments \( rer \) (a RegExp Record) and \( ch \) (a character) and returns a character. It performs the following steps when called:

1. If \( \text{HasEitherUnicodeFlag}(rer) \) is true and \( rer.\[\text{IgnoreCase}\] \) is true, then
   a. If the file CaseFolding.txt <https://unicode.org/Public/UCD/latest/ucd/CaseFolding.txt> of the Unicode Character Database provides a simple or common case folding mapping for \( ch \), return the result of applying that mapping to \( ch \).
   b. Return \( ch \).
2. If \( rer.\[\text{IgnoreCase}\] \) is false, return \( ch \).
3. **Assert:** \( ch \) is a UTF-16 code unit.
4. Let \( cp \) be the code point whose numeric value is the numeric value of \( ch \).
5. Let \( u \) be the result of toUppercase(« \( cp \) »), according to the Unicode Default Case Conversion algorithm.
6. Let \( uStr \) be CodePointsToString(\( u \)).
7. If the length of \( uStr \) \( \neq 1 \), return \( ch \).
8. Let \( cu \) be \( uStr \)’s single code unit element.
9. If the numeric value of \( ch \) \( \geq 128 \) and the numeric value of \( cu \) < 128, return \( ch \).
10. Return \( cu \).
In case-insignificant matches when HasEitherUnicodeFlag(re) is true, all characters are implicitly case-folded using the simple mapping provided by the Unicode Standard immediately before they are compared. The simple mapping always maps to a single code point, so it does not map, for example, ⌢ (U+00DF LATIN SMALL LETTER SHARP S) to ss or SS. It may however map code points outside the Basic Latin block to code points within it—for example, ⸻ (U+0073 LATIN SMALL LETTER S) case-folds to k (U+0068 LATIN SMALL LETTER K). Strings containing those code points are matched by regular expressions such as /[a-z]/ui.

In case-insignificant matches when HasEitherUnicodeFlag(re) is false, the mapping is based on Unicode Default Case Conversion algorithm toUppercase rather than toCasefold, which results in some subtle differences. For example, Ω (U+2126 OHM SIGN) is mapped by toUppercase to itself but by toCasefold to ω (U+03A9 GREEK CAPITAL LETTER OMEGA) along with Ω (U+03C9 GREEK SMALL LETTER OMEGA), so "lu2126" is matched by /[Ω]/ui and /[u03A9]/ui but not by /[ω]/i or /[u03A9]/i. Also, no code point outside the Basic Latin block is mapped to a code point within it, so strings such as "lu017f l" and "lu212a K" are not matched by /[a-z]/i.

### 22.2.2.8 Runtime Semantics: CompileCharacterClass

The syntax-directed operation CompileCharacterClass takes argument re (a RegExp Record) and returns a Record with fields [[CharSet]] (a CharSet) and [[Invert]] (a Boolean). It is defined piecewise over the following productions:

**CharacterClass :: []**

1. Let A be CompileToCharSet of ClassContents with argument re.
2. Return the Record { [[CharSet]]: A, [[Invert]]: false }.

**CharacterClass :: [^** ClassContents **]**

1. Let A be CompileToCharSet of ClassContents with argument re.
2. If re.[[UnicodeSets]] is true, then
   a. Return the Record { [[CharSet]]: CharacterComplement(re, A), [[Invert]]: false }.
3. Return the Record { [[CharSet]]: A, [[Invert]]: true }.

### 22.2.2.9 Runtime Semantics: CompileToCharSet

The syntax-directed operation CompileToCharSet takes argument re (a RegExp Record) and returns a CharSet.

It is defined piecewise over the following productions:

**ClassContents :: [empty]**

1. Return the empty CharSet.

**NonemptyClassRanges :: ClassAtom NonemptyClassRangesNoDash**

1. Let A be CompileToCharSet of ClassAtom with argument re.
2. Let B be CompileToCharSet of NonemptyClassRangesNoDash with argument re.
3. Return the union of CharSet A and B.

**NonemptyClassRanges :: ClassAtom - ClassAtom ClassContents**

1. Let A be CompileToCharSet of the first ClassAtom with argument re.
2. Let B be CompileToCharSet of the second ClassAtom with argument re.
3. Let C be CompileToCharSet of ClassContents with argument re.
4. Let \( D \) be CharacterRange\((A, B)\).
5. Return the union of \( D \) and \( C \).

**NonemptyClassRangesNoDash :: ClassAtomNoDash NonemptyClassRangesNoDash**

1. Let \( A \) be CompileToCharSet of ClassAtomNoDash with argument rer.
2. Let \( B \) be CompileToCharSet of NonemptyClassRangesNoDash with argument rer.
3. Return the union of CharSets \( A \) and \( B \).

**NonemptyClassRangesNoDash :: ClassAtomNoDash - ClassAtom ClassContents**

1. Let \( A \) be CompileToCharSet of ClassAtomNoDash with argument rer.
2. Let \( B \) be CompileToCharSet of ClassAtom with argument rer.
3. Let \( C \) be CompileToCharSet of ClassContents with argument rer.
4. Let \( D \) be CharacterRange\((A, B)\).
5. Return the union of \( D \) and \( C \).

**NOTE 2** *ClassContents* can expand into a single *ClassAtom* and/or ranges of two *ClassAtom* separated by dashes. In the latter case the *ClassContents* includes all characters between the first *ClassAtom* and the second *ClassAtom*, inclusive; an error occurs if either *ClassAtom* does not represent a single character (for example, if one is \w\) or if the first *ClassAtom*'s character value is strictly greater than the second *ClassAtom*'s character value.

**NOTE 3** Even if the pattern ignores case, the case of the two ends of a range is significant in determining which characters belong to the range. Thus, for example, the pattern \/[E-F]/i matches only the letters \(E\), \(F\), \(e\), and \(f\), while the pattern \/[E-\f]/i matches all uppercase and lowercase letters in the Unicode Basic Latin block as well as the symbols \[, \], ^, _`, and `.

**NOTE 4** A - character can be treated literally or it can denote a range. It is treated literally if it is the first or last character of *ClassContents*, the beginning or end limit of a range specification, or immediately follows a range specification.

*ClassAtom :: -*

1. Return the CharSet containing the single character - U+002D (HYPHEN-MINUS).

*ClassAtomNoDash :: SourceCharacter but not one of \ or ] or -*

1. Return the CharSet containing the character matched by SourceCharacter.

*ClassEscape ::
  b
  -
  CharacterEscape*

1. Let \( cv \) be the CharacterValue of this ClassEscape.
2. Let \( c \) be the character whose character value is \( cv \).
3. Return the CharSet containing the single character \( c \).

**NOTE 5** A *ClassAtom* can use any of the escape sequences that are allowed in the rest of the regular expression except for \b, \B, and backreferences. Inside a CharacterClass, \b means the backspace character, while \B and backreferences raise errors. Using a backreference inside a *ClassAtom* causes an error.
CharacterClassEscape :: d

1. Return the ten-element CharSet containing the characters 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

CharacterClassEscape :: D

1. Let S be the CharSet returned by CharacterClassEscape :: d.
2. Return CharacterComplement(rer, S).

CharacterClassEscape :: s

1. Return the CharSet containing all characters corresponding to a code point on the right-hand side of the WhiteSpace or LineTerminator productions.

CharacterClassEscape :: S

1. Let S be the CharSet returned by CharacterClassEscape :: s.
2. Return CharacterComplement(rer, S).

CharacterClassEscape :: w

1. Return MaybeSimpleCaseFolding(rer, WordCharacters(rer)).

CharacterClassEscape :: W

1. Let S be the CharSet returned by CharacterClassEscape :: w.
2. Return CharacterComplement(rer, S).

CharacterClassEscape :: p{ UnicodePropertyValueExpression }

1. Return CompileToCharSet of UnicodePropertyValueExpression with argument rer.

CharacterClassEscape :: P{ UnicodePropertyValueExpression }

1. Let S be CompileToCharSet of UnicodePropertyValueExpression with argument rer.
2. Assert: S contains only single code points.

UnicodePropertyValueExpression :: UnicodePropertyName = UnicodePropertyValue

1. Let ps be the source text matched by UnicodePropertyName.
2. Let p be UnicodeMatchProperty(rer, ps).
3. Assert: p is a Unicode property name or property alias listed in the “Property name and aliases” column of Table 67.
4. Let vs be the source text matched by UnicodePropertyValue.
5. Let v be UnicodeMatchPropertyValue(p, vs).
6. Let A be the CharSet containing all Unicode code points whose character database definition includes the property p with value v.

UnicodePropertyValueExpression :: LoneUnicodePropertyNameOrValue

1. Let s be the source text matched by LoneUnicodePropertyNameOrValue.
2. If UnicodeMatchPropertyValue(General_Category, s) is a Unicode property value or property value alias for the General_Category (gc) property listed in PropertyValueAliases.txt <https://unicode.org/Public/UCD/latest/ucd/PropertyValueAliases.txt>, then
   a. Return the CharSet containing all Unicode code points whose character database definition includes the property “General_Category” with value s.
3. Let p be UnicodeMatchProperty(rer, s).
4. Assert: p is a binary Unicode property or binary property alias listed in the “Property name and aliases” column of Table 68, or a binary Unicode property of strings listed in the “Property name” column of Table 69.
5. Let $A$ be the CharSet containing all CharSetElements whose character database definition includes the property $p$ with value “True”.
6. Return $\text{MaybeSimpleCaseFolding}(rer, A)$.

ClassUnion :: ClassSetRange ClassUnion opt

1. Let $A$ be CompileToCharSet of ClassSetRange with argument $rer$.
2. If ClassUnion is present, then
   a. Let $B$ be CompileToCharSet of ClassUnion with argument $rer$.
   b. Return the union of CharSet $A$ and $B$.
3. Return $A$.

ClassUnion :: ClassSetOperand ClassUnion opt

1. Let $A$ be CompileToCharSet of ClassSetOperand with argument $rer$.
2. If ClassUnion is present, then
   a. Let $B$ be CompileToCharSet of ClassUnion with argument $rer$.
   b. Return the union of CharSet $A$ and $B$.
3. Return $A$.

ClassIntersection :: ClassSetOperand && ClassSetOperand

1. Let $A$ be CompileToCharSet of the first ClassSetOperand with argument $rer$.
2. Let $B$ be CompileToCharSet of the second ClassSetOperand with argument $rer$.
3. Return the intersection of CharSet $A$ and $B$.

ClassIntersection :: ClassIntersection && ClassSetOperand

1. Let $A$ be CompileToCharSet of the ClassIntersection with argument $rer$.
2. Let $B$ be CompileToCharSet of the ClassSetOperand with argument $rer$.
3. Return the intersection of CharSet $A$ and $B$.

ClassSubtraction :: ClassSetOperand -- ClassSetOperand

1. Let $A$ be CompileToCharSet of the first ClassSetOperand with argument $rer$.
2. Let $B$ be CompileToCharSet of the second ClassSetOperand with argument $rer$.
3. Return the CharSet containing the CharSetElements of $A$ which are not also CharSetElements of $B$.

ClassSubtraction :: ClassSubtraction -- ClassSetOperand

1. Let $A$ be CompileToCharSet of the ClassSubtraction with argument $rer$.
2. Let $B$ be CompileToCharSet of the ClassSetOperand with argument $rer$.
3. Return the CharSet containing the CharSetElements of $A$ which are not also CharSetElements of $B$.

ClassSetRange :: ClassSetCharacter - ClassSetCharacter

1. Let $A$ be CompileToCharSet of the first ClassSetCharacter with argument $rer$.
2. Let $B$ be CompileToCharSet of the second ClassSetCharacter with argument $rer$.
3. Return $\text{MaybeSimpleCaseFolding}(rer, \text{CharacterRange}(A, B))$.

NOTE 6 The result will often consist of two or more ranges. When UnicodeSets is true and IgnoreCase is true, then $\text{MaybeSimpleCaseFolding}(rer, [Ā-Č])$ will include only the odd-numbered code points of that range.

ClassSetOperand :: ClassSetCharacter

1. Let $A$ be CompileToCharSet of ClassSetCharacter with argument $rer$.
2. Return $\text{MaybeSimpleCaseFolding}(rer, A)$. 
ClassSetOperand :: ClassStringDisjunction
1. Let \( A \) be CompileToCharSet of \( \text{ClassStringDisjunction} \) with argument \( rer \).
2. Return MaybeSimpleCaseFolding(\( rer, A \)).

ClassSetOperand :: NestedClass
1. Return CompileToCharSet of \( \text{NestedClass} \) with argument \( rer \).

NestedClass :: [ ClassContents ]
1. Return CompileToCharSet of \( \text{ClassContents} \) with argument \( rer \).

NestedClass :: [^ ClassContents ]
1. Let \( A \) be CompileToCharSet of \( \text{ClassContents} \) with argument \( rer \).
2. Return CharacterComplement(\( rer, A \)).

NestedClass :: \ CharacterClassEscape
1. Return CompileToCharSet of \( \text{CharacterClassEscape} \) with argument \( rer \).

ClassStringDisjunction :: \{ \} ClassStringDisjunctionContents \}
1. Return CompileToCharSet of \( \text{ClassStringDisjunctionContents} \) with argument \( rer \).

ClassStringDisjunctionContents :: ClassString
1. Let \( s \) be CompileClassSetString of \( \text{ClassString} \) with argument \( rer \).
2. Return the CharSet containing the one string \( s \).

ClassStringDisjunctionContents :: ClassString | ClassStringDisjunctionContents
1. Let \( s \) be CompileClassSetString of \( \text{ClassString} \) with argument \( rer \).
2. Let \( A \) be the CharSet containing the one string \( s \).
3. Let \( B \) be CompileToCharSet of \( \text{ClassStringDisjunctionContents} \) with argument \( rer \).
4. Return the union of CharSets \( A \) and \( B \).

ClassSetCharacter ::
SourceCharacter but not ClassSetSyntaxCharacter
\ CharacterEscape
\ ClassSetReservedPunctuator
1. Let \( cv \) be the CharacterValue of this ClassSetCharacter.
2. Let \( c \) be the character whose character value is \( cv \).
3. Return the CharSet containing the single character \( c \).

ClassSetCharacter :: \b
1. Return the CharSet containing the single character U+0008 (BACKSPACE).

22.2.2.9.1 CharacterRange ( \( A, B \) )
The abstract operation \( \text{CharacterRange} \) takes arguments \( A \) (a CharSet) and \( B \) (a CharSet) and returns a CharSet. It performs the following steps when called:
1. Assert: \( A \) and \( B \) each contain exactly one character.
2. Let \( a \) be the one character in CharSet \( A \).
3. Let \( b \) be the one character in CharSet \( B \).
4. Let \( i \) be the character value of character \( a \).
5. Let \( j \) be the character value of character \( b \).
6. Assert: \( i \leq j \).
7. Return the CharSet containing all characters with a character value in the inclusive interval from \( i \) to \( j \).

### 22.2.2.9.2 HasEitherUnicodeFlag (\( rer \))

The abstract operation HasEitherUnicodeFlag takes argument \( rer \) (a RegExp Record) and returns a Boolean. It performs the following steps when called:

1. If \( rer.[[Unicode]] \) is true or \( rer.[[UnicodeSets]] \) is true, then
   a. Return true.
   2. Return false.

### 22.2.2.9.3 WordCharacters (\( rer \))

The abstract operation WordCharacters takes argument \( rer \) (a RegExp Record) and returns a CharSet. Returns a CharSet containing the characters considered "word characters" for the purposes of \( \backslash b, \backslash B, \backslash w, \) and \( \backslash W \). It performs the following steps when called:

1. Let \( \text{basicWordChars} \) be the CharSet containing every character in the ASCII word characters.
2. Let \( \text{extraWordChars} \) be the CharSet containing all characters \( c \) such that \( c \) is not in \( \text{basicWordChars} \) but \( \text{Canonicalize}(rer, c) \) is in \( \text{basicWordChars} \).
3. Assert: \( \text{extraWordChars} \) is empty unless HasEitherUnicodeFlag\( (rer) \) is true and \( rer.[[IgnoreCase]] \) is true.
4. Return the union of \( \text{basicWordChars} \) and \( \text{extraWordChars} \).

### 22.2.2.9.4 AllCharacters (\( rer \))

The abstract operation AllCharacters takes argument \( rer \) (a RegExp Record) and returns a CharSet. Returns the set of "all characters" according to the regular expression flags. It performs the following steps when called:

1. If \( rer.[[UnicodeSets]] \) is true and \( rer.[[IgnoreCase]] \) is true, then
   a. Return the CharSet containing all Unicode code points \( c \) that do not have a Simple Case Folding <https://www.unicode.org/reports/tr44/#Simple_Case_Folding> mapping (that is, \( \text{scf}(c) = c \)).
2. Else if HasEitherUnicodeFlag\( (rer) \) is true, then
   a. Return the CharSet containing all code point values.
3. Else,
   a. Return the CharSet containing all code unit values.

### 22.2.2.9.5 MaybeSimpleCaseFolding (\( rer, A \))

The abstract operation MaybeSimpleCaseFolding takes arguments \( rer \) (a RegExp Record) and \( A \) (a CharSet) and returns a CharSet. If \( rer.[[UnicodeSets]] \) is false or \( rer.[[IgnoreCase]] \) is false, it returns \( A \). Otherwise, it uses the Simple Case Folding <https://www.unicode.org/reports/tr44/#Simple_Case_Folding> (\( \text{scf}(cp) \)) definitions in the file CaseFolding.txt <https://unicode.org/Public/UCD/latest/ucd/CaseFolding.txt> of the Unicode Character Database (each of which maps a single code point to another single code point) to map each CharSetElement of \( A \) character-by-character into a canonical form and returns the resulting CharSet. It performs the following steps when called:

1. If \( rer.[[UnicodeSets]] \) is false or \( rer.[[IgnoreCase]] \) is false, return \( A \).
2. Let \( B \) be a new empty CharSet.
3. For each CharSetElement \( s \) of \( A \), do
   a. Let \( t \) be an empty sequence of characters.
   b. For each single code point \( cp \) in \( s \), do
      i. Append \( \text{scf}(cp) \) to \( t \).
   c. Add \( t \) to \( B \).
4. Return \( B \).
22.2.2.9.6 CharacterComplement (rer, S)

The abstract operation CharacterComplement takes arguments rer (a RegExp Record) and S (a CharSet) and returns a CharSet. It performs the following steps when called:

1. Let A be AllCharacters(rer).
2. Return the CharSet containing the CharSetElements of A which are not also CharSetElements of S.

22.2.2.9.7 UnicodeMatchProperty (rer, p)

The abstract operation UnicodeMatchProperty takes arguments rer (a RegExp Record) and p (ECMAScript source text) and returns a Unicode property name. It performs the following steps when called:

1. If rer.([[UnicodeSets]]) is true and p is a Unicode property name listed in the “Property name” column of Table 69, then
   a. Return the List of Unicode code points p.
2. Assert: p is a Unicode property name or property alias listed in the “Property name and aliases” column of Table 67 or Table 68.
3. Let c be the canonical property name of p as given in the “Canonical property name” column of the corresponding row.
4. Return the List of Unicode code points c.

Implementations must support the Unicode property names and aliases listed in Table 67, Table 68, and Table 69. To ensure interoperability, implementations must not support any other property names or aliases.

---

**NOTE 1** For example, Script_Extensions (property name) and scx (property alias) are valid, but script_extensions or Scx aren’t.

**NOTE 2** The listed properties form a superset of what UTS18 RL1.2 (<https://unicode.org/reports/tr18/#RL1.2>) requires.

**NOTE 3** The spellings of entries in these tables (including casing) match the spellings used in the file PropertyAliases.txt (<https://unicode.org/Public/UCD/latest/ucd/PropertyAliases.txt>) in the Unicode Character Database. The precise spellings in that file are guaranteed to be stable (<https://www.unicode.org/policies/stability_policy.html#Alias_Stability>).

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**Table 67: Non-binary Unicode property aliases and their canonical property names**

<table>
<thead>
<tr>
<th>Property name and aliases</th>
<th>Canonical property name</th>
</tr>
</thead>
<tbody>
<tr>
<td>General_Category</td>
<td>General_Category</td>
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<td>Script_Extensions</td>
<td>Script_Extensions</td>
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<tr>
<td>scx</td>
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</tr>
</tbody>
</table>

**Table 68: Binary Unicode property aliases and their canonical property names**

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<tr>
<th>Property name and aliases</th>
<th>Canonical property name</th>
</tr>
</thead>
<tbody>
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<td>ASCII</td>
</tr>
<tr>
<td>Property name and aliases</td>
<td>Canonical property name</td>
</tr>
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<td>--------------------------</td>
<td>-------------------------</td>
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Table 69: Binary Unicode properties of strings

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<td>RGI_Emoji_Flag_Sequence</td>
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<td>RGI_Emoji_Tag_Sequence</td>
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</table>
### 22.2.2.9.8 UnicodeMatchPropertyValue \((p, v)\)

The abstract operation `UnicodeMatchPropertyValue` takes arguments `p` (ECMAScript source text) and `v` (ECMAScript source text) and returns a Unicode property value. It performs the following steps when called:

1. **Assert**: `p` is a canonical, unaliased Unicode property name listed in the “Canonical property name” column of Table 67.
2. **Assert**: `v` is a property value or property value alias for the Unicode property `p` listed in `PropertyValueAliases.txt` (<https://unicode.org/Public/UCD/latest/ucd/PropertyValueAliases.txt>).
3. Let `value` be the canonical property value of `v` as given in the “Canonical property value” column of the corresponding row.
4. Return the List of Unicode code points `value`.

Implementations must support the Unicode property values and property value aliases listed in `PropertyValueAliases.txt` (<https://unicode.org/Public/UCD/latest/ucd/PropertyValueAliases.txt>) for the properties listed in Table 67. To ensure interoperability, implementations must not support any other property values or property value aliases.

**NOTE 1** For example, `Xpeo` and `Old_Persian` are valid `Script_Extensions` values, but `xpeo` and `Old Persian` aren't.

**NOTE 2** This algorithm differs from the matching rules for symbolic values listed in UAX44 (<https://unicode.org/reports/tr44/#Matching_Symbolic>): case, whitespace, U+002D (HYPHEN-MINUS), and U+005F (LOW LINE) are not ignored, and the `Is` prefix is not supported.

### 22.2.2.10 Runtime Semantics: CompileClassSetString

The syntax-directed operation `CompileClassSetString` takes argument `rer` (a RegExp Record) and returns a sequence of characters. It is defined piecewise over the following productions:

- **ClassString** :: [empty]
  1. Return an empty sequence of characters.
- **ClassString** :: NonEmptyClassString
  1. Return `CompileClassSetString` of `NonEmptyClassString` with argument `rer`.
- **NonEmptyClassString** :: `ClassSetCharacter` `NonEmptyClassString`opt
  1. Let `cs` be `CompileToCharSet` of `ClassSetCharacter` with argument `rer`.
  2. Let `s1` be the sequence of characters that is the single `CharSetElement` of `cs`.
  3. If `NonEmptyClassString` is present, then
    a. Let `s2` be `CompileClassSetString` of `NonEmptyClassString` with argument `rer`.
    b. Return the concatenation of `s1` and `s2`.
  4. Return `s1`. 
22.2.3 Abstract Operations for RegExp Creation

22.2.3.1 RegExpCreate ( P, F )

The abstract operation RegExpCreate takes arguments P (an ECMAScript language value) and F (a String or undefined) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Let obj be ! RegExpAlloc(%RegExp%).
2. Return % RegExpInitialize(obj, P, F).%

22.2.3.2 RegExpAlloc ( newTarget )

The abstract operation RegExpAlloc takes argument newTarget (a constructor) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. Let obj be ? OrdinaryCreateFromConstructor(newTarget, "%RegExp.prototype%", « [[OriginalSource]], [[OriginalFlags]], [[RegExpRecord]], [[RegExpMatcher]] »).
2. Perform ! DefinePropertyOrThrow(obj, "lastIndex", PropertyDescriptor { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }).
3. Return obj.

22.2.3.3 RegExpInitialize ( obj, pattern, flags )

The abstract operation RegExpInitialize takes arguments obj (an Object), pattern (an ECMAScript language value), and flags (an ECMAScript language value) and returns either a normal completion containing an Object or a throw completion. It performs the following steps when called:

1. If pattern is undefined, let P be the empty String.
2. Else, let P be ? ToString(pattern).
3. If flags is undefined, let F be the empty String.
5. If F contains any code unit other than "d", "g", "i", "m", "s", "u", "v", or "y", or if F contains any code unit more than once, throw a SyntaxError exception.
6. If F contains "i", let i be true; else let i be false.
7. If F contains "m", let m be true; else let m be false.
8. If F contains "s", let s be true; else let s be false.
9. If F contains "u", let u be true; else let u be false.
10. If F contains "v", let v be true; else let v be false.
11. If u is true or v is true, then
   a. Let patternText be StringToCodePoints(P).
12. Else,
   a. Let patternText be the result of interpreting each of P's 16-bit elements as a Unicode BMP code point.
      UTF-16 decoding is not applied to the elements.
13. Let parseResult be ParsePattern(patternText, u, v).
14. If parseResult is a non-empty List of SyntaxError objects, throw a SyntaxError exception.
15. Assert: parseResult is a Pattern Parse Node.
16. Set obj.[[OriginalSource]] to P.
17. Set obj.[[OriginalFlags]] to F.
18. Let capturingGroupsCount be CountLeftCapturingParenWithin(parseResult).
19. Let rer be the RegExp Record { [[IgnoreCase]]: i, [[Multiline]]: m, [[DotAll]]: s, [[Unicode]]: u, [[UnicodeSets]]: v, [[CapturingGroupsCount]]: capturingGroupsCount }.
20. Set obj.[[RegExpRecord]] to rer.
22. Perform ? Set(obj, "lastIndex", +0F, true).
23. Return obj.
22.2.3.4 Static Semantics: ParsePattern (\textit{patternText}, \textit{u}, \textit{v})

The abstract operation ParsePattern takes arguments \textit{patternText} (a sequence of Unicode code points), \textit{u} (a Boolean), and \textit{v} (a Boolean) and returns a Parse Node or a non-empty List of SyntaxError objects.

\textbf{NOTE} This section is amended in B.1.2.9.

It performs the following steps when called:

1. If \textit{v} is \textit{true} and \textit{u} is \textit{true}, then
   a. Let \textit{parseResult} be a List containing one or more SyntaxError objects.
2. Else if \textit{v} is \textit{true}, then
3. Else if \textit{u} is \textit{true}, then
5. Return \textit{parseResult}.

22.2.4 The RegExp Constructor

The RegExp constructor:

- is \%RegExp\%.
- is the initial value of the "RegExp" property of the global object.
- creates and initializes a new RegExp object when called as a constructor.
- when called as a function rather than as a constructor, returns either a new RegExp object, or the argument itself if the only argument is a RegExp object.
- may be used as the value of an \texttt{extends} clause of a class definition. Subclass constructors that intend to inherit the specified RegExp behaviour must include a \texttt{super} call to the RegExp constructor to create and initialize subclass instances with the necessary internal slots.

22.2.4.1 RegExp (\textit{pattern}, \textit{flags})

This function performs the following steps when called:

1. Let \textit{patternIsRegExp} be \texttt{IsRegExp(\textit{pattern})}.
2. If NewTarget is \texttt{undefined}, then
   a. Let \textit{newTarget} be the active function object.
   b. If \textit{patternIsRegExp} is \textit{true} and \textit{flags} is \texttt{undefined}, then
      i. Let \textit{patternConstructor} be \texttt{Get(\textit{pattern}, "constructor")}.
      ii. If \texttt{SameValue(newTarget, patternConstructor)} is \texttt{true}, return \textit{pattern}.
3. Else,
   a. Let \textit{newTarget} be NewTarget.
4. If \textit{pattern} is an Object and \textit{pattern} has a [[RegExpMatcher]] internal slot, then
   a. Let \textit{P} be \textit{pattern}.[[OriginalSource]].
   b. If \textit{flags} is \texttt{undefined}, let \textit{F} be \textit{pattern}.[[OriginalFlags]].
   c. Else, let \textit{F} be \textit{flags}.
5. Else if \textit{patternIsRegExp} is \textit{true}, then
   a. Let \textit{P} be \texttt{Get(pattern, "source")}.
   b. If \textit{flags} is \texttt{undefined}, then
      i. Let \textit{F} be \texttt{Get(pattern, "flags")}.
   c. Else,
      i. Let \textit{F} be \textit{flags}.
6. Else,
a. Let \( P \) be `pattern`.

b. Let \( F \) be `flags`.

7. Let \( O \) be `RegExpAlloc(newTarget)`.


**NOTE** If pattern is supplied using a `StringLiteral`, the usual escape sequence substitutions are performed before the String is processed by this function. If pattern must contain an escape sequence to be recognized by this function, any U+005C (REVERSE SOLIDUS) code points must be escaped within the `StringLiteral` to prevent them being removed when the contents of the `StringLiteral` are formed.

### 22.2.5 Properties of the RegExp Constructor

The `RegExp` constructor:

- has a `[[Prototype]]` internal slot whose value is `%Function.prototype%`.
- has the following properties:

#### 22.2.5.1 RegExp.prototype

The initial value of `RegExp.prototype` is the RegEx prototype object.

This property has the attributes { `[[Writable]]`: false, `[[Enumerable]]`: false, `[[Configurable]]`: false }.

#### 22.2.5.2 get RegExp [ @@species ]

`RegExp[@@species]` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Return the `this` value.

The value of the "name" property of this function is "get [Symbol.species]".

**NOTE** RegEx prototype methods normally use their `this` value’s constructor to create a derived object. However, a subclass constructor may over-ride that default behaviour by redefining its `@@species` property.

### 22.2.6 Properties of the RegExp Prototype Object

The `RegExp prototype object`:

- is `%RegExp.prototype%`.
- is an ordinary object.
- is not a RegExp instance and does not have a `[[RegExpMatcher]]` internal slot or any of the other internal slots of RegExp instance objects.
- has a `[[Prototype]]` internal slot whose value is `%Object.prototype%`.

**NOTE** The RegEx prototype object does not have a "valueOf" property of its own; however, it inherits the "valueOf" property from the Object prototype object.

#### 22.2.6.1 RegExp.prototype.constructor

The initial value of `RegExp.prototype.constructor` is `%RegExp%`.
22.2.6.2 RegExp.prototype.exec (string)

This method searches string for an occurrence of the regular expression pattern and returns an Array containing the results of the match, or null if string did not match.

It performs the following steps when called:

1. Let R be the this value.
2. Perform ? RequireInternalSlot(R, [[RegExpMatcher]]).
3. Let S be ? ToString(string).

22.2.6.3 get RegExp.prototype.dotAll

RegExp.prototype.dotAll is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let R be the this value.
2. Let cu be the code unit 0x0073 (LATIN SMALL LETTER S).

22.2.6.4 get RegExp.prototype.flags

RegExp.prototype.flags is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let R be the this value.
2. If R is not an Object, throw a TypeError exception.
3. Let codeUnits be a new empty List.
4. Let hasIndices be ToBoolean(? Get(R, "hasIndices").
5. If hasIndices is true, append the code unit 0x0064 (LATIN SMALL LETTER D) to codeUnits.
6. Let global be ToBoolean(? Get(R, "global").
7. If global is true, append the code unit 0x0067 (LATIN SMALL LETTER G) to codeUnits.
8. Let ignoreCase be ToBoolean(? Get(R, "ignoreCase").
9. If ignoreCase is true, append the code unit 0x0069 (LATIN SMALL LETTER I) to codeUnits.
10. Let multiline be ToBoolean(? Get(R, "multiline").
11. If multiline is true, append the code unit 0x006D (LATIN SMALL LETTER M) to codeUnits.
12. Let dotAll be ToBoolean(? Get(R, "dotAll").
13. If dotAll is true, append the code unit 0x0073 (LATIN SMALL LETTER S) to codeUnits.
14. Let unicode be ToBoolean(? Get(R, "unicode").
15. If unicode is true, append the code unit 0x0075 (LATIN SMALL LETTER U) to codeUnits.
16. Let unicodeSets be ToBoolean(? Get(R, "unicodeSets").
17. If unicodeSets is true, append the code unit 0x0076 (LATIN SMALL LETTER V) to codeUnits.
18. Let sticky be ToBoolean(? Get(R, "sticky").
19. If sticky is true, append the code unit 0x0079 (LATIN SMALL LETTER Y) to codeUnits.
20. Return the String value whose code units are the elements of the List codeUnits. If codeUnits has no elements, the empty String is returned.

22.2.6.4.1 RegExpHasFlag (R, codeUnit)

The abstract operation RegExpHasFlag takes arguments R (an ECMAScript language value) and codeUnit (a code unit) and returns either a normal completion containing either a Boolean or undefined, or a throw completion. It performs the following steps when called:

1. If R is not an Object, throw a TypeError exception.
2. If R does not have an [[OriginalFlags]] internal slot, then
   a. IfSameValue(R, %RegExp.prototype%) is true, return undefined.
   b. Otherwise, throw a TypeError exception.
3. Let flags be R.[[OriginalFlags]].
4. If flags contains codeUnit, return true.
5. Return false.

22.2.6.5 get RegExp.prototype.global

RegExp.prototype.global is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let R be the this value.
2. Let cu be the code unit \text{0x0067} (LATIN SMALL LETTER G).

22.2.6.6 get RegExp.prototype.hasIndices

RegExp.prototype.hasIndices is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let R be the this value.
2. Let cu be the code unit \text{0x0064} (LATIN SMALL LETTER D).

22.2.6.7 get RegExp.prototype.ignoreCase

RegExp.prototype.ignoreCase is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let R be the this value.
2. Let cu be the code unit \text{0x0069} (LATIN SMALL LETTER I).

22.2.6.8 RegExp.prototype[@@match] (string)

This method performs the following steps when called:

1. Let rx be the this value.
2. If rx is not an Object, throw a TypeError exception.
3. Let S be ? ToString(string).
4. Let flags be ? ToString(? Get(rx, "flags")).
5. If flags does not contain "g", then
6. Else,
   a. If flags contains "u" or flags contains "v", let fullUnicode be true. Otherwise, let fullUnicode be false.
   b. Perform ? Set(rx, "lastIndex", +0𝔽, true).
   c. Let A be ! ArrayCreate(∅).
   d. Let n be 0.
   e. Repeat,
      i. Let result be ? RegExpExec(rx, S).
      ii. If result is null, then
          1. If n = 0, return null.
          2. Return A.
      iii. Else,
          1. Let matchStr be ? ToString(? Get(result, "0")).
          2. Perform ! CreateDataPropertyOrThrow(A, ! ToString(𝔽(n)), matchStr).
          3. If matchStr is the empty String, then
             a. Let thisIndex be ℝ(? ToLength(? Get(rx, "lastIndex")).
             b. Let nextIndex be AdvanceStringIndex(S, thisIndex, fullUnicode).
             c. Perform ? Set(rx, "lastIndex", 𝔸(nextIndex), true).
          4. Set n to n + 1.
The value of the "name" property of this method is "[Symbol.match]".

NOTE The @@match property is used by the `IsRegExp` abstract operation to identify objects that have the basic behaviour of regular expressions. The absence of a @@match property or the existence of such a property whose value does not Boolean coerce to true indicates that the object is not intended to be used as a regular expression object.

22.2.6.9 `RegExp.prototype @@matchAll (string)`

This method performs the following steps when called:

1. Let `R` be the this value.
2. If `R` is not an Object, throw a TypeError exception.
3. Let `S` be ? `ToString(string)`.
4. Let `C` be ? `SpeciesConstructor(R, %RegExp%)`.
5. Let `flags` be ? `ToString(??` `Get(R, "flags")` `)`.
7. Let `lastIndex` be ? `ToLength(?` `Get(R, "lastIndex")` `)`.
8. Perform ? `Set(matcher, "lastIndex", lastIndex, true)`.
9. If `flags` contains "g", let `global` be true.
10. Else, let `global` be false.
11. If `flags` contains "u" or `flags` contains "v", let `fullUnicode` be true.
12. Else, let `fullUnicode` be false.

The value of the "name" property of this method is "[Symbol.matchAll]".

22.2.6.10 `get RegExp.prototype.multiline`

`RegExp.prototype.multiline` is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let `R` be the this value.
2. Let `cu` be the code unit 0x006D (LATIN SMALL LETTER M).

22.2.6.11 `RegExp.prototype @@replace (string, replaceValue)`

This method performs the following steps when called:

1. Let `rx` be the this value.
2. If `rx` is not an Object, throw a TypeError exception.
3. Let `S` be ? `ToString(string)`.
4. Let `lengthS` be the length of `S`.
5. Let `functionalReplace` be `IsCallable(replaceValue)`.
6. If `functionalReplace` is false, then
   a. Set `replaceValue` to ? `ToString(replaceValue)`.
7. Let `flags` be ? `ToString(??` `Get(rx, "flags")` `)`.
8. If `flags` contains "g", let `global` be true. Otherwise, let `global` be false.
9. If `global` is true, then
   a. Perform ? `Set(rx, "lastIndex", +0𝔽, true)`.
10. Let `results` be a new empty List.
11. Let `done` be false.
12. Repeat, while `done` is false,
   a. Let `result` be ? `RegExpExec(rx, S)`.
   b. If `result` is null, then
      i. Set `done` to true.
   c. Else,
Append result to results.

ii. If global is false, then
   1. Set done to true.
iii. Else,
   1. Let matchStr be ? ToString(? Get(result, "$0"));
   2. If matchStr is the empty String, then
   a. Let thisIndex be ? ToLength(? Get(rx, "lastIndex"));
   b. If flags contains "u" or flags contains "v", let fullUnicode be true. Otherwise, let fullUnicode be false.
   c. Let nextIndex be AdvanceStringIndex(S, thisIndex, fullUnicode).
   d. Perform ? Set(rx, "lastIndex", F(nextIndex), true).

13. Let accumulatedResult be the empty String.
14. Let nextSourcePosition be 0.
15. For each element result of results, do
   a. Let resultLength be ? LengthOfStringLike(result).
   b. Let nCaptures be max(resultLength - 1, 0).
   c. Let matched be ? ToString(? Get(result, "$0"));
   d. Let matchLength be the length of matched.
   e. Let position be ? ToIntegerOrInfinity(? Get(result, "index")).
   f. Set position to the result of clamping position between 0 and lengthS.
   g. Let captures be a new empty List.
   h. Let n be 1.
   i. Repeat, while n ≤ nCaptures,
      1. Let capN be ? Get(result, ! ToString(F(n))).
      2. If capN is not undefined, then
      3. Append capN to captures.
      4. NOTE: When n = 1, the preceding step puts the first element into captures (at index 0). More generally, the n-th capture (the characters captured by the n-th set of capturing parentheses) is at captures[n - 1].
   v. Set n to n + 1.
   j. Let namedCaptures be ? Get(result, "groups").
   k. If functionalReplace is true, then
      1. Let replacerArgs be the list-concatenation of « matched », captures, and « F(position), S ».
      2. If namedCaptures is not undefined, then
         1. Append namedCaptures to replacerArgs.
      3. Let replValue be ? Call(replacerValue, undefined, replacerArgs).
   l. Else,
      1. If namedCaptures is not undefined, then
         1. Set namedCaptures to ? ToObject(namedCaptures).
   m. If position ≥ nextSourcePosition, then
      1. NOTE: position should not normally move backwards. If it does, it is an indication of an ill-behaving RegExp subclass or use of an access triggered side-effect to change the global flag or other characteristics of rx. In such cases, the corresponding substitution is ignored.
      2. Set accumulatedResult to the string-concatenation of accumulatedResult, the substring of S from nextSourcePosition to position, and replacement.
      3. Set nextSourcePosition to position + matchLength.
16. If nextSourcePosition ≥ lengthS, return accumulatedResult.
17. Return the string-concatenation of accumulatedResult and the substring of S from nextSourcePosition.

The value of the "name" property of this method is "[Symbol.replace]".
This method performs the following steps when called:

1. Let \( rx \) be the \( this \) value.
2. If \( rx \) is not an Object, throw a \( TypeError \) exception.
3. Let \( S \) be \( ?\) \( toString(string) \).
4. Let \( previousLastIndex \) be \( ?\) \( Get(rx, "lastIndex") \).
5. If \( \text{SameValue}(previousLastIndex, \_0_F) \) is \( false \), then
   a. Perform ? \( Set(rx, "lastIndex", \_0_F, true) \).
6. Let \( result \) be ? \( RegExpExec(rx, S) \).
7. Let \( currentLastIndex \) be \( ?\) \( Get(rx, "lastIndex") \).
8. If \( \text{SameValue}(currentLastIndex, previousLastIndex) \) is \( false \), then
   a. Perform ? \( Set(rx, "lastIndex", previousLastIndex, true) \).
9. If \( result \) is \( null \), return \(-1_F\).
10. Return \( ?\) \( Get(result, "index") \).

The value of the "name" property of this method is "[Symbol.search]".

NOTE The "lastIndex" and "global" properties of this RegExp object are ignored when performing the search. The "lastIndex" property is left unchanged.

get RegExp.prototype.source

\( \text{RegExp.prototype.source} \) is an accessor property whose set accessor function is \( \text{undefined} \). Its get accessor function performs the following steps when called:

1. Let \( R \) be the \( this \) value.
2. If \( R \) is not an Object, throw a \( TypeError \) exception.
3. If \( R \) does not have an [[OriginalSource]] internal slot, then
   a. If \( \text{SameValue}(R, %RegExp.prototype%) \) is \( true \), return "(?:)".
   b. Otherwise, throw a \( TypeError \) exception.
4. Assert: \( R \) has an [[OriginalFlags]] internal slot.
5. Let \( src \) be \( R.[[OriginalSource]] \).
6. Let \( flags \) be \( R.[[OriginalFlags]] \).
7. Return \( \text{EscapeRegExpPattern}(src, flags) \).

EscapeRegExpPattern \( (P, F) \)

The abstract operation \( \text{EscapeRegExpPattern} \) takes arguments \( P \) (a String) and \( F \) (a String) and returns a String. It performs the following steps when called:

1. If \( F \) contains "v", then
   a. Let \( \text{patternSymbol} \) be \( \text{Pattern}[+UnicodeMode, +UnicodeSetsMode] \).
2. Else if \( F \) contains "u", then
   a. Let \( \text{patternSymbol} \) be \( \text{Pattern}[+UnicodeMode, ~UnicodeSetsMode] \).
3. Else,
   a. Let \( \text{patternSymbol} \) be \( \text{Pattern}[-UnicodeMode, ~UnicodeSetsMode] \).
4. Let \( S \) be a String in the form of a \( \text{patternSymbol} \) equivalent to \( P \) interpreted as UTF-16 encoded Unicode code points (6.1.4), in which certain code points are escaped as described below. \( S \) may or may not differ from \( P \); however, the Abstract Closure that would result from evaluating \( S \) as a \( \text{patternSymbol} \) must behave identically to the Abstract Closure given by the constructed object's [[RegExpMatcher]] internal slot. Multiple calls to this abstract operation using the same values for \( P \) and \( F \) must produce identical results.
5. The code points / or any \( \text{LineTerminator} \) occurring in the pattern shall be escaped in \( S \) as necessary to ensure that the string-concatenation of "\\", ", ", and \( F \) can be parsed (in an appropriate lexical context) as a \( \text{RegularExpressionLiteral} \) that behaves identically to the constructed regular expression. For example, if \( P \) is "\"", then \( S \) could be "\\" or "\u002F", among other possibilities, but not "\"", because / / followed by \( F \)
would be parsed as a SingleLineComment rather than a RegularExpressionLiteral. If \( P \) is the empty String, this specification can be met by letting \( S \) be `'(?:)`.

6. Return \( S \).

22.6.14 RegExp.prototype [ @@split ] ( string, limit )

**NOTE 1** This method returns an Array into which substrings of the result of converting \( string \) to a String have been stored. The substrings are determined by searching from left to right for matches of the this value regular expression; these occurrences are not part of any String in the returned array, but serve to divide up the String value.

The this value may be an empty regular expression or a regular expression that can match an empty String. In this case, the regular expression does not match the empty substring at the beginning or end of the input String, nor does it match the empty substring at the end of the previous separator match. (For example, if the regular expression matches the empty String, the String is split up into individual code unit elements; the length of the result array equals the length of the String, and each substring contains one code unit.) Only the first match at a given index of the String is considered, even if backtracking could yield a non-empty substring match at that index. (For example, `/a*?[/Symbol.split]("ab")` evaluates to the array `['a', 'b']`, while `/a*/[Symbol.split]("ab")` evaluates to the array `['', 'b']`.)

If \( string \) is (or converts to) the empty String, the result depends on whether the regular expression can match the empty String. If it can, the result array contains no elements. Otherwise, the result array contains one element, which is the empty String.

If the regular expression contains capturing parentheses, then each time separator is matched the results (including any undefined results) of the capturing parentheses are spliced into the output array. For example,

```
/<\(\)/?\([^<>]+\)>[/Symbol.split]("A<B>bold</B>and<CODE>coded</CODE>")
```

evaluates to the array

```
["A", undefined, "B", "bold", "/", "B", "and", undefined, "CODE", "coded", '
```

If \( limit \) is not undefined, then the output array is truncated so that it contains no more than \( limit \) elements.

This method performs the following steps when called:

1. Let \( rx \) be the this value.
2. If \( rx \) is not an Object, throw a TypeError exception.
3. Let \( S \) be ? ToString(\( string \)).
4. Let \( C \) be ? SpeciesConstructor(\( rx \), %RegExp%).
5. Let \( flags \) be ? ToString(? Get(\( rx \), "flags")).
6. If \( flags \) contains "u" or \( flags \) contains "v", let unicodeMatching be true.
7. Else, let unicodeMatching be false.
8. If \( flags \) contains "y", let newFlags be \( flags \).
9. Else, let newFlags be the string-concatenation of \( flags \) and "y".
10. Let \( splitter \) be ? Construct(\( C \), « \( rx \), newFlags »).
11. Let \( A \) be ! ArrayCreate(0).
12. Let \( lengthA \) be 0.
13. If \( limit \) is undefined, let \( lim \) be \( 2^{32} - 1 \); else let \( lim \) be \( ? \) ToUint32(\( limit \)).
14. If \( lim = 0 \), return \( A \).
15. If \( S \) is the empty String, then
   a. Let \( z \) be ? RegExpExec(\( splitter \), \( S \)).
   b. If \( z \) is not null, return \( A \).
   c. Perform ! CreateDataPropertyOrThrow(\( A \), "\( \theta \)", \( S \)).
   d. Return \( A \).
Let \( size \) be the length of \( S \).

Let \( p \) be \( 0 \).

Let \( q \) be \( p \).

19. Repeat, while \( q < size \),
   a. Perform ? \( Set(splitter, "lastIndex", F(q), true) \).
   b. Let \( z \) be ? \( RegExpExec(splitter, S) \).
   c. If \( z \) is \( null \), then
      i. Set \( q \) to \( AdvanceStringIndex(S, q, unicodeMatching) \).
   d. Else,
      i. Let \( e \) be \( ℝ(? ToLength(? Get(splitter, "lastIndex"))) \).
      ii. Set \( e \) to \( \min(e, size) \).
      iii. If \( e = p \), then
         1. Set \( q \) to \( AdvanceStringIndex(S, q, unicodeMatching) \).
      iv. Else,
         1. Let \( T \) be the substring of \( S \) from \( p \) to \( q \).
         2. Perform ! \( CreateDataPropertyOrThrow(A, ! ToString(F(lengthA)), T) \).
         3. Set \( lengthA \) to \( lengthA + 1 \).
         4. If \( lengthA = lim \), return \( A \).
         5. Set \( p \) to \( e \).
         6. Let \( numberOfCaptures \) be ? \( LengthOfArrayLike(z) \).
         7. Set \( numberOfCaptures \) to \( \max(numberOfCaptures - 1, 0) \).
         8. Let \( i \) be \( 1 \).
         9. Repeat, while \( i \leq numberOfCaptures \),
            a. Let \( nextCapture \) be ? \( Get(z, ! ToString(F(i))) \).
            b. Perform ! \( CreateDataPropertyOrThrow(A, ! ToString(F(lengthA)), nextCapture) \).
            c. Set \( i \) to \( i + 1 \).
            d. Set \( lengthA \) to \( lengthA + 1 \).
            e. If \( lengthA = lim \), return \( A \).
   iv. Else,
      1. Let \( T \) be the substring of \( S \) from \( p \) to \( size \).
      2. Perform ! \( CreateDataPropertyOrThrow(A, ! ToString(F(lengthA)), T) \).
      3. Return \( A \).

The value of the "name" property of this method is "[Symbol.split]".

NOTE 2 This method ignores the value of the "global" and "sticky" properties of this RegExp object.

22.2.6.15 get RegExp.prototype.sticky

\( RegExp.prototype.sticky \) is an accessor property whose set accessor function is \( undefined \). Its get accessor function performs the following steps when called:

1. Let \( R \) be the \( this \) value.
2. Let \( cu \) be the code unit \( 0x0079 \) (LATIN SMALL LETTER Y).
3. Return ? \( RegExpHasFlag(R, cu) \).

22.2.6.16 RegExp.prototype.test ( \( S \) )

This method performs the following steps when called:

1. Let \( R \) be the \( this \) value.
2. If \( R \) is not an Object, throw a \( TypeError \) exception.
3. Let \( string \) be \( ! ToString(S) \).
4. Let \( match \) be ? \( RegExpExec(R, string) \).
5. If \( match \) is not \( null \), return \( true \); else return \( false \).
22.2.6.17 RegExp.prototype.toString()

1. Let \( R \) be the this value.
2. If \( R \) is not an Object, throw a TypeError exception.
3. Let \( pattern \) be ? ToString(? Get(\( R \), "source")).
4. Let \( flags \) be ? ToString(? Get(\( R \), "flags")).
5. Let \( result \) be the string-concatenation of "/", \( pattern \), "/", and \( flags \).
6. Return \( result \).

NOTE The returned String has the form of a RegularExpressionLiteral that evaluates to another RegExp object with the same behaviour as this object.

22.2.6.18 get RegExp.prototype.unicode

RegExp.prototype.unicode is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let \( R \) be the this value.
2. Let \( cu \) be the code unit 0x0075 (LATIN SMALL LETTER U).
3. Return ? RegExpHasFlag(\( R \), \( cu \)).

22.2.6.19 get RegExp.prototype.unicodeSets

RegExp.prototype.unicodeSets is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let \( R \) be the this value.
2. Let \( cu \) be the code unit 0x0076 (LATIN SMALL LETTER V).
3. Return ? RegExpHasFlag(\( R \), \( cu \)).

22.2.7 Abstract Operations for RegExp Matching

22.2.7.1 RegExpExec( \( R \), \( S \) )

The abstract operation RegExpExec takes arguments \( R \) (an Object) and \( S \) (a String) and returns either a normal completion containing either an Object or null, or a throw completion. It performs the following steps when called:

1. Let \( exec \) be ? Get(\( R \), "exec").
2. If IsCallable(\( exec \)) is true, then
   a. Let \( result \) be ? Call(\( exec \), \( R \), « \( S \) »).
   b. If \( result \) is not an Object and \( result \) is not null, throw a TypeError exception.
   c. Return \( result \).
3. Perform ? RequireInternalSlot(\( R \), [[RegExpMatcher]]).
4. Return ? RegExpBuiltInExec(\( R \), \( S \)).

NOTE If a callable "exec" property is not found this algorithm falls back to attempting to use the built-in RegExp matching algorithm. This provides compatible behaviour for code written for prior editions where most built-in algorithms that use regular expressions did not perform a dynamic property lookup of "exec".
22.2.7.2 RegExpBuiltInExec (R, S)

The abstract operation RegExpBuiltInExec takes arguments R (an initialized RegExp instance) and S (a String) and returns either a normal completion containing either an Array exotic object or null, or a throw completion. It performs the following steps when called:

1. Let length be the length of S.
2. Let lastIndex be R (? ToLength(? Get(R, "lastIndex"))).
3. Let flags be R.[[OriginalFlags]].
4. If flags contains "g", let global be true; else let global be false.
5. If flags contains "y", let sticky be true; else let sticky be false.
6. If flags contains "d", let hasIndices be true; else let hasIndices be false.
7. If global is false and sticky is false, set lastIndex to 0.
8. Let matcher be R.[[RegExpMatcher]].
9. If flags contains "u" or flags contains "v", let fullUnicode be true; else let fullUnicode be false.
10. Let matchSucceeded be false.
11. If fullUnicode is true, let input be StringToCodePoints(S). Otherwise, let input be a List whose elements are the code units that are the elements of S.
12. NOTE: Each element of input is considered to be a character.
13. Repeat, while matchSucceeded is false,
   a. If lastIndex > length, then
      i. If global is true or sticky is true, then
         1. Perform ? Set(R, "lastIndex", +0𝔽, true).
      ii. Return null.
   b. Let inputIndex be the index into input of the character that was obtained from element lastIndex of S.
   c. Let r be matcher(input, inputIndex).
   d. If r is FAILURE, then
      i. If sticky is true, then
         1. Perform ? Set(R, "lastIndex", +0𝔽, true).
         2. Return null.
      ii. Set lastIndex to AdvanceStringLength(S, lastIndex, fullUnicode).
   e. Else,
      i. Assert: r is a MatchState.
      ii. Set matchSucceeded to true.
14. Let e be r.[[EndIndex]].
15. If fullUnicode is true, set e to GetStringIndex(S, e).
16. If global is true or sticky is true, then
   a. Perform ? Set(R, "lastIndex", 𝔽(e), true).
17. Let n be the number of elements in r.[[Captures]].
18. Assert: n = R.[[RegExpRecord]].[[CapturingGroupsCount]].
19. Assert: n < 2^{52} - 1.
20. Let A be ! ArrayCreate(n + 1).
22. Perform ! CreateDataPropertyOrThrow(A, "index", 𝔽(lastIndex)).
24. Let match be the Match Record ( { [[StartIndex]]: lastIndex, [[EndIndex]]: e }).
25. Let indices be a new empty List.
26. Let groupNames be a new empty List.
27. Append match to indices.
28. Let matchedSubstr be GetMatchString(S, match).
29. Perform ! CreateDataPropertyOrThrow(A, "groups", matchedSubstr).
30. If R contains any GroupName, then
    a. Let groups be OrdinaryObjectCreate(null).
    b. Let hasGroups be true.
31. Else,
    a. Let groups be undefined.
    b. Let hasGroups be false.
32. Perform ! CreateDataPropertyOrThrow(A, "groups", groups).
33. For each integer i such that 1 ≤ i ≤ n, in ascending order, do
    a. Let capturei be r[i]th element of r.[[Captures]].
b. If capture is undefined, then
   i. Let capturedValue be undefined.
   ii. Append undefined to indices.

c. Else,
   i. Let captureStart be capture.[[StartIndex]].
   ii. Let captureEnd be capture.[[EndIndex]].
   iii. If fullUnicode is true, then
       1. Set captureStart to GetStringIndex(S, captureStart).
       2. Set captureEnd to GetStringIndex(S, captureEnd).
   iv. Let capture be the Match Record { [[StartIndex]]: captureStart, [[EndIndex]]: captureEnd }.
   v. Let capturedValue be GetMatchString(S, capture).
   vi. Append capture to indices.

d. Perform ! CreateDataPropertyOrThrow(A, ! ToString(F(i)), capturedValue).

e. If the i-th capture of R was defined with a GroupName, then
   i. Let s be the CapturingGroupName of that GroupName.
   ii. Perform ! CreateDataPropertyOrThrow(groups, s, capturedValue).
   iii. Append s to groupNames.

f. Else,
   i. Append undefined to groupNames.

34. If hasIndices is true, then
   a. Let indicesArray be MakeMatchIndicesIndexPairArray(S, indices, groupNames, hasGroups).
   b. Perform ! CreateDataPropertyOrThrow(A, "indices", indicesArray).

35. Return A.

22.2.7.3 AdvanceStringIndex ( S, index, unicode )

The abstract operation AdvanceStringIndex takes arguments S (a String), index (a non-negative integer), and unicode (a Boolean) and returns an integer. It performs the following steps when called:

1. Assert: index ≤ 2^{53} - 1.
2. If unicode is false, return index + 1.
3. Let length be the length of S.
4. If index + 1 ≥ length, return index + 1.
5. Let cp be CodePointAt(S, index).
6. Return index + cp.[[CodeUnitCount]].

22.2.7.4 GetStringIndex ( S, codePointIndex )

The abstract operation GetStringIndex takes arguments S (a String) and codePointIndex (a non-negative integer) and returns a non-negative integer. It interprets S as a sequence of UTF-16 encoded code points, as described in 6.1.4, and returns the code unit index corresponding to code point index codePointIndex when such an index exists. Otherwise, it returns the length of S. It performs the following steps when called:

1. If S is the empty String, return 0.
2. Let len be the length of S.
3. Let codeUnitCount be 0.
4. Let codePointCount be 0.
5. Repeat, while codeUnitCount < len,
   a. If codePointCount = codePointIndex, return codeUnitCount.
   b. Let cp be CodePointAt(S, codeUnitCount).
   c. Set codeUnitCount to codeUnitCount + cp.[[CodeUnitCount]].
   d. Set codePointCount to codePointCount + 1.
6. Return len.
22.2.7.5 Match Records

A Match Record is a Record value used to encapsulate the start and end indices of a regular expression match or capture.

Match Records have the fields listed in Table 70.

Table 70: Match Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[StartIndex]]</td>
<td>a non-negative integer</td>
<td>The number of code units from the start of a string at which the match begins (inclusive).</td>
</tr>
<tr>
<td>[[EndIndex]]</td>
<td>an integer ≥ [[StartIndex]]</td>
<td>The number of code units from the start of a string at which the match ends (exclusive).</td>
</tr>
</tbody>
</table>

22.2.7.6 GetMatchString ( S, match )

The abstract operation GetMatchString takes arguments S (a String) and match (a Match Record) and returns a String. It performs the following steps when called:

1. Assert: match.[[StartIndex]] ≤ match.[[EndIndex]] ≤ the length of S.
2. Return the substring of S from match.[[StartIndex]] to match.[[EndIndex]].

22.2.7.7 GetMatchIndexPair ( S, match )

The abstract operation GetMatchIndexPair takes arguments S (a String) and match (a Match Record) and returns an Array. It performs the following steps when called:

1. Assert: match.[[StartIndex]] ≤ match.[[EndIndex]] ≤ the length of S.
2. Return CreateArrayFromList(«(match.[[StartIndex]], match.[[EndIndex]])»).

22.2.7.8 MakeMatchIndicesIndexPairArray ( S, indices, groupNames, hasGroups )

The abstract operation MakeMatchIndicesIndexPairArray takes arguments S (a String), indices (a List of either Match Records or undefined), groupNames (a List of either Strings or undefined), and hasGroups (a Boolean) and returns an Array. It performs the following steps when called:

1. Let n be the number of elements in indices.
2. Assert: n < 2^{32} - 1.
3. Assert: groupNames has n - 1 elements.
4. NOTE: The groupNames List contains elements aligned with the indices List starting at indices[1].
5. Let A be ! ArrayCreate(n).
6. If hasGroups is true, then
   a. Let groups be OrdinaryObjectCreate(null).
7. Else,
   a. Let groups be undefined.
8. Perform ! CreateDataPropertyOrThrow(A, "groups", groups).
9. For each integer i such that 0 ≤ i < n, in ascending order, do
   a. Let matchIndices be indices[i].
   b. If matchIndices is not undefined, then
      i. Let matchIndexPair be GetMatchIndexPair(S, matchIndices).
   c. Else,
      i. Let matchIndexPair be undefined.
   d. Perform ! CreateDataPropertyOrThrow(A, ! ToString(E(i)), matchIndexPair).
   e. If i > 0 and groupNames[i - 1] is not undefined, then
22.2.8 Properties of RegEx Instances

RegEx instances are ordinary objects that inherit properties from the RegEx prototype object. RegEx instances have internal slots [[ OriginalSource ]], [[ OriginalFlags ]], [[ RegExpRecord ]], and [[ RegExpMatcher ]]. The value of the [[ RegExpMatcher ]] internal slot is an Abstract Closure representation of the Pattern of the RegEx object.

NOTE
Prior to ECMAScript 2015, RegEx instances were specified as having the own data properties " source", " global", " ignoreCase", and " multiline". Those properties are now specified as accessor properties of RegExp.prototype.

RegEx instances also have the following property:

22.2.8.1 lastIndex

The value of the " lastIndex " property specifies the String index at which to start the next match. It is coerced to an integral Number when used (see 22.2.7.2). This property shall have the attributes { [[ Writable ]]: true, [[ Enumerable ]]: false, [[ Configurable ]]: false }.

22.2.9 RegEx String Iterator Objects

A RegEx String Iterator is an object that represents a specific iteration over some specific String instance object, matching against some specific RegEx instance object. There is not a named constructor for RegEx String Iterator objects. Instead, RegEx String Iterator objects are created by calling certain methods of RegEx instance objects.

22.2.9.1 CreateRegExpStringIterator ( R , S , global , fullUnicode )

The abstract operation CreateRegExpStringIterator takes arguments R (an Object), S (a String), global (a Boolean), and fullUnicode (a Boolean) and returns a Generator. It performs the following steps when called:

1. Let closure be a new Abstract Closure with no parameters that captures R , S , global , and fullUnicode and performs the following steps when called:
   a. Repeat,
      ii. If match is null, return undefined.
      iii. If global is false, then
            1. Perform ? GeneratorYield( CreateIterResultObject( match , false )).
            2. Return undefined.
      iv. Let matchStr be ? ToString( Get( match , " 0").
       v. If matchStr is the empty String, then
            1. Let thisIndex be ⊤( ? ToLength( ? Get( R , " lastIndex" ) )).
            2. Let nextIndex be AdvanceStringIndex( S , thisIndex , fullUnicode ).
            3. Perform ? Set( R , " lastIndex" , F( nextIndex ) , true).
       vi. Perform ? GeneratorYield( CreateIterResultObject( match , false )).
   2. Return CreateIteratorFromClosure( closure , " % RegExpStringIteratorPrototype %" , % RegExpStringIteratorPrototypePrototype %).

22.2.9.2 The % RegExpStringIteratorPrototype % Object

The % RegExpStringIteratorPrototype % object:

- has properties that are inherited by all RegEx String Iterator Objects.
- is an ordinary object.
• has a [[Prototype]] internal slot whose value is %IteratorPrototype%.
• has the following properties:

22.2.9.2.1 %RegExpStringIteratorPrototype%.next ( )
1. Return ? GeneratorResume(this value, EMPTY, "%RegExpStringIteratorPrototype").

22.2.9.2.2 %RegExpStringIteratorPrototype% [ @@toStringTag ]
The initial value of the @@toStringTag property is the String value "RegExp String Iterator".
This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

23 Indexed Collections

23.1 Array Objects

Arrays are exotic objects that give special treatment to a certain class of property names. See 10.4.2 for a
definition of this special treatment.

23.1.1 The Array Constructor

The Array constructor:

• is %Array%.
• is the initial value of the "Array" property of the global object.
• creates and initializes a new Array when called as a constructor.
• also creates and initializes a new Array when called as a function rather than as a constructor. Thus the
  function call Array(...) is equivalent to the object creation expression new Array(...) with the same
  arguments.
• is a function whose behaviour differs based upon the number and types of its arguments.
• may be used as the value of an extends clause of a class definition. Subclass constructors that intend to
  inherit the exotic Array behaviour must include a super call to the Array constructor to initialize subclass
  instances that are Array exotic objects. However, most of the Array.prototype methods are generic
  methods that are not dependent upon their this value being an Array exotic object.

23.1.1.1 Array ( ...values )

This function performs the following steps when called:

1. If NewTarget is undefined, let newTarget be the active function object; else let newTarget be NewTarget.
2. Let proto be ? GetPrototypeFromConstructor(newTarget, "%Array.prototype").
3. Let numberOfArgs be the number of elements in values.
4. If numberOfArgs = 0, then
   a. Return ! ArrayCreate(0, proto).
5. Else if numberOfArgs = 1, then
   a. Let len be values[0].
   b. Let array be ! ArrayCreate(0, proto).
   c. If len is not a Number, then
      i. Perform ! CreateDataPropertyOrThrow(array, "0", len).
      ii. Let intLen be 1𝔽.
   d. Else,
      i. Let intLen be ! ToUint32(len).
      ii. If SameValueZero(intLen, len) is false, throw a RangeError exception.
e. Perform ! Set(array, "length", intLen, true).
   f. Return array.

6. Else,
   a. Assert: numberOfArgs ≥ 2.
   b. Let array be ArrayCreate(numberOfArgs, proto).
   c. Let k be 0.
   d. Repeat, while k < numberOfArgs,
      i. Let Pk be ! ToString(F(k)).
      ii. Let itemK be values[k].
      iii. Perform ! CreateDataPropertyOrThrow(array, Pk, itemK).
      iv. Set k to k + 1.
   e. Assert: The mathematical value of array's "length" property is numberOfArgs.
   f. Return array.

23.1.2 Properties of the Array Constructor

The Array constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has a "length" property whose value is 1𝔽.
- has the following properties:

23.1.2.1 Array.from (items [, mapfn [, thisArg]])

This method performs the following steps when called:

1. Let C be the this value.
2. If mapfn is undefined, then
   a. Let mapping be false.
3. Else,
   a. If IsCallable(mapfn) is false, throw a TypeError exception.
   b. Let mapping be true.
5. If usingIterator is not undefined, then
   a. If IsConstructor(C) is true, then
      i. Let A be ? Construct(C).
   b. Else,
      i. Let A be ! ArrayCreate(0).
   c. Let iteratorRecord be ? GetIteratorFromMethod(items, usingIterator).
   d. Let k be 0.
   e. Repeat,
      i. If k ≥ 2⁵³ - 1, then
         1. Let error be ThrowCompletion(a newly created TypeError object).
      ii. Let Pk be ! ToString(F(k)).
      iii. Let next be ? IteratorStepValue(iteratorRecord).
      iv. If next is DONE, then
         2. Return A.
      v. If mapping is true, then
         1. Let mappedValue be Completion(Call(mapfn, thisArg, « next, F(k) »)).
         2. IfAbruptCloseIterator(mappedValue, iteratorRecord).
      vi. Else,
         1. Let mappedValue be next.
         vii. Let defineStatus be Completion(CreateDataPropertyOrThrow(A, Pk, mappedValue)).
         viii. IfAbruptCloseIterator(defineStatus, iteratorRecord).
         ix. Set k to k + 1.
6. NOTE: items is not an iterable so assume it is an array-like object.
7. Let arrayLike be ! ToObject(items).
8. Let `len` be `LengthOfArrayLike(arrayLike)`.
9. If `IsConstructor(C)` is `true`, then
   a. Let `A` be `Construct(C, « `𝔽(len) » )`.
10. Else,
    a. Let `A` be `ArrayCreate(len)`.
11. Let `k` be `0`.
12. Repeat, while `k < len`,
   a. Let `Pk` be `ToString(𝔽(k))`.
   b. Let `kValue` be `Get(arrayLike, Pk)`.
   c. If `mapping` is `true`, then
      i. Let `mappedValue` be `Call(mapfn, thisArg, « kValue, 𝒇(k) » )`.
   d. Else,
      i. Let `mappedValue` be `kValue`.
   e. Perform `CreateDataPropertyOrThrow(A, Pk, mappedValue)`.
   f. Set `k` to `k + 1`.
13. Perform `Set(A, "length", 𝒇(len), true)`.

NOTE This method is an intentionally generic factory method; it does not require that its `this` value be the Array constructor. Therefore it can be transferred to or inherited by any other constructors that may be called with a single numeric argument.

23.1.2.2 Array.isArray (arg)

This function performs the following steps when called:
1. Return `IsArray(arg)`.

23.1.2.3 Array.of (...items)

This method performs the following steps when called:
1. Let `len` be the number of elements in `items`.
2. Let `lenNumber` be `𝔽(len)`.
3. Let `C` be the `this` value.
4. If `IsConstructor(C)` is `true`, then
   a. Let `A` be `Construct(C, « lenNumber »)`.
5. Else,
   a. Let `A` be `ArrayCreate(len)`.
6. Let `k` be `0`.
7. Repeat, while `k < len`,
   a. Let `kValue` be `items[k]`.
   b. Let `Pk` be `ToString(𝔽(k))`.
   c. Perform `CreateDataPropertyOrThrow(A, Pk, kValue)`.
   d. Set `k` to `k + 1`.
8. Perform `Set(A, "length", lenNumber, true)`.

NOTE This method is an intentionally generic factory method; it does not require that its `this` value be the Array constructor. Therefore it can be transferred to or inherited by other constructors that may be called with a single numeric argument.

23.1.2.4 Array.prototype

The value of `Array.prototype` is the Array prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.
23.1.2.5 get Array @@species 

Array[@@species] is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "get [Symbol.species]".

NOTE Array prototype methods normally use their this value's constructor to create a derived object. However, a subclass constructor may over-ride that default behaviour by redefining its @@species property.

23.1.3 Properties of the Array Prototype Object

The Array prototype object:

• is %Array.prototype%.
• is an Array exotic object and has the internal methods specified for such objects.
• has a "length" property whose initial value is +0 and whose attributes are { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }.
• has a [[Prototype]] internal slot whose value is %Object.prototype%.

NOTE The Array prototype object is specified to be an Array exotic object to ensure compatibility with ECMAScript code that was created prior to the ECMAScript 2015 specification.

23.1.3.1 Array.prototype.at ( index )

1. Let O be ?ToObject(this value).
2. Let len be ?LengthOfArrayLike(O).
3. Let relativeIndex be ?ToIntegerOrInfinity(index).
4. If relativeIndex ≥ 0, then
   a. Let k be relativeIndex.
5. Else,
   a. Let k be len + relativeIndex.
6. If k < 0 or k ≥ len, return undefined.
7. Return ?Get(O, !ToString(F(k))).

23.1.3.2 Array.prototype.concat ( ...items )

This method returns an array containing the array elements of the object followed by the array elements of each argument.

It performs the following steps when called:

1. Let O be ?ToObject(this value).
2. Let A be ?ArraySpeciesCreate(O, 0).
3. Let n be 0.
4. Prepend O to items.
5. For each element E of items, do
   a. Let spreadable be ?IsConcatSpreadable(E).
   b. If spreadable is true, then
      i. Let len be ?LengthOfArrayLike(E).
      ii. If n + len > 2^{53} - 1, throw a TypeError exception.
      iii. Let k be 0.
      iv. Repeat, while k < len,
1. Let \( P_k \) be \( \text{ToString}(𝔽(k)) \).
2. Let \( \exists \) be \( \text{HasProperty}(E, P_k) \).
3. If \( \exists \) is \text{true}, then
   a. Let \( \text{subElement} \) be \( \text{Get}(E, P_k) \).
   b. Perform \( \text{CreateDataPropertyOrThrow}(A, \text{ToString}(𝔽(n)), \text{subElement}) \).
4. Set \( n \) to \( n + 1 \).
5. Set \( k \) to \( k + 1 \).
6. Perform \( \text{Set}(A, "length", 𝔽(n), \text{true}) \).
7. Return \( A \).

The "length" property of this method is \( 1𝔽 \).

**NOTE 1** The explicit setting of the "length" property in step 6 is intended to ensure the length is correct when the final non-empty element of \( \text{items} \) has trailing holes or when \( A \) is not a built-in Array.

**NOTE 2** This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.2.1 IsConcatSpreadable (O)

The abstract operation IsConcatSpreadable takes argument \( O \) (an ECMAScript language value) and returns either a normal completion containing a Boolean or a throw completion. It performs the following steps when called:

1. If \( O \) is not an Object, return \text{false}.
2. Let \( \text{spreadable} \) be \( \text{Get}(O, @@isConcatSpreadable) \).
3. If \( \text{spreadable} \) is not \text{undefined}, return \text{ToBoolean}(\text{spreadable})
4. Return \( \text{IsArray}(O) \).

### 23.1.3.3 Array.prototype.constructor

The initial value of \text{Array.prototype.constructor} is \%Array\%.

### 23.1.3.4 Array.prototype.copyWithin (target, start [ , end ])

**NOTE 1** The end argument is optional. If it is not provided, the length of the this value is used.

**NOTE 2** If target is negative, it is treated as length + target where length is the length of the array. If start is negative, it is treated as length + start. If end is negative, it is treated as length + end.

This method performs the following steps when called:

1. Let \( O \) be ? \text{ToObject}(this value).
2. Let \( \text{len} \) be \( \text{LengthOfArrayLike}(O) \).
3. Let \( \text{relativeTarget} \) be \( \text{ToIntegerOrInfinity}(target) \).
4. If \( \text{relativeTarget} = -\infty \), let \( to \) be \( 0 \).
5. Else if \( \text{relativeTarget} < 0 \), let \( to \) be \( \text{max}(\text{len} + \text{relativeTarget}, 0) \).
6. Else, let \( to \) be \( \text{min}(\text{relativeTarget}, \text{len}) \).
7. Let \( \text{relativeStart} \) be ? \text{ToIntegerOrInfinity}(start).
8. If \( \text{relativeStart} = -\infty \), let \( from \) be \( 0 \).
9. Else if \( \text{relativeStart} < 0 \), let \( \text{from} \) be \( \max(\text{len} + \text{relativeStart}, 0) \).
10. Else, let \( \text{from} \) be \( \min(\text{relativeStart}, \text{len}) \).
11. If \( \text{end} \) is undefined, let \( \text{relativeEnd} \) be \( \text{len} \); else let \( \text{relativeEnd} \) be ? \( \text{TIntegerOrInfinity}(\text{end}) \).
12. If \( \text{relativeEnd} = -\infty \), let \( \text{final} \) be \( 0 \).
13. Else if \( \text{relativeEnd} < 0 \), let \( \text{final} \) be \( \max(\text{len} + \text{relativeEnd}, 0) \).
14. Else, let \( \text{final} \) be \( \min(\text{relativeEnd}, \text{len}) \).
15. Let \( \text{count} \) be \( \min(\text{final} - \text{from}, \text{len} - \text{to}) \).
16. If \( \text{from} < \text{to} \) and \( \text{to} < \text{from} + \text{count} \), then
   a. Let \( \text{direction} \) be \(-1\).
   b. Set \( \text{from} \) to \( \text{from} + \text{count} - 1 \).
   c. Set \( \text{to} \) to \( \text{to} + \text{count} - 1 \).
17. Else,
   a. Let \( \text{direction} \) be \( 1 \).
18. Repeat, while \( \text{count} > 0 \),
   a. Let \( \text{fromKey} \) be \( ! \) \( \text{ToString}(F(\text{from})) \).
   b. Let \( \text{toKey} \) be \( ! \) \( \text{ToString}(F(\text{to})) \).
   c. Let \( \text{fromPresent} \) be ? \( \text{HasProperty}(\text{O}, \text{fromKey}) \).
   d. If \( \text{fromPresent} \) is \( \text{true} \), then
      i. Let \( \text{fromVal} \) be ? \( \text{Get}(\text{O}, \text{fromKey}) \).
      ii. Perform ? \( \text{Set}(\text{O}, \text{toKey}, \text{fromVal}, \text{true}) \).
   e. Else,
      i. Assert: \( \text{fromPresent} \) is \( \text{false} \).
      ii. Perform ? \( \text{DeletePropertyOrThrow}(\text{O}, \text{toKey}) \).
   f. Set \( \text{from} \) to \( \text{from} + \text{direction} \).
   g. Set \( \text{to} \) to \( \text{to} + \text{direction} \).
   h. Set \( \text{count} \) to \( \text{count} - 1 \).
19. Return \( \text{O} \).

NOTE 3  This method is intentionally generic; it does not require that its \textbf{this} value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.5 Array.prototype.entries ( )

This method performs the following steps when called:

1. Let \( \text{O} \) be ? \( \text{ToObject}(\text{this} \text{ value}) \).
2. Return \( \text{CreateArrayIterator}(\text{O}, \text{KEY+VALUE}) \).
23.1.3.6 Array.prototype.every (callbackfn [, thisArg])

NOTE 1 callbackfn should be a function that accepts three arguments and returns a value that is coercible to a Boolean value. every calls callbackfn once for each element present in the array, in ascending order, until it finds one where callbackfn returns false. If such an element is found, every immediately returns false. Otherwise, if callbackfn returned true for all elements, every will return true. callbackfn is called only for elements of the array which actually exist; it is not called for missing elements of the array.

If a thisArg parameter is provided, it will be used as the this value for each invocation of callbackfn. If it is not provided, undefined is used instead.

callbackfn is called with three arguments: the value of the element, the index of the element, and the object being traversed.

every does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn.

The range of elements processed by every is set before the first call to callbackfn. Elements which are appended to the array after the call to every begins will not be visited by callbackfn. If existing elements of the array are changed, their value as passed to callbackfn will be the value at the time every visits them; elements that are deleted after the call to every begins and before being visited are not visited. every acts like the “for all” quantifier in mathematics. In particular, for an empty array, it returns true.

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(O).
3. If IsCallable(callbackfn) is false, throw a TypeError exception.
4. Let k be 0.
5. Repeat, while k < len,
   a. Let Pk be ! ToString(F(k)).
   b. Let kPresent be ? HasProperty(O, Pk).
   c. If kPresent is true, then
      i. Let kValue be ? Get(O, Pk).
      ii. Let testResult be ToBoolean(? Call(callbackfn, thisArg, « kValue, F(k), O »)).
      iii. If testResult is false, return false.
   d. Set k to k + 1.
6. Return true.

NOTE 2 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.7 Array.prototype.fill (value [, start [, end]])

NOTE 1 The start argument is optional. If it is not provided, +0[^1] is used.

The end argument is optional. If it is not provided, the length of the this value is used.

NOTE 2 If start is negative, it is treated as length + start where length is the length of the array. If end is negative, it is treated as length + end.
This method performs the following steps when called:

1. Let $O$ be $\text{ToObject}(\text{this value})$.
2. Let $\text{len}$ be $\text{LengthOfArrayLike}(O)$.
3. Let $\text{relativeStart}$ be $\text{ToIntegerOrInfinity}(\text{start})$.
4. If $\text{relativeStart} = -\infty$, let $k$ be 0.
5. Else if $\text{relativeStart} < 0$, let $k$ be $\text{max}(\text{len} + \text{relativeStart}, 0)$.
6. Else, let $k$ be $\text{min}(\text{relativeStart}, \text{len})$.
7. If $\text{end}$ is undefined, let $\text{relativeEnd}$ be $\text{len}$; else let $\text{relativeEnd}$ be $\text{ToIntegerOrInfinity}(\text{end})$.
8. If $\text{relativeEnd} = -\infty$, let $\text{final}$ be 0.
9. Else if $\text{relativeEnd} < 0$, let $\text{final}$ be $\text{max}(\text{len} + \text{relativeEnd}, 0)$.
10. Else, let $\text{final}$ be $\text{min}(\text{relativeEnd}, \text{len})$.
11. Repeat, while $k < \text{final}$,
   a. Let $P_k$ be $\text{ToString}(\mathbb{F}(k))$.
   b. Perform $\text{Set}(O, P_k, \text{value}, \text{true})$.
   c. Set $k$ to $k + 1$.
12. Return $O$.

NOTE 3 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.8 Array.prototype.filter (callbackfn [ , thisArg ])

**NOTE 1** callbackfn should be a function that accepts three arguments and returns a value that is coercible to a Boolean value. filter calls callbackfn once for each element in the array, in ascending order, and constructs a new array of all the values for which callbackfn returns true. callbackfn is called only for elements of the array which actually exist; it is not called for missing elements of the array.

If a thisArg parameter is provided, it will be used as the this value for each invocation of callbackfn. If it is not provided, undefined is used instead.

callbackfn is called with three arguments: the value of the element, the index of the element, and the object being traversed.

filter does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn.

The range of elements processed by filter is set before the first call to callbackfn. Elements which are appended to the array after the call to filter begins will not be visited by callbackfn. If existing elements of the array are changed their value as passed to callbackfn will be the value at the time filter visits them; elements that are deleted after the call to filter begins and before being visited are not visited.

This method performs the following steps when called:

1. Let $O$ be $\text{ToObject}(\text{this value})$.
2. Let $\text{len}$ be $\text{LengthOfArrayLike}(O)$.
3. If $\text{isCallable(callbackfn)}$ is false, throw a TypeError exception.
4. Let $A$ be $\text{ArraySpeciesCreate}(O, 0)$.
5. Let $k$ be 0.
6. Let $to$ be 0.
7. Repeat, while $k < \text{len}$,
   a. Let $P_k$ be $\text{ToString}(\mathbb{F}(k))$.
   b. Let $k\text{Present}$ be $\text{HasProperty}(O, P_k)$.
   c. If $k\text{Present}$ is true, then
      i. Let $k\text{Value}$ be $\text{Get}(O, P_k)$.
      ii. Let selected be $\text{ToBoolean}(\text{Call(callbackfn, thisArg, « kValue, F(k), O »})$.
      iii. If selected is true, then
1. Perform `CreateDataPropertyOrThrow(A, !ToString(F(to)), kValue)`.
2. Set `to` to `to + 1`.
3. Set `k` to `k + 1`.
4. Return `A`.

**NOTE 2** This method is intentionally generic; it does not require that its `this` value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.9 Array.prototype.find (`predicate [, thisArg]`)  

**NOTE 1** This method calls `predicate` once for each element of the array, in ascending index order, until it finds one where `predicate` returns a value that coerces to `true`. If such an element is found, `find` immediately returns that element value. Otherwise, `find` returns `undefined`.  

See `FindViaPredicate` for additional information.

This method performs the following steps when called:

1. Let `O` be `ToObject(this value)`.
2. Let `len` be `LengthOfArrayLike(O)`.
3. Let `findRec` be `FindViaPredicate(O, len, ASCENDING, predicate, thisArg)`.
4. Return `findRec.[[Value]]`.

**NOTE 2** This method is intentionally generic; it does not require that its `this` value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.10 Array.prototype.findIndex (`predicate [, thisArg]`)  

**NOTE 1** This method calls `predicate` once for each element of the array, in ascending index order, until it finds one where `predicate` returns a value that coerces to `true`. If such an element is found, `findIndex` immediately returns the index of that element value. Otherwise, `findIndex` returns `-1`.  

See `FindViaPredicate` for additional information.

This method performs the following steps when called:

1. Let `O` be `ToObject(this value)`.
2. Let `len` be `LengthOfArrayLike(O)`.
3. Let `findRec` be `FindViaPredicate(O, len, ASCENDING, predicate, thisArg)`.
4. Return `findRec.[[Index]]`.

**NOTE 2** This method is intentionally generic; it does not require that its `this` value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.11 Array.prototype.findLast (`predicate [, thisArg]`)  

**NOTE 1** This method calls `predicate` once for each element of the array, in descending index order, until it finds one where `predicate` returns a value that coerces to `true`. If such an element is found, `findLast` immediately returns that element value. Otherwise, `findLast` returns `undefined`.  

See `FindViaPredicate` for additional information.
This method performs the following steps when called:

1. Let $O$ be $\text{ToObject}(\text{this value})$.
2. Let $\text{len}$ be $\text{LengthOfArrayLike}(O)$.
3. Let $\text{findRec}$ be $\text{FindViaPredicate}(O, \text{len}, \text{DESCENDING}, \text{predicate}, \text{thisArg})$.
4. Return $\text{findRec}[[\text{Index}]]$.

**NOTE 2** This method is intentionally generic; it does not require that its $\text{this}$ value be an Array object. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.12 Array.prototype.findLastIndex ($\text{predicate} \ [, \ \text{thisArg}]$)

**NOTE 1** This method calls $\text{predicate}$ once for each element of the array, in descending index order, until it finds one where $\text{predicate}$ returns a value that coerces to $\text{true}$. If such an element is found, $\text{findLastIndex}$ immediately returns the index of that element value. Otherwise, $\text{findLastIndex}$ returns -1.

See $\text{FindViaPredicate}$ for additional information.

This method performs the following steps when called:

1. Let $O$ be $\text{ToObject}(\text{this value})$.
2. Let $\text{len}$ be $\text{LengthOfArrayLike}(O)$.
3. Let $\text{findRec}$ be $\text{FindViaPredicate}(O, \text{len}, \text{DESCENDING}, \text{predicate}, \text{thisArg})$.
4. Return $\text{findRec}[[\text{Index}]]$.

**NOTE 2** This method is intentionally generic; it does not require that its $\text{this}$ value be an Array object. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.12.1 FindViaPredicate ($O, \text{len}, \text{direction}, \text{predicate}, \text{thisArg}$)

The abstract operation $\text{FindViaPredicate}$ takes arguments $O$ (an Object), $\text{len}$ (a non-negative integer), $\text{direction}$ (ASCENDING or DESCENDING), $\text{predicate}$ (an ECMAScript language value), and $\text{thisArg}$ (an ECMAScript language value) and returns either a normal completion containing a $\text{Record}$ with fields [[Index]] (an integral Number) and [[Value]] (an ECMAScript language value) or a throw completion.

$O$ should be an array-like object or a TypedArray. This operation calls $\text{predicate}$ once for each element of $O$, in either ascending index order or descending index order (as indicated by $\text{direction}$), until it finds one where $\text{predicate}$ returns a value that coerces to $\text{true}$. At that point, this operation returns a $\text{Record}$ that gives the index and value of the element found. If no such element is found, this operation returns a $\text{Record}$ that specifies -1 for the index and $\text{undefined}$ for the value.

$\text{predicate}$ should be a function. When called for an element of the array, it is passed three arguments: the value of the element, the index of the element, and the object being traversed. Its return value will be coerced to a Boolean value.

$\text{thisArg}$ will be used as the $\text{this}$ value for each invocation of $\text{predicate}$.

This operation does not directly mutate the object on which it is called, but the object may be mutated by the calls to $\text{predicate}$.

The range of elements processed is set before the first call to $\text{predicate}$, just before the traversal begins. Elements that are appended to the array after this will not be visited by $\text{predicate}$. If existing elements of the array are changed, their value as passed to $\text{predicate}$ will be the value at the time that this operation visits them. Elements that are deleted after traversal begins and before being visited are still visited and are either looked up from the prototype or are $\text{undefined}$.
It performs the following steps when called:

1. If `IsCallable(predicate)` is `false`, throw a `TypeError` exception.
2. If `direction` is `ASCENDING`, then
   a. Let `indices` be a List of the integers in the interval from 0 (inclusive) to `len` (exclusive), in ascending order.
3. Else,
   a. Let `indices` be a List of the integers in the interval from 0 (inclusive) to `len` (exclusive), in descending order.
4. For each integer `k` of `indices`, do
   a. Let `Pk` be `ToString(F(k))`.
   b. NOTE: If `O` is a TypedArray, the following invocation of Get will return a normal completion.
   c. Let `kValue` be `Get(O, Pk)`.
   d. Let `testResult` be `Call(predicate, thisArg, « kValue, F(k), O »)`.
   e. If `ToBoolean(testResult)` is `true`, return the Record `{ [[Index]]: F(k), [[Value]]: kValue }`
5. Return the Record `{ [[Index]]: -1𝔽, [[Value]]: undefined }`

23.1.3.13 Array.prototype.flat ([ [ depth ] ])

This method performs the following steps when called:

1. Let `O` be `ToObject(this value)`.
2. Let `sourceLen` be `LengthOfArrayLike(O)`.
3. Let `depthNum` be 1.
4. If `depth` is not `undefined`, then
   a. Set `depthNum` to `ToIntegerOrInfinity(depth)`.
   b. If `depthNum < 0`, set `depthNum` to 0.
5. Let `A` be `ArraySpeciesCreate(O, 0)`.
6. Perform `FlattenIntoArray(A, O, sourceLen, 0, depthNum)`.
7. Return `A`.

23.1.3.13.1 FlattenIntoArray ( `target`, `source`, `sourceLen`, `start`, `depth` [ , `mapperFunction` [ , `thisArg` ] ] )

The abstract operation FlattenIntoArray takes arguments `target` (an Object), `source` (an Object), `sourceLen` (a non-negative integer), `start` (a non-negative integer), and `depth` (a non-negative integer or `+∞`) and optional arguments `mapperFunction` (a function object) and `thisArg` (an ECMAScript language value) and returns either a normal completion containing a non-negative integer or a throw completion. It performs the following steps when called:

1. Assert: If `mapperFunction` is present, then `IsCallable(mapperFunction)` is `true`, `thisArg` is present, and `depth` is 1.
2. Let `targetIndex` be `start`.
3. Let `sourceIndex` be `+0𝔽`.
4. Repeat, while `ℝ(sourceIndex) < sourceLen`,
   a. Let `P` be `ToString(sourceIndex)`.
   b. Let `exists` be `HasProperty(source, P)`.
   c. If `exists` is `true`, then
      i. Let `element` be `Get(source, P)`.
      ii. If `mapperFunction` is present, then
          1. Set `element` to `Call(mapperFunction, thisArg, « element, sourceIndex, source »)`.
      iii. Let `should Flatten` be `false`.
     iv. If `depth` > 0, then
         1. Set `should Flatten` to `IsArray(element)`.
    v. If `should Flatten` is `true`, then
        1. If `depth = +∞`, let `newDepth` be `+∞`.
        2. Else, let `newDepth` be `depth - 1`.
        3. Let `elementLen` be `LengthOfArrayLike(element)`.
        4. Set `targetIndex` to `FlattenIntoArray(target, element, elementLen, targetIndex, newDepth)`.
   vi. Else,
1. If \( \text{targetIndex} \geq 2^{53} - 1 \), throw a \textbf{TypeError} exception.
2. Perform \(? \text{CreateDataPropertyOrThrow} (\text{target}, ! \text{ToString}(F(\text{targetIndex})), \text{element})\).
3. Set \( \text{targetIndex} \) to \( \text{targetIndex} + 1 \).
   a. Set \( \text{sourceIndex} \) to \( \text{sourceIndex} + 1 \).
5. Return \( \text{targetIndex} \).

23.1.3.14 \texttt{Array.prototype.flatMap (mapperFunction [, thisArg])}

This method performs the following steps when called:

1. Let \( O \) be \(? \text{ToObject} (\text{this} \text{value})\).
2. Let \( \text{sourceLen} \) be \(? \text{LengthOfArrayLike} (O)\).
3. If \( \text{IsCallable}(\text{mapperFunction}) \) is \text{false}, throw a \textbf{TypeError} exception.
4. Let \( A \) be \(? \text{ArraySpeciesCreate} (O, 0)\).
5. Perform \(? \text{FlattenIntoArray} (A, O, \text{sourceLen}, 0, 1, \text{mapperFunction}, \text{thisArg})\).
6. Return \( A \).

23.1.3.15 \texttt{Array.prototype.forEach (callbackfn [, thisArg])}

\textbf{NOTE 1} \( \text{callbackfn} \) should be a function that accepts three arguments. \texttt{forEach} calls \( \text{callbackfn} \) once for each element present in the array, in ascending order. \( \text{callbackfn} \) is called only for elements of the array which actually exist; it is not called for missing elements of the array.

If a \( \text{thisArg} \) parameter is provided, it will be used as the \text{this} value for each invocation of \( \text{callbackfn} \). If it is not provided, \text{undefined} is used instead.

\( \text{callbackfn} \) is called with three arguments: the value of the element, the index of the element, and the object being traversed.

\texttt{forEach} does not directly mutate the object on which it is called but the object may be mutated by the calls to \( \text{callbackfn} \).

The range of elements processed by \texttt{forEach} is set before the first call to \( \text{callbackfn} \). Elements which are appended to the array after the call to \texttt{forEach} begins will not be visited by \( \text{callbackfn} \). If existing elements of the array are changed, their value as passed to \( \text{callbackfn} \) will be the value at the time \texttt{forEach} visits them; elements that are deleted after the call to \texttt{forEach} begins and before being visited are not visited.

This method performs the following steps when called:

1. Let \( O \) be \(? \text{ToObject} (\text{this} \text{value})\).
2. Let \( \text{len} \) be \(? \text{LengthOfArrayLike} (O)\).
3. If \( \text{IsCallable}(\text{callbackfn}) \) is \text{false}, throw a \textbf{TypeError} exception.
4. Let \( k \) be \( 0 \).
5. Repeat, while \( k < \text{len} \),
   a. Let \( Pk \) be \(! \text{ToString}(F(k))\).
   b. Let \( k\text{Present} \) be \(? \text{HasProperty}(O, Pk)\).
   c. If \( k\text{Present} \) is \text{true}, then
      i. Let \( k\text{Value} \) be \(? \text{Get}(O, Pk)\).
      ii. Perform \(? \text{Call}(\text{callbackfn}, \text{thisArg}, \langle k\text{Value}, F(k), O \rangle)\).
   d. Set \( k \) to \( k + 1 \).
6. Return \text{undefined}.

\textbf{NOTE 2} This method is intentionally generic; it does not require that its \text{this} value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.
23.1.3.16 Array.prototype.includes (searchElement[, fromIndex])

NOTE 1 This method compares searchElement to the elements of the array, in ascending order, using the SameValueZero algorithm, and if found at any position, returns true; otherwise, it returns false.

The optional second argument fromIndex defaults to +0_F (i.e. the whole array is searched). If it is greater than or equal to the length of the array, false is returned, i.e. the array will not be searched. If it is less than -0_F, it is used as the offset from the end of the array to compute fromIndex. If the computed index is less than or equal to +0_F, the whole array will be searched.

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(O).
3. If len = 0, return false.
4. Let n be ? ToIntegerOrInfinity(fromIndex).
5. Assert: If fromIndex is undefined, then n is 0.
6. If n = +∞, return false.
7. Else if n = -∞, set n to 0.
8. If n ≥ 0, then
   a. Let k be n.
9. Else,
   a. Let k be len + n.
   b. If k < 0, set k to 0.
10. Repeat, while k < len,
   a. Let elementK be ? Get(O, ! ToString(F(k))).
   b. If SameValueZero(searchElement, elementK) is true, return true.
   c. Set k to k + 1.
11. Return false.

NOTE 2 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

NOTE 3 This method intentionally differs from the similar indexOf method in two ways. First, it uses the SameValueZero algorithm, instead of IsStrictlyEqual, allowing it to detect NaN array elements. Second, it does not skip missing array elements, instead treating them as undefined.

23.1.3.17 Array.prototype.indexOf (searchElement[, fromIndex])

This method compares searchElement to the elements of the array, in ascending order, using the IsStrictlyEqual algorithm, and if found at one or more indices, returns the smallest such index; otherwise, it returns -1_F.

NOTE 1 The optional second argument fromIndex defaults to +0_F (i.e. the whole array is searched). If it is greater than or equal to the length of the array, -1_F is returned, i.e. the array will not be searched. If it is less than -0_F, it is used as the offset from the end of the array to compute fromIndex. If the computed index is less than or equal to +0_F, the whole array will be searched.

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(O).
3. If len = 0, return -1_F.
4. Let n be ? ToIntegerOrInfinity(fromIndex).
5. Assert: If fromIndex is undefined, then n is 0.
6. If n = +∞, return undefined.
7. Else if \( n = -\infty \), set \( n \) to 0.
8. If \( n \geq 0 \), then
   a. Let \( k \) be \( n \).
9. Else,
   a. Let \( k \) be \( len + n \).
   b. If \( k < 0 \), set \( k \) to 0.
10. Repeat, while \( k < len \),
    a. Let \( k_{\text{Present}} \) be \( \text{HasProperty}(O, !\text{ToString}(F(k))) \).
    b. If \( k_{\text{Present}} \) is true, then
       i. Let \( elementK \) be \( \text{Get}(O, !\text{ToString}(F(k))) \).
       ii. If \( \text{IsStrictlyEqual}(\text{searchElement}, elementK) \) is true, return \( F(k) \).
    c. Set \( k \) to \( k + 1 \).
11. Return \(-1_F\).

NOTE 2  This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.18  Array.prototype.join ( separator )

This method converts the elements of the array to Strings, and then concatenates these Strings, separated by occurrences of the separator. If no separator is provided, a single comma is used as the separator.

It performs the following steps when called:

1. Let \( O \) be ? \( \text{ToObject}(\text{this} \text{ value}) \).
2. Let \( len \) be \( \text{LengthOfArrayLike}(O) \).
3. If \( \text{separator} \) is undefined, let \( sep \) be ",".
4. Else, let \( sep \) be \( !\text{ToString}(\text{separator}) \).
5. Let \( R \) be the empty String.
6. Let \( k \) be 0.
7. Repeat, while \( k < len \),
   a. If \( k > 0 \), set \( R \) to the string-concatenation of \( R \) and \( sep \).
   b. Let \( element \) be \( \text{Get}(O, !\text{ToString}(F(k))) \).
   c. If \( element \) is either undefined or null, let \( next \) be the empty String; otherwise, let \( next \) be \( !\text{ToString}(element) \).
   d. Set \( R \) to the string-concatenation of \( R \) and \( next \).
   e. Set \( k \) to \( k + 1 \).
8. Return \( R \).

NOTE  This method is intentionally generic; it does not require that its this value be an Array. Therefore, it can be transferred to other kinds of objects for use as a method.

23.1.3.19  Array.prototype.keys ( )

This method performs the following steps when called:

1. Let \( O \) be ? \( \text{ToObject}(\text{this} \text{ value}) \).
2. Return \( \text{CreateArrayIterator}(O, \text{KEY}) \).
23.1.3.20 Array.prototype.lastIndexOf (searchElement [, fromIndex ])

NOTE 1 This method compares searchElement to the elements of the array in descending order using the IsStrictlyEqual algorithm, and if found at one or more indices, returns the largest such index; otherwise, it returns -1𝔽.

The optional second argument fromIndex defaults to the array’s length minus one (i.e. the whole array is searched). If it is greater than or equal to the length of the array, the whole array will be searched. If it is less than -0𝔽, it is used as the offset from the end of the array to compute fromIndex. If the computed index is less than or equal to +0𝔽, -1𝔽 is returned.

This method performs the following steps when called:

1. Let O be ?ToObject(this value).
2. Let len be ?LengthOfArrayLike(O).
3. If len = 0, return -1𝔽.
4. If fromIndex is present, let n be ?ToIntegerOrInfinity(fromIndex); else let n be len - 1.
5. If n = -∞, return -1𝔽.
6. If n ≥ 0, then
   a. Let k be min(n, len - 1).
7. Else,
   a. Let k be len + n.
8. Repeat, while k ≥ 0,
   a. Let kPresent be ?HasProperty(O, !ToString(F(k))).
   b. If kPresent is true, then
      i. Let elementK be ?Get(O, !ToString(F(k))).
      ii. If IsStrictlyEqual(searchElement, elementK) is true, return F(k).
   c. Set k to k - 1.
9. Return -1𝔽.

NOTE 2 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.21 Array.prototype.map (callbackfn [, thisArg ])

NOTE 1 callbackfn should be a function that accepts three arguments. map calls callbackfn once for each element in the array, in ascending order, and constructs a new Array from the results. callbackfn is called only for elements of the array which actually exist; it is not called for missing elements of the array.

If a thisArg parameter is provided, it will be used as the this value for each invocation of callbackfn. If it is not provided, undefined is used instead.

callbackfn is called with three arguments: the value of the element, the index of the element, and the object being traversed.

map does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn.

The range of elements processed by map is set before the first call to callbackfn. Elements which are appended to the array after the call to map begins will not be visited by callbackfn. If existing elements of the array are changed, their value as passed to callbackfn will be the value at the time map visits them; elements that are deleted after the call to map begins and before being visited are not visited.
This method performs the following steps when called:

1. Let \( O \) be \( \text{ToObject}(\text{this} \text{ value}) \).
2. Let \( \text{len} \) be \( \text{LengthOfArrayLike}(O) \).
3. If \( \text{isFunction}(\text{callbackfn}) \) is \( \text{false} \), throw a \( \text{TypeError} \) exception.
4. Let \( A \) be \( \text{ArraySpeciesCreate}(O, \text{len}) \).
5. Let \( k \) be \( 0 \).
6. Repeat, while \( k < \text{len} \),
   a. Let \( Pk \) be \( \text{ToString}(\text{𝔽}(k)) \).
   b. Let \( k\text{Present} \) be \( \text{HasProperty}(O, Pk) \).
   c. If \( k\text{Present} \) is \( \text{true} \), then
      i. Let \( k\text{Value} \) be \( \text{Get}(O, Pk) \).
      ii. Let \( \text{mappedValue} \) be \( \text{Call}(\text{callbackfn}, \text{thisArg}, \langle k\text{Value}, \text{𝔽}(k), O \rangle) \).
      iii. Perform \( \text{CreateDataPropertyOrThrow}(A, Pk, \text{mappedValue}) \).
   d. Set \( k \) to \( k + 1 \).
7. Return \( A \).

NOTE 2 This method is intentionally generic; it does not require that its \( \text{this} \) value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.22 Array.prototype.pop ( )

This method performs the following steps when called:

1. Let \( O \) be \( \text{ToObject}(\text{this} \text{ value}) \).
2. Let \( \text{len} \) be \( \text{LengthOfArrayLike}(O) \).
3. If \( \text{len} \) = \( 0 \), then
   a. Perform \( \text{Set}(O, "\text{length}", +0_F, \text{true}) \).
   b. Return \( \text{undefined} \).
4. Else,
   a. \( \text{Assert: len} > 0 \).
   b. Let \( \text{newLen} \) be \( \text{𝔽}(\text{len} - 1) \).
   c. Let \( \text{index} \) be \( \text{ToString}(\text{newLen}) \).
   d. Let \( \text{element} \) be \( \text{Get}(O, \text{index}) \).
   e. Perform \( \text{DeletePropertyOrThrow}(O, \text{index}) \).
   f. Perform \( \text{Set}(O, "\text{length}", \text{newLen}, \text{true}) \).
   g. Return \( \text{element} \).

NOTE 2 This method is intentionally generic; it does not require that its \( \text{this} \) value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.23 Array.prototype.push ( ...\text{items} )

This method performs the following steps when called:

1. Let \( O \) be \( \text{ToObject}(\text{this} \text{ value}) \).
2. Let \( \text{len} \) be \( \text{LengthOfArrayLike}(O) \).
3. Let \( \text{argCount} \) be the number of elements in \( \text{items} \).
4. If \( \text{len} + \text{argCount} > 2^{53} - 1 \), throw a \( \text{TypeError} \) exception.
5. For each element \( E \) of \( \text{items} \), do
a. Perform \( \text{Set}(O, \text{ToString}(\mathbb{F}(\text{len})), E, \text{true}). \)
b. Set \( \text{len} \) to \( \text{len} + 1 \).
6. Perform \( \text{Set}(O, \text{"length"}, \mathbb{F}(\text{len}), \text{true}). \)
7. Return \( \mathbb{F}(\text{len}) \).

The "length" property of this method is \( 1 \mathbb{F} \).

**NOTE 2** This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.24 Array.prototype.reduce ( \( \text{callbackfn} \) [, \( \text{initialValue} \) ] )

**NOTE 1** \( \text{callbackfn} \) should be a function that takes four arguments. \( \text{reduce} \) calls the callback, as a function, once for each element after the first element present in the array, in ascending order.

\( \text{callbackfn} \) is called with four arguments: the previousValue (value from the previous call to \( \text{callbackfn} \)), the currentValue (value of the current element), the currentIndex, and the object being traversed. The first time that callback is called, the previousValue and currentValue can be one of two values. If an \( \text{initialValue} \) was supplied in the call to \( \text{reduce} \), then previousValue will be \( \text{initialValue} \) and currentValue will be the first value in the array. If no \( \text{initialValue} \) was supplied, then previousValue will be the first value in the array and currentValue will be the second. It is a TypeError if the array contains no elements and \( \text{initialValue} \) is not provided.

\( \text{reduce} \) does not directly mutate the object on which it is called but the object may be mutated by the calls to \( \text{callbackfn} \).

The range of elements processed by \( \text{reduce} \) is set before the first call to \( \text{callbackfn} \). Elements that are appended to the array after the call to \( \text{reduce} \) begins will not be visited by \( \text{callbackfn} \). If existing elements of the array are changed, their value as passed to \( \text{callbackfn} \) will be the value at the time \( \text{reduce} \) visits them; elements that are deleted after the call to \( \text{reduce} \) begins and before being visited are not visited.

This method performs the following steps when called:

1. Let \( O \) be ? \( \text{ToObject}(\text{this} \text{ value}). \)
2. Let \( \text{len} \) be ? \( \text{LengthOfArrayLike}(O) \).
3. If \( \text{IsCallable}(\text{callbackfn}) \) is false, throw a TypeError exception.
4. If \( \text{len} = 0 \) and \( \text{initialValue} \) is not present, throw a TypeError exception.
5. Let \( k \) be 0.
6. Let \( \text{accumulator} \) be undefined.
7. If \( \text{initialValue} \) is present, then
   a. Set \( \text{accumulator} \) to \( \text{initialValue} \).
8. Else,
   a. Let \( k\text{Present} \) be false.
   b. Repeat, while \( k\text{Present} \) is false and \( k < \text{len} \),
      i. Let \( Pk \) be ! \( \text{ToString}(\mathbb{F}(k)) \).
      ii. Set \( k\text{Present} \) to ? \( \text{HasProperty}(O, Pk) \).
      iii. If \( k\text{Present} \) is true, then
          1. Set \( \text{accumulator} \) to ? \( \text{Get}(O, Pk) \).
      iv. Set \( k \) to \( k + 1 \).
   c. If \( k\text{Present} \) is false, throw a TypeError exception.
9. Repeat, while \( k < \text{len} \),
   a. Let \( Pk \) be ! \( \text{ToString}(\mathbb{F}(k)) \).
   b. Let \( k\text{Present} \) be ? \( \text{HasProperty}(O, Pk) \).
   c. If \( k\text{Present} \) is true, then
i. Let kValue be ? Get(O, Pk).
   ii. Set accumulator to ? Call(callbackfn, undefined, « accumulator, kValue, 𝔽(k), O »).
   d. Set k to k + 1.
10. Return accumulator.

NOTE 2  This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.25 Array.prototype.reduceRight (callbackfn[, initialValue])

NOTE 1 callbackfn should be a function that takes four arguments. reduceRight calls the callback, as a function, once for each element after the first element present in the array, in descending order.

callbackfn is called with four arguments: the previousValue (value from the previous call to callbackfn), the currentValue (value of the current element), the currentIndex, and the object being traversed. The first time the function is called, the previousValue and currentValue can be one of two values. If an initialValue was supplied in the call to reduceRight, then previousValue will be initialValue and currentValue will be the last value in the array. If no initialValue was supplied, then previousValue will be the last value in the array and currentValue will be the second-to-last value. It is a TypeError if the array contains no elements and initialValue is not provided.

reduceRight does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn.

The range of elements processed by reduceRight is set before the first call to callbackfn. Elements that are appended to the array after the call to reduceRight begins will not be visited by callbackfn. If existing elements of the array are changed by callbackfn, their value as passed to callbackfn will be the value at the time reduceRight visits them; elements that are deleted after the call to reduceRight begins and before being visited are not visited.

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(O).
3. If IsCallable(callbackfn) is false, throw a TypeError exception.
4. If len = 0 and initialValue is not present, throw a TypeError exception.
5. Let k be len - 1.
6. Let accumulator be undefined.
7. If initialValue is present, then
   a. Set accumulator to initialValue.
8. Else,
   a. Let kPresent be false.
   b. Repeat, while kPresent is false and k ≥ 0,
      i. Let Pk be ! ToString(𝔽(k)).
      ii. Set kPresent to ? HasProperty(O, Pk).
      iii. If kPresent is true, then
          1. Set accumulator to ? Get(O, Pk).
          4. Set k to k - 1.
   c. If kPresent is false, throw a TypeError exception.
9. Repeat, while k ≥ 0,
   a. Let Pk be ! ToString(𝔽(k)).
   b. Let kPresent be ? HasProperty(O, Pk).
   c. If kPresent is true, then
      i. Let kValue be ? Get(O, Pk).
      ii. Set accumulator to ? Call(callbackfn, undefined, « accumulator, kValue, 𝔽(k), O »).
   d. Set k to k - 1.
10. Return accumulator.
This method is intentionally generic; it does not require that its \texttt{this} value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.26 \texttt{Array.prototype.reverse ( )}

This method rearranges the elements of the array so as to reverse their order. It returns the object as the result of the call.

This method performs the following steps when called:

1. Let $O$ be \texttt{ToObject(this value)}.
2. Let $len$ be \texttt{LengthOfArrayLike(O)}.
3. Let $middle$ be $\text{floor}(len / 2)$.
4. Let $lower$ be 0.
5. Repeat, while $lower \neq middle$:
   a. Let $upper$ be $len - lower - 1$.
   b. Let $upperP$ be \texttt{ToString(F(upper))}.
   c. Let $lowerP$ be \texttt{ToString(F(lower))}.
   d. Let $lowerExists$ be \texttt{HasProperty(O, lowerP)}.
      i. If $lowerExists$ is true, then
         a. Let $lowerValue$ be \texttt{Get(O, lowerP)}.
      f. Let $upperExists$ be \texttt{HasProperty(O, upperP)}.
      g. If $upperExists$ is true, then
         i. Let $upperValue$ be \texttt{Get(O, upperP)}.
   h. If $lowerExists$ is true and $upperExists$ is true, then
      i. Perform \texttt{Set(O, lowerP, upperValue, true)}.
      ii. Perform \texttt{Set(O, upperP, lowerValue, true)}.
   i. Else if $lowerExists$ is false and $upperExists$ is true, then
      i. Perform \texttt{Set(O, lowerP, upperValue, true)}.
      ii. Perform \texttt{DeletePropertyOrThrow(O, upperP)}.
   j. Else if $lowerExists$ is true and $upperExists$ is false, then
      i. Perform \texttt{DeletePropertyOrThrow(O, lowerP)}.
      ii. Perform \texttt{Set(O, upperP, lowerValue, true)}.
   k. Else,
      i. \textbf{assert}: $lowerExists$ and $upperExists$ are both false.
      ii. NOTE: No action is required.
   l. Set $lower$ to $lower + 1$.
6. Return $O$.

This method is intentionally generic; it does not require that its \texttt{this} value be an Array. Therefore, it can be transferred to other kinds of objects for use as a method.

23.1.3.27 \texttt{Array.prototype.shift ( )}

This method removes the first element of the array and returns it.

It performs the following steps when called:

1. Let $O$ be \texttt{ToObject(this value)}.
2. Let $len$ be \texttt{LengthOfArrayLike(O)}.
3. If $len = 0$, then
   a. Perform \texttt{Set(O, "length", +0F, true)}.
   b. Return \texttt{undefined}.
4. Let $first$ be \texttt{Get(O, "0")}.
5. Let $k$ be 1.
6. Repeat, while $k < len$,
a. Let $\text{from}$ be $\text{ToString}(\mathbb{F}(k))$.
b. Let $\text{to}$ be $\text{ToString}(\mathbb{F}(k - 1))$.
c. Let $\text{fromPresent}$ be $\text{HasProperty}(O, \text{from})$.
d. If $\text{fromPresent}$ is true, then
   i. Let $\text{fromVal}$ be $\text{Get}(O, \text{from})$.
   ii. Perform ? $\text{Set}(O, \text{to}, \text{fromVal}, \text{true})$.
e. Else,
   i. Assert: $\text{fromPresent}$ is false.
   ii. Perform ? $\text{DeletePropertyOrThrow}(O, \text{to})$.
f. Set $k$ to $k + 1$.
7. Perform ? $\text{DeletePropertyOrThrow}(O, ! \text{ToString}(\mathbb{F}(\text{len} - 1)))$.
8. Perform ? $\text{Set}(O, "length", \mathbb{F}(\text{len} - 1), \text{true})$.
9. Return first.

NOTE 1 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

### 23.1.3.28 Array.prototype.slice (start, end)

This method returns an array containing the elements of the array from element start up to, but not including, element end (or through the end of the array if end is undefined). If start is negative, it is treated as length + start where length is the length of the array. If end is negative, it is treated as length + end where length is the length of the array.

It performs the following steps when called:

1. Let $O$ be ? $\text{ToObject}(\text{this value})$.
2. Let $\text{len}$ be $\text{LengthOfArrayLike}(O)$.
3. Let $\text{relativeStart}$ be $\text{ToIntegerOrInfinity}(\text{start})$.
4. If $\text{relativeStart} = -\infty$, let $k$ be 0.
5. Else if $\text{relativeStart} < 0$, let $k$ be $\text{max}(\text{len} + \text{relativeStart}, 0)$.
6. Else, let $k$ be $\text{min}(\text{relativeStart}, \text{len})$.
7. If end is undefined, let $\text{relativeEnd}$ be $\text{len}$; else let $\text{relativeEnd}$ be ? $\text{ToIntegerOrInfinity}(\text{end})$.
8. If $\text{relativeEnd} = -\infty$, let $\text{final}$ be 0.
9. Else if $\text{relativeEnd} < 0$, let $\text{final}$ be $\text{max}(\text{len} + \text{relativeEnd}, 0)$.
10. Else, let $\text{final}$ be $\text{min}(\text{relativeEnd}, \text{len})$.
11. Let $\text{count}$ be $\text{max}(\text{final} - k, 0)$.
12. Let $A$ be ? $\text{ArraySpeciesCreate}(O, \text{count})$.
13. Let $n$ be 0.
14. Repeat, while $k < \text{final}$,
   a. Let $P_k$ be ! $\text{ToString}(\mathbb{F}(k))$.
   b. Let $k\text{Present}$ be ? $\text{HasProperty}(O, P_k)$.
   c. If $k\text{Present}$ is true, then
      i. Let $k\text{Value}$ be $\text{Get}(O, P_k)$.
      ii. Perform ? $\text{CreateDataPropertyOrThrow}(A, ! \text{ToString}(\mathbb{F}(n)), k\text{Value})$.
   d. Set $k$ to $k + 1$.
   e. Set $n$ to $n + 1$.
15. Perform ? $\text{Set}(A, "length", \mathbb{F}(n), \text{true})$.

NOTE 1 The explicit setting of the "length" property in step 15 is intended to ensure the length is correct even when $A$ is not a built-in Array.

NOTE 2 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.
23.1.3.29 Array.prototype.some ( callbackfn [, thisArg ] )

NOTE 1 callbackfn should be a function that accepts three arguments and returns a value that is coercible to a Boolean value. some calls callbackfn once for each element present in the array, in ascending order, until it finds one where callbackfn returns true. If such an element is found, some immediately returns true. Otherwise, some returns false. callbackfn is called only for elements of the array which actually exist; it is not called for missing elements of the array.

If a thisArg parameter is provided, it will be used as the this value for each invocation of callbackfn. If it is not provided, undefined is used instead.

callbackfn is called with three arguments: the value of the element, the index of the element, and the object being traversed.

some does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn.

The range of elements processed by some is set before the first call to callbackfn. Elements that are appended to the array after the call to some begins will not be visited by callbackfn. If existing elements of the array are changed, their value as passed to callbackfn will be the value at the time that some visits them; elements that are deleted after the call to some begins and before being visited are not visited. some acts like the "exists" quantifier in mathematics. In particular, for an empty array, it returns false.

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(O).
3. If IsCallable(callbackfn) is false, throw a TypeError exception.
4. Let k be 0.
5. Repeat, while k < len,
   a. Let Pk be ! ToString(F(k)).
   b. Let kPresent be ? HasProperty(O, Pk).
   c. If kPresent is true, then
      i. Let kValue be ? Get(O, Pk).
      ii. Let testResult be ToBoolean(? Call(callbackfn, thisArg, « kValue, F(k), O »)).
      iii. If testResult is true, return true.
   d. Set k to k + 1.
6. Return false.

NOTE 2 This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.30 Array.prototype.sort ( comparefn )

This method sorts the elements of this array. The sort must be stable (that is, elements that compare equal must remain in their original order). If comparefn is not undefined, it should be a function that accepts two arguments x and y and returns a negative Number if \( x < y \), a positive Number if \( x > y \), or a zero otherwise.

It performs the following steps when called:

1. If comparefn is not undefined and IsCallable(comparefn) is false, throw a TypeError exception.
2. Let obj be ? ToObject(this value).
3. Let len be ? LengthOfArrayLike(obj).
4. Let SortCompare be a new Abstract Closure with parameters (x, y) that captures comparefn and performs the following steps when called:
   a. Return ? CompareArrayElements(x, y, comparefn).
5. Let sortedList be ? SortIndexedProperties(obj, len, SortCompare, SKIP-HOLES).
6. Let \( itemCount \) be the number of elements in \( sortedList \).
7. Let \( j \) be 0.
8. Repeat, while \( j < itemCount \),
   a. Perform \( \text{Set}(obj, !\text{ToString}(F(j)), sortedList[j], \text{true}) \).
   b. Set \( j \) to \( j + 1 \).
9. NOTE: The call to \( \text{SortIndexedProperties} \) in step 5 uses SKIP-HOLES. The remaining indices are deleted to preserve the number of holes that were detected and excluded from the sort.
10. Repeat, while \( j < \text{len} \),
    a. Perform \( \text{DeletePropertyOrThrow}(obj, !\text{ToString}(F(j))) \).
    b. Set \( j \) to \( j + 1 \).
11. Return \( obj \).

NOTE 1: Because non-existent property values always compare greater than \textit{undefined} property values, and \textit{undefined} always compares greater than any other value (see \textit{CompareArrayElements}), \textit{undefined} property values always sort to the end of the result, followed by non-existent property values.

NOTE 2: Method calls performed by the \textit{ToString} abstract operations in steps 5 and 6 have the potential to cause \textit{SortCompare} to not behave as a consistent comparator.

NOTE 3: This method is intentionally generic; it does not require that its \textit{this} value be an Array. Therefore, it can be transferred to other kinds of objects for use as a method.

23.1.3.30.1 \textit{SortIndexedProperties} ( \( obj, \text{len}, \text{SortCompare}, \text{holes} \) )

The abstract operation \( \text{SortIndexedProperties} \) takes arguments \( obj \) (an Object), \( \text{len} \) (a non-negative \textit{integer}), \textit{SortCompare} (an \textit{Abstract Closure} with two parameters), and \( \text{holes} \) (SKIP-HOLES or READ-THROUGH-HOLES) and returns either a normal completion containing a \textit{List} of ECMAScript language values or a throw completion.

It performs the following steps when called:

1. Let \( items \) be a new empty \textit{List}.
2. Let \( k \) be 0.
3. Repeat, while \( k < \text{len} \),
   a. Let \( Pk \) be \( !\text{ToString}(F(k)) \).
   b. If \( \text{holes} \) is SKIP-HOLES, then
      i. Let \( kRead \) be \( ?\text{HasProperty}(obj, Pk) \).
   c. Else,
      i. \textit{Assert: holes} is READ-THROUGH-HOLES.
      ii. Let \( kRead \) be \textit{true}.
   d. If \( kRead \) is \textit{true}, then
      i. Let \( kValue \) be \( ?\text{Get}(obj, Pk) \).
      ii. Append \( kValue \) to \( items \).
   e. Set \( k \) to \( k + 1 \).
4. Sort \( items \) using an implementation-defined sequence of calls to \textit{SortCompare}. If any such call returns an abrupt completion, stop before performing any further calls to \textit{SortCompare} and return that \textit{Completion Record}.
5. Return \( items \).

The \textit{sort order} is the ordering of \( items \) after completion of step 4 of the algorithm above. The \textit{sort order} is implementation-defined if \textit{SortCompare} is not a consistent comparator for the elements of \( items \). When \textit{SortIndexedProperties} is invoked by \textit{Array.prototype.sort}, the \textit{sort order} is also implementation-defined if \textit{comparefn} is \textit{undefined}, and all applications of \textit{ToString}, to any specific value passed as an argument to \textit{SortCompare}, do not produce the same result.

Unless the \textit{sort order} is specified to be implementation-defined, it must satisfy all of the following conditions:

- There must be some mathematical permutation \( \pi \) of the non-negative \textit{integers} less than \( itemCount \), such
that for every non-negative integer \( j \) less than \( \text{itemCount} \), the element \( \text{old}[j] \) is exactly the same as \( \text{new}[\pi(j)] \).

- Then for all non-negative integers \( j \) and \( k \), each less than \( \text{itemCount} \), if \( R(\text{SortCompare}(\text{old}[j], \text{old}[k])) < 0 \), then \( \pi(j) < \pi(k) \).

Here the notation \( \text{old}[j] \) is used to refer to \( \text{items}[j] \) before step 4 is executed, and the notation \( \text{new}[j] \) to refer to \( \text{items}[j] \) after step 4 has been executed.

An abstract closure or function \( \text{comparator} \) is a consistent comparator for a set of values \( S \) if all of the requirements below are met for all values \( a \), \( b \), and \( c \) (possibly the same value) in the set \( S \): The notation \( a \prec_c b \) means \( R(\text{comparator}(a, b)) < 0 \); \( a =_c b \) means \( R(\text{comparator}(a, b)) = 0 \); and \( a \succ_c b \) means \( R(\text{comparator}(a, b)) > 0 \).

- Calling \( \text{comparator}(a, b) \) always returns the same value \( v \) when given a specific pair of values \( a \) and \( b \) as its two arguments. Furthermore, \( v \) is a Number, and \( v \) is not \( \text{NaN} \). Note that this implies that exactly one of \( a \prec_c b \), \( a =_c b \), and \( a \succ_c b \) will be true for a given pair of \( a \) and \( b \).
- Calling \( \text{comparator}(a, b) \) does not modify \( \text{obj} \) or any object on \( \text{obj}'s \) prototype chain.
- \( a =_c a \) (reflexivity)
- If \( a =_c b \), then \( b =_c a \) (symmetry)
- If \( a =_c b \) and \( b =_c c \), then \( a =_c c \) (transitivity of \( =_c \))
- If \( a \prec_c b \) and \( b \prec_c c \), then \( a \prec_c c \) (transitivity of \( \prec_c \))
- If \( a \succ_c b \) and \( b \succ_c c \), then \( a \succ_c c \) (transitivity of \( \succ_c \))

**NOTE** The above conditions are necessary and sufficient to ensure that \( \text{comparator} \) divides the set \( S \) into equivalence classes and that these equivalence classes are totally ordered.

### 23.1.3.30.2 CompareArrayElements ( \( x, y, \text{comparefn} \) )

The abstract operation \( \text{CompareArrayElements} \) takes arguments \( x \) (an \text{ECMAScript language value}), \( y \) (an \text{ECMAScript language value}), and \( \text{comparefn} \) (a function object or \text{undefined}) and returns either a normal completion containing a Number or an abrupt completion. It performs the following steps when called:

1. If \( x \) and \( y \) are both \text{undefined}, return \( +0 \).F.
2. If \( x \) is \text{undefined}, return \( 1 \).F.
3. If \( y \) is \text{undefined}, return \( -1 \).F.
4. If \( \text{comparefn} \) is not \text{undefined}, then
   a. Let \( v \) be \( \text{ToNumber}(? \text{Call}(\text{comparefn}, \text{undefined}, \text{comparefn}, [x, y])) \).
   b. If \( v \) is \text{NaN}, return \( +0 \).F.
   c. Return \( v \).
5. Let \( x\text{String} \) be ? \( \text{ToString}(x) \).
6. Let \( y\text{String} \) be ? \( \text{ToString}(y) \).
7. Let \( x\text{Smaller} \) be \( \text{IsLessThan}(x\text{String}, y\text{String}, \text{true}) \).
8. If \( x\text{Smaller} \) is \text{true}, return \( -1 \).F.
9. Let \( y\text{Smaller} \) be \( \text{IsLessThan}(y\text{String}, x\text{String}, \text{true}) \).
10. If \( y\text{Smaller} \) is \text{true}, return \( 1 \).F.
11. Return \( +0 \).F.

### 23.1.3.31 Array.prototype.splice ( \( \text{start}, \text{deleteCount}, \ldots \text{items} \) )

**NOTE 1** This method deletes the \( \text{deleteCount} \) elements of the array starting at \text{integer index} \( \text{start} \) and replaces them with the elements of \( \text{items} \). It returns an Array containing the deleted elements (if any).

This method performs the following steps when called:

1. Let \( O \) be ? \( \text{ToObject}(\text{this} \text{ value}) \).
2. Let \( \text{len} \) be \( \text{LengthOfArrayLike}(O) \).
3. Let \( \text{relativeStart} \) be ? \( \text{ToIntegerOrInfinity}(\text{start}) \).
4. If `relativeStart` = -∞, let `actualStart` be 0.
5. Else if `relativeStart` < 0, let `actualStart` be `max(len + relativeStart, 0)`.
6. Else, let `actualStart` be `min(relativeStart, len)`.
7. Let `itemCount` be the number of elements in `items`.
8. If `start` is not present, then
   a. Let `actualDeleteCount` be 0.
9. Else if `deleteCount` is not present, then
   a. Let `actualDeleteCount` be `len - actualStart`.
10. Else,
    a. Let `dc` be ? `ToIntOrInfinity(deleteCount)`,
    b. Let `actualDeleteCount` be the result of clamping `dc` between 0 and `len - actualStart`.
11. If `len + itemCount - actualDeleteCount > 2^{53} - 1`, throw a `TypeError` exception.
12. Let `A` be ? `ArraySpeciesCreate(O, actualDeleteCount)`.
13. Let `k` be 0.
14. Repeat, while `k < actualDeleteCount`,
    a. Let `from` be ! `ToString(F(actualStart + k))`.
    b. If ? `HasProperty(O, from)` is true, then
       i. Let `fromValue` be ? `Get(O, from)`.
       ii. Perform ? `CreateDataPropertyOrThrow(A, ! ToString(F(k)), fromValue)`.
    c. Set `k` to `k + 1`.
16. If `itemCount < actualDeleteCount`, then
    a. Set `k` to `actualStart`.
    b. Repeat, while `k < (len - actualDeleteCount)`,
       i. Let `from` be ! `ToString(F(k + actualDeleteCount))`.
       ii. Let `to` be ! `ToString(F(k + itemCount))`.
       iii. If ? `HasProperty(O, from)` is true, then
            1. Let `fromValue` be ? `Get(O, from)`.
            2. Perform ? `Set(O, to, fromValue, true)`.
       iv. Else,
            1. Perform ? `DeletePropertyOrThrow(O, to)`.
            v. Set `k` to `k + 1`.
    c. Set `k` to `len`.
    d. Repeat, while `k > (len - actualDeleteCount + itemCount)`,
       i. Perform ? `DeletePropertyOrThrow(O, ! ToString(F(k - 1)))`.
       ii. Set `k` to `k - 1`.
17. Else if `itemCount > actualDeleteCount`, then
    a. Set `k` to `(len - actualDeleteCount)`.
    b. Repeat, while `k > actualStart`,
       i. Let `from` be ! `ToString(F(k + actualDeleteCount - 1))`.
       ii. Let `to` be ! `ToString(F(k + itemCount - 1))`.
       iii. If ? `HasProperty(O, from)` is true, then
            1. Let `fromValue` be ? `Get(O, from)`.
            2. Perform ? `Set(O, to, fromValue, true)`.
       iv. Else,
            1. Perform ? `DeletePropertyOrThrow(O, to)`.
            v. Set `k` to `k - 1`.
18. Set `k` to `actualStart`.
19. For each element `E` of `items`, do
    a. Perform ? `Set(O, ! ToString(F(k))), E, true)`.
    b. Set `k` to `k + 1`.
20. Perform ? `Set(O, "length", F(len - actualDeleteCount + itemCount), true)`.

NOTE 2 The explicit setting of the "length" property in steps 15 and 20 is intended to ensure the lengths are correct even when the objects are not built-in Arrays.
This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

An ECMAScript implementation that includes the ECMA-402 Internationalization API must implement this method as specified in the ECMA-402 specification. If an ECMAScript implementation does not include the ECMA-402 API the following specification of this method is used.

This method performs the following steps when called:

1. Let array be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(array).
3. Let separator be the implementation-defined list-separator String value appropriate for the host environment's current locale (such as ", ").
4. Let R be the empty String.
5. Let k be 0.
6. Repeat, while k < len,
   a. If k > 0, then
      i. Set R to the string-concatenation of R and separator.
   b. Let nextElement be ? Get(array, ! ToString(𝔽(k))).
   c. If nextElement is neither undefined nor null, then
      i. Let S be ? ToString(? Invoke(nextElement, "toLocaleString")).
      ii. Set R to the string-concatenation of R and S.
   d. Set k to k + 1.
7. Return R.

This method converts the elements of the array to Strings using their toLocaleString methods, and then concatenates these Strings, separated by occurrences of an implementation-defined locale-sensitive separator String. This method is analogous to toString except that it is intended to yield a locale-sensitive result corresponding with conventions of the host environment's current locale.

This method is intentionally generic; it does not require that its this value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

This method performs the following steps when called:

1. Let O be ? ToObject(this value).
2. Let len be ? LengthOfArrayLike(O).
3. Let A be ? ArrayCreate(len).
4. Let k be 0.
5. Repeat, while k < len,
   a. Let from be ! ToString(𝔽(len - k - 1)).
   b. LetPk be ! ToString(𝔽(k)).
   c. Let fromValue be ? Get(O, from).
d. Perform ! CreateDataPropertyOrThrow(A, Pk, fromValue).
e. Set \( k \) to \( k + 1 \).
6. Return \( A \).

23.1.3.34 Array.prototype.toSorted ( comparefn )

This method performs the following steps when called:

1. If \( \text{comparefn} \) is not \texttt{undefined} and \texttt{IsCallable(comparefn)} is \texttt{false}, throw a \texttt{TypeError} exception.
2. Let \( O \) be ? ToObject(this value).
3. Let \( \text{len} \) be ? LengthOfArrayLike\((O)\).
4. Let \( A \) be ? ArrayCreate\(\text{len}\).
5. Let \( \text{SortCompare} \) be a new \texttt{Abstract Closure} with parameters \((x, y)\) that captures \texttt{comparefn} and performs the following steps when called:
   a. Return ? CompareArrayElements\((x, y, \text{comparefn})\).
6. Let \( \text{sortedList} \) be ? SortIndexedProperties\((O, \text{len}, \text{SortCompare}, \text{READ-THROUGH-HOLES})\).
7. Let \( j \) be \( 0 \).
8. Repeat, while \( j < \text{len} \):
   a. Perform ! CreateDataPropertyOrThrow\((A, ! \text{ToString}(𝔽(j)), \text{sortedList}[j])\).
   b. Set \( j \) to \( j + 1 \).
9. Return \( A \).

23.1.3.35 Array.prototype.toSpliced ( start, skipCount, ...items )

This method performs the following steps when called:

1. Let \( O \) be ? ToObject(this value).
2. Let \( \text{len} \) be ? LengthOfArrayLike\((O)\).
3. Let \( \text{relativeStart} \) be ? ToIntegerOrInfinity\((\text{start})\).
4. If \( \text{relativeStart} \) is \( -\infty \), let \( \text{actualStart} \) be \( 0 \).
5. Else if \( \text{relativeStart} < 0 \), let \( \text{actualStart} \) be \( \max(\text{len} + \text{relativeStart}, 0) \).
6. Else, let \( \text{actualStart} \) be \( \min(\text{relativeStart}, \text{len}) \).
7. Let \( \text{insertCount} \) be the number of elements in \( \text{items} \).
8. If \( \text{start} \) is not present, then
   a. Let \( \text{actualSkipCount} \) be \( 0 \).
9. Else if \( \text{skipCount} \) is not present, then
   a. Let \( \text{actualSkipCount} \) be \( \text{len} - \text{actualStart} \).
10. Else,
    a. Let \( \text{sc} \) be ? ToIntegerOrInfinity\((\text{skipCount})\).
    b. Let \( \text{actualSkipCount} \) be the result of clamping \( \text{sc} \) between \( 0 \) and \( \text{len} - \text{actualStart} \).
11. Let \( \text{newLen} \) be \( \text{len} + \text{insertCount} - \text{actualSkipCount} \).
12. If \( \text{newLen} > 2^{53} - 1 \), throw a \texttt{TypeError} exception.
13. Let \( A \) be ? ArrayCreate\(\text{newLen}\).
14. Let \( i \) be \( 0 \).
15. Let \( r \) be \( \text{actualStart} + \text{actualSkipCount} \).
16. Repeat, while \( i < \text{actualStart} \):
    a. Let \( \text{Pi} \) be \( ! \text{ToString}(𝔽(i)) \).
    b. Let \( \text{iValue} \) be ? Get\((O, \text{Pi})\).
    c. Perform ! CreateDataPropertyOrThrow\((A, \text{Pi}, \text{iValue})\).
    d. Set \( i \) to \( i + 1 \).
17. For each element \( E \) of \( \text{items} \), do
    a. Let \( \text{Pi} \) be \( ! \text{ToString}(𝔽(i)) \).
    b. Perform ! CreateDataPropertyOrThrow\((A, \text{Pi}, E)\).
    c. Set \( i \) to \( i + 1 \).
18. Repeat, while \( i < \text{newLen} \):
    a. Let \( \text{Pi} \) be \( ! \text{ToString}(𝔽(i)) \).
    b. Let \( \text{from} \) be \( ! \text{ToString}(𝔽(r)) \).
    c. Let \( \text{fromValue} \) be ? Get\((O, \text{from})\).
    d. Perform ! CreateDataPropertyOrThrow\((A, \text{Pi}, \text{fromValue})\).
19. Return \text{\textit{A}}.

23.1.3.36 \texttt{Array.prototype.toString()} \\

This method performs the following steps when called:

1. Let \textit{array} be \texttt{ToObject(\textit{this} value)}.
2. Let \textit{func} be \texttt{Get(array, \text{"join"})}.
3. If \texttt{IsCallable(func)} is \texttt{false}, set \textit{func} to the intrinsic function \texttt{%Object.prototype.toString%}.
4. Return \texttt{Call(func, array)}.

\textbf{NOTE} This method is intentionally generic; it does not require that its \textit{this} value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.

23.1.3.37 \texttt{Array.prototype.unshift( ...\textit{items} )} \\

This method prepends the arguments to the start of the array, such that their order within the array is the same as the order in which they appear in the argument list.

It performs the following steps when called:

1. Let \textit{O} be \texttt{ToObject(\textit{this} value)}.
2. Let \textit{len} be \texttt{LengthOfArrayLike(\textit{O})}.
3. Let \textit{argCount} be the number of elements in \textit{items}.
4. If \texttt{argCount > 0}, then
   a. If \texttt{len + argCount > 2^{53} - 1}, throw a \texttt{TypeError} exception.
   b. Let \textit{k} be \textit{len}.
   c. Repeat, while \textit{k} > 0,
      i. Let \textit{from} be \texttt{ToString(\textit{O}(k - 1))}.
      ii. Let \textit{to} be \texttt{ToString(\textit{O}(k + argCount - 1))}.
      iii. Let \textit{fromPresent} be \texttt{HasProperty(\textit{O}, from)}.
      iv. If \textit{fromPresent} is \texttt{true}, then
          1. Let \textit{fromValue} be \texttt{Get(\textit{O}, from)}.
          2. Perform \texttt{Set(\textit{O}, to, fromValue, true)}.
      v. Else,
          1. \texttt{Assert: fromPresent is false}.
          2. Perform \texttt{DeletePropertyOrThrow(\textit{O}, to)}.
      vi. Set \textit{k} to \textit{k - 1}.
   d. Let \textit{j} be \texttt{+0F}.
   e. For each element \textit{E} of \textit{items}, do
      i. Perform \texttt{Set(\textit{O}, !ToString(\textit{j}), E, true)}.
      ii. Set \textit{j} to \textit{j + 1F}.
5. Perform \texttt{Set(\textit{O}, \text{"length"}, \texttt{F(len + argCount), true})}.
6. Return \texttt{F(len + argCount)}.

The \texttt{"length"} property of this method is \texttt{1F}.

\textbf{NOTE} This method is intentionally generic; it does not require that its \textit{this} value be an Array. Therefore it can be transferred to other kinds of objects for use as a method.
23.1.3.38 Array.prototype.values ( )

This method performs the following steps when called:

1. Let \( O \) be ?ToObject(this value).
2. Return CreateArrayIterator\( (O, VALUE) \).

23.1.3.39 Array.prototype.with ( index, value )

This method performs the following steps when called:

1. Let \( O \) be ?ToObject(this value).
2. Let \( len \) be ?LengthOfArrayLike\( (O) \).
3. Let relativeIndex be ?ToIntegerOrInfinity\( (index) \).
4. If relativeIndex ≥ 0, let actualIndex be relativeIndex.
5. Else, let actualIndex be \( len + relativeIndex \).
6. If actualIndex ≥ len or actualIndex < 0, throw a RangeError exception.
7. Let \( A \) be ?ArrayCreate\( (len) \).
8. Let \( k \) be 0.
9. Repeat, while \( k < len \),
   a. Let \( P_k \) be !ToString\( (𝔽(k)) \).
   b. If \( k \) is actualIndex, let fromValue be value.
   c. Else, let fromValue be ?Get\( (O, P_k) \).
   d. Perform !CreateDataPropertyOrThrow\( (A, P_k, fromValue) \).
   e. Set \( k \) to \( k + 1 \).
10. Return \( A \).

23.1.3.40 Array.prototype [ @@iterator ] ( )

The initial value of the @@iterator property is %Array.prototype.values%, defined in 23.1.3.38.

23.1.3.41 Array.prototype [ @@unscopables ]

The initial value of the @@unscopables data property is an object created by the following steps:

1. Let unscopableList be OrdinaryObjectCreate\( (null) \).
2. Perform !CreateDataPropertyOrThrow\( (unscopableList, "at", true) \).
3. Perform !CreateDataPropertyOrThrow\( (unscopableList, "copyWithin", true) \).
4. Perform !CreateDataPropertyOrThrow\( (unscopableList, "entries", true) \).
5. Perform !CreateDataPropertyOrThrow\( (unscopableList, "fill", true) \).
6. Perform !CreateDataPropertyOrThrow\( (unscopableList, "find", true) \).
7. Perform !CreateDataPropertyOrThrow\( (unscopableList, "findIndex", true) \).
8. Perform !CreateDataPropertyOrThrow\( (unscopableList, "findLast", true) \).
9. Perform !CreateDataPropertyOrThrow\( (unscopableList, "findLastIndex", true) \).
10. Perform !CreateDataPropertyOrThrow\( (unscopableList, "flat", true) \).
11. Perform !CreateDataPropertyOrThrow\( (unscopableList, "flatMap", true) \).
12. Perform !CreateDataPropertyOrThrow\( (unscopableList, "includes", true) \).
13. Perform !CreateDataPropertyOrThrow\( (unscopableList, "keys", true) \).
14. Perform !CreateDataPropertyOrThrow\( (unscopableList, "toReversed", true) \).
15. Perform !CreateDataPropertyOrThrow\( (unscopableList, "toSorted", true) \).
16. Perform !CreateDataPropertyOrThrow\( (unscopableList, "toSpliced", true) \).
17. Perform !CreateDataPropertyOrThrow\( (unscopableList, "values", true) \).
18. Return unscopableList.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.
23.1.4 Properties of Array Instances

Array instances are Array exotic objects and have the internal methods specified for such objects. Array instances inherit properties from the Array prototype object.

Array instances have a "length" property, and a set of enumerable properties with array index names.

23.1.4.1 length

The "length" property of an Array instance is a data property whose value is always numerically greater than the name of every configurable own property whose name is an array index.

The "length" property initially has the attributes { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }.

23.1.5 Array Iterator Objects

An Array Iterator is an object, that represents a specific iteration over some specific Array instance object. There is not a named constructor for Array Iterator objects. Instead, Array iterator objects are created by calling certain methods of Array instance objects.

23.1.5.1 CreateArrayIterator ( array, kind )

The abstract operation CreateArrayIterator takes arguments array (an Object) and kind (KEY+VALUE, KEY, or VALUE) and returns a Generator. It is used to create iterator objects for Array methods that return such iterators.

It performs the following steps when called:

1. Let closure be a new Abstract Closure with no parameters that captures kind and array and performs the following steps when called:
   a. Let index be 0.
   b. Repeat,
      i. If array has a [[TypedArrayName]] internal slot, then
         1. Let taRecord be MakeTypedArrayWithBufferWitnessRecord(array, SEQ-CST).
         2. If IsTypedArrayOutOfBounds(taRecord) is true, throw a TypeError exception.
         3. Let len be TypedArrayLength(taRecord).
      ii. Else,
         1. Let len be ? LengthOfArrayLike(array).
      iii. If index ≥ len, return NormalCompletion(undefined).
      iv. Let indexNumber be 𝔽(index).
      v. If kind is KEY, then
         1. Let result be indexNumber.
vi. Else,
   1. Let `elementKey` be `ToString(indexNumber)`.
   2. Let `elementValue` be `Get(array, elementKey)`.
   3. If `kind` is VALUE, then
      a. Let `result` be `elementValue`.
   4. Else,
      a. Assert: `kind` is KEY+VALUE.
      b. Let `result` be `CreateArrayFromList(« indexNumber, elementValue »)`.
   vii. Perform ? `GeneratorYield(CreateIterResultObject(result, false))`.
   viii. Set `index` to `index + 1`.

2. Return `CreateIteratorFromClosure(closure, "%ArrayIteratorPrototype%", %ArrayIteratorPrototype%)`.

23.1.5.2 The %ArrayIteratorPrototype% Object

The %ArrayIteratorPrototype% object:

- has properties that are inherited by all Array Iterator Objects.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is %IteratorPrototype%.
- has the following properties:

23.1.5.2.1 %ArrayIteratorPrototype% .next ( )

1. Return ? `GeneratorResume(this value, EMPTY, "%ArrayIteratorPrototype%")`.

23.1.5.2.2 %ArrayIteratorPrototype% [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "Array Iterator".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

23.2 TypedArray Objects

A **TypedArray** presents an array-like view of an underlying binary data buffer (25.1). A **TypedArray element type** is the underlying binary scalar data type that all elements of a **TypedArray** instance have. There is a distinct **TypedArray constructor**, listed in **Table 71**, for each of the supported element types. Each constructor in Table 71 has a corresponding distinct prototype object.

<table>
<thead>
<tr>
<th>Constructor Name and Intrinsic</th>
<th>Element Type</th>
<th>Element Size</th>
<th>Conversion Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int8Array %Int8Array%</td>
<td>INT8</td>
<td>1</td>
<td>ToInt8</td>
<td>8-bit two's complement signed integer</td>
</tr>
<tr>
<td>Uint8Array %Uint8Array%</td>
<td>UINT8</td>
<td>1</td>
<td>ToUint8</td>
<td>8-bit unsigned integer</td>
</tr>
<tr>
<td>Uint8ClampedArray %Uint8ClampedArray%</td>
<td>UINT8CLAMPED</td>
<td>1</td>
<td>ToUint8Clamp</td>
<td>8-bit unsigned integer (clamped conversion)</td>
</tr>
<tr>
<td>Int16Array %Int16Array%</td>
<td>INT16</td>
<td>2</td>
<td>ToInt16</td>
<td>16-bit two's complement signed integer</td>
</tr>
<tr>
<td>Uint16Array %Uint16Array%</td>
<td>UINT16</td>
<td>2</td>
<td>ToUint16</td>
<td>16-bit unsigned integer</td>
</tr>
</tbody>
</table>
Table 71: The TypedArray Constructors (continued)

<table>
<thead>
<tr>
<th>Constructor Name and Intrinsic</th>
<th>Element Type</th>
<th>Element Size</th>
<th>Conversion Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int32Array %Int32Array%</td>
<td>INT32</td>
<td>4</td>
<td>ToInt32</td>
<td>32-bit two’s complement signed integer</td>
</tr>
<tr>
<td>Uint32Array %Uint32Array%</td>
<td>UINT32</td>
<td>4</td>
<td>ToUint32</td>
<td>32-bit unsigned integer</td>
</tr>
<tr>
<td>BigInt64Array %BigInt64Array%</td>
<td>BIGINT64</td>
<td>8</td>
<td>ToBigInt64</td>
<td>64-bit two’s complement signed integer</td>
</tr>
<tr>
<td>BigUint64Array %BigUint64Array%</td>
<td>BIGUINT64</td>
<td>8</td>
<td>ToBigUint64</td>
<td>64-bit unsigned integer</td>
</tr>
<tr>
<td>Float32Array %Float32Array%</td>
<td>FLOAT32</td>
<td>4</td>
<td></td>
<td>32-bit IEEE floating point</td>
</tr>
<tr>
<td>Float64Array %Float64Array%</td>
<td>FLOAT64</td>
<td>8</td>
<td></td>
<td>64-bit IEEE floating point</td>
</tr>
</tbody>
</table>

In the definitions below, references to TypedArray should be replaced with the appropriate constructor name from the above table.

23.2.1 The %TypedArray% Intrinsic Object

The %TypedArray% intrinsic object:

- is a constructor function object that all of the TypedArray constructor objects inherit from.
- along with its corresponding prototype object, provides common properties that are inherited by all TypedArray constructors and their instances.
- does not have a global name or appear as a property of the global object.
- acts as the abstract superclass of the various TypedArray constructors.
- will throw an error when invoked, because it is an abstract class constructor. The TypedArray constructors do not perform a super call to it.

23.2.1.1 %TypedArray% ( )

This function performs the following steps when called:

1. Throw a TypeError exception.

The "length" property of this function is +0𝔽.

23.2.2 Properties of the %TypedArray% Intrinsic Object

The %TypedArray% intrinsic object:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has a "name" property whose value is "TypedArray".
- has the following properties:
**23.2.2.1 %TypedArray%.from ( source , mapfn , thisArg )**

This method performs the following steps when called:

1. Let C be the this value.
2. If IsConstructor(C) is false, throw a TypeError exception.
3. If mapfn is undefined, then
   a. Let mapping be false.
4. Else,
   a. If IsCallable(mapfn) is false, throw a TypeError exception.
   b. Let mapping be true.
6. If usingIterator is not undefined, then
   a. Let values be ? IteratorToList(? GetIteratorFromMethod(source, usingIterator)).
   b. Let len be the number of elements in values.
   c. Let targetObj be ? TypedArrayCreateFromConstructor(C, «𝔽(len)»).
   d. Let k be 0.
   e. Repeat, while k < len,
      i. Let Pk be ! ToString(F(k)).
      ii. Let kValue be the first element of values.
      iii. Remove the first element from values.
      iv. If mapping is true, then
         1. Let mappedValue be ? Call(mapfn, thisArg, «kValue, 𝔽(k)»).
      v. Else,
         1. Let mappedValue be kValue.
      vi. Perform Set(targetObj, Pk, mappedValue, true).
      vii. Set k to k + 1.
   f. Assert: values is now an empty List.
   g. Return targetObj.
7. NOTE: source is not an Iterable so assume it is already an array-like object.
8. Let arrayLike be ! ToObject(source).
9. Let len be ? LengthOfArrayLike(arrayLike).
10. Let targetObj be ? TypedArrayCreateFromConstructor(C, «𝔽(len)»).
11. Let k be 0.
12. Repeat, while k < len,
    a. Let Pk be ! ToString(F(k)).
    b. Let kValue be ? Get(arrayLike, Pk).
    c. If mapping is true, then
       i. Let mappedValue be ? Call(mapfn, thisArg, «kValue, 𝔽(k)»).
    d. Else,
       i. Let mappedValue be kValue.
    e. Perform ? Set(targetObj, Pk, mappedValue, true).
    f. Set k to k + 1.
13. Return targetObj.

**23.2.2.2 %TypedArray%.of ( ...items )**

This method performs the following steps when called:

1. Let len be the number of elements in items.
2. Let C be the this value.
3. If IsConstructor(C) is false, throw a TypeError exception.
4. Let newObj be ? TypedArrayCreateFromConstructor(C, «𝔽(len)»).
5. Let k be 0.
6. Repeat, while k < len,
   a. Let kValue be items[k].
   b. Let Pk be ! ToString(F(k)).
   c. Perform ? Set(newObj, Pk, kValue, true).
   d. Set k to k + 1.
7. Return newObj.
23.2.2.3 %TypedArray%.prototype

The initial value of %TypedArray%.prototype is the %TypedArray% prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

23.2.2.4 get %TypedArray%[@species]

%TypedArray%[@species] is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "get [Symbol.species]".

NOTE %TypedArray.prototype% methods normally use their this value's constructor to create a derived object. However, a subclass constructor may over-ride that default behaviour by redefining its @@species property.

23.2.3 Properties of the %TypedArray% Prototype Object

The %TypedArray% prototype object:

- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is %TypedArray.prototype%.
- is an ordinary object.
- does not have a [[ViewedArrayBuffer]] or any other of the internal slots that are specific to TypedArray instance objects.

23.2.3.1 %TypedArray%.prototype.at(index)

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let relativeIndex be ? ToIntegerOrInfinity(index).
5. If relativeIndex ≥ 0, then
   a. Let k be relativeIndex.
6. Else,
   a. Let k be len + relativeIndex.
7. If k < 0 or k ≥ len, return undefined.
8. Return ! Get(O, ! ToString(F(k))).

23.2.3.2 get %TypedArray%.prototype.buffer

%TypedArray%.prototype.buffer is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, [[TypedArrayName]]).
3. Assert: O has a [[ViewedArrayBuffer]] internal slot.
4. Let buffer be O.[[ViewedArrayBuffer]].
5. Return buffer.
23.2.3.3 get %TypedArray%.prototype.byteLength

%TypedArray%.prototype.byteLength is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, [[TypedArrayName]]).
3. Assert: O has a [[ViewedArrayBuffer]] internal slot.
4. Let taRecord be MakeTypedArrayWithBufferWitnessRecord(O, SEQ-CST).
5. Let size be TypedArrayByteLength(taRecord).
6. Return $\mathbb{F}(size)$.

23.2.3.4 get %TypedArray%.prototype.byteOffset

%TypedArray%.prototype.byteOffset is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, [[TypedArrayName]]).
3. Assert: O has a [[ViewedArrayBuffer]] internal slot.
4. Let taRecord be MakeTypedArrayWithBufferWitnessRecord(O, SEQ-CST).
5. If IsTypedArrayOutOfBounds(taRecord) is true, return $+0_\mathbb{F}$.
6. Let offset be O.[[ByteOffset]].
7. Return $\mathbb{F}(offset)$.

23.2.3.5 %TypedArray%.prototype.constructor

The initial value of %TypedArray%.prototype.constructor is %TypedArray%.

23.2.3.6 %TypedArray%.prototype.copyWithin ( target, start [, end ] )

The interpretation and use of the arguments of this method are the same as for Array.prototype.copyWithin as defined in 23.1.3.4.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let relativeTarget be ? ToIntegerOrInfinity(target).
5. If relativeTarget = $-\infty$, let targetIndex be 0.
6. Else if relativeTarget $< 0$, let targetIndex be max(len + relativeTarget, 0).
7. Else, let targetIndex be min(relativeTarget, len).
8. Let relativeStart be ? ToIntegerOrInfinity(start).
9. If relativeStart = $-\infty$, let startIndex be 0.
10. Else if relativeStart $< 0$, let startIndex be max(len + relativeStart, 0).
11. Else, let startIndex be min(relativeStart, len).
12. If end is undefined, let relativeEnd be len; else let relativeEnd be ? ToIntegerOrInfinity(end).
13. If relativeEnd = $-\infty$, let endIndex be 0.
14. Else if relativeEnd $< 0$, let endIndex be max(len + relativeEnd, 0).
15. Else, let endIndex be min(relativeEnd, len).
16. Let count be min(endIndex - startIndex, len - targetIndex).
17. If count $> 0$, then
   a. NOTE: The copying must be performed in a manner that preserves the bit-level encoding of the source data.
   b. Let buffer be O.[[ViewedArrayBuffer]].
   c. Set taRecord to MakeTypedArrayWithBufferWitnessRecord(O, SEQ-CST).
   d. If IsTypedArrayOutOfBounds(taRecord) is true, throw a TypeError exception.
   e. Set len to TypedArrayLength(taRecord).
f. Let `elementSize` be `TypedArrayElementSize(O)`.  
g. Let `byteOffset` be `O.[[ByteOffset]]`.  
h. Let `bufferByteLimit` be `(len × `elementSize`) + `byteOffset`.  
i. Let `fromByteIndex` be `(targetIndex × `elementSize`) + `byteOffset`.  
j. Let `countBytes` be `count × `elementSize`.  
k. If `fromByteIndex < toByteIndex` and `toByteIndex < fromByteIndex + countBytes`, then  
   i. Let `direction` be -1.  
   ii. Set `fromByteIndex` to `fromByteIndex + countBytes - 1`.  
   iii. Set `toByteIndex` to `toByteIndex + countBytes - 1`.  
   m. Else,  
      i. Let `direction` be 1.  
   n. Repeat, while `countBytes > 0`,  
      i. If `fromByteIndex < bufferByteLimit` and `toByteIndex < bufferByteLimit`, then  
         1. Let `value` be `GetValueFromBuffer(buffer, toByteIndex`, `UINT8`, `true`, `UNORDERED)`.  
         2. Perform `SetValueInBuffer(buffer, toByteIndex`, `UINT8`, `value`, `true`, `UNORDERED)`.
         3. Set `fromByteIndex` to `fromByteIndex + direction`.  
         4. Set `toByteIndex` to `toByteIndex + direction`.  
         5. Set `countBytes` to `countBytes - 1`.  
      ii. Else,  
         1. Set `countBytes` to `0`. 
18. Return `O`. 

23.2.3.7 %TypedArray%.prototype.entries ()

This method performs the following steps when called:
1. Let `O` be the `this` value.  
2. Perform `? ValidateTypedArray(O, SEQ-CST)`.  
3. Return `CreateArrayIterator(O, KEY+VALUE)`. 

23.2.3.8 %TypedArray%.prototype.every ( `callbackfn` [, `thisArg` ] )

The interpretation and use of the arguments of this method are the same as for `Array.prototype.every` as defined in 23.1.3.6.

This method performs the following steps when called:
1. Let `O` be the `this` value.  
2. Let `taRecord` be `? ValidateTypedArray(O, SEQ-CST)`.  
3. Let `len` be `TypedArrayLength(taRecord)`.  
4. If `IsCallable(callbackfn)` is `false`, throw a `TypeError` exception.  
5. Let `k` be `0`.  
6. Repeat, while `k < len`,  
   a. Let `Pk` be `ToString(F(k))`.  
   b. Let `kValue` be `Get(O, Pk)`.  
   c. Let `testResult` be `ToBoolean(? Call(callbackfn, thisArg, « kValue, F(k), O »))`.  
   d. If `testResult` is `false`, return `false`.  
   e. Set `k` to `k + 1`.  
7. Return `true`.

This method is not generic. The `this` value must be an object with a `[[TypedArrayName]]` internal slot.

23.2.3.9 %TypedArray%.prototype.fill ( `value` [, `start` [, `end` ] ] )

The interpretation and use of the arguments of this method are the same as for `Array.prototype.fill` as defined in 23.1.3.7.

This method performs the following steps when called:
1. Let $O$ be the this value.
2. Let $taRecord$ be $\text{ValidateTypedArray}(O, \text{SEQ-CST})$.
3. Let $len$ be $\text{TypedArrayLength}(taRecord)$.
4. If $O.[\text{ContentType}]$ is BIGINT, set value to $\text{ToBigInt}(value)$.
5. Otherwise, set value to $\text{ToNumber}(value)$.
6. Let relativeStart be $\text{ToIntegerOrInfinity}(start)$.
7. If relativeStart = $-\infty$, let startIndex be 0.
8. Else if relativeStart < 0, let startIndex be max($len + \text{relativeStart}, 0$).
9. Else, let startIndex be $\text{min}(\text{relativeStart}, len)$.
10. If end is undefined, let relativeEnd be $len$; else let relativeEnd be $\text{ToIntegerOrInfinity}(end)$.
11. If relativeEnd = $-\infty$, let endIndex be 0.
12. Else if relativeEnd < 0, let endIndex be max($len + \text{relativeEnd}, 0$).
13. Else, let endIndex be $\text{min}(\text{relativeEnd}, len)$.
14. Set $taRecord$ to $\text{MakeTypedArrayWithBufferWitnessRecord}(O, \text{SEQ-CST})$.
15. If $\text{IsTypedArrayOutOfBounds}(taRecord)$ is true, throw a TypeError exception.
16. Set $len$ to $\text{TypedArrayLength}(taRecord)$.
17. Set endIndex to $\text{min}(\text{endIndex}, len)$.
18. Let $k$ be startIndex.
19. Repeat, while $k < endIndex$, a. Let $Pk$ be $\text{ToString}(\mathbb{F}(k))$.
   b. Perform $\text{Set}(O, Pk, value, true)$.
   c. Set $k$ to $k + 1$.
20. Return $O$.

23.2.3.10 %TypedArray%.prototype.filter ( callbackfn [ , thisArg ] )

The interpretation and use of the arguments of this method are the same as for Array.prototype.filter as defined in 23.1.3.8.

This method performs the following steps when called:

1. Let $O$ be the this value.
2. Let $taRecord$ be $\text{ValidateTypedArray}(O, \text{SEQ-CST})$.
3. Let $len$ be $\text{TypedArrayLength}(taRecord)$.
4. If $\text{IsCallable}(\text{callbackfn})$ is false, throw a TypeError exception.
5. Let kept be a new empty List.
6. Let captured be 0.
7. Let $k$ be 0.
8. Repeat, while $k < len$, a. Let $Pk$ be $\text{ToString}(\mathbb{F}(k))$.
   b. Let $kValue$ be $\text{Get}(O, Pk)$.
   c. Let selected be $\text{ToBoolean}?(\text{Call}(\text{callbackfn}, \text{thisArg}, « kValue, \mathbb{F}(k), O »))$.
   d. If selected is true, then
      i. Append $kValue$ to kept.
      ii. Set captured to captured + 1.
   e. Set $k$ to $k + 1$.
9. Let $A$ be $\text{TypedArraySpeciesCreate}(O, « \mathbb{F}(\text{captured}) »)$.
10. Let $n$ be 0.
11. For each element $e$ of kept, do
    a. Perform $\text{Set}(A, !\text{ToString}(\mathbb{F}(n)), e, true)$.
    b. Set $n$ to $n + 1$.
12. Return $A$.

This method is not generic. The this value must be an object with a $[[\text{TypedArrayName}]]$ internal slot.
23.2.3.11 %TypedArray%.prototype.find (predicate [, thisArg])

The interpretation and use of the arguments of this method are the same as for Array.prototype.find as defined in 23.1.3.9.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let findRec be ? FindViaPredicate(O, len, ASCENDING, predicate, thisArg).
5. Return findRec.[[Value]].

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.12 %TypedArray%.prototype.findIndex (predicate [, thisArg])

The interpretation and use of the arguments of this method are the same as for Array.prototype.findIndex as defined in 23.1.3.10.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let findRec be ? FindViaPredicate(O, len, ASCENDING, predicate, thisArg).
5. Return findRec.[[Index]].

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.13 %TypedArray%.prototype.findLast (predicate [, thisArg])

The interpretation and use of the arguments of this method are the same as for Array.prototype.findLast as defined in 23.1.3.11.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let findRec be ? FindViaPredicate(O, len, DESCENDING, predicate, thisArg).
5. Return findRec.[[Value]].

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.14 %TypedArray%.prototype.findLastIndex (predicate [, thisArg])

The interpretation and use of the arguments of this method are the same as for Array.prototype.findLastIndex as defined in 23.1.3.12.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let findRec be ? FindViaPredicate(O, len, DESCENDING, predicate, thisArg).
5. Return findRec.[[Index]].

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.
23.2.3.15 %TypedArray%.prototype.forEach ( callbackfn [, thisArg ])

The interpretation and use of the arguments of this method are the same as for Array.prototype.forEach as defined in 23.1.3.15.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. If IsCallable(callbackfn) is false, throw a TypeError exception.
5. Let k be 0.
6. Repeat, while k < len,
   a. Let Pk be ! ToString(𝔽(k)).
   b. Let kValue be ! Get(O, Pk).
   c. Perform ? Call(callbackfn, thisArg, « kValue, 𝔽(k), O »).
   d. Set k to k + 1.
7. Return undefined.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.16 %TypedArray%.prototype.includes ( searchElement [, fromIndex ])

The interpretation and use of the arguments of this method are the same as for Array.prototype.includes as defined in 23.1.3.16.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. If len = 0, return false.
5. Let n be ? ToIntegerOrInfinity(fromIndex).
6. Assert: If fromIndex is undefined, then n is 0.
7. If n = +∞, return false.
8. Else if n = -∞, set n to 0.
9. If n ≥ 0, then
   a. Let k be n.
10. Else,
    a. Let k be len + n.
    b. If k < 0, set k to 0.
11. Repeat, while k < len,
    a. Let elementK be ! Get(O, ! ToString(𝔽(k))).
    b. If SameValueZero(searchElement, elementK) is true, return true.
    c. Set k to k + 1.
12. Return false.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.17 %TypedArray%.prototype.indexOf ( searchElement [, fromIndex ])

The interpretation and use of the arguments of this method are the same as for Array.prototype.indexOf as defined in 23.1.3.17.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. If len = 0, return -1𝔽.
5. Let \( n \) be \( \text{ToIntegerOrInfinity(fromIndex)} \).
6. Assert: If \( \text{fromIndex} \) is undefined, then \( n \) is 0.
7. If \( n = +\infty \), return \(-1 \mathbb{F}\).
8. Else if \( n = -\infty \), set \( n \) to 0.
9. If \( n \geq 0 \), then
   a. Let \( k \) be \( n \).
   b. Else, let \( k \) be \( \text{len + n} \).
10. Else, \( k \) < \( \text{len} \),
   a. Let \( k \) be \( \text{HasProperty(O, ! ToString(𝔽(k))}. \)
   b. If \( k \) is true, then
      i. Let \( \text{elementK} \) be \( \text{Get(O, ! ToString(𝔽(k)).} \)
      ii. If \( \text{IsStrictlyEqual(searchElement, elementK)} \) is true, return \( 𝔽(k) \).
   c. Set \( k \) to \( k + 1 \).
11. Repeat, while \( k \) < \( \text{len} \),
   a. If \( k \) > 0, set \( R \) to the string-concatenation of \( R \) and \( \text{sep} \).
   b. Let \( \text{element} \) be \( \text{Get(O, ! ToString(𝔽(k))}. \)
   c. If \( \text{element} \) is undefined, let \( \text{next} \) be the empty String; otherwise, let \( \text{next} \) be \( \text{ToString(element)} \).
   d. Set \( R \) to the string-concatenation of \( R \) and \( \text{next} \).
   e. Set \( k \) to \( k + 1 \).
12. Return \(-1 \mathbb{F}\).

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

### 23.2.3.18 %TypedArray%.prototype.join (separator)

The interpretation and use of the arguments of this method are the same as for \( \text{Array.prototype.join} \) as defined in 23.1.3.18.

This method performs the following steps when called:

1. Let \( O \) be the this value.
2. Let \( taRecord \) be ? ValidateTypedArray(\( O \), SEQ-CST).
3. Let \( \text{len} \) be \( \text{TypedArrayLength(taRecord)} \).
4. If \( \text{separator} \) is undefined, let \( \text{sep} \) be ",".
5. Else, let \( \text{sep} \) be ? \( \text{ToString(separator)} \).
6. Let \( R \) be the empty String.
7. Let \( k \) be 0.
8. Repeat, while \( k \) < \( \text{len} \),
   a. If \( k \) > 0, set \( R \) to the string-concatenation of \( R \) and \( \text{sep} \).
   b. Let \( \text{element} \) be ? \( \text{Get(O, ! ToString(𝔽(k))}. \)
   c. If \( \text{element} \) is undefined, let \( \text{next} \) be the empty String; otherwise, let \( \text{next} \) be \( \text{ToString(element)} \).
   d. Set \( R \) to the string-concatenation of \( R \) and \( \text{next} \).
   e. Set \( k \) to \( k + 1 \).
9. Return \( R \).

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

### 23.2.3.19 %TypedArray%.prototype.keys ()

This method performs the following steps when called:

1. Let \( O \) be the this value.
3. Return \( \text{CreateArrayIterator(O, KEY)} \).

### 23.2.3.20 %TypedArray%.prototype.lastIndexOf (searchElement [ , fromIndex ])

The interpretation and use of the arguments of this method are the same as for \( \text{Array.prototype.lastIndexOf} \) as defined in 23.1.3.20.

This method performs the following steps when called:
1. Let $O$ be the this value.
2. Let $taRecord$ be ? ValidateTypedArray($O$, SEQ-CST).
3. Let $len$ be TypedArrayLength($taRecord$).
4. If $len = 0$, return $-1F$.
5. If $fromIndex$ is present, let $n$ be $\text{ToIntegerOrInfinity}(fromIndex)$; else let $n$ be $len - 1$.
6. If $n = -\infty$, return $-1F$.
7. If $n \geq 0$, then
   a. Let $k$ be $\text{min}(n, len - 1)$.
8. Else,
   a. Let $k$ be $len + n$.
9. Repeat, while $k < len$,
   a. Let $kPresent$ be $\text{HasProperty}(O, \text{ToString}(F(k)))$.
   b. If $kPresent$ is true, then
      i. Let $elementK$ be $(O, \text{ToString}(F(k)))$.
      ii. If $\text{IsStrictlyEqual}(searchElement, elementK)$ is true, return $F(k)$.
   c. Set $k$ to $k + 1$.
10. Return $-1F$.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

### 23.2.3.21 get %TypedArray%.prototype.length

%TypedArray%.prototype.length is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let $O$ be the this value.
2. Perform ? RequireInternalSlot($O$, [[TypedArrayName]]).
3. Assert: $O$ has [[ViewedArrayBuffer]] and [[ArrayLength]] internal slots.
4. Let $taRecord$ be MakeTypedArrayWithBufferWitnessRecord($O$, SEQ-CST).
5. If $\text{IsTypedArrayOutOfBounds}(taRecord)$ is true, return $+0F$.
6. Let $length$ be TypedArrayLength($taRecord$).
7. Return $F(length)$.

This function is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

### 23.2.3.22 %TypedArray%.prototype.map ( callbackfn [, thisArg ] )

The interpretation and use of the arguments of this method are the same as for Array.prototype.map as defined in 23.1.3.21.

This method performs the following steps when called:

1. Let $O$ be the this value.
2. Let $taRecord$ be ? ValidateTypedArray($O$, SEQ-CST).
3. Let $len$ be TypedArrayLength($taRecord$).
4. If $\text{IsCallable}(callbackfn)$ is false, throw a TypeError exception.
5. Let $A$ be ? TypedArraySpeciesCreate($O$, « $F(len)$ »).
6. Let $k$ be $0$.
7. Repeat, while $k < len$,
   a. Let $Pk$ be $\text{ToString}(F(k))$.
   b. Let $kValue$ be $\text{Get}(O, Pk)$.
   c. Let $mappedValue$ be ? Call(callbackfn, thisArg, « kValue, $F(k)$, $O$ »).
   d. Perform ? Set($A$, $Pk$, mappedValue, true).
   e. Set $k$ to $k + 1$.
8. Return $A$.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.
23.2.3.23 %TypedArray%.prototype.reduce ( callbackfn [ , initialValue ])

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. If IsCallable(callbackfn) is false, throw a TypeError exception.
5. If len = 0 and initialValue is not present, throw a TypeError exception.
6. Let k be 0.
7. Let accumulator be undefined.
8. If initialValue is present, then
   a. Set accumulator to initialValue.
9. Else,
   a. Let Pk be ! ToString(F(k)).
   b. Set accumulator to ! Get(O, Pk).
   c. Set k to k + 1.
10. Repeat, while k < len,
    a. Let Pk be ! ToString(F(k)).
    b. Let kValue be ! Get(O, Pk).
    c. Set accumulator to ? Call(callbackfn, undefined, « accumulator, kValue, F(k), O »).
    d. Set k to k + 1.
11. Return accumulator.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.24 %TypedArray%.prototype.reduceRight ( callbackfn [ , initialValue ])

The interpretation and use of the arguments of this method are the same as for Array.prototype.reduceRight as defined in 23.1.3.25.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. If IsCallable(callbackfn) is false, throw a TypeError exception.
5. If len = 0 and initialValue is not present, throw a TypeError exception.
6. Let k be len - 1.
7. Let accumulator be undefined.
8. If initialValue is present, then
   a. Set accumulator to initialValue.
9. Else,
   a. Let Pk be ! ToString(F(k)).
   b. Set accumulator to ! Get(O, Pk).
   c. Set k to k - 1.
10. Repeat, while k ≥ 0,
    a. Let Pk be ! ToString(F(k)).
    b. Let kValue be ! Get(O, Pk).
    c. Set accumulator to ? Call(callbackfn, undefined, « accumulator, kValue, F(k), O »).
    d. Set k to k - 1.
11. Return accumulator.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.
23.2.3.25 %TypedArray%.prototype.reverse()

The interpretation and use of the arguments of this method are the same as for Array.prototype.reverse as defined in 23.1.3.26.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. Let middle be floor(len / 2).
5. Let lower be 0.
6. Repeat, while lower ≠ middle,
   a. Let upper be len - lower - 1.
   b. Let upperP be ! ToString(F(upper)).
   c. Let lowerP be ! ToString(F(lower)).
   d. Let lowerValue be ! Get(O, lowerP).
   e. Let upperValue be ! Get(O, upperP).
   f. Perform ! Set(O, lowerP, upperValue, true).
   g. Perform ! Set(O, upperP, lowerValue, true).
   h. Set lower to lower + 1.
7. Return O.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.26 %TypedArray%.prototype.set(source[, offset])

This method sets multiple values in this TypedArray, reading the values from source. The details differ based upon the type of source. The optional offset value indicates the first element index in this TypedArray where values are written. If omitted, it is assumed to be 0.

It performs the following steps when called:

1. Let target be the this value.
2. Perform ? RequireInternalSlot(target, [[TypedArrayName]]).
3. Assert: target has a [[ViewedArrayBuffer]] internal slot.
4. Let targetOffset be ? ToIntegerOrInfinity(offset).
5. If targetOffset < 0, throw a RangeError exception.
6. If source is an Object that has a [[TypedArrayName]] internal slot, then
   a. Perform ? SetTypedArrayFromTypedArray(target, targetOffset, source).
7. Else,
   a. Perform ? SetTypedArrayFromArrayLike(target, targetOffset, source).
8. Return undefined.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.26.1 SetTypedArrayFromTypedArray(target, targetOffset, source)

The abstract operation SetTypedArrayFromTypedArray takes arguments target (a TypedArray), targetOffset (a non-negative integer or +∞), and source (a TypedArray) and returns either a normal completion containing UNUSED or a throw completion. It sets multiple values in target, starting at index targetOffset, reading the values from source. It performs the following steps when called:

1. Let targetBuffer be target.[[ViewedArrayBuffer]].
2. Let targetRecord be MakeTypedArrayWithBufferWitnessRecord(target, SEQ-CST).
3. If IsTypedArrayOutOfBounds(targetRecord) is true, throw a TypeError exception.
4. Let targetLength be TypedArrayLength(targetRecord).
5. Let srcBuffer be source.[[ViewedArrayBuffer]].
6. Let srcRecord be MakeTypedArrayWithBufferWitnessRecord(source, SEQ-CST).
7. If IsTypedArrayOutOfBounds(srcRecord) is true, throw a TypeError exception.
Let \( \text{srcLength} \) be \( \text{TypedArrayLength}(\text{srcRecord}) \).
Let \( \text{targetType} \) be \( \text{TypedArrayElementType}(\text{target}) \).
Let \( \text{targetElementSize} \) be \( \text{TypedArrayElementSize}(\text{target}) \).
Let \( \text{srcByteOffset} \) be \( \text{target}[[\text{ByteOffset}]] \).
Let \( \text{srcType} \) be \( \text{TypedArrayElementType}(\text{source}) \).
Let \( \text{srcElementSize} \) be \( \text{TypedArrayElementSize}(\text{source}) \).
Let \( \text{srcByteOffset} \) be \( \text{source}[[\text{ByteOffset}]] \).

If \( \text{targetOffset} = +\infty \), throw a \text{RangeError} exception.
If \( \text{srcLength} + \text{targetOffset} > \text{targetLength} \), throw a \text{RangeError} exception.
If \( \text{target}[[\text{ContentType}]] \) is not \( \text{source}[[\text{ContentType}]] \), throw a \text{TypeError} exception.

If \( \text{IsSharedArrayBuffer}(\text{srcBuffer}) \) is \text{true}, \( \text{IsSharedArrayBuffer}(\text{targetBuffer}) \) is \text{true}, and
\( \text{srcBuffer}[[\text{ArrayBufferData}]] \) is \( \text{targetBuffer}[[\text{ArrayBufferData}]] \), let \( \text{sameSharedArrayBuffer} \) be \text{true};
otherwise, let \( \text{sameSharedArrayBuffer} \) be \text{false}.
If \( \text{SameValue}(\text{srcBuffer}, \text{targetBuffer}) \) is \text{true} or \( \text{sameSharedArrayBuffer} \) is \text{true}, then
Let \( \text{srcByteLength} \) be \( \text{TypedArrayByteLength}(\text{srcRecord}) \).
Let \( \text{srcElementSize} \times \text{srcByteLength} \) be \( \text{srcByteOffset} \).
Else, let \( \text{srcByteOffset} \) be 0.

Let \( \text{srcByteIndex} \) be \( \text{srcByteOffset} \).
Let \( \text{targetByteIndex} \) be \( (\text{targetOffset} \times \text{targetElementSize}) + \text{targetByteOffset} \).
Let \( \text{limit} \) be \( \text{targetByteIndex} + ((\text{targetElementSize} \times \text{srcLength}) \times \text{srcElementSize}) \).
If \( \text{srcType} \) is \( \text{targetType} \), then
Let \( \text{value} \) be \( \text{GetValueFromBuffer}(\text{srcBuffer}, \text{srcByteIndex}, \text{srcType}, \text{true}, \text{UNORDERED}) \).
Let \( \text{targetByteIndex} \) be \( \text{targetByteIndex} + 1 \).

Else, let \( \text{targetByteIndex} \) be \( \text{srcByteOffset} \).
Let \( \text{targetByteIndex} \) be \( \text{srcByteOffset} \).
Let \( \text{targetByteIndex} \) be \( \text{srcByteOffset} \).
Let \( \text{targetByteIndex} \) be \( \text{srcByteOffset} \).

23.2.3.26.2 \text{SetTypedArrayFromArrayLike} ( \text{target}, \text{targetOffset}, \text{source} )

The abstract operation \( \text{SetTypedArrayFromArrayLike} \) takes arguments \( \text{target} \) (a \text{TypedArray}), \( \text{targetOffset} \) (a non-negative integer or \( +\infty \)), and \( \text{source} \) (an \text{ECMAScript} language value, but not a \text{TypedArray}) and returns either a normal completion containing UNDEFINED or a throw completion. It sets multiple values in \( \text{target} \), starting at index \( \text{targetOffset} \), reading the values from \( \text{source} \). It performs the following steps when called:

Let \( \text{targetRecord} \) be \( \text{MakeTypedArrayWithBufferWitnessRecord}(\text{target}, \text{SEQ-CST}) \).
If \( \text{IsTypedArrayOutOfBounds}(\text{targetRecord}) \) is \text{true}, throw a \text{TypeError} exception.
Let \( \text{targetLength} \) be \( \text{TypedArrayLength}(\text{targetRecord}) \).
Let \( \text{src} \) be \( \text{ToObject}(\text{source}) \).
Let \( \text{srcLength} \) be \( \text{LengthOfArrayLike}(\text{src}) \).
If \( \text{targetOffset} = +\infty \), throw a \text{RangeError} exception.
If \( \text{srcLength} + \text{targetOffset} > \text{targetLength} \), throw a \text{RangeError} exception.
Let \( k \) be 0.
Repeat, while \( k < \text{srcLength} \),
Let \( \text{P} \) be \( \text{ToString}(\text{E}(k)) \).
Let \( \text{value} \) be \( \text{Get}(\text{src}, \text{P}) \).
Let \( \text{targetIndex} \) be \( \text{E}(\text{targetOffset} + k) \).
Perform \( \text{TypedArraySetElement}(\text{target}, \text{targetIndex}, \text{value}) \).
Set \( k \) to \( k + 1 \).
Return UNDEFINED.
23.2.3.27 \%TypedArray\%.prototype.slice ( start, end )

The interpretation and use of the arguments of this method are the same as for Array.prototype.slice as defined in 23.1.3.28.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let srcArrayLength be TypedArrayLength(taRecord).
4. Let relativeStart be ? ToIntegerOrInfinity(start).
5. If relativeStart = -\infty, let startIndex be 0.
6. Else if relativeStart < 0, let startIndex be max(srcArrayLength + relativeStart, 0).
7. Else, let startIndex be min(relativeStart, srcArrayLength).
8. If end is undefined, let relativeEnd be srcArrayLength; else let relativeEnd be ? ToIntegerOrInfinity(end).
9. If relativeEnd = -\infty, let endIndex be 0.
10. Else if relativeEnd < 0, let endIndex be max(srcArrayLength + relativeEnd, 0).
11. Else, let endIndex be min(relativeEnd, srcArrayLength).
12. Let countBytes be max(endIndex - startIndex, 0).
13. Let A be ? TypedArraySpeciesCreate(O, « \%TypedArray% »).
14. If countBytes > 0, then
   a. Set taRecord to MakeTypedArrayWithBufferWitnessRecord(O, SEQ-CST).
   b. If IsTypedArrayOutOfBounds(taRecord) is true, throw a TypeError exception.
   c. Set endIndex to min(endIndex, TypedArrayLength(taRecord)).
   d. Set countBytes to max(endIndex - startIndex, 0).
   e. Let srcType be TypedArrayElementType(O).
   f. Let targetType be TypedArrayElementType(A).
   g. If srcType is targetType, then
      i. NOTE: The transfer must be performed in a manner that preserves the bit-level encoding of the source data.
      ii. Let srcBuffer be O.[[ViewedArrayBuffer]].
      iii. Let targetBuffer be A.[[ViewedArrayBuffer]].
      iv. Let elementType be TypedArrayElementSize(O).
      v. Let srcByteOffset be O.[[ByteOffset]].
      vi. Let srcByteIndex be (startIndex × elementType) + srcByteOffset.
      vii. Let targetByteOffset be A.[[ByteOffset]].
      viii. Let endByteIndex be targetByteIndex + (countBytes × elementType).
      ix. Repeat, while targetByteIndex < endByteIndex,
         1. Let value be GetValueFromBuffer(srcBuffer, srcByteIndex, UINT8, true, UNORDERED).
         2. Perform SetValueInBuffer(targetBuffer, targetByteIndex, UINT8, value, true, UNORDERED).
         3. Set srcByteIndex to srcByteIndex + 1.
         4. Set targetByteIndex to targetByteIndex + 1.
   h. Else,
      i. Let n be 0.
      ii. Let k be startIndex.
      iii. Repeat, while k < endIndex,
         1. Let Pk be ! ToString(F(k)).
         2. Let kValue be ! Get(O, Pk).
         3. Perform ! Set(A, ! ToString(F(n)), kValue, true).
         4. Set k to k + 1.
         5. Set n to n + 1.
15. Return A.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.
23.2.3.28 %TypedArray%.prototype.some ( callbackfn [, thisArg ])

The interpretation and use of the arguments of this method are the same as for Array.prototype.some as defined in 23.1.3.29.

This method performs the following steps when called:

1. Let O be the this value.
2. Let taRecord be ? ValidateTypedArray(O, SEQ-CST).
3. Let len be TypedArrayLength(taRecord).
4. If IsCallable(callbackfn) is false, throw a TypeError exception.
5. Let k be 0.
6. Repeat, while k < len,
   a. Let Pk be ! ToString(F(k)).
   b. Let kValue be ! Get(O, Pk).
   c. Let testResult be ToBoolean(? Call(callbackfn, thisArg, « kValue, F(k), O »)).
   d. If testResult is true, return true.
   e. Set k to k + 1.
7. Return false.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

23.2.3.29 %TypedArray%.prototype.sort ( comparefn)

This is a distinct method that, except as described below, implements the same requirements as those of Array.prototype.sort as defined in 23.1.3.30. The implementation of this method may be optimized with the knowledge that the this value is an object that has a fixed length and whose integer-indexed properties are not sparse.

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

It performs the following steps when called:

1. If comparefn is not undefined and IsCallable(comparefn) is false, throw a TypeError exception.
2. Let obj be the this value.
3. Let taRecord be ? ValidateTypedArray(obj, SEQ-CST).
4. Let len be TypedArrayLength(taRecord).
5. NOTE: The following closure performs a numeric comparison rather than the string comparison used in 23.1.3.30.
6. Let SortCompare be a new Abstract Closure with parameters (x, y) that captures comparefn and performs the following steps when called:
   a. Return ? CompareTypedArrayElements(x, y, comparefn).
8. Let j be 0.
9. Repeat, while j < len,
   a. Perform ! Set(obj, ! ToString(F(j)), sortedList[j], true).
   b. Set j to j + 1.
10. Return obj.

NOTE Because NaN always compares greater than any other value (see CompareTypedArrayElements), NaN property values always sort to the end of the result when comparefn is not provided.
This method returns a new TypedArray whose element type is the element type of this TypedArray and whose ArrayBuffer is the ArrayBuffer of this TypedArray, referencing the elements in the interval from `start` (inclusive) to `end` (exclusive). If either `start` or `end` is negative, it refers to an index from the end of the array, as opposed to from the beginning.

It performs the following steps when called:

1. Let `O` be the this value.
2. Perform ? RequireInternalSlot(`O`, [[TypedArrayName]]).
3. Assert: `O` has a [[ViewedArrayBuffer]] internal slot.
4. Let `buffer` be `O`.[[ViewedArrayBuffer]].
5. Let `srcRecord` be MakeTypedArrayWithBufferWitnessRecord(`O`, SEQ-CST).
6. If `IsTypedArrayOutOfBounds(srcRecord)` is true, then
   a. Let `srcLength` be 0.
7. Else, a. Let `srcLength` be `TypedArrayLength(srcRecord)`.
8. Let `relativeStart` be ? ToIntegerOrInfinity(`start`).
9. If `relativeStart` = -∞, let `startIndex` be 0.
10. Else if `relativeStart` < 0, let `startIndex` be max(`srcLength` + `relativeStart`, 0).
11. Else, let `startIndex` be min(`relativeStart`, `srcLength`).
12. Let `elementSize` be `TypedArrayElementSize(O)`.
13. Let `srcByteOffset` be `O`.[[ByteOffset]].
14. Let `beginByteOffset` be `srcByteOffset` + (`startIndex` × `elementSize`).
15. If `O`.[[ArrayLength]] is AUTO and `end` is undefined, then
   a. Let `argumentsList` be « `buffer`, F(`beginByteOffset`) ».
16. Else, a. If `end` is undefined, let `relativeEnd` be `srcLength`; else let `relativeEnd` be ? ToIntegerOrInfinity(`end`).
   b. If `relativeEnd` = -∞, let `endIndex` be 0.
   c. Else if `relativeEnd` < 0, let `endIndex` be max(`srcLength` + `relativeEnd`, 0).
   d. Else, let `endIndex` be min(`relativeEnd`, `srcLength`).
   e. Let `newLength` be max(`endIndex` - `startIndex`, 0).
   f. Let `argumentsList` be « `buffer`, F(`beginByteOffset`), F(`newLength`) ».
17. Return ? TypedArraySpeciesCreate(`O`, `argumentsList`).

This method is not generic. The this value must be an object with a [[TypedArrayName]] internal slot.

This is a distinct method that implements the same algorithm as `Array.prototype.toLocaleString` as defined in 23.1.3.32 except that `TypedArrayLength` is called in place of performing a `[[Get]]` of "length". The implementation of the algorithm may be optimized with the knowledge that the this value has a fixed length when the underlying buffer is not resizeable and whose integer-indexed properties are not sparse. However, such optimization must not introduce any observable changes in the specified behaviour of the algorithm.

This method is not generic. ValidateTypedArray is called with the this value and SEQ-CST as arguments prior to evaluating the algorithm. If its result is an abrupt completion that exception is thrown instead of evaluating the algorithm.

NOTE If the ECMAScript implementation includes the ECMA-402 Internationalization API this method is based upon the algorithm for `Array.prototype.toLocaleString` that is in the ECMA-402 specification.
This method performs the following steps when called:

1. Let `O` be the this value.
2. Let `taRecord` be ? `ValidateTypedArray(O, SEQ-CST)`.
3. Let `length` be `TypedArrayLength(taRecord)`.
4. Let `A` be ? `TypedArrayCreateSameType(O, «𝔽(length)»)`.
5. Let `k` be 0.
6. Repeat, while `k < length`,
   a. Let `from` be ? `ToString(𝔽(length - k - 1))`.
   b. Let `Pk` be ? `ToString(𝔽(k))`.
   c. Let `fromValue` be ? `Get(O, from)`.
   d. Perform ! `Set(A, Pk, fromValue, true)`.
   e. Set `k` to `k + 1`.
7. Return `A`.

The initial value of the "toString" property is `%Array.prototype.toString%`, defined in 23.1.3.36.
5. If \( \text{relativeIndex} \geq 0 \), let \( \text{actualIndex} \) be \( \text{relativeIndex} \).
6. Else, let \( \text{actualIndex} \) be \( \text{len} + \text{relativeIndex} \).
7. If \( O.[[\text{ContentType}]] \) is \( \text{BIGINT} \), let \( \text{numericValue} \) be \( \text{ToBigInt}(\text{value}) \).
8. Else, let \( \text{numericValue} \) be \( \text{ToNumber}(\text{value}) \).
9. If \( \text{IsValidIntegerIndex}(O, \mathbb{F}(\text{actualIndex})) \) is \( \text{false} \), throw a \text{RangeError} \) exception.
10. Let \( A \) be \( \text{TypedArrayCreateSameType}(O, \llbracket \mathbb{F}(\text{len}) \rrbracket) \).
11. Let \( k \) be 0.
12. Repeat, while \( k < \text{len} \),
   a. Let \( P_k \) be \( \text{ToString}(\mathbb{F}(k)) \).
   b. If \( k \) is \( \text{actualIndex} \), let \( \text{fromValue} \) be \( \text{numericValue} \).
   c. Else, let \( \text{fromValue} \) be \( \text{Get}(O, P_k) \).
   d. Perform \( \text{Set}(A, P_k, \text{fromValue}, \text{true}) \).
   e. Set \( k \) to \( k + 1 \).
13. Return \( A \).

23.2.3.37 \%\text{TypedArray}.prototype[@@iterator]()

The initial value of the @@iterator property is \%\text{TypedArray}.prototype.values\%, defined in 23.2.3.35.

23.2.3.38 get \%\text{TypedArray}.prototype[@@toStringTag]

\%\text{TypedArray}.prototype[@@toStringTag] is an accessor property whose set accessor function is \text{undefined}. Its get accessor function performs the following steps when called:

1. Let \( O \) be the this value.
2. If \( O \) is not an Object, return \text{undefined}.
3. If \( O \) does not have a \([[[\text{TypedArrayName}]]\) internal slot, return \text{undefined}.
4. Let \( name \) be \( O.[[\text{TypedArrayName}]] \).
5. Assert: \( name \) is a String.
6. Return \( name \).

This property has the attributes \{ [[Enumerable]]: \text{false}, [[Configurable]]: \text{true} \}.

The initial value of the "name" property of this function is "get [\text{Symbol.toStringTag}]".

23.2.4 Abstract Operations for TypedArray Objects

23.2.4.1 \text{TypedArraySpeciesCreate}(\text{exemplar}, \text{argumentList})

The abstract operation \text{TypedArraySpeciesCreate} takes arguments \text{exemplar} (a \text{TypedArray}) and \text{argumentList} (a List of ECMAScript language values) and returns either a normal completion containing a \text{TypedArray} or a throw completion. It is used to specify the creation of a new \text{TypedArray} using a constructor function that is derived from \text{exemplar}. Unlike \text{ArraySpeciesCreate}, which can create non-Array objects through the use of @@species, this operation enforces that the constructor function creates an actual \text{TypedArray}. It performs the following steps when called:

1. Let \text{defaultConstructor} be the intrinsic object associated with the constructor name \text{exemplar}.[[\text{TypedArrayName}]] in Table 71.
2. Let \text{constructor} be \( \text{SpeciesConstructor}(\text{exemplar}, \text{defaultConstructor}) \).
3. Let \text{result} be \( \text{TypedArrayCreateFromConstructor}((\text{constructor}, \text{argumentList}) \).
4. Assert: \text{result} has [[\text{TypedArrayName}]] and [[\text{ContentType}]] internal slots.
5. If \text{result}.[[\text{ContentType}]] is not \text{exemplar}.[[\text{ContentType}]], throw a \text{TypeError} \) exception.
6. Return \text{result}.
The abstract operation `TypedArrayCreateFromConstructor` takes arguments `constructor` (a constructor) and `argumentList` (a List of ECMAScript language values) and returns either a normal completion containing a `TypedArray` or a throw completion. It is used to specify the creation of a new `TypedArray` using a constructor function. It performs the following steps when called:

1. Let `newTypedArray` be ? `Construct(constructor, argumentList)`.
2. Let `taRecord` be ? `ValidateTypedArray(newTypedArray, SEQ-CST)`.
3. If the number of elements in `argumentList` is 1 and `argumentList[0]` is a Number, then
   a. If `IsTypedArrayOutOfBounds(taRecord)` is true, throw a `TypeError` exception.
   b. Let `length` be `TypedArrayLength(taRecord)`.
   c. If `length < ℝ(argumentList[0])`, throw a `TypeError` exception.
4. Return `newTypedArray`.

The abstract operation `TypedArrayCreateSameType` takes arguments `exemplar` (a `TypedArray`) and `argumentList` (a List of ECMAScript language values) and returns either a normal completion containing a `TypedArray` or a throw completion. It is used to specify the creation of a new `TypedArray` using a constructor function that is derived from `exemplar`. Unlike `TypedArraySpeciesCreate`, which can construct custom `TypedArray` subclasses through the use of `@@species`, this operation always uses one of the built-in `TypedArray` constructors. It performs the following steps when called:

1. Let `constructor` be the intrinsic object associated with the `constructor` name `exemplar.@@TypedArrayName` in Table 71.
2. Let `result` be ? `TypedArrayCreateFromConstructor(constructor, argumentList)`.
3. Assert: `result` has `[[TypedArrayName]]` and `[[ContentType]]` internal slots.
4. Assert: `result.@@ContentType` is `exemplar.@@ContentType`.
5. Return `result`.

The abstract operation `ValidateTypedArray` takes arguments `O` (an ECMAScript language value) and `order` (SEQ-CST or UNORDERED) and returns either a normal completion containing a `TypedArray With Buffer Witness Record` or a throw completion. It performs the following steps when called:

1. Perform ? `RequireInternalSlot(O, [[TypedArrayName]])`.
2. Assert: `O` has a `[[ViewedArrayBuffer]]` internal slot.
3. Let `taRecord` be `MakeTypedArrayWithBufferWitnessRecord(O, order)`.
4. If `IsTypedArrayOutOfBounds(taRecord)` is true, throw a `TypeError` exception.
5. Return `taRecord`.

The abstract operation `TypedArrayElementSize` takes argument `O` (a `TypedArray`) and returns a non-negative integer. It performs the following steps when called:

1. Return the Element Size value specified in Table 71 for `O.@@TypedArrayName`.

The abstract operation `TypedArrayElementType` takes argument `O` (a `TypedArray`) and returns a `TypedArray` element type. It performs the following steps when called:

1. Return the Element Type value specified in Table 71 for `O.@@TypedArrayName`.
23.2.4.7 CompareTypedArrayElements (x, y, comparefn)

The abstract operation CompareTypedArrayElements takes arguments x (a Number or a BigInt), y (a Number or a BigInt), and comparefn (a function object or undefined) and returns either a normal completion containing a Number or an abrupt completion. It performs the following steps when called:

1. Assert: x is a Number and y is a Number, or x is a BigInt and y is a BigInt.
2. If comparefn is not undefined, then
   a. Let v be ?ToNumber(?Call(comparefn, undefined, «x, y»)).
   b. If v is NaN, return +0𝔽.
   c. Return v.
3. If x and y are both NaN, return +0𝔽.
4. If x is NaN, return 1𝔽.
5. If y is NaN, return -1𝔽.
6. If x < y, return -1𝔽.
7. If x > y, return 1𝔽.
8. If x is -0𝔽 and y is +0𝔽, return -1𝔽.
9. If x is +0𝔽 and y is -0𝔽, return 1𝔽.
10. Return +0𝔽.

NOTE This performs a numeric comparison rather than the string comparison used in 23.1.3.30.2.

23.2.5 The TypedArray Constructors

Each TypedArray constructor:

• is an intrinsic object that has the structure described below, differing only in the name used as the constructor name instead of TypedArray, in Table 71.
• is a function whose behaviour differs based upon the number and types of its arguments. The actual behaviour of a call of TypedArray depends upon the number and kind of arguments that are passed to it.
• is not intended to be called as a function and will throw an exception when called in that manner.
• may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified TypedArray behaviour must include a super call to the TypedArray constructor to create and initialize the subclass instance with the internal state necessary to support the %TypedArray%.prototype built-in methods.

23.2.5.1 TypedArray (...args)

Each TypedArray constructor performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. Let constructorName be the String value of the Constructor Name value specified in Table 71 for this TypedArray constructor.
3. Let proto be "%TypedArray%.prototype".
4. Let numberOfArgs be the number of elements in args.
5. If numberOfArgs = 0, then
   a. Return ?AllocateTypedArray(constructorName, NewTarget, proto, 0).
6. Else,
   a. Let firstArgument be args[0].
   b. If firstArgument is an Object, then
      i. Let O be ?AllocateTypedArray(constructorName, NewTarget, proto).
      ii. If firstArgument has a [[TypedArrayName]] internal slot, then
         1. Perform ?InitializeTypedArrayFromTypedArray(O, firstArgument).
      iii. Else if firstArgument has an [[ArrayBufferData]] internal slot, then
         1. If numberOfArgs > 1, let byteOffset be args[1]; else let byteOffset be undefined.
         2. If numberOfArgs > 2, let length be args[2]; else let length be undefined.
      iv. Else,
1. **Assert**: `firstArgument` is an Object and `firstArgument` does not have either a [[TypedArrayName]] or an [[ArrayBufferData]] internal slot.
2. Let `usingIterator` be ? `GetMethod(firstArgument, @@iterator)`.
3. If `usingIterator` is not `undefined`, then
   a. Let `values` be `IteratorToList(? GetIteratorFromMethod(firstArgument, usingIterator))`.
   b. Perform ? `InitializeTypedArrayFromList(O, values)`.
4. Else,
   a. NOTE: `firstArgument` is not an iterable so assume it is already an array-like object.
   b. Perform ? `InitializeTypedArrayFromArrayLike(O, firstArgument)`.
   c. Else,
      i. **Assert**: `firstArgument` is not an Object.
      ii. Let `elementLength` be `ToIndex(firstArgument)`.
      iii. Return ? `AllocateTypedArray(constructorName, NewTarget, proto, elementLength)`.

### 23.2.5.1.1 AllocateTypedArray ( constructorName, newTarget, defaultProto [ , length ] )

The abstract operation AllocateTypedArray takes arguments `constructorName` (a String which is the name of a TypedArray constructor in Table 71), `newTarget` (a constructor), and `defaultProto` (a String) and optional argument `length` (a non-negative integer) and returns either a normal completion containing a TypedArray or a throw completion. It is used to validate and create an instance of a TypedArray constructor. If the `length` argument is passed, an ArrayBuffer of that length is also allocated and associated with the new TypedArray instance. AllocateTypedArray provides common semantics that is used by `TypedArray`. It performs the following steps when called:

1. Let `proto` be ? `GetPrototypeFromConstructor(newTarget, defaultProto)`.
2. Let `obj` be `TypedArrayCreate(proto)`.
3. **Assert**: `obj.[[ViewedArrayBuffer]]` is `undefined`.
4. Set `obj.[[TypedArrayName]]` to `constructorName`.
5. If `constructorName` is either "BigInt64Array" or "BigUint64Array", set `obj.[[ContentType]]` to BIGINT.
6. Otherwise, set `obj.[[ContentType]]` to NUMBER.
7. If `length` is not present, then
   a. Set `obj.[[ByteLength]]` to 0.
   b. Set `obj.[[ByteOffset]]` to 0.
   c. Set `obj.[[ArrayLength]]` to 0.
8. Else,
   a. Perform ? `AllocateTypedArrayBuffer(obj, length)`.

### 23.2.5.1.2 InitializeTypedArrayFromTypedArray ( O, srcArray )

The abstract operation InitializeTypedArrayFromTypedArray takes arguments `O` (a `TypedArray`) and `srcArray` (a `TypedArray`) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let `srcData` be `srcArray.[[ViewedArrayBuffer]]`.
2. Let `elementType` be `TypedArrayElementType(O)`.
3. Let `elementSize` be `TypedArrayElementSize(O)`.
4. Let `srcType` be `TypedArrayElementType(srcArray)`.
5. Let `srcElementSize` be `TypedArrayElementSize(srcArray)`.
6. Let `srcByteOffset` be `srcArray.[[ByteOffset]]`.
7. Let `srcRecord` be `MakeTypedArrayWithBufferWitnessRecord(srcArray, SEQ-CST)`.
8. If `IsTypedArrayOutOfBounds(srcRecord)` is `true`, throw a `TypeError` exception.
9. Let `elementLength` be `TypedArrayLength(srcRecord)`.
10. Let `byteLength` be `elementSize × elementLength`.
11. If `elementType` is `srcType`, then
    a. Let `data` be ? `CloneArrayBuffer(srcData, srcByteOffset, byteLength)`.
12. Else,
    a. Let `data` be ? `AllocateArrayBuffer(%ArrayBuffer%, byteLength)`.
    b. If `srcArray.[[ContentType]]` is not `O.[[ContentType]]`, throw a `TypeError` exception.
c. Let `srcByteIndex` be `srcByteOffset`.
d. Let `targetByteIndex` be `0`.
e. Let `count` be `elementLength`.
f. Repeat, while `count > 0`,
   i. Let `value` be `GetValueFromBuffer(srcData, srcByteIndex, srcType, true, UNORDERED).
   ii. Perform `SetValueInBuffer(data, targetByteIndex, elementType, value, true, UNORDERED)`.
   iii. Set `srcByteIndex` to `srcByteIndex + srcElementSize`.
   iv. Set `targetByteIndex` to `targetByteIndex + elementSize`.
   v. Set `count` to `count - 1`.
13. Set `O.[[ViewedArrayBuffer]]` to `data`.
15. Set `O.[[ByteOffset]]` to `0`.
17. Return `UNUSED`.

### 23.2.5.1.3 InitializeTypedArrayFrom ArrayBuffer (O, buffer, byteOffset, length)

The abstract operation `InitializeTypedArrayFrom ArrayBuffer` takes arguments `O` (a `TypedArray`), `buffer` (an ArrayBuffer or a SharedArrayBuffer), `byteOffset` (an ECMAScript language value), and `length` (an ECMAScript language value) and returns either a normal completion containing `UNUSED` or a `throw completion`. It performs the following steps when called:

1. Let `elementSize` be `TypedArrayElementSize(O)`.
2. Let `offset` be `? ToIndex(byteOffset)`.
3. If `offset modulo elementSize ≠ 0`, throw a `RangeError` exception.
4. Let `bufferIsFixedLength` be `IsFixedLengthArrayBuffer(buffer)`.
5. If `length` is not `undefined`, then
   a. Let `newLength` be `? ToIndex(length)`.
6. If `isDetachedBuffer(buffer)` is `true`, throw a `TypeError` exception.
7. Let `bufferByteLength` be `ArrayBufferByteLength(buffer, SEQ-CST)`.
8. If `length` is `undefined` and `bufferIsFixedLength` is `false`, then
   a. If `offset > bufferByteLength`, throw a `RangeError` exception.
   b. Set `O.[[ByteLength]]` to `AUTO`.
   c. Set `O.[[ArrayLength]]` to `AUTO`.
9. Else,
   a. If `length` is `undefined`, then
      i. If `bufferByteLength modulo elementSize ≠ 0`, throw a `RangeError` exception.
      ii. Let `newByteLength` be `bufferByteLength - offset`.
      iii. If `newByteLength < 0`, throw a `RangeError` exception.
   b. Else,
      i. Let `newByteLength` be `newLength * elementSize`.
      ii. If `offset + newByteLength > bufferByteLength`, throw a `RangeError` exception.
   c. Set `O.[[ByteLength]]` to `newByteLength`.
   d. Set `O.[[ArrayLength]]` to `newByteLength / elementSize`.
10. Set `O.[[ViewedArrayBuffer]]` to `buffer`.
11. Set `O.[[ByteOffset]]` to `offset`.
12. Return `UNUSED`.

### 23.2.5.1.4 InitializeTypedArrayFrom List (O, values)

The abstract operation `InitializeTypedArrayFrom List` takes arguments `O` (a `TypedArray`) and `values` (a List of ECMAScript language values) and returns either a normal completion containing `UNUSED` or a `throw completion`. It performs the following steps when called:

1. Let `len` be the number of elements in `values`.
2. Perform `? AllocateTypedArrayBuffer(O, len)`.
3. Let `k` be `0`.
4. Repeat, while `k < len`,
   a. Let `Pk` be `! ToString(F(k))`.
   b. Let `kValue` be the first element of `values`. 
c. Remove the first element from values.
d. Perform \( \text{Set}(O, Pk, kValue, \text{true}) \).
e. Set \( k \) to \( k + 1 \).

5. Assert: values is now an empty List.
6. Return UNUSED.

23.2.5.1.5 InitializeTypedArrayFromArrayLike ( \( O, arrayLike \) )

The abstract operation InitializeTypedArrayFromArrayLike takes arguments \( O \) (a TypedArray) and \( arrayLike \) (an Object, but not a TypedArray or an ArrayBuffer) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let \( len \) be ? \( \text{LengthOfArrayLike}(arrayLike) \).
2. Perform ? \( \text{AllocateTypedArrayBuffer}(O, len) \).
3. Let \( k \) be 0.
4. Repeat, while \( k < len \),
   a. Let \( Pk \) be ! \( \text{ToString}(\mathbb{𝔽}(k)) \).
   b. Let \( kValue \) be ? \( \text{Get}(arrayLike, Pk) \).
   c. Perform ? \( \text{Set}(O, Pk, kValue, \text{true}) \).
   d. Set \( k \) to \( k + 1 \).
5. Return UNUSED.

23.2.5.1.6 AllocateTypedArrayBuffer ( \( O, length \) )

The abstract operation AllocateTypedArrayBuffer takes arguments \( O \) (a TypedArray) and \( length \) (a non-negative integer) and returns either a normal completion containing UNUSED or a throw completion. It allocates and associates an ArrayBuffer with \( O \). It performs the following steps when called:

1. Assert: \( O.[[\text{ViewedArrayBuffer}]] \) is undefined.
2. Let \( elementSize \) be \( \text{TypedArrayElementSize}(O) \).
3. Let \( byteLength \) be \( elementSize \times length \).
4. Let \( data \) be ? \( \text{AllocateArrayBuffer}(\%\text{ArrayBuffer}\%, byteLength) \).
5. Set \( O.[[\text{ViewedArrayBuffer}]] \) to \( data \).
6. Set \( O.[[\text{ByteLength}]] \) to \( byteLength \).
7. Set \( O.[[\text{ByteOffset}]] \) to 0.
8. Set \( O.[[\text{ArrayLength}]] \) to \( length \).
9. Return UNUSED.

23.2.6 Properties of the TypedArray Constructors

Each TypedArray constructor:

- has a \([\text{Prototype}]\) internal slot whose value is \%TypedArray\%.
- has a "length" property whose value is 3\( \mathbb{𝔽} \).
- has a "name" property whose value is the String value of the constructor name specified for it in Table 71.
- has the following properties:

23.2.6.1 TypedArray.BYTES_PER_ELEMENT

The value of TypedArray.BYTES_PER_ELEMENT is the Element Size value specified in Table 71 for TypedArray.

This property has the attributes { \([\text{Writable}]\): false, \([\text{Enumerable}]\): false, \([\text{Configurable}]\): false }.

23.2.6.2 TypedArray.prototype

The initial value of TypedArray.prototype is the corresponding TypedArray prototype intrinsic object (23.2.7).

This property has the attributes { \([\text{Writable}]\): false, \([\text{Enumerable}]\): false, \([\text{Configurable}]\): false }.
23.2.7 Properties of the `TypedArray` Prototype Objects

Each `TypedArray` prototype object:

- has a `[[Prototype]]` internal slot whose value is `%TypedArray.prototype%`.
- is an `ordinary object`.
- does not have a `[[ViewedArrayBuffer]]` or any other of the internal slots that are specific to `TypedArray` instance objects.

23.2.7.1 `TypedArray.prototype.BYTES_PER_ELEMENT`

The value of `TypedArray.prototype.BYTES_PER_ELEMENT` is the Element Size value specified in Table 71 for `TypedArray`.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

23.2.7.2 `TypedArray.prototype.constructor`

The initial value of the "constructor" property of the prototype for a given `TypedArray constructor` is the constructor itself.

23.2.8 Properties of `TypedArray` Instances

`TypedArray` instances are `TypedArrays`. Each `TypedArray` instance inherits properties from the corresponding `TypedArray` prototype object. Each `TypedArray` instance has the following internal slots: `[[TypedArrayName]]`, `[[ViewedArrayBuffer]]`, `[[ByteLength]]`, `[[ByteOffset]]`, and `[[ArrayLength]]`.

24 Keyed Collections

24.1 Map Objects

Maps are collections of key/value pairs where both the keys and values may be arbitrary ECMAScript language values. A distinct key value may only occur in one key/value pair within the Map's collection. Distinct key values are discriminated using the `SameValueZero` comparison algorithm.

Maps must be implemented using either hash tables or other mechanisms that, on average, provide access times that are sublinear on the number of elements in the collection. The data structure used in this specification is only intended to describe the required observable semantics of Maps. It is not intended to be a viable implementation model.

24.1.1 The Map Constructor

The Map constructor:

- is `%Map%`.
- is the initial value of the "Map" property of the `global object`.
- creates and initializes a new Map when called as a `constructor`.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value in an `extends` clause of a class definition. Subclass `constructors` that intend to inherit the specified Map behaviour must include a `super` call to the `Map constructor` to create and initialize the subclass instance with the internal state necessary to support the `Map.prototype` built-in methods.
This function performs the following steps when called:

1. If `NewTarget` is `undefined`, throw a `TypeError` exception.
2. Let `map` be `? OrdinaryCreateFromConstructor(NewTarget, "%Map.prototype%", « [[MapData]] »).
3. Set `map. [[MapData]]` to a new empty `List`.
4. If `iterable` is either `undefined` or `null`, return `map`.
5. Let `adder` be `? Get(map, "set")`.
6. If `IsCallable(adder)` is `false`, throw a `TypeError` exception.
7. Return `? AddEntriesFromIterable(map, iterable, adder)`.

**NOTE**
If the parameter `iterable` is present, it is expected to be an object that implements an `@@iterator` method that returns an iterator object that produces a two element `array-like object` whose first element is a value that will be used as a Map key and whose second element is the value to associate with that key.

**24.1.2 AddEntriesFromIterable ( target, iterable, adder )**

The abstract operation `AddEntriesFromIterable` takes arguments `target` (an Object), `iterable` (an ECMAScript language value, but not `undefined` or `null`), and `adder` (a function object) and returns either a normal completion containing an ECMAScript language value or a throw completion. `adder` will be invoked, with `target` as the receiver. It performs the following steps when called:

1. Let `iteratorRecord` be `? GetIterator(iterable, SYNC)`.
2. Repeat,
   a. Let `next` be `? IteratorStepValue(iteratorRecord)`.
   b. If `next` is `DONE`, return `target`.
   c. If `next` is not an Object, then
      i. Let `error` be `ThrowCompletion(a newly created TypeError object)`.
      ii. Return `? IteratorClose(iteratorRecord, error)`.
   d. Let `k` be `Completion(Get(next, "0"))`.
   e. IfAbruptCloseIterator(k, iteratorRecord).
   f. Let `v` be `Completion(Get(next, "1"))`.
   g. IfAbruptCloseIterator(v, iteratorRecord).
   h. Let `status` be `Completion(Call(adder, target, « k, v »))`.
   i. IfAbruptCloseIterator(status, iteratorRecord).

**NOTE**
The parameter `iterable` is expected to be an object that implements an `@@iterator` method that returns an iterator object that produces a two element `array-like object` whose first element is a value that will be used as a Map key and whose second element is the value to associate with that key.

**24.1.2 Properties of the Map Constructor**

The `Map` constructor:

- has a `[[Prototype]]` internal slot whose value is `%Function.prototype%`.
- has the following properties:
24.1.2.1 `Map.groupBy (items, callbackfn)`

NOTE: `callbackfn` should be a function that accepts two arguments. `groupBy` calls `callbackfn` once for each element in `items`, in ascending order, and constructs a new Map. Each value returned by `callbackfn` is used as a key in the Map. For each such key, the result Map has an entry whose key is that key and whose value is an array containing all the elements for which `callbackfn` returned that key.

`callbackfn` is called with two arguments: the value of the element and the index of the element.

The return value of `groupBy` is a Map.

This function performs the following steps when called:

1. Let `groups` be `GroupBy(items, callbackfn, ZERO)`.  
2. Let `map` be `%Construct(%)`.  
3. For each `Record { [[Key]], [[Elements]] } g` of `groups`, do
   a. Let `elements` be `CreateArrayFromList(g.[[Elements]])`.  
   b. Let `entry` be the `Record { [[Key]], g.[[Key]], [[Value]], elements }`.  
   c. Append `entry` to `map.[[MapData]]`.  
4. Return `map`.

24.1.2.2 `Map.prototype`

The initial value of `Map.prototype` is the `Map prototype object`.  

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

24.1.2.3 `get Map[@@species]`

`Map[@@species]` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "get [Symbol.species]".

NOTE: Methods that create derived collection objects should call `@@species` to determine the constructor to use to create the derived objects. Subclass constructor may over-ride `@@species` to change the default constructor assignment.

24.1.3 Properties of the Map Prototype Object

The `Map prototype object`:

- is `%Map.prototype%`.  
- has a `[[Prototype]]` internal slot whose value is `%Object.prototype%`.  
- is an ordinary object.  
- does not have a `[[MapData]]` internal slot.

24.1.3.1 `Map.prototype.clear()`

This method performs the following steps when called:

1. Let `M` be the this value.  
2. Perform ? `RequireInternalSlot(M, [[MapData]])`.  

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3. For each `Record { [[Key]], [[Value]] } p of M.[[MapData]], do
   a. Set `p. [[Key]]` to EMPTY.
   b. Set `p. [[Value]]` to EMPTY.
4. Return undefined.

NOTE The existing `[[MapData]] List` is preserved because there may be existing Map Iterator objects that are suspended midway through iterating over that `List`.

24.1.3.2 Map.prototype.constructor

The initial value of `Map.prototype.constructor` is `%Map%`.

24.1.3.3 Map.prototype.delete ( `key` )

This method performs the following steps when called:

1. Let `M` be the `this` value.
2. Perform `RequireInternalSlot(M, [[MapData]])`.
3. For each `Record { [[Key]], [[Value]] } p of M.[[MapData]], do
   a. If `p. [[Key]]` is not EMPTY and `SameValueZero(p. [[Key]], key)` is true, then
      i. Set `p. [[Key]]` to EMPTY.
      ii. Set `p. [[Value]]` to EMPTY.
      iii. Return true.
4. Return false.

NOTE The value EMPTY is used as a specification device to indicate that an entry has been deleted. Actual implementations may take other actions such as physically removing the entry from internal data structures.

24.1.3.4 Map.prototype.entries ( )

This method performs the following steps when called:

1. Let `M` be the `this` value.
2. Return `CreateMapIterator(M, KEY+VALUE)`.

24.1.3.5 Map.prototype.forEach ( `callbackfn [ , thisArg ]` )

This method performs the following steps when called:

1. Let `M` be the `this` value.
2. Perform `RequireInternalSlot(M, [[MapData]])`.
3. If `IsCallable(callbackfn)` is false, throw a ` TypeError` exception.
4. Let `entries` be `M.[[MapData]]`.
5. Let `numEntries` be the number of elements in `entries`.
6. Let `index` be 0.
7. Repeat, while `index < numEntries`,
   a. Let `e` be `entries[index]`.
   b. Set `index` to `index + 1`.
   c. If `e. [[Key]]` is not EMPTY, then
      i. Perform `Call(callbackfn, thisArg, « e. [[Value]], e. [[Key]], M »)`.
      ii. NOTE: The number of elements in `entries` may have increased during execution of `callbackfn`.
      iii. Set `numEntries` to the number of elements in `entries`.
8. Return undefined.
NOTE callbackfn should be a function that accepts three arguments. forEach calls callbackfn once for each key/value pair present in the Map, in key insertion order. callbackfn is called only for keys of the Map which actually exist; it is not called for keys that have been deleted from the Map.

If a thisArg parameter is provided, it will be used as the this value for each invocation of callbackfn. If it is not provided, undefined is used instead.

callbackfn is called with three arguments: the value of the item, the key of the item, and the Map being traversed.

forEach does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn. Each entry of a map's [[MapData]] is only visited once. New keys added after the call to forEach begins are visited. A key will be revisited if it is deleted after it has been visited and then re-added before the forEach call completes. Keys that are deleted after the call to forEach begins and before being visited are not visited unless the key is added again before the forEach call completes.

24.1.3.6 Map.prototype.get ( key )

This method performs the following steps when called:

1. Let M be the this value.
2. Perform ? RequireInternalSlot(M, [[MapData]]).
3. For each Record { [[Key]], [[Value]] } p of M.[[MapData]], do
   a. If p.[[Key]] is not EMPTY and SameValueZero(p.[[Key]], key) is true, return p.[[Value]].
4. Return undefined.

24.1.3.7 Map.prototype.has ( key )

This method performs the following steps when called:

1. Let M be the this value.
2. Perform ? RequireInternalSlot(M, [[MapData]])
3. For each Record { [[Key]], [[Value]] } p of M.[[MapData]], do
   a. If p.[[Key]] is not EMPTY and SameValueZero(p.[[Key]], key) is true, return true.
4. Return false.

24.1.3.8 Map.prototype.keys ( )

This method performs the following steps when called:

1. Let M be the this value.
2. Return ? CreateMapIterator(M, KEY).

24.1.3.9 Map.prototype.set ( key, value )

This method performs the following steps when called:

1. Let M be the this value.
2. Perform ? RequireInternalSlot(M, [[MapData]]).
3. For each Record { [[Key]], [[Value]] } p of M.[[MapData]], do
   a. If p.[[Key]] is not EMPTY and SameValueZero(p.[[Key]], key) is true, then
      i. Set p.[[Value]] to value.
      ii. Return M.
4. If key is -0𝔽, set key to +0𝔽.
5. Let p be the Record { [[Key]]: key, [[Value]]: value }.
6. Append \( p \) to \( M.[[\text{MapData}]] \).
7. Return \( M \).

24.1.3.10 get Map.prototype.size

Map.prototype.size is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let \( M \) be the this value.
2. Perform ? RequireInternalSlot(\( M, [[\text{MapData}]] \)).
3. Let \( count \) be 0.
4. For each Record \{ [[Key]], [[Value]] \} \( p \) of \( M.[[\text{MapData}]] \), do
   a. If \( p.\text{[[Key]]} \) is not EMPTY, set \( count \) to \( count + 1 \).
5. Return \( F(count) \).

24.1.3.11 Map.prototype.values ( )

This method performs the following steps when called:

1. Let \( M \) be the this value.
2. Return ? CreateMapIterator(\( M, \text{VALUE} \)).

24.1.3.12 Map.prototype [ @@iterator ] ( )

The initial value of the @@iterator property is %Map.prototype.entries%, defined in 24.1.3.4.

24.1.3.13 Map.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "Map".

This property has the attributes \{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true \}.

24.1.4 Properties of Map Instances

Map instances are ordinary objects that inherit properties from the Map prototype. Map instances also have a [[MapData]] internal slot.

24.1.5 Map Iterator Objects

A Map Iterator is an object, that represents a specific iteration over some specific Map instance object. There is not a named constructor for Map Iterator objects. Instead, map iterator objects are created by calling certain methods of Map instance objects.

24.1.5.1 CreateMapIterator ( map, kind )

The abstract operation CreateMapIterator takes arguments \( map \) (an ECMAScript language value) and \( kind \) (KEY+VALUE, KEY, or VALUE) and returns either a normal completion containing a Generator or a throw completion. It is used to create iterator objects for Map methods that return such iterators. It performs the following steps when called:

1. Perform ? RequireInternalSlot(\( map, [[\text{MapData}]] \)).
2. Let closure be a new Abstract Closure with no parameters that captures \( map \) and \( kind \) and performs the following steps when called:
   a. Let entries be \( map.[[\text{MapData}]] \).
   b. Let index be 0.
   c. Let numEntries be the number of elements in entries.
   d. Repeat, while index < numEntries,
i. Let $e$ be $entries[index]$.

ii. Set $index$ to $index + 1$.

iii. If $e[[Key]]$ is not EMPTY, then
   1. If $kind$ is KEY, then
      a. Let $result$ be $e[[Key]]$.
   2. Else if $kind$ is VALUE, then
      a. Let $result$ be $e[[Value]]$.
   3. Else,
      a. Assert: $kind$ is KEY+VALUE.
      b. Let $result$ be CreateArrayFromList(« $e[[Key]]$, $e[[Value]]$ »).

4. Perform ? GeneratorYield(CreateIterResultObject($result$, false)).

5. NOTE: The number of elements in $entries$ may have increased while execution of this abstract operation was paused by Yield.

6. Set $numEntries$ to the number of elements in $entries$.

7. Return $undefined$.

3. Return CreateIteratorFromClosure($closure$, "%MapIteratorPrototype%", %MapIteratorPrototype%).

24.1.5.2 The %MapIteratorPrototype% Object

The %MapIteratorPrototype% object:

- has properties that are inherited by all Map Iterator Objects.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is %IteratorPrototype%.
- has the following properties:

24.1.5.2.1 %MapIteratorPrototype%.next ( )

1. Return ? GeneratorResume($this$ value, EMPTY, "%MapIteratorPrototype%").

24.1.5.2.2 %MapIteratorPrototype% [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "Map Iterator".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

24.2 Set Objects

Set objects are collections of ECMAScript language values. A distinct value may only occur once as an element of a Set's collection. Distinct values are discriminated using the SameValueZero comparison algorithm.

Set objects must be implemented using either hash tables or other mechanisms that, on average, provide access times that are sublinear on the number of elements in the collection. The data structure used in this specification is only intended to describe the required observable semantics of Set objects. It is not intended to be a viable implementation model.

24.2.1 The Set Constructor

The Set constructor:

- is %Set%.
- is the initial value of the "Set" property of the global object.
- creates and initializes a new Set object when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value in an extends clause of a class definition. Subclass constructors that intend to inherit the specified Set behaviour must include a super call to the Set constructor to create and initialize the subclass instance with the internal state necessary to support the Set.prototype built-in methods.
24.2.1.1 Set ([ iterable ]) 

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. Let set be ? OrdinaryCreateFromConstructor(NewTarget, "%Set.prototype%", « [[SetData]] »).
3. Set set.[[SetData]] to a new empty List.
4. If iterable is either undefined or null, return set.
5. Let adder be ? Get(set, "add").
6. If IsCallable(adder) is false, throw a TypeError exception.
7. Let iteratorRecord be ? GetIterator(iterable, SYNC).
8. Repeat,
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is DONE, return set.
   c. Let status be Completion(Call(adder, set, « next »)).
   d. IfAbruptCloseIterator(status, iteratorRecord).

24.2.2 Properties of the Set Constructor

The Set constructor:

• has a [[Prototype]] internal slot whose value is %Function.prototype%.
• has the following properties:

24.2.2.1 Set.prototype

The initial value of Set.prototype is the Set prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

24.2.2.2 get Set [ @@species ]

Set[@@species] is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "get [Symbol.species]".

NOTE Methods that create derived collection objects should call @@species to determine the constructor to use to create the derived objects. Subclass constructor may over-ride @@species to change the default constructor assignment.

24.2.3 Properties of the Set Prototype Object

The Set prototype object:

• is %Set.prototype%.
• has a [[Prototype]] internal slot whose value is %Object.prototype%.
• is an ordinary object.
• does not have a [[SetData]] internal slot.
This method performs the following steps when called:

1. Let $S$ be the this value.
2. Perform ? RequireInternalSlot($S$, [[SetData]]).
3. For each element $e$ of $S$.[[SetData]], do
   a. If $e$ is not EMPTY and SameValueZero($e$, value) is true, then
      i. Return $S$.
4. If value is -0𝔽, set value to +0𝔽.
5. Append value to $S$.[[SetData]].
6. Return $S$.

This method performs the following steps when called:

1. Let $S$ be the this value.
2. Perform ? RequireInternalSlot($S$, [[SetData]]).
3. For each element $e$ of $S$.[[SetData]], do
   a. Replace the element of $S$.[[SetData]] whose value is $e$ with an element whose value is EMPTY.
4. Return undefined.

NOTE The existing [[SetData]] List is preserved because there may be existing Set Iterator objects that are suspended midway through iterating over that List.

The initial value of Set.prototype.constructor is %Set%.

This method performs the following steps when called:

1. Let $S$ be the this value.
2. Perform ? RequireInternalSlot($S$, [[SetData]]).
3. For each element $e$ of $S$.[[SetData]], do
   a. If $e$ is not EMPTY and SameValueZero($e$, value) is true, then
      i. Replace the element of $S$.[[SetData]] whose value is $e$ with an element whose value is EMPTY.
      ii. Return true.
4. Return false.

NOTE The value EMPTY is used as a specification device to indicate that an entry has been deleted. Actual implementations may take other actions such as physically removing the entry from internal data structures.

This method performs the following steps when called:

1. Let $S$ be the this value.
2. Return ? CreateSetIterator($S$, KEY+VALUE).
NOTE For iteration purposes, a Set appears similar to a Map where each entry has the same value for its key and value.

24.2.3.6 Set.prototype.forEach (callbackfn [ , thisArg ])

This method performs the following steps when called:

1. Let S be the this value.
2. Perform ? RequireInternalSlot(S, [[SetData]]).
3. If IsCallable(callbackfn) is false, throw a TypeError exception.
4. Let entries be S.[[SetData]].
5. Let numEntries be the number of elements in entries.
6. Let index be 0.
7. Repeat, while index < numEntries,
   a. Let e be entries[index].
   b. Set index to index + 1.
   c. If e is not EMPTY, then
      i. Perform ? Call(callbackfn, thisArg, « e, e, S »).
      ii. NOTE: The number of elements in entries may have increased during execution of callbackfn.
      iii. Set numEntries to the number of elements in entries.
8. Return undefined.

NOTE callbackfn should be a function that accepts three arguments. forEach calls callbackfn once for each value present in the Set object, in value insertion order. callbackfn is called only for values of the Set which actually exist; it is not called for keys that have been deleted from the set.

If a thisArg parameter is provided, it will be used as the this value for each invocation of callbackfn. If it is not provided, undefined is used instead.

forEach is called with three arguments: the first two arguments are a value contained in the Set. The same value is passed for both arguments. The Set object being traversed is passed as the third argument.

The callbackfn is called with three arguments to be consistent with the call back functions used by forEach methods for Map and Array. For Sets, each item value is considered to be both the key and the value.

forEach does not directly mutate the object on which it is called but the object may be mutated by the calls to callbackfn.

Each value is normally visited only once. However, a value will be revisited if it is deleted after it has been visited and then re-added before the forEach call completes. Values that are deleted after the call to forEach begins and before being visited are not visited unless the value is added again before the forEach call completes. New values added after the call to forEach begins are visited.

24.2.3.7 Set.prototype.has (value)

This method performs the following steps when called:

1. Let S be the this value.
2. Perform ? RequireInternalSlot(S, [[SetData]]).
3. For each element e of S.[[SetData]], do
   a. If e is not EMPTY and SameValueZero(e, value) is true, return true.
4. Return false.
24.2.3.8 Set.prototype.keys ( )

The initial value of the "keys" property is %Set.prototype.values%, defined in 24.2.3.10.

NOTE For iteration purposes, a Set appears similar to a Map where each entry has the same value for its key and value.

24.2.3.9 get Set.prototype.size

Set.prototype.size is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let S be the this value.
2. Perform ? RequireInternalSlot(S, [[SetData]]).
3. Let count be 0.
4. For each element e of S.[[SetData]], do
   a. If e is not EMPTY, set count to count + 1.
5. Return 𝔼(count).

24.2.3.10 Set.prototype.values ( )

This method performs the following steps when called:

1. Let S be the this value.
2. Return ? CreateSetIterator(S, VALUE).

24.2.3.11 Set.prototype @@iterator ()

The initial value of the @@iterator property is %Set.prototype.values%, defined in 24.2.3.10.

24.2.3.12 Set.prototype @@toStringTag

The initial value of the @@toStringTag property is the String value "Set".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

24.2.4 Properties of Set Instances

Set instances are ordinary objects that inherit properties from the Set prototype. Set instances also have a [[SetData]] internal slot.

24.2.5 Set Iterator Objects

A Set Iterator is an ordinary object, with the structure defined below, that represents a specific iteration over some specific Set instance object. There is not a named constructor for Set Iterator objects. Instead, set iterator objects are created by calling certain methods of Set instance objects.
The abstract operation CreateSetIterator takes arguments `set` (an ECMAScript language value) and `kind` (KEY+VALUE or VALUE) and returns either a normal completion containing a Generator or a throw completion. It is used to create iterator objects for Set methods that return such iterators. It performs the following steps when called:

1. Perform `? RequireInternalSlot(set, [[SetData]])`.
2. Let `closure` be a new Abstract Closure with no parameters that captures `set` and `kind` and performs the following steps when called:
   a. Let `index` be 0.
   b. Let `entries` be `set`,[[SetData]]
   c. Let `numEntries` be the number of elements in `entries`.
   d. Repeat, while `index < numEntries`,
      i. Let `e` be `entries`[`index`].
      ii. Set `index` to `index` + 1.
      iii. If `e` is not EMPTY, then
         1. If `kind` is KEY+VALUE, then
            a. Let `result` be `CreateArrayFromList(« e, e »)`.
            b. Perform `? GeneratorYield(CreateIterResultObject(result, false))`.
         2. Else,
            a. Assert: `kind` is VALUE.
            b. Perform `? GeneratorYield(CreateIterResultObject(e, false))`.
   3. NOTE: The number of elements in `entries` may have increased while execution of this abstract operation was paused by `Yield`.
   4. Set `numEntries` to the number of elements in `entries`.
   e. Return `undefined`.
3. Return `CreateIteratorFromClosure(closure, "%SetIteratorPrototype", %SetIteratorPrototype%)`.

The `%SetIteratorPrototype%` object:

- has properties that are inherited by all Set Iterator Objects.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is `%IteratorPrototype%`.
- has the following properties:

24.2.5.2.1 `%SetIteratorPrototype%.next ()`

1. Return `? GeneratorResume(this value, EMPTY, "%SetIteratorPrototype%")`.

24.2.5.2.2 `%SetIteratorPrototype% [ @@toStringTag ]`

The initial value of the `@@toStringTag` property is the String value "Set Iterator".

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

24.3 WeakMap Objects

WeakMaps are collections of key/value pairs where the keys are objects and/or symbols and values may be arbitrary ECMAScript language values. A WeakMap may be queried to see if it contains a key/value pair with a specific key, but no mechanism is provided for enumerating the values it holds as keys. In certain conditions, values which are not live are removed as WeakMap keys, as described in 9.10.3.

An implementation may impose an arbitrarily determined latency between the time a key/value pair of a WeakMap becomes inaccessible and the time when the key/value pair is removed from the WeakMap. If this latency was observable to ECMAScript program, it would be a source of indeterminacy that could impact program execution.
For that reason, an ECMAScript implementation must not provide any means to observe a key of a WeakMap that does not require the observer to present the observed key.

WeakMaps must be implemented using either hash tables or other mechanisms that, on average, provide access times that are sublinear on the number of key/value pairs in the collection. The data structure used in this specification is only intended to describe the required observable semantics of WeakMaps. It is not intended to be a viable implementation model.

NOTE

WeakMap and WeakSet are intended to provide mechanisms for dynamically associating state with an object or symbol in a manner that does not "leak" memory resources if, in the absence of the WeakMap or WeakSet instance, the object or symbol otherwise became inaccessible and subject to resource reclamation by the implementation's garbage collection mechanisms. This characteristic can be achieved by using an inverted per-object/symbol mapping of WeakMap or WeakSet instances to keys. Alternatively, each WeakMap or WeakSet instance may internally store its key and value data, but this approach requires coordination between the WeakMap or WeakSet implementation and the garbage collector. The following references describe mechanism that may be useful to implementations of WeakMap and WeakSet:


24.3.1 The WeakMap Constructor

The WeakMap constructor:

• is %WeakMap%.
• is the initial value of the "WeakMap" property of the global object.
• creates and initializes a new WeakMap when called as a constructor.
• is not intended to be called as a function and will throw an exception when called in that manner.
• may be used as the value in an extends clause of a class definition. Subclass constructors that intend to inherit the specified WeakMap behaviour must include a super call to the WeakMap constructor to create and initialize the subclass instance with the internal state necessary to support the WeakMap.prototype built-in methods.

24.3.1.1 WeakMap ( [ iterable ] )

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. Let map be ? OrdinaryCreateFromConstructor(NewTarget, "%WeakMap.prototype%", «[[WeakMapData]]»).
3. Set map.[[WeakMapData]] to a new empty List.
4. If iterable is either undefined or null, return map.
5. Let adder be ? Get(map, "set").
6. If isCallable(adder) is false, throw a TypeError exception.
7. Return ? AddEntriesFromIterable(map, iterable, adder).

NOTE

If the parameter iterable is present, it is expected to be an object that implements an @@iterator method that returns an iterator object that produces a two element array-like object whose first element is a value that will be used as a WeakMap key and whose second element is the value to associate with that key.
24.3.2 Properties of the WeakMap Constructor

The WeakMap constructor:

- has a [[Prototype]] internal slot whose value is `%Function.prototype%`.
- has the following properties:

24.3.2.1 WeakMap.prototype

The initial value of `WeakMap.prototype` is the WeakMap prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

24.3.3 Properties of the WeakMap Prototype Object

The `WeakMap.prototype` object:

- is `%WeakMap.prototype%`.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.
- is an ordinary object.
- does not have a [[WeakMapData]] internal slot.

24.3.3.1 WeakMap.prototype.constructor

The initial value of `WeakMap.prototype.constructor` is `%WeakMap%`.

24.3.3.2 WeakMap.prototype.delete (key)

This method performs the following steps when called:

1. Let $M$ be the this value.
2. Perform `? RequireInternalSlot($M$, [[WeakMapData]]).
3. If `CanBeHeldWeakly(key)` is `false`, return `false`.
4. For each `Record { [[Key]], [[Value]] } p` of $M$.[[WeakMapData]], do
   a. If $p$.[[Key]] is not EMPTY and `SameValue(p.[[Key]], key)` is `true`, then
      i. Set $p$.[[Key]] to EMPTY.
      ii. Set $p$.[[Value]] to EMPTY.
      iii. Return `true`.
5. Return `false`.

**NOTE** The value EMPTY is used as a specification device to indicate that an entry has been deleted. Actual implementations may take other actions such as physically removing the entry from internal data structures.

24.3.3.3 WeakMap.prototype.get (key)

This method performs the following steps when called:

1. Let $M$ be the this value.
2. Perform `? RequireInternalSlot($M$, [[WeakMapData]]).
3. If `CanBeHeldWeakly(key)` is `false`, return `undefined`.
4. For each `Record { [[Key]], [[Value]] } p` of $M$.[[WeakMapData]], do
   a. If $p$.[[Key]] is not EMPTY and `SameValue(p.[[Key]], key)` is `true`, return $p$.[[Value]].
5. Return `undefined`.

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24.3.3.4 WeakMap.prototype.has ( key )

This method performs the following steps when called:

1. Let $M$ be the this value.
2. Perform `RequireInternalSlot(M, [[WeakMapData]])`.
3. If `CanBeHeldWeakly(key)` is false, return false.
4. For each Record $\{ [[Key]], [[Value]] \} p$ of $M$.[[WeakMapData]], do
   a. If $p$.[[Key]] is not EMPTY and `SameValue(p.[[Key]], key)` is true, return true.
5. Return false.

24.3.3.5 WeakMap.prototype.set ( key, value )

This method performs the following steps when called:

1. Let $M$ be the this value.
2. Perform `RequireInternalSlot(M, [[WeakMapData]])`.
3. If `CanBeHeldWeakly(key)` is false, throw a TypeError exception.
4. For each Record $\{ [[Key]], [[Value]] \} p$ of $M$.[[WeakMapData]], do
   a. If $p$.[[Key]] is not EMPTY and `SameValue(p.[[Key]], key)` is true, then
      i. Set $p$.[[Value]] to value.
      ii. Return $M$.
6. Append $p$ to $M$.[[WeakMapData]].
7. Return $M$.

24.3.3.6 WeakMap.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "WeakMap".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

24.3.4 Properties of WeakMap Instances

WeakMap instances are ordinary objects that inherit properties from the WeakMap prototype. WeakMap instances also have a [[WeakMapData]] internal slot.

24.4 WeakSet Objects

WeakSets are collections of objects and/or symbols. A distinct object or symbol may only occur once as an element of a WeakSet's collection. A WeakSet may be queried to see if it contains a specific value, but no mechanism is provided for enumerating the values it holds. In certain conditions, values which are not live are removed as WeakSet elements, as described in 9.10.3.

An implementation may impose an arbitrarily determined latency between the time a value contained in a WeakSet becomes inaccessible and the time when the value is removed from the WeakSet. If this latency was observable to ECMAScript program, it would be a source of indeterminacy that could impact program execution. For that reason, an ECMAScript implementation must not provide any means to determine if a WeakSet contains a particular value that does not require the observer to present the observed value.

WeakSets must be implemented using either hash tables or other mechanisms that, on average, provide access times that are sublinear on the number of elements in the collection. The data structure used in this specification is only intended to describe the required observable semantics of WeakSets. It is not intended to be a viable implementation model.

NOTE See the NOTE in 24.3.
24.4.1 The WeakSet Constructor

The WeakSet constructor:

- is `%WeakSet%`.
- is the initial value of the "WeakSet" property of the global object.
- creates and initializes a new WeakSet when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value in an `extends` clause of a class definition. Subclass constructors that intend to inherit the specified WeakSet behaviour must include a `super` call to the WeakSet constructor to create and initialize the subclass instance with the internal state necessary to support the `WeakSet.prototype` built-in methods.

24.4.1.1 WeakSet ([ iterable ])

This function performs the following steps when called:

1. If NewTarget is `undefined`, throw a `TypeError` exception.
2. Let `set` be ? `OrdinaryCreateFromConstructor`(NewTarget, "%WeakSet.prototype%", « [[WeakSetData]] »).
3. Set `set`.[[WeakSetData]] to a new empty `List`.
4. If `iterable` is either `undefined` or `null`, return `set`.
5. Let `adder` be ? `Get`(set, "add").
6. If `IsCallable(adder)` is `false`, throw a `TypeError` exception.
7. Let `iteratorRecord` be ? `GetIterator`(iterable, SYNC).
8. Repeat,
   a. Let `next` be ? `IteratorStepValue(iteratorRecord)`.
   b. If `next` is DONE, return `set`.
   c. Let `status` be `Completion(Call(adder, set, « next »))`.
   d. `IfAbruptCloseIterator(status, iteratorRecord)`.

24.4.2 Properties of the WeakSet Constructor

The WeakSet constructor:

- has a [[Prototype]] internal slot whose value is `%Function.prototype%`.
- has the following properties:

24.4.2.1 WeakSet.prototype

The initial value of `WeakSet.prototype` is the WeakSet prototype object.

This property has the attributes { [[Writable]]: `false`, [[Enumerable]]: `false`, [[Configurable]]: `false` }.

24.4.3 Properties of the WeakSet Prototype Object

The `WeakSet prototype object`:

- is `%WeakSet.prototype%`.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.
- is an `ordinary object`.
- does not have a [[WeakSetData]] internal slot.

24.4.3.1 WeakSet.prototype.add ( value )

This method performs the following steps when called:

1. Let `S` be the this value.
2. Perform ? `RequireInternalSlot(S, [[WeakSetData]])`.
3. If `CanBeHeldWeakly(value)` is `false`, throw a `TypeError` exception.
4. For each element `e` of `S.[[WeakSetData]]`, do
   a. If `e` is not `EMPTY` and `SameValue(e, value)` is `true`, then
      i. Return `S`.
5. Append `value` to `S.[[WeakSetData]]`.
6. Return `S`.

### 24.4.3.2 WeakSet.prototype.constructor

The initial value of `WeakSet.prototype.constructor` is `%WeakSet%`.

### 24.4.3.3 WeakSet.prototype.delete ( value )

This method performs the following steps when called:

1. Let `S` be the `this` value.
2. Perform `? RequireInternalSlot(S, [[WeakSetData]])`.
3. If `CanBeHeldWeakly(value)` is `false`, return `false`.
4. For each element `e` of `S.[[WeakSetData]]`, do
   a. If `e` is not `EMPTY` and `SameValue(e, value)` is `true`, then
      i. Replace the element of `S.[[WeakSetData]]` whose value is `e` with an element whose value is `EMPTY`.
      ii. Return `true`.
5. Return `false`.

**NOTE** The value `EMPTY` is used as a specification device to indicate that an entry has been deleted. Actual implementations may take other actions such as physically removing the entry from internal data structures.

### 24.4.3.4 WeakSet.prototype.has ( value )

This method performs the following steps when called:

1. Let `S` be the `this` value.
2. Perform `? RequireInternalSlot(S, [[WeakSetData]])`.
3. If `CanBeHeldWeakly(value)` is `false`, return `false`.
4. For each element `e` of `S.[[WeakSetData]]`, do
   a. If `e` is not `EMPTY` and `SameValue(e, value)` is `true`, return `true`.
5. Return `false`.

### 24.4.3.5 WeakSet.prototype [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "WeakSet".

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

### 24.4.4 Properties of WeakSet Instances

WeakSet instances are `ordinary objects` that inherit properties from the WeakSet prototype. WeakSet instances also have a `[[WeakSetData]]` internal slot.
25 Structured Data

25.1 ArrayBuffer Objects

25.1.1 Notation

The descriptions below in this section, 25.4, and 29 use the read-modify-write modification function internal data structure.

A **read-modify-write modification function** is a mathematical function that is notationally represented as an abstract closure that takes two **Lists of byte values** as arguments and returns a **List of byte values**. These abstract closures satisfy all of the following properties:

- They perform all their algorithm steps atomically.
- Their individual algorithm steps are not observable.

**NOTE** To aid verifying that a read-modify-write modification function’s algorithm steps constitute a pure, mathematical function, the following editorial conventions are recommended:

- They do not access, directly or transitively via invoked **abstract operations** and abstract closures, any language or specification values except their parameters and captured values.
- They do not return **Completion Records**.

25.1.2 Fixed-length and Resizable ArrayBuffer Objects

A **fixed-length ArrayBuffer** is an ArrayBuffer whose byte length cannot change after creation.

A **resizable ArrayBuffer** is an ArrayBuffer whose byte length may change after creation via calls to `ArrayBuffer.prototype.resize (newLength)`.

The kind of ArrayBuffer object that is created depends on the arguments passed to `ArrayBuffer (length [, options])`.

25.1.3 Abstract Operations For ArrayBuffer Objects

25.1.3.1 AllocateArrayBuffer ( constructor, byteLength [, maxByteLength ] )

The abstract operation `AllocateArrayBuffer` takes arguments **constructor** (a **constructor**) and **byteLength** (a non-negative integer) and optional argument **maxByteLength** (a non-negative integer or **EMPTY**) and returns either a **normal completion containing** an ArrayBuffer or a **throw completion**. It is used to create an ArrayBuffer. It performs the following steps when called:

1. Let `slots` be « [[ArrayBufferData]], [[ArrayBufferByteLength]], [[ArrayBufferDetachKey]] ».
2. If `maxByteLength` is present and `maxByteLength` is not **EMPTY**, let `allocatingResizableBuffer` be **true**; otherwise let `allocatingResizableBuffer` be **false**.
3. If `allocatingResizableBuffer` is **true**, then
   a. If `byteLength > maxByteLength`, throw a **RangeError** exception.
   b. Append `[[ArrayBufferMaxByteLength]]` to `slots`.
4. Let `obj` be ? **OrdinaryCreateFromConstructor**(constructor, "%ArrayBuffer.prototype%", `slots`).
5. Let `block` be ? `CreateByteDataBlock(byteLength)`.
6. Set `obj.[[ArrayBufferData]]` to `block`.
7. Set `obj.[[ArrayBufferByteLength]]` to `byteLength`.
8. If `allocatingResizableBuffer` is **true**, then
   a. If it is not possible to create a **Data Block** `block` consisting of `maxByteLength` bytes, throw a **RangeError** exception.
b. NOTE: Resizable ArrayBuffers are designed to be implementable with in-place growth. Implementations may throw if, for example, virtual memory cannot be reserved up front.

c. Set \( \text{obj}.[\text{ArrayBufferMaxByteLength}] \) to \( \text{maxByteLength} \).

9. Return \( \text{obj} \).

25.1.3.2 ArrayBufferByteLength ( \( \text{arrayBuffer, order} \) )

The abstract operation ArrayBufferByteLength takes arguments \( \text{arrayBuffer} \) (an ArrayBuffer or SharedArrayBuffer) and \( \text{order} \) (SEQ-CST or UNORDERED) and returns a non-negative integer. It performs the following steps when called:

1. If \( \text{IsSharedArrayBuffer} (\text{arrayBuffer}) \) is true and \( \text{arrayBuffer} \) has an \( [[\text{ArrayBufferByteLengthData}]] \) internal slot, then
   a. Let \( \text{bufferByteLengthBlock} \) be \( \text{arrayBuffer}.[[\text{ArrayBufferByteLengthData}]] \).
   b. Let \( \text{rawLength} \) be \( \text{GetRawBytesFromSharedBlock}(\text{bufferByteLengthBlock}, 0, \text{BIGUINT64}, \text{true}, \text{order}) \).
   c. Let \( \text{isLittleEndian} \) be the value of the \( [[\text{LittleEndian}]] \) field of the surrounding agent's Agent Record.
   d. Return \( \text{R} (\text{RawBytesToNumeric}(\text{BIGUINT64}, \text{rawLength}, \text{isLittleEndian})) \).
2. Assert: \( \text{IsDetachedBuffer}(\text{arrayBuffer}) \) is false.
3. Return \( \text{arrayBuffer}.[[\text{ArrayBufferByteLength}]] \).

25.1.3.3 ArrayBufferCopyAndDetach ( \( \text{arrayBuffer, newLength, preserveResizability} \) )

The abstract operation ArrayBufferCopyAndDetach takes arguments \( \text{arrayBuffer} \) (an ECMAScript language value), \( \text{newLength} \) (an ECMAScript language value), and \( \text{preserveResizability} \) (PRESERVE-RESIZABILITY or FIXED-LENGTH) and returns either a normal completion containing an ArrayBuffer or a throw completion. It performs the following steps when called:

1. Perform \( \text{RequireInternalSlot}(\text{arrayBuffer}, [[\text{ArrayBufferData}]] \).
2. If \( \text{IsSharedArrayBuffer}(\text{arrayBuffer}) \) is true, throw a TypeError exception.
3. If \( \text{newLength} \) is undefined, then
   a. Let \( \text{newByteLength} \) be \( \text{arrayBuffer}.[[\text{ArrayBufferByteLength}]] \).
4. Else,
   a. Let \( \text{newByteLength} \) be \( \text{ToIndex}(\text{newLength}) \).
5. If \( \text{IsDetachedBuffer}(\text{arrayBuffer}) \) is true, throw a TypeError exception.
6. If \( \text{preserveResizability} \) is PRESERVE-RESIZABILITY and \( \text{IsFixedLengthArrayBuffer}(\text{arrayBuffer}) \) is false, then
   a. Let \( \text{newMaxByteLength} \) be \( \text{arrayBuffer}.[[\text{ArrayBufferMaxByteLength}]] \).
7. Else,
   a. Let \( \text{newMaxByteLength} \) be EMPTY.
8. If \( \text{arrayBuffer}.[[\text{ArrayBufferDetachKey}]] \) is not undefined, throw a TypeError exception.
9. Let \( \text{newBuffer} \) be \( \text{AllocateArrayBuffer}(\%\text{ArrayBuffer}%, \text{newByteLength}, \text{newMaxByteLength}) \).
10. Let \( \text{copyLength} \) be \( \text{min}(\text{newByteLength}, \text{arrayBuffer}.[[\text{ArrayBufferByteLength}]] \).
11. Let \( \text{fromBlock} \) be \( \text{arrayBuffer}.[[\text{ArrayBufferData}]] \).
12. Let \( \text{toBlock} \) be \( \text{newBuffer}.[[\text{ArrayBufferData}]] \).
13. Perform \( \text{CopyDataBlockBytes}(\text{fromBlock}, 0, \text{fromBlock}, 0, \text{copyLength}) \).
14. NOTE: Neither creation of the new Data Block nor copying from the old Data Block are observable. Implementations may implement this method as a zero-copy move or a realloc.
15. Perform \( !\text{DetachArrayBuffer}(\text{arrayBuffer}) \).
16. Return \( \text{newBuffer} \).

25.1.3.4 IsDetachedBuffer ( \( \text{arrayBuffer} \) )

The abstract operation IsDetachedBuffer takes argument \( \text{arrayBuffer} \) (an ArrayBuffer or a SharedArrayBuffer) and returns a Boolean. It performs the following steps when called:

1. If \( \text{arrayBuffer}.[[\text{ArrayBufferData}]] \) is null, return true.
2. Return false.
25.1.3.5 DetachArrayBuffer (arrayBuffer [ , key ])

The abstract operation DetachArrayBuffer takes argument arrayBuffer (an ArrayBuffer) and optional argument key (anything) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Assert: IsSharedArrayBuffer(arrayBuffer) is false.
2. If key is not present, set key to undefined.
3. If arrayBuffer.[[ArrayBufferDetachKey]] is not key, throw a TypeError exception.
4. Set arrayBuffer.[[ArrayBufferData]] to null.
5. Set arrayBuffer.[[ArrayBufferByteLength]] to 0.
6. Return UNUSED.

NOTE Detaching an ArrayBuffer instance disassociates the Data Block used as its backing store from the instance and sets the byte length of the buffer to 0.

25.1.3.6 CloneArrayBuffer (srcBuffer, srcByteOffset, srcLength)

The abstract operation CloneArrayBuffer takes arguments srcBuffer (an ArrayBuffer or a SharedArrayBuffer), srcByteOffset (a non-negative integer), and srcLength (a non-negative integer) and returns either a normal completion containing an ArrayBuffer or a throw completion. It creates a new ArrayBuffer whose data is a copy of srcBuffer’s data over the range starting at srcByteOffset and continuing for srcLength bytes. It performs the following steps when called:

1. Assert: IsDetachedBuffer(srcBuffer) is false.
2. Let targetBuffer be ? AllocateArrayBuffer(%ArrayBuffer%, srcLength).
3. Let srcBlock be srcBuffer.[[ArrayBufferData]].
4. Let targetBlock be targetBuffer.[[ArrayBufferData]].
5. Perform CopyDataBlockBytes(targetBlock, 0, srcBlock, srcByteOffset, srcLength).
6. Return targetBuffer.

25.1.3.7 GetArrayBufferMaxByteLengthOption (options)

The abstract operation GetArrayBufferMaxByteLengthOption takes argument options (an ECMAScript language value) and returns either a normal completion containing either a non-negative integer or EMPTY, or a throw completion. It performs the following steps when called:

1. If options is not an Object, return EMPTY.
2. Let maxByteLength be ? Get(options, "maxByteLength").
3. If maxByteLength is undefined, return EMPTY.
4. Return ? ToIndex(maxByteLength).

25.1.3.8 HostResizeArrayBuffer (buffer, newByteLength)

The host-defined abstract operation HostResizeArrayBuffer takes arguments buffer (an ArrayBuffer) and newByteLength (a non-negative integer) and returns either a normal completion containing either HANDLED or UNHANDLED, or a throw completion. It gives the host an opportunity to perform implementation-defined resizing of buffer. If the host chooses not to handle resizing of buffer, it may return UNHANDLED for the default behaviour.

The implementation of HostResizeArrayBuffer must conform to the following requirements:

- The abstract operation does not detach buffer.
- If the abstract operation completes normally with HANDLED, buffer.[[ArrayBufferByteLength]] is newByteLength.

The default implementation of HostResizeArrayBuffer is to return NormalCompletion(UNHANDLED).
25.1.3.9 IsFixedLengthArrayBuffer (arrayBuffer)

The abstract operation `IsFixedLengthArrayBuffer` takes argument `arrayBuffer` (an ArrayBuffer or a SharedArrayBuffer) and returns a Boolean. It performs the following steps when called:

1. If `arrayBuffer` has an `[[ArrayBufferMaxByteLength]]` internal slot, return `false`.
2. Return `true`.

25.1.3.10 IsUnsignedElementType (type)

The abstract operation `IsUnsignedElementType` takes argument `type` (a TypedArray element type) and returns a Boolean. It verifies if the argument `type` is an unsigned TypedArray element type. It performs the following steps when called:

1. If `type` is one of UINT8, UINT8CLAMPED, UINT16, UINT32, or BIGUINT64, return `true`.
2. Return `false`.

25.1.3.11 IsUnclampedIntegerElementType (type)

The abstract operation `IsUnclampedIntegerElementType` takes argument `type` (a TypedArray element type) and returns a Boolean. It verifies if the argument `type` is an Integer TypedArray element type not including UINT8CLAMPED. It performs the following steps when called:

1. If `type` is one of INT8, UINT8, INT16, UINT16, INT32, or UINT32, return `true`.
2. Return `false`.

25.1.3.12 IsBigIntElementType (type)

The abstract operation `IsBigIntElementType` takes argument `type` (a TypedArray element type) and returns a Boolean. It verifies if the argument `type` is a BigInt TypedArray element type. It performs the following steps when called:

1. If `type` is either BIGUINT64 or BIGINT64, return `true`.
2. Return `false`.

25.1.3.13 IsNotTearConfiguration (type, order)

The abstract operation `IsNotTearConfiguration` takes arguments `type` (a TypedArray element type) and `order` (SEQ-CST, UNORDERED, or INIT) and returns a Boolean. It performs the following steps when called:

1. If `IsUnclampedIntegerElementType(type)` is `true`, return `true`.
2. If `IsBigIntElementType(type)` is `true` and `order` is neither INIT nor UNORDERED, return `true`.
3. Return `false`.

25.1.3.14 RawBytesToNumeric (type, rawBytes, isLittleEndian)

The abstract operation `RawBytesToNumeric` takes arguments `type` (a TypedArray element type), `rawBytes` (a List of byte values), and `isLittleEndian` (a Boolean) and returns a Number or a BigInt. It performs the following steps when called:

1. Let `elementSize` be the Element Size value specified in Table 71 for Element Type `type`.
2. If `isLittleEndian` is `false`, reverse the order of the elements of `rawBytes`.
3. If `type` is FLOAT32, then
   a. Let `value` be the byte elements of `rawBytes` concatenated and interpreted as a little-endian bit string encoding of an IEEE 754-2019 binary32 value.
   b. If `value` is an IEEE 754-2019 binary32 NaN value, return the `NaN` Number value.
   c. Return the Number value that corresponds to `value`.
4. If `type` is FLOAT64, then
a. Let value be the byte elements of rawBytes concatenated and interpreted as a little-endian bit string encoding of an IEEE 754-2019 binary64 value.

b. If value is an IEEE 754-2019 binary64 NaN value, return the NaN Number value.

c. Return the Number value that corresponds to value.

5. If IsUnsignedElementType(type) is true, then
   a. Let intValue be the byte elements of rawBytes concatenated and interpreted as a bit string encoding of an unsigned little-endian binary number.

6. Else,
   a. Let intValue be the byte elements of rawBytes concatenated and interpreted as a bit string encoding of a binary little-endian two’s complement number of bit length elementSize × 8.

7. If IsBigIntElementType(type) is true, return the BigInt value that corresponds to intValue.

8. Otherwise, return the Number value that corresponds to intValue.

25.1.3.15 GetRawBytesFromSharedBlock ( block, byteIndex, type, isTypedArray, order )

The abstract operation GetRawBytesFromSharedBlock takes arguments block (a Shared Data Block), byteIndex (a non-negative integer), type (a TypedArray element type), isTypedArray (a Boolean), and order (SEQ-CST or UNORDERED) and returns a List of byte values. It performs the following steps when called:

1. Let elementSize be the Element Size value specified in Table 71 for Element Type type.

2. Let execution be the [[CandidateExecution]] field of the surrounding agent's Agent Record.

3. Let eventsRecord be the Agent Events Record of execution. [[EventsRecords]] whose [[AgentSignifier]] is AgentSignifier().

4. If isTypedArray is true and IsNotTearConfiguration(type, order) is true, let noTear be true; otherwise let noTear be false.

5. Let rawValue be a List of length elementSize whose elements are nondeterministically chosen byte values.

6. NOTE: In implementations, rawValue is the result of a non-atomic or atomic read instruction on the underlying hardware. The nondeterminism is a semantic prescription of the memory model to describe observable behaviour of hardware with weak consistency.

7. Let readEvent be ReadSharedMemory { [[Order]]: order, [[NoTear]]: noTear, [[Block]]: block, [[ByteIndex]]: byteIndex, [[ElementSize]]: elementSize }. 

8. Append readEvent to eventsRecord. [[EventList]].

9. Append Chosen Value Record { [[Event]]: readEvent, [[ChosenValue]]: rawValue } to execution. [[ChosenValues]].


25.1.3.16 GetValueFromBuffer ( arrayBuffer, byteIndex, type, isTypedArray, order [, , isLittleEndian ] )

The abstract operation GetValueFromBuffer takes arguments arrayBuffer (an ArrayBuffer or SharedArrayBuffer), byteIndex (a non-negative integer), type (a TypedArray element type), isTypedArray (a Boolean), and order (SEQ-CST or UNORDERED) and optional argument isLittleEndian (a Boolean) and returns a Number or a BigInt. It performs the following steps when called:

1. Assert: IsDetachedBuffer(arrayBuffer) is false.

2. Assert: There are sufficient bytes in arrayBuffer starting at byteIndex to represent a value of type.

3. Let block be arrayBuffer. [[ArrayBufferData]].

4. Let elementSize be the Element Size value specified in Table 71 for Element Type type.

5. If IsSharedArrayBuffer(arrayBuffer) is true, then
   a. Assert: block is a Shared Data Block.
   b. Let rawValue be GetRawBytesFromSharedBlock(block, byteIndex, type, isTypedArray, order).

6. Else,
   a. Let rawValue be a List whose elements are bytes from block at indices in the interval from byteIndex (inclusive) to byteIndex + elementSize (exclusive).

7. Assert: The number of elements in rawValue is elementSize.

8. If isLittleEndian is not present, set isLittleEndian to the value of the [[LittleEndian]] field of the surrounding agent's Agent Record.

9. Return RawBytesToNumeric(type, rawValue, isLittleEndian).
25.1.3.17 NumericToRawBytes (\(type, value, isLittleEndian\))

The abstract operation NumericToRawBytes takes arguments \(type\) (a TypedArray element type), \(value\) (a Number or a BigInt), and \(isLittleEndian\) (a Boolean) and returns a List of byte values. It performs the following steps when called:

1. If \(type\) is FLOAT32, then
   a. Let \(rawBytes\) be a List whose elements are the 4 bytes that are the result of converting \(value\) to IEEE 754-2019 binary32 format using roundTiesToEven mode. The bytes are arranged in little endian order. If \(value\) is \(NaN\), \(rawBytes\) may be set to any implementation chosen IEEE 754-2019 binary32 format Not-a-Number encoding. An implementation must always choose the same encoding for each implementation distinguishable \(NaN\) value.
2. Else if \(type\) is FLOAT64, then
   a. Let \(rawBytes\) be a List whose elements are the 8 bytes that are the IEEE 754-2019 binary64 format encoding of \(value\). The bytes are arranged in little endian order. If \(value\) is \(NaN\), \(rawBytes\) may be set to any implementation chosen IEEE 754-2019 binary64 format Not-a-Number encoding. An implementation must always choose the same encoding for each implementation distinguishable \(NaN\) value.
3. Else,
   a. Let \(n\) be the Element Size value specified in Table 71 for Element Type \(type\).
   b. Let \(convOp\) be the abstract operation named in the Conversion Operation column in Table 71 for Element Type \(type\).
   c. Let \(intValue\) be \(\mathbb{R}(\text{convOp}(value))\).
   d. If \(intValue \geq 0\), then
      i. Let \(rawBytes\) be a List whose elements are the \(n\)-byte binary encoding of \(intValue\). The bytes are ordered in little endian order.
   e. Else,
      i. Let \(rawBytes\) be a List whose elements are the \(n\)-byte binary two's complement encoding of \(intValue\). The bytes are ordered in little endian order.
4. If \(isLittleEndian\) is false, reverse the order of the elements of \(rawBytes\).
5. Return \(rawBytes\).

25.1.3.18 SetValueInBuffer (\(arrayBuffer, bytelnIndex, type, value, isTypedArray, order [, isLittleEndian\])

The abstract operation SetValueInBuffer takes arguments \(arrayBuffer\) (an ArrayBuffer or SharedArrayBuffer), \(byteIndex\) (a non-negative integer), \(type\) (a TypedArray element type), \(value\) (a Number or a BigInt), \(isTypedArray\) (a Boolean), and \(order\) (SEQ-CST, UNORDERED, or INIT) and optional argument \(isLittleEndian\) (a Boolean) and returns UNUSED. It performs the following steps when called:

1. Assert: IsDetachedBuffer(\(arrayBuffer\)) is false.
2. Assert: There are sufficient bytes in \(arrayBuffer\) starting at \(byteIndex\) to represent a value of \(type\).
3. Assert: \(value\) is a BigInt if IsBigIntElementType(\(type\)) is true; otherwise, \(value\) is a Number.
4. Let \(block\) be \(arrayBuffer.\{\text{ArrayBufferData}\}\).
5. Let \(elementSize\) be the Element Size value specified in Table 71 for Element Type \(type\).
6. If \(isLittleEndian\) is not present, set \(isLittleEndian\) to the value of the [\(isLittleEndian\)] field of the surrounding agent’s Agent Record.
7. Let \(rawBytes\) be NumericToRawBytes(\(type, value, isLittleEndian\)).
8. If IsSharedArrayBuffer(\(arrayBuffer\)) is true, then
   a. Let \(execution\) be the [\(\text{CandidateExecution}\)] field of the surrounding agent's Agent Record.
   b. Let \(eventsRecord\) be the Agent Events Record of \(execution.\{\text{EventsRecords}\}\) whose [\(\text{AgentSignifier}\)] is AgentSignifier().
   c. If \(isTypedArray\) is true and IsNoTearConfiguration(\(type, order\)) is true, let \(noTear\) be true; otherwise let \(noTear\) be false.
   d. Append WriteSharedMemory ({} [\(\text{Order}\): \(order\), [\(\text{NoTear}\): \(noTear\), [\(\text{Block}\): \(block\), [\(\text{ByteIndex}\): \(byteIndex\), [\(\text{ElementSize}\): \(elementSize\), [\(\text{Payload}\): \(rawBytes\) ] to \(eventsRecord.\{\text{EventList}\}\)).
9. Else,
   a. Store the individual bytes of \(rawBytes\) into \(block\), starting at \(block[\text{byteIndex}]\).
10. Return UNUSED.
25.1.3.19 GetModifySetValueInBuffer (arrayBuffer, byteIndex, type, value, op)

The abstract operation GetModifySetValueInBuffer takes arguments arrayBuffer (an ArrayBuffer or a SharedArrayBuffer), byteIndex (a non-negative integer), type (a TypedArray element type), value (a Number or a BigInt), and op (a read-modify-write modification function) and returns a Number or a BigInt. It performs the following steps when called:

1. Assert: IsDetachedBuffer(arrayBuffer) is false.
2. Assert: There are sufficient bytes in arrayBuffer starting at byteIndex to represent a value of type.
3. Assert: value is a BigInt if IsBigIntElementType(type) is true; otherwise, value is a Number.
4. Let block be arrayBuffer.[[ArrayBufferData]].
5. Let elementSize be the Element Size value specified in Table 71 for Element Type type.
6. Let isLittleEndian be the value of the [[LittleEndian]] field of the surrounding agent's Agent Record.
7. Let rawBytes be NumericToRawBytes(type, value, isLittleEndian).
8. If IsSharedArrayBuffer(arrayBuffer) is true, then
   a. Let execution be the [[CandidateExecution]] field of the surrounding agent's Agent Record.
   b. Let eventsRecord be the Agent Events Record of execution.[[EventsRecords]] whose [[AgentSignifier]] is AgentSignifier().
   c. Let rawBytesRead be a List of length elementSize whose elements are nondeterministically chosen byte values.
   d. NOTE: In implementations, rawBytesRead is the result of a load-link, of a load-exclusive, or of an operand of a read-modify-write instruction on the underlying hardware. The nondeterminism is a semantic prescription of the memory model to describe observable behaviour of hardware with weak consistency.
   e. Let rmwEvent be ReadModifyWriteSharedMemory ([[Order]]; SEQ-CST, [[NoTear]]; true, [[Block]]; block, [[ByteIndex]]; byteIndex, [[ElementSize]]; elementSize, [[Payload]]; rawBytes, [[ModifyOp]]; op).
   f. Append rmwEvent to eventsRecord.[[EventList]].
   g. Append Chosen Value Record ([[Event]]; rmwEvent, [[ChosenValue]]; rawBytesRead) to execution.[[ChosenValues]].
9. Else,
   a. Let rawBytesRead be a List of length elementSize whose elements are the sequence of elementSize bytes starting with block[byteIndex].
   b. Let rawBytesModified be op(rawBytesRead, rawBytes).
   c. Store the individual bytes of rawBytesModified into block, starting at block[byteIndex].
10. Return RawBytesToNumeric(type, rawBytesRead, isLittleEndian).

25.1.4 The ArrayBuffer Constructor

The ArrayBuffer constructor:

- is %ArrayBuffer%.
- is the initial value of the "ArrayBuffer" property of the global object.
- creates and initializes a new ArrayBuffer when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified ArrayBuffer behaviour must include a super call to the ArrayBuffer constructor to create and initialize subclass instances with the internal state necessary to support the ArrayBuffer.prototype built-in methods.

25.1.4.1 ArrayBuffer (length [, options])

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. Let byteLength be ? ToIndex(length).
3. Let requestedMaxByteLength be ? GetArrayBufferMaxByteLengthOption(options).
4. Return AllocateArrayBuffer(NewTarget, byteLength, requestedMaxByteLength).
25.1.5 Properties of the ArrayBuffer Constructor

The ArrayBuffer constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has the following properties:

25.1.5.1 ArrayBuffer.isView (arg)

This function performs the following steps when called:

1. If arg is not an Object, return false.
2. If arg has a [[ViewedArrayBuffer]] internal slot, return true.
3. Return false.

25.1.5.2 ArrayBuffer.prototype

The initial value of ArrayBuffer.prototype is the ArrayBuffer prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

25.1.5.3 get ArrayBuffer [@@species]

ArrayBuffer[@@species] is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "get [Symbol.species]".

NOTE ArrayBuffer.prototype.slice (start, end) normally uses its this value's constructor to create a derived object. However, a subclass constructor may over-ride that default behaviour for the ArrayBuffer.prototype.slice (start, end) method by redefining its @@species property.

25.1.6 Properties of the ArrayBuffer Prototype Object

The ArrayBuffer prototype object:

- is %ArrayBuffer.prototype%.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is an ordinary object.
- does not have an [[ArrayBufferData]] or [[ArrayBufferByteLength]] internal slot.

25.1.6.1 get ArrayBuffer.prototype.byteLength

ArrayBuffer.prototype.byteLength is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, [[ArrayBufferData]]).
3. If isSharedArrayBuffer(O) is true, throw a TypeError exception.
4. If isDetachedBuffer(O) is true, return +0𝔽.
5. Let length be O.[[ArrayBufferByteLength]].
6. Return 𝔽(length).
25.1.6.2 `ArrayBuffer.prototype.constructor`

The initial value of `ArrayBuffer.prototype.constructor` is `%ArrayBuffer%`.

25.1.6.3 `get ArrayBuffer.prototype.detached`

`ArrayBuffer.prototype.detached` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the `this` value.
2. Perform ? `RequireInternalSlot(O, [[ArrayBufferData]])`.
3. If `IsSharedArrayBuffer(O)` is `true`, throw a `TypeError` exception.
4. Return `IsDetachedBuffer(O)`.

25.1.6.4 `get ArrayBuffer.prototype.maxByteLength`

`ArrayBuffer.prototype.maxByteLength` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the `this` value.
2. Perform ? `RequireInternalSlot(O, [[ArrayBufferData]])`.
3. If `IsSharedArrayBuffer(O)` is `true`, throw a `TypeError` exception.
4. If `IsDetachedBuffer(O)` is `true`, return `\+\infty`.
5. If `IsFixedLengthArrayBuffer(O)` is `true`, then
   a. Let `length` be `O.[[ArrayBufferByteLength]]`.
6. Else,
   a. Let `length` be `O.[[ArrayBufferMaxByteLength]]`.
7. Return `\mathbb{F}(length)`.

25.1.6.5 `get ArrayBuffer.prototype.resizable`

`ArrayBuffer.prototype.resizable` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the `this` value.
2. Perform ? `RequireInternalSlot(O, [[ArrayBufferData]])`.
3. If `IsSharedArrayBuffer(O)` is `true`, throw a `TypeError` exception.
4. If `IsFixedLengthArrayBuffer(O)` is `false`, return `true`; otherwise return `false`.

25.1.6.6 `ArrayBuffer.prototype.resize (newLength)`

This method performs the following steps when called:

1. Let `O` be the `this` value.
2. Perform ? `RequireInternalSlot(O, [[ArrayBufferData]])`.
3. If `IsSharedArrayBuffer(O)` is `true`, throw a `TypeError` exception.
4. Let `newByteLength` be ? `ToIndex(newLength)`.
5. If `IsDetachedBuffer(O)` is `true`, throw a `TypeError` exception.
6. If `newByteLength > O.[[ArrayBufferMaxByteLength]]`, throw a `RangeError` exception.
7. Let `hostHandled` be ? `HostResizeArrayBuffer(O, newByteLength)`.
8. If `hostHandled` is `HANDLED`, return `undefined`.
9. Let `oldBlock` be `O.[[ArrayBufferData]]`.
10. Let `newBlock` be ? `CreateByteDataBlock(newByteLength)`.
11. Let `copyLength` be `min(newByteLength, O.[[ArrayBufferByteLength]])`.
12. Perform `CopyDataBlockBytes(newBlock, 0, oldBlock, 0, copyLength)`.
13. NOTE: Neither creation of the new Data Block nor copying from the old Data Block are observable. Implementations may implement this method as in-place growth or shrinkage.

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15. Set $O.[[ArrayBufferByteLength]]$ to $newByteLength$.
16. Return $undefined$.

25.1.6.7 $ArrayBuffer.prototype.slice (start, end)$

This method performs the following steps when called:

1. Let $O$ be the this value.
2. Perform ? $RequireInternalSlot(O, [[ArrayBufferData]])$.
3. If $isSharedArrayBuffer(O)$ is true, throw a $TypeError$ exception.
4. If $isDetachedBuffer(O)$ is true, throw a $TypeError$ exception.
5. Let $len$ be $O.[[ArrayBufferByteLength]]$.
6. Let $relativeStart$ be $ToIntegerOrInfinity(start)$.
7. If $relativeStart = -\infty$, let $first$ be 0.
8. Else if $relativeStart < 0$, let $first$ be $\max(len + relativeStart, 0)$.
9. Else, let $first$ be $\min(relativeStart, len)$.
10. If $end$ is undefined, let $relativeEnd$ be $len$; else let $relativeEnd$ be $ToIntegerOrInfinity(end)$.
11. If $relativeEnd = -\infty$, let $final$ be 0.
12. Else if $relativeEnd < 0$, let $final$ be $\max(len + relativeEnd, 0)$.
13. Else, let $final$ be $\min(relativeEnd, len)$.
14. Let $newLen$ be $\max(final - first, 0)$.
15. Let $ctor$ be ? $SpeciesConstructor(O, %ArrayBuffer%)$.
17. Perform ? $RequireInternalSlot(new, [[ArrayBufferData]])$.
18. If $isSharedArrayBuffer(new)$ is true, throw a $TypeError$ exception.
19. If $isDetachedBuffer(new)$ is true, throw a $TypeError$ exception.
20. If $SameValue(new, O)$ is true, throw a $TypeError$ exception.
21. If $new.[[ArrayBufferByteLength]] < newLen$, throw a $TypeError$ exception.
22. NOTE: Side-effects of the above steps may have detached or resized $O$.
23. If $isDetachedBuffer(O)$ is true, throw a $TypeError$ exception.
24. Let $fromBuf$ be $O.[[ArrayBufferData]]$.
25. Let $toBuf$ be $new.[[ArrayBufferData]]$.
26. Let $currentLen$ be $O.[[ArrayBufferByteLength]]$.
27. If $first < currentLen$, then
   a. Let $count$ be $\min(newLen, currentLen - first)$.
   b. Perform CopyDataBlockBytes($toBuf, 0, fromBuf, first, count$).

25.1.6.8 $ArrayBuffer.prototype.transfer ([newLength])$

This method performs the following steps when called:

1. Let $O$ be the this value.
2. Return ? $ArrayBufferCopyAndDetach(O, newLength, PRESERVE-RESIZABILITY)$.

25.1.6.9 $ArrayBuffer.prototype.transferToFixedLength ([newLength])$

This method performs the following steps when called:

1. Let $O$ be the this value.
2. Return ? $ArrayBufferCopyAndDetach(O, newLength, FIXED-LENGTH)$.

25.1.6.10 $ArrayBuffer.prototype [ @@toStringTag ]$

The initial value of the @@toStringTag property is the String value "ArrayBuffer".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.
25.1.7 Properties of ArrayBuffer Instances

ArrayBuffer instances inherit properties from the ArrayBuffer prototype object. ArrayBuffer instances each have an [[ArrayBufferData]] internal slot, an [[ArrayBufferByteLength]] internal slot, and an [[ArrayBufferDetachKey]] internal slot. ArrayBuffer instances which are resizable each have an [[ArrayBufferMaxByteLength]] internal slot.

ArrayBuffer instances whose [[ArrayBufferData]] is null are considered to be detached and all operators to access or modify data contained in the ArrayBuffer instance will fail.

ArrayBuffer instances whose [[ArrayBufferDetachKey]] is set to a value other than undefined need to have all DetachArrayBuffer calls passing that same "detach key" as an argument, otherwise a TypeError will result. This internal slot is only ever set by certain embedding environments, not by algorithms in this specification.

25.1.8 Resizable ArrayBuffer Guidelines

NOTE 1  The following are guidelines for ECMAScript programmers working with resizable ArrayBuffer.

We recommend that programs be tested in their deployment environments where possible. The amount of available physical memory differs greatly between hardware devices. Similarly, virtual memory subsystems also differ greatly between hardware devices as well as operating systems. An application that runs without out-of-memory errors on a 64-bit desktop web browser could run out of memory on a 32-bit mobile web browser.

When choosing a value for the "maxByteLength" option for resizable ArrayBuffer, we recommend that the smallest possible size for the application be chosen. We recommend that "maxByteLength" does not exceed 1,073,741,824 (2^30 bytes or 1GiB).

Please note that successfully constructing a resizable ArrayBuffer for a particular maximum size does not guarantee that future resizes will succeed.

NOTE 2  The following are guidelines for ECMAScript implementers implementing resizable ArrayBuffer.

Resizable ArrayBuffer can be implemented as copying upon resize, as in-place growth via reserving virtual memory up front, or as a combination of both for different values of the constructor’s "maxByteLength" option.

If a host is multi-tenanted (i.e. it runs many ECMAScript applications simultaneously), such as a web browser, and its implementations choose to implement in-place growth by reserving virtual memory, we recommend that both 32-bit and 64-bit implementations throw for values of "maxByteLength" ≥ 1GiB to 1.5GiB. This is to reduce the likelihood a single application can exhaust the virtual memory address space and to reduce interoperability risk.

If a host does not have virtual memory, such as those running on embedded devices without an MMU, or if a host only implements resizing by copying, it may accept any Number value for the "maxByteLength" option. However, we recommend a RangeError be thrown if a memory block of the requested size can never be allocated. For example, if the requested size is greater than the maximum amount of usable memory on the device.

25.2 SharedArrayBuffer Objects

25.2.1 Fixed-length and Growable SharedArrayBuffer Objects

A fixed-length SharedArrayBuffer is a SharedArrayBuffer whose byte length cannot change after creation.

A growable SharedArrayBuffer is a SharedArrayBuffer whose byte length may increase after creation via calls to SharedArrayBuffer.prototype.grow (newLength).
The kind of SharedArrayBuffer object that is created depends on the arguments passed to `SharedArrayBuffer (length [, options ])`.

### 25.2.2 Abstract Operations for SharedArrayBuffer Objects

#### 25.2.2.1 AllocateSharedArrayBuffer (`constructor, byteLength [, maxByteLength ]`)

The abstract operation `AllocateSharedArrayBuffer` takes arguments `constructor` (a constructor) and `byteLength` (a non-negative integer) and optional argument `maxByteLength` (a non-negative integer or EMPTY) and returns either a normal completion containing a SharedArrayBuffer or a throw completion. It is used to create a SharedArrayBuffer. It performs the following steps when called:

1. Let `slots` be `[[ArrayBufferData]]`.
2. If `maxByteLength` is present and `maxByteLength` is not EMPTY, let `allocatingGrowableBuffer` be `true`; otherwise let `allocatingGrowableBuffer` be `false`.
3. If `allocatingGrowableBuffer` is `true`, then
   a. If `byteLength > maxByteLength`, throw a `RangeError` exception.
   b. Append `[[ArrayBufferByteLengthData]]` and `[[ArrayBufferMaxByteLength]]` to `slots`.
4. Else,
   a. Append `[[ArrayBufferByteLength]]` to `slots`.
5. Let `obj` be `? OrdinaryCreateFromConstructor(constructor, "%SharedArrayBuffer.prototype%", slots)`.
6. If `allocatingGrowableBuffer` is `true`, let `allocLength` be `maxByteLength`; otherwise let `allocLength` be `byteLength`.
7. Let `block` be `? CreateSharedByteDataBlock(allocLength)`.
8. Set `obj.[[ArrayBufferData]]` to `block`.
9. If `allocatingGrowableBuffer` is `true`, then
   b. Let `byteLengthBlock` be `? CreateSharedByteDataBlock(8)`.
   c. Perform `SetValueInBuffer(byteLengthBlock, 8, BIGUINT64, Z(byteLength), true, SEQ-CST)`.
   d. Set `obj.[[ArrayBufferByteLengthData]]` to `byteLengthBlock`.
   e. Set `obj.[[ArrayBufferMaxByteLength]]` to `maxByteLength`.
10. Else,
    a. Set `obj.[[ArrayBufferByteLength]]` to `byteLength`.
11. Return `obj`.

#### 25.2.2.2 IsSharedArrayBuffer (`obj`)

The abstract operation `IsSharedArrayBuffer` takes argument `obj` (an ArrayBuffer or a SharedArrayBuffer) and returns a Boolean. It tests whether an object is an ArrayBuffer, a SharedArrayBuffer, or a subtype of either. It performs the following steps when called:

1. Let `bufferData` be `obj.[[ArrayBufferData]]`.
2. If `bufferData` is `null`, return `false`.
3. If `bufferData` is a Data Block, return `false`.
4. Assert: `bufferData` is a Shared Data Block.
5. Return `true`.

#### 25.2.2.3 HostGrowSharedArrayBuffer (`buffer, newByteLength`)

The host-defined abstract operation `HostGrowSharedArrayBuffer` takes arguments `buffer` (a SharedArrayBuffer) and `newByteLength` (a non-negative integer) and returns either a normal completion containing either HANDLED or UNHANDLED, or a throw completion. It gives the host an opportunity to perform implementation-defined growing of `buffer`. If the host chooses not to handle growing of `buffer`, it may return UNHANDLED for the default behaviour.

The implementation of `HostGrowSharedArrayBuffer` must conform to the following requirements:

- If the abstract operation does not complete normally with UNHANDLED, and `newByteLength < the current...`
byte length of the buffer or newByteLength > buffer.[[ArrayBufferMaxByteLength]], throw a RangeError exception.

- Let isLittleEndian be the value of the [[LittleEndian]] field of the surrounding agent's Agent Record. If the abstract operation completes normally with HANDED, a WriteSharedMemory or ReadModifyWriteSharedMemory event whose [[Order]] is SEQ-CST, [[Payload]] is NumericToRawBytes(BIGUINT64, newByteLength, isLittleEndian), [[Block]] is buffer.[[ArrayBufferByteLengthData]], [[ByteIndex]] is 0, and [[ElementSize]] is 8 is added to the surrounding agent's candidate execution such that racing calls to SharedArrayBuffer.prototype.grow are not "lost", i.e. silently do nothing.

NOTE The second requirement above is intentionally vague about how or when the current byte length of buffer is read. Because the byte length must be updated via an atomic read-modify-write operation on the underlying hardware, architectures that use load-link/store-conditional or load-exclusive/store-exclusive instruction pairs may wish to keep the paired instructions close in the instruction stream. As such, SharedArrayBuffer.prototype.grow itself does not perform bounds checking on newByteLength before calling HostGrowSharedArrayBuffer, nor is there a requirement on when the current byte length is read.

This is in contrast with HostResizeArrayBuffer, which is guaranteed that the value of newByteLength is ≥ 0 and ≤ buffer.[[ArrayBufferMaxByteLength]].

The default implementation of HostGrowSharedArrayBuffer is to return NormalCompletion(UNHANDLED).

25.2.3 The SharedArrayBuffer Constructor

The SharedArrayBuffer constructor:

- is %SharedArrayBuffer%.
- is the initial value of the "SharedArrayBuffer" property of the global object, if that property is present (see below).
- creates and initializes a new SharedArrayBuffer when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified SharedArrayBuffer behaviour must include a super call to the SharedArrayBuffer constructor to create and initialize subclass instances with the internal state necessary to support the SharedArrayBuffer.prototype built-in methods.

Whenever a host does not provide concurrent access to SharedArrayBuffers it may omit the "SharedArrayBuffer" property of the global object.

NOTE Unlike an ArrayBuffer, a SharedArrayBuffer cannot become detached, and its internal [[ArrayBufferData]] slot is never null.

25.2.3.1 SharedArrayBuffer ( length [, options ] )

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. Let byteLength be ? ToIndex(length).
3. Let requestedMaxByteLength be ? GetArrayBufferMaxByteLengthOption(options).

25.2.4 Properties of the SharedArrayBuffer Constructor

The SharedArrayBuffer constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%. 
• has the following properties:

25.2.4.1 SharedArrayBuffer.prototype

The initial value of `SharedArrayBuffer.prototype` is the `SharedArrayBuffer` prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

25.2.4.2 get SharedArrayBuffer [ @@species ]

`SharedArrayBuffer[@@species]` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Return the `this` value.

The value of the "name" property of this function is "get `[Symbol.species]".

25.2.5 Properties of the SharedArrayBuffer Prototype Object

The `SharedArrayBuffer prototype` object:

• is `%SharedArrayBuffer.prototype%`.
• has a `[[Prototype]]` internal slot whose value is `%Object.prototype%`.
• is an ordinary object.
• does not have an `[[ArrayBufferData]]` or `[[ArrayBufferByteLength]]` internal slot.

25.2.5.1 get SharedArrayBuffer.prototype.byteLength

`SharedArrayBuffer.prototype.byteLength` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the `this` value.
2. Perform `? RequireInternalSlot(O, [[ArrayBufferData]])`.
3. If `isSharedArrayBuffer(O)` is `false`, throw a `TypeError` exception.
4. Let `length` be `ArrayBufferByteLength(O, SEQ-CST)`.
5. Return `𝔽(length)`.

25.2.5.2 SharedArrayBuffer.prototype.constructor

The initial value of `SharedArrayBuffer.prototype.constructor` is `%SharedArrayBuffer%`.

25.2.5.3 SharedArrayBuffer.prototype.grow ( `newLength` )

This method performs the following steps when called:

1. Let `O` be the `this` value.
2. Perform `? RequireInternalSlot(O, [[ArrayBufferMaxByteLength]])`.
3. If `isSharedArrayBuffer(O)` is `false`, throw a `TypeError` exception.
4. Let `newByteLength` be `? ToIndex(newLength)`.
5. Let `hostHandled` be `? HostGrowSharedArrayBuffer(O, newByteLength)`.
6. If `hostHandled` is `HANDLED`, return `undefined`.
7. Let `isLittleEndian` be the value of the `[[[LittleEndian]]]` field of the surrounding agent’s Agent Record.
8. Let `byteLengthBlock` be `O.[[ArrayBufferByteLengthData]]`.
9. Let `currentByteLengthRawBytes` be `GetRawBytesFromSharedBlock(byteLengthBlock, 0, BIGUINT64, true, SEQ-CST)`.
10. Let `newByteLengthRawBytes` be `NumericToRawBytes(BIGUINT64, ℤ(newByteLength), isLittleEndian)`.
11. Repeat,
a. NOTE: This is a compare-and-exchange loop to ensure that parallel, racing grows of the same buffer are totally ordered, are not lost, and do not silently do nothing. The loop exits if it was able to attempt to grow uncontended.

b. Let currentByteLength be $\mathbf{R}(\text{RawBytesToNumeric}($BIGUINT64$, \text{currentByteLengthRawBytes}, \text{isLittleEndian}))$.

c. If newByteLength = currentByteLength, return undefined.

d. If newByteLength < currentByteLength or newByteLength > O.$[[\text{ArrayBufferMaxByteLength}}]]$, throw a RangeError exception.

e. Let byteLengthDelta be newByteLength - currentByteLength.

f. If it is impossible to create a new Shared Data Block value consisting of byteLengthDelta bytes, throw a RangeError exception.

g. NOTE: No new Shared Data Block is constructed and used here. The observable behaviour of growable SharedArrayBuffers is specified by allocating a max-sized Shared Data Block at construction time, and this step captures the requirement that implementations that run out of memory must throw a RangeError.

h. Let readByteLengthRawBytes be $\text{AtomicCompareExchangeInSharedBlock}($byteLengthBlock$, 0, 8, currentByteLengthRawBytes, newByteLengthRawBytes)$.

i. If ByteListEqual(readByteLengthRawBytes, currentByteLengthRawBytes) is true, return undefined.

j. Set currentByteLengthRawBytes to readByteLengthRawBytes.

NOTE Spurious failures of the compare-exchange to update the length are prohibited. If the bounds checking for the new length passes and the implementation is not out of memory, a ReadModifyWriteSharedMemory event (i.e. a successful compare-exchange) is always added into the candidate execution.

Parallel calls to SharedArrayBuffer.prototype.grow are totally ordered. For example, consider two racing calls: sab.$\text{grow}(10)$ and sab.$\text{grow}(20)$. One of the two calls is guaranteed to win the race. The call to sab.$\text{grow}(10)$ will never shrink sab even if sab.$\text{grow}(20)$ happened first; in that case it will instead throw a RangeError.

25.2.5.4 get SharedArrayBuffer.prototype.growable

SharedArrayBuffer.prototype.growable is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, $[[\text{ArrayBufferData}}]]$).
3. If IsSharedArrayBuffer(O) is false, throw a TypeError exception.
4. If IsFixedLengthArrayBuffer(O) is false, return true; otherwise return false.

25.2.5.5 get SharedArrayBuffer.prototype.maxByteLength

SharedArrayBuffer.prototype.maxByteLength is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, $[[\text{ArrayBufferData}}]]$).
3. If IsSharedArrayBuffer(O) is false, throw a TypeError exception.
4. If IsFixedLengthArrayBuffer(O) is true, then
   a. Let length be O.$[[\text{ArrayBufferByteLength}}]]$.
5. Else,
   a. Let length be O.$[[\text{ArrayBufferMaxByteLength}}]]$.
6. Return $\mathbb{F}(\text{length})$. 
25.2.5.6 SharedArrayBuffer.prototype.slice ( start, end )

This method performs the following steps when called:

1. Let O be the this value.
2. Perform ? RequireInternalSlot(O, [[ArrayBufferData]]).
3. If IsSharedArrayBuffer(O) is false, throw a TypeError exception.
4. Let len be ArrayBufferByteLength(O, SEQ-CST).
5. Let relativeStart be ? ToIntegerOrInfinity(start).
6. If relativeStart = -∞, let first be 0.
7. Else if relativeStart < 0, let first be max(len + relativeStart, 0).
8. Else, let first be min(relativeStart, len).
9. If end is undefined, let relativeEnd be len; else let relativeEnd be ? ToIntegerOrInfinity(end).
10. If relativeEnd = -∞, let final be 0.
11. Else if relativeEnd < 0, let final be max(len + relativeEnd, 0).
12. Else, let final be min(relativeEnd, len).
13. Let newLen be max(final - first, 0).
14. Let ctor be ? SpeciesConstructor(O, %SharedArrayBuffer%).
15. Let new be ? Construct(ctor, «𝔽(newLen) »).
16. Perform ? RequireInternalSlot(new, [[ArrayBufferData]]).
17. If IsSharedArrayBuffer(new) is false, throw a TypeError exception.
18. If new.[[ArrayBufferData]] is O.[[ArrayBufferData]], throw a TypeError exception.
19. If ArrayBufferByteLength(new, SEQ-CST) < newLen, throw a TypeError exception.
20. Let fromBuf be O.[[ArrayBufferData]].
21. Let toBuf be new.[[ArrayBufferData]].
22. Perform CopyDataBlockBytes(toBuf, 0, fromBuf, first, newLen).
23. Return new.

25.2.5.7 SharedArrayBuffer.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "SharedArrayBuffer".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

25.2.6 Properties of SharedArrayBuffer Instances

SharedArrayBuffer instances inherit properties from the SharedArrayBuffer prototype object. SharedArrayBuffer instances each have an [[ArrayBufferData]] internal slot. SharedArrayBuffer instances which are not growable each have an [[ArrayBufferByteLength]] internal slot. SharedArrayBuffer instances which are growable each have an [[ArrayBufferByteLengthData]] internal slot and an [[ArrayBufferMaxByteLength]] internal slot.

NOTE SharedArrayBuffer instances, unlike ArrayBuffer instances, are never detached.
25.2.7 Growable SharedArrayBuffer Guidelines

NOTE 1  The following are guidelines for ECMAScript programmers working with growable SharedArrayBuffer.

We recommend that programs be tested in their deployment environments where possible. The amount of available physical memory differ greatly between hardware devices. Similarly, virtual memory subsystems also differ greatly between hardware devices as well as operating systems. An application that runs without out-of-memory errors on a 64-bit desktop web browser could run out of memory on a 32-bit mobile web browser.

When choosing a value for the "maxByteLength" option for growable SharedArrayBuffer, we recommend that the smallest possible size for the application be chosen. We recommend that "maxByteLength" does not exceed 1073741824, or 1GiB.

Please note that successfully constructing a growable SharedArrayBuffer for a particular maximum size does not guarantee that future grows will succeed.

Not all loads of a growable SharedArrayBuffer's length are synchronizing SEQ-CST loads. Loads of the length that are for bounds-checking of an integer-indexed property access, e.g. u8[idx], are not synchronizing. In general, in the absence of explicit synchronization, one property access being in-bound does not imply a subsequent property access in the same agent is also in-bound. In contrast, explicit loads of the length via the length and byteLength getters on SharedArrayBuffer, %TypedArray%.prototype, and DataView.prototype are synchronizing. Loads of the length that are performed by built-in methods to check if a TypedArray is entirely out-of-bounds are also synchronizing.

NOTE 2  The following are guidelines for ECMAScript implementers implementing growable SharedArrayBuffer.

We recommend growable SharedArrayBuffer be implemented as in-place growth via reserving virtual memory up front.

Because grow operations can happen in parallel with memory accesses on a growable SharedArrayBuffer, the constraints of the memory model require that even unordered accesses do not "tear" (bits of their values will not be mixed). In practice, this means the underlying data block of a growable SharedArrayBuffer cannot be grown by being copied without stopping the world. We do not recommend stopping the world as an implementation strategy because it introduces a serialization point and is slow.

Grown memory must appear zeroed from the moment of its creation, including to any racy accesses in parallel. This can be accomplished via zero-filled-on-demand virtual memory pages, or careful synchronization if manually zeroing memory.

Integer-indexed property access on TypedArray views of growable SharedArrayBuffers is intended to be optimizable similarly to access on TypedArray views of non-growable SharedArrayBuffers, because integer-indexed property loads on are not synchronizing on the underlying buffer's length (see programmer guidelines above). For example, bounds checks for property accesses may still be hoisted out of loops.

In practice it is difficult to implement growable SharedArrayBuffer by copying on hosts that do not have virtual memory, such as those running on embedded devices without an MMU. Memory usage behaviour of growable SharedArrayBuffers on such hosts may significantly differ from that of hosts with virtual memory. Such hosts should clearly communicate memory usage expectations to users.
25.3 DataView Objects

25.3.1 Abstract Operations For DataView Objects

25.3.1.1 DataView With Buffer Witness Records

A DataView With Buffer Witness Record is a Record value used to encapsulate a DataView along with a cached byte length of the viewed buffer. It is used to help ensure there is a single shared memory read event of the byte length data block when the viewed buffer is a growable SharedArrayBuffers.

DataView With Buffer Witness Records have the fields listed in Table 72.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Object]]</td>
<td>a DataView</td>
<td>The DataView object whose buffer's byte length is loaded.</td>
</tr>
<tr>
<td>[[CachedBufferByteLength]]</td>
<td>a non-negative integer or DETACHED</td>
<td>The byte length of the object's [[ViewedArrayBuffer]] when the Record was created.</td>
</tr>
</tbody>
</table>

25.3.1.2 MakeDataViewWithBufferWitnessRecord ( obj, order )

The abstract operation MakeDataViewWithBufferWitnessRecord takes arguments obj (a DataView) and order (SEQ-CST or UNORDERED) and returns a DataView With Buffer Witness Record. It performs the following steps when called:

1. Let buffer be obj.[[ViewedArrayBuffer]].
2. If IsDetachedBuffer(buffer) is true, then
   a. Let byteLength be DETACHED.
3. Else,
   a. Let byteLength be ArrayBufferByteLength(buffer, order).
4. Return the DataView With Buffer Witness Record { [[Object]]: obj, [[CachedBufferByteLength]]: byteLength }.

25.3.1.3 GetViewByteLength ( viewRecord )

The abstract operation GetViewByteLength takes argument viewRecord (a DataView With Buffer Witness Record) and returns a non-negative integer. It performs the following steps when called:

1. Assert: IsViewOutOfBounds(viewRecord) is false.
2. Let view be viewRecord.[[Object]].
3. If view.[[ByteLength]] is not AUTO, return view.[[ByteLength]].
4. Assert: IsFixedLengthArrayBuffer(view,[[ViewedArrayBuffer]]) is false.
5. Let byteOffset be view.[[ByteOffset]].
6. Let byteLength be viewRecord.[[CachedBufferByteLength]].
7. Assert: byteLength is not DETACHED.

25.3.1.4 IsViewOutOfBounds ( viewRecord )

The abstract operation IsViewOutOfBounds takes argument viewRecord (a DataView With Buffer Witness Record) and returns a Boolean. It performs the following steps when called:

1. Let view be viewRecord.[[Object]].
2. Let bufferByteLength be viewRecord.[[CachedBufferByteLength]].
3. Assert: IsDetachedBuffer(view,[[ViewedArrayBuffer]]) is true if and only if bufferByteLength is DETACHED.
4. If `bufferByteLength` is DETACHED, return `true`.
5. Let `byteOffsetStart` be `view`.[[ByteOffset]].
6. If `view`.[[ByteLength]] is AUTO, then
   a. Let `byteOffsetEnd` be `bufferByteLength`.
7. Else,
   a. Let `byteOffsetEnd` be `byteOffsetStart + view`.[[ByteLength]].
8. If `byteOffsetStart > bufferByteLength` or `byteOffsetEnd > bufferByteLength`, return `true`.
9. NOTE: 0-length DataViews are not considered out-of-bounds.
10. Return `false`.

25.3.1.5 GetViewValue ( `view`, `requestIndex`, `isLittleEndian`, `type` )

The abstract operation GetViewValue takes arguments `view` (an ECMAScript language value), `requestIndex` (an ECMAScript language value), `isLittleEndian` (an ECMAScript language value), and `type` (a TypedArray element type) and returns either a normal completion containing either a Number or a BigInt, or a throw completion. It is used by functions on DataView instances to retrieve values from the view's buffer. It performs the following steps when called:

1. Perform `? RequireInternalSlot(view, [[DataView]])`.
2. Assert: `view` has a [[ViewedArrayBuffer]] internal slot.
3. Let `getIndex` be `? ToIndex(requestIndex)`.
4. Set `isLittleEndian` to `ToBoolean(isLittleEndian)`.
5. Let `viewOffset` be `view`.[[ByteOffset]].
6. Let `viewRecord` be `MakeDataViewWithBufferWitnessRecord(view, UNORDERED)`.
7. NOTE: Bounds checking is not a synchronizing operation when `view`'s backing buffer is a growable SharedArrayBuffer.
8. If `IsViewOutOfBounds(viewRecord)` is `true`, throw a `TypeError` exception.
9. Let `viewSize` be `GetViewByteLength(viewRecord)`.
10. Let `elementSize` be the Element Size value specified in Table 71 for Element Type `type`.
11. If `getIndex + elementSize > viewSize`, throw a `RangeError` exception.
12. Let `bufferIndex` be `getIndex + viewOffset`.
13. Return `GetValueFromBuffer(view.[[ViewedArrayBuffer]], bufferIndex, type, false, UNORDERED, isLittleEndian)`.

25.3.1.6 SetViewValue ( `view`, `requestIndex`, `isLittleEndian`, `type`, `value` )

The abstract operation SetViewValue takes arguments `view` (an ECMAScript language value), `requestIndex` (an ECMAScript language value), `isLittleEndian` (an ECMAScript language value), `type` (a TypedArray element type), and `value` (an ECMAScript language value) and returns either a normal completion containing `undefined` or a throw completion. It is used by functions on DataView instances to store values into the view's buffer. It performs the following steps when called:

1. Perform `? RequireInternalSlot(view, [[DataView]])`.
2. Assert: `view` has a [[ViewedArrayBuffer]] internal slot.
3. Let `get Index` be `? ToIndex(requestIndex)`.
4. If `IsBigIntElementType(type)` is `true`, let `numberValue` be `? ToBigInt(value)`.
5. Otherwise, let `numberValue` be `? ToNumber(value)`.
6. Set `isLittleEndian` to `ToBoolean(isLittleEndian)`.
7. Let `view offset` be `view`.[[ByteOffset]].
8. Let `viewRecord` be `MakeDataViewWithBufferWitnessRecord(view, UNORDERED)`.
9. NOTE: Bounds checking is not a synchronizing operation when `view`'s backing buffer is a growable SharedArrayBuffer.
10. If `IsViewOutOfBounds(viewRecord)` is `true`, throw a `TypeError` exception.
11. Let `viewSize` be `GetViewByteLength(viewRecord)`.
12. Let `elementSize` be the Element Size value specified in Table 71 for Element Type `type`.
13. If `getIndex + elementSize > viewSize`, throw a `RangeError` exception.
14. Let `bufferIndex` be `getIndex + viewOffset`.
15. Perform `SetValueInBuffer(view.[[ViewedArrayBuffer]], bufferIndex, type, numberValue, false, UNORDERED, isLittleEndian)`.
16. Return `undefined`.

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25.3.2 The DataView Constructor

The DataView constructor:

- is %DataView%.
- is the initial value of the "DataView" property of the global object.
- creates and initializes a new DataView when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value of an extends clause of a class definition. Subclass constructors that intend to inherit the specified DataView behaviour must include a super call to the DataView constructor to create and initialize subclass instances with the internal state necessary to support the DataView.prototype built-in methods.

25.3.2.1 DataView ( buffer [ , byteOffset [ , byteLength ] ] )

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. Perform ? RequireInternalSlot(buffer, [[ArrayBufferData]]).
3. Let offset be ? ToIndex(byteOffset).
4. If IsDetachedBuffer(buffer) is true, throw a TypeError exception.
5. Let bufferByteLength be ArrayBufferByteLength(buffer, SEQ-CST).
6. If offset > bufferByteLength, throw a RangeError exception.
7. Let bufferIsFixedLength be IsFixedLengthArrayBuffer(buffer).
8. If byteLength is undefined, then
   a. If bufferIsFixedLength is true, then
      i. Let viewByteLength be bufferByteLength - offset.
   b. Else,
      i. Let viewByteLength be AUTO.
9. Else,
   a. Let viewByteLength be ? ToIndex(byteLength).
   b. If offset + viewByteLength > bufferByteLength, throw a RangeError exception.
10. Let O be ? OrdinaryCreateFromConstructor(NewTarget, "%DataView.prototype%", « [[DataView]], [[ViewedArrayBuffer]], [[ByteLength]], [[ByteOffset]] »).
11. If IsDetachedBuffer(buffer) is true, throw a TypeError exception.
12. Set bufferByteLength to ArrayBufferByteLength(buffer, SEQ-CST).
13. If offset > bufferByteLength, throw a RangeError exception.
14. If byteLength is not undefined, then
   a. If offset + viewByteLength > bufferByteLength, throw a RangeError exception.
15. Set O.[[ViewedArrayBuffer]] to buffer.
16. Set O.[[ByteLength]] to viewByteLength.
17. Set O.[[ByteOffset]] to offset.
18. Return O.

25.3.3 Properties of the DataView Constructor

The DataView constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has the following properties:

25.3.3.1 DataView.prototype

The initial value of DataView.prototype is the DataView prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }. 

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25.3.4 Properties of the DataView Prototype Object

The `DataView.prototype` object:

- is `%DataView.prototype%`.
- has a `[[Prototype]]` internal slot whose value is `%Object.prototype%`.
- is an ordinary object.
- does not have a `[[DataView]]`, `[[ViewedArrayBuffer]]`, `[[ByteLength]]`, or `[[ByteOffset]]` internal slot.

### 25.3.4.1 `get DataView.prototype.buffer`

`DataView.prototype.buffer` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the this value.
2. Perform `? RequireInternalSlot(O, [[DataView]])`.
3. **Assert**: `O` has a `[[ViewedArrayBuffer]]` internal slot.
4. Let `buffer` be `O.[[ViewedArrayBuffer]]`.
5. Return `buffer`.

### 25.3.4.2 `get DataView.prototype.byteLength`

`DataView.prototype.byteLength` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the this value.
2. Perform `? RequireInternalSlot(O, [[DataView]])`.
3. **Assert**: `O` has a `[[ViewedArrayBuffer]]` internal slot.
4. Let `viewRecord` be `MakeDataViewWithBufferWitnessRecord(O, SEQ-CST)`.
5. If `IsViewOutOfBounds(viewRecord)` is `true`, throw a `TypeError` exception.
6. Let `size` be `GetViewByteLength(viewRecord)`.
7. Return `𝔽(size)`.

### 25.3.4.3 `get DataView.prototype.byteOffset`

`DataView.prototype.byteOffset` is an accessor property whose set accessor function is `undefined`. Its get accessor function performs the following steps when called:

1. Let `O` be the this value.
2. Perform `? RequireInternalSlot(O, [[DataView]])`.
3. **Assert**: `O` has a `[[ViewedArrayBuffer]]` internal slot.
4. Let `viewRecord` be `MakeDataViewWithBufferWitnessRecord(O, SEQ-CST)`.
5. If `IsViewOutOfBounds(viewRecord)` is `true`, throw a `TypeError` exception.
6. Let `offset` be `O.[[ByteOffset]]`.
7. Return `𝔽(offset)`.

### 25.3.4.4 `DataView.prototype.constructor`

The initial value of `DataView.prototype.constructor` is `%DataView%`.

### 25.3.4.5 `DataView.prototype.getBigInt64 (byteOffset [, littleEndian])`

This method performs the following steps when called:

1. Let `v` be the this value.
2. Return `? GetValue(v, byteOffset, littleEndian, BIGINT64)`.
25.3.4.6 DataView.prototype.getBigUint64 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let v be the this value.
2. Return ? GetViewValue(v, byteOffset, littleEndian, BIGUINT64).

25.3.4.7 DataView.prototype.getFloat32 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let v be the this value.
2. If littleEndian is not present, set littleEndian to false.

25.3.4.8 DataView.prototype.getFloat64 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let v be the this value.
2. If littleEndian is not present, set littleEndian to false.
3. Return ? GetViewValue(v, byteOffset, littleEndian, FLOAT64).

25.3.4.9 DataView.prototype.getInt8 (byteOffset)

This method performs the following steps when called:

1. Let v be the this value.
2. Return ? GetViewValue(v, byteOffset, true, INT8).

25.3.4.10 DataView.prototype.getInt16 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let v be the this value.
2. If littleEndian is not present, set littleEndian to false.

25.3.4.11 DataView.prototype.getInt32 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let v be the this value.
2. If littleEndian is not present, set littleEndian to false.

25.3.4.12 DataView.prototype.getUint8 (byteOffset)

This method performs the following steps when called:

1. Let v be the this value.
2. Return ? GetViewValue(v, byteOffset, true, UINT8).
25.3.4.13 DataView.prototype.getUint16 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. If littleEndian is not present, set littleEndian to false.
3. Return ? GetViewValue\( (v, \text{byteOffset}, \text{littleEndian}, \text{UINT16}) \).

25.3.4.14 DataView.prototype.getUint32 (byteOffset [, littleEndian])

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. If littleEndian is not present, set littleEndian to false.
3. Return ? GetViewValue\( (v, \text{byteOffset}, \text{littleEndian}, \text{UINT32}) \).

25.3.4.15 DataView.prototype.setBigInt64 (byteOffset, value [, littleEndian])

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. Return ? SetViewValue\( (v, \text{byteOffset}, \text{littleEndian}, \text{BIGINT64}, \text{value}) \).

25.3.4.16 DataView.prototype.setBigUint64 (byteOffset, value [, littleEndian])

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. Return ? SetViewValue\( (v, \text{byteOffset}, \text{littleEndian}, \text{BIGUINT64}, \text{value}) \).

25.3.4.17 DataView.prototype.setFloat32 (byteOffset, value [, littleEndian])

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. If littleEndian is not present, set littleEndian to false.
3. Return ? SetViewValue\( (v, \text{byteOffset}, \text{littleEndian}, \text{FLOAT32}, \text{value}) \).

25.3.4.18 DataView.prototype.setFloat64 (byteOffset, value [, littleEndian])

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. If littleEndian is not present, set littleEndian to false.
3. Return ? SetViewValue\( (v, \text{byteOffset}, \text{littleEndian}, \text{FLOAT64}, \text{value}) \).

25.3.4.19 DataView.prototype.setInt8 (byteOffset, value)

This method performs the following steps when called:

1. Let \( v \) be the this value.
2. Return ? SetViewValue\( (v, \text{byteOffset}, \text{true}, \text{INT8}, \text{value}) \).
This method performs the following steps when called:

1. Let \( v \) be the \texttt{this} value.
2. If \texttt{littleEndian} is not present, set \texttt{littleEndian} to \texttt{false}.
3. Return \texttt{SetViewValue}(\( v \), byteOffset, \texttt{littleEndian}, \texttt{INT16}, value).

This method performs the following steps when called:

1. Let \( v \) be the \texttt{this} value.
2. If \texttt{littleEndian} is not present, set \texttt{littleEndian} to \texttt{false}.
3. Return \texttt{SetViewValue}(\( v \), byteOffset, \texttt{littleEndian}, \texttt{INT32}, value).

This method performs the following steps when called:

1. Let \( v \) be the \texttt{this} value.
2. Return \texttt{SetViewValue}(\( v \), byteOffset, \texttt{true}, \texttt{UINT8}, value).

This method performs the following steps when called:

1. Let \( v \) be the \texttt{this} value.
2. If \texttt{littleEndian} is not present, set \texttt{littleEndian} to \texttt{false}.
3. Return \texttt{SetViewValue}(\( v \), byteOffset, \texttt{littleEndian}, \texttt{UINT16}, value).

This method performs the following steps when called:

1. Let \( v \) be the \texttt{this} value.
2. If \texttt{littleEndian} is not present, set \texttt{littleEndian} to \texttt{false}.
3. Return \texttt{SetViewValue}(\( v \), byteOffset, \texttt{littleEndian}, \texttt{UINT32}, value).

The initial value of the \texttt{@@toStringTag} property is the String value "DataView".

This property has the attributes \{ [[Writable]]: \texttt{false}, [[Enumerable]]: \texttt{false}, [[Configurable]]: \texttt{true} \}.

DataView instances are ordinary objects that inherit properties from the DataView prototype object. DataView instances each have [[DataView]], [[ViewedArrayBuffer]], [[ByteLength]], and [[ByteOffset]] internal slots.

\textbf{NOTE} The value of the [[DataView]] internal slot is not used within this specification. The simple presence of that internal slot is used within the specification to identify objects created using the DataView constructor.
25.4 The Atomics Object

The Atomics object:

- is `%Atomics%`.
- is the initial value of the "Atomics" property of the global object.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.
- does not have a [[Construct]] internal method; it cannot be used as a constructor with the `new` operator.
- does not have a [[Call]] internal method; it cannot be invoked as a function.

The Atomics object provides functions that operate indivisibly (atomically) on shared memory array cells as well as functions that let agents wait for and dispatch primitive events. When used with discipline, the Atomics functions allow multi-agent programs that communicate through shared memory to execute in a well-understood order even on parallel CPUs. The rules that govern shared-memory communication are provided by the memory model, defined below.

**NOTE** For informative guidelines for programming and implementing shared memory in ECMAScript, please see the notes at the end of the memory model section.

25.4.1 Waiter Record

A Waiter Record is a Record value used to denote a particular call to `Atomics.wait` or `Atomics.waitAsync`.

A Waiter Record has fields listed in Table 73.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[AgentSignifier]]</code></td>
<td>an agent signifier</td>
<td>The agent that called <code>Atomics.wait</code> or <code>Atomics.waitAsync</code></td>
</tr>
<tr>
<td><code>[[PromiseCapability]]</code></td>
<td>a PromiseCapability Record or BLOCKING</td>
<td>If denoting a call to <code>Atomics.waitAsync</code>, the resulting promise, otherwise BLOCKING.</td>
</tr>
<tr>
<td><code>[[TimeoutTime]]</code></td>
<td>a non-negative extended mathematical value</td>
<td>The earliest time by which timeout may be triggered; computed using time values.</td>
</tr>
<tr>
<td><code>[[Result]]</code></td>
<td>&quot;ok&quot; or &quot;timed-out&quot;</td>
<td>The return value of the call.</td>
</tr>
</tbody>
</table>

25.4.2 WaiterList Records

A WaiterList Record is used to explain waiting and notification of agents via `Atomics.wait`, `Atomics.waitAsync`, and `Atomics.notify`.

A WaiterList Record has fields listed in Table 74.
Table 74: **WaiterList Record** Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Waiters]]</td>
<td>a List of Waiter Records</td>
<td>The calls to <code>Atomics.wait</code> or <code>Atomics.waitAsync</code> that are waiting on the location with which this WaiterList is associated.</td>
</tr>
<tr>
<td>[[MostRecentLeaveEvent]]</td>
<td>a Synchronize event or EMPTY</td>
<td>The event of the most recent leaving of its critical section, or EMPTY if its critical section has never been entered.</td>
</tr>
</tbody>
</table>

There can be multiple **Waiter Records** in a WaiterList with the same **agent signifier**.

The **agent cluster** has a store of WaiterList Records; the store is indexed by \((block, i)\), where \(block\) is a **Shared Data Block** and \(i\) a byte offset into the memory of \(block\). WaiterList Records are **agent-independent**: a lookup in the store of WaiterList Records by \((block, i)\) will result in the same WaiterList Record in any **agent** in the **agent cluster**.

Each WaiterList Record has a critical section that controls exclusive access to that WaiterList Record during evaluation. Only a single **agent** may enter a WaiterList Record's critical section at one time. Entering and leaving a WaiterList Record's critical section is controlled by the abstract operations `EnterCriticalSection` and `LeaveCriticalSection`. Operations on a WaiterList Record—adding and removing waiting agents, traversing the list of agents, suspending and notifying agents on the list, setting and retrieving the Synchronize event—may only be performed by **agents** that have entered the WaiterList Record's critical section.

### 25.4.3 Abstract Operations for Atomics

#### 25.4.3.1 ValidateIntegerTypedArray ( \(\text{typedArray}, \text{waitable}\) )

The abstract operation `ValidateIntegerTypedArray` takes arguments `typedArray` (an ECMAScript language value) and `waitable` (a Boolean) and returns either a normal completion containing a **TypedArray With Buffer Witness Record**, or a throw completion. It performs the following steps when called:

1. Let `taRecord` be ? `ValidateTypedArray(typedArray, UNORDERED)`.  
2. **NOTE**: Bounds checking is not a synchronizing operation when `typedArray`'s backing buffer is a *growable* **SharedArrayBuffer**.
3. If `waitable` is **true**, then
   a. If `typedArray.[[TypedArrayName]]` is neither "Int32Array" nor "BigInt64Array", throw a **TypeError** exception.
4. Else,
   a. Let `type` be `TypedArrayElementType(typedArray)`.  
   b. If `IsUnclampedIntegerElementType(type)` is **false** and `IsBigIntElementType(type)` is **false**, throw a **TypeError** exception.
5. Return `taRecord`.

#### 25.4.3.2 ValidateAtomicAccess ( \(\text{taRecord}, \text{requestIndex}\) )

The abstract operation `ValidateAtomicAccess` takes arguments `taRecord` (a **TypedArray With Buffer Witness Record**) and `requestIndex` (an ECMAScript language value) and returns either a normal completion containing an integer or a throw completion. It performs the following steps when called:

1. Let `length` be `TypedArrayLength(taRecord)`.  
2. Let `accessIndex` be ? `ToIndex(requestIndex)`.  
3. Assert: `accessIndex \geq 0`.  
4. If `accessIndex > length`, throw a **RangeError** exception.
5. Let `typedArray` be `taRecord.[[Object]]`.  
6. Let `elementSize` be `TypedArrayElementSize(typedArray)`.
Let offset be \(\text{typedArray}.[[\text{ByteOffset}]]\).

Return \((\text{accessIndex} \times \text{elementSize}) + \text{offset}\).

25.4.3.3 ValidateAtomicAccessOnIntegerTypedArray (\(\text{typedArray}, \text{requestIndex}[, \text{waitable} ]\))

The abstract operation ValidateAtomicAccessOnIntegerTypedArray takes arguments \(\text{typedArray}\) (an ECMAScript language value) and \(\text{requestIndex}\) (an ECMAScript language value) and optional argument \(\text{waitable}\) (a Boolean) and returns either a normal completion containing an integer or a throw completion. It performs the following steps when called:

1. If \(\text{waitable}\) is not present, set \(\text{waitable}\) to false.
2. Let \(\text{taRecord}\) be ? ValidateIntegerTypedArray(\(\text{typedArray}, \text{waitable}\)).
3. Return ? ValidateAtomicAccess(\(\text{taRecord}, \text{requestIndex}\)).

25.4.3.4 RevalidateAtomicAccess (\(\text{typedArray}, \text{byteIndexInBuffer}\))

The abstract operation RevalidateAtomicAccess takes arguments \(\text{typedArray}\) (a TypedArray) and \(\text{byteIndexInBuffer}\) (an integer) and returns either a normal completion containing \(\text{UNUSED}\) or a throw completion. This operation revalidates the index within the backing buffer for atomic operations after all argument coercions are performed in Atomics methods, as argument coercions can have arbitrary side effects, which could cause the buffer to become out of bounds. This operation does not throw when \(\text{typedArray}\)'s backing buffer is a SharedArrayBuffer. It performs the following steps when called:

1. Let \(\text{taRecord}\) be MakeTypedArrayWithBufferWitnessRecord(\(\text{typedArray}, \text{UNORDERED}\)).
2. NOTE: Bounds checking is not a synchronizing operation when \(\text{typedArray}\)'s backing buffer is a growable SharedArrayBuffer.
3. If IsTypedArrayOutOfBounds(\(\text{taRecord}\)) is true, throw a TypeError exception.
4. Assert: \(\text{byteIndexInBuffer} \geq \text{typedArray}.[[\text{ByteOffset}]\)].
5. If \(\text{byteIndexInBuffer} \geq \text{taRecord}.[[\text{CachedBufferByteLength}]]\), throw a RangeError exception.
6. Return \(\text{UNUSED}\).

25.4.3.5 GetWaiterList (\(\text{block}, i\))

The abstract operation GetWaiterList takes arguments \(\text{block}\) (a Shared Data Block) and \(i\) (a non-negative integer that is evenly divisible by 4) and returns a WaiterList Record. It performs the following steps when called:

1. Assert: \(i\) and \(i + 3\) are valid byte offsets within the memory of \(\text{block}\).
2. Return the WaiterList Record that is referenced by the pair (\(\text{block}, i\)).

25.4.3.6 EnterCriticalSection (\(\text{WL}\))

The abstract operation EnterCriticalSection takes argument \(\text{WL}\) (a WaiterList Record) and returns \(\text{UNUSED}\). It performs the following steps when called:

1. Assert: The surrounding agent is not in the critical section for any WaiterList Record.
2. Wait until no agent is in the critical section for \(\text{WL}\), then enter the critical section for \(\text{WL}\) (without allowing any other agent to enter).
3. If \(\text{WL}.[[\text{MostRecentLeaveEvent}]]\) is not EMPTY, then
   a. NOTE: A \(\text{WL}\) whose critical section has been entered at least once has a Synchronize event set by LeaveCriticalSection.
   b. Let \(\text{execution}\) be the [[CandidateExecution]] field of the surrounding agent's Agent Record.
   c. Let \(\text{eventsRecord}\) be the Agent Events Record of \(\text{execution}\. [[\text{EventsRecords}]]\) whose [[AgentSignifier]] is AgentSignifier().
   d. Let \(\text{enterEvent}\) be a new Synchronize event.
   e. Append \(\text{enterEvent}\) to \(\text{eventsRecord}.[[\text{EventList}]]\).
   f. Append (\(\text{WL}.[[\text{MostRecentLeaveEvent}]], \text{enterEvent}\)) to \(\text{eventsRecord}.[[\text{AgentSynchronizesWith}]]\).
4. Return \(\text{UNUSED}\).
EnterCriticalSection has contention when an agent attempting to enter the critical section must wait for another agent to leave it. When there is no contention, FIFO order of EnterCriticalSection calls is observable. When there is contention, an implementation may choose an arbitrary order but may not cause an agent to wait indefinitely.

25.4.3.7 LeaveCriticalSection (WL)

The abstract operation LeaveCriticalSection takes argument WL (a WaiterList Record) and returns UNUSED. It performs the following steps when called:

1. Assert: The surrounding agent is in the critical section for WL.
2. Let execution be the [[CandidateExecution]] field of the surrounding agent’s Agent Record.
3. Let eventsRecord be the Agent Events Record of execution.[[EventsRecords]] whose [[AgentSignifier]] is AgentSignifier().
4. Let leaveEvent be a new Synchronize event.
5. Append leaveEvent to eventsRecord.]]([EventList]].
6. Set WL.[[MostRecentLeaveEvent]] to leaveEvent.
7. Leave the critical section for WL.
8. Return UNUSED.

25.4.3.8 AddWaiter (WL, waiterRecord)

The abstract operation AddWaiter takes arguments WL (a WaiterList Record) and waiterRecord (a Waiter Record) and returns UNUSED. It performs the following steps when called:

1. Assert: The surrounding agent is in the critical section for WL.
2. Assert: There is no Waiter Record in WL.[[Waiters]] whose [[PromiseCapability]] field is waiterRecord.[[PromiseCapability]] and whose [[AgentSignifier]] field is waiterRecord.[[AgentSignifier]].
3. Append waiterRecord to WL.[[Waiters]].
4. Return UNUSED.

25.4.3.9 RemoveWaiter (WL, waiterRecord)

The abstract operation RemoveWaiter takes arguments WL (a WaiterList Record) and waiterRecord (a Waiter Record) and returns UNUSED. It performs the following steps when called:

1. Assert: The surrounding agent is in the critical section for WL.
2. Assert: WL.[[Waiters]] contains waiterRecord.
3. Remove waiterRecord from WL.[[Waiters]].
4. Return UNUSED.

25.4.3.10 RemoveWaiters (WL, c)

The abstract operation RemoveWaiters takes arguments WL (a WaiterList Record) and c (a non-negative integer or +∞) and returns a List of Waiter Records. It performs the following steps when called:

1. Assert: The surrounding agent is in the critical section for WL.
2. Let len be the number of elements in WL.[[Waiters]].
3. Let n be min(c, len).
4. Let L be a List whose elements are the first n elements of WL.[[Waiters]].
5. Remove the first n elements of WL.[[Waiters]].
6. Return L.
25.4.3.11 SuspendThisAgent (WL, waiterRecord)

The abstract operation SuspendThisAgent takes arguments WL (a WaiterList Record) and waiterRecord (a WaiterRecord) and returns UNUSED. It performs the following steps when called:

1. Assert: The surrounding agent is in the critical section for WL.
2. Assert: WL.[[Waiters]] contains waiterRecord.
3. Let thisAgent be AgentSignifier().
4. Assert: waiterRecord.[[AgentSignifier]] is thisAgent.
5. Assert: waiterRecord.[[PromiseCapability]] is BLOCKING.
6. Assert: AgentCanSuspend() is true.
7. Perform LeaveCriticalSection(WL) and suspend the surrounding agent until the time is waiterRecord.[[TimeoutTime]], performing the combined operation in such a way that a notification that arrives after the critical section is exited but before the suspension takes effect is not lost. The surrounding agent can only wake from suspension due to a timeout or due to another agent calling NotifyWaiter with arguments WL and thisAgent (i.e. via a call to Atomics.notify).
8. Perform EnterCriticalSection(WL).
9. Return UNUSED.

25.4.3.12 NotifyWaiter (WL, waiterRecord)

The abstract operation NotifyWaiter takes arguments WL (a WaiterList Record) and waiterRecord (a WaiterRecord) and returns UNUSED. It performs the following steps when called:

1. Assert: The surrounding agent is in the critical section for WL.
2. If waiterRecord.[[PromiseCapability]] is BLOCKING, then
   a. Wake the agent whose signifier is waiterRecord.[[AgentSignifier]] from suspension.
   b. NOTE: This causes the agent to resume execution in SuspendThisAgent.
3. Else if AgentSignifier() is waiterRecord.[[AgentSignifier]], then
   a. Let promiseCapability be waiterRecord.[[PromiseCapability]].
   b. Perform ! Call(promiseCapability.[[Resolve]], undefined, « waiterRecord.[[Result]] »).
4. Else,
   a. Perform EnqueueResolveInAgentJob(waiterRecord.[[AgentSignifier]],
                                            waiterRecord.[[PromiseCapability]], waiterRecord.[[Result]]).
5. Return UNUSED.

NOTE An agent must not access another agent's promise capability in any capacity beyond passing it to the host.

25.4.3.13 EnqueueResolveInAgentJob (agentSignifier, promiseCapability, resolution)

The abstract operation EnqueueResolveInAgentJob takes arguments agentSignifier (an agent signifier), promiseCapability (a PromiseCapability Record), and resolution (an ECMAScript language value) and returns UNUSED. It performs the following steps when called:

1. Let resolveJob be a new Job Abstract Closure with no parameters that captures agentSignifier, promiseCapability, and resolution and performs the following steps when called:
   a. Assert: AgentSignifier() is agentSignifier.
   b. Perform ! Call(promiseCapability.[[Resolve]], undefined, « resolution »).
   c. Return UNUSED.
2. Let realmInTargetAgent be ! GetFunctionRealm(promiseCapability.[[Resolve]]).
3. Assert: agentSignifier is realmInTargetAgent.[[AgentSignifier]].
4. Perform HostEnqueueGenericJob(resolveJob, realmInTargetAgent).
5. Return UNUSED.
The abstract operation DoWait takes arguments `mode` (SYNC or ASYNC), `typedArray` (an ECMAScript language value), `index` (an ECMAScript language value), `value` (an ECMAScript language value), and `timeout` (an ECMAScript language value) and returns either a normal completion containing either an Object, "not-equal", "timed-out", or "ok", or a throw completion. It performs the following steps when called:

1. Let `taRecord` be ? `ValidateTypedArray(typedArray, true)`. If `taRecord` is `null` or `false`, throw a `TypeError` exception.
2. Let `buffer` be `taRecord`. If `buffer` is `null`, throw a `TypeError` exception.
3. If `isSharedArrayBuffer(buffer)` is `false`, throw a `TypeError` exception.
4. Let `t` be ? `ValidateAtomicAccess(taRecord, index)`. If `t` is `null`, throw a `TypeError` exception.
5. Let `arrayTypeName` be `typedArray`. If `arrayTypeName` is "BigInt64Array", let `v` be ? `ToBigInt64(value)`. Else, let `v` be ? `ToInt32(value)`.
6. Let `q` be ? `ToNumber(timeout)`.
7. If `q` is either `NaN` or `+∞`, let `t` be `+∞`; else if `q` is `-∞`, let `t` be `0`; else let `t` be `max(ℝ(q), 0)`.
8. If `mode` is SYNC and `AgentCanSuspend()` is `false`, throw a `TypeError` exception.
9. Let `block` be `buffer`. If `block` is `null`, throw a `TypeError` exception.
10. Let `offset` be `typedArray`. If `offset` is `null`, throw a `TypeError` exception.
11. Let `byteIndexInBuffer` be `(i × 4) + offset`.
12. Let `WL` be `GetWaiterList(block, byteIndexInBuffer)`.
13. If `mode` is SYNC, then
   a. Let `promiseCapability` be BLOCKING.
   b. Let `resultObject` be undefined.
14. Else,
   a. Let `promiseCapability` be `NewPromiseCapability(%Promise%)`
   b. Let `resultObject` be `OrdinaryObjectCreate(%Object.prototype%)`
15. Perform `EnterCriticalSection(WL)`.
16. Let `elementType` be `TypedArrayElementType(typedArray)`.
17. Let `w` be `GetValueFromBuffer(buffer, byteIndexInBuffer, elementType, true, SEQ-CST)`.
18. If `v ≠ w`, then
   a. Perform `LeaveCriticalSection(WL)`.
   b. If `mode` is SYNC, return "not-equal".
   c. Perform `CreateDataPropertyOrThrow(resultObject, "async", false)`.
   d. Perform `CreateDataPropertyOrThrow(resultObject, "value", "not-equal")`.
   e. Return `resultObject`.
19. If `f is 0 and mode` is ASYNC, then
   a. NOTE: There is no special handling of synchronous immediate timeouts. Asynchronous immediate timeouts have special handling in order to fail fast and avoid unnecessary Promise jobs.
   b. Perform `LeaveCriticalSection(WL)`.
   c. Perform `CreateDataPropertyOrThrow(resultObject, "async", false)`.
   d. Perform `CreateDataPropertyOrThrow(resultObject, "value", "timed-out")`.
   e. Return `resultObject`.
20. Let `thisAgent` be `AgentSignifier()`.
21. Let `now` be the time value (UTC) identifying the current time.
22. Let `additionalTimeout` be an implementation-defined non-negative mathematical value.
23. Let `endTime` be `ℝ(now) + t + additionalTimeout`.
24. NOTE: When `t` is `+∞`, `endTime` is also `+∞`.
25. Let `waiterRecord` be a new `Waiter Record` { [[AgentSignifier]]: `thisAgent`, [[PromiseCapability]]: `promiseCapability`, [[TimeoutTime]]: `endTime`, [[Result]]: "ok" }.
26. Perform `AddWaiter(WL, waiterRecord)`.
27. If `mode` is SYNC, then
   a. Perform `SuspendThisAgent(WL, waiterRecord)`.
   b. Let `endTime` be 
   c. Perform `RegisterAtomicWaitAsyncTimeoutJob(WL, waiterRecord)`.
   d. Perform `LeaveCriticalSection(WL)`.
28. If `mode` is SYNC, then
   a. Perform `CreateDataPropertyOrThrow(resultObject, "async", true)`.
   b. Perform `CreateDataPropertyOrThrow(resultObject, "value", promiseCapability [[Promise]])`.
29. Return `resultObject`.
25.4.3.15 EnqueueAtomsWaitAsyncTimeoutJob (WL, waiterRecord)

The abstract operation EnqueueAtomsWaitAsyncTimeoutJob takes arguments WL (a WaiterList Record) and waiterRecord (a Waiter Record) and returns UNUSED. It performs the following steps when called:

1. Let timeoutJob be a new Job Abstract Closure with no parameters that captures WL and waiterRecord and performs the following steps when called:
   a. Perform EnterCriticalSection(WL).
   b. If WL.[[Waiters]] contains waiterRecord, then
      i. Let timeOfJobExecution be the time value (UTC) identifying the current time.
      ii. Assert: \( \mathbb{R}(\text{timeOfJobExecution}) \geq \text{waiterRecord}.[[\text{TimeoutTime}]] \) (ignoring potential non-monotonicity of time values).
      iii. Set waiterRecord.[[Result]] to "timed-out".
      iv. Perform RemoveWaiter(WL, waiterRecord).
      v. Perform NotifyWaiter(WL, waiterRecord).
   c. Perform LeaveCriticalSection(WL).
   d. Return UNUSED.
2. Let now be the time value (UTC) identifying the current time.
3. Let currentRealm be the current Realm Record.
4. Perform HostEnqueueTimeoutJob(timeoutJob, currentRealm, \( \mathbb{F}(\text{waiterRecord}.[[\text{TimeoutTime}]] - \text{now}) \)).
5. Return UNUSED.

25.4.3.16 AtomicCompareExchangeInSharedBlock (block, bytelIndexInBuffer, elementSize, expectedBytes, replacementBytes)

The abstract operation AtomicCompareExchangeInSharedBlock takes arguments block (a Shared Data Block), bytelIndexInBuffer (an integer), elementSize (a non-negative integer), expectedBytes (a List of byte values), and replacementBytes (a List of byte values) and returns a List of byte values. It performs the following steps when called:

1. Let execution be the [[CandidateExecution]] field of the surrounding agent's Agent Record.
2. Let eventsRecord be the Agent Events Record of execution.[[EventsRecords]] whose [[AgentSignifier]] is AgentSignifier().
3. Let rawBytesRead be a List of length elementSize whose elements are nondeterministically chosen byte values.
4. NOTE: In implementations, rawBytesRead is the result of a load-link, of a load-exclusive, or of an operand of a read-modify-write instruction on the underlying hardware. The nondeterminism is a semantic prescription of the memory model to describe observable behaviour of hardware with weak consistency.
5. NOTE: The comparison of the expected value and the read value is performed outside of the read-modify-write modification function to avoid needlessly strong synchronization when the expected value is not equal to the read value.
6. If ByteListEqual(rawBytesRead, expectedBytes) is true, then
   a. Let second be a new read-modify-write modification function with parameters (oldBytes, newBytes) that captures nothing and performs the following steps atomically when called:
      i. Return newBytes.
   b. Let event be ReadModifyWriteSharedMemory { [[Order]]: SEQ-CST, [[NoTear]]: true, [[Block]]: block, [[ByteIndex]]: bytelIndexInBuffer, [[ElementSize]]: elementSize, [[Payload]]: replacementBytes, [[ModifyOp]]: second }.
7. Else,
   a. Let event be ReadSharedMemory { [[Order]]: SEQ-CST, [[NoTear]]: true, [[Block]]: block, [[ByteIndex]]: bytelIndexInBuffer, [[ElementSize]]: elementSize }.
8. Append event to eventsRecord.[[EventList]].

NOTE: additionalTimeout allows implementations to pad timeouts as necessary, such as for reducing power consumption or coarsening timer resolution to mitigate timing attacks. This value may differ from call to call of DoWait.
9. Append Chosen Value Record { [[Event]]: event, [[ChosenValue]]: rawBytesRead } to execution. [[ChosenValues]].
10. Return rawBytesRead.

25.4.3.17 AtomicReadModifyWrite ( typedArray, index, value, op )

The abstract operation AtomicReadModifyWrite takes arguments typedArray (an ECMAScript language value), index (an ECMAScript language value), value (an ECMAScript language value), and op (a read-modify-write modification function) and returns either a normal completion containing either a Number or a Bigint, or a throw completion. op takes two List of byte values arguments and returns a List of byte values. This operation atomically loads a value, combines it with another value, and stores the result of the combination. It returns the loaded value. It performs the following steps when called:

1. Let byteIndexInBuffer be ? ValidateAtomicAccessOnIntegerTypedArray(typedArray, index).
2. If typedArray. [[ContentType]] is BIGINT, let v be ? ToBigInt(value).
3. Otherwise, let v be𝔽(? ToIntegerOrInfinity(value)).
5. Let buffer be typedArray. [[ViewedArrayBuffer]].
6. Let elementType be TypedArrayElementType(typedArray).
7. Return GetModifySetValueInBuffer(buffer, byteIndexInBuffer, elementType, v, op).

25.4.3.18 ByteListBitwiseOp ( op, xBytes, yBytes )

The abstract operation ByteListBitwiseOp takes arguments op (&, ^, or |), xBytes (a List of byte values), and yBytes (a List of byte values) and returns a List of byte values. The operation atomically performs a bitwise operation on all byte values of the arguments and returns a List of byte values. It performs the following steps when called:

1. Assert: xBytes and yBytes have the same number of elements.
2. Let result be a new empty List.
3. Let i be 0.
4. For each element xByte of xBytes, do
   a. Let yByte be yBytes[i].
   b. If op is &, then
      i. Let resultByte be the result of applying the bitwise AND operation to xByte and yByte.
   c. Else if op is ^, then
      i. Let resultByte be the result of applying the bitwise exclusive OR (XOR) operation to xByte and yByte.
   d. Else,
      i. Assert: op is |.
      ii. Let resultByte be the result of applying the bitwise inclusive OR (XOR) operation to xByte and yByte.
   e. Set i to i + 1.
   f. Append resultByte to result.
5. Return result.

25.4.3.19 ByteListEqual ( xBytes, yBytes )

The abstract operation ByteListEqual takes arguments xBytes (a List of byte values) and yBytes (a List of byte values) and returns a Boolean. It performs the following steps when called:

1. If xBytes and yBytes do not have the same number of elements, return false.
2. Let i be 0.
3. For each element xByte of xBytes, do
   a. Let yByte be yBytes[i].
   b. If xByte ≠ yByte, return false.
   c. Set i to i + 1.
4. Return true.
25.4.4 Atomics.add ( typedArray, index, value )

This function performs the following steps when called:

1. Let type be TypedArrayElementType(typedArray).
2. Let isLittleEndian be the value of the [[LittleEndian]] field of the surrounding agent's Agent Record.
3. Let add be a new read-modify-write modification function with parameters (xBytes, yBytes) that captures type and isLittleEndian and performs the following steps atomically when called:
   a. Let \( x \) be RawBytesToNumeric(type, xBytes, isLittleEndian).
   b. Let \( y \) be RawBytesToNumeric(type, yBytes, isLittleEndian).
   c. If \( x \) is a Number, then
      i. Let \( \text{sum} \) be Number::add(\( x \), \( y \)).
   d. Else,
      i. Assert: \( x \) is a BigInt.
      ii. Let \( \text{sum} \) be BigInt::add(\( x \), \( y \)).
   e. Let \( \text{sumBytes} \) be NumericToRawBytes(type, \( \text{sum} \), isLittleEndian).
   f. Assert: \( \text{sumBytes} \), \( xBytes \), and \( yBytes \) have the same number of elements.
   g. Return \( \text{sumBytes} \).
4. Return ? AtomicReadModifyWrite(typedArray, index, value, add).

25.4.5 Atomics.and ( typedArray, index, value )

This function performs the following steps when called:

1. Let \( \text{and} \) be a new read-modify-write modification function with parameters (xBytes, yBytes) that captures nothing and performs the following steps atomically when called:
2. Return ? AtomicReadModifyWrite(typedArray, index, value, and).

25.4.6 Atomics.compareExchange ( typedArray, index, expectedValue, replacementValue )

This function performs the following steps when called:

1. Let byteIndexInBuffer be ? ValidateAtomicAccessOnIntegerTypedArray(typedArray, index).
2. Let buffer be typedArray.\[\text{ViewedArrayBuffer}\].
3. Let block be buffer.\[\text{ArrayBufferData}\].
4. If typedArray.\[\text{ContentType}\] is BIGINT, then
   a. Let expected be ? ToBigInt(expectedValue).
   b. Let replacement be ? ToBigInt(replacementValue).
5. Else,
   a. Let expected be \( \mathbb{F}(\text{ToIntegerOrInfinity}(\text{expectedValue})) \).
   b. Let replacement be \( \mathbb{F}(\text{ToIntegerOrInfinity}(\text{replacementValue})) \).
7. Let elementType be TypedArrayElementType(typedArray).
8. Let elementSize be TypedArrayElementSize(typedArray).
9. Let isLittleEndian be the value of the [[LittleEndian]] field of the surrounding agent's Agent Record.
10. Let expectedBytes be NumericToRawBytes(elementType, expected, isLittleEndian).
11. Let replacementBytes be NumericToRawBytes(elementType, replacement, isLittleEndian).
12. If IsSharedArrayBuffer(buffer) is true, then
    a. Let rawBytesRead be AtomicCompareExchangeInSharedBlock(block, byteIndexInBuffer, elementSize, expectedBytes, replacementBytes).
13. Else,
    a. Let rawBytesRead be a List of length elementSize whose elements are the sequence of elementSize bytes starting with block[byteIndexInBuffer].
    b. If ByteListEqual(rawBytesRead, expectedBytes) is true, then
       i. Store the individual bytes of replacementBytes into block, starting at block[byteIndexInBuffer].
14. Return RawBytesToNumeric(elementType, rawBytesRead, isLittleEndian).
25.4.7 Atomics.exchange ( `typedArray`, `index`, `value` )

This function performs the following steps when called:

1. Let `second` be a new read-modify-write modification function with parameters ( `oldBytes`, `newBytes` ) that captures nothing and performs the following steps atomically when called:
   a. Return `newBytes`.
2. Return `AtomicReadModifyWrite(typedArray, index, value, second)`.

25.4.8 Atomics.isLockFree ( `size` )

This function performs the following steps when called:

1. Let `n` be `ToIntegerOrInfinity(size)`.
2. Let `AR` be the Agent Record of the surrounding agent.
3. If `n = 1`, return `AR.[[IsLockFree1]]`.
4. If `n = 2`, return `AR.[[IsLockFree2]]`.
5. If `n = 4`, return `true`.
6. If `n = 8`, return `AR.[[IsLockFree8]]`.
7. Return `false`.

**NOTE** This function is an optimization primitive. The intuition is that if the atomic step of an atomic primitive (`compareExchange`, `load`, `store`, `add`, `sub`, `and`, `or`, `xor`, or `exchange`) on a datum of size `n` bytes will be performed without the surrounding agent acquiring a lock outside the `n` bytes comprising the datum, then `Atomics.isLockFree(n)` will return `true`. High-performance algorithms will use this function to determine whether to use locks or atomic operations in critical sections. If an atomic primitive is not lock-free then it is often more efficient for an algorithm to provide its own locking.

Regardless of the value returned by this function, all atomic operations are guaranteed to be atomic. For example, they will never have a visible operation take place in the middle of the operation (e.g., "tearing").

25.4.9 Atomics.load ( `typedArray`, `index` )

This function performs the following steps when called:

1. Let `byteIndexInBuffer` be `ValidateAtomicAccessOnIntegerTypedArray(typedArray, index)`.
2. Perform `RevalidateAtomicAccess(typedArray, byteIndexInBuffer)`.
3. Let `buffer` be `typedArray.[[ViewedArrayBuffer]]`.
4. Let `elementType` be `TypedArrayElementType(typedArray)`.
5. Return `GetValueFromBuffer(buffer, byteIndexInBuffer, elementType, true, SEQ-CST)`.

25.4.10 Atomics.or ( `typedArray`, `index`, `value` )

This function performs the following steps when called:

1. Let `or` be a new read-modify-write modification function with parameters ( `xBytes`, `yBytes` ) that captures nothing and performs the following steps atomically when called:
   a. Return `ByteListBitwiseOp(|, xBytes, yBytes)`.
2. Return `AtomicReadModifyWrite(typedArray, index, value, or)`.
25.4.11 `Atomsics.store ( typedArray, index, value )`

This function performs the following steps when called:

1. Let `byteIndexInBuffer` be `ValidateAtomicAccessOnIntegerTypedArray(typedArray, index)`.
2. If `typedArray`.[[ContentType]] is `BIGINT`, let `v` be `ToBigInt(value)`.
3. Otherwise, let `v` be `𝔽(ToIntegerOrInfinity(value))`.
4. Perform `RevalidateAtomicAccess(typedArray, byteIndexInBuffer)`.
5. Let `buffer` be `typedArray`.[[ViewedArrayBuffer]].
6. Let `elementType` be `TypedArrayElementType(typedArray)`.
7. Perform `SetValueInBuffer(buffer, byteIndexInBuffer, elementType, v, true, SEQ-CST)`.
8. Return `v`.

25.4.12 `Atomsics.sub ( typedArray, index, value )`

This function performs the following steps when called:

1. Let `type` be `TypedArrayElementType(typedArray)`.
2. Let `isLittleEndian` be the value of the `[[LittleEndian]]` field of the surrounding agent's `Agent Record`.
3. Let `subtract` be a new read-modify-write modification function with parameters (`xBytes, yBytes`) that captures `type` and `isLittleEndian` and performs the following steps atomically when called:
   a. Let `x` be `RawBytesToNumeric(type, xBytes, isLittleEndian)`.
   b. Let `y` be `RawBytesToNumeric(type, yBytes, isLittleEndian)`.
   c. If `x` is a Number, then
      i. Let `difference` be `Number::subtract(x, y)`.
   d. Else,
      i. `Assert: x` is a BigInt.
      ii. Let `difference` be `BigInt::subtract(x, y)`.
   e. Let `differenceBytes` be `NumericToRawBytes(type, difference, isLittleEndian)`.
   f. `Assert: differenceBytes, xBytes, and yBytes` have the same number of elements.
   g. Return `differenceBytes`.
4. Return `AtomicReadModifyWrite(typedArray, index, value, subtract)`.

25.4.13 `Atomsics.wait ( typedArray, index, value, timeout )`

This function puts the surrounding agent in a wait queue and suspends it until notified or until the wait times out, returning a String differentiating those cases.

It performs the following steps when called:

1. Return `DoWait(SYNC, typedArray, index, value, timeout)`.

25.4.14 `Atomsics.waitAsync ( typedArray, index, value, timeout )`

This function returns a Promise that is resolved when the calling agent is notified or the the timeout is reached.

It performs the following steps when called:

1. Return `DoWait(ASYNC, typedArray, index, value, timeout)`.

25.4.15 `Atomsics.notify ( typedArray, index, count )`

This function notifies some agents that are sleeping in the wait queue.

It performs the following steps when called:
1. Let `byteIndexInBuffer` be \( ? \) \( \text{ValidateAtomicAccessOnIntegerTypedArray}(\text{typedArray}, \text{index}, \text{true}) \).

2. If `count` is `undefined`, then
   a. Let `c` be `+\infty`.
3. Else,
   a. Let `intCount` be `?` \( \text{ToIntegerOrInfinity}(\text{count}) \).
   b. Let `c` be `max(intCount, 0)`.
4. Let `buffer` be `\text{typedArray}.[[\text{ViewedArrayBuffer}]]`.
5. Let `block` be `buffer.[[\text{ArrayBufferData}]]`.
6. If `isSharedArrayBuffer(buffer)` is `false`, return `+0_{\text{F}}`.
7. Let `WL` be `GetWaiterList(block, byteIndexInBuffer)`.
8. Perform `EnterCriticalSection(WL)`.
9. Let `S` be `RemoveWaiters(WL, c)`.
10. For each element `W` of `S`, do
    a. Perform `NotifyWaiter(WL, W)`.
11. Perform `LeaveCriticalSection(WL)`.
12. Let `n` be the number of elements in `S`.
13. Return `\mathbb{F}(n)`.

25.4.16 Atomics.xor \( (\text{typedArray}, \text{index}, \text{value}) \)

This function performs the following steps when called:

1. Let `xor` be a new `read-modify-write` modification function with parameters \( (xBytes, yBytes) \) that captures nothing and performs the following steps atomically when called:
   a. Return `ByteListBitwiseOp(^, xBytes, yBytes)`.
2. Return `? \text{AtomicReadModifyWrite}(\text{typedArray}, \text{index}, \text{value}, \text{xor})`.

25.4.17 Atomics \[ @@toStringTag \]

The initial value of the `@@toStringTag` property is the String value "Atomics".

This property has the attributes \{ [[Writable]]: `false`, [[Enumerable]]: `false`, [[Configurable]]: `true` \}.

25.5 The JSON Object

The JSON object:

- is `%JSON%`.
- is the initial value of the "JSON" property of the global object.
- is an ordinary object.
- contains two functions, `parse` and `stringify`, that are used to parse and construct JSON texts.
- has a [[Prototype]] internal slot whose value is `%Object.prototype%`.
- does not have a [[Construct]] internal method; it cannot be used as a constructor with the `new` operator.
- does not have a [[Call]] internal method; it cannot be invoked as a function.

The JSON Data Interchange Format is defined in ECMA-404. The JSON interchange format used in this specification is exactly that described by ECMA-404. Conforming implementations of `JSON.parse` and `JSON.stringify` must support the exact interchange format described in the ECMA-404 specification without any deletions or extensions to the format.

25.5.1 JSON.parse \( (\text{text}[, \text{reviver}]) \)

This function parses a JSON text (a JSON-formatted String) and produces an ECMAScript language value. The JSON format represents literals, arrays, and objects with a syntax similar to the syntax for ECMAScript literals, Array Initializers, and Object Initializers. After parsing, JSON objects are realized as ECMAScript objects. JSON
arrays are realized as ECMAScript Array instances. JSON strings, numbers, booleans, and null are realized as ECMAScript Strings, Numbers, Booleans, and null.

The optional `reviver` parameter is a function that takes two parameters, `key` and `value`. It can filter and transform the results. It is called with each of the `key/value` pairs produced by the parse, and its return value is used instead of the original value. If it returns what it received, the structure is not modified. If it returns `undefined` then the property is deleted from the result.

1. Let `jsonString` be `?ToString(text)`.  
2. Parse `StringToCodePoints(jsonString)` as a JSON text as specified in ECMA-404. Throw a `SyntaxError` exception if it is not a valid JSON text as defined in that specification.  
3. Let `scriptString` be the string-concatenation of "(", `jsonString`, and ");".  
4. Let `script` be `ParseText(StringToCodePoints(scriptString), Script)`.  
5. NOTE: The early error rules defined in 13.2.5.1 have special handling for the above invocation of `ParseText`.  
6. Assert: `script` is a Parse Node.  
7. Let `completion` be `Completion(Evaluation of script)`.  
8. NOTE: The `PropertyDefinitionEvaluation` semantics defined in 13.2.5.5 have special handling for the above evaluation.  
9. Let `unfiltered` be `completion.[[Value]]`.  
10. Assert: `unfiltered` is either a String, a Number, a Boolean, an Object that is defined by either an `ArrayLiteral` or an `ObjectLiteral`, or null.  
11. If `IsCallable(reviver)` is true, then  
   a. Let `root` be `OrdinaryObjectCreate(%Object.prototype%).`  
   b. Let `rootName` be the empty String.  
   c. Perform `CreateDataPropertyOrThrow(root, rootName, unfiltered)`.  
   d. Return `InternalizeJSONProperty(root, rootName, reviver)`.  
12. Else,  
   a. Return `unfiltered`.  

The "length" property of this function is $2^8$.

---

**NOTE**  
Valid JSON text is a subset of the ECMAScript `PrimaryExpression` syntax. Step 2 verifies that `jsonString` conforms to that subset, and step 10 asserts that that parsing and evaluation returns a value of an appropriate type.

However, because 13.2.5.5 behaves differently during `JSON.parse`, the same source text can produce different results when evaluated as a `PrimaryExpression` rather than as JSON. Furthermore, the Early Error for duplicate "__proto__" properties in object literals, which likewise does not apply during `JSON.parse`, means that not all texts accepted by `JSON.parse` are valid as a `PrimaryExpression`, despite matching the grammar.

### 25.5.1.1 `InternalizeJSONProperty ( holder, name, reviver )`

The abstract operation `InternalizeJSONProperty` takes arguments `holder` (an Object), `name` (a String), and `reviver` (a function object) and returns either a normal completion containing an ECMAScript language value or a throw completion.

**NOTE 1**  
This algorithm intentionally does not throw an exception if either `[[Delete]]` or `CreateDataProperty` return `false`.  

It performs the following steps when called:

1. Let `val` be `?Get(holder, name)`.  
2. If `val` is an Object, then  
   a. Let `isArray` be `?IsArray(val)`.  
   b. If `isArray` is true, then  
      i. Let `len` be `?LengthOfArrayLike(val)`.

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ii. Let \( I \) be 0.

iii. Repeat, while \( I < \text{len} \),
    1. Let \( \text{prop} \) be \(!\text{ToString}(F(I))\).
    2. Let \( \text{newElement} \) be \(?\text{InternalizeJSONProperty}(\text{val}, \text{prop}, \text{reviver})\).
    3. If \( \text{newElement} \) is \text{undefined}, then
        a. Perform \(?\text{val}[[\text{Delete}]][\text{prop}]\).
    4. Else,
        a. Perform \(?\text{CreateDataProperty}(\text{val}, \text{prop}, \text{newElement})\).
    5. Set \( I \) to \( I + 1 \).

c. Else,
    i. Let \( \text{keys} \) be \(?\text{EnumerableOwnProperties}(\text{val}, \text{KEY})\).
    ii. For each String \( P \) of \( \text{keys} \), do
        1. Let \( \text{newElement} \) be \(?\text{InternalizeJSONProperty}(\text{val}, P, \text{reviver})\).
        2. If \( \text{newElement} \) is \text{undefined}, then
            a. Perform \(?\text{val}[[\text{Delete}]](P)\).
        3. Else,
            a. Perform \(?\text{CreateDataProperty}(\text{val}, P, \text{newElement})\).

3. Return \(?\text{Call}(\text{reviver}, \text{holder}, \{\text{name}, \text{val} \})\).

It is not permitted for a conforming implementation of \texttt{JSON.parse} to extend the JSON grammars. If an implementation wishes to support a modified or extended JSON interchange format it must do so by defining a different parse function.

NOTE 2: In the case where there are duplicate name Strings within an object, lexically preceding values for the same key shall be overwritten.

### 25.5.2 \texttt{JSON.stringify (value [, replacer [, space ]])}

This function returns a String in UTF-16 encoded JSON format representing an \texttt{ECMAScript language value}, or \texttt{undefined}. It can take three parameters. The \texttt{value} parameter is an \texttt{ECMAScript language value}, which is usually an object or array, although it can also be a String, Boolean, Number or \texttt{null}. The optional \texttt{replacer} parameter is either a function that alters the way objects and arrays are stringified, or an array of Strings and Numbers that acts as an inclusion list for selecting the object properties that will be stringified. The optional \texttt{space} parameter is a String or Number that allows the result to have white space injected into it to improve human readability.

It performs the following steps when called:

1. Let \( \text{stack} \) be a new empty \texttt{List},
2. Let \( \text{indent} \) be the empty String,
3. Let \( \text{PropertyList} \) be \text{undefined},
4. Let \( \text{ReplacerFunction} \) be \text{undefined},
5. If \( \text{replacer} \) is an Object, then
    a. If \( \text{IsCallable}(\text{replacer}) \) is \text{true}, then
        i. Set \( \text{ReplacerFunction} \) to \( \text{replacer} \).
    b. Else,
        i. Let \( \text{isArray} \) be \(?\text{IsArray}(\text{replacer})\).
        ii. If \( \text{isArray} \) is \text{true}, then
            1. Set \( \text{PropertyList} \) to a new empty \texttt{List}.
            2. Let \( \text{len} \) be \(?\text{LengthOfArrayLike}(\text{replacer})\).
            3. Let \( k \) be 0.
            4. Repeat, while \( k < \text{len} \),
                a. Let \( \text{prop} \) be \(!\text{ToString}(\text{F}(k))\).
                b. Let \( v \) be \(?\text{Get}(\text{replacer}, \text{prop})\).
                c. Let \( \text{item} \) be \text{undefined}.
                d. If \( v \) is a String, then
                    i. Set \( \text{item} \) to \( v \).
                e. Else if \( v \) is a Number, then
                    i. Set \( \text{item} \) to \(!\text{ToString}(v)\).
f. Else if \( v \) is an Object, then
   i. If \( v \) has a [[StringData]] or [[NumberData]] internal slot, set \( item \) to ? `ToString(v)`.

   g. If \( item \) is not `undefined` and `PropertyList` does not contain \( item \), then
      i. Append \( item \) to `PropertyList`.

   h. Set \( k \) to \( k + 1 \).

6. If `space` is an Object, then
   a. If `space` has a [[NumberData]] internal slot, then
      i. Set `space` to ? `ToNumber(space)`.
   b. Else if `space` has a [[StringData]] internal slot, then
      i. Set `space` to ? `ToString(space)`.

7. If `space` is a Number, then
   a. Let `spaceMV` be `ToIntegerOrInfinity(space)`.
   b. Set `spaceMV` to `min(10, spaceMV)`.
   c. If `spaceMV < 1`, let \( gap \) be the empty String; otherwise let \( gap \) be the String value containing `spaceMV` occurrences of the code unit 0x0020 (SPACE).

8. Else if `space` is a String, then
   a. If the length of `space` ≤ 10, let \( gap \) be `space`; otherwise let \( gap \) be the substring of `space` from 0 to 10.

9. Else,
   a. Let \( gap \) be the empty String.

10. Let `wrapper` be ` OrdinaryObjectCreate(%Object.prototype%)`.

11. Perform ! `CreateDataPropertyOrThrow(wrapper, the empty String, value)`.

12. Let `state` be the JSON Serialization Record { [[ReplacerFunction]]: `ReplacerFunction`, [[Stack]]: `stack`, [[Indent]]: `indent`, [[Gap]]: `gap`, [[PropertyList]]: `PropertyList` }.

13. Return ? `SerializeJSONProperty(state, the empty String, wrapper)`.

The "length" property of this function is \( 3 \mathbb{F} \).

**NOTE 1**

JSON structures are allowed to be nested to any depth, but they must be acyclic. If `value` is or contains a cyclic structure, then this function must throw a `TypeError` exception. This is an example of a value that cannot be stringified:

```javascript
a = [];
a[0] = a;
my_text = JSON.stringify(a); // This must throw a TypeError.
```

**NOTE 2**

Symbolic primitive values are rendered as follows:

- The `null` value is rendered in JSON text as the String value "null".
- The `undefined` value is not rendered.
- The `true` value is rendered in JSON text as the String value "true".
- The `false` value is rendered in JSON text as the String value "false".

**NOTE 3**

String values are wrapped in QUOTATION MARK (""") code units. The code units " " and \ are escaped with \ prefixes. Control characters code units are replaced with escape sequences \uHHHH, or with the shorter forms, \b (BACKSPACE), \f (FORM FEED), \n (LINE FEED), \r (CARRIAGE RETURN), \t (CHARACTER TABULATION).

**NOTE 4**

Finite numbers are stringified as if by calling `ToString(number)`. `NaN` and `Infinity` regardless of sign are represented as the String value "null".
Values that do not have a JSON representation (such as `undefined` and functions) do not produce a String. Instead they produce the `undefined` value. In arrays these values are represented as the String value "null". In objects an unrepresentable value causes the property to be excluded from stringification.

An object is rendered as U+007B (LEFT CURLY BRACKET) followed by zero or more properties, separated with a U+002C (COMMA), closed with a U+007D (RIGHT CURLY BRACKET). A property is a quoted String representing the property name, a U+003A (COLON), and then the stringified property value. An array is rendered as an opening U+005B (LEFT SQUARE BRACKET) followed by zero or more values, separated with a U+002C (COMMA), closed with a U+005D (RIGHT SQUARE BRACKET).

### 25.5.2.1 JSON Serialization Record

A JSON Serialization Record is a Record value used to enable serialization to the JSON format.

JSON Serialization Records have the fields listed in Table 75.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[ReplacerFunction]]</code></td>
<td>a function object or <code>undefined</code></td>
<td>A function that can supply replacement values for object properties (from JSON.stringify's <code>replacer</code> parameter).</td>
</tr>
<tr>
<td><code>[[PropertyList]]</code></td>
<td>either a List of Strings or <code>undefined</code></td>
<td>The names of properties to include when serializing a non-array object (from JSON.stringify's <code>replacer</code> parameter).</td>
</tr>
<tr>
<td><code>[[Gap]]</code></td>
<td>a String</td>
<td>The unit of indentation (from JSON.stringify's <code>space</code> parameter).</td>
</tr>
<tr>
<td><code>[[Stack]]</code></td>
<td>a List of Objects</td>
<td>The set of nested objects that are in the process of being serialized. Used to detect cyclic structures.</td>
</tr>
<tr>
<td><code>[[Indent]]</code></td>
<td>a String</td>
<td>The current indentation.</td>
</tr>
</tbody>
</table>

### 25.5.2.2 SerializeJSONProperty ( `state, key, holder` )

The abstract operation SerializeJSONProperty takes arguments `state` (a JSON Serialization Record), `key` (a String), and `holder` (an Object) and returns either a normal completion containing either a String or `undefined`, or a throw completion. It performs the following steps when called:

1. Let `value` be ? Get(`holder`, `key`).
2. If `value` is an Object or `value` is a BigInt, then
   a. Let `toJson` be ? GetV(`value`, "toJSON").
   b. If IsCallable(`toJson`) is true, then
      i. Set `value` to ? Call(`toJson`, `value`, « `key` »).
3. If `state.``[[ReplacerFunction]]` is not `undefined`, then
   a. Set `value` to ? Call(`state.``[[ReplacerFunction]]`, `holder`, « `key`, `value` »).
4. If `value` is an Object, then
   a. If `value` has a `[[NumberData]]` internal slot, then
      i. Set `value` to ? ToNumber(`value`).
   b. Else if `value` has a `[[StringData]]` internal slot, then
      i. Set `value` to ? ToString(`value`).
c. Else if `value` has a `[[BooleanData]]` internal slot, then
   i. Set `value` to `value`. `[[BooleanData]]`.
d. Else if `value` has a `[[BigIntData]]` internal slot, then
   i. Set `value` to `value`. `[[BigIntData]]`.
5. If `value` is `null`, return "null".
6. If `value` is `true`, return "true".
7. If `value` is `false`, return "false".
8. If `value` is a String, return `QuoteJSONString(value)`.
9. If `value` is a Number, then
   a. If `value` is finite, return `!ToString(value)`.
   b. Return "null".
10. If `value` is a BigInt, throw a `TypeError` exception.
11. If `value` is an Object and `IsCallable(value)` is `false`, then
    a. Let `isArray` be `?IsArray(value)`.
    b. If `isArray` is `true`, return `?SerializeJSONArray(state, value)`.
    c. Return `?SerializeJSONObject(state, value)`.
12. Return undefined.

25.5.2.3 `QuoteJSONString ( value )`

The abstract operation `QuoteJSONString` takes argument `value` (a String) and returns a String. It wraps `value` in 0x0022 (QUOTATION MARK) code units and escapes certain other code units within it. This operation interprets `value` as a sequence of UTF-16 encoded code points, as described in 6.1.4. It performs the following steps when called:

1. Let `product` be the String value consisting solely of the code unit 0x0022 (QUOTATION MARK).
2. For each code point `C` of `StringToCodePoints(value)`, do
   a. If `C` is listed in the "Code Point" column of Table 76, then
      i. Set `product` to the string-concatenation of `product` and the escape sequence for `C` as specified in the "Escape Sequence" column of the corresponding row.
   b. Else if `C` has a numeric value less than 0x0020 (SPACE) or `C` has the same numeric value as a leading surrogate or trailing surrogate, then
      i. Let `unit` be the code unit whose numeric value is the numeric value of `C`.
      ii. Set `product` to the string-concatenation of `product` and `UnicodeEscape(unit)`.
   c. Else,
      i. Set `product` to the string-concatenation of `product` and `UTF16EncodeCodePoint(C)`.
3. Set `product` to the string-concatenation of `product` and the code unit 0x0022 (QUOTATION MARK).
4. Return `product`.

<table>
<thead>
<tr>
<th>Code Point</th>
<th>Unicode Character Name</th>
<th>Escape Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>U+0008</td>
<td>BACKSPACE</td>
<td>\b</td>
</tr>
<tr>
<td>U+0009</td>
<td>CHARACTER TABULATION</td>
<td>\t</td>
</tr>
<tr>
<td>U+000A</td>
<td>LINE FEED (LF)</td>
<td>\n</td>
</tr>
<tr>
<td>U+000C</td>
<td>FORM FEED (FF)</td>
<td>\f</td>
</tr>
<tr>
<td>U+000D</td>
<td>CARRIAGE RETURN (CR)</td>
<td>\r</td>
</tr>
<tr>
<td>U+0022</td>
<td>QUOTATION MARK</td>
<td>&quot;</td>
</tr>
<tr>
<td>U+005C</td>
<td>REVERSE SOLIDUS</td>
<td>\</td>
</tr>
</tbody>
</table>
25.5.2.4 UnicodeEscape (C)

The abstract operation UnicodeEscape takes argument C (a code unit) and returns a String. It represents C as a Unicode escape sequence. It performs the following steps when called:

1. Let \( n \) be the numeric value of C.
2. Assert: \( n \leq 0xFFFF \).
3. Let \( hex \) be the String representation of \( n \), formatted as a lowercase hexadecimal number.
4. Return the string-concatenation of the code unit 0x005C (REVERSE SOLIDUS), "u", and StringPad(\( hex \), 4, "\0", START).

25.5.2.5 SerializeJSONObject (state, value)

The abstract operation SerializeJSONObject takes arguments state (a JSON Serialization Record) and value (an Object) and returns either a normal completion containing a String or a throw completion. It serializes an object. It performs the following steps when called:

1. If state.[[Stack]] contains value, throw a TypeError exception because the structure is cyclical.
2. Append value to state.[[Stack]].
3. Let stepback be state.[[Indent]].
4. Set state.[[Indent]] to the string-concatenation of state.[[Indent]] and state.[[Gap]].
5. If state.[[PropertyList]] is not undefined, then
   a. Let \( K \) be state.[[PropertyList]].
6. Else,
   a. Let \( K \) be EnumerableOwnProperties(value, KEY).
7. Let partial be a new empty List.
8. For each element \( P \) of \( K \), do
   a. Let \( strP \) be ? SerializeJSONProperty(state, \( P \), value).
   b. If \( strP \) is not undefined, then
      i. Let member be QuoteJSONString(\( P \)).
      ii. Set member to the string-concatenation of member and ":".
      iii. If state.[[Gap]] is not the empty String, then
         1. Set member to the string-concatenation of member and the code unit 0x0020 (SPACE).
         viii. Set member to the string-concatenation of member and \( strP \).
      v. Append member to partial.
9. If partial is empty, then
   a. Let final be "\{".
10. Else,
   a. If state.[[Gap]] is the empty String, then
      i. Let properties be the String value formed by concatenating all the element Strings of partial with each adjacent pair of Strings separated with the code unit 0x002C (COMMA). A comma is not inserted either before the first String or after the last String.
      ii. Let final be the string-concatenation of "\{", properties, and "}".
   b. Else,
      i. Let separator be the string-concatenation of the code unit 0x002C (COMMA), the code unit 0x000A (LINE FEED), and state.[[Indent]].
      ii. Let properties be the String value formed by concatenating all the element Strings of partial with each adjacent pair of Strings separated with separator. The separator String is not inserted either before the first String or after the last String.
      iii. Let final be the string-concatenation of "\{", the code unit 0x000A (LINE FEED), state.[[Indent]], properties, the code unit 0x000A (LINE FEED), stepback, and "}
11. Remove the last element of state.[[Stack]].
12. Set state.[[Indent]] to stepback.
The abstract operation `SerializeJSONArray` takes arguments `state` (a JSON Serialization Record) and `value` (an ECMA-Script language value) and returns either a normal completion containing a String or a throw completion. It serializes an array. It performs the following steps when called:

1. If `state.``[[Stack]]` contains `value`, throw a `TypeError` exception because the structure is cyclical.
2. Append `value` to `state.``[[Stack]]`.
3. Let `stepback` be `state.``[[Indent]]`.
4. Set `state.``[[Indent]]` to the string-concatenation of `state.``[[Indent]]` and `state.``[[Gap]]`.
5. Let `partial` be a new empty List.
6. Let `len` be `LengthOfArrayLike(value)`.
7. Let `index` be 0.
8. Repeat, while `index < len`,
   a. Let `strP` be `SerializeJSONProperty(state, ToString(F(index)), value)`.
      b. If `strP` is `undefined`, then
         i. Append "null" to `partial`
      c. Else,
         i. Append `strP` to `partial`
         d. Set `index` to `index + 1`
9. If `partial` is empty, then
   a. Let `final` be "[]".
10. Else,
    a. If `state.``[[Gap]]` is the empty String, then
       i. Let `properties` be the String value formed by concatenating all the element Strings of `partial` with each adjacent pair of Strings separated with the code unit 0x002C (COMMA). A comma is not inserted either before the first String or after the last String.
       ii. Let `final` be the string-concatenation of "[", `properties`, and "]".
    b. Else,
       i. Let `separator` be the string-concatenation of the code unit 0x002C (COMMA), the code unit 0x000A (LINE FEED), and `state.``[[Indent]]`.
       ii. Let `properties` be the String value formed by concatenating all the element Strings of `partial` with each adjacent pair of Strings separated with `separator`. The `separator` String is not inserted either before the first String or after the last String.
       iii. Let `final` be the string-concatenation of "[", the code unit 0x000A (LINE FEED), `state.``[[Indent]]`, `properties`, the code unit 0x000A (LINE FEED), `stepback`, and "]".
11. Remove the last element of `state.``[[Stack]]`.
12. Set `state.``[[Indent]]` to `stepback`.

**NOTE** The representation of arrays includes only the elements in the interval from `𝔽(0)` (inclusive) to `array.length` (exclusive). Properties whose keys are not `array indices` are excluded from the stringification. An array is stringified as an opening LEFT SQUARE BRACKET, elements separated by COMMA, and a closing RIGHT SQUARE BRACKET.

### 25.5.3 JSON [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "JSON".

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.
26 Managing Memory

26.1 WeakRef Objects

A WeakRef is an object that is used to refer to a target object or symbol without preserving it from garbage collection. WeakRefs can be dereferenced to allow access to the target value, if the target hasn’t been reclaimed by garbage collection.

26.1.1 The WeakRef Constructor

The WeakRef constructor:

- is %WeakRef%.
- is the initial value of the "WeakRef" property of the global object.
- creates and initializes a new WeakRef when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value in an extends clause of a class definition. Subclass constructors that intend to inherit the specified WeakRef behaviour must include a super call to the WeakRef constructor to create and initialize the subclass instance with the internal state necessary to support the WeakRef.prototype built-in methods.

26.1.1.1 WeakRef ( target )

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. If CanBeHeldWeakly(target) is false, throw a TypeError exception.
3. Let weakRef be ? OrdinaryCreateFromConstructor(NewTarget, "%WeakRef.prototype%", « [[WeakRefTarget]] »).
4. Perform AddToKeptObjects(target).
5. Set weakRef.[[WeakRefTarget]] to target.
6. Return weakRef.

26.1.2 Properties of the WeakRef Constructor

The WeakRef constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has the following properties:

26.1.2.1 WeakRef.prototype

The initial value of WeakRef.prototype is the WeakRef prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

26.1.3 Properties of the WeakRef Prototype Object

The WeakRef prototype object:

- is %WeakRef.prototype%.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is an ordinary object.
- does not have a [[WeakRefTarget]] internal slot.
26.1.3.1  WeakRef.prototype.constructor

The initial value of WeakRef.prototype.constructor is %WeakRef%.
This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

26.1.3.2  WeakRef.prototype.deref ( )

This method performs the following steps when called:

1. Let weakRef be the this value.
2. Perform ? RequireInternalSlot(weakRef, [[WeakRefTarget]]).
3. Return WeakRefDeref(weakRef).

NOTE
If the WeakRef returns a target value that is not undefined, then this target value should not be garbage collected until the current execution of ECMAScript code has completed. The AddToKeptObjects operation makes sure read consistency is maintained.

let target = { foo() {} };
let weakRef = new WeakRef(target);
// ... later ...
if (weakRef.deref()) {
  weakRef.deref().foo();
}

In the above example, if the first deref does not evaluate to undefined then the second deref cannot either.

26.1.3.3  WeakRef.prototype[ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "WeakRef".
This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

26.1.4  WeakRef Abstract Operations

26.1.4.1  WeakRefDeref ( weakRef )

The abstract operation WeakRefDeref takes argument weakRef (a WeakRef) and returns an ECMAScript language value. It performs the following steps when called:

1. Let target be weakRef. [[WeakRefTarget]].
2. If target is not EMPTY, then
   a. Perform AddToKeptObjects(target).
   b. Return target.
3. Return undefined.

NOTE
This abstract operation is defined separately from WeakRef.prototype.deref strictly to make it possible to succinctly define liveness.
26.1.5 Properties of WeakRef Instances

WeakRef instances are ordinary objects that inherit properties from the WeakRef prototype. WeakRef instances also have a [[WeakRefTarget]] internal slot.

26.2 FinalizationRegistry Objects

A FinalizationRegistry is an object that manages registration and unregistration of cleanup operations that are performed when target objects and symbols are garbage collected.

26.2.1 The FinalizationRegistry Constructor

The FinalizationRegistry constructor:

- is %FinalizationRegistry%.
- is the initial value of the "FinalizationRegistry" property of the global object.
- creates and initializes a new FinalizationRegistry when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value in an extends clause of a class definition. Subclass constructors that intend to inherit the specified FinalizationRegistry behaviour must include a super call to the FinalizationRegistry constructor to create and initialize the subclass instance with the internal state necessary to support the FinalizationRegistry.prototype built-in methods.

26.2.1.1 FinalizationRegistry ( cleanupCallback )

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. If IsCallable(cleanupCallback) is false, throw a TypeError exception.
3. Let finalizationRegistry be ? OrdinaryCreateFromConstructor(NewTarget, "%FinalizationRegistry.prototype%", « [[Realm]], [[CleanupCallback]], [[Cells]] »).
4. Let fn be the active function object.
5. Set finalizationRegistry.[[Realm]] to fn.[[Realm]].
6. Set finalizationRegistry.[[CleanupCallback]] to HostMakeJobCallback(cleanupCallback).
7. Set finalizationRegistry.[[Cells]] to a new empty List.
8. Return finalizationRegistry.

26.2.2 Properties of the FinalizationRegistry Constructor

The FinalizationRegistry constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- has the following properties:

26.2.2.1 FinalizationRegistry.prototype

The initial value of FinalizationRegistry.prototype is the FinalizationRegistry prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

26.2.3 Properties of the FinalizationRegistry Prototype Object

The FinalizationRegistry prototype object:

- is %FinalizationRegistry.prototype%.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is an ordinary object.
• does not have `[[Cells]]` and `[[CleanupCallback]]` internal slots.

### 26.2.3.1 FinalizationRegistry.prototype.constructor

The initial value of `FinalizationRegistry.prototype.constructor` is `%FinalizationRegistry%`.

### 26.2.3.2 FinalizationRegistry.prototype.register (target, heldValue [, unregisterToken])

This method performs the following steps when called:

1. Let `finalizationRegistry` be the this value.
3. If `CanBeHeldWeakly(target)` is `false`, throw a `TypeError` exception.
4. If `SameValue(target, heldValue)` is `true`, throw a `TypeError` exception.
5. If `CanBeHeldWeakly(unregisterToken)` is `false`, then
   a. If `unregisterToken` is not `undefined`, throw a `TypeError` exception.
   b. Set `unregisterToken` to `EMPTY`.
6. Let `cell` be the `Record` `{ `[[WeakRefTarget]]`: target, `[[HeldValue]]`: heldValue, `[[UnregisterToken]]`: unregisterToken }.
7. Append `cell` to `finalizationRegistry`.[[Cells]].
8. Return `undefined`.

**NOTE** Based on the algorithms and definitions in this specification, `cell`.[[HeldValue]] is live when `finalizationRegistry`.[[Cells]] contains `cell`; however, this does not necessarily mean that `cell`.[[UnregisterToken]] or `cell`.[[Target]] are live. For example, registering an object with itself as its unregister token would not keep the object alive forever.

### 26.2.3.3 FinalizationRegistry.prototype.unregister (unregisterToken)

This method performs the following steps when called:

1. Let `finalizationRegistry` be the this value.
3. If `CanBeHeldWeakly(unregisterToken)` is `false`, throw a `TypeError` exception.
4. Let `removed` be `false`.
5. For each `Record` `{ `[[WeakRefTarget]], `[[HeldValue]], `[[UnregisterToken]] } `cell` of `finalizationRegistry`.[[Cells]], do
   a. If `cell`.[[UnregisterToken]] is not `EMPTY` and `SameValue(cell`.[[UnregisterToken]], unregisterToken) is `true`, then
      i. Remove `cell` from `finalizationRegistry`.[[Cells]].
      ii. Set `removed` to `true`.
6. Return `removed`.

### 26.2.4 FinalizationRegistry.prototype [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "FinalizationRegistry".

This property has the attributes `{ `[[Writable]]: `false, `[[Enumerable]]: `false, `[[Configurable]]: `true }.

### 26.2.4 Properties of FinalizationRegistry Instances

FinalizationRegistry instances are ordinary objects that inherit properties from the FinalizationRegistry prototype. FinalizationRegistry instances also have `[[Cells]]` and `[[CleanupCallback]]` internal slots.
27 Control Abstraction Objects

27.1 Iteration

27.1.1 Common Iteration Interfaces

An interface is a set of property keys whose associated values match a specific specification. Any object that provides all the properties as described by an interface's specification conforms to that interface. An interface is not represented by a distinct object. There may be many separately implemented objects that conform to any interface. An individual object may conform to multiple interfaces.

27.1.1.1 The Iterable Interface

The Iterable interface includes the property described in Table 77:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>@@iterator</td>
<td>a function that returns an Iterator object</td>
<td>The returned object must conform to the Iterator interface.</td>
</tr>
</tbody>
</table>

27.1.1.2 The Iterator Interface

An object that implements the Iterator interface must include the property in Table 78. Such objects may also implement the properties in Table 79.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;next&quot;</td>
<td>a function that returns an IteratorResult object</td>
<td>The returned object must conform to the IteratorResult interface. If a previous call to the next method of an Iterator has returned an IteratorResult object whose &quot;done&quot; property is true, then all subsequent calls to the next method of that object should also return an IteratorResult object whose &quot;done&quot; property is true. However, this requirement is not enforced.</td>
</tr>
</tbody>
</table>

NOTE 1 Arguments may be passed to the next function but their interpretation and validity is dependent upon the target Iterator. The for-of statement and other common users of Iterators do not pass any arguments, so Iterator objects that expect to be used in such a manner must be prepared to deal with being called with no arguments.
Table 79: Iterator Interface Optional Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;return&quot;</td>
<td>a function that returns an IteratorResult object</td>
<td>The returned object must conform to the IteratorResult interface. Invoking this method notifies the Iterator object that the caller does not intend to make any more next method calls to the Iterator. The returned IteratorResult object will typically have a &quot;done&quot; property whose value is true, and a &quot;value&quot; property with the value passed as the argument of the return method. However, this requirement is not enforced.</td>
</tr>
<tr>
<td>&quot;throw&quot;</td>
<td>a function that returns an IteratorResult object</td>
<td>The returned object must conform to the IteratorResult interface. Invoking this method notifies the Iterator object that the caller has detected an error condition. The argument may be used to identify the error condition and typically will be an exception object. A typical response is to throw the value passed as the argument. If the method does not throw, the returned IteratorResult object will typically have a &quot;done&quot; property whose value is true.</td>
</tr>
</tbody>
</table>

NOTE 2 Typically callers of these methods should check for their existence before invoking them. Certain ECMAScript language features including for-of, yield*, and array destructuring call these methods after performing an existence check. Most ECMAScript library functions that accept Iterable objects as arguments also conditionally call them.

27.1.1.3 The AsyncIterable Interface

The AsyncIterable interface includes the properties described in Table 80:

Table 80: AsyncIterable Interface Required Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>@@asyncIterator</td>
<td>a function that returns an AsyncIterator object</td>
<td>The returned object must conform to the AsyncIterator interface.</td>
</tr>
</tbody>
</table>

27.1.1.4 The AsyncIterator Interface

An object that implements the AsyncIterator interface must include the properties in Table 81. Such objects may also implement the properties in Table 82.

Table 81: AsyncIterator Interface Required Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;next&quot;</td>
<td>a function that returns a promise for an IteratorResult object</td>
<td>The returned promise, when fulfilled, must fulfill with an object that conforms to the IteratorResult interface. If a previous call to the next method of an AsyncIterator has returned a promise for an IteratorResult object whose &quot;done&quot; property is true, then all subsequent calls to the next method of that object should also return a promise for an IteratorResult object whose &quot;done&quot; property is true. However, this requirement is not enforced. Additionally, the IteratorResult object that serves as a fulfillment value should have a &quot;value&quot; property whose value is not a promise (or &quot;thenable&quot;). However, this requirement is also not enforced.</td>
</tr>
</tbody>
</table>
Arguments may be passed to the `next` function but their interpretation and validity is dependent upon the target `AsyncIterator`. The `for-await-of` statement and other common users of `AsyncIterators` do not pass any arguments, so `AsyncIterator` objects that expect to be used in such a manner must be prepared to deal with being called with no arguments.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
</table>
| "return" | a function that returns a promise for an `IteratorResult` object | The returned promise, when fulfilled, must fulfill with an object that conforms to the `IteratorResult` interface. Invoking this method notifies the `AsyncIterator` object that the caller does not intend to make any more `next` method calls to the `AsyncIterator`. The returned promise will fulfill with an `IteratorResult` object which will typically have a "done" property whose value is `true`, and a "value" property with the value passed as the argument of the `return` method. However, this requirement is not enforced.

Additionally, the `IteratorResult` object that serves as a fulfillment value should have a "value" property whose value is not a promise (or "thenable"). If the argument value is used in the typical manner, then if it is a rejected promise, a promise rejected with the same reason should be returned; if it is a fulfilled promise, then its fulfillment value should be used as the "value" property of the returned promise’s `IteratorResult` object fulfillment value. However, these requirements are also not enforced. |
| "throw" | a function that returns a promise for an `IteratorResult` object | The returned promise, when fulfilled, must fulfill with an object that conforms to the `IteratorResult` interface. Invoking this method notifies the `AsyncIterator` object that the caller has detected an error condition. The argument may be used to identify the error condition and typically will be an exception object. A typical response is to return a rejected promise which rejects with the value passed as the argument.

If the returned promise is fulfilled, the `IteratorResult` fulfillment value will typically have a "done" property whose value is `true`. Additionally, it should have a "value" property whose value is not a promise (or "thenable"), but this requirement is not enforced. |

Typically callers of these methods should check for their existence before invoking them. Certain ECMAScript language features including `for-await-of` and `yield*` call these methods after performing an existence check.

### 27.1.1.5 The `IteratorResult` Interface

The `IteratorResult` interface includes the properties listed in Table 83:
### Table 83: IteratorResult Interface Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;done&quot;</td>
<td>a Boolean</td>
<td>This is the result status of an iterator <code>next</code> method call. If the end of the iterator was reached &quot;done&quot; is <code>true</code>. If the end was not reached &quot;done&quot; is <code>false</code> and a value is available. If a &quot;done&quot; property (either own or inherited) does not exist, it is considered to have the value <code>false</code>.</td>
</tr>
<tr>
<td>&quot;value&quot;</td>
<td>an ECMAScript language value</td>
<td>If done is <code>false</code>, this is the current iteration element value. If done is <code>true</code>, this is the return value of the iterator, if it supplied one. If the iterator does not have a return value, &quot;value&quot; is <code>undefined</code>. In that case, the &quot;value&quot; property may be absent from the conforming object if it does not inherit an explicit &quot;value&quot; property.</td>
</tr>
</tbody>
</table>

#### 27.1.2 The %IteratorPrototype% Object

The %IteratorPrototype% object:

- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is an ordinary object.

**NOTE**

All objects defined in this specification that implement the Iterator interface also inherit from %IteratorPrototype%. ECMAScript code may also define objects that inherit from %IteratorPrototype%. The %IteratorPrototype% object provides a place where additional methods that are applicable to all iterator objects may be added.

The following expression is one way that ECMAScript code can access the %IteratorPrototype% object:

```
Object.getPrototypeOf(Object.getPrototypeOf([][Symbol.iterator]()))
```

#### 27.1.2.1 %IteratorPrototype% `[@@iterator]` ()

This function performs the following steps when called:

1. Return the `this` value.

The value of the "name" property of this function is "[Symbol.iterator]".

#### 27.1.3 The %AsyncIteratorPrototype% Object

The %AsyncIteratorPrototype% object:

- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is an ordinary object.

**NOTE**

All objects defined in this specification that implement the AsyncIterator interface also inherit from %AsyncIteratorPrototype%. ECMAScript code may also define objects that inherit from %AsyncIteratorPrototype%. The %AsyncIteratorPrototype% object provides a place where additional methods that are applicable to all async iterator objects may be added.
This function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "[Symbol.asyncIterator]".

### 27.1.4 Async-from-Sync Iterator Objects

An Async-from-Sync Iterator object is an async iterator that adapts a specific synchronous iterator. There is not a named constructor for Async-from-Sync Iterator objects. Instead, Async-from-Sync iterator objects are created by the CreateAsyncFromSyncIterator abstract operation as needed.

#### 27.1.4.1 CreateAsyncFromSyncIterator ( syncIteratorRecord )

The abstract operation CreateAsyncFromSyncIterator takes argument syncIteratorRecord (an Iterator Record) and returns an Iterator Record. It is used to create an async Iterator Record from a synchronous Iterator Record. It performs the following steps when called:

1. Let asyncIterator be OrdinaryObjectCreate(%AsyncFromSyncIteratorPrototype%, « [[SyncIteratorRecord]] »).
2. Set asyncIterator.[[SyncIteratorRecord]] to syncIteratorRecord.
3. Let nextMethod be ! Get(asyncIterator, "next").
4. Let iteratorRecord be the Iterator Record { [[Iterator]]: asyncIterator, [[NextMethod]]: nextMethod, [[Done]]: false }.  
5. Return iteratorRecord.

#### 27.1.4.2 The %AsyncFromSyncIteratorPrototype% Object

The %AsyncFromSyncIteratorPrototype% object:

- has properties that are inherited by all Async-from-Sync Iterator Objects.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is %AsyncIteratorPrototype%.
- has the following properties:

#### 27.1.4.2.1 %AsyncFromSyncIteratorPrototype%.next ( [ value ] )

1. Let O be the this value.
2. Assert: O is an Object that has a [[SyncIteratorRecord]] internal slot.
3. Let promiseCapability be ! NewPromiseCapability(%Promise%).
4. Let syncIteratorRecord be O.[[SyncIteratorRecord]].
5. If value is present, then
   a. Let result be Completion(IteratorNext(syncIteratorRecord, value)).
6. Else,
   a. Let result be Completion(IteratorNext(syncIteratorRecord)).
7. LetAbruptRejectPromise(result, promiseCapability).
8. Return AsyncFromSyncIteratorContinuation(result, promiseCapability).

#### 27.1.4.2.2 %AsyncFromSyncIteratorPrototype%.return ( [ value ] )

1. Let O be the this value.
2. Assert: O is an Object that has a [[SyncIteratorRecord]] internal slot.
3. Let promiseCapability be ! NewPromiseCapability(%Promise%).
4. Let syncIterator be O.[[SyncIteratorRecord]].[[Iterator]].
5. Let return be Completion(GetMethod(syncIterator, "return")).
6. IfAbruptRejectPromise(return, promiseCapability).
7. If `return` is undefined, then
   a. Let `iterResult` be `CreateIterResultObject(value, true)`. 
   b. Perform `!PromiseCapability.[[Resolve]], undefined, « iterResult »).` 
   c. Return `promiseCapability.[[Promise]]`. 
8. If `value` is present, then
   a. Let `result` be `Completion(Call((return, syncIterator, « value »))`. 
9. Else, 
   a. Let `result` be `Completion(Call((return, syncIterator))`. 
10. `IfAbruptRejectPromise(result, promiseCapability)`. 
11. If `result` is not an Object, then 
   a. Perform `!PromiseCapability.[[Reject]], undefined, « a newly created TypeError object »).` 
   b. Return `promiseCapability.[[Promise]]`. 
12. Return `AsyncFromSyncIteratorContinuation(result, promiseCapability)`. 

### %AsyncFromSyncIteratorPrototype%.throw ( [ value ] )

**NOTE** In this specification, `value` is always provided, but is left optional for consistency with `${AsyncFromSyncIteratorPrototype}.return( [ value ] )`.

1. Let `O` be the `this` value. 
2. Assert: `O` is an Object that has a `[[SyncIteratorRecord]]` internal slot. 
3. Let `promiseCapability` be ! NewPromiseCapability(%Promise%). 
4. Let `syncIterator` be `O.[[SyncIteratorRecord]].[[Iterator]]`. 
5. Let `throw` be `Completion(GetMethod(syncIterator, "throw"))`. 
6. `IfAbruptRejectPromise(throw, promiseCapability)`. 
7. If `throw` is undefined, then 
   a. Perform `!PromiseCapability.[[Reject]], undefined, « value »).` 
   b. Return `promiseCapability.[[Promise]]`. 
8. If `value` is present, then 
   a. Let `result` be `Completion(Call((throw, syncIterator, « value »))`. 
9. Else, 
   a. Let `result` be `Completion(Call((throw, syncIterator))`. 
10. `IfAbruptRejectPromise(result, promiseCapability)`. 
11. If `result` is not an Object, then 
   a. Perform `!PromiseCapability.[[Reject]], undefined, « a newly created TypeError object »).` 
   b. Return `promiseCapability.[[Promise]]`. 
12. Return `AsyncFromSyncIteratorContinuation(result, promiseCapability)`. 

### 27.1.4.3 Properties of Async-from-Sync Iterator Instances

Async-from-Sync Iterator instances are ordinary objects that inherit properties from the `%AsyncFromSyncIteratorPrototype%` intrinsic object. Async-from-Sync Iterator instances are initially created with the internal slots listed in Table 84. Async-from-Sync Iterator instances are not directly observable from ECMAScript code.

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[SyncIteratorRecord]]</code></td>
<td>an Iterator Record</td>
<td>Represents the original synchronous iterator which is being adapted.</td>
</tr>
</tbody>
</table>
The abstract operation AsyncFromSyncIteratorContinuation takes arguments `result` (an Object) and `promiseCapability` (a PromiseCapability Record for an intrinsic `%Promise%`) and returns a Promise. It performs the following steps when called:

1. **NOTE:** Because `promiseCapability` is derived from the intrinsic `%Promise%`, the calls to `promiseCapability`.[[Reject]] entailed by the use of `IfAbruptRejectPromise` below are guaranteed not to throw.

2. Let `done` be `Completion(IteratorComplete(result))`.
3. `IfAbruptRejectPromise(done, promiseCapability)`.
4. Let `value` be `Completion(IteratorValue(result))`.
5. `IfAbruptRejectPromise(value, promiseCapability)`.
6. Let `valueWrapper` be `Completion(PromiseResolve(%Promise%, value))`.
7. `IfAbruptRejectPromise(valueWrapper, promiseCapability)`.
8. Let `unwrap` be a new Abstract Closure with parameters `(v)` that captures `done` and performs the following steps when called:
   a. Return `CreateIterResultObject(v, done)`.
9. Let `onFulfilled` be `CreateBuiltinFunction(unwrap, 1, "", « »)`.
10. **NOTE:** `onFulfilled` is used when processing the "value" property of an IteratorResult object in order to wait for its value if it is a promise and re-package the result in a new "unwrapped" IteratorResult object.
11. Perform `PerformPromiseThen(valueWrapper, onFulfilled, undefined, promiseCapability)`.
12. Return `promiseCapability`.[[Promise]].

### 27.2 Promise Objects

A Promise is an object that is used as a placeholder for the eventual results of a deferred (and possibly asynchronous) computation.

Any Promise is in one of three mutually exclusive states: `fulfilled`, `rejected`, and `pending`:

- A promise `p` is fulfilled if `p.then(f, x)` will immediately enqueue a Job to call the function `f`.
- A promise `p` is rejected if `p.then(f, x)` will immediately enqueue a Job to call the function `x`.
- A promise is pending if it is neither fulfilled nor rejected.

A promise is said to be `settled` if it is not pending, i.e. if it is either fulfilled or rejected.

A promise is `resolved` if it is settled or if it has been "locked in" to match the state of another promise. Attempting to resolve or reject a resolved promise has no effect. A promise is `unresolved` if it is not resolved. An unresolved promise is always in the pending state. A resolved promise may be pending, fulfilled or rejected.

### 27.2.1 Promise Abstract Operations

#### 27.2.1.1 PromiseCapability Records

A `PromiseCapability Record` is a `Record` value used to encapsulate a Promise or promise-like object along with the functions that are capable of resolving or rejecting that promise. PromiseCapability Records are produced by the `NewPromiseCapability` abstract operation.

PromiseCapability Records have the fields listed in Table 85.
Table 85: PromiseCapability Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Promise]]</td>
<td>an Object</td>
<td>An object that is usable as a promise.</td>
</tr>
<tr>
<td>[[Resolve]]</td>
<td>a function object</td>
<td>The function that is used to resolve the given promise.</td>
</tr>
<tr>
<td>[[Reject]]</td>
<td>a function object</td>
<td>The function that is used to reject the given promise.</td>
</tr>
</tbody>
</table>

27.2.1.1 IfAbruptRejectPromise (value, capability)

IfAbruptRejectPromise is a shorthand for a sequence of algorithm steps that use a PromiseCapability Record. An algorithm step of the form:

1. IfAbruptRejectPromise(value, capability).

means the same thing as:

1. Assert: value is a Completion Record.
2. If value is an abrupt completion, then
   a. Perform Call(capability. [[Reject]], undefined, « value.[[Value]] »).
   b. Return capability. [[Promise]].
3. Else,
   a. Set value to ! value.

27.2.1.2 PromiseReaction Records

A PromiseReaction Record is a Record value used to store information about how a promise should react when it becomes resolved or rejected with a given value. PromiseReaction Records are created by the PerformPromiseThen abstract operation, and are used by the Abstract Closure returned by NewPromiseReactionJob.

PromiseReaction Records have the fields listed in Table 86.

Table 86: PromiseReaction Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Capability]]</td>
<td>a PromiseCapability Record or undefined</td>
<td>The capabilities of the promise for which this record provides a reaction handler.</td>
</tr>
<tr>
<td>[[Type]]</td>
<td>FULFILL or REJECT</td>
<td>The [[Type]] is used when [[Handler]] is EMPTY to allow for behaviour specific to the settlement type.</td>
</tr>
<tr>
<td>[[Handler]]</td>
<td>a JobCallback Record or EMPTY</td>
<td>The function that should be applied to the incoming value, and whose return value will govern what happens to the derived promise. If [[Handler]] is EMPTY, a function that depends on the value of [[Type]] will be used instead.</td>
</tr>
</tbody>
</table>

27.2.1.3 CreateResolvingFunctions (promise)

The abstract operation CreateResolvingFunctions takes argument promise (a Promise) and returns a Record with fields [[Resolve]] (a function object) and [[Reject]] (a function object). It performs the following steps when called:

1. Let alreadyResolved be the Record { [[Value]]: false }.
2. Let stepsResolve be the algorithm steps defined in Promise Resolve Functions.
3. Let \( lengthResolve \) be the number of non-optional parameters of the function definition in Promise Resolve Functions.
4. Let \( resolve \) be CreateBuiltinFunction\((stepsResolve, lengthResolve, \"\", \[[\text{Promise}]], [[\text{AlreadyResolved}]] \)\).
5. Set \( resolve.\[[\text{Promise}]\] to promise.
6. Set \( resolve.\[[\text{AlreadyResolved}]\] to alreadyResolved.
7. Let \( stepsReject \) be the algorithm steps defined in Promise Reject Functions.
8. Let \( lengthReject \) be the number of non-optional parameters of the function definition in Promise Reject Functions.
9. Let \( reject \) be CreateBuiltinFunction\((stepsReject, lengthReject, \"\", \[[\text{Promise}]], [[\text{AlreadyResolved}]] \)\).
10. Set \( reject.\[[\text{Promise}]\] to promise.
11. Set \( reject.\[[\text{AlreadyResolved}]\] to alreadyResolved.
12. Return the Record \{ [[Resolve]]: resolve, [[Reject]]: reject \}.

27.2.1.3.1 Promise Reject Functions

A promise reject function is an anonymous built-in function that has [[Promise]] and [[AlreadyResolved]] internal slots.

When a promise reject function is called with argument \( reason \), the following steps are taken:

1. Let \( F \) be the active function object.
2. Assert: \( F \) has a [[Promise]] internal slot whose value is an Object.
3. Let \( promise \) be \( F.\[[\text{Promise}]\] .
4. Let \( alreadyResolved \) be \( F.\[[\text{AlreadyResolved}]\] .
5. If \( alreadyResolved.\[[\text{Value}]\] is true, return undefined.
6. Set \( alreadyResolved.\[[\text{Value}]\] to true.
7. Perform RejectPromise\((promise, reason)\).
8. Return undefined.

The "length" property of a promise reject function is \( 1 \).

27.2.1.3.2 Promise Resolve Functions

A promise resolve function is an anonymous built-in function that has [[Promise]] and [[AlreadyResolved]] internal slots.

When a promise resolve function is called with argument \( resolution \), the following steps are taken:

1. Let \( F \) be the active function object.
2. Assert: \( F \) has a [[Promise]] internal slot whose value is an Object.
3. Let \( promise \) be \( F.\[[\text{Promise}]\] .
4. Let \( alreadyResolved \) be \( F.\[[\text{AlreadyResolved}]\] .
5. If \( alreadyResolved.\[[\text{Value}]\] is true, return undefined.
6. Set \( alreadyResolved.\[[\text{Value}]\] to true.
7. If SameValue\((resolution, promise)\) is true, then
   a. Let \( selfResolutionError \) be a newly created TypeError object.
   b. Perform RejectPromise\((promise, selfResolutionError)\).
   c. Return undefined.
8. If \( resolution \) is not an Object, then
   a. Perform FulfillPromise\((promise, resolution)\).
   b. Return undefined.
9. Let \( then \) be Completion\((\text{Get}(resolution, "then"))\).
10. If \( then \) is an abrupt completion, then
    a. Perform RejectPromise\((promise, then.\[[\text{Value}]\])\).
    b. Return undefined.
11. Let \( thenAction \) be then.\[[\text{Value}]\].
12. If IsCallable\((thenAction)\) is false, then
    a. Perform FulfillPromise\((promise, resolution)\).
    b. Return undefined.
13. Let \( thenJobCallback \) be HostMakeJobCallback\((thenAction)\).
14. Let $job$ be NewPromiseResolveThenableJob($promise$, $resolution$, $thenJobCallback$).
15. Perform HostEnqueuePromiseJob($job$. [[Job]], $job$. [[Realm]]).
16. Return undefined.

The "length" property of a promise resolve function is 1.

27.2.1.4 FulfillPromise ( $promise$, $value$ )

The abstract operation FulfillPromise takes arguments $promise$ (a Promise) and $value$ (an ECMAScript language value) and returns UNUSED. It performs the following steps when called:

1. Assert: The value of $promise$. [[PromiseState]] is PENDING.
2. Let $reactions$ be $promise$. [[PromiseFulfillReactions]].
3. Set $promise$. [[PromiseResult]] to $value$.
4. Set $promise$. [[PromiseFulfillReactions]] to undefined.
5. Set $promise$. [[PromiseRejectReactions]] to undefined.
6. Set $promise$. [[PromiseState]] to FULFILLED.
7. Perform TriggerPromiseReactions($reactions$, $value$).
8. Return UNUSED.

27.2.1.5 NewPromiseCapability ( $C$ )

The abstract operation NewPromiseCapability takes argument $C$ (an ECMAScript language value) and returns either a normal completion containing a PromiseCapability Record or a throw completion. It attempts to use $C$ as a constructor in the fashion of the built-in Promise constructor to create a promise and extract its resolve and reject functions. The promise plus the resolve and reject functions are used to initialize a new PromiseCapability Record. It performs the following steps when called:

1. If IsConstructor($C$) is false, throw a TypeError exception.
2. NOTE: $C$ is assumed to be a constructor function that supports the parameter conventions of the Promise constructor (see 27.2.3.1).
3. Let $resolvingFunctions$ be the Record { [[Resolve]]: undefined, [[Reject]]: undefined }.
4. Let $executorClosure$ be a new Abstract Closure with parameters (resolve, reject) that captures $resolvingFunctions$ and performs the following steps when called:
   a. If $resolvingFunctions$. [[Resolve]] is not undefined, throw a TypeError exception.
   b. If $resolvingFunctions$. [[Reject]] is not undefined, throw a TypeError exception.
   c. Set $resolvingFunctions$. [[Resolve]] to resolve.
   d. Set $resolvingFunctions$. [[Reject]] to reject.
   e. Return undefined.
5. Let $executor$ be CreateBuiltinFunction($executorClosure$, 2, "", « »).
6. Let $promise$ be $Construct(C$, « $executor$ »).
7. If IsCallable($resolvingFunctions$. [[Resolve]]) is false, throw a TypeError exception.
8. If IsCallable($resolvingFunctions$. [[Reject]]) is false, throw a TypeError exception.
9. Return the PromiseCapability Record { [[Promise]]: $promise$, [[Resolve]]: $resolvingFunctions$. [[Resolve]], [[Reject]]: $resolvingFunctions$. [[Reject]] }.

NOTE This abstract operation supports Promise subclassing, as it is generic on any constructor that calls a passed executor function argument in the same way as the Promise constructor. It is used to generalize static methods of the Promise constructor to any subclass.

27.2.1.6 IsPromise ( $x$ )

The abstract operation IsPromise takes argument $x$ (an ECMAScript language value) and returns a Boolean. It checks for the promise brand on an object. It performs the following steps when called:

1. If $x$ is not an Object, return false.
2. If $x$ does not have a [[PromiseState]] internal slot, return false.
3. Return true.
27.2.1.7 RejectPromise (promise, reason)

The abstract operation RejectPromise takes arguments promise (a Promise) and reason (an ECMA Script language value) and returns UNUSED. It performs the following steps when called:

1. Assert: The value of promise.[[PromiseState]] is PENDING.
2. Let reactions be promise.[[PromiseRejectReactions]].
3. Set promise.[[PromiseResult]] to reason.
4. Set promise.[[PromiseFulfillReactions]] to undefined.
5. Set promise.[[PromiseRejectReactions]] to undefined.
6. Set promise.[[PromiseState]] to REJECTED.
7. If promise.[[PromisesHandled]] is false, perform HostPromiseRejectionTracker(promise, "reject").
8. Perform TriggerPromiseReactions(reactions, reason).
9. Return UNUSED.

27.2.1.8 TriggerPromiseReactions (reactions, argument)

The abstract operation TriggerPromiseReactions takes arguments reactions (a List of PromiseReaction Records) and argument (an ECMA Script language value) and returns UNUSED. It enqueues a new Job for each record in reactions. Each such Job processes the [[Type]] and [[Handler]] of the PromiseReaction Record, and if the [[Handler]] is not EMPTY, calls it passing the given argument. If the [[Handler]] is EMPTY, the behaviour is determined by the [[Type]]. It performs the following steps when called:

1. For each element reaction of reactions, do
   a. Let job be NewPromiseReactionJob(reaction, argument).
   b. Perform HostEnqueuePromiseJob(job.[[Job]], job.[[Realm]]).
2. Return UNUSED.

27.2.1.9 HostPromiseRejectionTracker (promise, operation)

The host-defined abstract operation HostPromiseRejectionTracker takes arguments promise (a Promise) and operation ("reject" or "handle") and returns UNUSED. It allows host environments to track promise rejections.

The default implementation of HostPromiseRejectionTracker is to return UNUSED.

NOTE 1 HostPromiseRejectionTracker is called in two scenarios:

- When a promise is rejected without any handlers, it is called with its operation argument set to "reject".
- When a handler is added to a rejected promise for the first time, it is called with its operation argument set to "handle".

A typical implementation of HostPromiseRejectionTracker might try to notify developers of unhandled rejections, while also being careful to notify them if such previous notifications are later invalidated by new handlers being attached.

NOTE 2 If operation is "handle", an implementation should not hold a reference to promise in a way that would interfere with garbage collection. An implementation may hold a reference to promise if operation is "reject", since it is expected that rejections will be rare and not on hot code paths.
27.2.2 Promise Jobs

27.2.2.1 NewPromiseReactionJob (reaction, argument)

The abstract operation NewPromiseReactionJob takes arguments reaction (a PromiseReaction Record) and argument (an ECMAScript language value) and returns a Record with fields [[Job]] (a Job Abstract Closure) and [[Realm]] (a Realm Record or null). It returns a new Job Abstract Closure that applies the appropriate handler to the incoming value, and uses the handler’s return value to resolve or reject the derived promise associated with that handler. It performs the following steps when called:

1. Let job be a new Job Abstract Closure with no parameters that captures reaction and argument and performs the following steps when called:
   a. Let promiseCapability be reaction.[[Capability]].
   b. Let type be reaction.[[Type]].
   c. Let handler be reaction.[[Handler]].
   d. If handler is EMPTY, then
      i. If type is FULFILL, then
         1. Let handlerResult be NormalCompletion(argument).
      ii. Else,
         1. Assert: type is REJECT.
         2. Let handlerResult be ThrowCompletion(argument).
   e. Else,
      i. Let handlerResult be Completion(HostCallJobCallback(handler, undefined, « argument »)).
   f. If promiseCapability is undefined, then
      i. Assert: handlerResult is not an abrupt completion.
      ii. Return EMPTY.
   g. Assert: promiseCapability is a PromiseCapability Record.
   h. If handlerResult is an abrupt completion, then
      i. Return Call(promiseCapability.[[Reject]], undefined, « handlerResult.[[Value]] »).
      ii. Else,
      i. Return Call(promiseCapability.[[Resolve]], undefined, « handlerResult.[[Value]] »).
2. Let handlerRealm be null.
3. If reaction.[[Handler]] is not EMPTY, then
   a. Let getHandlerRealmResult be Completion(GetFunctionRealm(reaction.[[Handler]].[[Callback]])).
   b. If getHandlerRealmResult is a normal completion, set handlerRealm to getHandlerRealmResult.[[Value]].
   c. Else, set handlerRealm to the current Realm Record.
   d. NOTE: handlerRealm is never null unless the handler is undefined. When the handler is a revoked Proxy and no ECMAScript code runs, handlerRealm is used to create error objects.
4. Return the Record { [[Job]]: job, [[Realm]]: handlerRealm }.

27.2.2.2 NewPromiseResolveThenableJob (promiseToResolve, thenable, then)

The abstract operation NewPromiseResolveThenableJob takes arguments promiseToResolve (a Promise), thenable (an Object), and then (a JobCallback Record) and returns a Record with fields [[Job]] (a Job Abstract Closure) and [[Realm]] (a Realm Record). It performs the following steps when called:

1. Let job be a new Job Abstract Closure with no parameters that captures promiseToResolve, thenable, and then and performs the following steps when called:
   a. Let resolvingFunctions be CreateResolvingFunctions(promiseToResolve).
   b. Let thenCallResult be Completion(HostCallJobCallback(then, thenable, « resolvingFunctions.[[Resolve]], resolvingFunctions.[[Reject]] »)).
   c. If thenCallResult is an abrupt completion, then
      i. Return Call(resolvingFunctions.[[Reject]], undefined, « thenCallResult.[[Value]] »).
   d. Return thenCallResult.
2. Let getThenRealmResult be Completion(GetFunctionRealm(then.[[Callback]])).
3. If getThenRealmResult is a normal completion, let thenRealm be getThenRealmResult.[[Value]].
4. Else, let thenRealm be the current Realm Record.
5. NOTE: `thenRealm` is never null. When `then.[[Callback]]` is a revoked Proxy and no code runs, `thenRealm` is used to create error objects.

6. Return the `Record` { [[Job]]: `job`, [[Realm]]: `thenRealm` }.

**NOTE** This Job uses the supplied thenable and its `then` method to resolve the given promise. This process must take place as a Job to ensure that the evaluation of the `then` method occurs after evaluation of any surrounding code has completed.

27.2.3 The Promise Constructor

The Promise constructor:

- is `%Promise%`.
- is the initial value of the "Promise" property of the global object.
- creates and initializes a new Promise when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.
- may be used as the value in an extends clause of a class definition. Subclass constructors that intend to inherit the specified Promise behaviour must include a super call to the Promise constructor to create and initialize the subclass instance with the internal state necessary to support the `Promise` and `Promise.prototype` built-in methods.

27.2.3.1 Promise (executor)

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.
2. If `IsCallable(executor)` is false, throw a TypeError exception.
3. Let promise be ? OrdinaryCreateFromConstructor(NewTarget, "%Promise.prototype%", « [[PromiseState]], [[PromiseResult]], [[PromiseFulfillReactions]], [[PromiseRejectReactions]], [[PromisesHandled]] »).
4. Set promise.[[PromiseState]] to PENDING.
5. Set promise.[[PromiseFulfillReactions]] to a new empty List.
6. Set promise.[[PromiseRejectReactions]] to a new empty List.
7. Set promise.[[PromisesHandled]] to false.
8. Let resolvingFunctions be CreateResolvingFunctions(promise).
9. Let completion be Completion(Call(executor, undefined, « resolvingFunctions.[[Resolve]], resolvingFunctions.[[Reject]] »)).
10. If completion is an abrupt completion, then
    a. Perform ? Call(resolvingFunctions.[[Reject]], undefined, « completion.[[Value]] »).
11. Return promise.
The executor argument must be a function object. It is called for initiating and reporting completion of the possibly deferred action represented by this Promise. The executor is called with two arguments: resolve and reject. These are functions that may be used by the executor function to report eventual completion or failure of the deferred computation. Returning from the executor function does not mean that the deferred action has been completed but only that the request to eventually perform the deferred action has been accepted.

The resolve function that is passed to an executor function accepts a single argument. The executor code may eventually call the resolve function to indicate that it wishes to resolve the associated Promise. The argument passed to the resolve function represents the eventual value of the deferred action and can be either the actual fulfillment value or another promise which will provide the value if it is fulfilled.

The reject function that is passed to an executor function accepts a single argument. The executor code may eventually call the reject function to indicate that the associated Promise is rejected and will never be fulfilled. The argument passed to the reject function is used as the rejection value of the promise. Typically it will be an Error object.

The resolve and reject functions passed to an executor function by the Promise constructor have the capability to actually resolve and reject the associated promise. Subclasses may have different constructor behaviour that passes in customized values for resolve and reject.

27.2.4 Properties of the Promise Constructor

The Promise constructor:

• has a [[Prototype]] internal slot whose value is %Function.prototype%.
• has the following properties:

27.2.4.1 Promise.all ( iterable )

This function returns a new promise which is fulfilled with an array of fulfillment values for the passed promises, or rejects with the reason of the first passed promise that rejects. It resolves all elements of the passed iterable to promises as it runs this algorithm.

1. Let C be the this value.
2. Let promiseCapability be ? NewPromiseCapability(C).
3. Let promiseResolve be Completion(GetPromiseResolve(C)).
4. IfAbruptRejectPromise(promiseResolve, promiseCapability).
5. Let iteratorRecord be Completion(GetIterator(iterable, SYNC)).
6. IfAbruptRejectPromise(iteratorRecord, promiseCapability).
7. Let result be Completion(PerformPromiseAll(iteratorRecord, C, promiseCapability, promiseResolve)).
8. If result is an abrupt completion, then
   a. If iteratorRecord.[[Done]] is false, set result to Completion(IteratorClose(iteratorRecord, result)).
   b. IfAbruptRejectPromise(result, promiseCapability).
27.2.4.1.1 GetPromiseResolve (promiseConstructor)

The abstract operation GetPromiseResolve takes argument promiseConstructor (a constructor) and returns either a normal completion containing a function object or a throw completion. It performs the following steps when called:

1. Let promiseResolve be ? Get(promiseConstructor, "resolve").
2. If IsCallable(promiseResolve) is false, throw a TypeError exception.
3. Return promiseResolve.

27.2.4.1.2 PerformPromiseAll (iteratorRecord, constructor, resultCapability, promiseResolve)

The abstract operation PerformPromiseAll takes arguments iteratorRecord (an Iterator Record), constructor (a constructor), resultCapability (a PromiseCapability Record), and promiseResolve (a function object) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let values be a new empty List.
2. Let remainingElementsCount be the Record { [[Value]]: 1 }.
3. Let index be 0.
4. Repeat,
   a. Let next be ? IteratorStepValue(iteratorRecord).
   b. If next is DONE, then
      i. Set remainingElementsCount.[[Value]] to remainingElementsCount.[[Value]] - 1.
      ii. If remainingElementsCount.[[Value]] = 0, then
          1. Let valuesArray be CreateArrayFromList(values).
          2. Perform ? Call(resultCapability.[[Resolve]], undefined, « valuesArray »).
      iii. Return resultCapability.[[Promise]].
   c. Append undefined to values.
   d. Let nextPromise be ? Call(promiseResolve, constructor, « next »).
   e. Let steps be the algorithm steps defined in Promise.all Resolve Element Functions.
   f. Let length be the number of non-optional parameters of the function definition in Promise.all Resolve Element Functions.
   g. Let onFulfilled be CreateBuiltinFunction(steps, length, "", « [[AlreadyCalled]], [[Index]], [[Values]].[[Capability]], [[RemainingElements]] »).
   h. Set onFulfilled.[[AlreadyCalled]] to false.
   i. Set onFulfilled.[[Index]] to index.
   j. Set onFulfilled.[[Values]] to values.
   k. Set onFulfilled.[[Capability]] to resultCapability.
   l. Set onFulfilled.[[RemainingElements]] to remainingElementsCount.
   m. Set remainingElementsCount.[[Value]] to remainingElementsCount.[[Value]] + 1.
   n. Perform ? Invoke(nextPromise, "then", « onFulfilled, resultCapability.[[Reject]] »).
   o. Set index to index + 1.

27.2.4.1.3 Promise.all Resolve Element Functions

A Promise.all resolve element function is an anonymous built-in function that is used to resolve a specific Promise.all element. Each Promise.all resolve element function has [[Index]], [[Values]], [[Capability]], [[RemainingElements]], and [[AlreadyCalled]] internal slots.

When a Promise.all resolve element function is called with argument x, the following steps are taken:

1. Let F be the active function object.
2. If F.[[AlreadyCalled]] is true, return undefined.
3. Set F.[[AlreadyCalled]] to true.
4. Let index be F.[[Index]].
5. Let values be F.[[Values]].
6. Let promiseCapability be F.[[Capability]].
7. Let remainingElementsCount be F.[[RemainingElements]].
8. Set `values[index]` to `x`.
9. Set `remainingElementsCount.[[Value]]` to `remainingElementsCount.[[Value]] - 1`.
10. If `remainingElementsCount.[[Value]]` = 0, then
    a. Let `valuesArray` be `CreateArrayFromList(values)`.
    b. Return ? `Call(promiseCapability.[[Resolve]], undefined, « valuesArray »)`.
11. Return `undefined`.

The "length" property of a `Promise.all` resolve element function is 1.

27.2.4.2 `Promise.allSettled` ( `iterable` )

This function returns a promise that is fulfilled with an array of promise state snapshots, but only after all the original promises have settled, i.e. become either fulfilled or rejected. It resolves all elements of the passed iterable to promises as it runs this algorithm.

1. Let `C` be the this value.
2. Let `promiseCapability` be ? `NewPromiseCapability(C)`.
3. Let `promiseResolve` be `Completion(GetPromiseResolve(C))`.
4. IfAbruptRejectPromise(`promiseResolve`, `promiseCapability`).
5. Let `iteratorRecord` be `Completion(GetIterator(iterable, SYNC))`.
6. IfAbruptRejectPromise(`iteratorRecord`, `promiseCapability`).
7. Let `result` be `Completion(PerformPromiseAllSettled(iteratorRecord, C, promiseCapability, promiseResolve))`.
8. If `result` is an abrupt completion, then
   a. If `iteratorRecord.[[Done]]` is false, set `result` to `Completion(IteratorClose(iteratorRecord, result))`.
   b. IfAbruptRejectPromise(`result`, `promiseCapability`).

**NOTE**
This function requires its this value to be a constructor function that supports the parameter conventions of the Promise constructor.

27.2.4.2.1 `PerformPromiseAllSettled` ( `iteratorRecord, constructor, resultCapability, promiseResolve` )

The abstract operation `PerformPromiseAllSettled` takes arguments `iteratorRecord` (an `Iterator Record`), `constructor` (a constructor), `resultCapability` (a `PromiseCapability Record`), and `promiseResolve` (a function object) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let `values` be a new empty List.
2. Let `remainingElementsCount` be the Record { [[Value]]: 1 }.
3. Let `index` be 0.
4. Repeat,
   a. Let `next` be ? `IteratorStepValue(iteratorRecord)`.
   b. If `next` is DONE, then
      i. Set `remainingElementsCount.[[Value]]` to `remainingElementsCount.[[Value]] - 1`.
      ii. If `remainingElementsCount.[[Value]]` = 0, then
          1. Let `valuesArray` be `CreateArrayFromList(values)`.
          2. Perform ? `Call(resultCapability.[[Resolve]], undefined, « valuesArray »)`.
          3. Return `resultCapability.[[Promise]]`.
   c. Append `undefined` to `values`.
   d. Let `nextPromise` be ? `Call(promiseResolve, constructor, « next »)`.
   e. Let `stepsFulfilled` be the algorithm steps defined in `Promise.allSettled` Resolve Element Functions.
   f. Let `lengthFulfilled` be the number of non-optional parameters of the function definition in `Promise.allSettled` Resolve Element Functions.
   g. Let `onFulfilled` be `CreateBuiltInFunction(stepsFulfilled, lengthFulfilled, "", [[AlreadyCalled]], [[Index]], [[Values]], [[Capability]], [[RemainingElements]] »).
   h. Let `alreadyCalled` be the Record { [[Value]]: `false` }.
   i. Set `onFulfilled.[[AlreadyCalled]]` to `alreadyCalled`.
27.2.4.2.2 \texttt{Promise.allSettled} Resolve Element Functions

A \texttt{Promise.allSettled} resolve element function is an anonymous built-in function that is used to resolve a specific \texttt{Promise.allSettled} element. Each \texttt{Promise.allSettled} resolve element function has [[Index]], [[Values]], [[Capability]], [[RemainingElements]], and [[AlreadyCalled]] internal slots.

When a \texttt{Promise.allSettled} resolve element function is called with argument \(x\), the following steps are taken:

1. Let \(F\) be the active function object.
2. Let alreadyCalled be \(F.[[AlreadyCalled]]\).
3. If alreadyCalled.[[Value]] is true, return undefined.
4. Set alreadyCalled.[[Value]] to true.
5. Let index be \(F.[[Index]]\).
6. Let values be \(F.[[Values]]\).
7. Let promiseCapability be \(F.[[Capability]]\).
8. Let remainingElementsCount be \(F.[[RemainingElements]]\).
9. Let \(obj\) be OrdinaryObjectCreate(%Object.prototype%).
10. Perform ! CreateDataPropertyOrThrow(\(obj\), "status", "fulfilled").
11. Perform ! CreateDataPropertyOrThrow(\(obj\), "value", \(x\)).
12. Set values[index] to \(obj\).
13. Set remainingElementsCount.[[Value]] to remainingElementsCount.[[Value]] - 1.
14. If remainingElementsCount.[[Value]] = 0, then
   a. Let valuesArray be CreateArrayFromList(values).
   b. Return ? Call(promiseCapability.[[Resolve]], undefined, « valuesArray »).
15. Return undefined.

The "length" property of a \texttt{Promise.allSettled} resolve element function is \(1_F\).

27.2.4.2.3 \texttt{Promise.allSettled} Reject Element Functions

A \texttt{Promise.allSettled} reject element function is an anonymous built-in function that is used to reject a specific \texttt{Promise.allSettled} element. Each \texttt{Promise.allSettled} reject element function has [[Index]], [[Values]], [[Capability]], [[RemainingElements]], and [[AlreadyCalled]] internal slots.

When a \texttt{Promise.allSettled} reject element function is called with argument \(x\), the following steps are taken:

1. Let \(F\) be the active function object.
2. Let alreadyCalled be \(F.[[AlreadyCalled]]\).
3. If alreadyCalled.[[Value]] is true, return undefined.
4. Set alreadyCalled.[[Value]] to true.
5. Let index be \(F.[[Index]]\).
6. Set values be \(F.[[Values]]\).
7. Let `promiseCapability` be `F.[[Capability]]`.  
8. Let `remainingElementsCount` be `F.[[RemainingElements]]`.  
9. Let `obj` be ` OrdinaryObjectCreate(%Object.prototype%)`.  
10. Perform ! CreateDataPropertyOrThrow(`obj`, "status", "rejected").  
11. Perform ! CreateDataPropertyOrThrow(`obj`, "reason", x).  
12. Set `values[index]` to `obj`.  
13. Set `remainingElementsCount.[[Value]]` to `remainingElementsCount.[[Value]] - 1`.  
14. If `remainingElementsCount.[[Value]] = 0`, then  
   a. Let `valuesArray` be `CreateArrayFromList(values)`.  
15. Return `undefined`.  

The "length" property of a `Promise.allSettled` reject element function is `1⪞`.  

### 27.2.4.3 `Promise.any` (iterable)  

This function returns a promise that is fulfilled by the first given promise to be fulfilled, or rejected with an `AggregateError` holding the rejection reasons if all of the given promises are rejected. It resolves all elements of the passed iterable to promises as it runs this algorithm.  

1. Let `C` be the `this` value.  
2. Let `promiseCapability` be `? NewPromiseCapability(C)`.  
3. Let `promiseResolve` be `Completion(GetPromiseResolve(C))`.  
4. IfAbruptRejectPromise(`promiseResolve`, `promiseCapability`).  
5. Let `iteratorRecord` be `Completion(GetIterator(iterable, SYNC))`.  
6. IfAbruptRejectPromise(`iteratorRecord`, `promiseCapability`).  
7. Let `result` be `Completion(PerformPromiseAny(`iteratorRecord`, `C`, `promiseCapability`, `promiseResolve`))`.  
8. If `result` is an abrupt completion, then  
   a. If `iteratorRecord.[[Done]]` is `false`, set `result` to `Completion(IteratorClose(iteratorRecord, result))`.  
   b. IfAbruptRejectPromise(`result`, `promiseCapability`).  
9. Return `result`.  

NOTE This function requires its `this` value to be a constructor function that supports the parameter conventions of the Promise constructor.  

### 27.2.4.3.1 `PerformPromiseAny` (iteratorRecord, constructor, resultCapability, promiseResolve)  

The abstract operation `PerformPromiseAny` takes arguments `iteratorRecord` (an Iterator Record), `constructor` (a constructor), `resultCapability` (a PromiseCapability Record), and `promiseResolve` (a function object) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:  

1. Let `errors` be a new empty `List`.  
2. Let `remainingElementsCount` be the `Record` `{ [[Value]]: 1 }`.  
3. Let `index` be `0`.  
4. Repeat,  
   a. Let `next` be ? `IteratorStepValue(iteratorRecord)`.  
   b. If `next` is `DONE`, then  
      i. Set `remainingElementsCount.[[Value]]` to `remainingElementsCount.[[Value]] - 1`.  
      ii. If `remainingElementsCount.[[Value]] = 0`, then  
          1. Let `error` be a newly created `AggregateError` object.  
          2. Perform ! `DefinePropertyOrThrow(error, "errors", PropertyDescriptor { [[Configurable]]: true, [[Enumerable]]: false, [[Writable]]: true, [[Value]]: CreateArrayFromList(errors) })`.  
          3. Return `ThrowCompletion(error)`.  
      iii. Return `resultCapability.[[Promise]]`.  
   c. Append `undefined` to `errors`.  
   d. Let `nextPromise` be ? Call(`promiseResolve, constructor, « next »`).  
   e. Let `stepsRejected` be the algorithm steps defined in `Promise.any` Reject Element Functions.
Let \( \text{lengthRejected} \) be the number of non-optional parameters of the function definition in \text{Promise.any} Reject Element Functions.

g. Let \( \text{onRejected} \) be \text{CreateBuiltinFunction}(\text{stepsRejected, lengthRejected, "", \"[[AlreadyCalled]], [[Index]], [[Errors]], [[Capability]], [[RemainingElements]] \}}).  

h. Set \( \text{onRejected}[[\text{AlreadyCalled}]] \) to false.

i. Set \( \text{onRejected}[[\text{Index}]] \) to index.

j. Set \( \text{onRejected}[[\text{Errors}]] \) to errors.

k. Set \( \text{onRejected}[[\text{Capability}]] \) to resultCapability.

l. Set \( \text{onRejected}[[\text{RemainingElements}]] \) to remainingElementsCount.

m. Set \( \text{remainingElementsCount}[[\text{Value}]] \) to \( \text{remainingElementsCount}[[\text{Value}]] + 1 \).

n. Perform ? \( \text{Invoke}(\text{nextPromise, "then"}, « \text{resultCapability}[[\text{Resolve}]], \text{onRejected} ») \).

o. Set \( \text{index} \) to \( \text{index} + 1 \).

27.2.4.3.2 \text{Promise.any} Reject Element Functions

A \text{Promise.any} reject element function is an anonymous built-in function that is used to reject a specific \text{Promise.any} element. Each \text{Promise.any} reject element function has [[Index]], [[Errors]], [[Capability]], [[RemainingElements]], and [[AlreadyCalled]] internal slots.

When a \text{Promise.any} reject element function is called with argument \( x \), the following steps are taken:

1. Let \( F \) be the active function object.
2. If \( F[[\text{AlreadyCalled}]] \) is true, return undefined.
3. Set \( F[[\text{AlreadyCalled}]] \) to true.
4. Let \( \text{index} \) be \( F[[\text{Index}]] \).
5. Let \( \text{errors} \) be \( F[[\text{Errors}]] \).

6. Let \( \text{promiseCapability} \) be \( F[[\text{Capability}]] \).
7. Let \( \text{remainingElementsCount} \) be \( F[[\text{RemainingElements}]] \).
8. Set \( \text{errors}[\text{index}] \) to \( x \).
9. Set \( \text{remainingElementsCount}[[\text{Value}]] \) to \( \text{remainingElementsCount}[[\text{Value}]] - 1 \).
10. If \( \text{remainingElementsCount}[[\text{Value}]] = 0 \), then:
    a. Let \( \text{error} \) be a newly created \text{AggregateError} object.
    b. Perform \( \text{DefinePropertyOrThrow}(\text{error}, " \text{errors} \text{"}, \text{PropertyDescriptor} \{ [[\text{Configurable}]]: \text{true}, [[\text{Enumerable}]]: \text{false}, [[\text{Writable}]]: \text{true}, [[\text{Value}]]: \text{CreateArrayFromList}(\text{errors}) \}) \).
    c. Return ? \( \text{Call}(\text{promiseCapability}[[\text{Reject}]], \text{undefined}, « \text{error} ») \).

11. Return undefined.

The "length" property of a \text{Promise.any} reject element function is 1 \( \mathbb{F} \).

27.2.4.4 \text{Promise.prototype}

The initial value of \text{Promise.prototype} is the \text{Promise prototype object}.

This property has the attributes \{ [[\text{Writable}]]: false, [[\text{Enumerable}]]: false, [[\text{Configurable}]]: false \}.

27.2.4.5 \text{Promise.race} ( \text{iterable} )

This function returns a new promise which is settled in the same way as the first passed promise to settle. It resolves all elements of the passed \text{iterable} to promises as it runs this algorithm.

1. Let \( C \) be the this value.
2. Let \( \text{promiseCapability} \) be ? \text{NewPromiseCapability}(C).
3. Let \( \text{promiseResolve} \) be \text{Completion}(\text{GetPromiseResolve}(C)).
4. IfAbruptRejectPromise(\text{promiseResolve, promiseCapability}).
5. Let \( \text{iteratorRecord} \) be \text{Completion}(\text{GetIterator}(\text{iterable, \text{SYNC}})).
6. IfAbruptRejectPromise(\text{iteratorRecord, promiseCapability}).
7. Let \( \text{result} \) be \text{Completion}(\text{PerformPromiseRace}(\text{iteratorRecord, C, promiseCapability, promiseResolve})).
8. If \( \text{result} \) is an abrupt completion, then
a. If `iteratorRecord.[[Done]]` is false, set `result` to `Completion(IteratorClose(iteratorRecord, result))`.
b. IfAbruptRejectPromise(`result, promiseCapability`).

9. Return `result`.

**NOTE 1** If the `iterable` argument yields no values or if none of the promises yielded by `iterable` ever settle, then the pending promise returned by this method will never be settled.

**NOTE 2** This function expects its `this` value to be a `constructor` function that supports the parameter conventions of the Promise `constructor`. It also expects that its `this` value provides a `resolve` method.

### 27.2.4.5.1 PerformPromiseRace ( `iteratorRecord`, `constructor`, `resultCapability`, `promiseResolve` )

The abstract operation PerformPromiseRace takes arguments `iteratorRecord` (an Iterator Record), `constructor` (a constructor), `resultCapability` (a PromiseCapability Record), and `promiseResolve` (a function object) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Repeat,
   a. Let `next` be ? `IteratorStepValue(iteratorRecord)`.
   b. If `next` is DONE, then
      i. Return `resultCapability.[[Promise]]`.
   c. Let `nextPromise` be ? `Call(promiseResolve, constructor, « next »)`.
   d. Perform ? `Invoke(nextPromise, "then", « resultCapability.[[Resolve]], resultCapability.[[Reject]] »)`.

### 27.2.4.6 Promise.reject ( `r` )

This function returns a new promise rejected with the passed argument.

1. Let `C` be the `this` value.
2. Let `promiseCapability` be ? `NewPromiseCapability(C)`.
4. Return `promiseCapability.[[Promise]]`.

**NOTE** This function expects its `this` value to be a `constructor` function that supports the parameter conventions of the Promise `constructor`.

### 27.2.4.7 Promise.resolve ( `x` )

This function returns either a new promise resolved with the passed argument, or the argument itself if the argument is a promise produced by this `constructor`.

1. Let `C` be the `this` value.
2. If `C` is not an Object, throw a `TypeError` exception.
3. Return ? `PromiseResolve(C, x)`.

**NOTE** This function expects its `this` value to be a `constructor` function that supports the parameter conventions of the Promise `constructor`. 
27.2.4.7.1 PromiseResolve (C, x)

The abstract operation PromiseResolve takes arguments C (a constructor) and x (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or a throw completion. It returns a new promise resolved with x. It performs the following steps when called:

1. If isPromise(x) is true, then
   a. Let xConstructor be ? Get(x, "constructor").
   b. If SameValue(xConstructor, C) is true, return x.
2. Let promiseCapability be ? NewPromiseCapability(C).
3. Perform ? Call(promiseCapability.[[Resolve]], undefined, « x »).
4. Return promiseCapability.[[Promise]].

27.2.4.8 Promise.withResolvers ()

This function returns an object with three properties: a new promise together with the resolve and reject functions associated with it.

1. Let C be the this value.
2. Let promiseCapability be ? NewPromiseCapability(C).
3. Let obj be OrdinaryObjectCreate(%Object.prototype%).
4. Perform ! CreateDataPropertyOrThrow(obj, "promise", promiseCapability.[[Promise]]).
5. Perform ! CreateDataPropertyOrThrow(obj, "resolve", promiseCapability.[[Resolve]]).
6. Perform ! CreateDataPropertyOrThrow(obj, "reject", promiseCapability.[[Reject]]).
7. Return obj.

27.2.4.9 get Promise [ @@species ]

Promise[@@species] is an accessor property whose set accessor function is undefined. Its get accessor function performs the following steps when called:

1. Return the this value.

The value of the "name" property of this function is "get [Symbol.species]".

NOTE Promise prototype methods normally use their this value’s constructor to create a derived object. However, a subclass constructor may over-ride that default behaviour by redefining its @@species property.

27.2.5 Properties of the Promise Prototype Object

The Promise prototype object:

- is %Promise.prototype%.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is an ordinary object.
- does not have a [[PromiseState]] internal slot or any of the other internal slots of Promise instances.

27.2.5.1 Promise.prototype.catch ( onRejected )

This method performs the following steps when called:

1. Let promise be the this value.
2. Return ? Invoke(promise, "then", « undefined, onRejected »).
27.2.5.2 Promise.prototype.constructor

The initial value of Promise.prototype.constructor is %Promise%.

27.2.5.3 Promise.prototype.finally (onFinally)

This method performs the following steps when called:

1. Let promise be the this value.
2. If promise is not an Object, throw a TypeError exception.
3. Let C be ? SpeciesConstructor(promise, %Promise%).
4. Assert: IsConstructor(C) is true.
5. If IsCallable(onFinally) is false, then
   a. Let thenFinally be onFinally.
   b. Let catchFinally be onFinally.
6. Else,
   a. Let thenFinallyClosure be a new Abstract Closure with parameters (value) that captures onFinally and C and performs the following steps when called:
      i. Let result be ? Call(onFinally, undefined).
      ii. Let p be ? PromiseResolve(C, result).
      iii. Let returnValue be a new Abstract Closure with no parameters that captures value and performs the following steps when called:
          1. Return value.
      iv. Let valueThunk be CreateBuiltinFunction(returnValue, 0, "", « »).
      v. Return ? Invoke(p, "then", « valueThunk »).
   b. Let thenFinally be CreateBuiltinFunction_thenFinallyClosure, 1, "", « »).
   c. Let catchFinallyClosure be a new Abstract Closure with parameters (reason) that captures onFinally and C and performs the following steps when called:
      i. Let result be ? Call(onFinally, undefined).
      ii. Let p be ? PromiseResolve(C, result).
      iii. Let throwReason be a new Abstract Closure with no parameters that captures reason and performs the following steps when called:
          1. Return ThrowCompletion(reason).
      iv. Let thrower be CreateBuiltinFunction(throwReason, 0, "", « »).
      v. Return ? Invoke(p, "then", « thrower »).
   d. Let catchFinally be CreateBuiltinFunction(catchFinallyClosure, 1, "", « »).
7. Return ? Invoke(promise, "then", « thenFinally, catchFinally »).

27.2.5.4 Promise.prototype.then (onFulfilled, onRejected)

This method performs the following steps when called:

1. Let promise be the this value.
2. If IsPromise(promise) is false, throw a TypeError exception.
3. Let C be ? SpeciesConstructor(promise, %Promise%).
4. Let resultCapability be ? NewPromiseCapability(C).
5. Return PerformPromiseThen(promise, onFulfilled, onRejected, resultCapability).

27.2.5.4.1 PerformPromiseThen (promise, onFulfilled, onRejected[, resultCapability])

The abstract operation PerformPromiseThen takes arguments promise (a Promise), onFulfilled (an ECMAScript language value), and onRejected (an ECMAScript language value) and optional argument resultCapability (a PromiseCapability Record) and returns an ECMAScript language value. It performs the “then” operation on promise using onFulfilled and onRejected as its settlement actions. If resultCapability is passed, the result is
stored by updating `resultCapability`’s promise. If it is not passed, then `PerformPromiseThen` is being called by a specification-internal operation where the result does not matter. It performs the following steps when called:

1. **Assert:** `IsPromise(promise)` is true.
2. If `resultCapability` is not present, then
   a. Set `resultCapability` to `undefined`.
3. If `isCallable(onFulfilled)` is false, then
   a. Let `onFulfilledJobCallback` be `EMPTY`.
4. Else,
   a. Let `onFulfilledJobCallback` be `HostMakeJobCallback(onFulfilled)`.
5. If `isCallable(onRejected)` is false, then
   a. Let `onRejectedJobCallback` be `EMPTY`.
6. Else,
   a. Let `onRejectedJobCallback` be `HostMakeJobCallback(onRejected)`.
7. Let `fulfillReaction` be the `PromiseReaction Record` `[[Capability]]: resultCapability, [[Type]]: FULFILL, [[Handler]]: onFulfilledJobCallback`.
8. Let `rejectReaction` be the `PromiseReaction Record` `[[Capability]]: resultCapability, [[Type]]: REJECT, [[Handler]]: onRejectedJobCallback`.
9. If `promise.[[PromiseState]]` is PENDING, then
   a. Append `fulfillReaction` to `promise.[[PromiseFulfillReactions]]`.
   b. Append `rejectReaction` to `promise.[[PromiseRejectReactions]]`.
10. Else if `promise.[[PromiseState]]` is FULFILLED, then
    a. Let `value` be `promise.[[PromiseResult]]`.
    b. Let `fulfillJob` be `NewPromiseReactionJob(fulfillReaction, value)`.
    c. Perform `HostEnqueuePromiseJob(fulfillJob.[[Job]], fulfillJob.[[Realm]])`.
11. Else,
    a. **Assert:** The value of `promise.[[PromiseState]]` is REJECTED.
    b. Let `reason` be `promise.[[PromiseResult]]`.
    c. If `promise.[[PromisesHandled]]` is false, perform `HostPromiseRejectionTracker(promise, "handle")`.
    d. Let `rejectJob` be `NewPromiseReactionJob(rejectReaction, reason)`.
    e. Perform `HostEnqueuePromiseJob(rejectJob.[[Job]], rejectJob.[[Realm]])`.
12. Set `promise.[[PromiseState]]` to true.
13. If `resultCapability` is `undefined`, then
    a. Return `undefined`.
14. Else,
    a. Return `resultCapability`.[[Promise]].

### 27.2.5.5 Promise.prototype [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "Promise".

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }`.

### 27.2.6 Properties of Promise Instances

Promise instances are ordinary objects that inherit properties from the `Promise prototype object` (the intrinsic, `%Promise.prototype%`). Promise instances are initially created with the internal slots described in Table 87.

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>[[PromiseState]]</code></td>
<td>PENDING, FULFILLED, or REJECTED</td>
<td>Governs how a promise will react to incoming calls to its <code>then</code> method.</td>
</tr>
<tr>
<td><code>[[PromiseResult]]</code></td>
<td>an ECMAScript language value</td>
<td>The value with which the promise has been fulfilled or rejected, if any. Only meaningful if <code>[[PromiseState]]</code> is not PENDING.</td>
</tr>
</tbody>
</table>
Table 87: Internal Slots of Promise Instances (continued)

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[PromiseFulfillReactions]]</td>
<td>a List of PromiseReaction Records</td>
<td>Records to be processed when/if the promise transitions from the PENDING state to the FULFILLED state.</td>
</tr>
<tr>
<td>[[PromiseRejectReactions]]</td>
<td>a List of PromiseReaction Records</td>
<td>Records to be processed when/if the promise transitions from the PENDING state to the REJECTED state.</td>
</tr>
<tr>
<td>[[PromiseIsHandled]]</td>
<td>a Boolean</td>
<td>Indicates whether the promise has ever had a fulfillment or rejection handler; used in unhandled rejection tracking.</td>
</tr>
</tbody>
</table>

### 27.3 GeneratorFunction Objects

GeneratorFunctions are functions that are usually created by evaluating `GeneratorDeclarations`, `GeneratorExpressions`, and `GeneratorMethods`. They may also be created by calling the `%GeneratorFunction% intrinsic.

Figure 6 (Informative): Generator Objects Relationships

```
class %GeneratorFunction% extends Function { }
```

A typical generator function. It is not a constructor.

Each Generator Function has an associated prototype that does not have a constructor property. Hence a generator instance does not expose access to its generator function. But the prototype may be used to add additional behavior to its generator function's instances.

### 27.3.1 The GeneratorFunction Constructor

The `GeneratorFunction` constructor:

- is `%GeneratorFunction%`.

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is a subclass of `Function`.
- creates and initializes a new `GeneratorFunction` when called as a function rather than as a `constructor`. Thus the function call `GeneratorFunction (...)` is equivalent to the object creation expression `new GeneratorFunction (...)` with the same arguments.
- may be used as the value of an `extends` clause of a class definition. Subclass `constructors` that intend to inherit the specified `GeneratorFunction` behaviour must include a `super` call to the `GeneratorFunction constructor` to create and initialize subclass instances with the internal slots necessary for built-in `GeneratorFunction` behaviour. All ECMAScript syntactic forms for defining generator `function objects` create direct instances of `GeneratorFunction`. There is no syntactic means to create instances of `GeneratorFunction` subclasses.

27.3.1.1 `GeneratorFunction ( ...parameterArgs, bodyArg )`

The last argument (if any) specifies the body (executable code) of a generator function; any preceding arguments specify formal parameters.

This function performs the following steps when called:

1. Let `C` be the active function object.
2. If `bodyArg` is not present, set `bodyArg` to the empty String.

NOTE See NOTE for 20.2.1.1.

27.3.2 Properties of the `GeneratorFunction` Constructor

The `GeneratorFunction constructor`:

- is a standard built-in `function object` that inherits from the `Function constructor`.
- has a `[[Prototype]]` internal slot whose value is `%Function%`.
- has a `"length"` property whose value is `1𝔽`.
- has a `"name"` property whose value is "`GeneratorFunction"".
- has the following properties:

27.3.2.1 `GeneratorFunction.prototype`

The initial value of `GeneratorFunction.prototype` is the `GeneratorFunction` prototype object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

27.3.3 Properties of the `GeneratorFunction` Prototype Object

The `GeneratorFunction.prototype object`:

- is `%GeneratorFunction.prototype%` (see Figure 6).
- is an `ordinary object`.
- is not a `function object` and does not have an `[[ECMAScriptCode]]` internal slot or any other of the internal slots listed in Table 30 or Table 88.
- has a `[[Prototype]]` internal slot whose value is `%Function.prototype%`.

27.3.3.1 `GeneratorFunction.prototype.constructor`

The initial value of `GeneratorFunction.prototype.constructor` is `%GeneratorFunction%`.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.
27.3.2 GeneratorFunction.prototype.prototype

The initial value of `GeneratorFunction.prototype.prototype` is the Generator prototype object.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

27.3.3 GeneratorFunction.prototype [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "GeneratorFunction".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

27.3.4 GeneratorFunction Instances

Every GeneratorFunction instance is an ECMAScript function object and has the internal slots listed in Table 30. The value of the [[IsClassConstructor]] internal slot for all such instances is false.

Each GeneratorFunction instance has the following own properties:

27.3.4.1 length

The specification for the "length" property of Function instances given in 20.2.4.1 also applies to GeneratorFunction instances.

27.3.4.2 name

The specification for the "name" property of Function instances given in 20.2.4.2 also applies to GeneratorFunction instances.

27.3.4.3 prototype

Whenever a GeneratorFunction instance is created another ordinary object is also created and is the initial value of the generator function's "prototype" property. The value of the prototype property is used to initialize the [[Prototype]] internal slot of a newly created Generator when the generator function object is invoked using [[Call]].

This property has the attributes { [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }.

NOTE Unlike Function instances, the object that is the value of a GeneratorFunction's "prototype" property does not have a "constructor" property whose value is the GeneratorFunction instance.

27.4 AsyncGeneratorFunction Objects

AsyncGeneratorFunctions are functions that are usually created by evaluating AsyncGeneratorDeclaration, AsyncGeneratorExpression, and AsyncGeneratorMethod syntactic productions. They may also be created by calling the `%AsyncGeneratorFunction%` intrinsic.

27.4.1 The AsyncGeneratorFunction Constructor

The AsyncGeneratorFunction constructor:

• is `%AsyncGeneratorFunction%`.
• is a subclass of `Function`.
• creates and initializes a new AsyncGeneratorFunction when called as a function rather than as a constructor. Thus the function call `AsyncGeneratorFunction (...)` is equivalent to the object creation
expression **new AsyncGeneratorFunction (...)** with the same arguments.

- may be used as the value of an **extends** clause of a class definition. Subclass **constructors** that intend to inherit the specified AsyncGeneratorFunction behaviour must include a **super** call to the AsyncGeneratorFunction **constructor** to create and initialize subclass instances with the internal slots necessary for built-in AsyncGeneratorFunction behaviour. All ECMAScript syntactic forms for defining async generator function objects create direct instances of AsyncGeneratorFunction. There is no syntactic means to create instances of AsyncGeneratorFunction subclasses.

### 27.4.1.1 AsyncGeneratorFunction ( ...**parameterArgs**, **bodyArg** )

The last argument (if any) specifies the body (executable code) of an async generator function; any preceding arguments specify formal parameters.

This function performs the following steps when called:

1. Let **C** be the **active function object**.
2. If **bodyArg** is not present, set **bodyArg** to the empty String.

#### NOTE

See NOTE for 20.2.1.1.

### 27.4.2 Properties of the AsyncGeneratorFunction Constructor

The AsyncGeneratorFunction **constructor**:

- is a standard built-in **function object** that inherits from the Function **constructor**.
- has a [[Prototype]] internal slot whose value is %Function%.
- has a "length" property whose value is 1_F.
- has a "name" property whose value is "AsyncGeneratorFunction".
- has the following properties:

#### 27.4.2.1 AsyncGeneratorFunction.prototype

The initial value of **AsyncGeneratorFunction.prototype** is the AsyncGeneratorFunction prototype object.

This property has the attributes { [[Writable]]: **false**, [[Enumerable]]: **false**, [[Configurable]]: **false** }.

### 27.4.3 Properties of the AsyncGeneratorFunction Prototype Object

The AsyncGeneratorFunction prototype object:

- is %AsyncGeneratorFunction.prototype%.
- is an ordinary object.
- is not a function object and does not have an [[ECMAScriptCode]] internal slot or any other of the internal slots listed in Table 30 or Table 89.
- has a [[Prototype]] internal slot whose value is %Function.prototype%.

#### 27.4.3.1 AsyncGeneratorFunction.prototype.constructor

The initial value of **AsyncGeneratorFunction.prototype.constructor** is %AsyncGeneratorFunction%. This property has the attributes { [[Writable]]: **false**, [[Enumerable]]: **false**, [[Configurable]]: **true** }. 
27.4.3.2 AsyncGeneratorFunction.prototype.prototype

The initial value of `AsyncGeneratorFunction.prototype.prototype` is the `AsyncGenerator prototype` object.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

27.4.3.3 AsyncGeneratorFunction.prototype[@@toStringTag]

The initial value of the `@@toStringTag` property is the String value "AsyncGeneratorFunction".

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

27.4.4 AsyncGeneratorFunction Instances

Every AsyncGeneratorFunction instance is an ECMAScript function object and has the internal slots listed in Table 30. The value of the [[IsClassConstructor]] internal slot for all such instances is false.

Each AsyncGeneratorFunction instance has the following own properties:

27.4.4.1 length

The value of the "length" property is an integral Number that indicates the typical number of arguments expected by the AsyncGeneratorFunction. However, the language permits the function to be invoked with some other number of arguments. The behaviour of an AsyncGeneratorFunction when invoked on a number of arguments other than the number specified by its "length" property depends on the function.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }. 

27.4.4.2 name

The specification for the "name" property of Function instances given in 20.2.4.2 also applies to AsyncGeneratorFunction instances.

27.4.4.3 prototype

Whenever an AsyncGeneratorFunction instance is created, another ordinary object is also created and is the initial value of the async generator function's "prototype" property. The value of the prototype property is used to initialize the [[Prototype]] internal slot of a newly created AsyncGenerator when the generator function object is invoked using [[Call]].

This property has the attributes `{ [[Writable]]: true, [[Enumerable]]: false, [[Configurable]]: false }.

**NOTE** Unlike function instances, the object that is the value of an AsyncGeneratorFunction's "prototype" property does not have a "constructor" property whose value is the AsyncGeneratorFunction instance.

27.5 Generator Objects

A Generator is an instance of a generator function and conforms to both the `Iterator` and `Iterable` interfaces.

Generator instances directly inherit properties from the object that is the initial value of the "prototype" property of the Generator function that created the instance. Generator instances indirectly inherit properties from the Generator Prototype intrinsic, `%GeneratorFunction.prototype.prototype%`. 

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27.5.1 Properties of the Generator Prototype Object

The Generator prototype object:

- is %GeneratorFunction.prototype.prototype%.
- is an ordinary object.
- is not a Generator instance and does not have a [[GeneratorState]] internal slot.
- has a [[Prototype]] internal slot whose value is %IteratorPrototype%.
- has properties that are indirectly inherited by all Generator instances.

### 27.5.1.1 Generator.prototype.constructor

The initial value of `Generator.prototype.constructor` is %GeneratorFunction.prototype%.

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

### 27.5.1.2 Generator.prototype.next (value)

1. Return `GeneratorResume(this value, value, EMPTY)`.

### 27.5.1.3 Generator.prototype.return (value)

This method performs the following steps when called:

1. Let `g` be the this value.
2. Let `C` be `Completion Record` `{ [[Type]]: RETURN, [[Value]]: value, [[Target]]: EMPTY }`.
3. Return `GeneratorResumeAbrupt(g, C, EMPTY)`.

### 27.5.1.4 Generator.prototype.throw (exception)

This method performs the following steps when called:

1. Let `g` be the this value.
2. Let `C` be `ThrowCompletion(exception)`.
3. Return `GeneratorResumeAbrupt(g, C, EMPTY)`.

### 27.5.1.5 Generator.prototype [ @@toStringTag ]

The initial value of the `@@toStringTag` property is the String value "Generator".

This property has the attributes `{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

#### 27.5.2 Properties of Generator Instances

Generator instances are initially created with the internal slots described in Table 88.
Table 88: Internal Slots of Generator Instances

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[GeneratorState]]</td>
<td>undefined, SUSPENDED-START, SUSPENDED-YIELD, EXECUTING, or COMPLETED</td>
<td>The current execution state of the generator.</td>
</tr>
<tr>
<td>[[GeneratorContext]]</td>
<td>an execution context</td>
<td>The execution context that is used when executing the code of this generator.</td>
</tr>
<tr>
<td>[[GeneratorBrand]]</td>
<td>a String or EMPTY</td>
<td>A brand used to distinguish different kinds of generators. The [[GeneratorBrand]] of generators declared by ECMAScript source text is always EMPTY.</td>
</tr>
</tbody>
</table>

27.5.3 Generator Abstract Operations

27.5.3.1 GeneratorStart (generator, generatorBody)

The abstract operation GeneratorStart takes arguments generator (a Generator) and generatorBody (a FunctionBody Parse Node or an Abstract Closure with no parameters) and returns UNUSED. It performs the following steps when called:

1. Assert: The value of generator. [[GeneratorState]] is undefined.
2. Let genContext be the running execution context.
3. Set the Generator component of genContext to generator.
4. Let closure be a new Abstract Closure with no parameters that captures generatorBody and performs the following steps when called:
   a. Let acGenContext be the running execution context.
   b. Let acGenerator be the Generator component of acGenContext.
   c. If generatorBody is a Parse Node, then
      i. Let result be Completion(Evaluation of generatorBody).
   d. Else,
      i. Assert: generatorBody is an Abstract Closure with no parameters.
      ii. Let result be generatorBody().
   e. Assert: If we return here, the generator either threw an exception or performed either an implicit or explicit return.
   f. Remove acGenContext from the execution context stack and restore the execution context that is at the top of the execution context stack as the running execution context.
   g. Set acGenerator. [[GeneratorState]] to COMPLETED.
   h. NOTE: Once a generator enters the COMPLETED state it never leaves it and its associated execution context is never resumed. Any execution state associated with acGenerator can be discarded at this point.
      i. If result is a normal completion, then
         i. Let resultValue be undefined.
      j. Else if result is a return completion, then
         i. Let resultValue be result. [[Value]].
   k. Else,
      i. Assert: result is a throw completion.
      ii. Return ? result.
 l. Return CreateIterResultObject(resultValue, true).
5. Set the code evaluation state of genContext such that when evaluation is resumed for that execution context, closure will be called with no arguments.
7. Set generator. [[GeneratorState]] to SUSPENDED-START.
8. Return UNUSED.
27.5.3.2 GeneratorValidate (generator, generatorBrand)

The abstract operation GeneratorValidate takes arguments generator (an ECMAScript language value) and generatorBrand (a String or EMPTY) and returns either a normal completion containing one of SUSPENDED-START, SUSPENDED-YIELD, or COMPLETED, or a throw completion. It performs the following steps when called:

1. Perform ? RequireInternalSlot(generator, [[GeneratorState]]).
2. Perform ? RequireInternalSlot(generator, [[GeneratorBrand]]).
3. If generator.[[GeneratorBrand]] is not generatorBrand, throw a TypeError exception.
4. Assert: generator also has a [[GeneratorContext]] internal slot.
5. Let state be generator.[[GeneratorState]].
6. If state is EXECUTING, throw a TypeError exception.
7. Return state.

27.5.3.3 GeneratorResume (generator, value, generatorBrand)

The abstract operation GeneratorResume takes arguments generator (an ECMAScript language value), value (an ECMAScript language value or EMPTY), and generatorBrand (a String or EMPTY) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let state be ? GeneratorValidate(generator, generatorBrand).
2. If state is COMPLETED, return CreateIterResultObject(undefined, true).
3. Assert: state is either SUSPENDED-START or SUSPENDED-YIELD.
4. Let genContext be generator.[[GeneratorContext]].
5. Let methodContext be the running execution context.
7. Set generator.[[GeneratorState]] to EXECUTING.
8. Push genContext onto the execution context stack; genContext is now the running execution context.
9. Resume the suspended evaluation of genContext using NormalCompletion(value) as the result of the operation that suspended it. Let result be the value returned by the resumed computation.
10. Assert: When we return here, genContext has already been removed from the execution context stack and methodContext is the currently running execution context.

27.5.3.4 GeneratorResumeAbrupt (generator, abruptCompletion, generatorBrand)

The abstract operation GeneratorResumeAbrupt takes arguments generator (an ECMAScript language value), abruptCompletion (a return completion or a throw completion), and generatorBrand (a String or EMPTY) and returns either a normal completion containing an ECMAScript language value or a throw completion. It performs the following steps when called:

1. Let state be ? GeneratorValidate(generator, generatorBrand).
2. If state is SUSPENDED-START, then
   a. Set generator.[[GeneratorState]] to COMPLETED.
   b. NOTE: Once a generator enters the COMPLETED state it never leaves it and its associated execution context is never resumed. Any execution state associated with generator can be discarded at this point.
   c. Set state to COMPLETED.
3. If state is COMPLETED, then
   a. If abruptCompletion is a return completion, then
      i. Return CreateIterResultObject(abruptCompletion.[[Value]], true).
   b. Return ? abruptCompletion.
4. Assert: state is SUSPENDED-YIELD.
5. Let genContext be generator.[[GeneratorContext]].
6. Let methodContext be the running execution context.
7. Suspend methodContext.
8. Set generator.[[GeneratorState]] to EXECUTING.
9. Push genContext onto the execution context stack; genContext is now the running execution context.
10. Resume the suspended evaluation of genContext using abruptCompletion as the result of the operation that suspended it. Let result be the Completion Record returned by the resumed computation.
11. Assert: When we return here, genContext has already been removed from the execution context stack and methodContext is the currently running execution context.

27.5.3.5 GetGeneratorKind ( )

The abstract operation GetGeneratorKind takes no arguments and returns NON-GENERATOR, SYNC, or ASYNC. It performs the following steps when called:

1. Let genContext be the running execution context.
2. If genContext does not have a Generator component, return NON-GENERATOR.
3. Let generator be the Generator component of genContext.
4. If generator has an [[AsyncGeneratorState]] internal slot, return ASYNC.
5. Else, return SYNC.

27.5.3.6 GeneratorYield ( iterNextObj )

The abstract operation GeneratorYield takes argument iterNextObj (an Object that conforms to the IteratorResult interface) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. Let genContext be the running execution context.
2. Assert: genContext is the execution context of a generator.
3. Let generator be the value of the Generator component of genContext.
4. Assert: GetGeneratorKind() is SYNC.
5. Set generator.[[GeneratorState]] to SUSPENDED-YIELD.
6. Remove genContext from the execution context stack and restore the execution context that is at the top of the execution context stack as the running execution context.
7. Let callerContext be the running execution context.
8. Resume callerContext passing NormalCompletion(iterNextObj). If genContext is ever resumed again, let resumptionValue be the Completion Record with which it is resumed.
9. Assert: If control reaches here, then genContext is the running execution context again.
10. Return resumptionValue.

27.5.3.7 Yield ( value )

The abstract operation Yield takes argument value (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. Let generatorKind be GetGeneratorKind().
2. If generatorKind is ASYNC, return ? AsyncGeneratorYield(? Await(value)).
3. Otherwise, return ? GeneratorYield(CreateIterResultObject(value, false)).

27.5.3.8 CreateIteratorFromClosure ( closure, generatorBrand, generatorPrototype )

The abstract operation CreateIteratorFromClosure takes arguments closure (an Abstract Closure with no parameters), generatorBrand (a String or EMPTY), and generatorPrototype (an Object) and returns a Generator. It performs the following steps when called:

1. NOTE: closure can contain uses of the Yield operation to yield an IteratorResult object.
2. Let internalSlotsList be « [[GeneratorState]], [[GeneratorContext]], [[GeneratorBrand]] ».
3. Let generator be OrdinaryObjectCreate(generatorPrototype, internalSlotsList).
4. Set generator.[[GeneratorBrand]] to generatorBrand.
5. Set generator.[[GeneratorState]] to undefined.
6. Let callerContext be the running execution context.
7. Let calleeContext be a new execution context.
8. Set the Function of calleeContext to null.
9. Set the Realm of calleeContext to the current Realm Record.
10. Set the ScriptOrModule of calleeContext to callerContext's ScriptOrModule.
11. If calleeContext is not already suspended, suspend calleeContext.
12. Push calleeContext onto the execution context stack; calleeContext is now the running execution context.
13. Perform GeneratorStart(generator, closure).
14. Remove calleeContext from the execution context stack and restore callerContext as the running execution context.
15. Return generator.

27.6 AsyncGenerator Objects

An AsyncGenerator is an instance of an async generator function and conforms to both the AsyncIterator and AsyncIterable interfaces.

AsyncGenerator instances directly inherit properties from the object that is the initial value of the prototype property of the AsyncGenerator function that created the instance. AsyncGenerator instances indirectly inherit properties from the AsyncGenerator Prototype intrinsic, %AsyncGeneratorFunction.prototype.prototype%.

27.6.1 Properties of the AsyncGenerator Prototype Object

The AsyncGenerator prototype object:

- is %AsyncGeneratorFunction.prototype.prototype%.
- is an ordinary object.
- is not an AsyncGenerator instance and does not have an [[AsyncGeneratorState]] internal slot.
- has a [[Prototype]] internal slot whose value is %AsyncIteratorPrototype%.
- has properties that are indirectly inherited by all AsyncGenerator instances.

27.6.1.1 AsyncGenerator.prototype.constructor

The initial value of AsyncGenerator.prototype.constructor is %AsyncGeneratorFunction.prototype.prototype%.

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

27.6.1.2 AsyncGenerator.prototype.next ( value )

1. Let generator be the this value.
2. Let promiseCapability be ! NewPromiseCapability(%Promise%).
3. Let result be Completion(AsyncGeneratorValidate(generator, EMPTY)).
4. IfAbruptRejectPromise(result, promiseCapability).
5. Let state be generator.[[AsyncGeneratorState]].
6. If state is COMPLETED, then
   a. Let iteratorResult be CreateIterResultObject(undefined, true).
   b. Perform ! Call(promiseCapability.[[Resolve]], undefined, « iteratorResult »).
   c. Return promiseCapability.[[Promise]].
7. Let completion be NormalCompletion(value).
8. Perform AsyncGeneratorEnqueue(generator, completion, promiseCapability).
9. If state is either SUSPENDED-START or SUSPENDED-YIELD, then
   a. Perform AsyncGeneratorResume(generator, completion).
10. Else,
   a. Assert: state is either EXECUTING or AWAITING-RETURN.
11. Return promiseCapability.[[Promise]].
27.6.1.3 AsyncGenerator.prototype.return (value)

1. Let generator be the this value.
2. Let promiseCapability be ! NewPromiseCapability(%Promise%).
3. Let result be Completion(AsyncGeneratorValidate(generator, EMPTY)).
4. IfAbruptRejectPromise(result, promiseCapability).
5. Let completion be Completion Record { [[Type]]: RETURN, [[Value]]: value, [[Target]]: EMPTY }.
6. Perform AsyncGeneratorEnqueue(generator, completion, promiseCapability).
7. Let state be generator.[[AsyncGeneratorState]].
8. If state is either Suspended-Start or Completed, then
   a. Set generator.[[AsyncGeneratorState]] to AWAITING-RETURN.
   b. Perform ! AsyncGeneratorAwaitReturn(generator).
9. Else if state is Suspended-Yield, then
   a. Perform AsyncGeneratorResume(generator, completion).
10. Else,
    a. Assert: state is either Executing or AWAITING-RETURN.
11. Return promiseCapability.[[Promise]].

27.6.1.4 AsyncGenerator.prototype.throw (exception)

1. Let generator be the this value.
2. Let promiseCapability be ! NewPromiseCapability(%Promise%).
3. Let result be Completion(AsyncGeneratorValidate(generator, EMPTY)).
4. IfAbruptRejectPromise(result, promiseCapability).
5. Let state be generator.[[AsyncGeneratorState]].
6. If state is Suspended-Start, then
   a. Set generator.[[AsyncGeneratorState]] to COMPLETED.
   b. Set state to COMPLETED.
7. If state is Completed, then
   a. Perform ! Call(promiseCapability.[[Reject]], undefined, « exception »).
   b. Return promiseCapability.[[Promise]].
8. Let completion be ThrowCompletion(exception).
10. If state is Suspended-Yield, then
    a. Perform AsyncGeneratorResume(generator, completion).
11. Else,
    a. Assert: state is either Executing or AWAITING-RETURN.
12. Return promiseCapability.[[Promise]].

27.6.1.5 AsyncGenerator.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "AsyncGenerator".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

27.6.2 Properties of AsyncGenerator Instances

AsyncGenerator instances are initially created with the internal slots described below:
Table 89: Internal Slots of AsyncGenerator Instances

<table>
<thead>
<tr>
<th>Internal Slot</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[AsyncGeneratorState]]</td>
<td>undefined, SUSPENDED-START, SUSPENDED-</td>
<td>The current execution state of the async generator.</td>
</tr>
<tr>
<td></td>
<td>YIELD, EXECUTING, AWAITING-RETURN, or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COMPLETED</td>
<td></td>
</tr>
<tr>
<td>[[AsyncGeneratorContext]]</td>
<td>an execution context</td>
<td>The execution context that is used when executing the code of this async</td>
</tr>
<tr>
<td></td>
<td></td>
<td>generator.</td>
</tr>
<tr>
<td>[[AsyncGeneratorQueue]]</td>
<td>a List of AsyncGeneratorRequest Records</td>
<td>Records which represent requests to resume the async generator. Except during</td>
</tr>
<tr>
<td></td>
<td></td>
<td>state transitions, it is non-empty if and only if [[AsyncGeneratorState]]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is either EXECUTING or AWAITING-RETURN.</td>
</tr>
<tr>
<td>[[GeneratorBrand]]</td>
<td>a String or EMPTY</td>
<td>A brand used to distinguish different kinds of async generators. The [[</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GeneratorBrand]] of async generators declared by ECMAScript source text is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>always EMPTY.</td>
</tr>
</tbody>
</table>

27.6.3 AsyncGenerator Abstract Operations

27.6.3.1 AsyncGeneratorRequest Records

An AsyncGeneratorRequest is a Record value used to store information about how an async generator should be resumed and contains capabilities for fulfilling or rejecting the corresponding promise.

They have the following fields:

Table 90: AsyncGeneratorRequest Record Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Completion]]</td>
<td>a Completion Record</td>
<td>The Completion Record which should be used to resume the async generator.</td>
</tr>
<tr>
<td>[[Capability]]</td>
<td>a PromiseCapability Record</td>
<td>The promise capabilities associated with this request.</td>
</tr>
</tbody>
</table>

27.6.3.2 AsyncGeneratorStart ( generator, generatorBody )

The abstract operation AsyncGeneratorStart takes arguments generator (an AsyncGenerator) and generatorBody (a FunctionBody Parse Node or an Abstract Closure with no parameters) and returns UNUSED. It performs the following steps when called:

1. Assert: generator.([[AsyncGeneratorState]]) is undefined.
2. Let genContext be the running execution context.
3. Set the Generator component of genContext to generator.
4. Let closure be a new Abstract Closure with no parameters that captures generatorBody and performs the following steps when called:
   a. Let acGenContext be the running execution context.
   b. Let acGenerator be the Generator component of acGenContext.
   c. If generatorBody is a Parse Node, then
      i. Let result be Completion(Evaluation of generatorBody).
   d. Else,
27.6.3 AsyncGeneratorValidate ( generator, generatorBrand )

The abstract operation AsyncGeneratorValidate takes arguments `generator` (an ECMAScript language value) and `generatorBrand` (a String or EMPTY) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Perform ? RequireInternalSlot(generator, [[AsyncGeneratorContext]]).
2. Perform ? RequireInternalSlot(generator, [[AsyncGeneratorState]]).
3. Perform ? RequireInternalSlot(generator, [[AsyncGeneratorQueue]]).
4. If `generator`.[[GeneratorBrand]] is not `generatorBrand`, throw a TypeError exception.
5. Return UNUSED.

27.6.3.4 AsyncGeneratorEnqueue ( generator, completion, promiseCapability )

The abstract operation AsyncGeneratorEnqueue takes arguments `generator` (an AsyncGenerator), `completion` (a Completion Record), and `promiseCapability` (a PromiseCapability Record) and returns UNUSED. It performs the following steps when called:

1. Let `request` be AsyncGeneratorRequest { [[Completion]]: completion, [[Capability]]: promiseCapability }.
2. Append `request` to `generator`.[[AsyncGeneratorQueue]].
3. Return UNUSED.

27.6.3.5 AsyncGeneratorCompleteStep ( generator, completion, done [, realm ] )

The abstract operation AsyncGeneratorCompleteStep takes arguments `generator` (an AsyncGenerator), `completion` (a Completion Record), and `done` (a Boolean) and optional argument `realm` (a Realm Record) and returns UNUSED. It performs the following steps when called:

1. Assert: `generator`.[[AsyncGeneratorQueue]] is not empty.
2. Let `next` be the first element of `generator`.[[AsyncGeneratorQueue]].
3. Remove the first element from `generator`.[[AsyncGeneratorQueue]].
4. Let `promiseCapability` be `next`.[[Capability]].
5. Let `value` be completion.[[Value]].
6. If `completion` is a throw completion, then
   a. Perform ! Call(promiseCapability.[[Reject]], undefined, « value »).
7. Else,
   a. Assert: `completion` is a normal completion.
   b. If `realm` is present, then
      i. Let `oldRealm` be the running execution context's Realm.
      ii. Set the running execution context's Realm to `realm`.
   c. Set the code evaluation state of `genContext` such that when evaluation is resumed for that execution context, closure will be called with no arguments.
   d. Set `generator`.[[AsyncGeneratorContext]] to `genContext`.
   e. Set `generator`.[[AsyncGeneratorState]] to SUSPENDED-START.
   f. Set `generator`.[[AsyncGeneratorQueue]] to a new empty List.
   g. Return UNUSED.
iii. Let `iteratorResult` be `CreateIterResultObject(value, done)`.
iv. Set the running execution context's Realm to `oldRealm`.

8. Return UNUSED.

### 27.6.3.6 AsyncGeneratorResume (generator, completion)

The abstract operation `AsyncGeneratorResume` takes arguments `generator` (an AsyncGenerator) and `completion` (a Completion Record) and returns UNUSED. It performs the following steps when called:

1. **Assert:** `generator` is either SUSPENDED-START or SUSPENDED-YIELD.
2. Let `genContext` be `generator`. 
3. Let `callerContext` be the running execution context.
5. Set `generator` to EXECUTING.
6. Push `genContext` onto the execution context stack; `genContext` is now the running execution context.
7. Resume the suspended evaluation of `genContext` using `completion` as the result of the operation that suspended it. Let `result` be the Completion Record returned by the resumed computation.
8. **Assert:** `result` is never an abrupt completion.
9. **Assert:** When we return here, `genContext` has already been removed from the execution context stack and `callerContext` is the currently running execution context.
10. Return UNUSED.

### 27.6.3.7 AsyncGeneratorUnwrapYieldResumption (resumptionValue)

The abstract operation `AsyncGeneratorUnwrapYieldResumption` takes argument `resumptionValue` (a Completion Record) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. If `resumptionValue` is not a return completion, return ? `resumptionValue`.
2. Let `awaited` be `Completion(Await(resumptionValue.[[Value]])).
3. If `awaited` is a throw completion, return ? `awaited`.
4. **Assert:** `awaited` is a normal completion.
5. Return Completion Record { [[Type]]: RETURN, [[Value]]: `awaited`[[Value]], [[Target]]: EMPTY }.

### 27.6.3.8 AsyncGeneratorYield (value)

The abstract operation `AsyncGeneratorYield` takes argument `value` (an ECMAScript language value) and returns either a normal completion containing an ECMAScript language value or an abrupt completion. It performs the following steps when called:

1. Let `genContext` be the running execution context.
2. **Assert:** `genContext` is the execution context of a generator.
3. Let `generator` be the value of the Generator component of `genContext`.
4. **Assert:** `GetGeneratorKind()` is ASYNC.
5. Let `completion` be `NormalCompletion(value)`.
6. **Assert:** The execution context stack has at least two elements.
7. Let `previousContext` be the second to top element of the execution context stack.
8. Let `previousRealm` be `previousContext`'s Realm.
9. Perform `AsyncGeneratorCompleteStep(generator, completion, false, previousRealm)`.
10. Let `queue` be `generator`. 
11. If `queue` is not empty, then
a. NOTE: Execution continues without suspending the generator.
    b. Let `toYield` be the first element of `queue`.
    c. Let `resumptionValue` be `Completion(toYield.[[Completion]])`.
    d. Return `AsyncGeneratorUnwrapYieldResumption(resumptionValue)`.
12. Else,
27.6.3.9 AsyncGeneratorAwaitReturn (generator)

The abstract operation AsyncGeneratorAwaitReturn takes argument generator (an AsyncGenerator) and returns either a normal completion containing UNUSED or a throw completion. It performs the following steps when called:

1. Let queue be generator.[[AsyncGeneratorQueue]].
2. Assert: queue is not empty.
3. Let next be the first element of queue.
4. Let completion be Completion(next, [[Completion]]).
5. Assert: completion is a return completion.
6. Let promise be ? PromiseResolve(%Promise%, completion, [[Value]]).
7. Let fulfilledClosure be a new Abstract Closure with parameters (value) that captures generator and performs the following steps when called:
   a. Set generator.[[AsyncGeneratorState]] to COMPLETED.
   b. Let result be NormalCompletion(value).
   c. Perform AsyncGeneratorCompleteStep(generator, result, true).
   d. Perform AsyncGeneratorDrainQueue(generator).
   e. Return undefined.
8. Let onFulfilled be CreateBuiltInFunction(fulfilledClosure, 1, "", " »).
9. Let rejectedClosure be a new Abstract Closure with parameters (reason) that captures generator and performs the following steps when called:
   a. Set generator.[[AsyncGeneratorState]] to COMPLETED.
   b. Let result be ThrowCompletion(reason).
   c. Perform AsyncGeneratorCompleteStep(generator, result, true).
   d. Perform AsyncGeneratorDrainQueue(generator).
   e. Return undefined.
10. Let onRejected be CreateBuiltInFunction(rejectedClosure, 1, "", " »).
11. Perform PerformPromiseThen(promise, onFulfilled, onRejected).
12. Return UNUSED.

27.6.3.10 AsyncGeneratorDrainQueue (generator)

The abstract operation AsyncGeneratorDrainQueue takes argument generator (an AsyncGenerator) and returns UNUSED. It drains the generator's AsyncGeneratorQueue until it encounters an AsyncGeneratorRequest which holds a return completion. It performs the following steps when called:

1. Assert: generator.[[AsyncGeneratorState]] is COMPLETED.
2. Let queue be generator.[[AsyncGeneratorQueue]].
3. If queue is empty, return UNUSED.
4. Let done be false.
5. Repeat, while done is false,
   a. Let next be the first element of queue.
   b. Let completion be Completion(next, [[Completion]]).
   c. If completion is a return completion, then
      i. Set generator.[[AsyncGeneratorState]] to AWAITING-RETURN.
      ii. Perform ! AsyncGeneratorAwaitReturn(generator).
      iii. Set done to true.
   d. Else,
      i. If completion is a normal completion, then
         1. Set completion to NormalCompletion(undefined).
ii. Perform `AsyncGeneratorCompleteStep(generator, completion, true)`.

iii. If `queue` is empty, set `done` to `true`.

6. Return `UNUSED`.

27.6.3.11 CreateAsyncIteratorFromClosure ( `closure`, `generatorBrand`, `generatorPrototype` )

The abstract operation `CreateAsyncIteratorFromClosure` takes arguments `closure` (an `Abstract Closure` with no parameters), `generatorBrand` (a String or `EMPTY`), and `generatorPrototype` (an Object) and returns an `AsyncGenerator`. It performs the following steps when called:

1. **NOTE:** `closure` can contain uses of the `Await` operation and uses of the `Yield` operation to yield an `IteratorResult` object.

2. Let `internalSlotsList` be «[[AsyncGeneratorState]], [[AsyncGeneratorContext]], [[AsyncGeneratorQueue]], [[GeneratorBrand]]».

3. Let `generator` be `OrdinaryObjectCreate(generatorPrototype, internalSlotsList)`.

4. Set `generator.[[GeneratorBrand]]` to `generatorBrand`.

5. Set `generator.[[AsyncGeneratorState]]` to `undefined`.

6. Let `calleeContext` be the running execution context.

7. Let `calleeContext` be a new execution context.

8. Set the Function of `calleeContext` to `null`.

9. Set the Realm of `calleeContext` to the current Realm Record.

10. Set the ScriptOrModule of `calleeContext` to `calleeContext`'s ScriptOrModule.

11. If `calleeContext` is not already suspended, suspend `calleeContext`.

12. Push `calleeContext` onto the execution context stack; `calleeContext` is now the running execution context.

13. Perform `AsyncGeneratorStart(generator, closure)`.

14. Remove `calleeContext` from the execution context stack and restore `calleeContext` as the running execution context.

15. Return `generator`.

27.7 AsyncFunction Objects

AsyncFunctions are functions that are usually created by evaluating `AsyncFunctionDeclarations`, `AsyncFunctionExpressions`, `AsyncMethods`, and `AsyncArrowFunctions`. They may also be created by calling the `%AsyncFunction%` intrinsic.

27.7.1 The AsyncFunction Constructor

The AsyncFunction constructor:

- is `%AsyncFunction%`.
- is a subclass of `Function`.
- creates and initializes a new AsyncFunction when called as a function rather than as a `constructor`. Thus the function call `AsyncFunction(...)` is equivalent to the object creation expression `new AsyncFunction(...)` with the same arguments.
- may be used as the value of an `extends` clause of a class definition. Subclass constructors that intend to inherit the specified AsyncFunction behaviour must include a `super` call to the AsyncFunction constructor to create and initialize a subclass instance with the internal slots necessary for built-in async function behaviour. All ECMAScript syntactic forms for defining async function objects create direct instances of AsyncFunction. There is no syntactic means to create instances of AsyncFunction subclasses.

27.7.1.1 AsyncFunction ( `...parameterArgs, bodyArg` )

The last argument (if any) specifies the body (executable code) of an async function. Any preceding arguments specify formal parameters.

This function performs the following steps when called:
1. Let \( C \) be the active function object.
2. If \( bodyArg \) is not present, set \( bodyArg \) to the empty String.
3. Return \( ? \) \( \text{CreateDynamicFunction}(C, \text{NewTarget, ASYNC, parameterArgs, bodyArg}) \).

**NOTE** See NOTE for 20.2.1.1.

### 27.7.2 Properties of the AsyncFunction Constructor

The AsyncFunction constructor:

- is a standard built-in function object that inherits from the Function constructor.
- has a [[Prototype]] internal slot whose value is %Function%.
- has a "length" property whose value is 1.
- has a "name" property whose value is "AsyncFunction".
- has the following properties:

#### 27.7.2.1 AsyncFunction.prototype

The initial value of AsyncFunction.prototype is the AsyncFunction prototype object.

This property has the attributes \{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false \}.

### 27.7.3 Properties of the AsyncFunction Prototype Object

The AsyncFunction prototype object:

- is %AsyncFunction.prototype%.
- is an ordinary object.
- is not a function object and does not have an [[ECMAScriptCode]] internal slot or any other of the internal slots listed in Table 30.
- has a [[Prototype]] internal slot whose value is %Function.prototype%.

#### 27.7.3.1 AsyncFunction.prototype.constructor

The initial value of AsyncFunction.prototype.constructor is %AsyncFunction%.

This property has the attributes \{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true \}.

#### 27.7.3.2 AsyncFunction.prototype [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "AsyncFunction".

This property has the attributes \{ [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true \}.

### 27.7.4 AsyncFunction Instances

Every AsyncFunction instance is an ECMAScript function object and has the internal slots listed in Table 30. The value of the [[IsClassConstructor]] internal slot for all such instances is false. AsyncFunction instances are not constructors and do not have a [[Construct]] internal method. AsyncFunction instances do not have a prototype property as they are not constructible.

Each AsyncFunction instance has the following own properties:
27.7.4.1 length

The specification for the "length" property of Function instances given in 20.2.4.1 also applies to AsyncFunction instances.

27.7.4.2 name

The specification for the "name" property of Function instances given in 20.2.4.2 also applies to AsyncFunction instances.

27.7.5 Async Functions Abstract Operations

27.7.5.1 AsyncFunctionStart ( promiseCapability, asyncFunctionBody )

The abstract operation AsyncFunctionStart takes arguments promiseCapability (a PromiseCapability Record) and asyncFunctionBody (a FunctionBody Parse Node or an ExpressionBody Parse Node) and returns UNUSED. It performs the following steps when called:

1. Let runningContext be the running execution context.
2. Let asyncContext be a copy of runningContext.
3. NOTE: Copying the execution state is required for AsyncBlockStart to resume its execution. It is ill-defined to resume a currently executing context.
5. Return UNUSED.

27.7.5.2 AsyncBlockStart ( promiseCapability, asyncBody, asyncContext )

The abstract operation AsyncBlockStart takes arguments promiseCapability (a PromiseCapability Record), asyncBody (a Parse Node), and asyncContext (an execution context) and returns UNUSED. It performs the following steps when called:

1. Assert: promiseCapability is a PromiseCapability Record.
2. Let runningContext be the running execution context.
3. Let closure be a new Abstract Closure with no parameters that captures promiseCapability and asyncBody and performs the following steps when called:
   a. Let acAsyncContext be the running execution context.
   b. Let result be Completion(Evaluation of asyncBody).
   c. Assert: If we return here, the async function either threw an exception or performed an implicit or explicit return; all awaiting is done.
   d. Remove acAsyncContext from the execution context stack and restore the execution context that is at the top of the execution context stack as the running execution context.
   e. If result is a normal completion, then
      i. Perform ! Call(promiseCapability.[[Resolve]], undefined, « undefined »).
   f. Else if result is a return completion, then
      i. Perform ! Call(promiseCapability.[[Resolve]], undefined, « result.[[Value]] »).
   g. Else,
      i. Assert: result is a throw completion.
      ii. Perform ! Call(promiseCapability.[[Reject]], undefined, « result.[[Value]] »).
   h. Return UNUSED.
4. Set the code evaluation state of asyncContext such that when evaluation is resumed for that execution context, closure will be called with no arguments.
5. Push asyncContext onto the execution context stack; asyncContext is now the running execution context.
6. Resume the suspended evaluation of asyncContext. Let result be the value returned by the resumed computation.
7. Assert: When we return here, asyncContext has already been removed from the execution context stack and runningContext is the currently running execution context.
8. **Assert**: result is a normal completion with a value of UNUSED. The possible sources of this value are Await or, if the async function doesn't await anything, step 3.h above.

9. Return UNUSED.

### 27.7.5.3 Await (value)

The abstract operation Await takes argument value (an ECMAScript language value) and returns either a normal completion containing either an ECMAScript language value or EMPTY, or a throw completion. It performs the following steps when called:

1. Let asyncContext be the running execution context.
2. Let promise be ? PromiseResolve(%Promise%, value).
3. Let fulfilledClosure be a new Abstract Closure with parameters (v) that captures asyncContext and performs the following steps when called:
   a. Let prevContext be the running execution context.
   b. Suspend prevContext.
   c. Push asyncContext onto the execution context stack; asyncContext is now the running execution context.
   d. Resume the suspended evaluation of asyncContext using NormalCompletion(v) as the result of the operation that suspended it.
   e. **Assert**: When we reach this step, asyncContext has already been removed from the execution context stack and prevContext is the currently running execution context.
   f. Return undefined.

4. Let onFulfilled be CreateBuiltinFunction(fulfilledClosure, 1, "", « »).
5. Let rejectedClosure be a new Abstract Closure with parameters (reason) that captures asyncContext and performs the following steps when called:
   a. Let prevContext be the running execution context.
   b. Suspend prevContext.
   c. Push asyncContext onto the execution context stack; asyncContext is now the running execution context.
   d. Resume the suspended evaluation of asyncContext using ThrowCompletion(reason) as the result of the operation that suspended it.
   e. **Assert**: When we reach this step, asyncContext has already been removed from the execution context stack and prevContext is the currently running execution context.
   f. Return undefined.

6. Let onRejected be CreateBuiltinFunction(rejectedClosure, 1, "", « »).
7. Perform PerformPromiseThen(promise, onFulfilled, onRejected).
8. Remove asyncContext from the execution context stack and restore the execution context that is at the top of the execution context stack as the running execution context.
9. Let callerContext be the running execution context.
10. Resume callerContext passing EMPTY. If asyncContext is ever resumed again, let completion be the Completion Record with which it is resumed.
11. **Assert**: If control reaches here, then asyncContext is the running execution context again.
12. Return completion.

### 28 Reflection

#### 28.1 The Reflect Object

The Reflect object:

- is %Reflect%.
- is the initial value of the "Reflect" property of the global object.
- is an ordinary object.
- has a [[Prototype]] internal slot whose value is %Object.prototype%.
- is not a function object.
- does not have a [[Construct]] internal method; it cannot be used as a constructor with the new operator.
- does not have a [[Call]] internal method; it cannot be invoked as a function.
28.1.1 Reflect.apply (target, thisArgument, argumentsList)

This function performs the following steps when called:

1. If IsCallable(target) is false, throw a TypeError exception.
2. Let args be ? CreateListFromArrayLike(argumentsList).
3. Perform PrepareForTailCall().
4. Return ? Call(target, thisArgument, args).

28.1.2 Reflect.construct (target, argumentsList [, newTarget ])

This function performs the following steps when called:

1. If IsConstructor(target) is false, throw a TypeError exception.
2. If newTarget is not present, set newTarget to target.
3. Else if IsConstructor(newTarget) is false, throw a TypeError exception.
4. Let args be ? CreateListFromArrayLike(argumentsList).

28.1.3 Reflect.defineProperty (target, propertyKey, attributes)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let key be ? ToPropertyKey(propertyKey).
3. Let desc be ? ToPropertyDescriptor(attributes).
4. Return ? target.[[DefineOwnProperty]](key, desc).

28.1.4 Reflect.deleteProperty (target, propertyKey)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let key be ? ToPropertyKey(propertyKey).

28.1.5 Reflect.get (target, propertyKey [, receiver ])

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let key be ? ToPropertyKey(propertyKey).
3. If receiver is not present, then
   a. Set receiver to target.

28.1.6 Reflect.getOwnPropertyDescriptor (target, propertyKey)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let key be ? ToPropertyKey(propertyKey).
3. Let desc be ? target.[[GetOwnProperty]](key).
4. Return FromPropertyDescriptor(desc).
28.1.7 Reflect.getPrototypeOf (target)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Return ? target.[[GetPrototypeOf]]().

28.1.8 Reflect.has (target, propertyKey)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let key be ? ToPropertyKey(propertyKey).

28.1.9 Reflect.isExtensible (target)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Return ? target.[[IsExtensible]]().

28.1.10 Reflect.ownKeys (target)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let keys be ? target.[[OwnPropertyKeys]]().
3. Return CreateArrayFromList(keys).

28.1.11 Reflect.preventExtensions (target)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Return ? target.[[PreventExtensions]]().

28.1.12 Reflect.set (target, propertyKey, V [ , receiver ])

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. Let key be ? ToPropertyKey(propertyKey).
3. If receiver is not present, then
   a. Set receiver to target.

28.1.13 Reflect.setPrototypeOf (target, proto)

This function performs the following steps when called:

1. If target is not an Object, throw a TypeError exception.
2. If proto is not an Object and proto is not null, throw a TypeError exception.
28.1.14 Reflect [ @@toStringTag ]

The initial value of the @@toStringTag property is the String value "Reflect".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: true }.

28.2 Proxy Objects

28.2.1 The Proxy Constructor

The Proxy constructor:

- is %Proxy%.
- is the initial value of the "Proxy" property of the global object.
- creates and initializes a new Proxy object when called as a constructor.
- is not intended to be called as a function and will throw an exception when called in that manner.

28.2.1.1 Proxy ( target, handler )

This function performs the following steps when called:

1. If NewTarget is undefined, throw a TypeError exception.

28.2.2 Properties of the Proxy Constructor

The Proxy constructor:

- has a [[Prototype]] internal slot whose value is %Function.prototype%.
- does not have a "prototype" property because Proxy objects do not have a [[Prototype]] internal slot that requires initialization.
- has the following properties:

28.2.2.1 Proxy.revocable ( target, handler )

This function creates a revocable Proxy object.

It performs the following steps when called:

1. Let proxy be ? ProxyCreate(target, handler).
2. Let revokerClosure be a new Abstract Closure with no parameters that captures nothing and performs the following steps when called:
   a. Let F be the active function object.
   b. Let p be F.[[RevocableProxy]].
   c. If p is null, return undefined.
   d. Set F.[[RevocableProxy]] to null.
   e. Assert: p is a Proxy exotic object.
   f. Set p.[[ProxyTarget]] to null.
   g. Set p.[[ProxyHandler]] to null.
   h. Return undefined.
3. Let revoker be CreateBuiltInFunction(revokerClosure, 0, "", « [[RevocableProxy]] »).
4. Set revoker.[[RevocableProxy]] to proxy.
5. Let result be OrdinaryObjectCreate(%Object.prototype%).
6. Perform ! CreateDataPropertyOrThrow(result, "proxy", proxy).
7. Perform ! CreateDataPropertyOrThrow(result, "revoke", revoker).
8. Return result.
28.3 Module Namespace Objects

A Module Namespace Object is a module namespace exotic object that provides runtime property-based access to a module's exported bindings. There is no constructor function for Module Namespace Objects. Instead, such an object is created for each module that is imported by an ImportDeclaration that contains a NameSpaceImport.

In addition to the properties specified in 10.4.6 each Module Namespace Object has the following own property:

28.3.1 @@toStringTag

The initial value of the @@toStringTag property is the String value "Module".

This property has the attributes { [[Writable]]: false, [[Enumerable]]: false, [[Configurable]]: false }.

29 Memory Model

The memory consistency model, or memory model, specifies the possible orderings of Shared Data Block events, arising via accessing TypedArray instances backed by a SharedArrayBuffer and via methods on the Atomics object. When the program has no data races (defined below), the ordering of events appears as sequentially consistent, i.e., an interleaving of actions from each agent. When the program has data races, shared memory operations may appear sequentially inconsistent. For example, programs may exhibit causality-violating behaviour and other astonishments. These astonishments arise from compiler transforms and the design of CPUs (e.g., out-of-order execution and speculation). The memory model defines both the precise conditions under which a program exhibits sequentially consistent behaviour as well as the possible values read from data races. To wit, there is no undefined behaviour.

The memory model is defined as relational constraints on events introduced by abstract operations on SharedArrayBuffer or by methods on the Atomics object during an evaluation.

NOTE This section provides an axiomatic model on events introduced by the abstract operations on SharedArrayBuffers. It bears stressing that the model is not expressible algorithmically, unlike the rest of this specification. The nondeterministic introduction of events by abstract operations is the interface between the operational semantics of ECMAScript evaluation and the axiomatic semantics of the memory model. The semantics of these events is defined by considering graphs of all events in an evaluation. These are neither Static Semantics nor Runtime Semantics. There is no demonstrated algorithmic implementation, but instead a set of constraints that determine if a particular event graph is allowed or disallowed.

29.1 Memory Model Fundamentals

Shared memory accesses (reads and writes) are divided into two groups, atomic accesses and data accesses, defined below. Atomic accesses are sequentially consistent, i.e., there is a strict total ordering of events agreed upon by all agents in an agent cluster. Non-atomic accesses do not have a strict total ordering agreed upon by all agents, i.e., unordered.

NOTE 1 No orderings weaker than sequentially consistent and stronger than unordered, such as release-acquire, are supported.

A Shared Data Block event is either a ReadSharedMemory, WriteSharedMemory, or ReadModifyWriteShared-Memory Record.
### Table 91: ReadSharedMemory Event Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Order]]</td>
<td>SEQ-CST or UNORDERED</td>
<td>The weakest ordering guaranteed by the memory model for the event.</td>
</tr>
<tr>
<td>[[NoTear]]</td>
<td>a Boolean</td>
<td>Whether this event is allowed to read from multiple write events with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>equal range as this event.</td>
</tr>
<tr>
<td>[[Block]]</td>
<td>a Shared Data Block</td>
<td>The block the event operates on.</td>
</tr>
<tr>
<td>[[ByteIndex]]</td>
<td>a non-negative integer</td>
<td>The byte address of the read in [[Block]].</td>
</tr>
<tr>
<td>[[ElementSize]]</td>
<td>a non-negative integer</td>
<td>The size of the read.</td>
</tr>
</tbody>
</table>

### Table 92: WriteSharedMemory Event Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Order]]</td>
<td>SEQ-CST, UNORDERED, or INIT</td>
<td>The weakest ordering guaranteed by the memory model for the event.</td>
</tr>
<tr>
<td>[[NoTear]]</td>
<td>a Boolean</td>
<td>Whether this event is allowed to be read from multiple read events with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>equal range as this event.</td>
</tr>
<tr>
<td>[[Block]]</td>
<td>a Shared Data Block</td>
<td>The block the event operates on.</td>
</tr>
<tr>
<td>[[ByteIndex]]</td>
<td>a non-negative integer</td>
<td>The byte address of the write in [[Block]].</td>
</tr>
<tr>
<td>[[ElementSize]]</td>
<td>a non-negative integer</td>
<td>The size of the write.</td>
</tr>
<tr>
<td>[[Payload]]</td>
<td>a List of byte values</td>
<td>The List of byte values to be read by other events.</td>
</tr>
</tbody>
</table>

### Table 93: ReadModifyWriteSharedMemory Event Fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[Order]]</td>
<td>SEQ-CST</td>
<td>Read-modify-write events are always sequentially consistent.</td>
</tr>
<tr>
<td>[[NoTear]]</td>
<td>true</td>
<td>Read-modify-write events cannot tear.</td>
</tr>
<tr>
<td>[[Block]]</td>
<td>a Shared Data Block</td>
<td>The block the event operates on.</td>
</tr>
<tr>
<td>[[ByteIndex]]</td>
<td>a non-negative integer</td>
<td>The byte address of the read-modify-write in [[Block]].</td>
</tr>
<tr>
<td>[[ElementSize]]</td>
<td>a non-negative integer</td>
<td>The size of the read-modify-write.</td>
</tr>
<tr>
<td>[[Payload]]</td>
<td>a List of byte values</td>
<td>The List of byte values to be passed to [[ModifyOp]].</td>
</tr>
<tr>
<td>[[ModifyOp]]</td>
<td>a read-modify-write modification function</td>
<td>An abstract closure that returns a modified List of byte values from a read List of byte values and [[Payload]].</td>
</tr>
</tbody>
</table>

These events are introduced by abstract operations or by methods on the Atomics object.

Some operations may also introduce Synchronize events. A Synchronize event has no fields, and exists purely to directly constrain the permitted orderings of other events.
In addition to **Shared Data Block** and Synchronize events, there are **host**-specific events.

Let the range of a ReadSharedMemory, WriteSharedMemory, or ReadModifyWriteSharedMemory event be the Set of contiguous **integers** from its $[[\text{ByteIndex}]]$ to $[[\text{ByteIndex}]] + [[\text{ElementSize}]] - 1$. Two events’ ranges are equal when the events have the same $[[\text{Block}]]$, and the ranges are element-wise equal. Two events’ ranges are overlapping when the events have the same $[[\text{Block}]]$, the ranges are not equal and their intersection is non-empty. Two events’ ranges are disjoint when the events do not have the same $[[\text{Block}]]$ or their ranges are neither equal nor overlapping.

**NOTE 2** Examples of host-specific synchronizing events that should be accounted for are: sending a SharedArrayBuffer from one agent to another (e.g., by `postMessage` in a browser), starting and stopping agents, and communicating within the agent cluster via channels other than shared memory. It is assumed those events are appended to agent-order during evaluation like the other SharedArrayBuffer events.

Events are ordered within **candidate executions** by the relations defined below.

### 29.2 Agent Events Records

An **Agent Events Record** is a **Record** with the following fields.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[[\text{AgentSignifier}]]$</td>
<td>an agent signifier</td>
<td>The agent whose evaluation resulted in this ordering.</td>
</tr>
<tr>
<td>$[[\text{EventList}]]$</td>
<td>a List of events</td>
<td>Events are appended to the list during evaluation.</td>
</tr>
<tr>
<td>$[[\text{AgentSynchronizesWith}]]$</td>
<td>a List of pairs of Synchronize events</td>
<td>Synchronize relationships introduced by the operational semantics.</td>
</tr>
</tbody>
</table>

### 29.3 Chosen Value Records

A **Chosen Value Record** is a **Record** with the following fields.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[[\text{Event}]]$</td>
<td>a Shared Data Block event</td>
<td>The ReadSharedMemory or ReadModifyWriteSharedMemory event that was introduced for this chosen value.</td>
</tr>
<tr>
<td>$[[\text{ChosenValue}]]$</td>
<td>a List of byte values</td>
<td>The bytes that were nondeterministically chosen during evaluation.</td>
</tr>
</tbody>
</table>
29.4 Candidate Executions

A candidate execution of the evaluation of an agent cluster is a Record with the following fields.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[[EventsRecords]]</td>
<td>a List of Agent Events Records</td>
<td>Maps an agent to Lists of events appended during the evaluation.</td>
</tr>
<tr>
<td>[[ChosenValues]]</td>
<td>a List of Chosen Value Records</td>
<td>Maps ReadSharedMemory or ReadModifyWriteSharedMemory events to the List of byte values chosen during the evaluation.</td>
</tr>
<tr>
<td>[[AgentOrder]]</td>
<td>an agent-order Relation</td>
<td>Defined below.</td>
</tr>
<tr>
<td>[[ReadsBytesFrom]]</td>
<td>a reads-bytes-from mathematical function</td>
<td>Defined below.</td>
</tr>
<tr>
<td>[[ReadsFrom]]</td>
<td>a reads-from Relation</td>
<td>Defined below.</td>
</tr>
<tr>
<td>[[HostSynchronizesWith]]</td>
<td>a host-synchronizes-with Relation</td>
<td>Defined below.</td>
</tr>
<tr>
<td>[[SynchronizesWith]]</td>
<td>a synchronizes-with Relation</td>
<td>Defined below.</td>
</tr>
<tr>
<td>[[HappensBefore]]</td>
<td>a happens-before Relation</td>
<td>Defined below.</td>
</tr>
</tbody>
</table>

An empty candidate execution is a candidate execution Record whose fields are empty Lists and Relations.

29.5 Abstract Operations for the Memory Model

29.5.1 EventSet (execution)

The abstract operation EventSet takes argument execution (a candidate execution) and returns a Set of events. It performs the following steps when called:

1. Let events be an empty Set.
2. For each Agent Events Record aer of execution.[[EventsRecords]], do
   a. For each event $E$ of aer.[[EventList]], do
      i. Add $E$ to events.
3. Return events.
29.5.2 SharedDataBlockEventSet (execution)

The abstract operation SharedDataBlockEventSet takes argument execution (a candidate execution) and returns a Set of events. It performs the following steps when called:

1. Let events be an empty Set.
2. For each event $E$ of EventSet(execution), do
   a. If $E$ is a ReadSharedMemory, WriteSharedMemory, or ReadModifyWriteSharedMemory event, add $E$ to events.
3. Return events.

29.5.3 HostEventSet (execution)

The abstract operation HostEventSet takes argument execution (a candidate execution) and returns a Set of events. It performs the following steps when called:

1. Let events be an empty Set.
2. For each event $E$ of EventSet(execution), do
   a. If $E$ is not in SharedDataBlockEventSet(execution), add $E$ to events.
3. Return events.

29.5.4 ComposeWriteEventBytes (execution, byteIndex, Ws)

The abstract operation ComposeWriteEventBytes takes arguments execution (a candidate execution), byteIndex (a non-negative integer), and Ws (a List of either WriteSharedMemory or ReadModifyWriteSharedMemory events) and returns a List of byte values. It performs the following steps when called:

1. Let byteLocation be byteIndex.
2. Let bytesRead be a new empty List.
3. For each element $W$ of Ws, do
   a. Assert: $W$ has byteLocation in its range.
   b. Let payloadIndex be byteLocation - $W$.[[ByteIndex]].
   c. If $W$ is a WriteSharedMemory event, then
      i. Let byte be $W$.[[Payload]][[payloadIndex]].
   d. Else,
      i. Assert: $W$ is a ReadModifyWriteSharedMemory event.
      ii. Let bytes be ValueOfReadEvent(execution, $W$).
      iii. Let bytesModified be $W$.[[ModifyOp]](bytes, $W$.[[Payload]]).
      iv. Let byte be bytesModified[payloadIndex].
   e. Append byte to bytesRead.
   f. Set byteLocation to byteLocation + 1.
4. Return bytesRead.

NOTE 1 The read-modify-write modification [[ModifyOp]] is given by the function properties on the Atomics object that introduce ReadModifyWriteSharedMemory events.

NOTE 2 This abstract operation composes a List of write events into a List of byte values. It is used in the event semantics of ReadSharedMemory and ReadModifyWriteSharedMemory events.
29.5.5 ValueOfReadEvent (execution, R)

The abstract operation ValueOfReadEvent takes arguments execution (a candidate execution) and R (a ReadSharedMemory or ReadModifyWriteSharedMemory event) and returns a List of byte values. It performs the following steps when called:

1. Let Ws be execution.[[ReadsBytesFrom]](R).
2. Assert: Ws is a List of WriteSharedMemory or ReadModifyWriteSharedMemory events with length equal to R.[[ElementSize]].
3. Return ComposeWriteEventBytes(execution, R.[[ByteIndex]], Ws).

29.6 Relations of Candidate Executions

29.6.1 agent-order

For a candidate execution execution, execution.[[AgentOrder]] is a Relation on events that satisfies the following.

- For each pair (E, D) in EventSet(execution), execution.[[AgentOrder]] contains (E, D) if there is some Agent Events Record aer in execution.[[EventsRecords]] such that E and D are in aer.[[EventList]] and E is before D in List order of aer.[[EventList]].

**NOTE** Each agent introduces events in a per-agent strict total order during the evaluation. This is the union of those strict total orders.

29.6.2 reads-bytes-from

For a candidate execution execution, execution.[[ReadsBytesFrom]] is a mathematical function mapping events in SharedDataBlockEventSet(execution) to Lists of events in SharedDataBlockEventSet(execution) that satisfies the following conditions.

- For each ReadSharedMemory or ReadModifyWriteSharedMemory event R in SharedDataBlockEventSet(execution), execution.[[ReadsBytesFrom]](R) is a List of length R.[[ElementSize]] whose elements are WriteSharedMemory or ReadModifyWriteSharedMemory events Ws such that all of the following are true.
  - Each event W with index i in Ws has R.[[ByteIndex]] + i in its range.
  - R is not in Ws.

29.6.3 reads-from

For a candidate execution execution, execution.[[ReadsFrom]] is the least Relation on events that satisfies the following.

- For each pair (R, W) in SharedDataBlockEventSet(execution), execution.[[ReadsFrom]] contains (R, W) if execution.[[ReadsBytesFrom]](R) contains W.

29.6.4 host-synchronizes-with

For a candidate execution execution, execution.[[HostSynchronizesWith]] is a host-provided strict partial order on host-specific events that satisfies at least the following.

- If execution.[[HostSynchronizesWith]] contains (E, D), E and D are in HostEventSet(execution).
- There is no cycle in the union of execution.[[HostSynchronizesWith]] and execution.[[AgentOrder]].

**NOTE 1** For two host-specific events E and D, E host-synchronizes-with D implies E happens-before D.
29.6.5 synchronizes-with

For a candidate execution `execution`, `execution`.[[SynchronizesWith]] is the least Relation on events that satisfies the following.

- For each pair `(R, W)` in `execution`.[[ReadsFrom]], `execution`.[[SynchronizesWith]] contains `(W, R)` if `R`.[[Order]] is SEQ-CST, `W`.[[Order]] is SEQ-CST, and `R` and `W` have equal ranges.
- For each event `eventsRecord` of `execution`.[[EventsRecords]], the following is true.
  - For each pair `(S, Sw)` in `eventsRecord`.[[AgentSynchronizesWith]], `execution`.[[SynchronizesWith]] contains `(S, Sw)`.
  - For each pair `(E, D)` in `execution`.[[HostSynchronizesWith]], `execution`.[[SynchronizesWith]] contains `(E, D)`.

29.6.6 happens-before

For a candidate execution `execution`, `execution`.[[HappensBefore]] is the least Relation on events that satisfies the following.

- For each pair `(E, D)` in `execution`.[[AgentOrder]], `execution`.[[HappensBefore]] contains `(E, D)`.
- For each pair `(E, D)` in `execution`.[[SynchronizesWith]], `execution`.[[HappensBefore]] contains `(E, D)`.
- For each pair `(E, D)` in `SharedDataBlockEventSet(execution)`, `execution`.[[HappensBefore]] contains `(E, D)` if `E`.[[Order]] is INIT and `E` and `D` have overlapping ranges.
- For each pair `(E, D)` in `EventSet(execution)`, `execution`.[[HappensBefore]] contains `(E, D)` if there is an event `F` such that the pairs `(E, F)` and `(F, D)` are in `execution`.[[HappensBefore]].

Because happens-before is a superset of agent-order, candidate executions are consistent with the single-thread evaluation semantics of ECMAScript.

29.7 Properties of Valid Executions

29.7.1 Valid Chosen Reads

A candidate execution `execution` has valid chosen reads if the following algorithm returns true.

1. For each `ReadSharedMemory` or `ReadModifyWriteSharedMemory` event `R` of `SharedDataBlockEventSet(execution)`, do
   a. Let `chosenValueRecord` be the element of `execution`.[[ChosenValues]] whose `[[Event]]` field is `R`. 

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b. Let chosenValue be chosenValueRecord.[[ChosenValue]].
c. Let readValue be ValueOfReadEvent(execution, R).
d. Let chosenLen be the number of elements in chosenValue.
e. Let readLen be the number of elements in readValue.
f. If chosenLen ≠ readLen, then
   i. Return false.
g. If chosenValue[i] ≠ readValue[i] for some integer i in the interval from 0 (inclusive) to chosenLen (exclusive), then
   i. Return false.
2. Return true.

29.7.2 Coherent Reads

A candidate execution execution has coherent reads if the following algorithm returns true.

1. For each ReadSharedMemory or ReadModifyWriteSharedMemory event R of SharedDataBlockEventSet(execution), do
   a. Let Ws be execution.[[ReadsBytesFrom]](R).
   b. Let byteLocation be R.[[ByteIndex]].
   c. For each element W of Ws, do
      i. If execution.[[HappensBefore]] contains (R, W), then
         1. Return false.
      ii. If there exists a WriteSharedMemory or ReadModifyWriteSharedMemory event V that has byteLocation in its range such that the pairs (W, V) and (V, R) are in execution.[[HappensBefore]], then
         1. Return false.
      iii. Set byteLocation to byteLocation + 1.
2. Return true.

29.7.3 Tear Free Reads

A candidate execution execution has tear free reads if the following algorithm returns true.

1. For each ReadSharedMemory or ReadModifyWriteSharedMemory event R of SharedDataBlockEventSet(execution), do
   a. If R.[[NoTear]] is true, then
      i. Assert: The remainder of dividing R.[[ByteIndex]] by R.[[ElementSize]] is 0.
      ii. For each event W such that execution.[[ReadsFrom]] contains (R, W) and W.[[NoTear]] is true, do
         1. If R and W have equal ranges and there exists an event V such that V and W have equal ranges, V.[[NoTear]] is true, W is not V, and execution.[[ReadsFrom]] contains (R, V), then
            a. Return false.
   2. Return true.

NOTE An event’s [[NoTear]] field is true when that event was introduced via accessing an integer TypedArray, and false when introduced via accessing a floating point TypedArray or DataView.

Intuitively, this requirement says when a memory range is accessed in an aligned fashion via an integer TypedArray, a single write event on that range must "win" when in a data race with other write events with equal ranges. More precisely, this requirement says an aligned read event cannot read a value composed of bytes from multiple, different write events all with equal ranges. It is possible, however, for an aligned read event to read from multiple write events with overlapping ranges.
29.7.4 Sequentially Consistent Atomics

For a candidate execution execution, memory-order is a strict total order of all events in EventSet(execution) that satisfies the following.

- For each pair \((E, D)\) in execution.[[HappensBefore]], \((E, D)\) is in memory-order.
- For each pair \((R, W)\) in execution.[[ReadsFrom]], there is no WriteSharedMemory or ReadModifyWriteSharedMemory event \(V\) in SharedDataBlockEventSet(execution) such that \(V.[[Order]]\) is SEQ-CST, the pairs \((W, V)\) and \((V, R)\) are in memory-order, and any of the following conditions are true.
  - The pairs \((W, R)\) and \((V, R)\) are in execution.[[HappensBefore]], \(W.[[Order]]\) is SEQ-CST, and \(W\) and \(V\) have equal ranges.
  - The pairs \((W, R)\) and \((W, V)\) are in execution.[[HappensBefore]], \(R.[[Order]]\) is SEQ-CST, and \(V\) and \(R\) have equal ranges.

NOTE 1 This clause additionally constrains SEQ-CST events on equal ranges.

- For each WriteSharedMemory or ReadModifyWriteSharedMemory event \(W\) in SharedDataBlockEventSet(execution), if \(W.[[Order]]\) is SEQ-CST, then it is not the case that there is an infinite number of ReadSharedMemory or ReadModifyWriteSharedMemory events in SharedDataBlockEventSet(execution) with equal range that is memory-order before \(W\).

NOTE 2 This clause together with the forward progress guarantee on agents ensure the liveness condition that SEQ-CST writes become visible to SEQ-CST reads with equal range in finite time.

A candidate execution has sequentially consistent atomics if a memory-order exists.

NOTE 3 While memory-order includes all events in EventSet(execution), those that are not constrained by happens-before or synchronizes-with are allowed to occur anywhere in the order.

29.7.5 Valid Executions

A candidate execution execution is a valid execution (or simply an execution) if all of the following are true.

- The host provides a host-synchronizes-with Relation for execution.[[HostSynchronizesWith]].
- execution.[[HappensBefore]] is a strict partial order.
- execution has valid chosen reads.
- execution has coherent reads.
- execution has tear free reads.
- execution has sequentially consistent atomics.

All programs have at least one valid execution.

29.8 Races

For an execution execution, two events \(E\) and \(D\) in SharedDataBlockEventSet(execution) are in a race if the following algorithm returns true.

1. If \(E\) is not \(D\), then
   a. If the pairs \((E, D)\) and \((D, E)\) are not in execution.[[HappensBefore]], then
i. If \( E \) and \( D \) are both \( \text{WriteSharedMemory} \) or \( \text{ReadModifyWriteSharedMemory} \) events and \( E \) and \( D \) do not have disjoint ranges, then
   1. Return \text{true}.

ii. If \( \text{execution}.[[\text{ReadsFrom}]] \) contains either \((E, D)\) or \((D, E)\), then
   1. Return \text{true}.

2. Return \text{false}.

### 29.9 Data Races

For an execution \( \text{execution} \), two events \( E \) and \( D \) in \( \text{SharedDataBlockEventSet}(\text{execution}) \) are in a data race if the following algorithm returns \text{true}.

1. If \( E \) and \( D \) are in a race in \( \text{execution} \), then
   a. If \( E.\text{[[Order]]} \) is not SEQ-CST or \( D.\text{[[Order]]} \) is not SEQ-CST, then
      i. Return \text{true}.
   b. If \( E \) and \( D \) have overlapping ranges, then
      i. Return \text{true}.
2. Return \text{false}.

### 29.10 Data Race Freedom

An execution \( \text{execution} \) is data race free if there are no two events in \( \text{SharedDataBlockEventSet}(\text{execution}) \) that are in a data race.

A program is data race free if all its executions are data race free.

The memory model guarantees sequential consistency of all events for data race free programs.

### 29.11 Shared Memory Guidelines

**NOTE 1** The following are guidelines for ECMAScript programmers working with shared memory.

We recommend programs be kept data race free, i.e., make it so that it is impossible for there to be concurrent non-atomic operations on the same memory location. Data race free programs have interleaving semantics where each step in the evaluation semantics of each agent are interleaved with each other. For data race free programs, it is not necessary to understand the details of the memory model. The details are unlikely to build intuition that will help one to better write ECMAScript.

More generally, even if a program is not data race free it may have predictable behaviour, so long as atomic operations are not involved in any data races and the operations that race all have the same access size. The simplest way to arrange for atomics not to be involved in races is to ensure that different memory cells are used by atomic and non-atomic operations and that atomic accesses of different sizes are not used to access the same cells at the same time. Effectively, the program should treat shared memory as strongly typed as much as possible. One still cannot depend on the ordering and timing of non-atomic accesses that race, but if memory is treated as strongly typed the racing accesses will not "tear" (bits of their values will not be mixed).

**NOTE 2** The following are guidelines for ECMAScript implementers writing compiler transformations for programs using shared memory.
It is desirable to allow most program transformations that are valid in a single-agent setting in a multi-agent setting, to ensure that the performance of each agent in a multi-agent program is as good as it would be in a single-agent setting. Frequently these transformations are hard to judge. We outline some rules about program transformations that are intended to be taken as normative (in that they are implied by the memory model or stronger than what the memory model implies) but which are likely not exhaustive. These rules are intended to apply to program transformations that precede the introductions of the events that make up the agent-order.

Let an agent-order slice be the subset of the agent-order pertaining to a single agent.

Let possible read values of a read event be the set of all values of ValueOfReadEvent for that event across all valid executions.

Any transformation of an agent-order slice that is valid in the absence of shared memory is valid in the presence of shared memory, with the following exceptions.

• **Atoms are carved in stone:** Program transformations must not cause the SEQ-CST events in an agent-order slice to be reordered with its UNORDERED operations, nor its SEQ-CST operations to be reordered with each other, nor may a program transformation remove a SEQ-CST operation from the agent-order.

  (In practice, the prohibition on reorderings forces a compiler to assume that every SEQ-CST operation is a synchronization and included in the final memory-order, which it would usually have to assume anyway in the absence of inter-agent program analysis. It also forces the compiler to assume that every call where the callee’s effects on the memory-order are unknown may contain SEQ-CST operations.)

• **Reads must be stable:** Any given shared memory read must only observe a single value in an execution.

  (For example, if what is semantically a single read in the program is executed multiple times then the program is subsequently allowed to observe only one of the values read. A transformation known as rematerialization can violate this rule.)

• **Writes must be stable:** All observable writes to shared memory must follow from program semantics in an execution.

  (For example, a transformation may not introduce certain observable writes, such as by using read-modify-write operations on a larger location to write a smaller datum, writing a value to memory that the program could not have written, or writing a just-read value back to the location it was read from, if that location could have been overwritten by another agent after the read.)

• **Possible read values must be non-empty:** Program transformations cannot cause the possible read values of a shared memory read to become empty.

  (Counterintuitively, this rule in effect restricts transformations on writes, because writes have force in memory model insofar as to be read by read events. For example, writes may be moved and coalesced and sometimes reordered between two SEQ-CST operations, but the transformation may not remove every write that updates a location; some write must be preserved.)

Examples of transformations that remain valid are: merging multiple non-atomic reads from the same location, reordering non-atomic reads, introducing speculative non-atomic reads, merging multiple non-atomic writes to the same location, reordering non-atomic writes to different locations, and hoisting non-atomic reads out of loops even if that affects termination. Note in general that aliased TypedArrays make it hard to prove that locations are different.
NOTE 3 The following are guidelines for ECMAScript implementers generating machine code for shared memory accesses.

For architectures with memory models no weaker than those of ARM or Power, non-atomic stores and loads may be compiled to bare stores and loads on the target architecture. Atomic stores and loads may be compiled down to instructions that guarantee sequential consistency. If no such instructions exist, memory barriers are to be employed, such as placing barriers on both sides of a bare store or load. Read-modify-write operations may be compiled to read-modify-write instructions on the target architecture, such as LOCK-prefixed instructions on x86, load-exclusive/store-exclusive instructions on ARM, and load-link/store-conditional instructions on Power.

Specifically, the memory model is intended to allow code generation as follows.

• Every atomic operation in the program is assumed to be necessary.
• Atomic operations are never rearranged with each other or with non-atomic operations.
• Functions are always assumed to perform atomic operations.
• Atomic operations are never implemented as read-modify-write operations on larger data, but as non-lock-free atomics if the platform does not have atomic operations of the appropriate size. (We already assume that every platform has normal memory access operations of every interesting size.)

Naive code generation uses these patterns:

• Regular loads and stores compile to single load and store instructions.
• Lock-free atomic loads and stores compile to a full (sequentially consistent) fence, a regular load or store, and a full fence.
• Lock-free atomic read-modify-write accesses compile to a full fence, an atomic read-modify-write instruction sequence, and a full fence.
• Non-lock-free atomics compile to a spinlock acquire, a full fence, a series of non-atomic load and store instructions, a full fence, and a spinlock release.

That mapping is correct so long as an atomic operation on an address range does not race with a non-atomic write or with an atomic operation of different size. However, that is all we need: the memory model effectively demotes the atomic operations involved in a race to non-atomic status. On the other hand, the naive mapping is quite strong: it allows atomic operations to be used as sequentially consistent fences, which the memory model does not actually guarantee.

Local improvements to those basic patterns are also allowed, subject to the constraints of the memory model. For example:

• There are obvious platform-dependent improvements that remove redundant fences. For example, on x86 the fences around lock-free atomic loads and stores can always be omitted except for the fence following a store, and no fence is needed for lock-free read-modify-write instructions, as these all use LOCK-prefixed instructions. On many platforms there are fences of several strengths, and weaker fences can be used in certain contexts without destroying sequential consistency.
• Most modern platforms support lock-free atomics for all the data sizes required by ECMAScript atomics. Should non-lock-free atomics be needed, the fences surrounding the body of the atomic operation can usually be folded into the lock and unlock steps. The simplest solution for non-lock-free atomics is to have a single lock word per SharedArrayBuffer.
• There are also more complicated platform-dependent local improvements, requiring some code analysis. For example, two back-to-back fences often have the same effect as a single fence, so if code is generated for two atomic operations in sequence, only a single fence needs to separate them. On x86, even a single fence separating atomic stores can be omitted, as the fence following a store is only needed to separate the store from a subsequent load.
A.1 Lexical Grammar

SourceCharacter ::
    any Unicode code point

InputElementDiv ::
    WhiteSpace
    LineTerminator
    Comment
    CommonToken
    DivPunctuator
    RightBracePunctuator

InputElementRegExp ::
    WhiteSpace
    LineTerminator
    Comment
    CommonToken
    RightBracePunctuator
    RegularExpressionLiteral

InputElementRegExpOrTemplateTail ::
    WhiteSpace
    LineTerminator
    Comment
    CommonToken
    RegularExpressionLiteral
    TemplateSubstitutionTail

InputElementTemplateTail ::
    WhiteSpace
    LineTerminator
    Comment
    CommonToken
    DivPunctuator
    TemplateSubstitutionTail

InputElementHashbangOrRegExp ::
    WhiteSpace
    LineTerminator
    Comment
    CommonToken
    HashbangComment
    RegularExpressionLiteral

WhiteSpace ::
    <TAB>
    <VT>
    <FF>
    <ZWNBSP>
    <USP>
LineTerminator ::
  <LF>
  <CR>
  <LS>
  <PS>

LineTerminatorSequence ::
  <LF>
  <CR> [lookahead ≠ <LF>]
  <LS>
  <PS>
  <CR> <LF>

Comment ::
  MultiLineComment
  SingleLineComment

MultiLineComment ::
  /* MultiLineCommentChars opt */

MultiLineCommentChars ::
  MultiLineNotAsteriskChar MultiLineCommentChars opt
  * PostAsteriskCommentChars opt

PostAsteriskCommentChars ::
  MultiLineNotForwardSlashOrAsteriskChar MultiLineCommentChars opt
  * PostAsteriskCommentChars opt

MultiLineNotAsteriskChar ::
  SourceCharacter but not *

MultiLineNotForwardSlashOrAsteriskChar ::
  SourceCharacter but not one of / or *

SingleLineComment ::
  // SingleLineCommentChars opt

SingleLineCommentChars ::
  SingleLineCommentChar SingleLineCommentChars opt

SingleLineCommentChar ::
  SourceCharacter but not LineTerminator

HashbangComment ::
  #! SingleLineCommentChars opt

CommonToken ::
  IdentifierName
  PrivateIdentifier
  Punctuator
  NumericLiteral
  StringLiteral
  Template

PrivateIdentifier ::
  # IdentifierName

IdentifierName ::
  IdentifierStart
  IdentifierName IdentifierPart

IdentifierStart ::
  IdentifierStartChar
  \ UnicodeEscapeSequence

IdentifierPart ::
  IdentifierPartChar
  \ UnicodeEscapeSequence
IdentifierStartChar ::
    UnicodeIDStart
    $

IdentifierPartChar ::
    UnicodeIDContinue
    $
    <ZWNJ>
    <ZWJ>
AsciiLetter :: one of
    a b c d e f g h i j k l m n o p q r s t u v w x y z
    A B C D E F G H I J K L M N
    O P Q R S T U V W X Y Z
UnicodeIDStart ::
    any Unicode code point with the Unicode property “ID_Start”
UnicodeIDContinue ::
    any Unicode code point with the Unicode property “ID_Continue”
ReservedWord :: one of
    await break case catch class const continue debugger default delete do else enum export extends false finally for function if import instanceof new null return super switch this throw true try typeof var void while with yield
Punctuator ::
    OptionalChainingPunctuator
    OtherPunctuator
OptionalChainingPunctuator ::
    ?. [lookahead $ DecimalDigit]
OtherPunctuator :: one of
    { ( ) [ ] . . . ; , < > <= == !== !== + * % ** -- << >> >>> & | ^ !
DivPunctuator ::
    /
    /=
RightBracePunctuator ::
    }
NullLiteral ::
    null
BooleanLiteral ::
    true
    false
NumericLiteralSeparator ::

NumericalLiteral ::
    DecimalLiteral
    DecimalBigIntegerLiteral
    NonDecimalIntegerLiteral[+Sep]
    NonDecimalIntegerLiteral[+Sep] BigIntLiteralSuffix
    LegacyOctalIntegerLiteral
DecimaBigIntegerLiteral ::
    0 BigIntLiteralSuffix
    NonZeroDigit DecimalDigits[+Sep] opt BigIntLiteralSuffix
    NonZeroDigit NumericLiteralSeparator DecimalDigits[+Sep] BigIntLiteralSuffix

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NonDecimalIntegerLiteral[Sep] ::
  BinaryIntegerLiteral[?Sep]
  OctalIntegerLiteral[?Sep]
  HexIntegerLiteral[?Sep]

BigIntLiteralSuffix ::
  n

DecimalLiteral ::
  DecimalIntegerLiteral . DecimalDigits[+Sep] opt ExponentPart[+Sep] opt
  . DecimalDigits[+Sep] ExponentPart[+Sep] opt
  DecimalIntegerLiteral ExponentPart[+Sep] opt

DecimalIntegerLiteral ::
  0
  NonZeroDigit
  NonZeroDigit NumericLiteralSeparatoropt DecimalDigits[+Sep]
  NonOctalDecimalIntegerLiteral

DecimalDigits[Sep] ::
  DecimalDigit
  DecimalDigits[?Sep] DecimalDigit
  [+Sep] DecimalDigits[+Sep] NumericLiteralSeparator DecimalDigit

DecimalDigit :: one of
  0 1 2 3 4 5 6 7 8 9

NonZeroDigit :: one of
  1 2 3 4 5 6 7 8 9

ExponentPart[Sep] ::
  ExponentIndicator SignedInteger[?Sep]

ExponentIndicator :: one of
  e E

SignedInteger[Sep] ::
  DecimalDigits[?Sep]
  + DecimalDigits[?Sep]
  - DecimalDigits[?Sep]

BinaryIntegerLiteral[Sep] ::
  0b BinaryDigits[?Sep]
  0B BinaryDigits[?Sep]

BinaryDigits[Sep] ::
  BinaryDigit
  BinaryDigits[?Sep] BinaryDigit
  [+Sep] BinaryDigits[+Sep] NumericLiteralSeparator BinaryDigit

BinaryDigit :: one of
  0 1

OctalIntegerLiteral[Sep] ::
  0o OctalDigits[?Sep]
  0O OctalDigits[?Sep]

OctalDigits[Sep] ::
  OctalDigit
  OctalDigits[?Sep] OctalDigit
  [+Sep] OctalDigits[+Sep] NumericLiteralSeparator OctalDigit

LegacyOctalIntegerLiteral ::
  0 OctalDigit
  LegacyOctalIntegerLiteral OctalDigit
NonOctalDecimalIntegerLiteral ::
  0 NonOctalDigit
  LegacyOctalLikeDecimalIntegerLiteral NonOctalDigit
  NonOctalDecimalIntegerLiteral DecimalDigit

LegacyOctalLikeDecimalIntegerLiteral ::
  0 OctalDigit
  LegacyOctalLikeDecimalIntegerLiteral OctalDigit

OctalDigit :: one of
  0 1 2 3 4 5 6 7

NonOctalDigit :: one of
  8 9

HexIntegerLiteral[Sep] ::
  0x HexDigits[?Sep]
  0X HexDigits[?Sep]

HexDigits[Sep] ::
  HexDigit
  HexDigits[?Sep] HexDigit
  [+Sep] HexDigits[+Sep] NumericLiteralSeparator HexDigit

HexDigit :: one of
  0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F

StringLiteral ::
  " DoubleStringCharacters<opt> "
  ' SingleStringCharacters<opt> '

DoubleStringCharacters ::
  DoubleStringCharacter DoubleStringCharacters<opt>

SingleStringCharacters ::
  SingleStringCharacter SingleStringCharacters<opt>

DoubleStringCharacter ::
  SourceCharacter but not one of " or \ or LineTerminator
  <LS>
  <PS>
  \ EscapeSequence
  LineContinuation

SingleStringCharacter ::
  SourceCharacter but not one of ' or \ or LineTerminator
  <LS>
  <PS>
  \ EscapeSequence
  LineContinuation

LineContinuation ::
  \ LineTerminatorSequence

EscapeSequence ::
  CharacterEscapeSequence
  0 [lookahead ≠ DecimalDigit]
  LegacyOctalEscapeSequence
  NonOctalDecimalEscapeSequence
  HexEscapeSequence
  UnicodeEscapeSequence

CharacterEscapeSequence ::
  SingleEscapeCharacter
  NonEscapeCharacter

SingleEscapeCharacter :: one of
  " \ b f n r t v
NonEscapeCharacter ::
SourceCharacter but not one of EscapeCharacter or LineTerminator

EscapeCharacter ::
SingleEscapeCharacter
DecimalDigit x u

LegacyOctalEscapeSequence ::
\0 [lookahead ∈ { 8 , 9 }]
NonZeroOctalDigit [lookahead ∈ OctalDigit]
ZeroToThree OctalDigit [lookahead ∈ OctalDigit]
FourToSeven OctalDigit
ZeroToThree OctalDigit OctalDigit

NonZeroOctalDigit ::
OctalDigit but not \0

ZeroToThree :: one of
\0 1 2 3

FourToSeven :: one of
4 5 6 7

NonOctalDecimalEscapeSequence :: one of
8 9

HexEscapeSequence ::
x HexDigit HexDigit

UnicodeEscapeSequence ::
u Hex4Digits
u{ CodePoint }

Hex4Digits ::
HexDigit HexDigit HexDigit HexDigit

RegularExpressionLiteral ::
/ RegularExpressionBody / RegularExpressionFlags

RegularExpressionBody ::
RegularExpressionFirstChar RegularExpressionChars

RegularExpressionChars ::
[empty]
RegularExpressionChars RegularExpressionChar

RegularExpressionFirstChar ::
RegularExpressionNonTerminator but not one of * or \ or / or [
RegularExpressionBackslashSequence
RegularExpressionClass

RegularExpressionChar ::
RegularExpressionNonTerminator but not one of \ or / or [
RegularExpressionBackslashSequence
RegularExpressionClass

RegularExpressionBackslashSequence ::
\ RegularExpressionNonTerminator

RegularExpressionNonTerminator ::
SourceCharacter but not LineTerminator

RegularExpressionClass ::
[ RegularExpressionClassChars ]

RegularExpressionClassChars ::
[empty]
RegularExpressionClassChars RegularExpressionClassChar
RegularExpressionClassChar ::
  RegularExpressionNon Terminator but not one of ] or \  
RegularExpressionBackslashSequence
RegularExpressionFlags ::
  [empty]
  RegularExpressionFlags IdentifierPartChar
Template ::
  NoSubstitutionTemplate
  TemplateHead
NoSubstitutionTemplate ::
  ` TemplateCharacters opt `
TemplateHead ::
  ` TemplateCharacters opt ${}
TemplateSubstitutionTail ::
  TemplateMiddle
  TemplateTail
TemplateMiddle ::
  } TemplateCharacters opt ${}
TemplateTail ::
  } TemplateCharacters opt `
TemplateCharacters ::
  TemplateCharacter TemplateCharacters opt
TemplateCharacter ::
  $ [lookahead ≠ {} ]
  \ TemplateEscapeSequence
  \ NotEscapeSequence
  LineContinuation
  LineTerminatorSequence
  SourceCharacter but not one of ` or \ or $ or LineTerminator
TemplateEscapeSequence ::
  CharacterEscapeSequence
  0 [lookahead ∈ DecimalDigit]
  HexEscapeSequence
  UnicodeEscapeSequence
NotEscapeSequence ::
  0 DecimalDigit
  DecimalDigit but not 0
  x [lookahead ≠ HexDigit]
  x HexDigit [lookahead ∈ HexDigit]
  u [lookahead ≠ HexDigit ] [lookahead ≠ {} ]
  u HexDigit [lookahead ∈ HexDigit]
  u HexDigit HexDigit [lookahead ∈ HexDigit]
  u HexDigit HexDigit HexDigit [lookahead ∈ HexDigit]
  u {} [lookahead ∈ HexDigit]
  u {} NotCodePoint [lookahead ∈ HexDigit]
  u {} CodePoint [lookahead ∈ HexDigit ] [lookahead ≠ {} ]
NotCodePoint ::
  HexDigits [-Sep] but only if MV of HexDigits > 0x10FFFF
CodePoint ::
  HexDigits [-Sep] but only if MV of HexDigits ≤ 0x10FFFF
A.2 Expressions

IdentifierReference[Yield, Await] :
   Identifier
   [-Yield] yield
   [-Await] await

BindingIdentifier[Yield, Await] :
   Identifier
   yield
   await

LabelIdentifier[Yield, Await] :
   Identifier
   [-Yield] yield
   [-Await] await

Identifier :
   IdentifierName but not ReservedWord

PrimaryExpression[Yield, Await] :
   this
   IdentifierReference[?Yield, ?Await]
   Literal
   ArrayLiteral[?Yield, ?Await]
   ObjectLiteral[?Yield, ?Await]
   FunctionExpression
   ClassExpression[?Yield, ?Await]
   GeneratorExpression
   AsyncFunctionExpression
   AsyncGeneratorExpression
   RegularExpressionLiteral
   TemplateLiteral[?Yield, ?Await, ~Tagged]
   CoverParenthesizedExpressionAndArrowParameterList[?Yield, ?Await]

CoverParenthesizedExpressionAndArrowParameterList[Yield, Await] :
   ( Expression[+In, ?Yield, ?Await] )
   ( Expression[+In, ?Yield, ?Await], )
   ()
   ( ... BindingIdentifier[?Yield, ?Await] )
   ( ... BindingPattern[?Yield, ?Await] )
   ( Expression[+In, ?Yield, ?Await], ... BindingIdentifier[?Yield, ?Await] )
   ( Expression[+In, ?Yield, ?Await], ... BindingPattern[?Yield, ?Await] )

When processing an instance of the production

PrimaryExpression[Yield, Await] :

CoverParenthesizedExpressionAndArrowParameterList[?Yield, ?Await]

the interpretation of CoverParenthesizedExpressionAndArrowParameterList is refined using the following grammar:

ParenthesizedExpression[Yield, Await] :
   ( Expression[+In, ?Yield, ?Await] )
Literal:
  NullLiteral
  BooleanLiteral
  NumericLiteral
  StringLiteral

ArrayLiteral[Yield, Await] :
  [ Elisionopt ]
  [ ElementList[Yield, Await] ]
  [ ElementList[Yield, Await], Elisionopt ]

ElementList[Yield, Await] :
  Elisionopt AssignmentExpression [+In, Yield, Await]
  Elisionopt SpreadElement[Yield, Await]
  ElementList[Yield, Await], Elisionopt AssignmentExpression [+In, Yield, Await]
  ElementList[Yield, Await], Elisionopt SpreadElement[Yield, Await]

Elision:
  ,
  Elision,

SpreadElement[Yield, Await] :
  ... AssignmentExpression [+In, Yield, Await]

ObjectLiteral[Yield, Await] :
  { }
  { PropertyDefinitionList[Yield, Await] }
  { PropertyDefinitionList[Yield, Await], }

PropertyDefinitionList[Yield, Await] :
  PropertyDefinition[Yield, Await]
  PropertyDefinitionList[Yield, Await], PropertyDefinition[Yield, Await]

PropertyDefinition[Yield, Await] :
  IdentifierReference[Yield, Await]
  CoverInitializedName[Yield, Await]
  PropertyName[Yield, Await] : AssignmentExpression [+In, Yield, Await]
  MethodDefinition[Yield, Await]
  ... AssignmentExpression [+In, Yield, Await]

PropertyName[Yield, Await] :
  LiteralPropertyName
  ComputedPropertyName[Yield, Await]

LiteralPropertyName :
  IdentifierName
  StringLiteral
  NumericLiteral

ComputedPropertyName[Yield, Await] :
  [ AssignmentExpression [+In, Yield, Await] ]

CoverInitializedName[Yield, Await] :
  IdentifierReference[Yield, Await] Initializer [+In, Yield, Await]

Initializer[In, Yield, Await] :
  = AssignmentExpression [In, Yield, Await]

TemplateLiteral[Yield, Await, Tagged] :
  NoSubstitutionTemplate
  SubstitutionTemplate[Yield, Await, Tagged]

SubstitutionTemplate[Yield, Await, Tagged] :
  TemplateHead Expression [+In, Yield, Await] TemplateSpans[Yield, Await, Tagged]
When processing an instance of the production

\[ \text{CallExpression}[	ext{Yield, Await}] : \text{CoverCallExpressionAndAsyncArrowHead}[	ext{Yield, Await}] \]

the interpretation of \text{CoverCallExpressionAndAsyncArrowHead} is refined using the following grammar:

\[ \text{CallMemberExpression}[	ext{Yield, Await}] : \text{MemberExpression}[	ext{Yield, Await}] \text{ Arguments}[	ext{Yield, Await}] \]

\[ \text{SuperCall}[	ext{Yield, Await}] \]

\[ \text{ImportCall}[	ext{Yield, Await}] : \text{import } ( \text{AssignmentExpression} [+ \text{In}, \text{Yield}, \text{Await}] ) \]
Arguments [Yield, Await] :

( )
( ArgumentList [Yield, Await] )
( ArgumentList [Yield, Await] , )

ArgumentList [Yield, Await] :
AssignmentExpression [+In, Yield, Await]
... AssignmentExpression [+In, Yield, Await]
ArgumentList [Yield, Await], AssignmentExpression [+In, Yield, Await]
ArgumentList [Yield, Await], ...

OptionalExpression [Yield, Await] :
MemberExpression [Yield, Await] OptionalChain [Yield, Await]
CallExpression [Yield, Await] OptionalChain [Yield, Await]
OptionalExpression [Yield, Await] OptionalChain [Yield, Await]

OptionalChain [Yield, Await] :
?. Arguments [Yield, Await]
?. [ Expression [+In, Yield, Await] ]
?. IdentifierName
?. TemplateLiteral [Yield, Await, +Tagged]
?. PrivateIdentifier

OptionalChain [Yield, Await] Arguments [Yield, Await]
OptionalChain [Yield, Await] [ Expression [+In, Yield, Await] ]
OptionalChain [Yield, Await] IdentifierName
OptionalChain [Yield, Await] TemplateLiteral [Yield, Await, +Tagged]
OptionalChain [Yield, Await] PrivateIdentifier

LeftHandSideExpression [Yield, Await] :
NewExpression [Yield, Await]
CallExpression [Yield, Await]
OptionalExpression [Yield, Await]

UpdateExpression [Yield, Await] :
LeftHandSideExpression [Yield, Await]
LeftHandSideExpression [Yield, Await] [no LineTerminator here] ++
LeftHandSideExpression [Yield, Await] [no LineTerminator here] --
++ UnaryExpression [Yield, Await]
-- UnaryExpression [Yield, Await]

UnaryExpression [Yield, Await] :
UpdateExpression [Yield, Await]
delete UnaryExpression [Yield, Await]
void UnaryExpression [Yield, Await]
typeof UnaryExpression [Yield, Await]
+ UnaryExpression [Yield, Await]
- UnaryExpression [Yield, Await]
~ UnaryExpression [Yield, Await]
! UnaryExpression [Yield, Await]
[+Await] AwaitExpression [Yield]

ExponentiationExpression [Yield, Await] :
UnaryExpression [Yield, Await]
UpdateExpression [Yield, Await] ★★ ExponentiationExpression [Yield, Await]
"MultiplicativeExpression" [Yield, Await] :
  ExponentiationExpression [?Yield, ?Await]
  MultiplicativeExpression [?Yield, ?Await]  MultiplicativeOperator
  ExponentiationExpression [?Yield, ?Await]

"MultiplicativeOperator" : one of
  * / %

"AdditiveExpression" [Yield, Await] :
  MultiplicativeExpression [?Yield, ?Await]

"ShiftExpression" [Yield, Await] :
  AdditiveExpression [?Yield, ?Await]

"RelationalExpression" [In, Yield, Await] :
  ShiftExpression [?Yield, ?Await]
  [+In] PrivateIdentifier in ShiftExpression [?Yield, ?Await]

"EqualityExpression" [In, Yield, Await] :
  RelationalExpression [?In, ?Yield, ?Await]

"BitwiseANDExpression" [In, Yield, Await] :
  EqualityExpression [?In, ?Yield, ?Await]

"BitwiseXORExpression" [In, Yield, Await] :
  BitwiseANDExpression [?In, ?Yield, ?Await]

"BitwiseORExpression" [In, Yield, Await] :
  BitwiseXORExpression [?In, ?Yield, ?Await]

"LogicalANDExpression" [In, Yield, Await] :
  BitwiseORExpression [?In, ?Yield, ?Await]

"LogicalORExpression" [In, Yield, Await] :
  LogicalANDExpression [?In, ?Yield, ?Await]
  LogicalANDExpression [?In, ?Yield, ?Await] | LogicalANDExpression [?In, ?Yield, ?Await]

"CoalesceExpression" [In, Yield, Await] :
  CoalesceExpressionHead [?In, ?Yield, ?Await]
  BitwiseORExpression [?In, ?Yield, ?Await]

"CoalesceExpressionHead" [In, Yield, Await] :
  CoalesceExpression [?In, ?Yield, ?Await]
  BitwiseORExpression [?In, ?Yield, ?Await]

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In certain circumstances when processing an instance of the production
the interpretation of LeftHandSideExpression is refined using the following grammar:

AssignmentPattern: [Yield, Await] :

ObjectAssignmentPattern: [Yield, Await] :

ArrayAssignmentPattern: [Yield, Await] :
... DestructuringAssignmentTarget: [?Yield, ?Await]
AssignmentPropertyList: [Yield, Await] :
AssignmentElementList: [Yield, Await] :
AssignmentElisionElement: [Yield, Await] :
Elision opt AssignmentElement: [?Yield, ?Await]
AssignmentProperty: [Yield, Await] :
AssignmentElement[Yield, Await] :
AssignmentRestElement[Yield, Await] :
  ... DestructuringAssignmentTarget[Yield, ?Await]
DestructuringAssignmentTarget[Yield, Await] :
  LeftHandSideExpression[Yield, ?Await]

Expression[In, Yield, Await] :
  AssignmentExpression[In, Yield, ?Await]
  Expression[In, Yield, ?Await] , AssignmentExpression[In, Yield, ?Await]

A.3 Statements
Statement[Yield, Await, Return] :
  BlockStatement[Yield, ?Await, Return]
  VariableStatement[Yield, Await]
  EmptyStatement
  ExpressionStatement[Yield, Await]
  IfStatement[Yield, ?Await, Return]
  BreakableStatement[Yield, ?Await, Return]
  ContinueStatement[Yield, ?Await]
  BreakStatement[Yield, ?Await]
  WithStatement[Yield, ?Await, Return]
  LabeledStatement[Yield, ?Await, Return]
  ThrowStatement[Yield, ?Await]
  TryStatement[Yield, ?Await, Return]
  DebuggerStatement
Declaration[Yield, Await] :
  HoistableDeclaration[Yield, ?Await, ~Default]
  ClassDeclaration[Yield, ?Await, ~Default]
  LexicalDeclaration[In, Yield, ?Await]
HoistableDeclaration[Yield, Await, Default] :
  FunctionDeclaration[Yield, ?Await, Default]
  GeneratorDeclaration[Yield, ?Await, Default]
  AsyncFunctionDeclaration[Yield, ?Await, Default]
  AsyncGeneratorDeclaration[Yield, ?Await, Default]
BreakableStatement[Yield, Await, Return] :
  IterationStatement[Yield, ?Await, Return]
  SwitchStatement[Yield, ?Await, Return]
BlockStatement[Yield, Await, Return] :
  Block[Yield, ?Await, Return]
Block[Yield, Await, Return] :
  { StatementList[Yield, ?Await, Return] opt }
StatementList[Yield, Await, Return] :
  StatementListItem[Yield, ?Await, Return]
  StatementList[Yield, ?Await, Return]
  StatementListItem[Yield, ?Await, Return]
StatementListItem[Yield, Await, Return] :
  Statement[Yield, ?Await, Return]
Declaration[Yield, ?Await]
LetOrConst BindingList[?In, ?Yield, ?Await] ;

let const

BindingList[In, Yield, Await] :
  LexicalBinding[?In, ?Yield, ?Await]

LexicalBinding[In, Yield, Await] :

VariableStatement[Yield, Await] :
  var VariableDeclarationList[?In, ?Yield, ?Await] ;

VariableDeclarationList[In, Yield, Await] :
  VariableDeclaration[?In, ?Yield, ?Await]

VariableDeclaration[In, Yield, Await] :

BindingPattern[Yield, Await] :
  ObjectBindingPattern[?Yield, ?Await]
  ArrayBindingPattern[?Yield, ?Await]

ObjectBindingPattern[Yield, Await] :
  { }
  { BindingRestProperty[?Yield, ?Await] }
  { BindingPropertyList[?Yield, ?Await] }

ArrayBindingPattern[Yield, Await] :
  [ Elision opt BindingRestElement[?Yield, ?Await] opt ]

BindingRestProperty[Yield, Await] :
  ... BindingIdentifier[?Yield, ?Await]

BindingPropertyList[Yield, Await] :
  BindingProperty[?Yield, ?Await]

BindingElementList[Yield, Await] :
  BindingElisionElement[?Yield, ?Await]

BindingElisionElement[Yield, Await] :
  Elision opt BindingElement[?Yield, ?Await]

BindingProperty[Yield, Await] :
  SingleNameBinding[?Yield, ?Await]

BindingElement[Yield, Await] :
  SingleNameBinding[?Yield, ?Await]

SingleNameBinding[Yield, Await] :
BindingRestElement[Yield, Await] :
  ... BindingIdentifier[Yield, Await]
  ... BindingPattern[Yield, Await]

EmptyStatement :
  ;

ExpressionStatement[Yield, Await] :
  [lookahead \notin \{ [], function, async [no LineTerminator here] function, class, let [] \}]
  Expression[+In, Yield, Await]

IfStatement[Yield, Await, Return] :
  if ( Expression[+In, Yield, Await] ) Statement[Yield, Await, Return] else
  if ( Expression[+In, Yield, Await] ) Statement[Yield, Await, Return] [lookahead \neq]

IterationStatement[Yield, Await, Return] :
  DoWhileStatement[Yield, Await, Return]
  WhileStatement[Yield, Await, Return]
  ForStatement[Yield, Await, Return]
  ForInOfStatement[Yield, Await, Return]

DoWhileStatement[Yield, Await, Return] :
  do Statement[Yield, Await, Return] while ( Expression[+In, Yield, Await] )

WhileStatement[Yield, Await, Return] :
  while ( Expression[+In, Yield, Await] ) Statement[Yield, Await, Return]

ForStatement[Yield, Await, Return] :
  for ( [lookahead \neq let []] Expression[-In, Yield, Await] opt ;
  Expression[+In, Yield, Await] opt ;
  Expression[+In, Yield, Await] opt )
  Statement[Yield, Await, Return]

  for ( var VariableDeclarationList[-In, Yield, Await] ;
  Expression[+In, Yield, Await] opt ;
  Expression[+In, Yield, Await] opt )
  Statement[Yield, Await, Return]

  for ( LexicalDeclaration[-In, Yield, Await] Expression[+In, Yield, Await] opt ;
  Expression[+In, Yield, Await] opt )
  Statement[Yield, Await, Return]

ForInOfStatement[Yield, Await, Return] :
  for ( [lookahead \neq let []] LeftHandSideExpression[Yield, Await] in
  Expression[+In, Yield, Await] ) Statement[Yield, Await, Return]

  for ( var ForBinding[Yield, Await] in Expression[+In, Yield, Await] )
  Statement[Yield, Await, Return]

  for ( ForDeclaration[Yield, Await] in Expression[+In, Yield, Await] )
  Statement[Yield, Await, Return]

  for ( [lookahead \neq \{ let, async of \}] LeftHandSideExpression[Yield, Await] of
  AssignmentExpression[+In, Yield, Await] ) Statement[Yield, Await, Return]

  for ( var ForBinding[Yield, Await] of AssignmentExpression[+In, Yield, Await] )
  Statement[Yield, Await, Return]

  for ( ForDeclaration[Yield, Await] of AssignmentExpression[+In, Yield, Await] )
  Statement[Yield, Await, Return]

  [+Await] for await ( [lookahead \neq let] LeftHandSideExpression[Yield, Await] of
  AssignmentExpression[+In, Yield, Await] ) Statement[Yield, Await, Return]

  [+Await] for await ( var ForBinding[Yield, Await] of
  AssignmentExpression[+In, Yield, Await] ) Statement[Yield, Await, Return]

  [+Await] for await ( ForDeclaration[Yield, Await] of
  AssignmentExpression[+In, Yield, Await] ) Statement[Yield, Await, Return]

ForDeclaration[Yield, Await] :
  LetOrConst ForBinding[Yield, Await]
ForBinding: [Yield, Await] :
  BindingIdentifier: [Yield, Await]
  BindingPattern: [Yield, Await]
ContinueStatement: [Yield, Await] :
  continue;
  continue [no LineTerminator here] LabelIdentifier: [Yield, Await];
BreakStatement: [Yield, Await] :
  break;
  break [no LineTerminator here] LabelIdentifier: [Yield, Await];
ReturnStatement: [Yield, Await] :
  return;
  return [no LineTerminator here] Expression: [+In, Yield, Await];
WithStatement: [Yield, Await, Return] :
  with (Expression: [+In, Yield, Await]) Statement: [Yield, Await, Return]
SwitchStatement: [Yield, Await, Return] :
  switch (Expression: [+In, Yield, Await]) CaseBlock: [Yield, Await, Return]
CaseBlock: [Yield, Await, Return] :
  { CaseClauses: [Yield, Await, Return] opt }
  { CaseClauses: [Yield, Await, Return] opt DefaultClause: [Yield, Await, Return]
    CaseClauses: [Yield, Await, Return] opt }
CaseClauses: [Yield, Await, Return] :
  CaseClause: [Yield, Await, Return]
  CaseClauses: [Yield, Await, Return] CaseClause: [Yield, Await, Return]
CaseClause: [Yield, Await, Return] :
  case Expression: [+In, Yield, Await] : StatementList: [Yield, Await, Return] opt
DefaultClause: [Yield, Await, Return] :
  default : StatementList: [Yield, Await, Return] opt
LabelledStatement: [Yield, Await, Return] :
  LabelIdentifier: [Yield, Await] : LabelledItem: [Yield, Await, Return]
LabelledItem: [Yield, Await, Return] :
  Statement: [Yield, Await, Return]
  FunctionDeclaration: [Yield, Await, ~Default]
ThrowStatement: [Yield, Await, Return] :
  throw [no LineTerminator here] Expression: [+In, Yield, Await];
TryStatement: [Yield, Await, Return] :
  try Block: [Yield, Await, Return] Catch: [Yield, Await, Return]
  try Block: [Yield, Await, Return] Finally: [Yield, Await, Return]
  try Block: [Yield, Await, Return] Catch: [Yield, Await, Return]
  Finally: [Yield, Await, Return]
Catch: [Yield, Await, Return] :
  catch (CatchParameter: [Yield, Await]) Block: [Yield, Await, Return]
  catch Block: [Yield, Await, Return]
Finally: [Yield, Await, Return] :
  finally Block: [Yield, Await, Return]
CatchParameter: [Yield, Await] :
  BindingIdentifier: [Yield, Await]
  BindingPattern: [Yield, Await]
DebuggerStatement :
  debugger;
A.4 Functions and Classes

UniqueFormalParameters[Yield, Await] :
  FormalParameters[Yield, ?Await]
FormalParameters[Yield, Await] :
  [empty]
  FunctionRestParameter[Yield, Await]
  FormalParameterList[Yield, Await],
  FormalParameterList[Yield, Await],
  FunctionRestParameter[Yield, Await]
FormalParameterList[Yield, Await] :
  FormalParameter[Yield, ?Await]
  FunctionRestParameterList[Yield, Await],
  FormalParameterList[Yield, Await],
  FormalParameterList[Yield, Await]
FunctionRestParameter[Yield, Await] :
  BindingRestElement[Yield, ?Await]
FormalParameter[Yield, Await] :
  BindingElement[Yield, ?Await]
FunctionDeclaration[Yield, Await, Default] :
  function BindingIdentifier[Yield, Await] ( FormalParameters[~Yield, ~Await] ) {
    FunctionBody[~Yield, ~Await] }
  [+Default] function ( FormalParameters[~Yield, ~Await] ) { FunctionBody[~Yield, ~Await] }
FunctionExpression :
  function BindingIdentifier[~Yield, ~Await] opt ( FormalParameters[~Yield, ~Await] ) {
    FunctionBody[~Yield, ~Await] }
FunctionBody[Yield, Await] :
  FunctionStatementList[Yield, ?Await]
FunctionStatementList[Yield, Await] :
  StatementList[Yield, ?Await, +Return] opt
ArrowFunction[In, Yield, Await] :
  ArrowParameters[Yield, ?Await] [no LineTerminator here] => ConciseBody[?In]
ArrowParameters[Yield, Await] :
  BindingIdentifier[Yield, Await]
  CoverParenthesizedExpressionAndArrowParameterList[Yield, ?Await]
ConciseBody[In] :
  [lookahead ≠ ] ExpressionBody[?In, ~Await]
  { FunctionBody[~Yield, ~Await] }
ExpressionBody[In, Await] :
  AssignmentExpression[?In, ~Yield, ?Await]

When processing an instance of the production
ArrowParameters[Yield, Await] :
CoverParenthesizedExpressionAndArrowParameterList[Yield, ?Await]
the interpretation of CoverParenthesizedExpressionAndArrowParameterList is refined using the following grammar:

ArrowFormalParameters[Yield, Await] :
  ( UniqueFormalParameters[Yield, ?Await] )
When processing an instance of the production

AsyncArrowFunction\[[In, Yield, Await]\] : CoverCallExpressionAndAsyncArrowHead\[[Yield, ?Await]\] [no LineTerminator here] => AsyncConciseBody\[[?In]\]

the interpretation of CoverCallExpressionAndAsyncArrowHead is refined using the following grammar:

AsyncArrowHead:

AsyncArrowFunction\[[In, Yield, Await]\] : CoverCallExpressionAndAsyncArrowHead\[[Yield, ?Await]\] [no LineTerminator here] => AsyncConciseBody\[[?In]\] ArrowFormalParameters\[-Yield, +Await]\n
MethodDefinition\[Yield, Await\] :

ClassElementName\[[Yield, ?Await]\] ( UniqueFormalParameters\[-Yield, ~Await]\) \{ FunctionBody\[-Yield, ~Await]\ \}

GeneratorMethod\[[Yield, ?Await]\]
AsyncMethod\[[Yield, ?Await]\]
AsyncGeneratorMethod\[[Yield, ?Await]\]

get ClassElementName\[[Yield, ?Await]\] ( ) \{ FunctionBody\[-Yield, ~Await]\ \}

set ClassElementName\[[Yield, ?Await]\] ( PropertySetParameterList ) \{ FunctionBody\[-Yield, ~Await]\ \}

PropertySetParameterList :

FormalParameter\[-Yield, ~Await]\n
GeneratorDeclaration\[Yield, Await, Default\] :

function * BindingIdentifier\[?Yield, ?Await\] ( FormalParameters\[+Yield, ~Await\] ) \{ GeneratorBody \}

[+Default] function * ( FormalParameters\[+Yield, ~Await\] ) \{ GeneratorBody \}

GeneratorExpression :

function * BindingIdentifier\[+Yield, ~Await\] opt ( FormalParameters\[+Yield, ~Await\] ) \{ GeneratorBody \}

GeneratorMethod\[Yield, Await\] :

* ClassElementName\[Yield, ?Await\] ( UniqueFormalParameters\[+Yield, ~Await\] ) \{ GeneratorBody \}

GeneratorBody :

FunctionBody\[+Yield, ~Await\]

YieldExpression\[In, Await\] :

yield

yield [no LineTerminator here] AssignmentExpression\[?In, +Yield, ?Await\]
yield [no LineTerminator here] * AssignmentExpression\[?In, +Yield, ?Await\]
AsyncGeneratorDeclaration[Yield, Await, Default] :
  [Default] async [no LineTerminator here] function ★ (FormalParameters[Yield, Await] ) { AsyncGeneratorBody }

AsyncGeneratorExpression :

AsyncGeneratorMethod[Yield, Await] :

AsyncGeneratorBody :
  FunctionBody[Yield, Await]

AsyncFunctionDeclaration[Yield, Await, Default] :
  [Default] async [no LineTerminator here] function (FormalParameters[Yield, Await] ) { AsyncFunctionBody }

AsyncFunctionExpression :

AsyncMethod[Yield, Await] :

AsyncFunctionBody :
  FunctionBody[Yield, Await]

AwaitExpression[Yield] :
  await UnaryExpression[Yield, Await]

ClassDeclaration[Yield, Await, Default] :
  class BindingIdentifier[Yield, Await] ClassTail[Yield, Await]
  [Default] class ClassTail[Yield, Await]

ClassExpression[Yield, Await] :
  class BindingIdentifier[Yield, Await] opt ClassTail[Yield, Await]

ClassTail[Yield, Await] :
  ClassHeritage[Yield, Await] opt { ClassBody[Yield, Await] opt }

ClassHeritage[Yield, Await] :
  extends LeftHandSideExpression[Yield, Await]

ClassBody[Yield, Await] :
  ClassElementList[Yield, Await]

ClassElementList[Yield, Await] :
  ClassElement[Yield, Await]
  ClassElementList[Yield, Await] ClassElement[Yield, Await]

ClassElement[Yield, Await] :
  MethodDefinition[Yield, Await]
  static MethodDefinition[Yield, Await]
  FieldDefinition[Yield, Await];
  static FieldDefinition[Yield, Await];
  ClassStaticBlock;

FieldDefinition[Yield, Await] :
  ClassElementName[Yield, Await]Initializer[Yield, Await] opt
A.5 Scripts and Modules

Script:
  ScriptBodyopt

ScriptBody:
  StatementList[~Yield, ~Await, ~Return]

Module:
  ModuleBodyopt

ModuleBody:
  ModuleItemList

ModuleItemList:
  ModuleItem

ModuleItem:
  ImportDeclaration
  ExportDeclaration
  StatementListItem[~Yield, ~Await, ~Return]

ModuleExportName:
  IdentifierName
  StringLiteral

ImportDeclaration:
  import ImportClause FromClause ;
  import ModuleSpecifier ;

ImportClause:
  ImportedDefaultBinding
  NameSpaceImport
  NamedImports
  ImportedDefaultBinding, NameSpaceImport
  ImportedDefaultBinding, NamedImports

ImportedDefaultBinding:
  ImportedBinding

NameSpaceImport:
  * as ImportedBinding

NamedImports:
  { } { ImportsList } { ImportsList , }

FromClause:
  from ModuleSpecifier

ImportsList:
  ImportSpecifier
  ImportsList , ImportSpecifier

ImportSpecifier:
  ImportedBinding
  ModuleExportName as ImportedBinding
ModuleSpecifier : StringLiteral
ImportedBinding : BindingIdentifier[-Yield, +Await]
ExportDeclaration : export ExportFromClause FromClause ;
                   export NamedExports ;
                   export VariableStatement[-Yield, +Await]
                   export Declaration[-Yield, +Await]
                   export default HoistableDeclaration[-Yield, +Await, +Default]
                   export default ClassDeclaration[-Yield, +Await, +Default]
                   export default [lookahead ∉ {function, async [no LineTerminator here] function, class } ] AssignmentExpression[+In, ~Yield, +Await] ;
ExportFromClause : *
                   * as ModuleExportName
NamedExports : { } { ExportsList } { ExportsList , }
ExportsList : ExportSpecifier ExportsList , ExportSpecifier
ExportSpecifier : ModuleExportName ModuleExportName as ModuleExportName

A.6 Number Conversions
StringNumericLiteral ::: StrWhiteSpaceopt StrWhiteSpaceopt StrNumericLiteral StrWhiteSpaceopt
StrWhiteSpace ::: StrWhiteSpaceChar StrWhiteSpaceopt
StrWhiteSpaceChar ::: 
                   StrWhiteSpaceChar 
                   
                   StrNumericLiteral ::: StrDecimalLiteral
                   NonDecimalIntegerLiteral[-Sep]
StrDecimalLiteral ::: StrUnsignedDecimalLiteral
                   + StrUnsignedDecimalLiteral
                   - StrUnsignedDecimalLiteral
StrUnsignedDecimalLiteral ::: Infinity
                   . DecimalDigits[-Sep] ExponentPart[-Sep] opt
                   DecimalDigits[-Sep] ExponentPart[-Sep] opt

All grammar symbols not explicitly defined by the StringNumericLiteral grammar have the definitions used in the Lexical Grammar for numeric literals.
A.7 Time Zone Offset String Format

UTCOffset :::
  TemporalSign Hour
  TemporalSign Hour HourSubcomponents[+Extended]
  TemporalSign Hour HourSubcomponents[~Extended]

TemporalSign :::
  ASCIISign
  <MINUS>

ASCIISign ::: one of
  +  -

Hour :::
  0 DecimalDigit
  1 DecimalDigit
  20
  21
  22
  23

HourSubcomponents[Extended] :::
  TimeSeparator[?Extended] MinuteSecond
  TemporalDecimalFractionopt

TimeSeparator[Extended] :::
  [+Extended] :
  [-Extended] [empty]

MinuteSecond :::
  0 DecimalDigit
  1 DecimalDigit
  2 DecimalDigit
  3 DecimalDigit
  4 DecimalDigit
  5 DecimalDigit

TemporalDecimalFraction :::
  TemporalDecimalSeparator DecimalDigit
  TemporalDecimalSeparator DecimalDigit DecimalDigit
  TemporalDecimalSeparator DecimalDigit DecimalDigit DecimalDigit DecimalDigit
  TemporalDecimalSeparator DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit
  TemporalDecimalSeparator DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit
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  TemporalDecimalSeparator DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit DecimalDigit
TemporalDecimalSeparator ::: one of 
   ,

A.8 Regular Expressions

Pattern[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] :::
   Disjunction[?UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups]

Disjunction[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] :::
   Alternative[?UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups] |
   Alternative[?UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups]

Alternative[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] :::
   [empty]
   Term[?UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups]

Term[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] :::
   Assertion[?UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups]
   Atom[?UnicodeMode, ?UnicodeSetsMode, ?NamedCaptureGroups]

Assertion[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] :::
   ^
   $ 
   \b 
   \B

Quantifier ::
   QuantifierPrefix
   QuantifierPrefix ?

QuantifierPrefix ::
   * + ?
   { DecimalDigits[-Sep] }
   { DecimalDigits[-Sep] ,}
   { DecimalDigits[-Sep] , DecimalDigits[-Sep] }

Atom[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] :::
   PatternCharacter
   \ AtomEscape[?UnicodeMode, ?NamedCaptureGroups]
   CharacterClass[?UnicodeMode, ?UnicodeSetsMode]
   ( GroupSpecifier[?UnicodeMode] opt

SyntaxCharacter :: one of
   ^ $ \ . * + ? ( ) [ ] { } |

PatternCharacter ::
   SourceCharacter but not SyntaxCharacter
AtomEscape[UnicodeMode, NamedCaptureGroups] ::
  DecimalEscape
CharacterClassEscape[?UnicodeMode]
CharacterEscape[?UnicodeMode]
  [+NamedCaptureGroups] k GroupName[?UnicodeMode]
CharacterEscape[UnicodeMode] ::
  ControlEscape
  c AsciiLetter
  θ [lookahead ∉ DecimalDigit]
  HexEscapeSequence
  RegExpUnicodeEscapeSequence[?UnicodeMode]
IdentityEscape[?UnicodeMode]

ControlEscape :: one of
  ñ ñ ñ ñ

GroupSpecifier[UnicodeMode] ::
  ? GroupName[?UnicodeMode]

GroupName[UnicodeMode] ::
  < RegExpIdentifierName[?UnicodeMode] >

RegExpIdentifierName[UnicodeMode] ::
  RegExpIdentifierStart[?UnicodeMode]
    RegExpIdentifierName[?UnicodeMode]  RegExpIdentifierPart[?UnicodeMode]

RegExpIdentifierStart[UnicodeMode] ::
  IdentifierStartChar
    \ RegExpUnicodeEscapeSequence[+UnicodeMode]
      [~UnicodeMode] UnicodeLeadSurrogate  UnicodeTrailSurrogate
  IdentifierPartChar
    \ RegExpUnicodeEscapeSequence[+UnicodeMode]
      [~UnicodeMode] UnicodeLeadSurrogate  UnicodeTrailSurrogate

RegExpUnicodeEscapeSequence[UnicodeMode] ::
  [+UnicodeMode] u HexLeadSurrogate \u HexTrailSurrogate
  [+UnicodeMode] u HexLeadSurrogate
  [+UnicodeMode] u HexTrailSurrogate
  [+UnicodeMode] u HexNonSurrogate
  [-UnicodeMode] u Hex4Digits
  [+UnicodeMode] uf{ CodePoint }

UnicodeLeadSurrogate ::
  any Unicode code point in the inclusive interval from U+D800 to U+DBFF

UnicodeTrailSurrogate ::
  any Unicode code point in the inclusive interval from U+DC00 to U+DFFF

Each \u HexTrailSurrogate for which the choice of associated \u HexLeadSurrogate is ambiguous shall be associated with the nearest possible \u HexLeadSurrogate that would otherwise have no corresponding \u HexTrailSurrogate.

HexLeadSurrogate ::
  Hex4Digits but only if the MV of Hex4Digits is in the inclusive interval from 0xD800 to 0xDBFF

HexTrailSurrogate ::
  Hex4Digits but only if the MV of Hex4Digits is in the inclusive interval from 0xDC00 to 0xDFFF

HexNonSurrogate ::
  Hex4Digits but only if the MV of Hex4Digits is not in the inclusive interval from 0xD800 to 0xDBFF
IdentityEscape[UnicodeMode] ::
  [+UnicodeMode] SyntaxCharacter
  [-UnicodeMode] / SourceCharacter but not UnicodeIDContinue

DecimalEscape ::
  NonZeroDigit DecimalDigits[~Sep] opt [lookahead ≠ DecimalDigit]

CharacterClassEscape[UnicodeMode] ::
  d D s S w W

  [+UnicodeMode] p{ UnicodePropertyValueExpression } [+UnicodeMode] P{ UnicodePropertyValueExpression }

UnicodePropertyValueExpression ::
  UnicodePropertyName = UnicodePropertyValue
  LoneUnicodePropertyNameOrValue

UnicodePropertyName ::
  UnicodePropertyNameCharacters

UnicodePropertyNameCharacters ::
  UnicodePropertyNameCharacter UnicodePropertyNameCharacters opt

UnicodePropertyValue ::
  UnicodePropertyValueCharacters

LoneUnicodePropertyNameOrValue ::
  UnicodePropertyValueCharacters

UnicodePropertyValueCharacters ::
  UnicodePropertyValueCharacter UnicodePropertyValueCharacters opt

UnicodePropertyValueCharacter ::
  UnicodePropertyNameCharacter
  DecimalDigit

UnicodePropertyNameCharacter ::
  AsciiLetter

  CharacterClass[UnicodeMode, UnicodeSetsMode] ::
    [ ^ ClassContents[?UnicodeMode, ?UnicodeSetsMode] ]

ClassContents[UnicodeMode, UnicodeSetsMode] ::
  [empty]
  [-UnicodeSetsMode] NonemptyClassRanges[?UnicodeMode]
  [+UnicodeSetsMode] ClassSetExpression

NonemptyClassRanges[UnicodeMode] ::
  ClassAtom[?UnicodeMode]
  ClassAtom[?UnicodeMode] NonemptyClassRangesNoDash[?UnicodeMode]
  ClassAtom[?UnicodeMode] - ClassAtom[?UnicodeMode]
  ClassAtoms[?UnicodeMode, ~UnicodeSetsMode]

NonemptyClassRangesNoDash[UnicodeMode] ::
  ClassAtom[?UnicodeMode]
  ClassAtomNoDash[?UnicodeMode] NonemptyClassRangesNoDash[?UnicodeMode]
  ClassAtomNoDash[?UnicodeMode] - ClassAtom[?UnicodeMode]
  ClassContents[?UnicodeMode, ~UnicodeSetsMode]
ClassAtom [UnicodeMode] ::
  -
  ClassAtomNoDash [UnicodeMode]
ClassAtomNoDash [UnicodeMode] ::
  SourceCharacter but not one of \ or ] or -
  ClassEscape [UnicodeMode]
ClassEscape [UnicodeMode] ::
  b
  [UnicodeMode] -
  CharacterClassEscape [UnicodeMode]
  CharacterEscape [UnicodeMode]
ClassSetExpression ::
  ClassUnion
  ClassIntersection
  ClassSubtraction
ClassUnion ::
  ClassSetExpression ClassUnion opt
  ClassSetOperand ClassUnion opt
ClassIntersection ::
  ClassSetOperand && [lookahead ≠ &] ClassSetOperand
  ClassIntersection && [lookahead ≠ &] ClassSetOperand
ClassSubtraction ::
  ClassSetOperand -- ClassSetOperand
  ClassSubtraction -- ClassSetOperand
ClassSetRange ::
  ClassSetCharacter - ClassSetCharacter
ClassSetOperand ::
  NestedClass
  ClassStringDisjunction
  ClassSetCharacter
NestedClass ::
  [ [lookahead ≠ ^] ClassContents [UnicodeMode, +UnicodeSetsMode] ]
  [ ^ ClassContents [UnicodeMode, +UnicodeSetsMode] ]
  \ CharacterClassEscape [UnicodeMode]
ClassStringDisjunction ::
  \q{ ClassStringDisjunctionContents };
ClassStringDisjunctionContents ::
  ClassString
  ClassString | ClassStringDisjunctionContents
ClassString ::
  [empty]
  NonEmptyClassString
NonEmptyClassString ::
  ClassSetCharacter NonEmptyClassString opt
ClassSetCharacter ::
  [lookahead ∉ ClassSetReservedDoublePunctuator] SourceCharacter but not
  ClassSetSyntaxCharacter
  \ CharacterEscape [UnicodeMode]
  \ ClassSetReservedPunctuator
  \b
ClassSetReservedDoublePunctuator :: one of
  && !! #$ %& ** ++ , . ; : ; ; ; < <= >> ?? @@ ^ ^ ' ` ~

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767
ClassSetSyntaxCharacter :: one of
   ( ) [ ] { } / - \ |
ClassSetReservedPunctuator :: one of
   & - ! # % , ; < = > @ ' "
Annex B
(normative)
Additional ECMAScript Features for Web Browsers

The ECMAScript language syntax and semantics defined in this annex are required when the ECMAScript host is a web browser. The content of this annex is normative but optional if the ECMAScript host is not a web browser.

NOTE
This annex describes various legacy features and other characteristics of web browser ECMAScript hosts. All of the language features and behaviours specified in this annex have one or more undesirable characteristics and in the absence of legacy usage would be removed from this specification. However, the usage of these features by large numbers of existing web pages means that web browsers must continue to support them. The specifications in this annex define the requirements for interoperable implementations of these legacy features.

These features are not considered part of the core ECMAScript language. Programmers should not use or assume the existence of these features and behaviours when writing new ECMAScript code. ECMAScript implementations are discouraged from implementing these features unless the implementation is part of a web browser or is required to run the same legacy ECMAScript code that web browsers encounter.

B.1 Additional Syntax

B.1.1 HTML-like Comments

The syntax and semantics of 12.4 is extended as follows except that this extension is not allowed when parsing source text using the goal symbol Module:

**Syntax**

```plaintext
InputElementHashbangOrRegExp ::
    WhiteSpace
    LineTerminator
    Comment
    CommonToken
    HashbangComment
    RegularExpressionLiteral
    HTMLCloseComment

Comment ::
    MultiLineComment
    SingleLineComment
    SingleLineHTMLOpenComment
    SingleLineHTMLCloseComment
    SingleLineDelimitedComment

MultiLineComment ::
    /* FirstCommentLine opt LineTerminator MultiLineCommentChars opt */
    HTMLCloseComment opt

FirstCommentLine ::
    SingleLineDelimitedCommentChars
```

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Similar to a MultiLineComment that contains a line terminator code point, a SingleLineHTMLCloseComment is considered to be a LineTerminator for purposes of parsing by the syntactic grammar.

B.1.2 Regular Expressions Patterns

The syntax of 22.2.1 is modified and extended as follows. These changes introduce ambiguities that are broken by the ordering of grammar productions and by contextual information. When parsing using the following grammar, each alternative is considered only if previous production alternatives do not match.

This alternative pattern grammar and semantics only changes the syntax and semantics of BMP patterns. The following grammar extensions include productions parameterized with the [UnicodeMode] parameter. However, none of these extensions change the syntax of Unicode patterns recognized when parsing with the [UnicodeMode] parameter present on the goal symbol.
Syntax

Term[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] ::
  [-UnicodeMode] QuantifiableAssertion[?NamedCaptureGroups] Quantifier
  [-UnicodeMode] Assertion[-UnicodeMode, ~UnicodeSetsMode, ?NamedCaptureGroups]
  [-UnicodeMode] ExtendedAtom[?NamedCaptureGroups] Quantifier
  [-UnicodeMode] ExtendedAtom[?NamedCaptureGroups]

Assertion[UnicodeMode, UnicodeSetsMode, NamedCaptureGroups] ::
  ^
  $  \\b  \B
  [-UnicodeMode] QuantifiableAssertion[?NamedCaptureGroups]

QuantifiableAssertion[NamedCaptureGroups] ::
  (?! Disjunction[-UnicodeMode, ~UnicodeSetsMode, ?NamedCaptureGroups] )
  (?! Disjunction[-UnicodeMode, ~UnicodeSetsMode, ?NamedCaptureGroups] )

ExtendedAtom[NamedCaptureGroups] ::
  .
  \ AtomEscape[~UnicodeMode, ?NamedCaptureGroups]
  \[lookahead = c|]
  CharacterClass[~UnicodeMode, ~UnicodeSetsMode]
  ( GroupSpecifier[~UnicodeMode] opt
    Disjunction[~UnicodeMode, ~UnicodeSetsMode, ?NamedCaptureGroups] )
  (?! Disjunction[~UnicodeMode, ~UnicodeSetsMode, ?NamedCaptureGroups] )

InvalidBracedQuantifier
  ExtendedPatternCharacter

InvalidBracedQuantifier ::
  { DecimalDigits[~Sep] }
  { DecimalDigits[~Sep] },
  { DecimalDigits[~Sep], DecimalDigits[~Sep] }

ExtendedPatternCharacter ::
  SourceCharacter but not one of ^ $ \ . * + ? ( ) |

AtomEscape[UnicodeMode, NamedCaptureGroups] ::
  [+UnicodeMode] DecimalEscape
  [-UnicodeMode] DecimalEscape but only if the CapturingGroupNumber of DecimalEscape is ≤ CountLeftCapturingParensWithin(the Pattern containing DecimalEscape)
  CharacterClassEscape[?UnicodeMode]
  CharacterEscape[?UnicodeMode, ?NamedCaptureGroups]
  [+NamedCaptureGroups] k GroupName[?UnicodeMode]
NOTE: When the same left-hand sides occurs with both [+UnicodeMode] and [~UnicodeMode] guards it is to control the disambiguation priority.

B.1.2.1 Static Semantics: Early Errors

The semantics of 22.2.1.1 is extended as follows:

ExtendedAtom :: InvalidBracedQuantifier

- It is a Syntax Error if any source text is matched by this production.

Additionally, the rules for the following productions are modified with the addition of the highlighted text:

NonemptyClassRanges :: ClassAtom - ClassAtom ClassContents

- It is a Syntax Error if IsCharacterClass of the first ClassAtom is true or IsCharacterClass of the second ClassAtom is true and this production has a [UnicodeMode] parameter.
- It is a Syntax Error if IsCharacterClass of the first ClassAtom is false, IsCharacterClass of the second ClassAtom is false, and the CharacterValue of the first ClassAtom is strictly greater than the CharacterValue of the second ClassAtom.
NonemptyClassRangesNoDash :: ClassAtomNoDash - ClassAtom ClassContents

- It is a Syntax Error if IsCharacterClass of ClassAtomNoDash is true or IsCharacterClass of ClassAtom is true and this production has a \[UnicodeMode\] parameter.
- It is a Syntax Error if IsCharacterClass of ClassAtomNoDash is false, IsCharacterClass of ClassAtom is false, and the CharacterValue of ClassAtomNoDash is strictly greater than the CharacterValue of ClassAtom.

B.1.2.2 Static Semantics: CountLeftCapturingParensWithin and CountLeftCapturingParensBefore

In the definitions of CountLeftCapturingParensWithin and CountLeftCapturingParensBefore, references to “\Atom :: ( GroupSpecifier\opt Disjunction ) “ are to be interpreted as meaning “\Atom :: ( GroupSpecifier\opt Disjunction ) “ or “\ExtendedAtom :: ( GroupSpecifier\opt Disjunction ) “.

B.1.2.3 Static Semantics: IsCharacterClass

The semantics of 22.2.1.5 is extended as follows:

ClassAtomNoDash :: | [lookahead = c]

1. Return false.

B.1.2.4 Static Semantics: CharacterValue

The semantics of 22.2.1.6 is extended as follows:

ClassAtomNoDash :: | [lookahead = c]

1. Return the numeric value of U+005C (REVERSE SOLIDUS).

ClassEscape :: c ClassControlLetter

1. Let ch be the code point matched by ClassControlLetter.
2. Let i be the numeric value of ch.
3. Return the remainder of dividing i by 32.

CharacterEscape :: LegacyOctalEscapeSequence

1. Return the MV of LegacyOctalEscapeSequence (see 12.9.4.3).

B.1.2.5 Runtime Semantics: CompileSubpattern

The semantics of CompileSubpattern is extended as follows:

The rule for Term :: QuantifiableAssertion Quantifier is the same as for Term :: Atom Quantifier but with QuantifiableAssertion substituted for Atom.

The rule for Term :: ExtendedAtom Quantifier is the same as for Term :: Atom Quantifier but with ExtendedAtom substituted for Atom.

The rule for Term :: ExtendedAtom is the same as for Term :: Atom but with ExtendedAtom substituted for Atom.
B.1.2.6 Runtime Semantics: CompileAssertion

CompileAssertion rules for the Assertion :: (?= Disjunction ) and Assertion :: (?! Disjunction ) productions are also used for the QuantifiableAssertion productions, but with QuantifiableAssertion substituted for Assertion.

B.1.2.7 Runtime Semantics: CompileAtom

CompileAtom rules for the Atom productions except for Atom :: PatternCharacter are also used for the ExtendedAtom productions, but with ExtendedAtom substituted for Atom. The following rules, with parameter direction, are also added:

ExtendedAtom :: \ [lookahead = c]

1. Let A be the CharSet containing the single character \ U+005C (REVERSE SOLIDUS).
2. Return CharSetMatcher(re, A, false, direction).

ExtendedAtom :: ExtendedPatternCharacter

1. Let ch be the character represented by ExtendedPatternCharacter.
2. Let A be a one-element CharSet containing the character ch.
3. Return CharSetMatcher(re, A, false, direction).

B.1.2.8 Runtime Semantics: CompileToCharSet

The semantics of 22.2.2.9 is extended as follows:

The following two rules replace the corresponding rules of CompileToCharSet.

NonemptyClassRanges :: ClassAtom - ClassAtom ClassContents

1. Let A be CompileToCharSet of the first ClassAtom with argument rer.
2. Let B be CompileToCharSet of the second ClassAtom with argument rer.
3. Let C be CompileToCharSet of ClassContents with argument rer.
4. Let D be CharacterRangeOrUnion(re, A, B).
5. Return the union of D and C.

NonemptyClassRangesNoDash :: ClassAtomNoDash - ClassAtom ClassContents

1. Let A be CompileToCharSet of ClassAtomNoDash with argument rer.
2. Let B be CompileToCharSet of ClassAtom with argument rer.
3. Let C be CompileToCharSet of ClassContents with argument rer.
4. Let D be CharacterRangeOrUnion(re, A, B).
5. Return the union of D and C.

In addition, the following rules are added to CompileToCharSet.

ClassEscape :: c ClassControlLetter

1. Let cv be the CharacterValue of this ClassEscape.
2. Let c be the character whose character value is cv.
3. Return the CharSet containing the single character c.

ClassAtomNoDash :: \ [lookahead = c]

1. Return the CharSet containing the single character \ U+005C (REVERSE SOLIDUS).
NOTE  This production can only be reached from the sequence \c within a character class where it is not followed by an acceptable control character.

### B.1.2.8.1 CharacterRangeOrUnion (rer, A, B)

The abstract operation CharacterRangeOrUnion takes arguments rer (a RegExp Record), A (a CharSet), and B (a CharSet) and returns a CharSet. It performs the following steps when called:

1. If HasEitherUnicodeFlag(rer) is false, then
   a. If A does not contain exactly one character or B does not contain exactly one character, then
      i. Let C be the CharSet containing the single character - U+002D (HYPHEN-MINUS).
      ii. Return the union of CharSets A, B and C.
2. Return CharacterRange(A, B).

### B.1.2.9 Static Semantics: ParsePattern (patternText, u, v)

The semantics of 22.2.3.4 is extended as follows:

The abstract operation ParsePattern takes arguments patternText (a sequence of Unicode code points), u (a Boolean), and v (a Boolean). It performs the following steps when called:

1. If v is true and u is true, then
   a. Let parseResult be a List containing one or more SyntaxError objects.
2. Else if v is true, then
   a. Let parseResult be ParseText(patternText, Pattern[+UnicodeMode, +UnicodeSetsMode, +NamedCaptureGroups]).
3. Else if u is true, then
   a. Let parseResult be ParseText(patternText, Pattern[+UnicodeMode, ~UnicodeSetsMode, +NamedCaptureGroups]).
4. Else,
   a. Let parseResult be ParseText(patternText, Pattern[~UnicodeMode, ~UnicodeSetsMode, ~NamedCaptureGroups]).
   b. If parseResult is a Parse Node and parseResult contains a GroupName, then
      i. Set parseResult to ParseText(patternText, Pattern[~UnicodeMode, ~UnicodeSetsMode, +NamedCaptureGroups]).
5. Return parseResult.

### B.2 Additional Built-in Properties

When the ECMAScript host is a web browser the following additional properties of the standard built-in objects are defined.

#### B.2.1 Additional Properties of the Global Object

The entries in Table 97 are added to Table 6.

<table>
<thead>
<tr>
<th>Intrinsic Name</th>
<th>Global Name</th>
<th>ECMAScript Language Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>%escape%</td>
<td>escape</td>
<td>The escape function (B.2.1.1)</td>
</tr>
<tr>
<td>%unescape%</td>
<td>unescape</td>
<td>The unescape function (B.2.1.2)</td>
</tr>
</tbody>
</table>
B.2.1.1 `escape (string)`

This function is a property of the global object. It computes a new version of a String value in which certain code units have been replaced by a hexadecimal escape sequence.

When replacing a code unit of numeric value less than or equal to 0x00FF, a two-digit escape sequence of the form `%xx` is used. When replacing a code unit of numeric value strictly greater than 0x00FF, a four-digit escape sequence of the form `%uxxxx` is used.

It is the `%escape% intrinsic object.

It performs the following steps when called:

1. Set `string` to `ToString(string)`.  
2. Let `len` be the length of `string`.  
3. Let `R` be the empty String.  
4. Let `unescapeSet` be the string-concatenation of the ASCII word characters and "@*+-./".  
5. Let `k` be 0.  
6. Repeat, while `k < len`,  
   a. Let `C` be the code unit at index `k` within `string`.  
   b. If `unescapeSet` contains `C`, then  
      i. Let `S` be `C`.  
   c. Else,  
      i. Let `n` be the numeric value of `C`.  
      ii. If `n < 256`, then  
         1. Let `hex` be the String representation of `n`, formatted as an uppercase hexadecimal number.  
         2. Let `S` be the string-concatenation of "%" and `StringPad(hex, 2, "0", START)`.  
      iii. Else,  
         1. Let `hex` be the String representation of `n`, formatted as an uppercase hexadecimal number.  
         2. Let `S` be the string-concatenation of "%u" and `StringPad(hex, 4, "0", START)`.  
   d. Set `R` to the string-concatenation of `R` and `S`.  
   e. Set `k` to `k + 1`.  
7. Return `R`.

NOTE The encoding is partly based on the encoding described in RFC 1738, but the entire encoding specified in this standard is described above without regard to the contents of RFC 1738. This encoding does not reflect changes to RFC 1738 made by RFC 3986.

B.2.1.2 `unescape (string)`

This function is a property of the global object. It computes a new version of a String value in which each escape sequence of the sort that might be introduced by the `escape` function is replaced with the code unit that it represents.

It is the `%unescape% intrinsic object.

It performs the following steps when called:

1. Set `string` to `ToString(string)`.  
2. Let `len` be the length of `string`.  
3. Let `R` be the empty String.  
4. Let `k` be 0.  
5. Repeat, while `k < len`,  
   a. Let `C` be the code unit at index `k` within `string`.  
   b. If `C` is the code unit 0x0025 (PERCENT SIGN), then  
      i. Let `hexDigits` be the empty String.  
      ii. Let `optionalAdvance` be 0.  
      iii. If `k + 5 < len` and the code unit at index `k + 1` within `string` is the code unit 0x0075 (LATIN SMALL LETTER U), then
1. Set `hexDigits` to the substring of `string` from \( k + 2 \) to \( k + 6 \).
2. Set `optionalAdvance` to 5.

iv. Else if \( k + 3 \leq \text{len} \), then
   1. Set `hexDigits` to the substring of `string` from \( k + 1 \) to \( k + 3 \).
   2. Set `optionalAdvance` to 2.

v. Let `parseResult` be `ParseText(StringToCodePoints(hexDigits), HexDigits[-Sep])`.

vi. If `parseResult` is a Parse Node, then
   1. Let \( n \) be the MV of `parseResult`.
   2. Set \( C \) to the code unit whose numeric value is \( n \).
   3. Set \( k \) to \( k + \text{optionalAdvance} \).
   
   c. Set \( R \) to the string-concatenation of \( R \) and \( C \).
   d. Set \( k \) to \( k + 1 \).

6. Return \( R \).

### B.2.2 Additional Properties of the String.prototype Object

#### B.2.2.1 String.prototype.substr ( `start`, `length` )

This method returns a substring of the result of converting the this value to a String, starting from index `start` and running for `length` code units (or through the end of the String if `length` is `undefined`). If `start` is negative, it is treated as `sourceLength + start` where `sourceLength` is the length of the String. The result is a String value, not a String object.

It performs the following steps when called:

1. Let \( O \) be `RequireObjectCoercible(this value)`.
2. Let \( S \) be `ToString(O)`.
3. Let `size` be the length of \( S \).
4. Let `intStart` be `ToIntegerOrInfinity(start)`.
5. If `intStart` = \( -\infty \), set `intStart` to 0.
6. Else if `intStart` < 0, set `intStart` to \( \max(size + intStart, 0) \).
7. Else, set `intStart` to \( \min(intStart, size) \).
8. If `length` is `undefined`, let `intLength` be `size`; otherwise let `intLength` be `ToIntegerOrInfinity(length)`.
9. Set `intLength` to the result of clamping `intLength` between 0 and `size`.
10. Let `intEnd` be \( \min(intStart + intLength, size) \).
11. Return the substring of \( S \) from `intStart` to `intEnd`.

**NOTE**

This method is intentionally generic; it does not require that its this value be a String object. Therefore it can be transferred to other kinds of objects for use as a method.

#### B.2.2.2 String.prototype.anchor ( `name` )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return `CreateHTML(S, "a", "name", name)`.

#### B.2.2.2.1 CreateHTML ( `string`, `tag`, `attribute`, `value` )

The abstract operation CreateHTML takes arguments `string` (an ECMAScript language value), `tag` (a String), `attribute` (a String), and `value` (an ECMAScript language value) and returns either a normal completion containing a String or a throw completion. It performs the following steps when called:

1. Let `str` be `RequireObjectCoercible(string)`.
2. Let \( S \) be `ToString(str)`.
3. Let `p1` be the string-concatenation of "<" and `tag`.
4. If `attribute` is not the empty String, then
a. Let \( V \) be \( \text{ToString}(value) \).
b. Let \( \text{escapedV} \) be the String value that is the same as \( V \) except that each occurrence of the code unit 0x0022 (QUOTATION MARK) in \( V \) has been replaced with the six code unit sequence "&quot;.
c. Set \( p_1 \) to the string-concatenation of:
   - \( \text{p1} \)
   - the code unit 0x0020 (SPACE)
   - \( \text{attribute} \)
   - the code unit 0x003D (EQUALS SIGN)
   - the code unit 0x0022 (QUOTATION MARK)
   - \( \text{escapedV} \)
   - the code unit 0x0022 (QUOTATION MARK)

5. Let \( p_2 \) be the string-concatenation of \( p_1 \) and "">
6. Let \( p_3 \) be the string-concatenation of \( p_2 \) and \( S \).
7. Let \( p_4 \) be the string-concatenation of \( p_3 \), "</", \( \text{tag} \), and "">
8. Return \( p_4 \).

B.2.2.3 String.prototype.big ( )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return \( \text{CreateHTML}(S, "\text{big}", ", ", ") \).

B.2.2.4 String.prototype.blink ( )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return \( \text{CreateHTML}(S, "\text{blink}", ", ", ") \).

B.2.2.5 String.prototype.bold ( )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return \( \text{CreateHTML}(S, "\text{b}", ", ", ") \).

B.2.2.6 String.prototype.fixed ( )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return \( \text{CreateHTML}(S, "\text{tt}" ", ", ") \).

B.2.2.7 String.prototype.fontcolor ( \( \text{color} \) )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return \( \text{CreateHTML}(S, "\text{font}" ", \text{color}, \text{color}) \).

B.2.2.8 String.prototype.fontsize ( \( \text{size} \) )

This method performs the following steps when called:

1. Let \( S \) be the this value.
2. Return \( \text{CreateHTML}(S, "\text{font}" ", \text{size}, \text{size}) \).
B.2.2.9  String.prototype.italics ( )

This method performs the following steps when called:

1. Let S be the this value.
2. Return ? CreateHTML(S, "i", "", "").

B.2.2.10  String.prototype.link ( url )

This method performs the following steps when called:

1. Let S be the this value.

B.2.2.11  String.prototype.small ( )

This method performs the following steps when called:

1. Let S be the this value.
2. Return ? CreateHTML(S, "small", "", "").

B.2.2.12  String.prototype.strike ( )

This method performs the following steps when called:

1. Let S be the this value.
2. Return ? CreateHTML(S, "strike", "", "").

B.2.2.13  String.prototype.sub ( )

This method performs the following steps when called:

1. Let S be the this value.
2. Return ? CreateHTML(S, "sub", "", "").

B.2.2.14  String.prototype.sup ( )

This method performs the following steps when called:

1. Let S be the this value.
2. Return ? CreateHTML(S, "sup", "", "").

B.2.2.15  String.prototype.trimLeft ( )

NOTE The property "trimStart" is preferred. The "trimLeft" property is provided principally for compatibility with old code. It is recommended that the "trimStart" property be used in new ECMAScript code.

The initial value of the "trimLeft" property is %String.prototype.trimStart%, defined in 22.1.3.34.
NOTE The property "trimEnd" is preferred. The "trimRight" property is provided principally for compatibility with old code. It is recommended that the "trimEnd" property be used in new ECMAScript code.

The initial value of the "trimRight" property is %String.prototype.trimEnd%, defined in 22.1.3.33.

B.2.3 Additional Properties of the Date.prototype Object

B.2.3.1 Date.prototype.getYear ( )

NOTE The getFullYear method is preferred for nearly all purposes, because it avoids the "year 2000 problem."

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. If t is NaN, return NaN.
5. Return YearFromTime(LocalTime(t)) - 1900𝔽.

B.2.3.2 Date.prototype.setYear ( year )

NOTE The setFullYear method is preferred for nearly all purposes, because it avoids the "year 2000 problem."

This method performs the following steps when called:

1. Let dateObject be the this value.
2. Perform ? RequireInternalSlot(dateObject, [[DateValue]]).
3. Let t be dateObject.[[DateValue]].
4. Let y be ? ToNumber(year).
5. If t is NaN, set t to +0𝔽; otherwise, set t to LocalTime(t).
6. Let yyyy be MakeFullYear(y).
7. Let d be MakeDay(yyyy, MonthFromTime(t), DateFromTime(t)).
8. Let date be MakeDate(d, TimeWithinDay(t)).
9. Let u be TimeClip(UTC(date)).
10. Set dateObject.[[DateValue]] to u.
11. Return u.

B.2.3.3 Date.prototype.toGMTString ( )

NOTE The toUTCString method is preferred. This method is provided principally for compatibility with old code.

The initial value of the "toGMTString" property is %Date.prototype.toUTCString%, defined in 21.4.4.43.
B.2.4 Additional Properties of the RegExp.prototype Object

B.2.4.1 RegExp.prototype.compile (pattern, flags)

This method performs the following steps when called:

1. Let \(O\) be the this value.
2. Perform ? RequireInternalSlot(\(O\), [[RegExpMatcher]]).
3. If \(pattern\) is an Object and \(pattern\) has a [[RegExpMatcher]] internal slot, then
   a. If flags is not undefined, throw a TypeError exception.
   b. Let \(P\) be \(pattern\).[[OriginalSource]].
   c. Let \(F\) be \(pattern\).[[OriginalFlags]].
4. Else,
   a. Let \(P\) be \(pattern\).
   b. Let \(F\) be flags.
5. Return ? RegExpInitialize(\(O\), \(P\), \(F\)).

NOTE This method completely reinitializes the this value RegExp with a new pattern and flags. An implementation may interpret use of this method as an assertion that the resulting RegExp object will be used multiple times and hence is a candidate for extra optimization.

B.3 Other Additional Features

B.3.1 Labelled Function Declarations

Prior to ECMAScript 2015, the specification of LabelledStatement did not allow for the association of a statement label with a FunctionDeclaration. However, a labelled FunctionDeclaration was an allowable extension for non-strict code and most browser-hosted ECMAScript implementations supported that extension. In ECMAScript 2015 and later, the grammar production for LabelledStatement permits use of FunctionDeclaration as a LabelledItem but 14.13.1 includes an Early Error rule that produces a Syntax Error if that occurs. That rule is modified with the addition of the highlighted text:

LabelledItem : FunctionDeclaration

- It is a Syntax Error if any source text that is strict mode code is matched by this production.

NOTE The early error rules for WithStatement, IfStatement, and IterationStatement prevent these statements from containing a labelled FunctionDeclaration in non-strict code.

B.3.2 Block-Level Function Declarations Web Legacy Compatibility Semantics

Prior to ECMAScript 2015, the ECMAScript specification did not define the occurrence of a FunctionDeclaration as an element of a Block statement's StatementList. However, support for that form of FunctionDeclaration was an allowable extension and most browser-hosted ECMAScript implementations permitted them. Unfortunately, the semantics of such declarations differ among those implementations. Because of these semantic differences, existing web ECMAScript source text that uses Block level function declarations is only portable among browser implementations if the usage only depends upon the semantic intersection of all of the browser implementations for such declarations. The following are the use cases that fall within that intersection semantics:

1. A function is declared and only referenced within a single block.
   - One or more FunctionDeclarations whose BindingIdentifier is the name \(f\) occur within the function code of an enclosing function \(g\) and that declaration is nested within a Block.
   - No other declaration of \(f\) that is not a var declaration occurs within the function code of \(g\).
   - All occurrences of \(f\) as an IdentifierReference are within the StatementList of the Block containing the declaration of \(f\).
2. A function is declared and possibly used within a single Block but also referenced by an inner function definition that is not contained within that same Block.

   - One or more FunctionDeclarations whose BindingIdentifier is the name_f occur within the function code of an enclosing function_g and that declaration is nested within a Block.
   - No other declaration of f that is not a var declaration occurs within the function code of g.
   - There may be occurrences of f as an IdentifierReference within the StatementList of the Block containing the declaration of f.
   - There is at least one occurrence of f as an IdentifierReference within another function_h that is nested within g and no other declaration of f shadows the references to f from within h.
   - All invocations of h after the declaration of f has been evaluated.

3. A function is declared and possibly used within a single block but also referenced within subsequent blocks.

   - One or more FunctionDeclaration whose BindingIdentifier is the name_f occur within the function code of an enclosing function_g and that declaration is nested within a Block.
   - No other declaration of f that is not a var declaration occurs within the function code of g.
   - There may be occurrences of f as an IdentifierReference within the StatementList of the Block containing the declaration of f.
   - There is at least one occurrence of f as an IdentifierReference within the function code of g that lexically follows the Block containing the declaration of f.

The first use case is interoperable with the semantics of Block level function declarations provided by ECMA-Script 2015. Any pre-existing ECMAScript source text that employs that use case will operate using the Block level function declarations semantics defined by clauses 10, 14, and 15.

ECMAScript 2015 interoperability for the second and third use cases requires the following extensions to the clause 10, clause 15, clause 19.2.1 and clause 16.1.7 semantics.

If an ECMAScript implementation has a mechanism for reporting diagnostic warning messages, a warning should be produced when code contains a FunctionDeclaration for which these compatibility semantics are applied and introduce observable differences from non-compatibility semantics. For example, if a var binding is not introduced because its introduction would create an early error, a warning message should not be produced.

B.3.2.1 Changes to FunctionDeclarationInstantiation

During FunctionDeclarationInstantiation the following steps are performed in place of step 29:

29. If strict is false, then
   a. For each FunctionDeclaration_f that is directly contained in the StatementList of a Block, CaseClause, or DefaultClause, do
      i. Let F be StringValue of the BindingIdentifier of_f.
      ii. If replacing the FunctionDeclaration_f with a VariableStatement that has F as a BindingIdentifier would not produce any Early Errors for func and parameterNames does not contain_F, then
          1. NOTE: A var binding for F is only instantiated here if it is neither a VarDeclaredName, the name of a formal parameter, or another FunctionDeclaration.
          2. If instantiatedVarNames does not contain_F and_F is not "arguments", then
              a. Perform ! varEnv.CreateMutableBinding(F, false).
              b. Perform ! varEnv.InitializeBinding(F, undefined).
              c. Append F to instantiatedVarNames.
      iii. When the FunctionDeclaration_f is evaluated, perform the following steps in place of the FunctionDeclaration Evaluation algorithm provided in 15.2.6:
          a. Let fenv be the running execution context’s VariableEnvironment.
          b. Let benv be the running execution context’s LexicalEnvironment.
          c. Let fobj be ! benv.GetBindingValue(F, false).
          d. Perform ! fenv.SetMutableBinding(F, fobj, false).
          e. Return UNUSED.
B.3.2.2 Changes to GlobalDeclarationInstantiation

During GlobalDeclarationInstantiation the following steps are performed in place of step 12:

12. Perform the following steps:
   a. Let strict be IsStrict of script.
   b. If strict is false, then
      i. Let declaredFunctionOrVarNames be the list-concatenation of declaredFunctionNames and declaredVarNames.
      ii. For each FunctionDeclaration f that is directly contained in the StatementList of a Block, CaseClause, or DefaultClause Contained within script, do
         1. Let F be StringValue of the BindingIdentifier of f.
         2. If replacing the FunctionDeclaration f with a VariableStatement that has F as a BindingIdentifier would not produce any Early Errors for script, then
            a. If env.HasLexicalDeclaration(F) is false, then
               i. Let fnDefinable be ? env.CanDeclareGlobalVar(F).
               ii. If fnDefinable is true, then
                  i. NOTE: A var binding for F is only instantiated here if it is neither a VarDeclaredName nor the name of another FunctionDeclaration.
                  ii. If declaredFunctionOrVarNames does not contain F, then
                     ii. Append F to declaredFunctionOrVarNames.
               iii. When the FunctionDeclaration f is evaluated, perform the following steps in place of the FunctionDeclaration Evaluation algorithm provided in 15.2.6:
                  i. Let genv be the running execution context’s VariableEnvironment.
                  ii. Let benv be the running execution context’s LexicalEnvironment.
                  iii. Let fobj be ! benv.GetBindingValue(F, false).
                  v. Return UNUSED.
   
B.3.2.3 Changes to EvalDeclarationInstantiation

During EvalDeclarationInstantiation the following steps are performed in place of step 13:

13. If strict is false, then
   a. Let declaredFunctionOrVarNames be the list-concatenation of declaredFunctionNames and declaredVarNames.
   b. For each FunctionDeclaration f that is directly contained in the StatementList of a Block, CaseClause, or DefaultClause Contained within body, do
      i. Let F be StringValue of the BindingIdentifier of f.
      ii. If replacing the FunctionDeclaration f with a VariableStatement that has F as a BindingIdentifier would not produce any Early Errors for body, then
         1. Let bindingExists be false.
         2. Let thisEnv be lexEnv.
         3. Assert: The following loop will terminate.
         4. Repeat, while thisEnv is not varEnv,
            a. If thisEnv is not an Object Environment Record, then
               i. If ! thisEnv.HasBinding(F) is true, then
                  i. Let bindingExists be true.
            b. Set thisEnv to thisEnv.([OuterEnv]).
         5. If bindingExists is false and varEnv is a Global Environment Record, then
            a. If varEnv.HasLexicalDeclaration(F) is false, then
               i. Let fnDefinable be ? varEnv.CanDeclareGlobalVar(F).
            b. Else,
               i. Let fnDefinable be false.
         6. Else,
            a. Let fnDefinable be true.
         7. If bindingExists is false and fnDefinable is true, then
            a. If declaredFunctionOrVarNames does not contain F, then
i. If `varEnv` is a Global Environment Record, then
   i. Perform `varEnv.CreateGlobalVarBinding(F, true)`.
ii. Else,
   i. Let `bindingExists` be `!varEnv.HasBinding(F)`.
   ii. If `bindingExists` is `false`, then
       i. Perform `!varEnv.CreateMutableBinding(F, true)`.
       ii. Perform `varEnv.InitializeBinding(F, undefined)`.
   iii. Append `F` to `declaredFunctionOrVarNames`.

b. When the `FunctionDeclaration` `f` is evaluated, perform the following steps in place of the `FunctionDeclaration Evaluation` algorithm provided in 15.2.6:
   i. Let `genv` be the running execution context's VariableEnvironment.
   ii. Let `benv` be the running execution context's LexicalEnvironment.
   iii. Let `fobj` be `!benv.GetBindingValue(F, false)`.
   v. Return `UNUSED`.

B.3.2.4 Changes to Block Static Semantics: Early Errors

The rules for the following production in 14.2.1 are modified with the addition of the highlighted text:

```
Block : { StatementList }
```

- It is a Syntax Error if the `LexicallyDeclaredNames` of `StatementList` contains any duplicate entries, unless the source text matched by this production is not strict mode code and the duplicate entries are only bound by `FunctionDeclarations`.
- It is a Syntax Error if any element of the `LexicallyDeclaredNames` of `StatementList` also occurs in the `VarDeclaredNames` of `StatementList`.

B.3.2.5 Changes to switch Statement Static Semantics: Early Errors

The rules for the following production in 14.12.1 are modified with the addition of the highlighted text:

```
SwitchStatement : switch ( Expression ) CaseBlock
```

- It is a Syntax Error if the `LexicallyDeclaredNames` of `CaseBlock` contains any duplicate entries, unless the source text matched by this production is not strict mode code and the duplicate entries are only bound by `FunctionDeclarations`.
- It is a Syntax Error if any element of the `LexicallyDeclaredNames` of `CaseBlock` also occurs in the `VarDeclaredNames` of `CaseBlock`.

B.3.2.6 Changes to BlockDeclarationInstantiation

During `BlockDeclarationInstantiation` the following steps are performed in place of step 3.a.ii.1:

1. If `!env.HasBinding(dn)` is `false`, then

During `BlockDeclarationInstantiation` the following steps are performed in place of step 3.b.iii:

iii. Perform the following steps:
   1. If the binding for `fn` in `env` is an uninitialized binding, then
      a. Perform `env.InitializeBinding(fn, fo)`.
   2. Else,
      a. Assert: `d` is a `FunctionDeclaration`.
      b. Perform `!env.SetMutableBinding(fn, fo, false)`. 
B.3.3 FunctionDeclarations in IfStatement Statement Clauses

The following augments the IfStatement production in 14.6:

\[
\text{IfStatement}[\text{Yield, Await, Return}] : \\
\text{if ( Expression} [+In, ?Yield, ?Await] ) \\
\quad \text{FunctionDeclaration}[?Yield, ?Await, ~Default] \text{ else} \\
\text{if ( Expression} [+In, ?Yield, ?Await] ) \\
\quad \text{Statement}[?Yield, ?Await, ?Return] \text{ else} \\
\text{if ( Expression} [+In, ?Yield, ?Await] ) \\
\quad \text{FunctionDeclaration}[?Yield, ?Await, ~Default] \\
\text{if ( Expression} [+In, ?Yield, ?Await] ) \\
\quad \text{FunctionDeclaration}[?Yield, ?Await, ~Default] \text{ else} \\
\text{if ( Expression} [+In, ?Yield, ?Await] ) \\
\quad \text{FunctionDeclaration}[?Yield, ?Await, ~Default] \text{ else} \\
\text{FunctionDeclaration}[?Yield, ?Await, ~Default] \\
\text{[lookahead ≠ else]}
\]

This production only applies when parsing non-strict code. Source text matched by this production is processed as if each matching occurrence of FunctionDeclaration[?Yield, ?Await, ~Default] was the sole StatementListItem of a BlockStatement occupying that position in the source text. The semantics of such a synthetic BlockStatement includes the web legacy compatibility semantics specified in B.3.2.

B.3.4 VariableStatements in Catch Blocks

The content of subclause 14.15.1 is replaced with the following:

\[
\text{Catch} : \text{catch ( CatchParameter ) Block}
\]

- It is a Syntax Error if BoundNames of CatchParameter contains any duplicate elements.
- It is a Syntax Error if any element of the BoundNames of CatchParameter also occurs in the LexicallyDeclaredNames of Block.
- It is a Syntax Error if any element of the BoundNames of CatchParameter also occurs in the VarDeclaredNames of Block unless CatchParameter is BindingIdentifier.

NOTE The Block of a Catch clause may contain var declarations that bind a name that is also bound by the CatchParameter. At runtime, such bindings are instantiated in the VariableDeclarationEnvironment. They do not shadow the same-named bindings introduced by the CatchParameter and hence the Initializer for such var declarations will assign to the corresponding catch parameter rather than the var binding.

This modified behaviour also applies to var and function declarations introduced by direct eval calls contained within the Block of a Catch clause. This change is accomplished by modifying the algorithm of 19.2.1.3 as follows:

Step 3.d.i.2.a.i is replaced by:

i. If thisEnv is not the Environment Record for a Catch clause, throw a SyntaxError exception.

Step 13.b.ii.4.a.i is replaced by:

i. If thisEnv is not the Environment Record for a Catch clause, let bindingExists be true.
B.3.5 Initializers in ForIn Statement Heads

The following augments the ForInOfStatement production in 14.7.5:

```
ForInOfStatement[Yield, Await, Return] :
```

This production only applies when parsing non-strict code.

The static semantics of ContainsDuplicateLabels in 8.3.1 are augmented with the following:

```
ForInOfStatement : for ( var BindingIdentifier Initializer in Expression ) Statement
1. Return ContainsDuplicateLabels of Statement with argument labelSet.
```

The static semantics of ContainsUndefinedBreakTarget in 8.3.2 are augmented with the following:

```
ForInOfStatement : for ( var BindingIdentifier Initializer in Expression ) Statement
1. Return ContainsUndefinedBreakTarget of Statement with argument labelSet.
```

The static semantics of ContainsUndefinedContinueTarget in 8.3.3 are augmented with the following:

```
ForInOfStatement : for ( var BindingIdentifier Initializer in Expression ) Statement
1. Return ContainsUndefinedContinueTarget of Statement with arguments iterationSet and « ».
```

The static semantics of IsDestructuring in 14.7.5.2 are augmented with the following:

```
BindingIdentifier :
  Identifier
    yield
    await
1. Return false.
```

The static semantics of VarDeclaredNames in 8.2.6 are augmented with the following:

```
ForInOfStatement : for ( var BindingIdentifier Initializer in Expression ) Statement
1. Let names1 be the BoundNames of BindingIdentifier.
2. Let names2 be the VarDeclaredNames of Statement.
3. Return the list-concatenation of names1 and names2.
```

The static semantics of VarScopedDeclarations in 8.2.7 are augmented with the following:

```
ForInOfStatement : for ( var BindingIdentifier Initializer in Expression ) Statement
1. Let declarations1 be « BindingIdentifier ».
2. Let declarations2 be the VarScopedDeclarations of Statement.
3. Return the list-concatenation of declarations1 and declarations2.
```

The runtime semantics of ForInOfLoopEvaluation in 14.7.5.5 are augmented with the following:

```
ForInOfStatement : for ( var BindingIdentifier Initializer in Expression ) Statement
1. Let bindingId be StringValue of BindingIdentifier.
2. Let lhs be ? ResolveBinding(bindingId).
```
3. If `IsAnonymousFunctionDefinition(Initializer)` is `true`, then
   a. Let `value` be ? `NamedEvaluation` of `Initializer` with argument `bindingId`.
4. Else,
   a. Let `rhs` be ? `Evaluation` of `Initializer`.
   b. Let `value` be ? `GetValue(rhs)`.
5. Perform ? `PutValue(lhs, value)`.
6. Let `keyResult` be ? `ForIn/OfHeadEvaluation(« », Expression, ENUMERATE)`.
7. Return ? `ForIn/OfBodyEvaluation(BindingIdentifier, Statement, keyResult, ENUMERATE, VAR-BINDING, labelSet)`.

### B.3.6 The [[IsHTMLDDA]] Internal Slot

An `[[IsHTMLDDA]]` internal slot may exist on host-defined objects. Objects with an `[[IsHTMLDDA]]` internal slot behave like `undefined` in the `ToBoolean` and `IsLooselyEqual` abstract operations and when used as an operand for the `typeof` operator.

**NOTE** Objects with an `[[IsHTMLDDA]]` internal slot are never created by this specification. However, the `document.all` object in web browsers is a host-defined exotic object with this slot that exists for web compatibility purposes. There are no other known examples of this type of object and implementations should not create any with the exception of `document.all`.

### B.3.6.1 Changes to `ToBoolean`

The following step replaces step 3 of `ToBoolean`:

3. If `argument` is an `Object` and `argument` has an `[[IsHTMLDDA]]` internal slot, return `false`.

### B.3.6.2 Changes to `IsLooselyEqual`

The following steps replace step 4 of `IsLooselyEqual`:

4. Perform the following steps:
   a. If `x` is an `Object`, `x` has an `[[IsHTMLDDA]]` internal slot, and `y` is either `undefined` or `null`, return `true`.
   b. If `x` is either `undefined` or `null`, `y` is an `Object`, and `y` has an `[[IsHTMLDDA]]` internal slot, return `true`.

### B.3.6.3 Changes to the `typeof` Operator

The following step replaces step 12 of the evaluation semantics for `typeof`:

12. If `val` has an `[[IsHTMLDDA]]` internal slot, return "`undefined`".

### B.3.7 Non-default behaviour in HostMakeJobCallback

The `HostMakeJobCallback` abstract operation allows hosts which are web browsers to specify non-default behaviour.

### B.3.8 Non-default behaviour in HostEnsureCanAddPrivateElement

The `HostEnsureCanAddPrivateElement` abstract operation allows hosts which are web browsers to specify non-default behaviour.
Annex C
(informative)
The Strict Mode of ECMAScript

The strict mode restriction and exceptions

- **implements, interface, let, package, private, protected, public, static, and yield** are reserved words within strict mode code. (12.7.2).
- A conforming implementation, when processing strict mode code, must disallow instances of the productions
  - `NumericLiteral :: LegacyOctalIntegerLiteral` and `DecimalIntegerLiteral :: NonOctalDecimalLiteral`.
  - `EscapeSequence :: LegacyOctalEscapeSequence` and `EscapeSequence :: NonOctalDecimalEscapeSequence`.
  - Assignment to an undeclared identifier or otherwise unresolvable reference does not create a property in the global object. When a simple assignment occurs within strict mode code, its LeftHandSideExpression must not evaluate to an unresolvable Reference. If it does a `ReferenceError` exception is thrown (6.2.5.6). The LeftHandSideExpression also may not be a reference to a data property with the attribute value `{ [[Writable]]: false }, to an accessor property with the attribute value `{ [[Set]]: undefined }, nor to a non-existent property of an object whose {[Extensible]} internal slot is false. In these cases a `TypeError` exception is thrown (13.15).
  - An IdentifierReference with the `StringValue "eval"` or "arguments" may not appear as the LeftHandSideExpression of an Assignment operator (13.15) or of an UpdateExpression (13.4) or as the UnaryExpression operated upon by a Prefix Increment (13.4.4) or a Prefix Decrement (13.4.5) operator.
  - Arguments objects for strict functions define a non-configurable accessor property "callee" which throws a `TypeError` exception on access (10.4.4.6).
  - Arguments objects for strict functions do not dynamically share their array-indexed property values with the corresponding formal parameter bindings of their functions. (10.4.4).
  - For strict functions, if an arguments object is created the binding of the local identifier arguments to the arguments object is immutable and hence may not be the target of an assignment expression. (10.2.11).
  - It is a SyntaxError if the `StringValue of a BindingIdentifier` is either "eval" or "arguments" within strict mode code (13.1.1).
  - Strict mode eval code cannot instantiate variables or functions in the variable environment of the caller to eval. Instead, a new variable environment is created and that environment is used for declaration binding instantiation for the eval code (19.2.1).
  - If this is evaluated within strict mode code, then the this value is not coerced to an object. A this value of either undefined or null is not converted to the global object and primitive values are not converted to wrapper objects. The this value passed via a function call (including calls made using `Function.prototype.apply` and `Function.prototype.call`) do not coerce the passed this value to an object (10.2.1.2, 20.2.3.1, 20.2.3.3).
  - When a delete operator occurs within strict mode code, a SyntaxError is thrown if its UnaryExpression is a direct reference to a variable, function argument, or function name (13.5.1.1).
  - When a delete operator occurs within strict mode code, a TypeError is thrown if the property to be deleted has the attribute `{ [[Configurable]]: false }` or otherwise cannot be deleted (13.5.1.2).
  - Strict mode code may not include a WithStatement. The occurrence of a WithStatement in such a context is a SyntaxError (14.11.1).
  - It is a SyntaxError if a CatchParameter occurs within strict mode code and BoundNames of CatchParameter contains either eval or arguments (14.15.1).
  - It is a SyntaxError if the same BindingIdentifier appears more than once in the FormalParameters of a strict function. An attempt to create such a function using a Function, Generator, or AsyncFunction constructor is a SyntaxError (15.2.1, 20.2.1.1.1).
  - An implementation may not extend, beyond that defined in this specification, the meanings within strict functions of properties named "callee" or "arguments" of function instances.
Annex D
(informative)
Host Layering Points

See 4.2 for the definition of host.

D.1 Host Hooks

HostCallJobCallback(...)
HostEnqueueFinalizationRegistryCleanupJob(...)
HostEnqueueGenericJob(...)
HostEnqueuePromiseJob(...)
HostEnqueueTimeoutJob(...)
HostEnsureCanCompileStrings(...)
HostFinalizeImportMeta(...)
HostGetImportMetaProperties(...)
HostGrowSharedArrayBuffer(...)
HostHasSourceTextAvailable(...)
HostLoadImportedModule(...)
HostMakeJobCallback(...)
HostPromiseRejectionTracker(...)
HostResizeArrayBuffer(...)
InitializeHostDefinedRealm(...)

D.2 Host-defined Fields

[[HostDefined]] on Realm Records: See Table 24.
[[HostDefined]] on Script Records: See Table 40.
[[HostDefined]] on Module Records: See Table 41.
[[HostDefined]] on JobCallback Records: See Table 28.
[[HostSynchronizesWith]] on Candidate Executions: See Table 96.
[[IsHTMLDDA]]: See B.3.6.

D.3 Host-defined Objects

The global object: See clause 19.
D.4 Running Jobs

Preparation steps before, and cleanup steps after, invocation of Job Abstract Closures. See 9.5.

D.5 Internal Methods of Exotic Objects

Any of the essential internal methods in Table 4 for any exotic object not specified within this specification.

D.6 Built-in Objects and Methods

Any built-in objects and methods not defined within this specification, except as restricted in 17.1.
Annex E
(informative)

Corrections and Clarifications in ECMAScript 2015 with Possible Compatibility Impact

9.1.1.4.15-9.1.1.4.18: Edition 5 and 5.1 used a property existence test to determine whether a global object property corresponding to a new global declaration already existed. ECMAScript 2015 uses an own property existence test. This corresponds to what has been most commonly implemented by web browsers.

10.4.2.1: The 5th Edition moved the capture of the current array length prior to the integer conversion of the array index or new length value. However, the captured length value could become invalid if the conversion process has the side-effect of changing the array length. ECMAScript 2015 specifies that the current array length must be captured after the possible occurrence of such side-effects.

21.4.1.31: Previous editions permitted the TimeClip abstract operation to return either \( \pm 0_F \) or \(-0_F\) as the representation of a 0 time value. ECMAScript 2015 specifies that \( +0_F \) always returned. This means that for ECMAScript 2015 the time value of a Date is never observably \(-0_F\) and methods that return time values never return \(-0_F\).

21.4.1.32: If a UTC offset representation is not present, the local time zone is used. Edition 5.1 incorrectly stated that a missing time zone should be interpreted as "z".

21.4.4.36: If the year cannot be represented using the Date Time String Format specified in 21.4.1.32 a RangeError exception is thrown. Previous editions did not specify the behaviour for that case.

21.4.4.41: Previous editions did not specify the value returned by `Date.prototype.toString` when the time value is NaN. ECMAScript 2015 specifies the result to be the String value "Invalid Date".

22.2.4.1, 22.2.6.13.1: Any LineTerminator code points in the value of the "source" property of a RegExp instance must be expressed using an escape sequence. Edition 5.1 only required the escaping of `/`.

22.2.6.8, 22.2.6.11: In previous editions, the specifications for `String.prototype.match` and `String.prototype.replace` was incorrect for cases where the pattern argument was a RegExp value whose global flag is set. The previous specifications stated that for each attempt to match the pattern, if `lastIndex` did not change, it should be incremented by 1. The correct behaviour is that `lastIndex` should be incremented by 1 only if the pattern matched the empty String.

23.1.3.30: Previous editions did not specify how a NaN value returned by a `comparefn` was interpreted by `Array.prototype.sort`. ECMAScript 2015 specifies that such as value is treated as if \( +0_F \) was returned from the `comparefn`. ECMAScript 2015 also specifies that `ToNumber` is applied to the result returned by a `comparefn`. In previous editions, the effect of a `comparefn` result that is not a Number value was implementation-defined. In practice, implementations call `ToNumber`.
6.2.5: In ECMAScript 2015, Function calls are not allowed to return a Reference Record.

7.1.4.1: In ECMAScript 2015, ToNumber applied to a String value now recognizes and converts BinaryIntegerLiteral and OctalIntegerLiteral numeric strings. In previous editions such strings were converted to NaN.

9.3: In ECMAScript 2018, Template objects are canonicalized based on Parse Node (source location), instead of across all occurrences of that template literal or tagged template in a Realm in previous editions.

12.2: In ECMAScript 2016, Unicode 8.0.0 or higher is mandated, as opposed to ECMAScript 2015 which mandated Unicode 5.1. In particular, this caused U+180E MONGOLIAN VOWEL SEPARATOR, which was in the Space_Separator (Zs) category and thus treated as whitespace in ECMAScript 2015, to be moved to the Format (Cf) category (as of Unicode 6.3.0). This causes whitespace-sensitive methods to behave differently. For example, "$\u180E".trim().length was 0 in previous editions, but 1 in ECMAScript 2016 and later. Additionally, ECMAScript 2017 mandated always using the latest version of the Unicode Standard.

12.7: In ECMAScript 2015, the valid code points for an IdentifierName are specified in terms of the Unicode properties “ID_Start” and “ID_Continue”. In previous editions, the valid IdentifierName or Identifier code points were specified by enumerating various Unicode code point categories.

12.10.1: In ECMAScript 2015, Automatic Semicolon Insertion adds a semicolon at the end of a do-while statement if the semicolon is missing. This change aligns the specification with the actual behaviour of most existing implementations.

13.2.5.1: In ECMAScript 2015, it is no longer an early error to have duplicate property names in Object Initializers.

13.15.1: In ECMAScript 2015, strict mode code containing an assignment to an immutable binding such as the function name of a FunctionExpression does not produce an early error. Instead it produces a runtime error.

14.2: In ECMAScript 2015, a StatementList beginning with the token let followed by the input elements LineTerminator then Identifier is the start of a LexicalDeclaration. In previous editions, automatic semicolon insertion would always insert a semicolon before the Identifier input element.

14.5: In ECMAScript 2015, a StatementListItem beginning with the token let followed by the token [ is the start of a LexicalDeclaration. In previous editions such a sequence would be the start of an ExpressionStatement.

14.6.2: In ECMAScript 2015, the normal result of an IfStatement is never the value EMPTY. If no Statement part is evaluated or if the evaluated Statement part produces a normal completion containing EMPTY, the result of the IfStatement is undefined.

14.7: In ECMAScript 2015, if the ( token of a for statement is immediately followed by the token sequence let [ then the let is treated as the start of a LexicalDeclaration. In previous editions such a token sequence would be the start of an Expression.

14.7: In ECMAScript 2015, if the ( token of a for-in statement is immediately followed by the token sequence let [ then the let is treated as the start of a ForDeclaration. In previous editions such a token sequence would be the start of an LeftHandSideExpression.

14.7: Prior to ECMAScript 2015, an initialization expression could appear as part of the VariableDeclaration that precedes the in keyword. In ECMAScript 2015, the ForBinding in that same position does not allow the occurrence of such an initializer. In ECMAScript 2017, such an initializer is permitted only in non-strict code.

14.7: In ECMAScript 2015, the result of evaluating an IterationStatement is never a normal completion whose [[Value]] is EMPTY. If the Statement part of an IterationStatement is not evaluated or if the final evaluation
of the Statement part produces a normal completion whose [[Value]] is EMPTY, the result of evaluating the IterationStatement is a normal completion whose [[Value]] is undefined.

14.11.2: In ECMAScript 2015, the result of evaluating a WithStatement is never a normal completion whose [[Value]] is EMPTY. If evaluation of the Statement part of a WithStatement produces a normal completion whose [[Value]] is EMPTY, the result of evaluating the WithStatement is a normal completion whose [[Value]] is undefined.

14.12.4: In ECMAScript 2015, the result of evaluating a SwitchStatement is never a normal completion whose [[Value]] is EMPTY. If evaluation of the CaseBlock part of a SwitchStatement produces a normal completion whose [[Value]] is EMPTY, the result of evaluating the SwitchStatement is a normal completion whose [[Value]] is undefined.

14.15: In ECMAScript 2015, it is an early error for a Catch clause to contain a var declaration for the same Identifier that appears as the Catch clause parameter. In previous editions, such a variable declaration would be instantiasted in the enclosing variable environment but the declaration's Initializer value would be assigned to the Catch parameter.

14.15, 19.2.1.3: In ECMAScript 2015, a runtime SyntaxError is thrown if a Catch clause evaluates a non-strict direct eval whose eval code includes a var or FunctionDeclaration declaration that binds the same Identifier that appears as the Catch clause parameter.

14.15.3: In ECMAScript 2015, the result of a TryStatement is never the value EMPTY. If the Block part of a TryStatement evaluates to a normal completion containing EMPTY, the result of the TryStatement is undefined. If the Block part of a TryStatement evaluates to a throw completion and it has a Catch part that evaluates to a normal completion containing EMPTY, the result of the TryStatement is undefined if there is no Finally clause or if its Finally clause evaluates to an EMPTY normal completion.

15.4.5 In ECMAScript 2015, the function objects that are created as the values of the [[Get]] or [[Set]] attribute of accessor properties in an ObjectLiteral are not constructor functions and they do not have a "prototype" own property. In the previous edition, they were constructors and had a "prototype" property.

20.1.2.6: In ECMAScript 2015, if the argument to Object.freeze is not an object it is treated as if it was a non-extensible ordinary object with no own properties. In the previous edition, a non-object argument always causes a TypeError to be thrown.

20.1.2.8: In ECMAScript 2015, if the argument to Object.getOwnPropertyDescriptor is not an object an attempt is made to coerce the argument using ToObject. If the coercion is successful the result is used in place of the original argument value. In the previous edition, a non-object argument always causes a TypeError to be thrown.

20.1.2.10: In ECMAScript 2015, if the argument to Object.getOwnPropertyNames is not an object an attempt is made to coerce the argument using ToObject. If the coercion is successful the result is used in place of the original argument value. In the previous edition, a non-object argument always causes a TypeError to be thrown.

20.1.2.12: In ECMAScript 2015, if the argument to Object.getPrototypeOf is not an object an attempt is made to coerce the argument using ToObject. If the coercion is successful the result is used in place of the original argument value. In the previous edition, a non-object argument always causes a TypeError to be thrown.

20.1.2.16: In ECMAScript 2015, if the argument to Object.isExtensible is not an object it is treated as if it was a non-extensible ordinary object with no own properties. In the previous edition, a non-object argument always causes a TypeError to be thrown.

20.1.2.17: In ECMAScript 2015, if the argument to Object.isFrozen is not an object it is treated as if it was a non-extensible ordinary object with no own properties. In the previous edition, a non-object argument always causes a TypeError to be thrown.

20.1.2.18: In ECMAScript 2015, if the argument to Object.isSealed is not an object it is treated as if it was a non-extensible ordinary object with no own properties. In the previous edition, a non-object argument always causes a TypeError to be thrown.
20.1.2.19: In ECMAScript 2015, if the argument to \texttt{Object.keys} is not an object an attempt is made to coerce the argument using \texttt{ToObject}. If the coercion is successful the result is used in place of the original argument value. In the previous edition, a non-object argument always causes a \texttt{TypeError} to be thrown.

20.1.2.20: In ECMAScript 2015, if the argument to \texttt{Object.preventExtensions} is not an object it is treated as if it was a non-extensible ordinary object with no own properties. In the previous edition, a non-object argument always causes a \texttt{TypeError} to be thrown.

20.1.2.22: In ECMAScript 2015, if the argument to \texttt{Object.seal} is not an object it is treated as if it was a non-extensible ordinary object with no own properties. In the previous edition, a non-object argument always causes a \texttt{TypeError} to be thrown.

20.2.3.2: In ECMAScript 2015, the \texttt{[[Prototype]]} internal slot of a bound function is set to the \texttt{[[GetPrototypeOf]]} value of its target function. In the previous edition, \texttt{[[Prototype]]} was always set to \texttt{%Function.prototype%}.

20.2.4.1: In ECMAScript 2015, the \texttt{"length"} property of function instances is configurable. In previous editions it was non-configurable.

20.5.6.2: In ECMAScript 2015, the \texttt{[[Prototype]]} internal slot of a \texttt{NativeError} constructor is the \texttt{Error} constructor. In previous editions it was the \texttt{Function prototype object}.

21.4.4 In ECMAScript 2015, the \texttt{Date prototype object} is not a \texttt{Date} instance. In previous editions it was a \texttt{Date} instance whose \texttt{TimeValue} was \texttt{NaN}.

22.1.3.12 In ECMAScript 2015, the \texttt{String.prototype.localeCompare} function must treat Strings that are canonically equivalent according to the Unicode Standard as being identical. In previous editions implementations were permitted to ignore canonical equivalence and could instead use a bit-wise comparison.

22.1.3.28 and 22.1.3.30 In ECMAScript 2015, lowercase/upper conversion processing operates on code points. In previous editions such the conversion processing was only applied to individual code units. The only affected code points are those in the Deseret block of Unicode.

22.1.3.32 In ECMAScript 2015, the \texttt{String.prototype.trim} method is defined to recognize white space code points that may exist outside of the Unicode BMP. However, as of Unicode 7 no such code points are defined. In previous editions such code points would not have been recognized as white space.

22.2.4.1 In ECMAScript 2015, if the \texttt{pattern} argument is a RegExp instance and the \texttt{flags} argument is not \texttt{undefined}, a new RegExp instance is created just like \texttt{pattern} except that \texttt{pattern}'s flags are replaced by the argument \texttt{flags}. In previous editions a \texttt{TypeError} exception was thrown when \texttt{pattern} was a RegExp instance and \texttt{flags} was not \texttt{undefined}.

22.2.6 In ECMAScript 2015, the \texttt{RegExp prototype object} is not a RegExp instance. In previous editions it was a RegExp instance whose pattern is the empty String.

22.2.6 In ECMAScript 2015, "source", "global", "ignoreCase", and "multiline" are accessor properties defined on the \texttt{RegExp prototype object}. In previous editions they were data properties defined on RegExp instances.

25.4.15: In ECMAScript 2019, \texttt{Atomics.wake} has been renamed to \texttt{Atomics.notify} to prevent confusion with \texttt{Atomics.wait}.

27.1.4.4, 27.6.3.6: In ECMAScript 2019, the number of \texttt{Jobs} enqueued by \texttt{await} was reduced, which could create an observable difference in resolution order between a \texttt{then()} call and an \texttt{await} expression.
Colophon

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Prior editions of this specification were authored using Word—the Ecmarkup source text that formed the basis of this edition was produced by converting the ECMAScript 2015 Word document to Ecmarkup using an automated conversion tool.
Bibliography


   NOTE There are no normative changes between IEEE 754-2008 and IEEE 754-2019 that affect the ECMA-262 specification.

11. IANA Time Zone Database, available at https://www.iana.org/time-zones
12. ISO 8601:2004(E) Data elements and interchange formats — Information interchange — Representation of dates and times
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