



LUND
UNIVERSITY

JavaScript

EDAF90 WEB PROGRAMMING

PER ANDERSSON



JavaScript

- “the world’s most misunderstood programming language”
- working name at Netscape 1995: *LiveScript*
- syntax and name in common with Java
- object function oriented language
- interpreted
- dynamically typed
- run in any web browser and node.js

Interpreted

- no compilation → no compilation errors
- JS language design leads to:
 - many silent errors
 - weird and unexpected behaviour
 - for example a miss spelled property name
- the programmer have more responsibility
- programmers needs extended language knowledge
- use jslint to check your code
- write test cases to catch compilation errors
- work with small increments

Types

Six data types that are primitives (immutable):

- `undefined`
- `boolean`
- `number`
- `bigint` - **literal syntax**: `42n`
- `string`
- `symbol` - unique and immutable

Structural types:

- `object`
- `function`

Structural root:

- `null`

Types

The `typeof` operator returns a string indicating the type of the operand.

```
typeof null === "object"
```

Wrapper objects:

- Boolean, Number, BigInt, String, Symbol
- Object, Function

```
typeof "EDAF90" === "string"
```

```
typeof new String("EDAF90") === "object"
```

Dynamically Typed Language

JavaScript is dynamically typed.

A variable have a value and a type. Both can change.

This includes objects. You can add and remove properties.

valid JavaScript

```
let a = 'Per';  
a = 0;  
a = null;  
a = undefined;
```

typeof

```
typeof 'Per' === 'string';  
typeof 0 === 'number';  
typeof null === 'object';  
typeof undefined = 'undefined';
```

`typeof` returns a string. 8 possible values, all types except **null**.

Automatic Type Conversion

JavaScript will automatically convert values when needed.

There is a strong preference to convert to `string`.

The type conversion algorithm have some non intuitive side effect. This is the root of some of the *bad parts* of JavaScript.

automatic type conversion

```
3 + '42'; // '342'
```

```
null + 'Per'; // 'nullPer'
```

```
3 == '3' // true
```

Type Conversion

Enforce type conversion with expressions.

type converting expressions

```
typeof (+'42') // 'number'  
typeof (!!null) // 'boolean'
```

Use type converting functions: `Number()`, `String()`, and `Boolean()`.

type converting expressions

```
typeof Number('42') // 'number'  
typeof new Number('42') // 'object'  
typeof Number('Per') // 'number (NaN)'  
typeof Boolean('false') // 'boolean'  
typeof String(42) // 'string'
```


Parameter Types

- variable and parameter declarations are untyped
- they get a type when assigned
- can not enforce argument types
- hard to write functions that can handle any value
- `typeof` can handle some cases

Strings

String literals and templates

- `'single quotation mark'`
- `"double quotation mark"`
- ``string templates``
can span multiple lines
and contain embedded expressions: `1+2=${1+2}``

Operations

- `'Per' + ' ' + 'Andersson'`
- `'Per'.length`
- `'Per'.toUpperCase()`
- `'Per'[0]`

Note

strings are immutable

Truthy / Falsy

Falsy:

- false
- 0
- 0n
- "", '', ``
- null
- undefined
- NaN

no need for

```
if (name == null || name.length == 0) {  
  name = 'anonymous';  
}
```

Short Circuit

Logic operations return the value of one operand.

some expressions

```
a = 'Per' || 'default value';  
b = '' || 'default value';  
c = 'Per' || null;  
d = NaN || undefined;  
  
e = 'Per' && 'Andersson';  
f = undefined && 'Andersson';  
g = 'Per' && NaN;  
h = null && 0;  
i = ref && ref.value;
```

evaluates to

```
a = 'Per';  
b = 'default value';  
c = 'Per';  
d = undefined;  
  
e = 'Andersson';  
f = undefined;  
g = NaN;  
h = null;  
i = ref ? ref.value : ref;
```

Optional Chaining operator

- `object?.property`
- access a property or calls a function
- short-circuit and return **undefined** if:
 - property is not a property of object, or
 - object is **null** or **undefined**

throws no exceptions

```
function myFunction(obj) {  
  console.log( obj?.prop );  
  console.log( obj?.[1] );  
  console.log( obj.func?.() );  
  obj.func = 3;  
  console.log( obj.func?.() ); // Uncaught TypeError:  
  obj?.a?.b?.[0]?.().c;  
}
```

Equality and sameness

There are four equality algorithms in ES2015:

- Abstract/Loose Equality: `==`, `!=`
 - not symmetric $a == b \not\Rightarrow b == a$
- Strict Equality: `===`, `!==` (`Object.is`)
- conform to IEEE 754 (so **NaN** `!=` **NaN**, and `-0 == +0`)
- `===` and `Object.is()` only differs when comparing NaN, -0, and +0

evaluates to true

```
1 == '1';  
[1, 2] == '1,2';  
[1, 2] != '1, 2';  
'true' != true;
```

evaluates to true

```
-0 == +0;  
0 == false  
1 !== '1';  
null == undefined;  
null !== undefined;
```

Check out the JavaScript Equality Table

Functions

- functions are values - `Function` objects
 - assign functions to variables
 - use functions as arguments to other functions
- call by value - like in Java (objects are references)
- default return value:
 - **undefined**
 - **this** in constructors
- three ways to create functions:
 - function declaration
 - function expression
 - `Function` constructor (not recommended)

Function Declaration

- is a statement
- no need to use semicolon after a function declaration
- creates
 - a `Function` object
 - a variable with the function name

function declaration

```
function calcRectArea(width, height) {  
    return width * height;  
}  
  
console.log(calcRectArea(5, 6));
```


Function Expression

- is an expression
- creates a `Function` object
- the function name is optional, omitting it creates an anonymous function
- the name is stored in the `Function` object, can only be used inside the function
- you must store the value to use the function

function expression

```
let calcRectArea = function foo(width, height) {  
  return width * height;  
}  
  
console.log(calcRectArea(5, 6));
```

Default Parameters

- function parameters default to **undefined**
- parameters can have other default values (ES2015)
- parameters are available to later default parameters
- default parameters are evaluated at call time

rest parameters

```
function multiply(a, b = 1) {  
    return a * b;  
}  
  
function greet(name,  
               greeting,  
               message = greeting + ' ' + name) {  
    return [name, greeting, message];  
}
```

Rest Parameters

- must be the last named parameter
- all remaining arguments are wrapped into an `Array`

rest parameters

```
function sloppySum(first, ...theRest) {  
  return theRest.reduce((previous, current) => {  
    return previous + current;  
  });  
}
```

Arguments Object

- `arguments` is an Array-like object
- contains all arguments
- doesn't have Array's built-in methods like `forEach()` and `map()`
- properties
 - `arguments.callee`
 - `arguments.caller`
 - `arguments.length`
 - `arguments[@@iterator]`

arguments

```
function foo(a, b, c) {  
  console.log(arguments[1]);  
}  
foo(1, 2, 3);
```

Arrow Function

- convenient syntax
- is an expression
- creates an anonymous function
- without own bindings to the **this**, **arguments**, **super**, or **new.target**
- these values are retained from enclosing lexical context
- ill suited as methods, and they cannot be used as constructors

syntax

```
([param[, param]]) => {  
  statements  
}
```

```
param => expression
```

Arrow Function, examples

example of arrow functions

```
let sqr = x => x*x;

let calcRectArea = (width, height) => width * height;

let pi = _ => Math.PI;

let myLogger = (msg) => {
  console.log(new Date() + ': ' + msg);
};

let foo = (width, height) => { width * height };
```

Function Oriented Programming

JavaScript have all features of a function oriented language.

function oriented programming

```
let list = [1, 2, 3, 4, 5];  
let a = list.map(x => x + 2);  
let b = a.filter((x) => x % 2 === 0);  
b.forEach(x => console.log(x));  
let c = b.reduce((sum, x) => sum + x, 0);
```

chaining

```
let sum = [1, 2, 3, 4, 5];  
sum.map(x => x + 2)  
.filter((x) => x % 2 === 0)  
.reduce((sum, x) => sum + x, 0);
```

Closure

- lexical scope
- a closure gives you access to an outer function's scope from an inner function
- closures are created every time a function is created, at function creation time

closure

```
let name = 'Per Andersson';  
let foo = function() {  
  name = 'anonymous';  
}  
console.log(name);  
foo();  
console.log(name);
```


Closure

- remember, functions are values.
- inner functions can be returned from a function.

closure

```
let foo = function() {  
  let cnt = 0;  
  return _ => cnt++;  
}  
  
let idGenerator = foo();  
  
console.log(idGenerator());  
some_async_function(idGenerator);  
another_async_function(idGenerator);
```

Name Spaces

- one name space for variables and parameters
- object properties are stored in a separate dictionary
- you must use **this** when accessing object properties

Global name space

- shared by all functions and modules
- high risk of name conflict
- do not use
- reading an undeclared name throws a `ReferenceError`
- assigning to an undeclared name creates it as a global variable

Scope Rules

Two different kind of scopes:

- function scope
 - **var**
- block scope (ES2015)
 - **let**
 - **const**
 - works like scope in Java

Function Scope

- declare variables using **var**
- the scope is the current execution context
 - the function
 - the global context
- redeclaration of names are allowed
- considered bad practice today

Name Hoisting

In function scope

- all declared variables are created before any code is executed
- name declarations are lifted to top of function
- initialisation remain in place
- function expressions are not hoisted

```
function foo() {  
  console.log(x); // undefined  
  var x = 3;  
  console.log(x); // 3  
}
```

Function Scope, example 1

```
function foo() {  
  y = 1; // Throws a ReferenceError in strict mode.  
  var x = 3;  
  if (true) {  
    var x = 2;  
  }  
  return x;  
}  
  
try {  
  console.log(y);  
} catch (e) { console.log('Oops'); }  
foo();  
console.log(y); // 1
```

Function Scope, example 2

```
function foo() {  
  for (var i=0; i<2; i++) {  
    for (var i=0; i<2; i++) {  
      console.log(i);  
    }  
  }  
  return x;  
}  
foo() // 0, 1
```

Function Scope, example 3

```
var a = [];  
for (var i=0; i<3; i++) {  
  a[i] = function() { console.log(i); };  
}  
a[0] ();  
a[1] ();  
a[2] ();
```


Immediately Invoked Function Expressions

- creates a new scope level, do not pollute surrounding
- if inside a loop
 - one scope for each loop iteration
 - local variables are instantiated in each loop iteration
 - can be used to clone and freeze outer state (loop variable)

```
// outer scope
var x = 2;
(function() {
  // inner hidden scope
  var x = 3;
})();

console.log(x);
// more outer scope
```

IIFE, example 2

```
var domElements = [...];  
for (var i=0; i<10; i++) {  
  (function () {  
    var id = i;  
    domElement[i].onClick(  
      _ => { alert('clicked ' + id); }  
    );  
  }) ();  
}
```

JavaScript modules

Introduced in ES6

my-module.js

```
function cube(x) {  
  return x * x * x;  
}  
  
export { cube, foo };  
const foo = Math.PI + Math.SQRT2;
```

some-code.js

```
import { cube, foo } from './my-module.js';  
  
console.log(cube(3));  
console.log(foo);
```

CommonJS modules

Common in environments not supporting JavaScript Modules, for example node.

my-module.js

```
function cube(x) {  
  return x * x * x;  
}  
const foo = Math.PI + Math.SQRT2;
```

some-code.js

```
const stuff = require('./my-module.js');  
  
console.log(stuff.cube(3));  
console.log(stuff.foo);
```

Objects

- an object is a dictionary: `string → any value`
- objects have properties - a (string, value) pair in the dictionary (attributes, methods)
- properties can have any name, including reserved words and operations
- access properties using:
 - dot notation: `myObj.prop`
 - array index notation: `myObj['prop']`
- properties are not in scope of methods, must use **this**
- `typeof objRef === 'object'`
- add properties by writing to them `myObj.newProp = 'adding stuff';`
- remove properties by: `delete myObj.newProp`

Create Objects

- object literals *{prop : value}*
- **new** `ConstructorFunction(args);`

Object Literals

- superset of JSON
- comma separated list of properties inside { }
- a property is defined by:
 - `property-name : value`
 - `method(parameters){ statements }`
- name in plain text, quotes if needed
- value is any JavaScript expression
- `{a:a}` is the same as `{a}`

Object Literals

object literal

```
const familyName = 'Andersson';  
const myObject = {  
  givenName: 'Per',  
  familyName,  
  selector: 'givenName',  
  getValue: function () {  
    return this[this.selector];  
  },  
  setValue(value) {  
    this[this.selector] = value;  
  },  
  '+': 'plus'  
}
```


Object Literals

- object literals are cheap
- use them frequently
- they bring structure and readability to programs

object literals

```
let myPoints = [{x: 0, y: 0}, {x:10, y:15}];

function foo(x, y, a, b, c, d) {
  console.log('b = ' + b);
}

function bar(x, y, options) {
  console.log('b = ' + options?.b);
}
```

Named Parameters

Remember, `foo` and `bar` prints option `b`.

What is printed?

```
foo(0, 0, 0, 0, 1, undefined, 1);  
bar(0, 0, {a: 0, b: 1, d:1});
```

Did you notice that `foo` has one extra parameter compared to the arguments list?
Too few, or extra parameters do not raise errors in JavaScript.

Constructor Functions

- same purpose as classes in Java
 - initialises objects when used with **new**
- are function, intended use differs
 - **function** `ConstructorFunction(args) { ... }`
 - by convention: use leading capital letter
- **new** `ConstructorFunction(args)` will:
 1. creates an empty object
 2. set up inheritance
 3. calls `ConstructorFunction(args)` with the new object as **this**
 4. the constructor function adds properties to **this** and assign them values
 5. the result of **new** is the value returned by the *constructor function*
remember: the default return value of functions called by **new** is **this**

Constructor Function Example

class definition

```
function Point(x, y) {  
  this.x = x || 0;  
  this.y = y || 0;  
  this.getX = function() {  
    return this.x;  
  }  
}
```

create instances

```
let point1 = new Point(3, 6);  
let point2 = new Point();  
let point2 = new Point(5);  
let point3 =  
  new Point(undefined, 5);
```

this

- **this** is defined in all functions
- its value depends on how the function is called:
 - function call: `foo()` - the global object
 - dot notation: `obj.foo()` - the object left of the dot
 - explicit: `Function.prototype.call()`
 - explicit: `Function.prototype.bind()` - creates a new function with a predefined value for **this**
 - as an DOM event handler - the element the event fired from (not all cases for all browsers)
 - as an inline DOM event handler - the DOM element on which the listener is placed
- arrow functions: **this** from the enclosing scope is used

self

When a function is a “object method”

- you do not know if **this** refers to the right object
- use closure to fix this
- or use arrow functions

```
function Person() {  
  const self = this; // Some choose 'that' instead of 'self'.  
                    // Choose one and be consistent.  
  
  self.age = 0;  
  this.birthday = function() { self.age++; };  
  this.birthday2 = _ => this.age++;  
}  
let per = new Person();  
setInterval(per.birthday, 1000);
```

Prototype Based Inheritance

- all object inherit from another object or **null**
- default is `Object`
- objects forms a *prototype chain*
- property name lookup follows the prototype chain
- the chain ends with **null**
- you can access the prototype chain (but don't):
 - `Object.getPrototypeOf(object)`
 - `Object.setPrototypeOf(object, chain)`

Prototype Chain

```
let per = new Person()
```



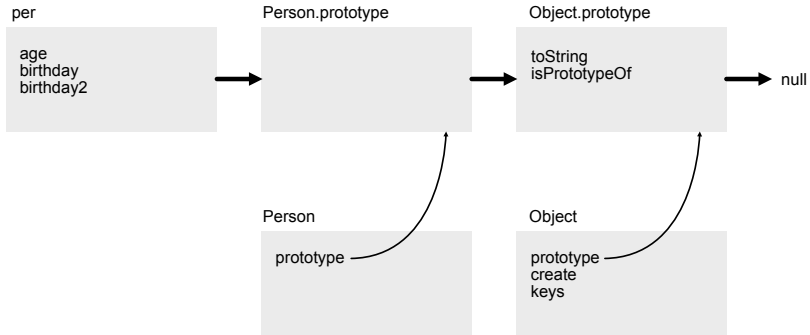
Function Object

Every functions is stored in a function object:

- Function object:
 - stores the function body
 - the value of function expression: **function** () { }
 - is callable, left hand side of ()
 - store static properties
 - inherits from `Function.prototype`
 - constructor functions must have the property `prototype`
 - » all functions except: methods, arrow functions, or async functions
- Prototype object:
 - added to the *prototype chain* by **new**
 - store inherited properties
 - `constructor` refers to the function object

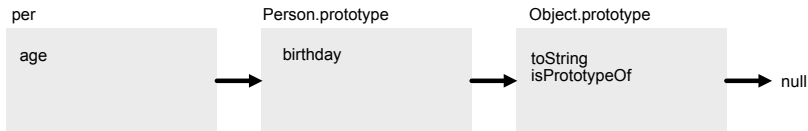
Prototype Chain

```
let per = new Person()
```



prototype

```
function Person() {  
  this.age = 0;  
}  
Person.prototype.birthday = function() { this.age++; };  
let per = new Person();
```



Set up Prototype Chain

Setting up the prototype chain:

- **new** do the work for you
 - all constructor functions have the `prototype` property
 - **new**:
 - » creates an empty object
 - » **and** set its parent in the prototype chain to the `prototype` in the constructor function
 - all properties in the `prototype` of the constructor function are now in the prototype chain of the new object
- you can do it manually: `Object.create()`

Property Name Lookup

Property read:

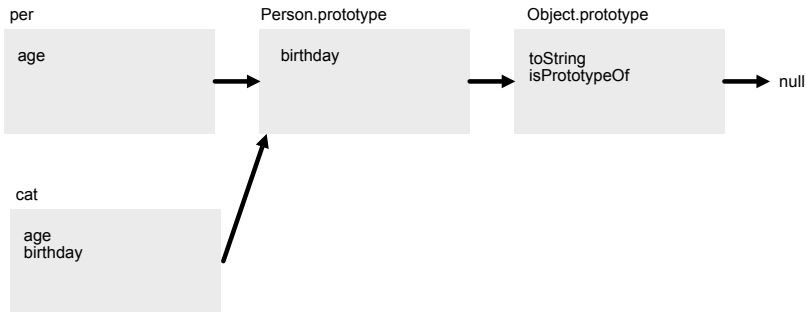
- follows the prototype chain
- return the first value found
- return **undefined** if the end of the prototype chain is reached

Property write:

- do not follows the prototype chain
- writes to the referenced object (left hand side of the dot)
- update if the name existed
- adds the property if the name did not exist

prototype

```
let cat = new Person();  
cat.birthday = function() { this.age += 7; }
```



Inheritance

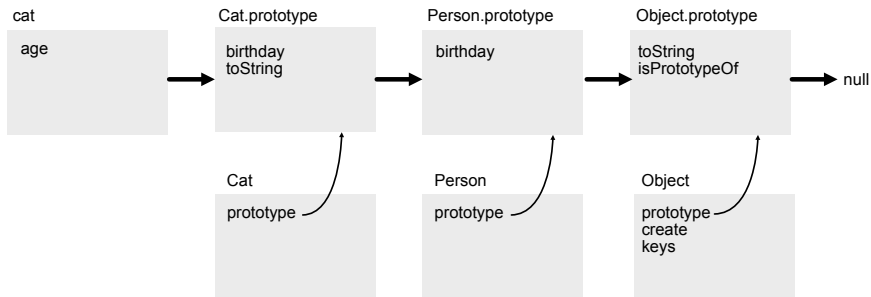
- `Object.create()` creates an object with a given prototype chain
- store it as the `prototype` property in the constructor function
- explicit call the constructor of the superclass

Cat extends Person

```
function Cat() {  
  this = Person.call(this);  
}  
Cat.prototype = Object.create(Person.prototype);  
Cat.prototype.birthday = function() { this.age += 7; }  
Cat.prototype.toString = function() {  
  return 'I am a cat of age ' + this.age;  
}
```

prototype

```
let cat = new Cat()
```



Class

a "Java class" corresponds to two objects in JavaScript

- a constructor function:
 - its name is part of the variable name space
 - place static stuff here
- a prototype object
 - the object to add to the prototype chain
 - place any stuff to be inherited by the instances here

`Class` was introduced in ECMAScript 2015

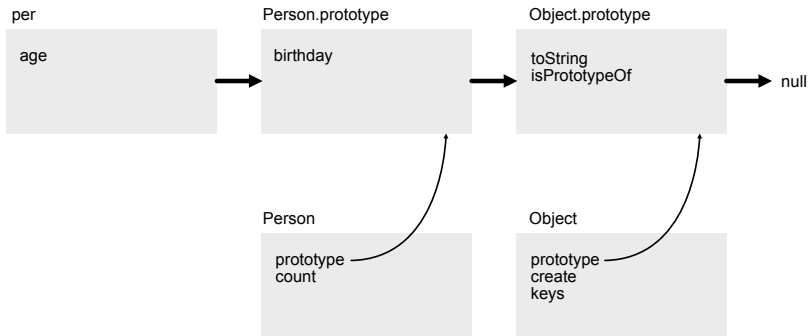
- syntactical sugar, set up the prototype chain as outlined above
- **static** will add the property to the constructor function object
- **public** or **#private**

Class Example

```
class Person {  
  static #count = 0;  
  
  constructor(age) {  
    this.age = age || 0;  
    Person.#count = Person.#count + 1;  
  }  
  
  birthday() {  
    this.age++;  
  }  
}
```

prototype

```
let per = new Person()
```



Class Extends

The constructor:

- in a derived class must call **super()** before you can access **this**
- in a base class may not call **super()**

```
class Cat extends Person {  
  constructor(age) {  
    super(age);  
  }  
  birthday() {  
    this.age += 7;  
  }  
  toString() {  
    return 'I am a cat of age ' + this.age;  
  }  
}
```

Access to Undefined Names

Variables and properties have distinct name spaces.

Name Scope: Variables and Parameters

- read: throws `ReferenceError`
- write: creates a variable in the global scope

Objects: Properties

- read: evaluates to **`undefined`**
- write: adds the property to the object

Standard Classes

In JavaScript there are many standard classes. Some important:

- `Object` - default base class for all objects
- `Function` **extends** `Object` - base class for all functions
- `Array` - base class for array literals

Property Descriptors

Distinction between

- *own properties*
- *inherited properties*

Object properties have descriptors (metadata)

- *value*
- *writable*
- *configurable*
- *enumerable*

Iteration

Iterating over object property names and values

- **for ... in** — all enumerable string properties (include inherited)
- `Object.keys()` — own enumerable
- `Object.values()` — own enumerable
- `Object.entries()` — own enumerable
- `Object.getOwnPropertyNames()` — own
- `...`, `spread` — own enumerable

More to learn

The JavaScript syntax only give you access to a subset of the language...

```
Object.defineProperty(obj, "prop", {  
  value: "test",  
  writable: false  
});
```

This is however out of scope for this course.

Arrays

- variable size and type
- `myArray = [1, 'two', new Number(3)]`
- index must be number
- `myArray['per'] = 3` - adds a property to the array object
- `push()`, `pop()`, `slice()`
- `map()`, `reduce()`, `forEach()`
- **for ... of** - iterates over elements
- **for ... in** - iterates over enumerable object properties

Destructuring assignment

- unpack arrays and objects
- use:
 - left hand side of assignment
 - function parameters
- can have default values
- can be nested
- the tail of an array can be stored in a variable: `...remainingValues`

```
const foo = ['red', 'green'];  
const [one, two, three = 'blue'] = foo;  
console.log(one); // "red"  
console.log(three); // "default three"  
const [one, ...rest] = foo;
```

Destructuring assignment

```
const user = {  
  id: 42,  
  displayName: 'jdoe',  
  fullName: {  
    firstName: 'John',  
    lastName: 'Doe'  
  }  
};  
  
const {id:selectedId} = user;  
  
function whoIs({displayName, fullName: {firstName: name}}) {  
  return `${displayName} is ${name}`;  
}
```

Spread Syntax

The spread syntax `...` can be used on

An iterable, such as an array or string, can be expanded instead of:

- zero or more arguments (for function calls)
- elements (for array literals)

An object expression to be expanded instead of

- zero or more key-value pairs (for object literals)

```
function sum(x, y, z) {  
  return x + y + z;  
}  
  
const numbers = [1, 2, 3];  
  
const total = sum(...numbers);
```

Spread Syntax

```
const parts = ['shoulders', 'knees'];  
const lyrics = ['head', ...parts, 'and', 'toes'];  
  
const obj1 = { foo: 'bar', x: 42 };  
const obj2 = { foo: 'baz', y: 13 };  
  
const clonedObj = { ...obj1 };  
  
const augmentedObj = { ...obj1, name: 'Per' };  
  
const mergedObj = { ...obj1, ...obj2 };
```

Automatic Semicolon Insertion

If needed, a semicolon is added at the end of a line.

returns undefined

```
function() { return  
1; }
```

Common to use minify to minimise script download size. All white spaces are removed.

works

```
let myVar = 9  
if (myVar === 9) {  
}
```

syntax error after minify

```
var myVar = 9 if (myVar === 9) {}
```

Use jslint to detect these problems.

Strict mode

Converting mistakes into errors.

Whole-script strict mode syntax

```
'use strict';  
var v = "Hi! I'm a strict mode script!";
```

Function-level strict mode syntax

```
function strict() {  
  'use strict';  
  function nested() { return 'And so am I!'; }  
  return "Hi! I'm a strict mode function! " + nested();  
}  
function notStrict() { return "I'm not strict."; }
```