JavaScript: Fundamentals, Concepts, Object Model

Prof. Ing. Andrea Omicini
Ingegneria Due, Università di Bologna a Cesena
andrea.omicini@unibo.it

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JavaScript

- A scripting language: interpreted, not compiled
- History
  - Originally defined by Netscape (LiveScript) - Name modified in JavaScript after an agreement with Sun in 1995
  - Microsoft calls it JScript (minimal differences)
  - Reference: standard ECMAScript 262
- Object based (but not object oriented)
- JavaScript programs are directly inserted in the HTML source of web pages

The Web Page

```
<html>
  <head><title>...</title></head>
  <body>
  ...
  <script language="JavaScript">
  <!-- HTML comment to avoid puzzling old browsers
  ... put here your JavaScript program ...
  // JavaScript comment to avoid puzzling old browsers -->
  </script>
  </body>
</html>
```

An HTML page may contain multiple `<script>` tags

Document Object Model

- JavaScript as a language references the Document Object Model (DOM)
- Following that model, every document has the following structure

```
window
    document
    ...
```

- The `window` object represents the current object (i.e. `this`) the current browser window
  - the visualising entity
- The `document` object represents the content of the web page in the current browser window
  - the visualised entity

The `document` object

- The document object represents the current web page (not the current browser window!)
- You can invoke many different methods on it. The write method prints a value on the page:

```
document.write("Scrooge McDuck")
document.write(18.45 - 34.44)
document.write('Donald Duck')
document.write('<img src="image.gif">')
```

- The `this` reference to the `window` object is omitted:

`document.write` is equivalent to `this.document.write`

The `window` object (1/2)

- The `window` object is the root of the DOM hierarchy and represents the browser window
- Amongst the `window` object's methods there is `alert`, which makes an alert window appear, displaying the given message

```
x = -1.55; y = 31.85; sum = x + y;
mess = "La somma di " + x + " e " + y + " è " + sum;
alert(mess); // returns undefined
```

- You can use `alert` in an HTML anchor

The `window` object (2/2)

Other methods of the `window` object:

- use `confirm` to display a dialog to confirm or dismiss a message
  - returns a boolean value: `false` if the Cancel button has been pushed, `true` if the OK button has been pushed
- use `prompt` to display a dialog to input a value
  - returns a `string` value containing the input

The DOM model

The `window` object's main components:

- **`self`**
- **`window`**
- **`parent`**
- **`top`**
- **`navigator`**
  - **`plugins`** (array), **`navigator`**, **`mimeTypes`** (array)
- **`frames`** (array)
- **`location`**
- **`history`**
- **`document`**

...and here follows an entire hierarchy of objects

The `document` object

The `document` object's main components (all arrays):

- **`forms`**
- **`anchors`**
- **`links`**
- **`images`**
- **`applets`**

The `document` object's main API methods:

- **`getElementsByTagName(tagname)`**
- **`getElementById(elementId)`**
- **`getElementsByName(elementName)`**

Referencing / modifying an element in a document

- An element in a document is referred to by the value of its `id` attribute
  - or the **`name`** attribute in older browsers - deprecated!
- e.g. for an image identified as **`image0`** you would call **`document.getElementById("image0")`**
- or use the document properties through an array: **`document.images["image0"]`**
- then, to modify e.g. that image's width, you would write **`document.images["image0"].width = 40`**

Strings

- Strings can be delimited by using single or double quotes
- If you need to nest different kind of quotes, you have to alternate them
  - e.g. `document.write('<img src="img.gif">')`
  - e.g. `document.write("<img src='img.gif'>")`
- Use + to concatenate strings
  - e.g. `document.write('donald' + 'duck')`
- Strings are JavaScript objects with properties, e.g. `length`, and methods, e.g. `substring(first, last)`

Constants and comments

- Numeric constants are sequences of numeric characters not enclosed between quotes - their type is **`number`**
- Boolean constants are **`true`** and **`false`** - their type is **`boolean`**
- Other constants are **`null`**, **`NaN`**, **`undefined`**

- Comments can be
  - **`// on a single line`**
  - **`/* multi line */`**

Expressions

These are legal expressions in JavaScript

- numeric expressions, with operators like + - * / % ...
- conditional expressions, using the ?: ternary operator
- string expressions, concatenating with the + operator
- assignment expressions, using =

Some examples

- `window.alert(18/4)`
- `window.alert(3>5 ? 'yes' : "no")`
- `window.alert("donald" + 'duck')`

Variables

- Variables in JavaScript are dynamically typed: you can assign values of different types to the same variable at different times

```
a=19; b= 'bye'; a='world'; // different types!
```

- Legal operators include increment (++), decrement (--), extended assignment (e.g. +=)

Variables and scope

- Variable scope in JavaScript is
  - global for variables defined outside functions
  - local for variables explicitly defined inside functions (received parameters included)
- Warning: a block does not define a scope

```
x = '3' + 2 // the string '32'
{
    { x = 5 } // internal block
    y = x + 3 // here x is 5, not '32'
}
```

Dynamic types

- The **`typeof`** operator is used to retrieve the (dynamic) type of an expression or a variable

```
typeof(18/4) returns number
typeof "aaa" returns string
typeof false returns boolean
typeof document returns object
typeof document.write returns function
```

- When used with variables, the value returned by typeof is the current type of the variable

```
a = 18; typeof a // returns number
a = 'hi'; typeof a // returns string
```

Instructions

- Instructions must be separated by an end-of-line character or by a semicolon

```
alpha = 19 // end-of-line
bravo = 'donald duck'; charlie = true
window.alert(bravo + alpha)
```

- Concatenation between strings and numbers leads to an automatic conversion of the number value into a string value (be careful...)

```
window.alert(bravo + alpha + 2)
window.alert(bravo + (alpha + 2))
```

Control structures

- JavaScript features the usual control structures: `if`, `switch`, `for`, `while`, `do/while`
- Boolean conditions in an `if` can be expressed using the usual comparison operators (==, !=, >, <, >=, <=) and logic operators (&&, ||, !)
- Besides there are special structures used to work on objects: `for/in` and `with`

Functions definition

- Functions are introduced by the keyword **`function`** and their body is enclosed in a block
- They can be either procedures or proper functions (there's no keyword **`void`**)
- Formal parameters are written without their type declaration
- Functions can be defined inside other functions

```
function sum(a,b) { return a+b }

function printSum(a,b) {
   window.alert(a+b)
}
```

Function parameters

- Functions are called in the usual way, giving the list of actual parameters
- The number of actual parameters can be different from the number of formal ones
- If actual parameters are more than necessary, extra parameters are ignored
- If actual parameters are less than necessary, missing parameters are initialized to **`undefined`**
- Parameters are always passed by value (working with objects, references are copied)

Variable declarations

- Variable declarations can be explicit or implicit for global variables, but must necessarily be explicit for local variables
- A variable is explicitly declared using `var`

```
var goofy = 19 // explicit declaration
pluto = 18 // implicit declaration
```

- Implicit declaration always introduces global variables, while explicit declaration has a different effect depending on the context where it is located

Explicit variable declarations

- Outside functions, the `var` keyword is not important: the variable is defined as global
- Inside functions, using `var` means to introduce a new local variable having the function as its scope
- Inside functions, declaring a variable without using `var` means to introduce a global variable

```
x = 6 // global
function test() {
  x = 18 // global
}
test()
// the value of x is 18
```

```
var x = 6 // global
function test() {
  var x = 18 // local
}
test()
// the value of x is 6
```

Referencing environment

- Using an already declared variable, its name resolution starts from the environment local to its use
- If the variable is not defined in the environment local to its use, the global environment is checked for name resolution

```
f = 3
function test() {
  var f = 4
  g = f * 3
}
test(); g // 12
```

```
f = 3
function test() {
  var g = 4
  g = f * 3
}
test(); g // nd
```

```
f = 3
function test() {
  var h = 4
  g = f * 3
}
test(); g // 9
```

Functions and closures (1/3)

- Since JavaScript is an interpreted language and given the existence of a global environment...
- When a function uses a symbol not defined inside its body, which definition holds for that?
  - Does the symbol use the value it holds in the environment where the function is defined, or...
  - does the symbol use the value it holds in the environment where the function is called?

Functions and closures (2/3)

```
var x = 20
function testEnv(z) { return z + x }
alert(testEnv(18)) // definitely displays 38
function newTestEnv() {
    var x = -1
    return testEnv(18) // what does it return?
}
```

- The `newTestEnv` function redefines `x`, then invokes `testEnv`, which uses `x`... but, which `x`?
- In the environment where `testEnv` is defined, the symbol `x` has a different value from the environment where `testEnv` is called

Functions and closures (3/3)

```
var x = 20
function testEnv(z) { return z + x }
function newTestEnv() {
    var x = -1
    return testEnv(18) // what does it return?
}
```

- If the calling environment is used to resolve symbols, a dynamic closure is applied
- If the defining environment is used to resolve symbols, a lexical closure is applied
- JavaScript uses lexical closures, so `newTestEnv` returns 38, not 17

Functions as data

- Variables can reference functions

```
var square = function(x) { return x*x }
```

- Function literals have not a name: they are usually invoked by the name of the variable referencing them

```
var result = square(4)
```

- Assignments like `g = f` produce aliasing
- This enables programmers to pass functions as parameters to other functions

```
function exe(f, x) { return f(x) }
```

Functions as data - Examples

Given `function exe(f, x) { return f(x) }`

`exe(Math.sin, .8)` returns `0.7173560908995228`

`exe(Math.log, .8)` returns `-0.2231435513142097`

`exe(x*x, .8)` throws an error because `x*x` is an expression, not a function object in the program

`exe(fun, .8)` works only if the `fun` variable references a function object in the program

`exe("Math.sin", .8)` throws an error because a string is passed, not a function: don't mistake a function for its name

Functions as data - Consequences

- You need to have a **`function`** object (not just its name) to use a function
- You cannot use functions as data to execute a function knowing only its name or its code

```
exe(“Math.sin”, .8) // error
exe(x*x, .8) // error
```

- How to solve this problem?
  - Access the function using the properties of the global object
  - Build an appropriate **`function`** object

Objects

- An object is a data collection with a name: each datum is called property
- Use the dot notation to access any property, e.g. `object.property`
- A special function called constructor builds an object, creating its structure and setting up its properties
- Constructors are invoked using the `new` operator
- There are no classes in JavaScript: the name of the constructor can be choosed by the user

Defining objects

- The structure of an object is defined by the constructor used to create it
- Initial properties of the object are specified inside the constructor, using the dot notation and the `this` keyword
- The `this` keyword is necessary, otherwise properties would be referenced by the environment local to the constructor function

```
Point = function(i, j) {
  this.x = i
  this.y = j
}
```

```
function Point(i, j) {
  this.x = i
  this.y = j
}
```

Building objects

- To build an object, apply the `new` operator to a constructor function

```
p1 = new Point(3, 4)
p2 = new Point(0, 1)
```

- The argument of new is just a function name, not the name of a class
- Starting with JavaScript 1.2 objects can be built just listing couples of properties and values between braces

```
p3 = {x:10, y:7}
```

Accessing object properties

- All properties of an object are public

```
p1.x = 10 // p1 passes from (3,4) to (10,4)
```

- There are indeed some invisible system properties you can not enumerate using the usual appropriate constructs
- The `with` construct let you access several properties of an object without repeating its name every time

```
with (p1) x = 22, y = 2
with (p1) {x = 3; y = 4}
```

Adding and removing properties

- Constructors only specify initial properties for an object: you can dynamically add new properties by naming them and using them

```
p1.z = -3
// from {x:10, y:4} to {x:10, y:4, z:-3}
```

- It is possible to dynamically remove properties using the delete operator

```
delete p1.x
// from {x:10, y:4, z:-3} to {y:4, z:-3}
```

Methods for (single) objects

- Methods definition is a special case of property addition where the property is a function object

```
p1.getX = function() { return this.x }
```

- In this case, a method is defined for a single object, not for every instance created using the `Point` constructor function

Methods for multiple objects

- You can define the same method for multiple objects by assigning it to other objects

```
p2.getX = p1.getX
```

- To use the new method on the `p2` object, just call it using the `()` invoke operator

```
document.write(p2.getX() + "<br/>")
```

- If a nonexistent method is invoked, JavaScript throws a runtime error and halts execution

Methods for objects of a kind

- Since the concept of class is missing, ensuring that objects "of the same kind" have the same behaviour requires an adequate methodology
- A first approach is to define common methods in the constructor function

```
Point = function(i, j) {
    this.x = i; this.y = j
    this.getX = function() { return x }
    this.getY = function() { return y }
}
```

- Another approach is based on the concept of prototype (see later)

Simulating private properties

- Even if an object's properties are public, it is possible to simulate private properties using variables local to the constructor function

```
Rectangle = function() {
    var sideX, sideY
    this.setX = function(a) { sideX = a }
    this.setY = function(a) { sideY = a }
    this.getX = function() { return sideX }
    this.getY = function() { return sideY }
}
```

- While the four methods are publicly visible, the two variables are visible in the constructor's local environment only, being matter-of-factly private

Class variables and methods

- Class variables and methods can be modeled as properties of the constructor function object

```
p1 = new Point(3, 4); Point.color = “black”
Point.commonMethod = function(...) { ... }
```

- The complete `Point.property` notation is necessary even if the property is defined inside the constructor function, because property alone would define a local variable to the function, not a property of the constructor

`Function` objects (1/2)

- Every function is an object built on the basis of the `Function` constructor
  - implicitly, building functions inside the program by using the `function` construct
    - its arguments are the formal parameters of the function
    - the body (the code) of the function in enclosed in a block
- e.g. `square = function(x) { return x*x }`
- the construct is evaluated only once, it's efficient but not flexible

`Function` objects (2/2)

- Every function is an object built on the basis of the `Function` constructor
  - explicitly, building functions from strings by using the `Function` constructor
    - its arguments are all strings
    - first N-1 arguments are the names of the parameters of the function
    - the last argument is the body (the code)
- e.g. `square = new Function('x', 'return x*x')`
- the construct is evaluated every time it's read, it's not efficient but very flexible

Functions as data - Revision (1/4)

- The `exe` function executes a function

```
function exe(f, x) { return f(x) }
```

- It works only if the `f` argument represents a `function` object, not a body code or a string name

```
exe(x*x, .8) // error
exe("Math.sin", .8) // error
```

- These cases become manageable by using the `Function` constructor to dynamically build a function object

Functions as data - Revision (2/4)

- Dynamic building using the `Function` constructor
  - when only the body is known

```
exe(x*x, .8) // error
exe(new Function('x', 'return x*x'), .8) // returns .64
```

  - when only the name is known

```
exe('Math.sin', .8) // error
exe(new Function('z', 'return Math.sin(z)'), .8) //
returns 0.7173560908995228
```

Functions as data - Revision (3/4)

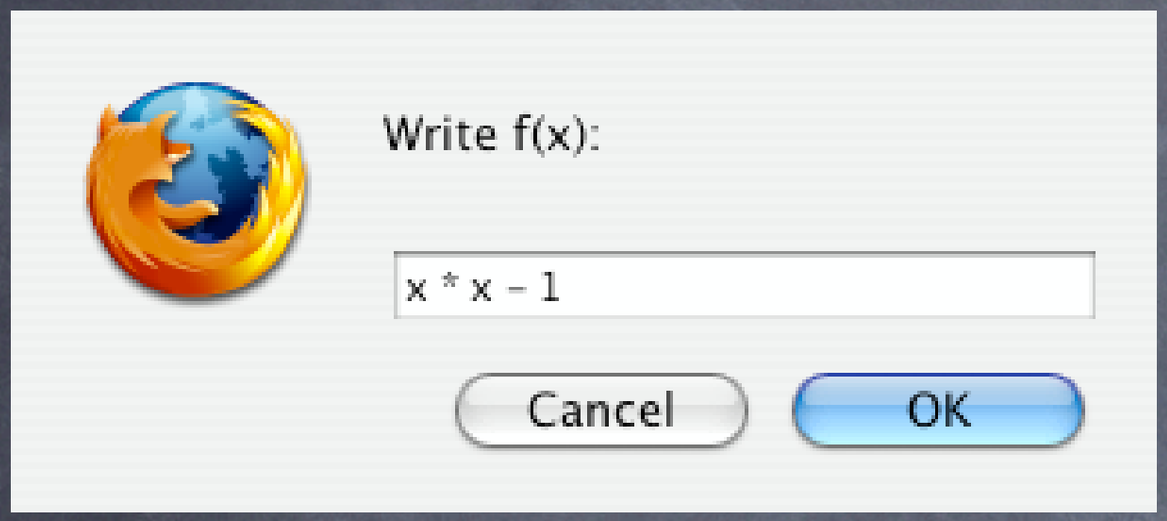
- Generalizing the approach:

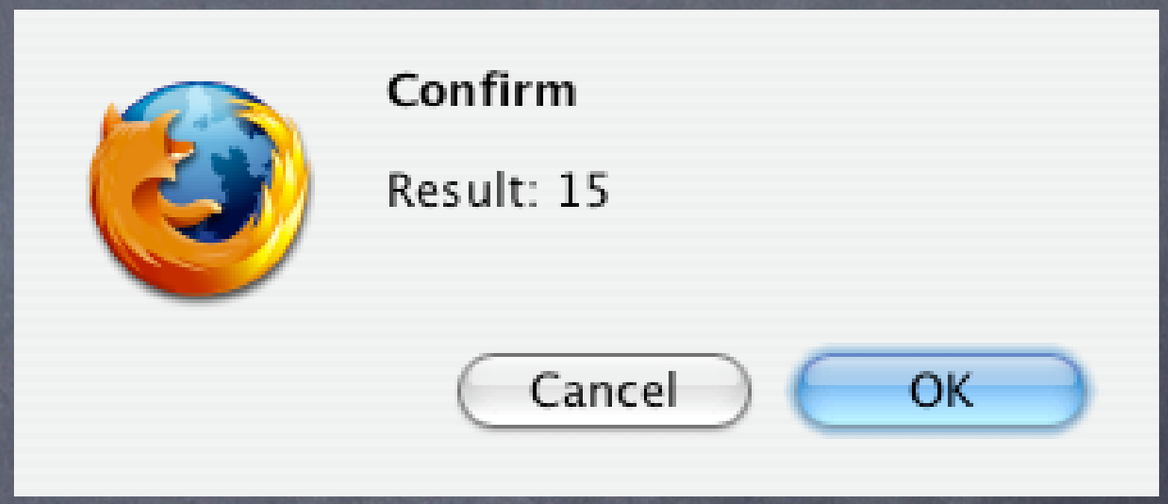
```
var fun = prompt('Write f(x): ')
var x = prompt('Calculate for x = ?')
var f = new Function('x', 'return ' + fun)
```

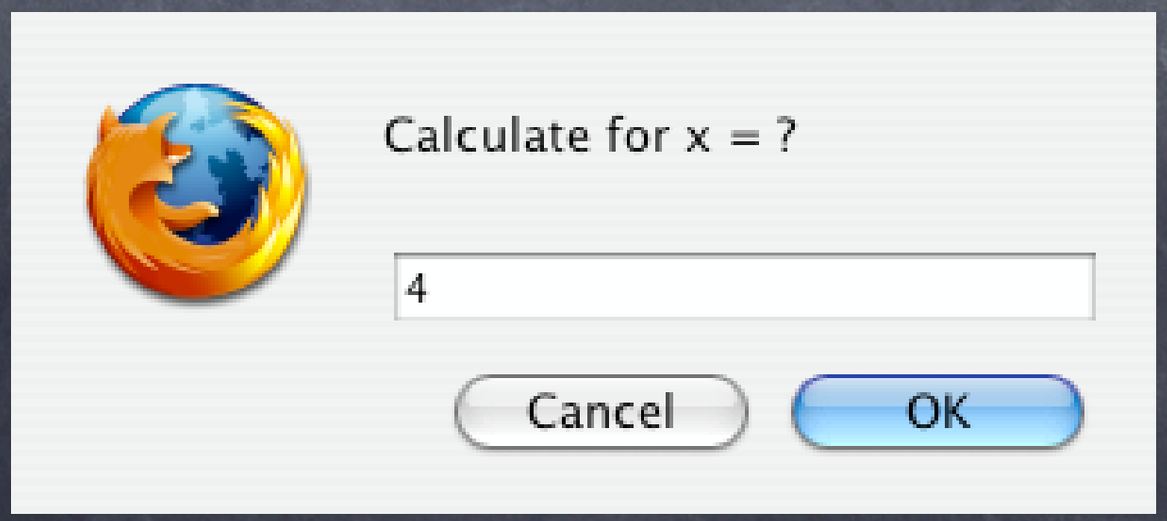
- The user can now type the code of the desired function and the value where to calculate it, then invoke it using a reflexive mechanism
- Show the result using

```
confirm('Result: ' + f(x))
```

Functions as data - Revision (4/4)







Functions as data - A problem

- Values returned by prompt are strings: so the + operation is interpreted as a concatenation of strings rather than a sum between numbers
- If the user gives `x+1` as a function, when `x=4` the function returns `41` as a result
- Possible solutions:
  - let the user write in input an explicit type conversion, e.g. `parseInt(x) + 1`
  - impose the type conversion from within the program, e.g. `var x = parseInt(prompt(...))`

`Function` objects - Properties

Static properties (available while not executing):

`length` - the number of formal expected parameters

Dynamic properties (available during execution only):

`arguments` - array containing actual parameters

`arguments.length` - number of actual parameters

`arguments.callee` - the executing function itself

`caller` - the caller (`null` if invoked from top level)

`constructor` - reference to the constructor object

`prototype` - reference to the prototype object

`Function` objects - Methods

Callable methods on a `function` object:

`toString` - returns a string representation of the function

`valueOf` - returns the function itself

`call` and `apply` - call the function on the object passed as a parameter giving the function the specified parameters

- e.g. `f.apply(obj, arrayOfParameters)` is equivalent to `obj.f(arrayOfParameters)`
- e.g. `f.call(obj, arg1, arg2, ...)` is equivalent to `obj.f(arg1, arg2, ...)`

`call` and `apply` - Example 1

- Definition of a function object

```
test = function(x, y, z) { return x + y + z }
```

- Invocation in the current context

```
test.apply(obj, [3, 4, 5])
test.call(obj, 8, 1, -2)
```

- Parameters to the callee are optional
- In this example the receiving object `obj` is irrelevant because the invoked `test` function does not use `this` references in its body

`call` and `apply` - Example 2

- A function object using this references

```
test = function(v) { return v + this.x }
```

- In this example the receiving object is relevant because it determines the evaluation environment for the variable `x`

```
x = 88

test.call(this, 3)

// Result: 3 + 88 = 91
```

```
x = 88
function Obj(u) {
  this.x = u
}
obj = new Obj(-4)
test.call(obj, 3)

// Result: 3 + -4 = -1
```

Prototypes (1/2)

- Every object has always a prototype specifying its basic properties
- The prototype itself is an object
- If P is prototype of X, every property of P is also available as a property of X and thus redefinable by X
- The prototype is stored in a typically invisible system property called `__proto__`

Prototypes (2/2)

- Every constructor has a building prototype defined in its `prototype` property
- It serves to define the properties of the objects it builds
- By default, the building prototype coincides with the prototype, but while the latter is unchangeable, the former can be modified
- The modifiability of the building prototype leads to prototype-based inheritance techniques

Prototypes: architecture

Object

Constructor

Predefined prototypes

- JavaScript makes available a series of predefined constructors whose **`prototype`** is the prototype for all the objects of that kind
  - The **`prototype`** of the **`Function`** constructor is the prototype for every function
  - The **`prototype`** of the **`Array`** constructor is the prototype of all the arrays
  - The **`prototype`** of the **`Object`** constructor is the prototype of all user defined objects built using the **`new`** operator
- Other predefined constructors are **`Number`**, **`Boolean`**, **`Date`**, **`RegExp`**

Taxonomy of prototypes (1/2)

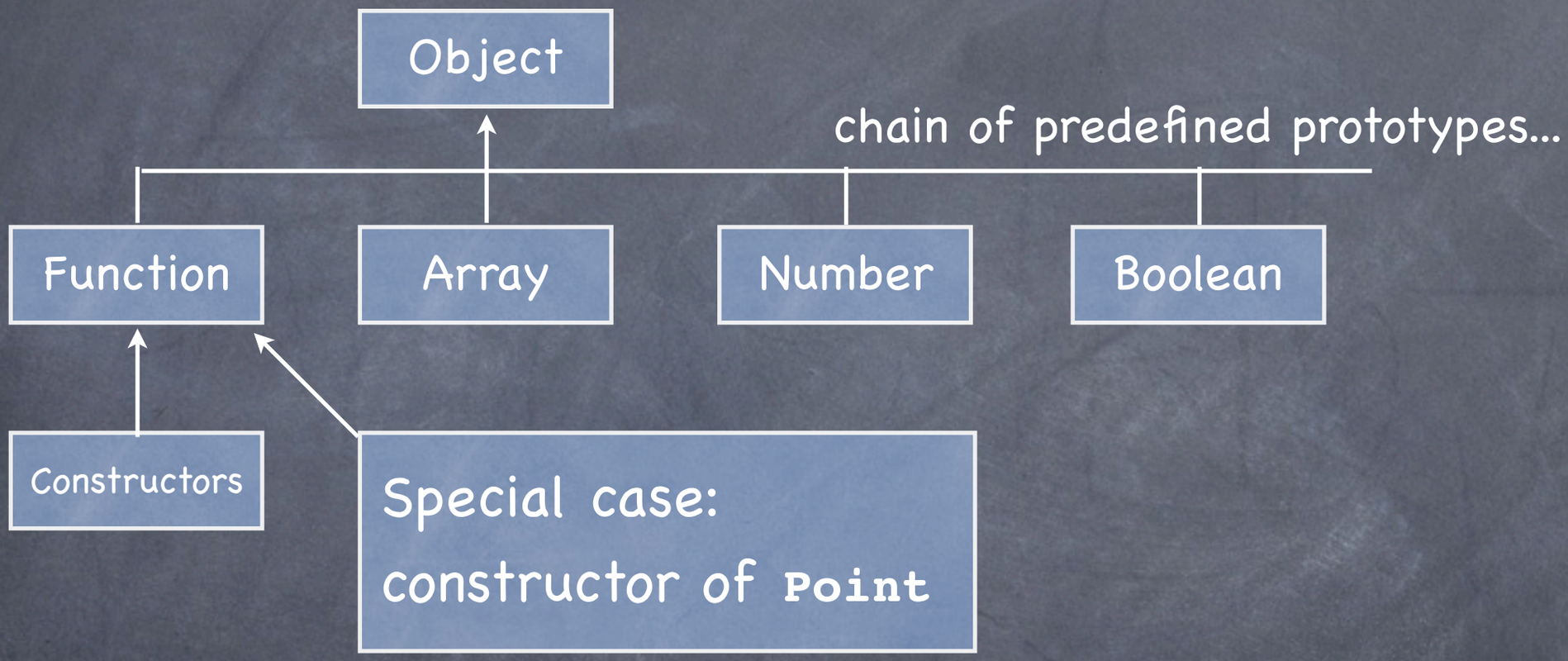
- Since constructors themselves are objects, they have a prototype too
- A taxonomy of prototypes is created, rooted in the prototype for the `Object` constructor
- The prototype of `Object` defines the properties:

  `constructor` - the function which built the object

  `toString()` - a method to print the object

  `valueOf()` - returns the underlying primitive type
- These properties are available for every object (functions and constructors included)

Taxonomy of prototypes (2/2)



- All functions and in particular all constructors are attached to the prototype of **`Function`**
- That prototype defines common properties (e.g. **`arguments`**) for every function (including constructors) and inherits properties from the prototype of **`Object`** (e.g. **`constructor`**)

Experiments

- The predefined method `isPrototypeOf()` tests if an object is included in another object's chain of prototypes

```
Object.prototype.isPrototypeOf(Function) // true
Object.prototype.isPrototypeOf(Array) // true
```

- The `Point` constructor is both a function and an object

```
Function.prototype.isPrototypeOf(Point) // true
Object.prototype.isPrototypeOf(Point) // true
```

The `prototype` property

- The building prototype exists only for constructors and defines properties for all the objects built by that constructor
- To define a specific building prototype you need to:
  - define an object with desired properties playing the prototype role
  - assign that object to the `prototype` property of the constructor
- The `prototype` property can be dynamically changed but it affects only newly created objects

Example (1/2)

- Given the constructor

```
Point = function(i, j) {
    this.x = i
    this.y = j
  }
```

- we want to associate a prototype to it so that `getX` and `getY` functions will be defined
- Note that the form `function Point()` does not make the `Point` identifier global, leading to problems if the prototype is added from an environment where `Point` is invisible

Example (2/2)

- Define the constructor for the object which will play the prototype role

```
GetXY = function() {
    this.getX = function() { return this.x }
    this.getY = function() { return this.y }
}
```

- Create it and assign it to the `prototype` property of the `Point` constructor

```
myProto = new GetXY(); Point.prototype = myProto
```

- You can invoke `getX` and `getY` on newly created `Point` objects only

```
p4 = new Point(7, 8); alert(p4.getX())
```

Architecture

BEFORE

Constructor

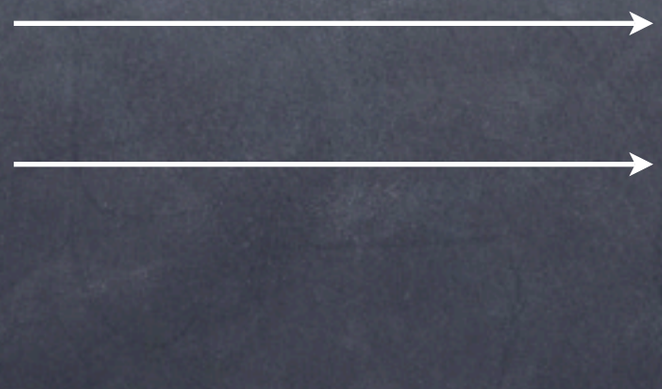
`__proto__`
`prototype`
properties

prototype =
building prototype

AFTER

Constructor

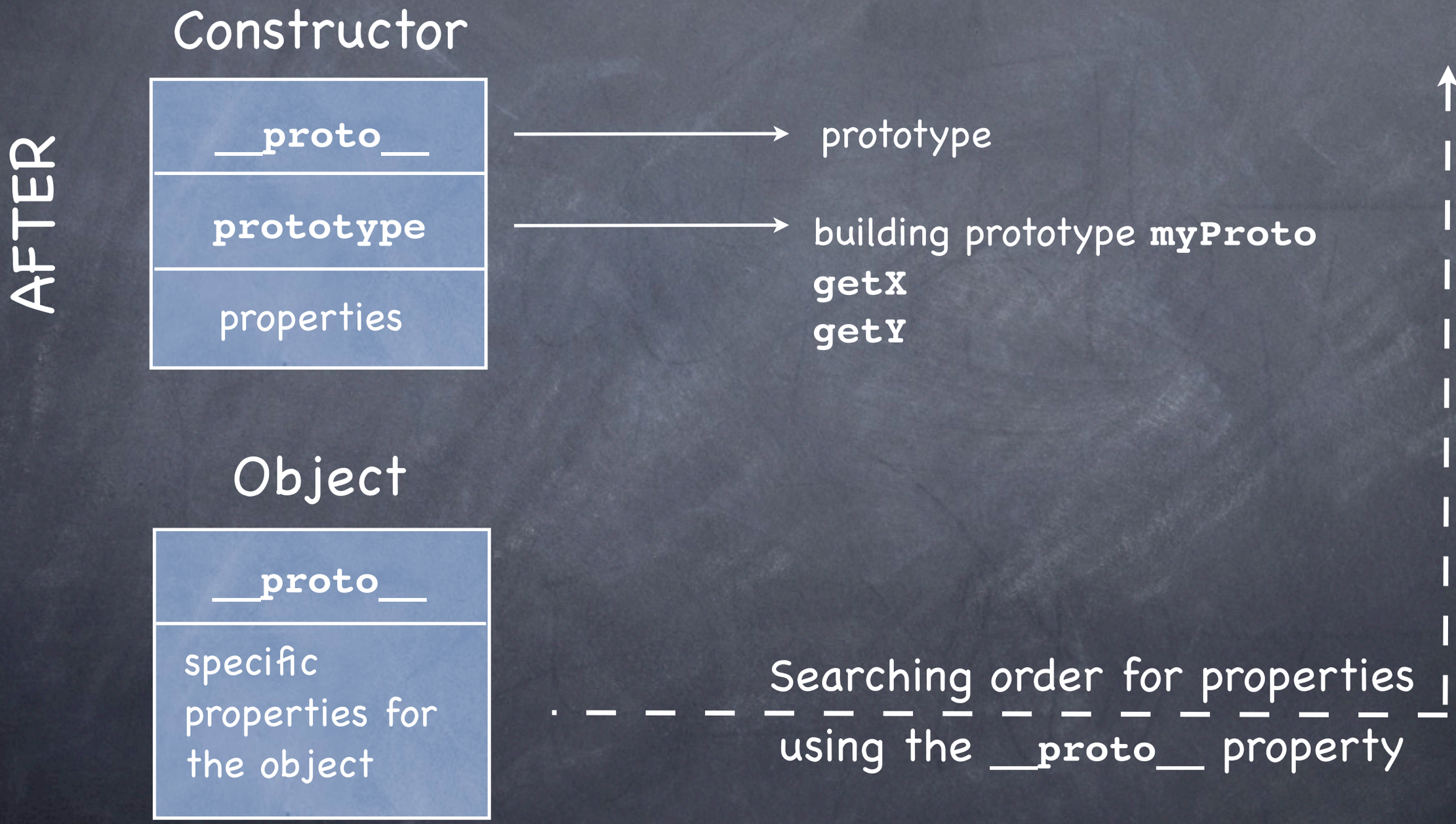
`__proto__`
`prototype`
properties



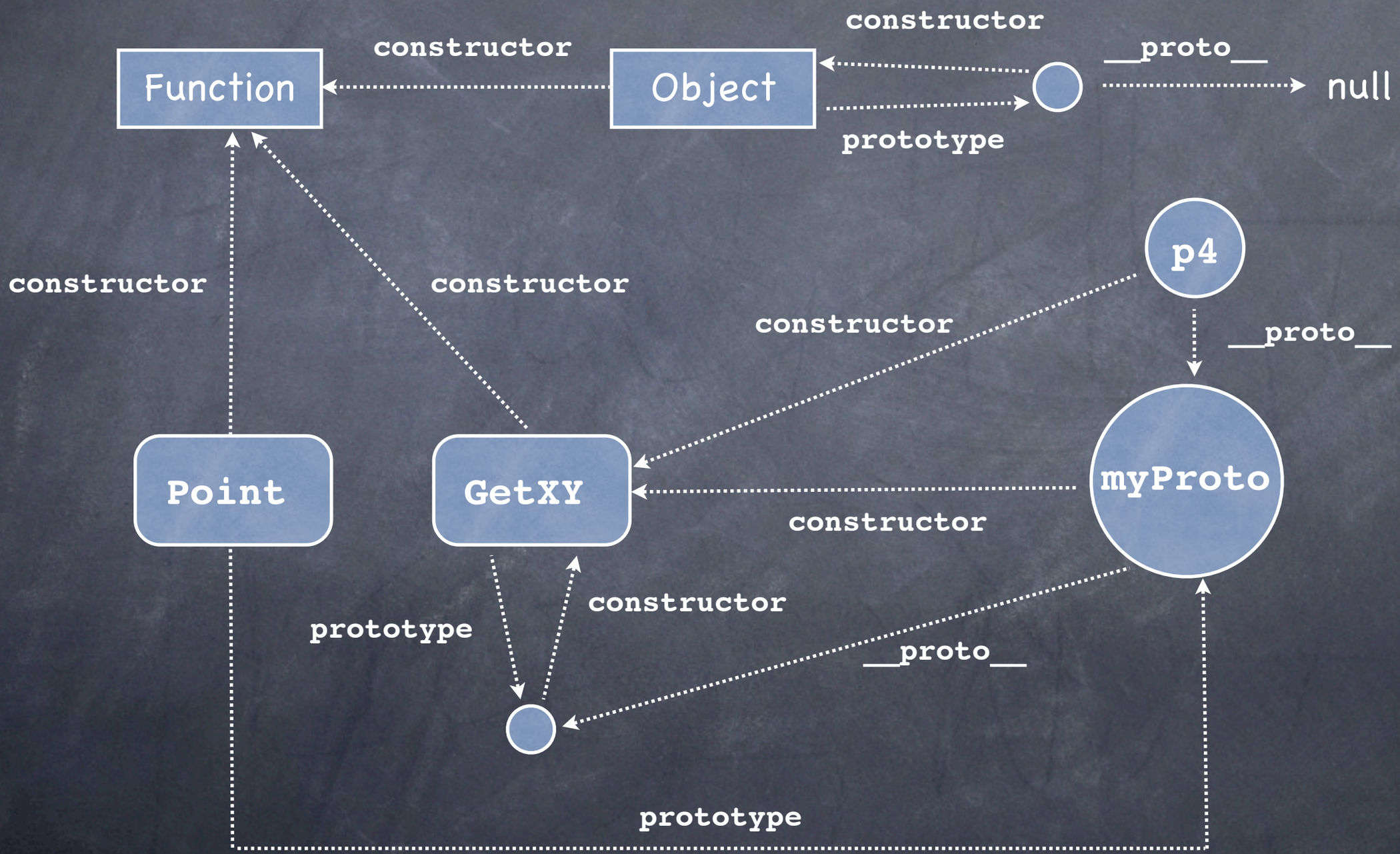
prototype

building prototype **`myProto`**
`getX`
`getY`

Searching properties



New experiments (1/2)



New experiments (1/2)

- Searching for `p4` identity

```
myProto.isPrototypeOf(p4) // true
GetXY.prototype.isPrototypeOf(p4) // true
Point.prototype.isPrototypeOf(p4) // true
Object.prototype.isPrototypeOf(p4) // true
Function.prototype.isPrototypeOf(p4) // false
```

- Searching for `myProto` and `GetXY` identities

```
Point.prototype.isPrototypeOf(myProto) // true
Object.prototype.isPrototypeOf(myProto) // true
Function.prototype.isPrototypeOf(myProto) // false
Point.prototype.isPrototypeOf(GetXY) // false
Object.prototype.isPrototypeOf(GetXY) // true
Function.prototype.isPrototypeOf(GetXY) // true
```

Building prototypes: an alternative approach

- Instead of associating a new prototype to an existing constructor, it is possible to add new properties to the existing constructor

```
Point.prototype.getX = function() { ... }
Point.prototype.getY = function() { ... }
```

- The two approaches are not equivalent
  - A change in the existing prototype affects also existing objects
  - A new prototype affects only objects newly created from then on

Example (1/2)

- Given the constructor

```
Point = function(i, j) {
    this.x = i
    this.y = j
}
```

- we want to modify the existing prototype so that `getX` and `getY` functions will be included
- Note that those functions will work for existing objects and for objects created from then on

Example (2/2)

- Create a first object

```
p1 = new Point(1, 2)
```

- The function `getX` is not supported

```
p1.getX // returns undefined
```

- Modify the existing prototype

```
Point.prototype.getX = function() { return this.x }
Point.prototype.getY = function() { return this.y }
```

- Now `getX` works even on existing objects

```
p1.getX() // returns 1
```

Prototype-based inheritance

- Chains of prototypes are the mechanism offered by JavaScript to support a sort of inheritance
- It is an inheritance between objects, not between classes as in object-oriented languages
- When a new object is created using `new`, the system links that object with the building prototype for the constructor used
- This is also true for constructors, which have `Function.prototype` as their prototype

Expressing inheritance

- To express the idea of a subclass **`Student`** inheriting from an existing class **`Person`** you need to
  - explicitly link **`Student.prototype`** with a new **`Person`** object
  - explicitly change the **`constructor`** property of **`Student.prototype`** (which now would link the **`Person`** constructor) to make it reference the **`Student`** constructor

Example (1/2)

- Base constructor

```
Person = function(n, y) {
    this.name = n; this.year = y
    this.toString = function() {
        return this.name + ' was born in ' + this.year
    }
}
```

- Derived constructor

```
Student = function(n, y, m) {
    this.name = n; this.year = y; this.matr = m;
    this.toString = function() {
        return this.name + ' was born in ' + this.year + '
        and has matriculation ' + this.matr
    }
}
```

Example (2/2)

- Setting the chain of prototypes

```
Student.prototype = new Person()
Student.prototype.constructor = Student
```

- Test

```
function test() {
    var p = new Person(“Andrew”, 1965)
    var s = new Student(“Luke”, 1980, “001923”)
    // displays: Andrew was born in 1965
    alert(p)
    // displays: Luke was born in 1980 and has
    matriculation 001923
    alert(s)
}
```

Inheritance: an alternative (1/2)

- An alternative approach can be employed without touching prototypes: reusing by `call` the base constructor function, simulating other languages, e.g. the use of `super` in Java

```
Rectangle = function(a, b) {
    this.x = a; this.y = b
    this.getX = function() { return this.x }
    this.getY = function() { return this.y }
}
Square = function(a) {
    Rectangle.call(this, a, a)
}
```

Inheritance: "`super`" in constructors

- Base constructor

```
Person = function(n, y) {
    this.name = n; this.year = y
    this.toString = function() {
        return this.name + ' was born in ' + this.year
    }
}
```

- Derived constructor

```
Student = function(n, y, m) {
    Person.call(this, n, y); this.matr = m;
    this.toString = function() {
        return this.name + ' was born in ' + this.year + '
        and has matriculation ' + this.matr
    }
}
```

Inheritance: "`super`" in methods

- When prototypes are explicitly manipulated, the `prototype` property can be used to call methods defined in the base constuctor

```
Student = function(n, y, m) {
    Person.call(this, n, y); this.matr = m
    this.toString = function() {
        return Student.prototype.toString.call(this) + '
        and has matriculation ' + this.matr
    }
}
```

- The `Student.prototype` is a `Person` object, so `call` calls the `toString` function of that object

An alternative: "`super`" in methods

- Avoiding the use of prototypes, it is necessary to explicitly exploit an object of the kind of the prototype to invoke the desired method

```
Student = function(n, y, m) {
    Person.call(this, n, y); this.matr = m
    this.toString = function() {
        return p.toString.call(this) + ' and has
        matriculation ' + this.matr
    }
}
```

- The `p` object must be a `Person` object which must exist when the function is called, so that `call` calls the `toString` function of that object

Inheritance: experiments

- Using the `Student` and `Person` constructor setting explicitly the chain of prototypes, the following results are obtained with `p` a `Person` object and `s` a `Student` object

```
p.isPrototypeOf(s) // false
Person.isPrototypeOf(s) // false
Object.isPrototypeOf(s) // false
Object.prototype.isPrototypeOf(s) // true
Person.isPrototypeOf(Student) // false
Student.prototype.isPrototypeOf(Student) // false
Student.prototype.isPrototypeOf(Student.prototype) // false
Student.prototype.isPrototypeOf(s) // true
```

Inheritance: more experiments

- Using the same environment as before, but without explicitly setting the chain of prototypes, the following results are obtained:

```
p.isPrototypeOf(s) // false
Person.isPrototypeOf(s) // false
Object.isPrototypeOf(s) // false
Object.prototype.isPrototypeOf(s) // true
Person.isPrototypeOf(Student) // false
(new Person()).isPrototypeOf(Student) // false
(new Person()).isPrototypeOf(Student.prototype) // false
(new Person()).isPrototypeOf(s) // false
```

Arrays (1/2)

- An array is built using the `Array` constructor, whose arguments are the initial content of the array

```
colors = new Array('red', 'green', 'blue')
```

- Elements are enumerated starting with `0` and can be accessed using square brackets, e.g. `colors[2]`
- The `length` attribute contains the dynamic length of the array
- Cells in an array are not constrained to contain elements of the same kind

Arrays (2/2)

- It is also possible to define an empty array and add elements later using assignments

```
colors = new Array(); colors[0] = 'red'
```

- Starting with JavaScript 1.2, an array can be built listing the initial elements, separated by commas, between square brackets

```
numbers = [1, 2, 'three']
```

Dynamic and fragmented arrays

- It is possible to dynamically add elements to arrays whenever it is necessary

  `letters = ['a', 'b', 'c']; letters[3] = 'd'`

- Arrays can be fragmented: indexes have not to be in a set of adjacent numbers

  `letters[9] = 'j'`

  `letters.length` returns `10`

  `letters.toString()` returns `a,b,c,d,,,,,,j`

Objects as arrays (1/2)

- Every JavaScript object is defined by the set of its properties: this is why they are internally represented as arrays
- This mapping between objects and arrays let object access be possible through an array-like notation using the property name as a selector
- Let `p` be an object, `s` a string containing the name of the property `x` of `p`; then the notation `p[s]` gives access to the property named `x` like the dot notation `p.x` does

Objects as arrays (2/2)

- What is the advantage of the array notation over the dot notation?
- Using the dot notation `p.x` implies that the name of the property is known when writing the program
- The array notation `p[s]` let the programmer access a property whose name can be known during execution and saved in the string variable `s` for future use

Introspection

- Since the set of an object's properties can dynamically change, it may be necessary to discover which properties an object has at runtime
- A special construct is available to iterate on the visible properties of the object

```
for (variable in object) { … }
```

- For example, to list the name of all properties:

```
function showProperties(obj) {
    for (var p in obj) { document.write(p + '<br>') }
}
```

From introspection to intercession

- Using the `for/in` construct it is possible to discover the visible properties of an object
- To access those properties you need to obtain a reference to them starting from a string containing the name of each property

```
function showProperties(obj) {
    for (var p in obj) {
        var property = obj[p]
        document.write('The property ' + p + ' has type
        ' + typeof(property) + '<br>')
    }
}
```

The global object

- JavaScript does not distinguish object methods from global functions: global functions are methods of a system-defined global object
- The global object features
  - as methods, functions not owned by specific objects and predefined functions
  - as data, global variables
  - as functions, predefined functions

Global predefined functions

`eval` - evaluate the JavaScript program passed as a string (reflection, intecession)

`escape` - convert a string in a portable format, substituting "illegal" characters with escaped sequences (e.g. '`%20`' for ' ')

`unescape` - convert a string from the portable format to the original format

`isFinite`, **`isNan`**, **`parseFloat`**, **`parseInt`**, …

…

(Constructors of) Predefined objects

- Most common are **`Array`**, **`Boolean`**, **`Function`**, **`Number`**, **`Object`**, **`String`**
- The **`Math`** object contains a mathematical library: constants (**`E`**, **`PI`**, **`LN10`**, **`LN2`**, **`LOG10E`**, **`LOG2E`**, **`SQRT1_2`**, **`SQRT2`**) and functions of all sorts
  - Don't instantiate it: use it as a static component
- The **`Date`** object contains features to represent date and time concepts and work with them
- The **`RegExp`** object supports working with regular expressions

Date: construction (1/2)

- Constructors

  `Date()`, `Date(milliseconds)`, …

  - The **`Date()`** constructor creates an object representing current day and hour on the system in use
  - In **`Date(milliseconds)`**, milliseconds are calculated starting from 00:00:00 of January 1st, 1970, using the UTC standard day of 86.4M sec

Date: construction (2/2)

- Constructors

  `Date(string)`, `Date(year, month, day [, hh, mm, ss, ms])`

- UTC and GMT are supported
- Days go from -100M to +100M around 1/1/1970
- In `Date(string)`, `string` must be in the format recognized by `Date.parse`
- In `Date(y, m, d)`, year, month and day must be provided; other parameters are optional; parameters not provided are set to `0`

Date: methods

- Methods

  `getDay` returns the day of the week from `0` (Sunday) to `6` (Saturday)

  `getDate` returns the day from `1` to `31`

  `getMonth` returns the month from `0` (January) to `11` (December)

  `getFullYear` returns the year on four digits

  `getHours` returns the hour from `0` to `23`

  `getMinutes` returns the minute from `0` to `59`

  `getSeconds` returns the seconds from `0` to `59`

  …

Date: example

- Example

```
d = new Date(); millennium = new Date(3000, 00, 01)
s = new String((millennium – d) / 86400000)
days = s.substring(0, s.indexOf('.')) // integer part
alert(days + 'days to the year 3000')
```

- Output (on March 5th, 2006)

```
362987 days to the year 3000
```

Who is the global object?

- The global object is unique and it is always created by the interpreter before executing anything
- There is no global identifier: in every situation there is a given object used as global object
  - in a browser, that object is typically **`window`**
  - but on the server side, it would probably be another object to play the role of global object
- Could it be a problem not to know which object plays the role of global object?

The global object: warnings

- Function and variables not assigned to a specific object are assigned to the global object...
- ...but if they appear in a function's scope they are assigned as local to that scope
- There are no problems, if global properties are used without making the global object emerge
- There can be problems if `eval` or another reflexive function is used, since `eval("var f")` is different from `var f` because the first definition is not executed in the global environment

Global object and functions as data (1/4)

- JavaScript lets variables reference functions and functions be passed as arguments to other functions

```
var square = function(z) { return z*z }
function exe(f, x) { return f(x) }
```

- But the `f` variable
  - must reference a `function` object
  - cannot be a string containing the name of an already defined function

```
exe("Math.sin", .8) // error
```

Global object and functions as data (2/4)

- Beside the approach based on the `Function` constructor, the global object can be exploited to obtain a reference to a `function` object corresponding to a given function name
- Let `p` be a reference to an object, and `s` a string containing the name of the `x` property of `p`, then the array-like notation `p[s]` returns a reference to the property `x`
- In this case, `p` is the global object, `s` a function name, `x` the `function` object corresponding to the name in `s`

Global object and functions as data (3/4)

- The following notation

  ```
  var name = Math["sin"]
  ```

- puts in the `name` variable a reference to the function object `Math.sin`
- So, after defining the function

  ```
  function exe(f, x) { return f(x) }
  ```

- we can invoke
  - `exe(name, .8) // returns 0.7173560908995228`
  - because the "`sin`" string has been translated into a reference to the `Math.sin` object, suitable for invocation

Global object and functions as data (4/4)

- Generalizing

```
var fun = prompt("Enter a function name")
var f = Math[fun]
```

- Now the user can specify a function name and let it be searched and invoked by a reflexive mechanism
- The result can be showed in another window

```
confirm("Result: " + exe(f, x))
```

- Note that in this example the `Math` object plays the role of the global object since functions are searched in it only

Forms and their management (1/3)

- JavaScript is often used in the context of HTML forms
- A form usually contains text fields and buttons

```
<form name="aForm">
    <input type="text" name="textField" size="30"
    maxlength="30">
    <input type="button" name="button" value="Click
    here">
</form>
```

- When the button is pressed, it is possible to invoke a JavaScript function

Forms and their management (2/3)

- When a button is pressed, the button pressed event can be intercepted by the `onclick` attribute

```
<form name="aForm">
    <input type="button" name="button" value="Click
    here" onclick="alert('You clicked me!')">
</form>
```

- Remember to alternate double and single quotes when writing JavaScript code in HTML attributes

Forms and their management (3/3)

- As an alternative example, when the button is pressed we can make the browser write the result of one of our functions

```
<form name="aForm">
    <input type="button" name="button" value="Click
    here" onclick="document.write(square(6))">
</form>
```

- Note that `square` must be already defined

Forms: which events?

- Events which can be intercepted on an element (managed on the correspondent tag)

  `onclick`, `onmouseover`, `onmouseout`, …

- Events which can be intercepted on a window (managed in the body tag)

  `onload`, `onunload`, `onblur`, …

- Example

```
<body onload="alert('Loaded!')">
    <form name="aForm">
        <input type="button" name="button" value="Click
        here" onclick="alert(square(6))">
    </form>
</body>
```

Forms: events management

- To reuse the value returned by **`confirm`**, **`prompt`**, or other functions, a whole JavaScript program has to be inserted as the value of the **`onclick`** attribute (as a sequence or a function call)
- Examples

```
onclick="x = prompt('Name and surname');
document.write(x)"

onclick="ok = confirm('Is this OK?'); if (!ok)
alert('Warning!')"
```

Forms and text fields

- Text fields can be objects with a name within a form object with a name
- As such, they can be referenced using the dot notation, e.g. **`document.aForm.aTextField`**

- Text fields are characterized by the **`value`** property
- Example

```
<form name=“aForm">
    <input type="text" name=“surname" size=“20”>
    <input type="button" name="button" value="Show“
    onclick="alert(document.aForm.surname.value)">
</form>
```

Functions as links

- A JavaScript function can be used as a valid link usable as the `href` attribute of the `a` element
- The effect of a click on that link is the execution of the function and the display of the result in a new HTML page within the same window
- Example

```
<a href="javascript:square(10)">This should be 100</
a>
```