# JavaScript: fundamentals, concepts, object model

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# Prototypes (1/2)

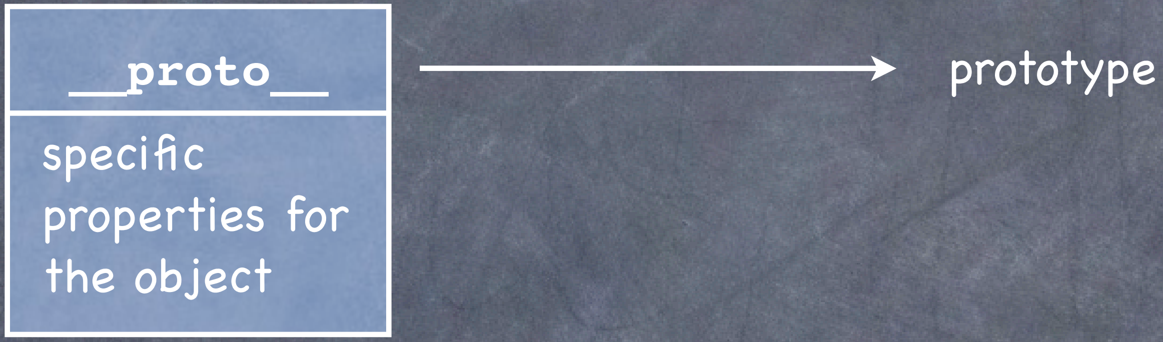
- Every object has always a prototype specifying its basic properties
- The prototype itself is an object
- If P is prototype of X, every property of P is also available as a property of X and thus redefinable by X
- The prototype is stored in a typically invisible system property called `__proto__`

# 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

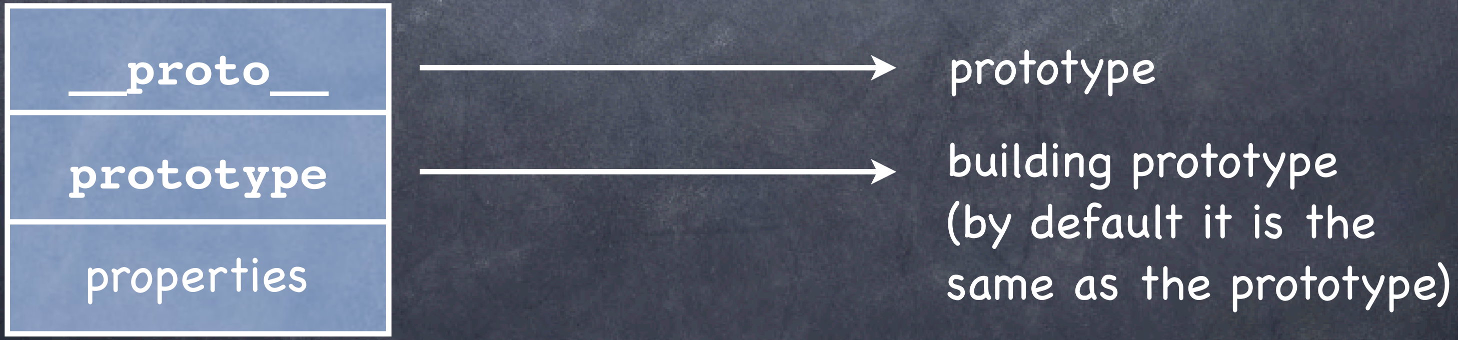
## Object



`__proto__` → prototype

specific properties for the object

## Constructor



`__proto__` → prototype

`prototype` → building prototype (by default it is the same as the prototype)

properties

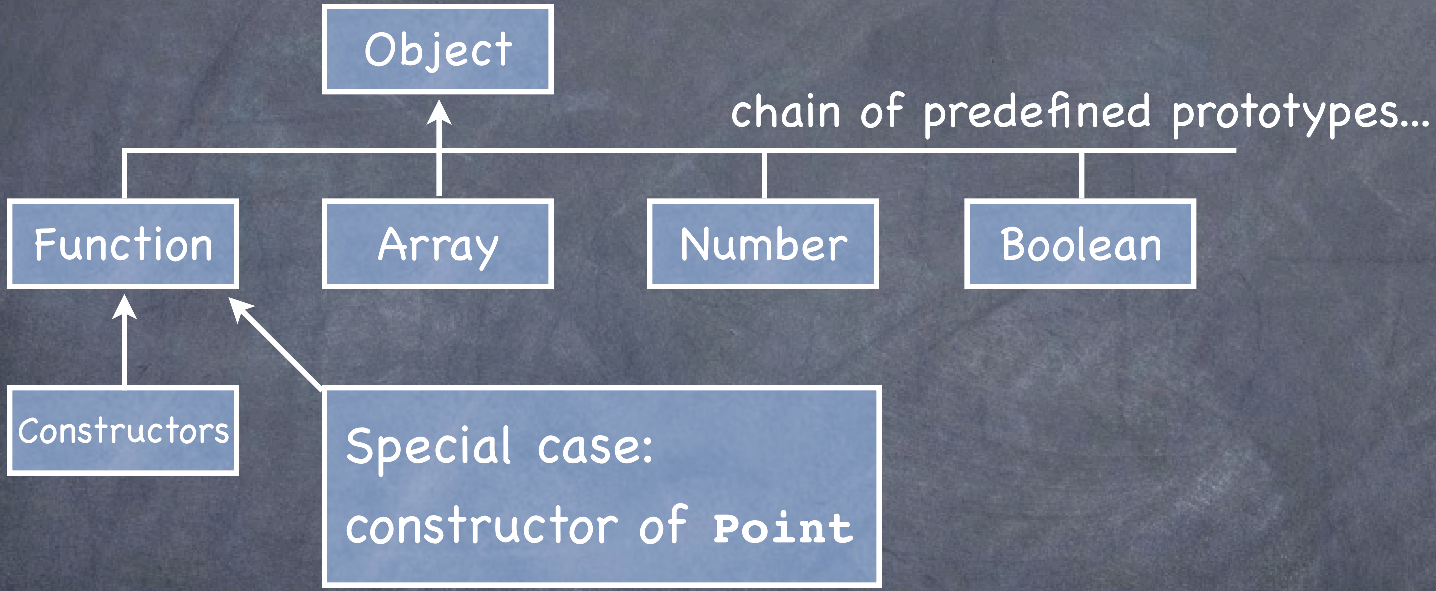
# Predefined prototypes

- 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 }
}
```

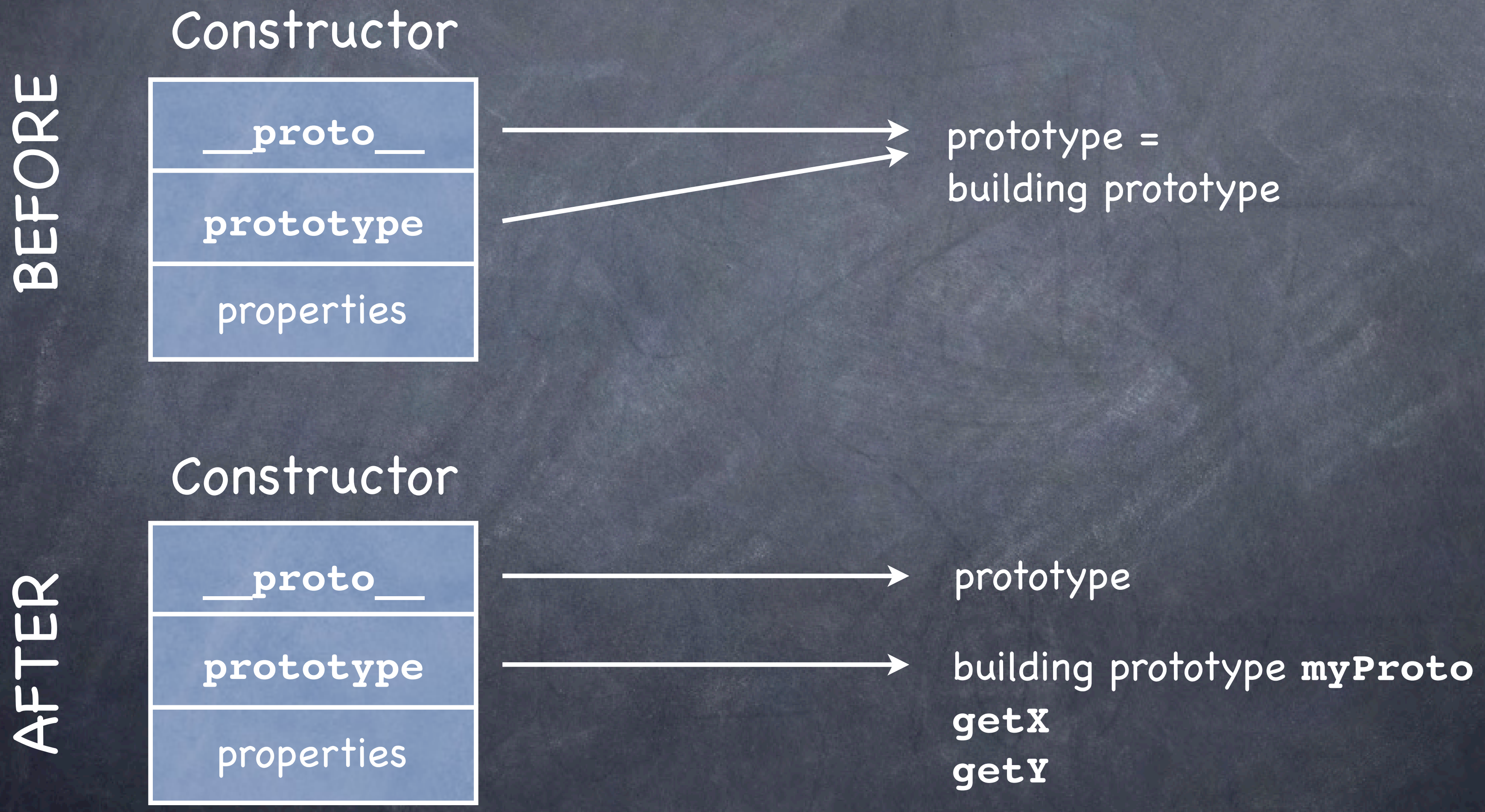
- Create it and assign it to the `prototype` property of the `Point` constructor

```
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__`

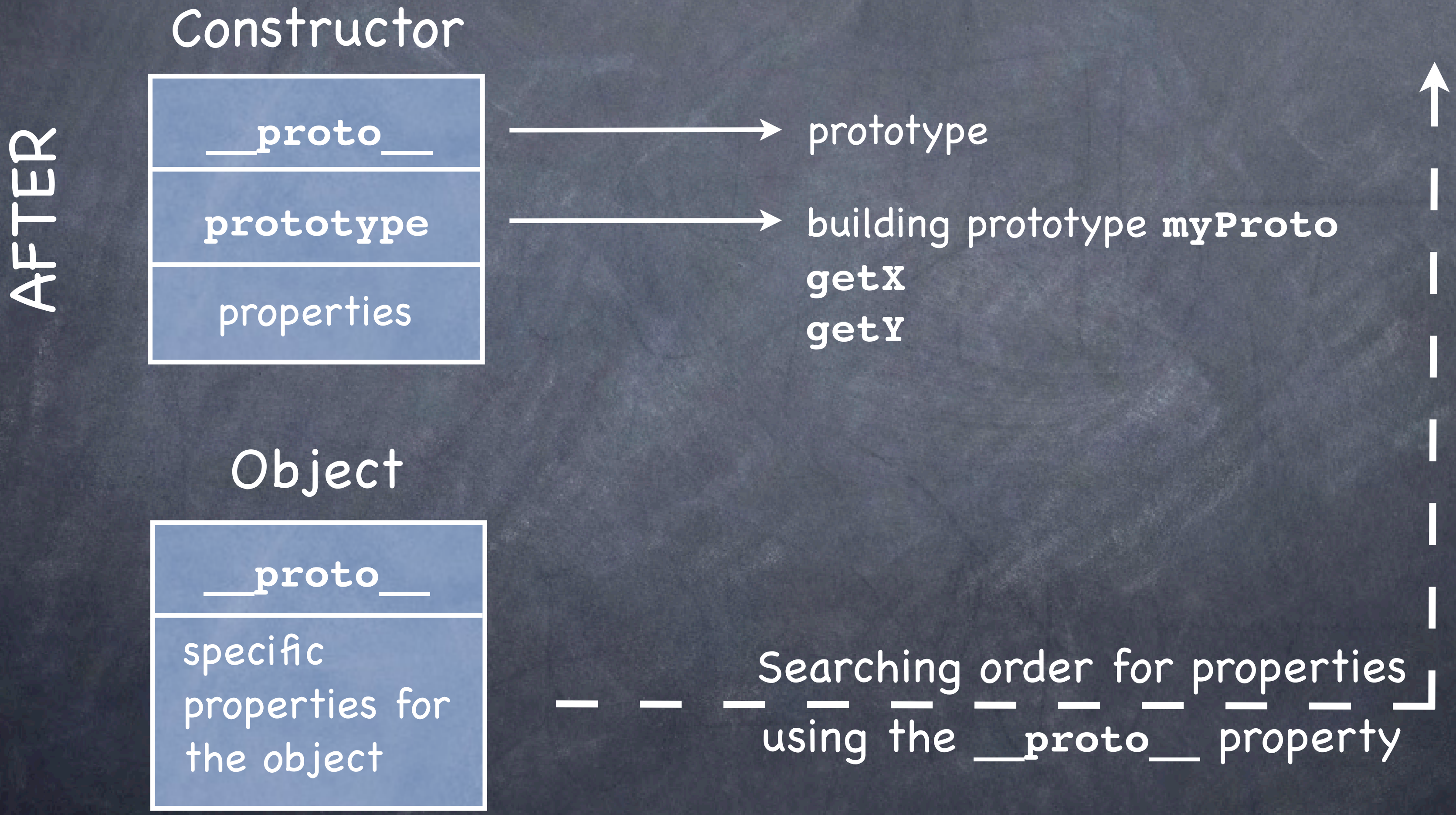
`prototype`

properties

prototype

building prototype `myProto`
`getX`
`getY`

# Searching properties



AFTER

Constructor

__proto__ → prototype

prototype → building prototype **myProto**

**getX**

**getY**

properties

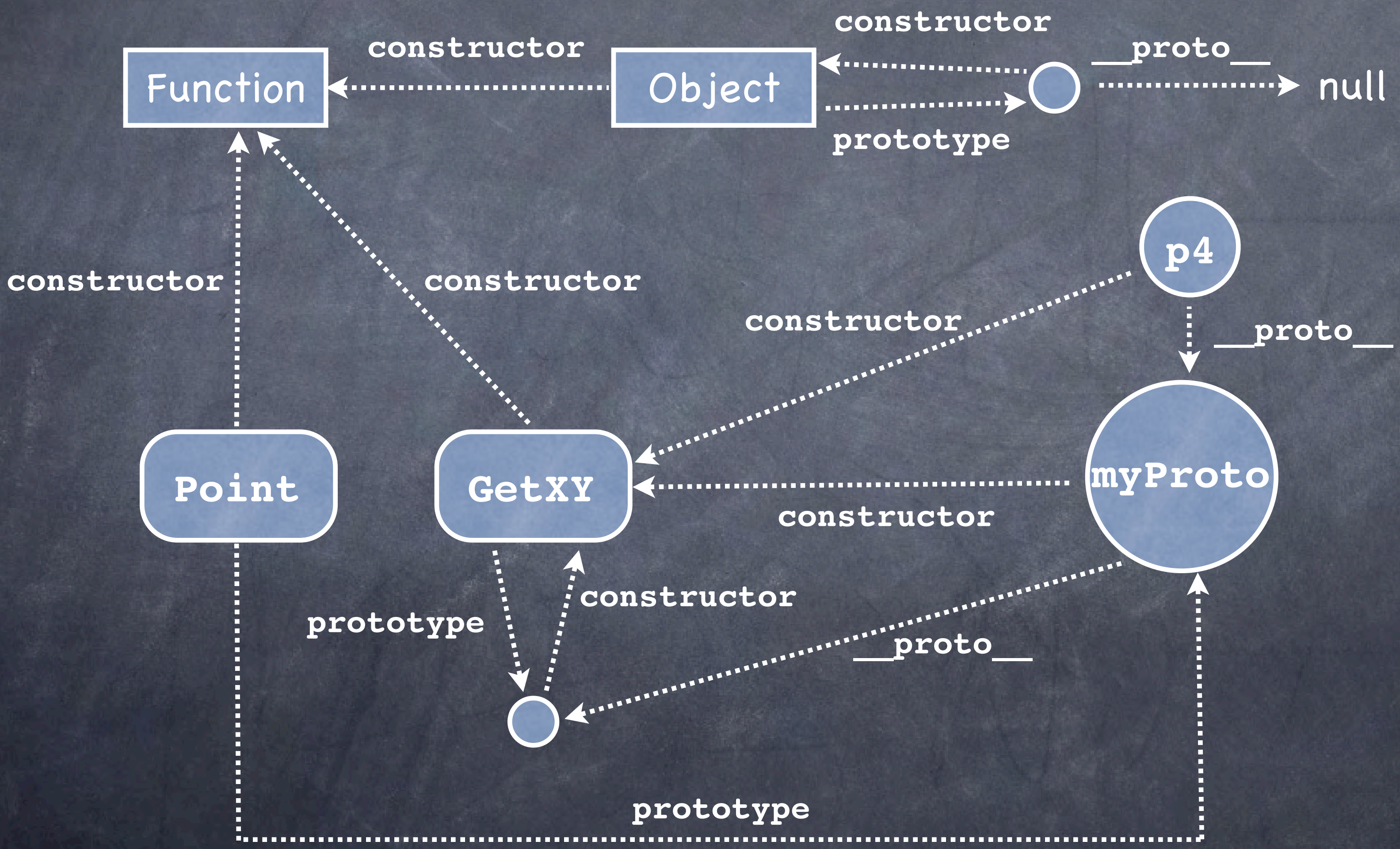
Object

__proto__

specific properties for the object

Searching order for properties using the **__proto__** property

# 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>
```