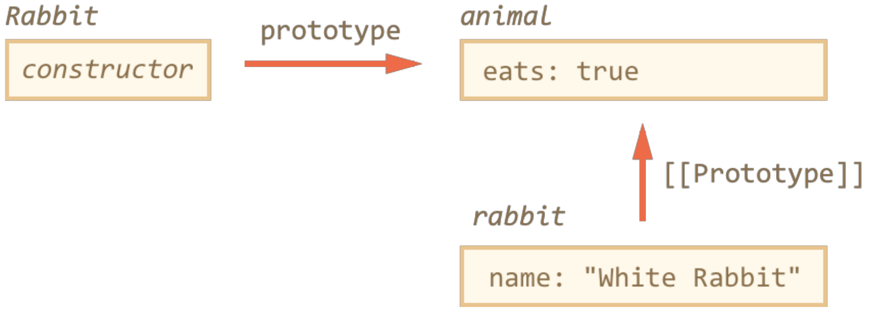
The “prototype” Property

- As we know already, new F() creates a new object
- When a new object is created with new F(), the object’s [[Prototype]] is set to F.prototype
  - Note that F.prototype here means a regular property named "prototype" on F
- In other words, functions have a **prototype** property, and when you invoke functions with new, they will construct an object having a [[Prototype]] identical to the constructor function's prototype property

The “prototype” Property

```
let animal = {
    eats: true
};

function Rabbit(name) {
    this.name = name;
}
Rabbit.prototype = animal;

let rabbit = new Rabbit("White Rabbit"); //  rabbit.__proto__ == animal
alert(rabbit.eats); // true
```

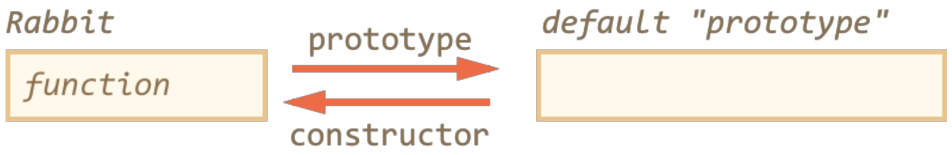
- Setting Rabbit.prototype = animal literally states the following: "When a new Rabbit is created, assign its [[Prototype]] to animal"



Default F.prototype

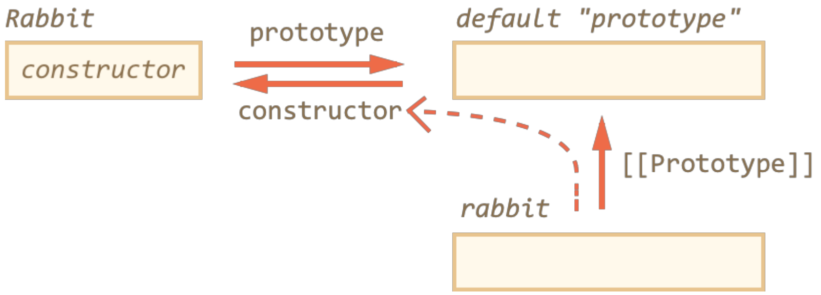
- Every function has the "prototype" property even if we don’t supply it
- The default "prototype" is an object with the only property **constructor**, that points back to the function itself

```
function Rabbit() { }
// by default:
// Rabbit.prototype = { constructor: Rabbit };

alert(Rabbit.prototype.constructor === Rabbit); // true
```



- Naturally, the constructor property is available to all rabbits through [[Prototype]]:

```
let rabbit = new Rabbit(); // inherits from {constructor: Rabbit}
alert(rabbit.constructor === Rabbit); // true (from prototype)
```



Native Prototypes

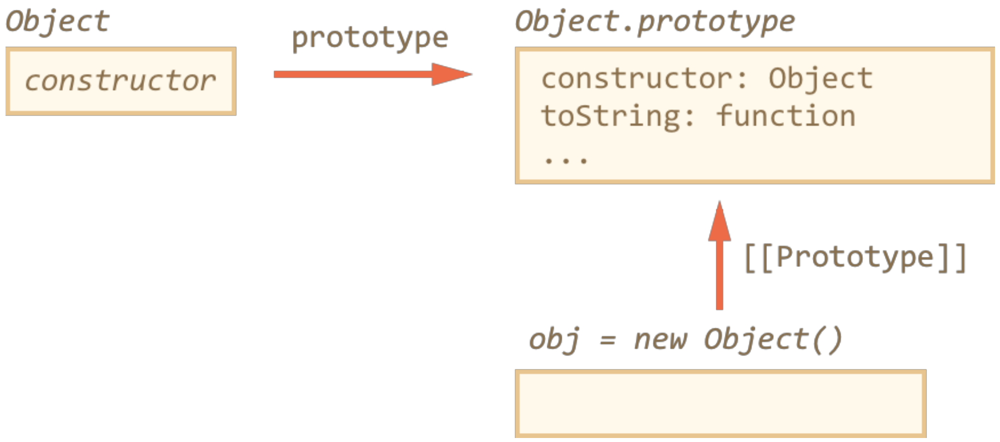
- The "prototype" property is widely used by the core of JavaScript itself
  - All built-in constructor functions use it
- We’ll see how it is for plain objects first, and then for more complex ones
- Let’s say we output an empty object:

```
let obj = {};
alert(obj); // "[object Object]"
```

- Where’s the code that generates the string "[object Object]"?
  - The short notation obj = {} is the same as obj = new Object(), where **Object** is a built-in object constructor function
  - That function has Object.prototype that references a large object with toString() and other functions

Native Prototypes

- When new Object() is called (or a literal object {...} is created), the [[Prototype]] of it is set to Object.prototype



- Afterwards when obj.toString() is called – the method is taken from Object.prototype

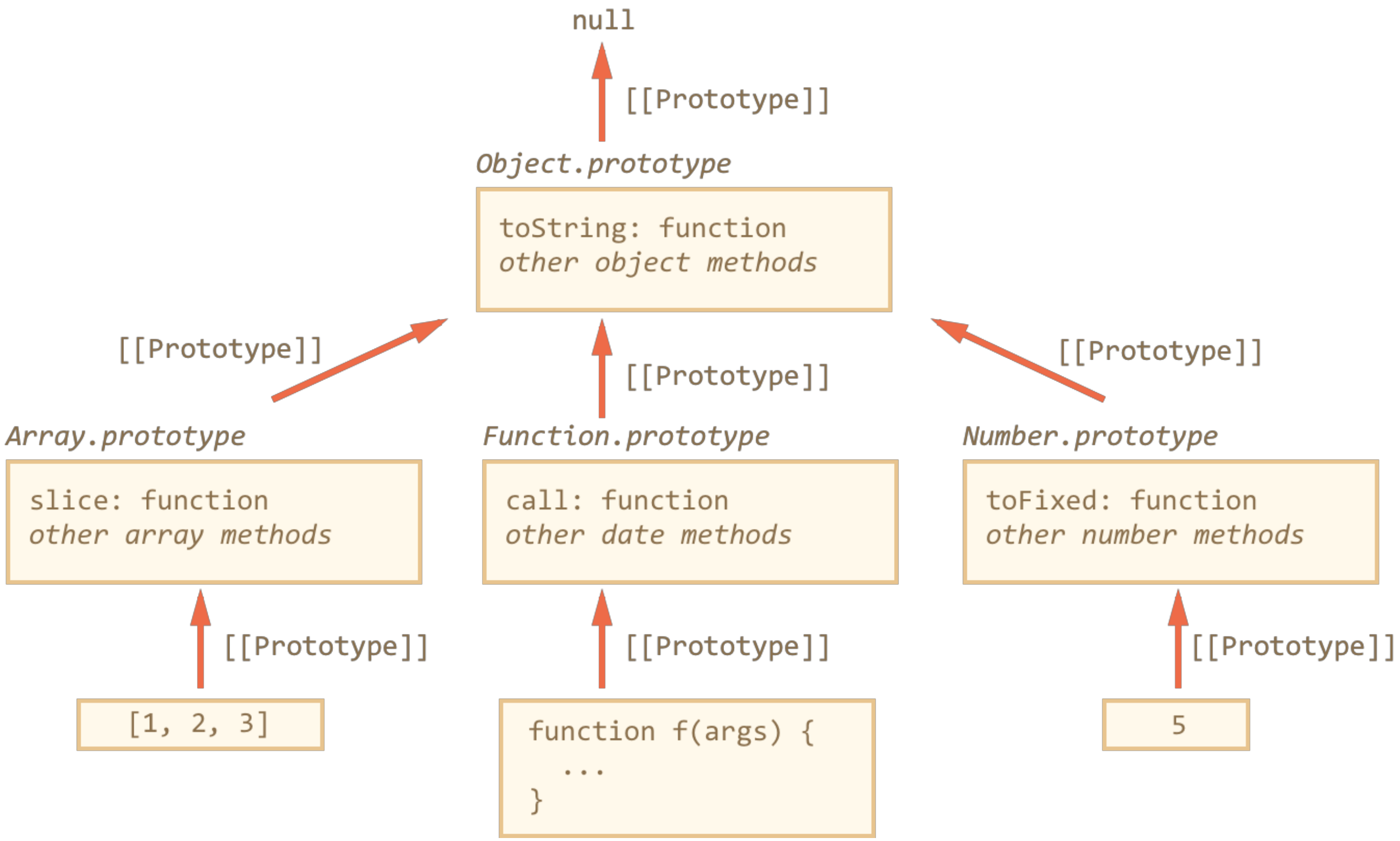
```
let obj = {};
alert(obj); // "[object Object]"

alert(obj.toString === obj.__proto__.toString); // true
alert(obj.toString === Object.prototype.toString); // true
```

Native Prototypes

- Other built-in objects such as Array, Date, Function and others also keep methods in prototypes
- For instance, when we create an array [1, 2, 3], the default new Array() constructor is used internally, which writes the array data into the new object, and assigns Array.prototype to its prototype
  - The Array.prototype provides the methods for the new array
- All built-in prototypes have Object.prototype on the top
  - “everything inherits from objects”

Native Prototypes

- All built-in prototypes have Object.prototype on the top
  - “everything inherits from objects”

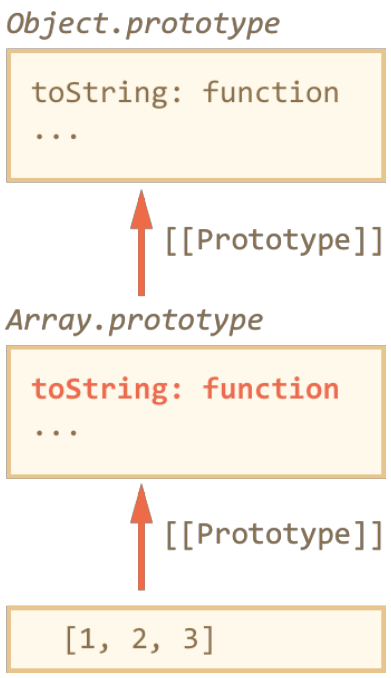


Native Prototypes

- Some methods in prototypes may overlap
- For example, Array.prototype has its own toString that lists comma-delimited elements:

```
let arr = [1, 2, 3]
alert(arr); // 1,2,3 <-- the result of Array.prototype.toString
```

- Object.prototype has toString as well, but Array.prototype is closer in the chain, so the array variant is used



Object.prototype

toString: function
...

[[Prototype]]

Array.prototype

toString: function
...

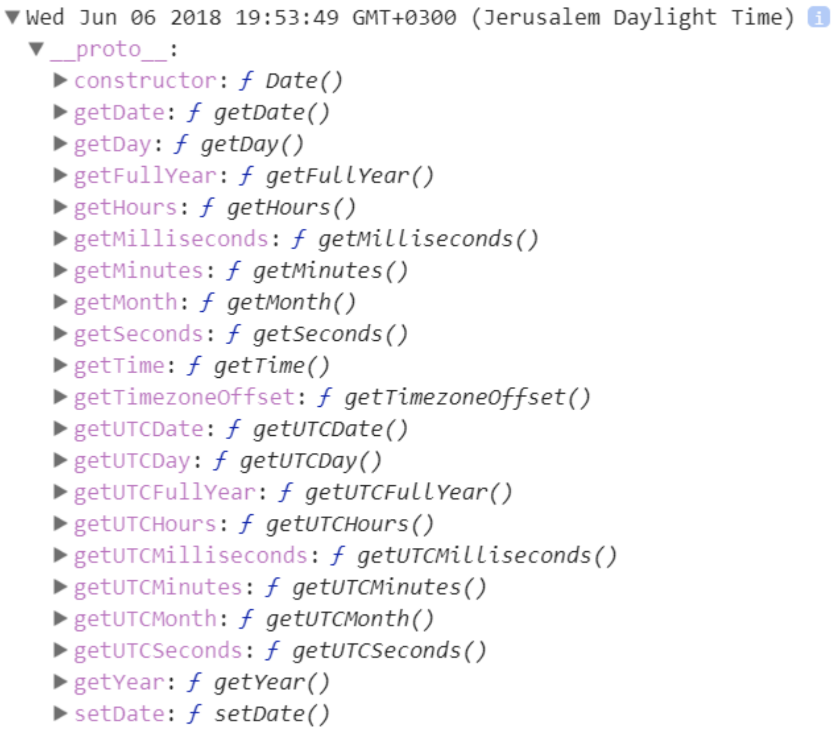
[[Prototype]]

[1, 2, 3]

Inspecting the Prototype Chain

- In-browser tools like Chrome developer console shows the prototype inheritance when using console.log() (may need to use console.dir() for built-in objects):

```
let date = new Date();
console.dir(date);
```



```
▼Wed Jun 06 2018 19:53:49 GMT+0300 (Jerusalem Daylight Time)
  ▼__proto__:
    ▶constructor: ƒ Date()
    ▶getDate: ƒ getDate()
    ▶getDay: ƒ getDay()
    ▶getFullYear: ƒ getFullYear()
    ▶getHours: ƒ getHours()
    ▶getMilliseconds: ƒ getMilliseconds()
    ▶getMinutes: ƒ getMinutes()
    ▶getMonth: ƒ getMonth()
    ▶getSeconds: ƒ getSeconds()
    ▶getTime: ƒ getTime()
    ▶getTimezoneOffset: ƒ getTimezoneOffset()
    ▶getUTCDate: ƒ getUTCDate()
    ▶getUTCDay: ƒ getUTCDay()
    ▶getUTCFullYear: ƒ getUTCFullYear()
    ▶getUTCHours: ƒ getUTCHours()
    ▶getUTCMilliseconds: ƒ getUTCMilliseconds()
    ▶getUTCMinutes: ƒ getUTCMinutes()
    ▶getUTCMonth: ƒ getUTCMonth()
    ▶getUTCSeconds: ƒ getUTCSeconds()
    ▶getYear: ƒ getYear()
    ▶setDate: ƒ setDate()
```

Primitives

- As we remember, primitives such as strings and numbers are not objects
- But if we try to access their properties, then temporary wrapper objects are created using built-in constructors **String**, **Number**, **Boolean,** which provide the methods and disappear
- Methods of these objects also reside in prototypes, available as String.prototype, Number.prototype and Boolean.prototype

```
let str = "hello";
alert(str.__proto__ === String.prototype); // true

let num = 5;
alert(num.__proto__ === Number.prototype); // true
```

Exercise (28)

- What is the output of the following script?

```
let arr = [1, 2, 3];

alert(arr.__proto__ === Array.prototype); // ?

alert(arr.__proto__.__proto__ === Object.prototype); // ?

alert(arr.__proto__.__proto__.__proto__); // ?

alert(arr.constructor === Array.prototype.constructor); // ?

alert(arr.__proto__ === new Array().__proto__); // ?

alert(arr.toString === Object.prototype.toString); // ?
```

Changing Native Prototypes

- Native prototypes can be modified
  - For instance, if we add a method to String.prototype, it becomes available to all strings:

```
String.prototype.show = function () {
    alert(this);
};
"Hello!".show(); // Hello!
```

- That is generally a bad idea, since prototypes are global, so it’s easy to get a conflict
- Modifying native prototypes is normally used for polyfills
  - i.e., if there’s a method in JavaScript specification that is not yet supported by our JavaScript engine, then we may implement it manually

```
if (!String.prototype.repeat) { // if there's no such method add it to the prototype
    String.prototype.repeat = function (n) {
        // repeat the string n times
        return new Array(n + 1).join(this);
    };
}
alert("La".repeat(3)); // LaLaLa
```

Classes in JavaScript

- In OOP, a **class** is an extensible program-code-template for creating objects, providing initial values for state (member variables) and implementations of behavior (member functions or methods)
- In JavaScript there are several programming patterns to make classes
- In ES6, the class construct was introduced, but it's a "syntax sugar" and an extension of one of the patterns that we'll study now

Functional Class Pattern

- The constructor function below can be considered a “class” according to the definition:

```
function User(name) {
    this.sayHi = function () {
        alert(name);
    };
}

let user = new User("John");
user.sayHi(); // John
```

- It follows all parts of the definition:
  - It is a “program-code-template” for creating objects (callable with new)
  - It provides initial values for the state (name from parameters)
  - It provides methods (sayHi)

Functional Class Pattern

- Local variables and nested functions inside User, that are not assigned to **this**, are visible from inside, but not accessible by the outer code

```
function User(name, birthday) {
    // only visible from other methods inside User
    function calcAge() {
        return new Date().getFullYear() - birthday.getFullYear();
    }
    this.sayHi = function () {
        alert(`${name}, age:${calcAge()}`);
    };
}
let user = new User("John", new Date(2000, 0, 1));
user.sayHi(); // John, age:18
```

- name, birthday and the function calcAge() are internal, *private* to the object
  - They are only visible from inside of it
- On the other hand, sayHi is the external, *public* method.
  - The external code that creates user can access it

Factory Class Pattern

- We can create a class without using new at all

```
function User(name, birthday) {
    // only visible from other methods inside User
    function calcAge() {
        return new Date().getFullYear() - birthday.getFullYear();
    }

    return {
        sayHi() {
            alert(`${name}, age:${calcAge()}`);
        }
    };
}

let user = User("John", new Date(2000, 0, 1));
user.sayHi(); // John, age:18
```

- The only benefit of this method is that we can omit new: write let user = User(...) instead of let user = new User(...). In other aspects it’s almost the same as the functional pattern.

Prototype-Based Classes

- Prototype-based classes are the most important and generally the best

```
function User(name, birthday) {
    this._name = name;
    this._birthday = birthday;
}

User.prototype._calcAge = function () {
    return new Date().getFullYear() - this._birthday.getFullYear();
};
User.prototype.sayHi = function () {
    alert(`${this._name}, age:${this._calcAge()}`);
};

let user = new User("John", new Date(2000, 0, 1));
user.sayHi(); // John, age:18
```

- The code structure:
  - The constructor User only initializes the current object state
  - Methods are added to User.prototype

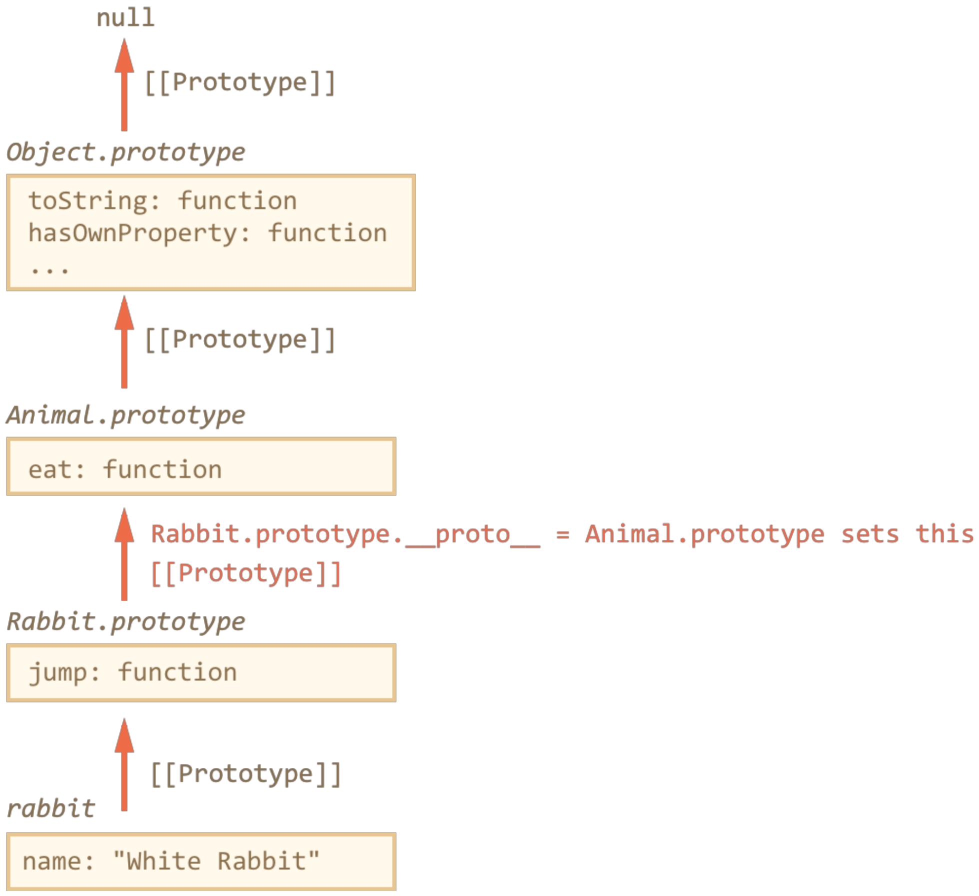
Prototype-Based Classes

- As we can see, methods are lexically not inside function User
  - If we declare variables inside function User, then they won't be visible to methods
- So, there is a widely known agreement that internal properties and methods are prepended with an underscore "_", like _name or _calcAge()
  - Technically, that's just an agreement, the outer code still can access them
- The advantages over the functional pattern:
  - In the functional pattern, each object has its own copy of every method
    - We assign a separate copy of this.sayHi = function() {...} and other methods in the constructor.
  - In the prototypal pattern, all methods are in User.prototype that is shared between all objects
    - An object itself only stores the data
  - Prototypes also allows us to setup the inheritance in a really efficient way (see next slide)
  - Built-in JavaScript objects all use prototypes

Prototype-Based Inheritance

- We can set up a prototype inheritance chain between classes and their sub-classes:

```
function Animal(name) {
    this.name = name;
}
Animal.prototype.eat = function () {
    alert(`${this.name} eats.`);
};

function Rabbit(name) {
    this.name = name;
}
Rabbit.prototype.jump = function () {
    alert(`${this.name} jumps!`);
};

// setup the inheritance chain
Rabbit.prototype.__proto__ = Animal.prototype;

let rabbit = new Rabbit("White Rabbit");
rabbit.eat(); // rabbits can eat too
rabbit.jump();
```



null

[[Prototype]]

Object.prototype

```
toString: function
hasOwnProperty: function
...
```

[[Prototype]]

Animal.prototype

```
eat: function
```

Rabbit.prototype.__proto__ = Animal.prototype sets this [[Prototype]]

Rabbit.prototype

```
jump: function
```

[[Prototype]]

rabbit

```
name: "White Rabbit"
```

Classes

- The “class” construct allows to define prototype-based classes with a clean, nice-looking syntax
- Here’s a class User and its equivalent prototype-based syntax:

```
class User {
    constructor(name) {
        this.name = name;
    }

    sayHi() {
        alert(this.name);
    }
}

let user = new User("John");
user.sayHi();
```

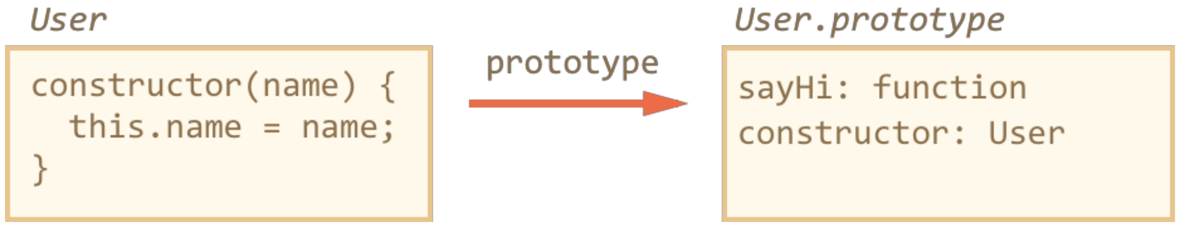
=

```
function User(name) {
    this.name = name;
}

User.prototype.sayHi = function () {
    alert(this.name);
}

let user = new User("John");
user.sayHi();
```

- Note that methods in a class do not have a comma between them

Classes

- The class User {...} here actually does two things:
  - Declares a variable User that references the function named "constructor"
  - Puts the methods listed in the definition into User.prototype



- There are a few subtle differences between the new class syntax and the previous one:
  - Unlike a regular function, a class constructor can't be called without new
  - Class methods are non-enumerable (they don't appear in a for..in loop over the objects)
  - A default constructor() {} is generated, if there is no constructor defined in the class construct
  - All code inside the class construct is automatically in strict mode

Property Getters/Setters

- Getters and setters are functions that work on getting and setting a value, but look like regular properties to an external code
  - They can be used as wrappers over “real” property values to gain more control over them
- The getter works when obj.propName is read, the setter – when it is assigned

```
class User {
    constructor(name) {
        this.name = name; // invokes the setter
    }
    get name() {
        return this._name;
    }
    set name(value) {
        if (value.length == 0) {
            alert("Name cannot be empty");
            return;
        }
        this._name = value;
    }
}
```

```
let user = new User("John");
alert(user.name); // John

user = new User(""); // Name cannot be empty
```

Methods Only

- Unlike object literals, no property:value assignments are allowed inside class
- There may be only methods and getters/setters
- If we really need to put a non-function value into the prototype, then we can alter prototype manually, like this:

```
class User { }

User.prototype.test = 5;

alert(new User().test); // 5
```

- Note that such properties will be shared among all objects of the class

Class Expression

- Just like functions, classes can be defined inside another expression, passed around, returned, etc.
- For example, here's a class-returning function ("class factory"):

```javascript
function makeClass(phrase) {
    // declare a class and return it
    return class {
        sayHi() {
            alert(phrase);
        };
    };
}

let User = makeClass("Hello");
new User().sayHi(); // Hello
```

  - That's quite normal if we recall that class is just a special form of a function-with-prototype definition

Static Methods

- We can also assign methods to the class function, not to its "prototype“
  - Such methods are called *static*

```
class User {
    static staticMethod() {
        alert(this === User);
    }
}
User.staticMethod(); // true
```

=

```
function User() { }

User.staticMethod = function () {
    alert(this === User);
};
User.staticMethod(); // true
```

  - The value of this inside User.staticMethod() is the class constructor User itself (the “object before dot” rule)

Static Methods

- Static methods are usually used to implement functions that belong to the class, but not to any particular object of it
- For instance, we have Article objects and need a function to compare them
- The natural choice would be Article.compare, like this:

```
class Article {
    constructor(title, date) {
        this.title = title;
        this.date = date;
    }

    static compare(articleA, articleB) {
        return articleA.date - articleB.date;
    }
}
```

```
// usage
let articles = [
    new Article("Mind", new Date(2018, 1, 1)),
    new Article("Body", new Date(2018, 0, 1)),
    new Article("JavaScript", new Date(2018, 6, 5))
];

articles.sort(Article.compare);
alert(articles[0].title); // Body
```

Summary

- The basic class syntax looks like this:

```
class MyClass {
    constructor(...) {
        // ...
    }
    method1(...) { }
    method2(...) { }
    get something() { }
    set something(...) { }
    static staticMethod(..) { }
    // ...
}
```

- The value of MyClass is a function provided as constructor
  - If there’s no constructor, then an empty function
- Methods listed in the class declaration become members of its prototype
  - With the exception of static methods that are written into the function itself and callable as MyClass.staticMethod()

Exercise (29)

- Write a class Product with the following properties:
  - id (a read-only property)
  - name
  - price – must be a positive number
- Add the following methods to the class:
  - makeDiscount(discount) - changes the price of the product according to the specified discount
  - print() – prints the product's details to the console
- Add a static method to the class that compares two products according to their price
- Your class code should be in a file product.js
- In an HTML page create an array of 3 products and sort them by their price
- Print the products in the array after the sort

Class Inheritance

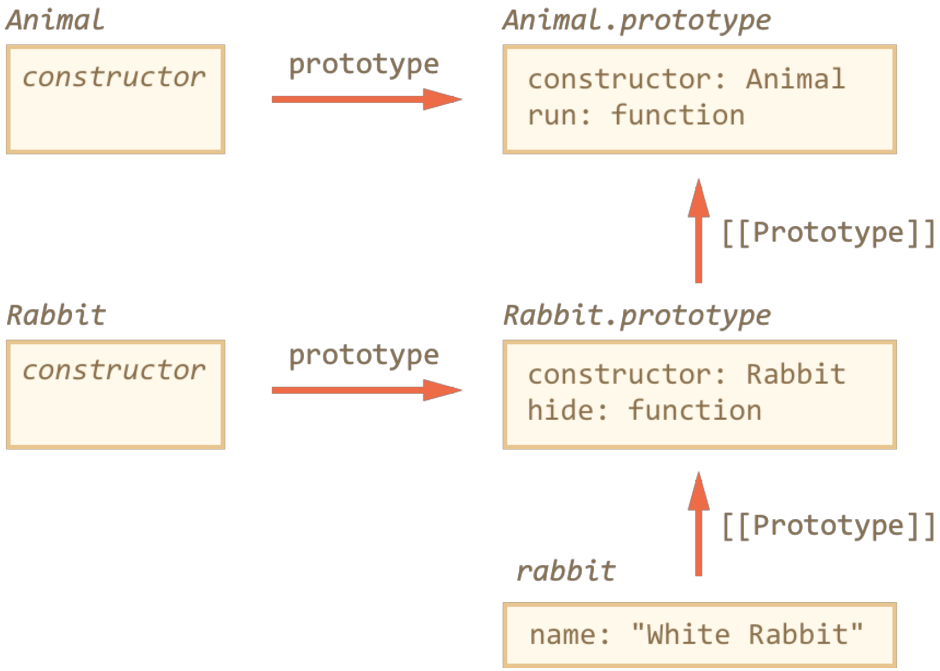
- To inherit from another class, you should specify "**extends**" and the parent class before the brackets {..}:

```
// Base class
class Animal {
    constructor(name) {
        this.name = name;
        this.speed = 0;
    }

    run(speed) {
        this.speed += speed;
        alert(`${this.name} runs with speed
${this.speed}.`);
    }

    stop() {
        this.speed = 0;
        alert(`${this.name} stopped.`);
    }
}
```

```
// Inherit from Animal
class Rabbit extends Animal {
    hide() {
        alert(`${this.name} hides!`);
    }
}

let rabbit = new Rabbit("White Rabbit");

rabbit.run(5); // White Rabbit runs with speed 5.
rabbit.hide(); // White Rabbit hides!
```

Class Inheritance

- The **extends** keyword actually adds a [[Prototype]] reference from a Rabbit.prototype to Animal.prototype, as we've seen before
- So now rabbit has access both to its own methods and to methods of Animal



Overriding a Method

- As of now, Rabbit inherits the stop method that sets this.speed = 0 from Animal
- If we specify our own stop in Rabbit, then it will be used instead:

```
class Rabbit extends Animal {
    stop() {
        // ...this will be used for rabbit.stop()
    }
}
```

- But usually we don't want to totally replace a parent method, but rather to build on top of it, tweak or extend its functionality
  - We do something in our method, but call the parent method before/after it or in the process
- Classes provide "**super**" keyword for that:
  - super.method(...) to call a parent method
  - super(...) to call a parent constructor (inside our constructor only)

Overriding a Method

- For instance, let our rabbit autohide when stopped:

```
class Rabbit extends Animal {
    hide() {
        alert(`${this.name} hides!`);
    }

    stop() {
        super.stop(); // call parent stop
        this.hide(); // and then hide
    }
}

let rabbit = new Rabbit("White Rabbit");

rabbit.run(5); // White Rabbit runs with speed 5.
rabbit.stop(); // White Rabbit stopped. White rabbit hides!
```

- Now Rabbit has the stop method that calls the parent super.stop() in the process

Overriding Constructor

- Till now, Rabbit did not have its own constructor
- If a class extends another class and has no constructor, then the following constructor is generated:

```
class Rabbit extends Animal {
    // generated for extending classes without own constructors
    constructor(...args) {
        super(...args);
    }
}
```

- As we can see, it basically calls the parent constructor passing it all the arguments
- Custom constructors must also call super(...), and do it before using this

Overriding Constructor

- For example, let's add a custom constructor to Rabbit, that will specify the earLength in addition to name:

```
class Rabbit extends Animal {
    constructor(name, earLength) {
        super(name);
        this.earLength = earLength;
    }
    // ...
}

let rabbit = new Rabbit("White Rabbit", 10);
alert(rabbit.name); // White Rabbit
alert(rabbit.earLength); // 10
```

  - For the constructor to work, we need to call super() before using this

Static Methods and Inheritance

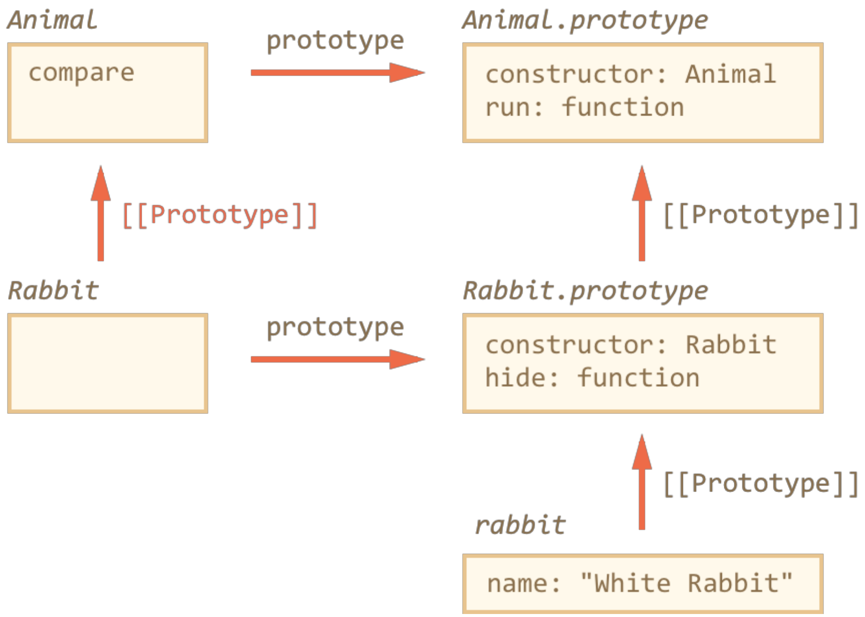
- The class syntax supports inheritance for static properties too

```
class Animal {
    constructor(name, speed) {
        this.speed = speed;
        this.name = name;
    }
    run(speed = 0) {
        this.speed += speed;
        alert(`${this.name} runs with speed
${this.speed}.`);
    }
    static compare(animalA, animalB) {
        return animalA.speed - animalB.speed;
    }
}

// Inherit from Animal
class Rabbit extends Animal {
    hide() {
        alert(`${this.name} hides!`);
    }
}
```

```
let rabbits = [
    new Rabbit("White Rabbit", 10),
    new Rabbit("Black Rabbit", 5)
];

// We can call Rabbit.compare assuming that the
inherited Animal.compare will be called
rabbits.sort(Rabbit.compare);
rabbits[0].run(); // Black Rabbit runs with speed 5.
```

Static Methods and Inheritance

- How does it work? Again, using prototypes
- The keyword **extends** also gives the Rabbit function a [[Prototype]] reference to Animal



- So, the Rabbit constructor function now inherits from the Animal constructor function
  - which itself has [[Prototype]] referencing Function.Prototype

Natives are Extendable

- Built-in classes like Array, Map and others are extendable too
- For instance, here PowerArray inherits from the native Array:

```
// add one more method to it (can do more)
class PowerArray extends Array {
    isEmpty() {
        return this.length === 0;
    }
}

let arr = new PowerArray(1, 2, 5, 10, 50);
alert(arr.isEmpty()); // false

let filteredArr = arr.filter(item => item >= 10);
alert(filteredArr); // 10, 50
alert(filteredArr.isEmpty()); // false
```

  - Note that built-in methods like filter, map, etc. return new objects of exactly the inherited type
  - And we can keep using its methods further down the chain

Class Checking: instanceof

- The instanceof operator allows to check whether an object belongs to a certain class
- The syntax is:

```
obj instanceof Class
```

- It returns true if obj belongs to the Class (or a class inheriting from it)
- For instance:

```
class Animal { }
class Rabbit extends Animal { }

let rabbit = new Rabbit();
alert(rabbit instanceof Rabbit); // true
alert(rabbit instanceof Animal); // true
alert(rabbit instanceof Object); // true, because Animal inherits from Object
```

- The instanceof operator examines the prototype chain for the check

Exercise (30)

- Create a class Book that extends the Product class from the previous exercise, and adds the following properties to it:
  - authors – an array of author names
  - pubDate – publication date
- Override the print() method so after calling the Product's print method, it should print the authors names and the publication date
- Place your code in the file book.js
- Test your code in an HTML page that creates an array of 3 books and prints them to the console