Targeted Topics

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JavaScript Classes and the Prototype

Calling Functions Through Objects

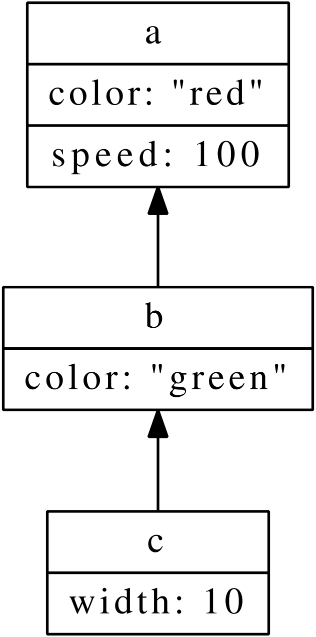
```
let apple  = {name: "Apple",  color: "red"   };
let orange = {name: "Orange", color: "orange"};

let logColor = function() {
  console.log(this.color);
};

apple.logColor  = logColor;
orange.logColor = logColor;

apple.logColor();
orange.logColor();
```

Inheriting Properties from Other Objects



a

color: "red"

speed: 100

b

color: "green"

c

width: 10

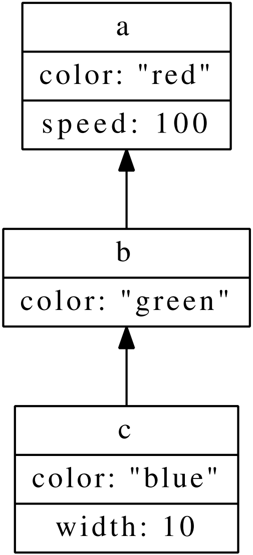
```
c.color === "green";
c.speed === 100;
```

Manual Configuration of Inheritance

```
let a = {color: "red", speed: 100};
let b = Object.create(a);
let c = Object.create(b);

c.speed; // 100
```

Setting Properties and Inheritance



a

color: "red"

speed: 100

b

color: "green"

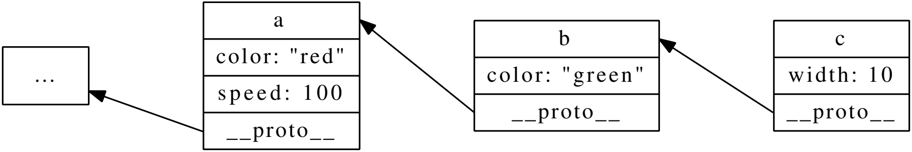
c

color: "blue"

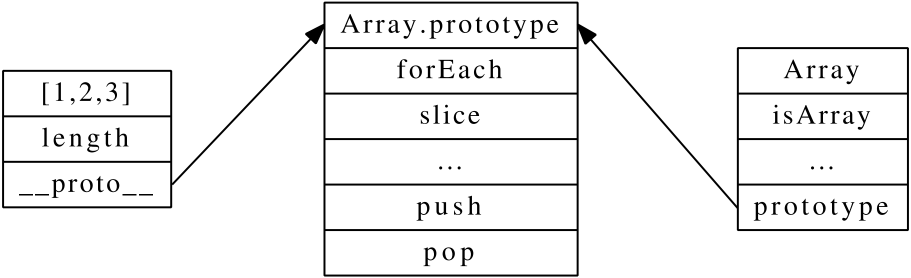
width: 10

```
c.color = "blue";
c.color === "blue";
```

Inheritance with `__proto__`



Looking at `Array` Instances



Constructor Functions and OOP

```
let Rectangle = function(width, height) {
  this.width  = width;
  this.height = height;
};

Rectangle.prototype.area = function() {
  return this.width * this.height;
};

let rect = new Rectangle(10, 20);
rect.area(); // 200
```

ES2015 Classes (Hidden Prototypes)

```javascript
class Rectangle {
  constructor(width, height) {
    this.width  = width;
    this.height = height;
  }

  area() {
    return this.width * this.height;
  }
}

var rect = new Rectangle(10, 20);
rect.area(); // 200
```

Exercise: Constructor Functions

1. Open the following file: src/www/js/constructors/constructors.js
2. Complete the exercise.
3. Run the tests by opening the `index.html` file in your browser.

Constructor Functions and Inheritance

```
let Square = function(width) {
  Rectangle.call(this, width, width);
};

Square.prototype = Object.create(Rectangle.prototype);
Square.prototype.sideSize = function() {return this.width;};

let sq = new Square(10);
sq.area(); // 100
```

ES2015 Classes and Inheritance

```
class Square extends Rectangle {
  constructor(width) {
    super(width, width);
  }

  sideSize() {
    return this.width;
  }
}

var sq = new Square(10);
sq.area(); // 100
```

Generic Functions (Static Class Methods)

Functions that are defined as properties of the constructor function are known as *generic* functions:

```
Rectangle.withWidth = function(width) {
  return new Rectangle(width, width);
};

let rect = Rectangle.withWidth(10);
rect.area(); // 100
```

ES2015 Static Class Methods

```
class Rectangle {
  constructor(width, height) {
    this.width  = width;
    this.height = height;
  }

  static withWidth(width) {
    return new Rectangle(width, width);
  }

  area() {
    return this.width * this.height;
  }
}

var rect = Rectangle.withWidth(10);
rect.area(); // 100
```

Property Getters and Setters

```
function Car() {
  this._speed = 0;
}

Object.defineProperty(Car.prototype, "speed", {
  get: function() { return this._speed; },

  set: function(x) {
    if (x < 0 || x > 100) throw "I don't think so";
    this._speed = x;
  }
});

let toyota = new Car();
toyota.speed = 55; // Calls the `set' function.
```

ES2015 Getters and Setters

```
class Car {
  constructor() {
    this._speed = 0;
  }

  get speed() {
    return this._speed;
  }

  set speed(x) {
    if (x < 0 || x > 100) throw "I don't think so";
    this._speed = x;
  }
}

var toyota = new Car();
toyota.speed = 55; // Calls the `set speed' function.
```

Object-Oriented Programming: Gotcha

What's wrong with the following code?

```
function Parent(children) {
  this.children = [];

  // Add children that have valid names:
  children.forEach(function(name) {
    if (name.match(/\S/)) {
      this.children.push(name);
    }
  });
}

let p = new Parent(["Peter", "Paul", "Mary"]);
```

Accessing this via the bind Function

Notice where bind is used:

```javascript
function ParentWithBind(children) {
  this.children = [];

  // Add children that have valid names:
  children.forEach(function(name) {
    if (name.match(/\S/)) {
      this.children.push(name);
    }
  }.bind(this));
}
```

Accessing `this` via a Closure Variable

Create an alias for `this`:

```
function ParentWithAlias(children) {
  let self = this;
  this.children = [];

  // Add children that have valid names:
  children.forEach(function(name) {
    if (name.match(/\S/)) {
      self.children.push(name);
    }
  });
}
```

Accessing `this` Directly via ES2015 Arrow Functions

Using the ES2015 *arrow function* syntax:

```
function ParentWithArrow(children) {
  this.children = [];

  // Add children that have valid names:
  children.forEach(name => {
    if (name.match(/\S/)) {
      this.children.push(name);
    }
  });
}
```

Passing Objects to Functions

JavaScript uses *call by sharing* when you pass arguments to a function:

```
const x = {color: "purple", shape: "round"};

function mutator(someObject) {
  delete someObject.shape;
}

mutator(x);
console.log(x);
```

Produces:

```
{ color: 'purple' }
```

Object.freeze

```
Object.freeze(obj);

assert(Object.isFrozen(obj) === true);
```

- Can't add new properties
- Can't change values of existing properties
- Can't delete properties
- Can't change property descriptors

Exercise: Class Builder

1. Open the following files:
   - `src/www/js/builder/builder.spec.js` (read only!)
   - `src/www/js/builder/builder.js`
2. Implement the `Builder` function:
   It should generate a constructor function using the `constructor` property given to it. The remaining properties become prototype properties.
3. Use the `index.html` file to run the tests

Functional Programming with JavaScript

Defining a Function

There are several ways of defining functions:

- Function statements (named functions)
- Function expression (anonymous functions)
- Arrow functions (new in ES2015)

Function Definition (Statement)

```
function add(a, b) {
  return a + b;
}

let result = add(1, 2); // 3
```

- This syntax is know as a *function definition statement*. It is only allowed where statements are allowed.
- In modern JavaScript you will mostly use the expression form of function definitions or the arrow function syntax.

Function Definition (Expression)

```
let add = function(a, b) {
  return a + b;
};

let result = add(1, 2); // 3
```

- Function is callable through a variable
- Name after `function` is optional
- We'll see it used later

Function Definition (Arrow Functions)

Short form (single expression, implicit `return`):

```
let add = (a, b) => a + b;
add(1, 2);
```

Long form (multiple expressions, explicit `return`):

```
let add = (a, b) => {
  return a + b;
};

add(1, 2);
```

Function Invocation

- Parentheses are mandatory in JavaScript for function invocation
- Any number of arguments can be passed, regardless of the number defined
- Extra arguments won't be bound to a name
- Missing arguments will be `undefined`

Function Invocation (Example)

```
let add = function(a, b) {
  return a + b;
};

add(1)       // a is 1, b is undefined
add(1, 2)    // a is 1, b is 2
add(1, 2, 3) // No name for 3.
```

(Note: ES2015 has default parameters.)

Function Arity

A function's *arity* is the number of arguments it expects. In JavaScript you can access a function's arity with its `length` property:

```
function foo(x, y, z) { /* ... */ }
foo.length; // => 3
```

Default Parameters

```
let add = function(x, y=1) {
  return x + y;
};

add(2); // 3
```

- Parameters can have *default* values
- When a parameter isn't bound by an argument it takes on the default value, or `undefined` if no default is set
- Default parameters are evaluated at *call time*
- May refer to any other variables in scope

Rest Parameters

```
let last = function(x, y, ...args) {
  return args.length;
};

last(1, 2, 3, 4); // 2
```

- When an argument name is prefixed with "`...`" it will be an array containing all of the arguments that are not bound to names
- Unlike `arguments`, the rest parameter only contains arguments that are not bound to names
- Unlike `arguments`, the rest parameter is a real `Array`

Functions as Data

Functions can be treated like any other type of JavaScript value:

```
let add = function(a, b) {return a + b;};

let x = add;         // x is now a function object
x(1, 2);             // Same as add(1, 2);
```

Passing Functions as Arguments

It's very common to create functions *on the fly* and pass them to other functions as arguments:

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

a.forEach(function(n) {
  console.log(n);
});
```

Functions that Return Functions

Functions can create *nested functions* and return them:

```
function recordStartTime() {
  let d = new Date();

  return function() {
    return d;
  };
};

let getStartTime = recordStartTime();
getStartTime(); // 2018-07-03T23:16:00.383Z
```

(Note: this creates what's known as a *closure*.)

Demonstrating Closures: An Example

```
let makeCounter = function(startingValue) {
  let n = startingValue;

  return function() {
    return n += 1;
  };
};

let counter = makeCounter(0);
counter(); // 1
counter(); // 2
```

(Open `src/examples/js/closure.html` and play in the debugger.)

A Practical Example of Using Closures: Private Variables

Using closures to create truly private variables in JavaScript:

```
let Foo = function() {
  let privateVar = 42;

  return {
    getPrivateVar: function() {
      return privateVar;
    },
    setPrivateVar: function(n) {
      if (n) privateVar = n;
    }
  };
};

let x = Foo();
x.getPrivateVar(); // 42
```

Closure Gotcha: Loops, Functions, and Closures

```javascript
// What will this output?
for (var i=0; i<3; i++) {
  setTimeout(function(){
    console.log(i);
  }, 1000*i);
}
console.log("Howdy!");
```

Exercise: Sharing Scope

1. Open the following file:
   src/www/js/closure/closure.js
2. Complete the exercise.
3. Run the tests by opening the `index.html` file in your browser.

Immediately-Invoked Function Expressions: Basics

The module pattern:

```
(function() {
  let x = 1;
  return x;
})();
```

Example: Module Pattern

```
let Car = (function() {
  // Private variable.
  let speed = 0;

  // Private method.
  let setSpeed = function(x) {
    if (x >= 0 && x < 100) {speed = x;}
  };

  // Return the public interface.
  return {
    stop: function() {setSpeed(0);},
    inc:  function() {setSpeed(speed + 10);},
  };
})();
```

Introducing Higher-order Functions

The `forEach` function is a good example of a *higer-order* function:

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

a.forEach(function(val, index, array) {
  // Do something...
});
```

Or, less idiomatic:

```
let f = function(val) { /* ... */ };
a.forEach(f);
```

Array Testing

- Test if a function returns `true` on all elements:

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

a.every(function(val) {
  return val > 0;
});
```

- Test if a function returns `true` at least once:

```
a.some(function(val) {
  return val > 2;
});
```

Filter Example

```
let numbers = [10, 7, 23, 42, 95];

let even = numbers.filter(function(n) {
  return n % 2 === 0;
});

even;           // [10, 42]
even.length;    // 2
numbers.length; // 5
```

(See: `src/examples/js/filter.js`)

Map Example

```
let strings = [
  "Mon, 14 Aug 2006 02:34:56 GMT",
  "Thu, 05 Jul 2018 22:09:06 GMT"
];

let dates = strings.map(function(s) {
  return new Date(s);
});

dates; // [Date, Date]
```

(See: `src/examples/js/map.js`)

Example: Folding an Array with `reduce`

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

// Sum numbers in `a'.
let sum = a.reduce(function(acc, elm) {
  // 1. `acc' is the accumulator
  // 2. `elm' is the current element
  // 3. You must return a new accumulator
  return acc + elm;
}, 0);

sum; // 6
```

(See: `src/examples/js/reduce.js`)

Function.prototype.call

Calling a function and explicitly setting `this`:

```
let x = {color: "red"};
let f = function() {console.log(this.color);};

f.call(x);          // this.color === "red"
f.call(x, 1, 2, 3); // `this' + arguments.
```

Function.prototype.apply

The `apply` method is similar to `call` except that additional arguments are given with an array:

```
let x = {color: "red"};
let f = function() {console.log(this.color);};

f.apply(x); // this.color === "red"

let args = [1, 2, 3];
f.apply(x, args); // `this' + arguments.
```

Function.prototype.bind

The `bind` method creates a new function which ensures your original function is always invoked with `this` set as you desire, as well as any arguments you want to supply:

```
let x = {color: "red"};
let f = function() {console.log(this.color);};

x.f = f;

let g = f.bind(x);
let h = f.bind(x, 1, 2, 3);

g(); // Same as x.f();
h(); // Same as x.f(1, 2, 3);
```

Introduction to Partial Function Application

- What happens when you call a function with fewer arguments than it was defined to take?
- Sometimes it's useful to provide fewer arguments and get back a function that accepts the remaining functions.

Simple Example Using Haskell

```haskell
-- Add two numbers:
add :: Int -> Int -> Int
add x y = x + y

-- Call a function three times:
tick :: (Int -> Int) -> [Int]
tick f = [f 1, f 2, f 3]

-- Prints "[11,12,13]"
main = print (tick (add 10))
```

Example Using the `bind` Method

```
let add = function(x, y) {
  return x + y;
};

let add10 = add.bind(undefined, 10);

console.log(add10(2));
```

Exercise: Better Partial Functions

Write a `Function.prototype.curry` function that let's the following code work:

```
let obj = {
  magnitude: 10,

  add: function(x, y) {
    return (x + y) * this.magnitude;
  }.curry()
};

let add10 = obj.add(10);
add10(2); // Should return 120
```

- Use the following file: `src/www/js/partial/partial.js`

What is a *Pure* Function?

Pure functions are functions that have the same properties as their mathematical cousins. Some of these properties include:

- Can only access bound variables (i.e., their arguments)
- Cannot have side effects (e.g., update the DOM)
- Given the same inputs, always produces the same output

In other words, a pure function always produces a return value and that return value can only be calculated using the function's arguments.

What's the Point of Pure Functions?

Pure functions make programming *a lot* easier!

- Everything you need to know about a function is there in its definition
- They don't rely on the state of the program, user, or machine
- Simple to test (can even be automated)

Writing Pure Functions in JavaScript

Like everything in JavaScript, you get little help from the language when trying to write pure functions. Here are some tips:

- Don't access global or closure variables
- Don't mutate any arguments or call functions that mutate arguments
- Don't change the state of the program or runtime

Pure Function Quiz: Part 1

```javascript
let checkUserPermission = function(code, roles, cache) {
  if (cache.includes(code)) {
    return true;
  } else if (Object.values(roles).includes(code)) {
    cache.push(code);
    return true;
  }

  return false;
};

let cache = [];
let roles = {view: 1, edit: 2, remove: 3};

if (checkUserPermission(3, roles, cache)) {
  console.log("user can remove page");
}
```

Pure Function Quiz: Part 2

```
let emailMatches = function(email, f) {
  return f(email.subject) || f(email.body);
};

let email = {subject: "Foo", body: "Bar"};

bool = emailMatches(email, function(str) {
  return str.match(/oo/);
});
```

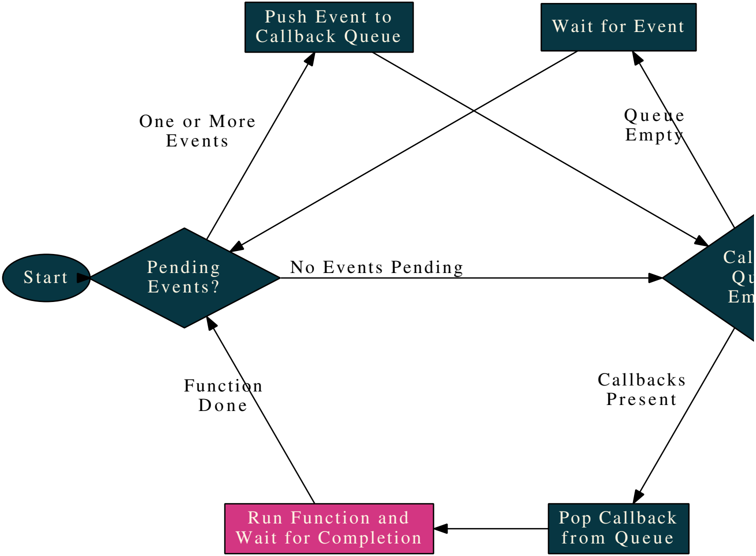
Asynchronous Programming

Introduction to the Runtime

- JavaScript has a single-threaded runtime
- Work is therefore split up into small chucks (functions)
- Callbacks are used to divide work and call the next chunk
- The runtime maintains a work queue where callbacks are kept

(See the demo: `src/www/js/runtime/index.html`)

Visualizing the Runtime



(See the demo: `src/www/js/runtime/index.html`)

Callbacks without Promises

```
$.getJSON("/a", function(data_a) {
  $.getJSON("/b/" + data_a.id, function(data_b) {
    $.getJSON("/c/" + data_b.id, function(data_c) {
      console.log("Got C: ", data_c);
    }, function() {
      console.error("Call failed");
    });
  }, function() {
    console.error("Call failed");
  });
}, function() {
  console.error("Call failed");
});
```

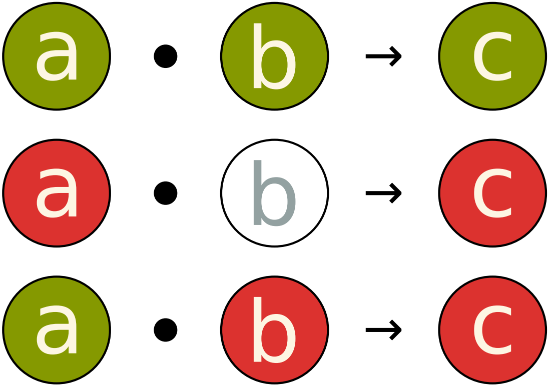
Callbacks Using Promises

```
$.getJSON("/a")
  .then(function(data) {
    return $.getJSON("/b/" + data.id);
  })
  .then(function(data) {
    return $.getJSON("/c/" + data.id);
  })
  .then(function(data) {
    console.log("Got C: ", data);
  })
  .catch(function(message) {
    console.error("Something failed:", message);
  });
```

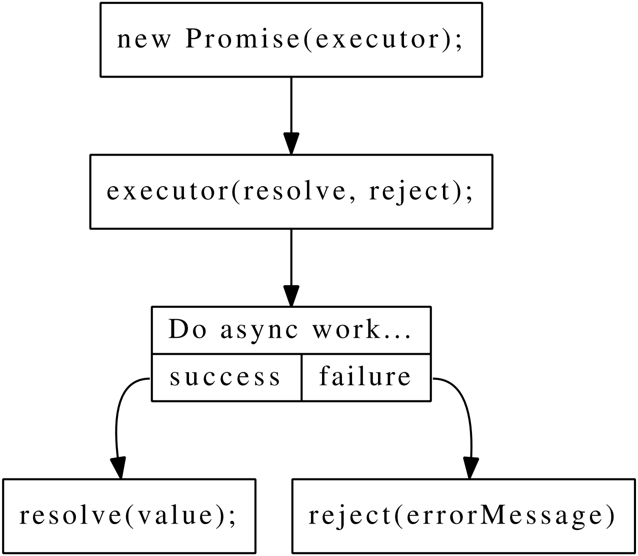
Promise Details

- Guarantee that callbacks are invoked (no race conditions)
- Composable (can be chained together)
- Flatten code that would otherwise be deeply nested

Visualizing Promises (Composition)



Visualizing Promises (Owner)



new Promise(executor);

executor(resolve, reject);

Do async work...

success

failure

resolve(value);

reject(errorMessage)

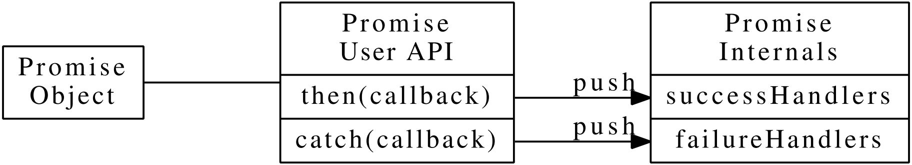
Example: Promise Owner

```
var delayed = function() {
  return new Promise(function(resolve, reject) {
    setTimeout(function() {

      if (/* some condition */ true) {
        resolve(/* resolved value */ 100);
      } else {
        reject(/* rejection value */ 0);
      }

    }, 500);
  });
};
```

Visualizing Promises (User)



Promise Composition Example

```
// Taken from the `src/spec/promise.spec.js' file.
var p = new Promise(function(resolve, reject) {
  resolve(1);
});

p.then(function(val) {
  expect(val).toEqual(1);
  return 2;
}).then(function(val) {
  expect(val).toEqual(2);
  done();
});
```

Traditional XHR (Ajax) Requests

```
let req = new XMLHttpRequest();

req.addEventListener("load", function() {
  if (req.status >= 200 && req.status < 300) {
    console.log(req.responseText);
  }
});

req.addEventListener("error", function() {
  console.error("WTF?");
});

req.open("GET", "/example/foo.json");
req.send(/* data to send for POST, PATCH, etc. */);
```

Using the fetch Function

```
fetch("/api/artists", {credentials: "same-origin"})
  .then(function(response) {
    return response.json();
  })
  .then(function(data) {
    updateUI(data);
  })
  .catch(function(error) {
    console.log("Ug, fetch failed", error);
  });
```

Options and Results for `fetch`

```
fetch(url, {
  method: "POST",
  credentials: "same-origin",
  headers: {"Content-Type": "application/json; charset=utf-8"}
  body: JSON.stringify(data),
})
.then(function(response) {
  if (response.ok) return response.json();
  throw `expected ~ 200 but got ${response.status}`;
})
.then(console.log);
```

Browser Support

Browsers:

- IE (no support)
- Edge $>=$ 14
- Firefox $>=$ 34
- Safari $>=$ 10.1
- Chrome $>=$ 42
- Opera $>=$ 29

Using REST+JSON

- Fetch all artists (no body):

  `GET /api/artists`

- Fetch a single artist (no body):

  `GET /api/artists/2`

- Create a new artist (JSON body):

  `POST /api/artists`

- Update an artist (JSON body):

  `PATCH /api/artists/2`

- Delete an artist (no body):

  `DELETE /api/artists/2`

Exercise: Using the Fetch API

1. Start your server if it isn't running
2. Open `src/www/js/fetch/fetch.js`
3. Fill in the missing pieces
4. To test and debug, open

   `http://localhost:3000/js/fetch/`

What are async Functions?

Functions marked as `async` become asynchronous and automatically return promises:

```
async function example() {
  return "Hello World";
}

example().then(function(str) {
  console.log(str); // "Hello World"
});
```

The `await` Keyword

Functions marked as `async` get to use the `await` keyword:

```
async function example2() {
  let str = await example();
  console.log(str); // "Hello World"
}
```

Question: What does the `example2` function return?

Example of async/await

```
async function getArtist() {
  try {
    let response1 = await fetch("/api/artists/1");
    let artist = await response1.json();

    let response2 = await fetch("/api/artists/1/albums");
    artist.albums = await response2.json();

    return artist;
  } catch(e) {
    // Rejected promises throw exceptions
    // when using `await'.
  }
}
```

An Even Better Example of async/await

```
async function getArtistP() {
  // Kick off two requests in parallel:
  let p1 = fetch("/api/artists/1").then(r => r.json());
  let p2 = fetch("/api/artists/1/albums").then(r => r.json());

  // Wait for both requests to finish:
  let [artist, albums] = await Promise.all([p1, p2]);

  artist.albums = albums;
  return artist;
}
```

Exercise: Using `async` and `await`

1. Start your server if it isn't running
2. Open `src/www/js/ajax/ajax.js`
3. Fill in the missing pieces
4. To test and debug, open

   `http://localhost:3000/js/ajax/`

Modern JavaScript: ES2015 - ES2018

ES2015 Summary

- New keywords: `let`, `const`, `class`, `import`, `exprort`, etc.
- New function syntax (i.e. arrow functions)
- New syntax for function parameters
- New syntax for destructuring
- New built-in objects
- Lots more

The New `let` Keyword

- ES2015 introduces `let`
- Declare a variable in the scope of containing block:

```
if (expression) {
  var a = 1; // scoped to wrapping function
  let b = 2; // scoped to the block
} // Woah!
```

Hoisting and `let`

It does not hoist!

```
{
  console.log(b); // Error!

  let b = 12;
  console.log(b); // No problem.
}
```

Looping with `let`

Using let with a for loop is possible in ES2015:

```
for (let i=0; i<10; i++) {
  // i is bound to a new scope each iteration
  // getting its value reassigned
  // at the end of the iteration
}
```

Preventing Reassignment

The const keyword defines a block-level variable that must be initialized when it's declared and can't be reassigned:

```
let f = function() {
  const x = "foo";

  // ...

  x = 1;  // Ignored.
};
```

Arrow Functions

```
element.addEventListener("click", function(e) {
  // ...
});

// Becomes:
```

```
element.addEventListener("click", e => {
  // ...
});
```

Implicit `return` for Arrow Expressions

If you omit curly braces you can write a single expression that automatically becomes the return value of the function:

```
a.map(function(e) {
  return e + 1;
});

// Becomes:

a.map(e => e + 1);
```

Arrow Warnings

- Arrow function do not have a `this` or an `arguments` variable!
- If you use curly braces you need to use `return`.

Default Parameters

```
let add = function(x, y=1) {
  return x + y;
};

add(2); // 3
```

- Parameters can have *default* values
- When a parameter isn't bound by an argument it takes on the default value, or `undefined` if no default is set
- Default parameters are evaluated at *call time*
- May refer to any other variables in scope

Rest Parameters

```
let last = function(x, y, ...args) {
  return args.length;
};

last(1, 2, 3, 4); // 2
```

- When an argument name is prefixed with "`...`" it will be an array containing all of the arguments that are not bound to names
- Unlike `arguments`, the rest parameter only contains arguments that are not bound to names
- Unlike `arguments`, the rest parameter is a real `Array`

Spread Syntax

```
let max = function(x, y) {
  return x > y ? x : y;
};

let ns = [42, 99];

max(...ns); // 99
```

- When the name of an array is prefixed with "`...`" in an expression that expects arguments or elements, the array is expanded
- Works when calling functions and creating array literals
- Can be used to splice arrays together

(Object spreading is part of ES2018.)

Array Destructuring

```javascript
let firstPrimes = function() {
  return [2, 3, 5, 7];
};

let x, y, rest;
[x, y, ...rest] = firstPrimes();

console.log(x); // 2
console.log(y); // 3
console.log(rest); // [ 5, 7 ]
```

- Similar to *pattern matching* from functional languages
- The *lvalue* can be an array of names to bind from the *rvalue*

(Object destructuring is part of ES2018.)

Classes

New `class` keyword that provides syntactic sugar over prototypal inheritance:

```
class Square extends Rectangle {
  constructor(width) {
    super(width, width);
  }
  someMethod() {
    return "Interesting";
  }
}
```

Class Features

- Class statements are *not* hoisted.
- Classes can also be defined using an expression syntax:

```
let Person = class {
  // ..
};
```

Same-Value Equality

Similar to “===” with a few small changes:

```
Object.is(NaN, NaN); // true

Object.is(+0, -0);   // false
```

(This function first appeared in ECMAScript Edition 6, 2015.)

The Object.assign Function

Copies properties from one object to another:

```
var o1 = {a: 1, b: 2, c: 3};
var o2 = { };

Object.assign(o2, o1);
console.log(o2);
```

Produces this output:

```
{ a: 1, b: 2, c: 3 }
```

(This function first appeared in ECMAScript Edition 6, 2015.)

Exporting and Importing Identifiers

- Export identifiers from a library:

```
const magicNumber = 42;

function sayMagicNumber() {
  console.log(magicNumber);
}

export { sayMagicNumber };
```

- Import those identifiers elsewhere:

```
import sayMagicNumber from './module.js';
sayMagicNumber();
```

Explicit Dependencies in JavaScript

When using ES2015 modules:

- Dependencies are explicit through imports
- Removes global namespace pollution
- You can import part of a library, or the entire thing
- Strict mode enabled by default

New Generic `for` Loop

The new `for-of` loop can work with any object that supports iteration:

```
var anything = [1, 2, 3];

for (let x of anything) {
  console.log(x);
}
```

Generators

```
let something = {
  [Symbol.iterator]: function*() {
    for (let i=0; i<10; ++i) {
      yield i;
    }
  },
};

for (let x of something) {
  console.log(x);
}
```

Iterators

```
let something = {
  [Symbol.iterator]: function() {
    let n = 0;

    return {
      next: () => ({value: n, done: n++ >= 10}),
    };
  },
};

for (let x of something) {
  console.log(x);
}
```

Maps

```
let characters = new Map();

characters.set("Ripley", "Alien");
characters.set("Watney", "The Martian");

characters.has("Ripley"); // true
characters.get("Ripley"); // "Alien"
```

WeakMaps

- Like a `Map`, but *keys* can be garbage collected
- Similar API as a `Map` (missing some functions)
  - `WeakMap.prototype.delete`
  - `WeakMap.prototype.get`
  - `WeakMap.prototype.set`
  - `WeakMap.prototype.has`

Others

- `Set` and `WeekSet`
  Mathematical sets, as well as a weak version.
- `Proxy` and `Reflect`
  Powerful objects for metaprogramming.
- `Symbol`
  Create and use runtime unique entries in the symbol table.
- Template Literals
  String interpolation:

  ```
  `Hello ${name}`
  ```

ES2016 Summary

- New operator: `**`
- New function: `Array.prototype.includes`

Exponentiation Operator

Prior to ES2016:

```
Math.pow(4, 2);
```

New in ES2016:

```
4 ** 2;
```

`Array.prototype.includes`

A new prototype function to test if a value is in an array.

Prior to ES2016:

```
[1, 2, 3].indexOf(3) >= 0;
```

New in ES2016:

```
[1, 2, 3].includes(3);
```

ES2017 Summary

- Aync functions!!
- Updates to the `String` object
- Small changes to `Object.prototype`
- A few others

Async Functions

Major improvement to asynchronous functions thanks to promises and generators. Asynchronous callbacks are hidden with new syntax.

```
async function getArtist() {
  try {
    let response1 = await fetch("/api/artists/1");
    let artist = await response1.json();

    let response2 = await fetch("/api/artists/1/albums");
    artist.albums = await response2.json();

    return artist;
  } catch(e) {
    // Rejected promises throw exceptions
    // when using `await'.
  }
}
```

Summary of Other Changes

- String padding (ensuring a string is the proper length)
  - `String.prototype.padStart`
  - `String.prototype.padEnd`
- `Object.values` and `Object.entries`
- `Object.getOwnPropertyDescriptors`
- Trailing commas in function parameters and call arguments
- Shared memory (`SharedArrayBuffer`)
- Atomic operations (e.g., `Atomics.store`)

ES2018 Summary

- Rest and spread operations for properties (proposal)
- New function: `Promise.prototype.finally` (proposal)
- Asynchronous iterators and generators (proposal)
- Regular expression improvements (s flag, groups, lookbehind, unicode)
- Template literal improvements (proposal)

Object Destructuring and Rest Property Assignment

```javascript
let x = {a: 1, b: 2, c: 3, d: 4};
let {a, b, ...z} = x;

a; // 1
b; // 2
z; // { c: 3, d: 4 }
```

Object Initialization Spreading

```
let z = {c: 3, d: 4};
let x = {a: 1, b: 2, ...z};

x; // { a: 1, b: 2, c: 3, d: 4 }
```

Promise.prototype.finally

The `finally` function allows you to respond to a promise being resolved *or* rejected. It's perfect for updating the UI after a network call finishes:

```
startSpinner();

$getJSON("/foo")
  .finally(() => stopSpinner())
  .then(data  => updateUI(data));
```

Asynchronous Iterators for JavaScript

- `async` iterator and generator functions that yield promises
- `await` version of the `for-of` loop

```
for await (const line of readLines(filePath)) {
  console.log(line);
}
```

Regular Expressions: New Engine Flag

The new `s` engine flag turns on the *dot all* mode:

```
"foo\nbar".match(/foo.bar/); // null

"foo\nbar".match(/foo.bar/s); // Array(...)
```

Regular Expressions: Named Capture Groups

Regular expressions can now have named capture groups:

```
m = "2018-06-26".match(/^(?<year>\d{4})-/);
m.groups.year; // "2018"
```

Regular Expressions: Lookbehind Assertions

Regular expressions can have lookbehind assertions:

```
// Positive Lookbehind:
m = "$9.99".match(/(?<=\$)\d+\.\d+/);
m[0]; // "9.99"

// Negative Lookbehind:
m = "A1B2C3".match(/(?<!1)[BC]/);
m[0]; // "C"
```

Regular Expressions: Unicode Property Matching

Match Unicode *properties* such as *script*:

```
// U+3C0 is the Greek pi character
"\u03c0".match(/\p{Script=Greek}/u);
```

(Note the new `u` engine flag.)

Template Literals and Escape Sequences

Tagged template literals may contain invalid escape sequences. Those sequences are reserved and made available in a `raw` property:

```
function foo(strings) {
  strings[0];     // undefined
  strings.raw[0]; // "I like \\u"

  return strings.raw[0].replace("\\u", "you");
}

foo`I like \u`; // "I like you"
```

What are Decorators?

Decorators provide an official mechanism in JavaScript for metaprogramming. In other words, they add the ability for run-time code generation.

- Functions that generate code
- Are given an object that fully describes the code from which they were invoked
- Are invoked by using `@` in front of their name, and placed before classes, methods, properties, etc.

Example Decorator

```javascript
function final(descriptor) {
  let { kind } = descriptor;
  console.assert(kind === "class");

  function finisher(klass) {
    Object.freeze(klass);
    Object.freeze(klass.prototype);
  }

  return { ...descriptor, finisher };
}
```

Using the Decorator

```
@final
class Hello {
  say() { console.log("Hello!") };
}
```

Observable Basics

Observables are:

- Sort of like promises, but for multiple values over time
- A functional way of dealing with events (push-based values)
- Another way to embrace functional programming in JavaScript
- Blends functional programming and the Observer Pattern

Example: Subscribing to Events

When subscribing to an Observable you provide a function that will get called each time a value is delivered:

```
const button = document.querySelector("button");
const span   = button.parentNode.querySelector("span");

// `countClicks' is a function that returns an observable:
countClicks(button)
  .subscribe(n => span.textContent = n);
```

(See: `src/www/js/apis/rxjs/example.js`)

Example: Observables from Events

There are many ways to create an Observable. The `fromEvent` function creates an Observable that delivers event objects:

```
function countClicks(element) {
  return fromEvent(element, "click")
    .pipe(
      // Limit to two clicks per second:
      throttleTime(500),

      // A running counter of clicks:
      scan(n => n + 1, 0)
    );
}
```

(See: `src/www/js/apis/rxjs/example.js`)

Important Browser APIs

Traditional XHR (Ajax) Requests

```
let req = new XMLHttpRequest();

req.addEventListener("load", function() {
  if (req.status >= 200 && req.status < 300) {
    console.log(req.responseText);
  }
});

req.addEventListener("error", function() {
  console.error("WTF?");
});

req.open("GET", "/example/foo.json");
req.send(/* data to send for POST, PATCH, etc. */);
```

Using the fetch Function

```
fetch("/api/artists", {credentials: "same-origin"})
  .then(function(response) {
    return response.json();
  })
  .then(function(data) {
    updateUI(data);
  })
  .catch(function(error) {
    console.log("Ug, fetch failed", error);
  });
```

Options and Results for `fetch`

```
fetch(url, {
  method: "POST",
  credentials: "same-origin",
  headers: {"Content-Type": "application/json; charset=utf-8"}
  body: JSON.stringify(data),
})
.then(function(response) {
  if (response.ok) return response.json();
  throw `expected ~ 200 but got ${response.status}`;
})
.then(console.log);
```

Browser Support

Browsers:

- IE (no support)
- Edge $>=$ 14
- Firefox $>=$ 34
- Safari $>=$ 10.1
- Chrome $>=$ 42
- Opera $>=$ 29

Using REST+JSON

- Fetch all artists (no body):

  ```
  GET /api/artists
  ```

- Fetch a single artist (no body):

  ```
  GET /api/artists/2
  ```

- Create a new artist (JSON body):

  ```
  POST /api/artists
  ```

- Update an artist (JSON body):

  ```
  PATCH /api/artists/2
  ```

- Delete an artist (no body):

  ```
  DELETE /api/artists/2
  ```

Exercise: Using the Fetch API

1. Start your server if it isn't running
2. Open `src/www/js/fetch/fetch.js`
3. Fill in the missing pieces
4. To test and debug, open

   `http://localhost:3000/js/fetch/`

Custom HTML Elements

The Web Components standard allows us to create custom HTML elements:

- Create an ES2015 class that inherits from `HTMLElement`
- Pick the name for your new HTML element (must contain a hyphen (“-”))
- Register your class as a handler for the custom element name

Autonomous Custom Elements

Create new HTML elements that do whatever you want!

```
class ChatBox extends HTMLElement { }
customElements.define("chat-box", ChatBox);
```

and in your HTML:

```
<chat-box></chat-box>
```

Lifecycle Callbacks

Custom element classes can respond to a small number of events by defining methods:

`constructor`: Element created (don't forget to call `super()`)
`connectedCallback`: The custom element was added to the DOM
`disconnectedCallback`: Removed from the DOM
`attributeChangedCallback`: Notification for observed attributes

Example: Autonomous Custom Element

```
class HelloAutonomous extends HTMLElement {
  constructor() {
    super();
    this.textContent = "Hello World";
  }
}

customElements.define("hello-autonomous", HelloAutonomous);
```

(See: `src/www/js/apis/components/example.js`)

The Shadow DOM

Custom elements can have their own DOM which is private and hidden. It's call the *shadow* DOM.

- A single element may have a complicated DOM behind it (think of the `<video>` element)
- Isolates JavaScript and CSS so only the shadow DOM is affected
- Perfect for encapsulated components!

Example: Creating and Using a Shadow DOM

```
class HelloShadow extends HTMLElement {
  constructor() {
    super();

    const shadowRoot = this.attachShadow({mode: "open"})

    const style = document.createElement("style");
    style.textContent = "p { color: red; }";
    shadowRoot.appendChild(style);

    const p = document.createElement("p");
    p.textContent = "Hello World in red!";
    shadowRoot.appendChild(p);
  }
}

customElements.define("hello-shadow", HelloShadow);
```

HTML Templates

A standard way of dealing with reusable HTML templates:

- The `<template>` element for creating templates
- The `<slot>` element to mark placeholders in templates

Example: HTML Templates

```html
<!-- Create a template and slots: -->
<template id="with-name">
  <ul>
    <li>Hello <slot name="first-name">World</slot>!</li>
    <li>Your name came from a slot</li>
  </ul>
</template>

<!-- Custom element that fills in a slot: -->
<hello-template>
  <span slot="first-name">Alice</span>
</hello-template>
```

(See: `src/www/js/apis/components/index.html`)

Example: Custom Elements, Shadow DOM, and Templates

```
class HelloTemplate extends HTMLElement {
  constructor() {
    super();

    const template = document.getElementById("with-name");
    const shadowRoot = this.attachShadow({mode: "open"})

    shadowRoot.appendChild(template.content.cloneNode(true));
  }
}

customElements.define("hello-template", HelloTemplate);
```

(See: `src/www/js/apis/components/example.js`)

Browser Support

- Custom Elements and Templates
  - IE (No support)
  - Edge (No support)
  - Firefox >= 63 (2018)
  - Safari >= 10.1 (2017)
  - Chrome >= 53 (2016)
- Shadow DOM
  - IE (No support)
  - Edge (No support)
  - Firefox >= 63 (2018)
  - Safari >= 11.1 (2018)
  - Chrome >= 66 (2018)

(Polyfills exist for most browsers.)

Exercise: Creating a Web Component

1. Start your server if it isn't running
2. Open the following files:
   - `src/www/js/discography/components/index.js`
   - `src/www/js/discography/index.html`
3. Fill in the missing pieces for exercises 1 and 2
4. Play with your web component:

   `http://localhost:3000/js/discography/`

WebSockets Basics

- Full duplex connection to a server
- Create your own protocol on top of WebSockets frames
- Not subject to the same origin policy (SOP) or CORS

How It Works

1. The browser requests that a new HTTP connection be *upgraded* to a raw TCP/IP connection
2. The server responds with `HTTP/1.1 101 Switching Protocols`
3. A simple binary protocol is used to support bi-directional communications between the client and server over the upgraded port 80 connection

Example: WebSockets

```
let ws = new WebSocket("ws://localhost:3000/");

ws.onopen = function() {
  log("connected to WebSocket server");
};

ws.onmessage = function(e) {
  log("incoming message: " + e.data);
};

ws.send("PING");
```

(See: `src/www/js/apis/websockets/main.js`)

Security Considerations

- There are no host restrictions on WebSockets connections
- Encrypt traffic and confirm identity when using WebSockets
- Never allow foreign JavaScript to execute in a user's browser

Browser Support

- IE $>=$ 10
- Firefox $>=$ 6
- Safari $>=$ 6
- Chrome $>=$ 14
- Opera $>=$ 12.10

Exercise: A Live Chatroom

1. Start your server if it isn't running
2. Open the following files:
    - `src/www/js/discography/components/chat.js`
    - `src/www/js/discography/index.html`
3. Fill in the missing pieces
4. Play with your chat room:

    `http://localhost:3000/js/discography/`

What is Web Storage?

- Allows you to store key/value pairs
- Two levels of persistence and sharing
- Very simple interface
- Keys and values *must* be strings

Session Storage

- Lifetime: same as the containing window/tab
- Sharing: Only code in the same window/tab
- 5MB user-changeable limit (10MB in IE)
- Basic API:

```
sessionStorage.setItem("key", "value");
let item = sessionStorage.getItem("key");
sessionStorage.removeItem("key");
```

Local Storage

- Lifetime: unlimited
- Sharing: All code from the same domain
- 5MB user-changeable limit (10MB in IE)
- Basic API:

```
localStorage.setItem("key", "value");
let item = localStorage.getItem("key");
localStorage.removeItem("key");
```

The `Storage` Object

Properties and methods:

- `length`: The number of items in the store.
- `key(n)`: Returns the name of the key in slot `n`.
- `clear()`: Remove all items in the storage object.
- `getItem(key)`, `setItem(key, value)`, `removeItem(key)`.

Browser Support

- IE $>=$ 8
- Firefox $>=$ 2
- Safari $>=$ 4
- Chrome $>=$ 4
- Opera $>=$ 10.50

Exercise: Chatroom Replay

1. Start your server if it isn't running
2. When receiving an incoming message from the chat server cache the message in the `sessionStorage`.
3. When the page first loads insert all of the cached chat messages into the UI.
4. Open the following files:
    - `src/www/js/discography/components/chat.js`
5. Fill in the missing pieces
6. Send some chat messages then reload:

    `http://localhost:3000/js/discography/`

Web Worker Basics

- Allows you to start a new background “thread”
- Messages can be sent to and from the worker
- Message handling is done through events
- Load scripts with: `importScripts("name.js");`

Browser Support

- IE $>=$ 10
- Firefox $>=$ 3.5
- Safari $>=$ 4
- Chrome $>=$ 4
- Opera $>=$ 10.6

Service Worker Basics

- Intended to replace AppCache
- Can intercept network requests and decide how to respond (make real request, pull from cache, etc.)
- Can cache all assets when started
- Allows for complete offline experience

Registering a Service Worker

From your site's JavaScript:

```
navigator.serviceWorker.register("worker.js")
  .then(function(registration) {
    console.log("registration complete");
  })
  .catch(function(error) {
    console.log("ERROR: " + error);
  });
```

(See `src/www/js/apis/serviceworkers/main.js`)

Caching Resources

```
self.addEventListener("install", function(event) {
  console.log("installed");

  async function ready() {
    let cache = await caches.open("v1");
    await cache.addAll(["/api/artists"]);
    self.skipWaiting(); // activate a new version.
  }

  event.waitUntil(ready());
});
```

(See `src/www/js/apis/serviceworkers/worker.js`)

Additional Uses of Service Workers

- Push notifications for mobile and desktop
- Background sync (wait for network connection, then send a request)
- Installable Web Apps (web apps that act like native mobile applications)
- Work with a Transactional High-Performance Key-Value Store

Browser Support

- IE (no support)
- Edge >= 17 (2015)
- Firefox >= 44.0 (2016)
- Safari >= 11.1 (2018)
- Chrome >= 40 (2015)
- Opera >= 27 (2015)

JavaScript Development Tools

Node.js

- Server-side JavaScript engine
- Also provides a general-purpose environment
- Write servers, or GUI programs in JavaScript
- Most development tools are written in JavaScript and use Node.
- `https://nodejs.org/`

Node Package Manager (npm)

- Repository of JavaScript libraries, frameworks, and tools
- Tool to create or install packages
- Run scripts or build processes
- 800k+ packages available
- If it has something to do with JavaScript you install it with npm
- `https://www.npmjs.com/`

Introduction to Linting Tools

- Linting tools parse your source code and look for problems
- The two most popular linters for JavaScript are JSLint and ESLint
- ESLint is about 3x more popular than JSLint

About ESLint

- Integrates with most text editors via plugins
- Fully configurable, easy to add custom rules
- Enforce project style guidelines

Using ESLint Manually

```
$ npm install -g eslint
$ eslint yourfile.js
```

ESLint Plugins

- Visual Studio Code
- Sublime Text
- Emacs
- vim
- Official Integration List

Introduction to Babel

- Automated JavaScript restructuring, refactoring, and rewriting
- Parses JavaScript into an Abstract Syntax Tree (AST)
- The AST can be manipulated in JavaScript
- Includes *presets* to convert from one form of JavaScript to another
  - ESNEXT to ES5
  - React's JSX files to ES5
  - Vue's VUE files to ES5
  - etc.

Manually Using Bable

Process all files from the input directory and put all generated files in the output directory:

```
$ npm install --save-dev babel-cli babel-preset-env
$ ./node_modules/.bin/babel --presets env -d output input
```

(Note: Babel 7 will use a slightly different command line.)

Integrating Babel with Your Build Tools

Most build tools (Grunt, Gulp, Webpack) support a Babel phase.

Simple overview of a build process:

1. Gather up all necessary JavaScript files
2. Run the files through a linter like ESLint
3. Concatenate them into a single file in the right order
4. Run that file through Babel
5. Minify and compress the file Bable produced

What is Webpack?

Webpack is a build tool for web applications:

- Uses ES2015 modules to bundle JavaScript into a single file ready for deployment to production
- Transpiles JavaScript (i.e. ES20* to ES5)
- Lint code and run tests
- Bundles many types of assets (CSS, HTML templates, etc.)
- Can load remote assets on-demand

Exporting and Importing Identifiers

- Export identifiers from a library:

```
const magicNumber = 42;

function sayMagicNumber() {
  console.log(magicNumber);
}

export { sayMagicNumber };
```

- Import those identifiers elsewhere:

```
import sayMagicNumber from './module.js';
sayMagicNumber();
```

Explicit Dependencies in JavaScript

When using ES2015 modules:

- Dependencies are explicit through imports
- Removes global namespace pollution
- You can import part of a library, or the entire thing
- Strict mode enabled by default

Bundling JavaScript Modules

Webpack will:

1. Start with your main JavaScript file
2. Follow all `import` statements
3. Generate a single file containing all JavaScript

The generated file is know as a *bundle*.

More Power Through Loaders

Webpack becomes a full build tool via *loaders*. Here are some example loaders:

`babel-loader` Transpiles JavaScript using Babel
`eslint-loader` Lints JavaScript using ESLint
`mocha-loader` Run tests before building
`html-loader` Bundle HTML templates
`sass-loader` Process and bundle Sass

Configuring Webpack

Webpack is configured through a JavaScript file named `webpack.config.js`. Using this file you can:

- Tell Webpack what file is the main JavaScript file
- Specify which loaders you are using and in which order
- Add additional JavaScript snippets such as polyfills to the bundle
- Go crazy since you are writing in JavaScript

Webpack Demonstration

Let's take a look at a Webpack demonstration application:

1. Open the following folder in your text editor:
   src/www/js/tools/webpack
2. Review the example files:
   - `index.html`
   - `src/index.js`
   - `src/template.html`
   - `webpack.config.js`
3. Build the application with:
   $ npm run build

If you are running your Node.js server you can access this application at `http://localhost:3000/js/tools/webpack/`

What is Jasmine?

- Specification-based testing
- Expectations instead of assertions
- Provides the testing framework
- Only provides a very simple way to run tests

Example: Writing Jasmine Tests

```
describe("ES2015 String Methods", function() {
  describe("Prototype Methods", function() {
    it("has a find method", function() {
      expect("foo".find).toBeDefined();
    });
  });
});
```

Basic Expectation Matchers

`toBe(x)`: Compares with `x` using ===.

`toMatch(/hello/)`: Tests against regular expressions or strings.

`toBeDefined()`: Confirms expectation is not `undefined`.

`toBeUndefined()`: Opposite of `toBeDefined()`.

`toBeNull()`: Confirms expectation is `null`.

`toBeTruthy()`: Should be true `true` when cast to a Boolean.

`toBeFalsy()`: Should be `false` when cast to a Boolean.

Numeric Expectation Matchers

`toBeLessThan(n)`: Should be less than `n`.

`toBeGreaterThan(n)`: Should be greater than `n`.

`toBeCloseTo(e, p)`: Difference within `p` places of precision.

Smart Expectation Matchers

`toEqual(x)`: Can test object and array equality.

`toContain(x)`: Expect an array to contain `x` as an element.

Exercise: Writing a Test with Jasmine

1. Open `src/www/js/jasmine/adder.spec.js`
2. Read the code then do exercise 1 (we'll do exercise 2 later)
3. To test and debug, open

   `src/www/js/jasmine/index.html`

Life Cycle Callbacks

Each of the following functions takes a callback as an argument:

`beforeEach`: Before each `it` is executed.

`beforeAll`: Once before any `it` is executed.

`afterEach`: After each `it` is executed.

`afterAll`: After all `it` specs are executed.

Deferred (Pending) Tests

Tests can be marked as pending either by:

```
it("declared without a body!");
```

or:

```
it("uses the pending function", function() {
  expect(0).toBe(1);
  pending("this isn't working yet!");
});
```

Spying on a Function or Callback (Setup)

```
let foo;

beforeEach(function() {
  foo = {
    plusOne: function(n) { return n + 1; },
  };
});
```

Spying on a Function or Callback (Call Counting)

```
it("should be called", function() {
  spyOn(foo, 'plusOne');
  let x = foo.plusOne(42);

  expect(foo.plusOne).toHaveBeenCalled();
  expect(foo.plusOne).toHaveBeenCalledTimes(1);
  expect(foo.plusOne).toHaveBeenCalledWith(42);

  expect(x).toBeUndefined();
});
```

Spying on a Function or Callback (Call Through)

```javascript
it("should call through and execute", function() {
  spyOn(foo, 'plusOne').and.callThrough();
  let x = foo.plusOne(42);

  expect(foo.plusOne).toHaveBeenCalled();
  expect(x).toBe(43);
});
```

Spying on a Function or Callback (Call Fake)

```
it("should call a fake implementation", function() {
  spyOn(foo, 'plusOne').and.callFake(n => n + 2);
  let x = foo.plusOne(42);

  expect(foo.plusOne).toHaveBeenCalled();
  expect(x).toBe(44);
});
```

Exercise: Using Jasmine Spies

1. Open `src/www/js/jasmine/adder.spec.js`
2. Read the code then do exercise 2
3. To test and debug, open

   `src/www/js/jasmine/index.html`

Testing Time-Based Logic (The Setup)

```
let timedFunction;

beforeEach(function() {
  timedFunction = jasmine.createSpy("timedFunction");
  jasmine.clock().install();
});

afterEach(function() {
  jasmine.clock().uninstall();
});
```

Testing Time-Based Logic (setTimeout)

```
it("function that uses setTimeout", function() {
  inFiveSeconds(timedFunction);

  // The callback shouldn't have been called yet:
  expect(timedFunction).not.toHaveBeenCalled();

  // Move the clock forward and trigger timeout:
  jasmine.clock().tick(5001);

  // Now it's been called:
  expect(timedFunction).toHaveBeenCalled();
});
```

Testing Time-Based Logic (setInterval)

```
it("function that uses setInterval", function() {
  everyFiveSeconds(timedFunction);

  // The callback shouldn't have been called yet:
  expect(timedFunction).not.toHaveBeenCalled();

  // Move the clock forward a bunch of times:
  for (let i=0; i<10; ++i) jasmine.clock().tick(5001);

  // It should have been called 10 times:
  expect(timedFunction.calls.count()).toEqual(10);
});
```

Testing Asynchronous Functions

```
describe("asynchronous function testing", function() {
  it("uses an asynchronous function", function(done) {

    // `setTimeout' returns immediately,
    // so this test does too!
    setTimeout(function() {
      expect(done instanceof Function).toBeTruthy();
      done(); // tell Jasmine we were called.
    }, 1000);

  });
});
```

Exercise: Using Jasmine Spies

1. Open `src/www/js/jasmine/delayed.spec.js`
2. Read the code then do exercise 3
3. To test and debug, open

   `src/www/js/jasmine/index.html`

Running Jasmine Tests

- Standalone runner:
  - List files in `SpecRunner.html`
  - Opening that file in your browser runs the tests
- Node.js runner:
  - Provides a `jasmine` tool
  - Runs tests inside Node.js
- Karma-Jasmine runner:
  - Automatically manages browser farms
  - Runs tests in parallel on all browsers
  - Can use headless browsers (PhantomJS)
  - Support for continuous integration

Introduction to TypeScript

What is TypeScript

- A language based on ESNEXT
- Compiles to ES5
- Contains the following additional features:
  - Types and type inference!
  - Generics (polymorphic types)
  - Interfaces and namespaces
  - Enums and union types

Type Annotations

```
function add(x: number, y: number): number {
  return x + y;
}
```

Type Checking

```
// Works!
const sum = add(1, 2);

// error: Argument of type '"1"' is not assignable
// to parameter of type 'number'.
add("1", "2");
```

Type Inference

```
// Works!
const sum = add(1, 2);

// error: Property 'length' does not exist
// on type 'number'.
console.log(sum.length);
```