"One JavaScript"

- Approach named by David Herman
- Allows JavaScript to evolve without versioning
  - avoids migration issues like Python 2 to Python 3
- "Don't break the web!"
  - removing features would cause existing web apps to stop working
  - can add new, better features
  - ES5 strict mode was a bit of a mistake since it broke some existing code
    - this is why ES6 supports "sloppy mode" code outside modules and class definitions
- Use linting tools to detect use of "deprecated" features
  - ex. switching from **`var`** to **`let`** and **`const`** and
    using rest parameters in place of **`arguments`** object

Transpilers

- Compilers translate code one language to another
  - ex. Java to bytecode
- Transpilers translate code to the same language
- There are several transpilers that translate ES6 code to ES5

ES6 Transpilers

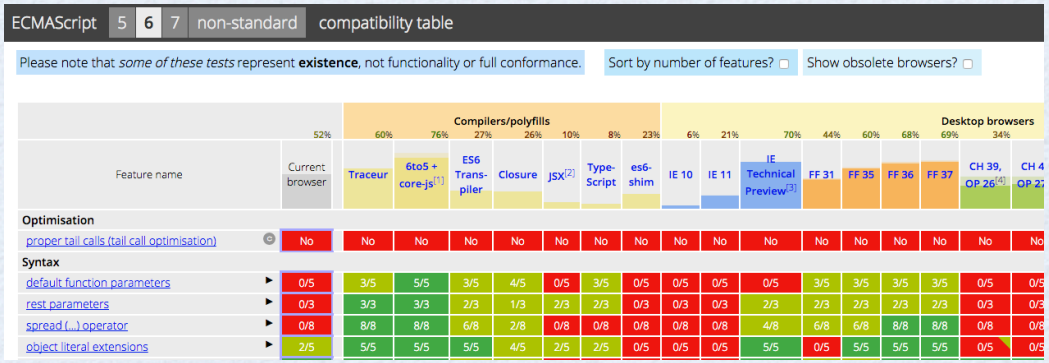
percentages are as of 3/18/15

- **Traceur - 64%**
  - from Google
  - generates source maps
  - doesn't work with IE8 and below
    - due to use of ES5 `get`/`set` syntax
  - https://github.com/google/traceur-compiler/
- **Babel - 76%**
  - aims to generate ES5 code that is as close a possible to the input ES6 code
  - generates source maps
  - some features don't work with IE10 and below
    - see https://babeljs.io/docs/usage/caveats/#internet-explorer
  - https://babeljs.io
- **TypeScript - 9%**
  - from Microsoft
  - "a typed superset of JavaScript that compiles to plain JavaScript. Any browser. Any host. Any OS. Open Source."
  - supports optional type specifications for variables, function return values, and function parameters
  - has goal to support all of ES6
  - generates source maps
  - to install, `npm install -g typescript`
  - to compile, `tsc some-file.ts`
    - generates `some-file.js`
  - http://www.typescriptlang.org

there are more, but these are the most popular and/or support the most features

Use ES6 Today?

- It **may take years** for all the features in ES6 to be supported in all major browsers
- That's **too long to wait** and you **don't have to wait**
- **Use a transpiler** to get comfortable with new features sooner and allow writing more compact, more expressive code now
- For a **summary of ES6 feature support in browsers**, and in the Traceur tool discussed next, see ES6 compatibility table from Juriy Zaytsev (a.k.a. kangax)
  - http://kangax.github.io/compat-table/es6/
  - try selecting "Sort by number of features?" checkbox



Traceur

- **Implemented in ES6** and uses itself to transpile to ES5 code that runs on Node.js
- https://github.com/google/traceur-compiler
- **Online tool** at http://google.github.io/traceur-compiler/demo/repl.html
  - enter ES6 on left side and see resulting ES5 code on right
  - useful for testing support for specific ES6 features and gaining an understanding of what Traceur generates
  - does not execute code
  - "Options" menu includes ability to enable experimental features
- **To install**
  - install Node.js
  - `npm install -g traceur`

AngularJS 2 uses Traceur for ES6 support

Running Traceur

- To get help on options
  - **`traceur --help`**
  - **`traceur --longhelp`**
- To run code in an ES6 file
  - **`traceur`** *`es6-file-path`*
  - requires file extension to be **`.js`**, but it can be omitted in the command
- To compile an ES6 file to an ES5 file
  - **`traceur --out`** *`es5-file-path es6-file-path`*
  - generated code depends on provided file **`traceur-runtime.js`**
    - can be copied from directory where Traceur is installed
  - to use generated code in a browser, include a script tag for **`traceur-runtime.js`**
- Experimental features
  - to use, add **`--experimental`** option
  - examples of features currently considered experimental include symbols, **`async`**/**`await`** keywords, and type annotations

doesn't check for native browser support; does some feature detection like not adding shim methods if already present

Babel

- **Implemented in ES6** and uses itself to transpile to ES5 code that runs on Node.js
- http://babeljs.io
- **Online tool** at http://babeljs.io/repl/
  - enter ES6 on left side and see resulting ES5 code on right
  - useful for testing support for specific ES6 features and gaining an understanding of what Babel generates
  - optionally executes code (when "Evaluate" checkbox is checked)
    - output is at bottom of ES5 code
  - "Experimental" and "Playground" checkboxes enable ES7 features and other "ideas"
- **To install**
  - install Node.js
  - `npm install -g babel`

"Babel works perfectly with React, featuring a built-in JSX transformer."

Running Babel

- To get help on options
  - **`babel --help`**
- To run code in an ES6 file
  - **`babel-node`** *`es6-file-path`*
  - file extension can be omitted and defaults to **`.js`**
- To compile an ES6 file to an ES5 file
  - **`babel`** *`es6-file-path`* **`-o`** *`es5-file-path`*
- To compile a many ES6 files to ES5 files
  - **`babel`** *`es6-dir`* **`-o`** *`es5-dir`*
- Experimental features
  - to use some ES7 features, add **`--experimental`** option
- Optional babel-runtime
  - http://babeljs.io/docs/usage/transformers/#self-contained

in *nix environments, can use redirection
`babel` ***`es6-file-path > es5-file-path`***

Source Maps

- Allow browser debuggers to step through code that was transpiled from another language into JavaScript
  - for example, debug CoffeeScript code
  - can debug ES6 code that was transpiled to ES5
- **Traceur**
  - option `--source-maps` causes it to generate a source map
  - places them in same directory as generated ES5 files
  - browser looks for them there
- **Babel**
  - plugins for Grunt and Gulp can generate source maps

Using Source Maps

- In Chrome
  - open a page that uses transpiled ES6 code
  - open Developer Tools (cmd-option-i on Mac, ctrl-shift-i on Windows)
  - click gear icon in upper-right to see settings
  - check "Search in content scripts"
  - check "Enable JavaScript source maps"
  - select ES6 .js files from "Sources" tab
  - set breakpoints and refresh page
- In Firefox
  - open Firefox debugger by selecting Tools ... Web Developer ... Debugger (cmd-option-s on Mac, ctrl-shift-s on Windows?)
  - click gear icon in upper-right to see "Debugger Options" and verify that "Show Original Sources" is selected
  - select ES6 .js files from "Sources" tab
  - set breakpoints and refresh page

Linting

- It is important to use some linting tool when writing JavaScript
- Saves time and reduces errors by catching coding issues before code is run
- Can be run from command-line,
  integrated into editors/IDEs, and
  run automatically when files are saved from any editor using tools like Grunt/Gulp
- Most popular JavaScript linting tools
  - JSLint - http://jslint.org; unclear if or when JSLint will support ES6
  - JSHint - http://jshint.org; has good support now using "**esnext**" option
  - ESLint - http://eslint.org; recently added support ES6; needs more testing
- I highly recommend using JSHint to check ES6 code

Automation

- **Grunt** - http://gruntjs.com
  - great tool for automating web development tasks
  - 4,472 plugins available as of 3/8/15
    - for Traceur support, see these plugins: traceur, traceur-latest, traceur-build, **traceur-simple**, and node-traceur
    - for Babel support, see the plugin grunt-babel
  - see example `Gruntfile.js` in article
    - uses "**watch**" plugin to watch for changes to HTML, CSS and JavaScript files
    - when watch detects these, it automatically runs specified tasks including linting CSS and JavaScript, running Traceur to generate ES5 code, and refreshing browser to immediately show results of changes
    - last part is enabled by "**livereload**" option and including a special script tag in main HTML file
- **Gulp** - http://gulpjs.com
  - similar in goal to Grunt, but configuration is different
  - 1,457 plugins available as of 3/8/15
  - also supports watch and livereload
  - emphasizes use of file streaming for better efficiency
  - see gulp-traceur and gulp-babel plugins

see Grunt and Gulp examples at https://github.com/mvolkmann/gulp-traceur-demo

ES6 Features

- The following slides describe most of the features in ES6
- Also see Luke Hoban's (TC39 member) summary
  - https://github.com/lukehoban/es6features

Block Scope ...

- **`const`** declares constants with block scope
  - must be initialized
  - reference can't be modified, but object values can
    - to prevent changes to object values, use `Object.freeze(obj)`
- **`let`** declares variables like **`var`**, but they have block scope
  - not hoisted to beginning of enclosing block, so references before declaration are errors
  - most uses of **`var`** can be replaced with **`let`** (not if they depend on hoisting)
  - when a file defines a module, top-level uses of **`let`** are file-scoped, unlike **`var`**
  - Traceur and Babel implement block scopes by renaming variables declared in block
  - when a **`let`** variable is accessed out of its scope,
    a `ReferenceError` is thrown with message "***`name` is not defined***"

... Block Scope

- block functions
  - functions declared in a block are scoped to that block
  - for example, in if and for-loop blocks

```
function outer() {
  console.log('in outer');
}

{
  function inner() {
    console.log('in inner');
  }

  outer(); // works
  inner(); // works
}

outer(); // works
inner(); // throws ReferenceError
```

Default Parameters

- Example

```
let today = new Date();

function makeDate(day, month = today.getMonth(), year = today.getFullYear()) {
  return new Date(year, month, day).toDateString();
}

console.log(makeDate(16, 3, 1961)); // Sun Apr 16 1961
console.log(makeDate(16, 3)); // Wed Apr 16 2014
console.log(makeDate(16)); // Sun Feb 16 2014
```

run on 2/28/14

- Default value expressions can return to preceding parameters
- Explicitly passing undefined triggers use of default value
- Idiom for required parameters (from Allen Wirfs-Brock)

```
function req() { throw new Error('missing argument'); }
function foo(p1 = req(), p2 = req(), p3 = undefined) {
  ...
}
```

Rest Operator

- Gather variable number of arguments after named parameters into an array
- If no corresponding arguments are supplied, value is an empty array, not undefined
- Removes need to use **`arguments`** object

```
function report(firstName, lastName, ...colors) {
  let phrase = colors.length === 0 ? 'no colors' :
    colors.length === 1 ? 'the color ' + colors[0]:
    'the colors ' + colors.join(' and ');
  console.log(firstName, lastName, 'likes', phrase + '.');
}

report('John', 'Doe');
// John Doe likes no colors.
report('Mark', 'Volkmann', 'yellow');
// Mark Volkmann likes the color yellow.
report('Tami', 'Volkmann', 'pink', 'blue');
// Tami Volkmann likes the colors pink and blue.
```

Spread Operator

- Spreads out elements of any "iterable" (discussed later) so they are treated as separate arguments to a function
- Mostly removes need to use `Function apply` method
- Examples

examples of things that are iterable include arrays, sets, and strings

```
let arr1 = [1, 2];
let arr2 = [3, 4];
arr1.push(...arr2);
console.log(arr1); // [1, 2, 3, 4]

let dateParts = [1961, 3, 16];
let birthday = new Date(...dateParts);
console.log(birthday.toDateString());
// Sun Apr 16, 1961
```

alternative to

```
arr1.push.apply(arr1, arr2);
```

Destructuring ...

- Assigns values to any number of variables from values in arrays and objects

```
// Positional destructuring of iterables
let [var1, var2] = some-iterable;
// Can skip elements (elision)
let [,,var1,,var2] = some-iterable;

// Property destructuring of objects
let {prop1: var1, prop2: var2} = some-obj;
// Can omit variable name if same as property name
let {prop1, prop2} = some-obj;
```

- Can be used in variable declarations/assignments, parameter lists, and for-of loops (covered later)
- Can't start statement with `{`, so add parens when assigning to existing variables using object destructuring,

```
({prop1: var1, prop2: var2}) = some-obj;
```

- LHS expression can be nested to any depth
  - arrays of objects, objects whose property values are arrays, ...

... Destructuring ...

- LHS variables can specify default values

```
[var1 = 19, var2] = some-iterable;
```

  - default values can refer to variables that precede their variable
- Positional destructuring can use rest operator for last variable

```
[var1, ...others] = some-iterable;
```

- When assigning rather than declaring variables, any valid LHS variable expression can be used
  - ex. `obj.prop` and `arr[index]`
- Can be used to swap variable values

```
[a, b] = [b, a];
```

- Useful with functions that have multiple return values
  - really one array or object

… Destructuring …

- Great for getting parenthesized groups of a **RegExp** match

```
let dateStr = 'I was born on 4/16/1961 in St. Louis.';
let re = /(\\d{1,2})\\/(\\d{1,2})\\/(\\d{4})/;
let [, month, day, year] = re.exec(dateStr);
console.log('date pieces =', month, day, year);
```

- Great for configuration kinds of parameters of any time named parameters are desired (common when many)

```
function config({color, size, speed = 'slow', volume}) {
  console.log('color =', color); // yellow
  console.log('size =', size); // 33
  console.log('speed =', speed); // slow
  console.log('volume =', volume); // 11
}

config({
  size: 33,
  volume: 11,
  color: 'yellow'
});
```

order is irrelevant

… Destructuring


```
function report([name, color]) {
  console.log(name + "'s favorite color is", color + '.');
}
let data = ['Mark', 'yellow'];
report(data); // Mark's favorite color is yellow.

let arr = [1, [2, 3], [[4, 5], [6, 7, 8]]];
let [a, [, b], [[c], [,, d]]] = arr;
console.log('a =', a); // 1
console.log('b =', b); // 3
console.log('c =', c); // 4
console.log('d =', d); // 8

let obj = {color: 'blue', weight: 1, size: 32};
let {color, size} = obj;
console.log('color =', color); // blue
console.log('size =', size); // 32

function report2(p1, {weight, color}) {
  console.log(p1, color, weight);
}
report2(19, obj); // 19 blue 1
```

extracting array elements by position

extracting object property values by name

Arrow Functions ...

- **(*params*) => { *expressions* }**
  - if only one parameter and not using destructuring, can omit parens
  - need parens if no parameters
  - cannot insert line feed between parameters and **=>**
  - if only one expression, can omit braces and its value is returned without using **`return`** keyword
    - ***`expression`*** can be another arrow function that is returned
  - if expression is an object literal, wrap it in parens to distinguish it from a block of code

```
let arr = [1, 2, 3, 4];
let doubled = arr.map(x => x * 2);
console.log(doubled); // [2, 4, 6, 8]

let product = (a, b) => a * b;
console.log(product(2, 3)); // 6

let average = numbers => {
  let sum = numbers.reduce((a, b) => a + b);
  return sum / numbers.length;
};
console.log(average(arr)); // 2.5
```

Arrow functions are typically used for anonymous functions like those passed to **`map`** and **`reduce`**.

Functions like **`product`** and **`average`** are better defined the normal way so their names appear in stack traces.

… Arrow Functions

- Inside arrow function, **`this`** has same value as containing scope, not a new value (called "lexical this")
  - so can't use to define constructor functions or methods, only plain functions
- Also provides "lexical super"
- Immediately invoked functions (IIFEs)
  - not typically needed in ES6 since modules provide file scope
  - can write like this

```
(() => {
  ...
})();
```

  - ending like this is a syntax error

```
(() => {
  ...
}()));
```

Symbols ...

- Immutable identifiers that are guaranteed to be unique
  - unlike strings
- To create a symbol
  - `let sym = Symbol(description);`
  - note `new` keyword is not used
    - throws `TypeError`; it's a function, not a constructor
  - description is optional and mainly useful for debugging
- To retrieve description
  - `sym.toString()` or `String(sym)`
  - returns `'Symbol(description)'`
  - concatenating a symbol to a string throws `TypeError`
- A new primitive type
  - `typeof sym === 'symbol'`

… Symbols

- Can use as object keys
  - `obj[sym] = value;`
- They become non-enumerable properties
  - `Object.getOwnPropertyNames(obj)` gets string keys, but not symbol keys
  - `Object.getOwnPropertySymbols(obj)` gets symbol keys, but not string keys
  - `Reflect.ownKeys(obj)` gets both string and symbol keys
- Can use for constants that only serve as unique identifiers
  - `const NAME = Symbol();`
- Can use to add "meta-level" properties or internal methods to an object that avoid clashing with normal properties
  - `Symbol.iterator` is an example (described later)
- To use in Traceur and Babel, enable experimental mode

```
// Using computed
// property syntax
let obj = {
  [sym1]: value,
  [sym2](params) {
    ...
  }
};
```

Public Symbols

- There are several predefined symbols
  that can be used as method names
  to customize how JavaScript treats specific objects
- To customize **`instanceof`**, implement **`Symbol.hasInstance`** method
- To customize conversion to a primitive, implement **`Symbol.toPrimitive`** method
- To customize conversion to a string, implement **`Symbol.toStringTag`** method
- To make an object "iterable", implement **`Symbol.iterator`** method

unlike constants whose
names are all uppercase,
these have camelcase names

Enhanced Object Literals ...

- Literal objects can omit value for a key if it's in a variable with the same name
  - similar to destructuring syntax
- Example

```
let fruit = 'apple', number = 19;
let obj = {fruit, foo: 'bar', number};
console.log(obj);
// {fruit: 'apple', foo: 'bar', number: 19}
```

... Enhanced Object Literals ...

- Computed properties names can be specified inline

```
// Old style
let obj = {};
obj[expression] = value;

// New style
let obj = {
  [expression]: value
};
```

one use is to define properties whose keys are symbols instead of strings

... Enhanced Object Literals

- Property method assignment
  - alternative way to attach a method to a literal object
  - example

```
let obj = {
  number: 2,
  multiply: function (n) { // old way
    return this.number * n;
  },
  times(n) { // new way
    return this.number * n;
  },
  // This doesn't work because the
  // arrow function "this" value is not obj.
  product: n => this.number * n
};

console.log(obj.multiply(2)); // 4
console.log(obj.times(3)); // 6
console.log(obj.product(4)); // NaN
```

Classes ...

- Use `class` keyword
- Define constructor and methods inside
  - one constructor function per class
- Really just sugar over existing prototypal inheritance mechanism
  - creates a constructor function with same name as class
  - adds methods to prototype
- Code in class definition is always evaluated in strict mode

```
class Shoe {
  constructor(brand, model, size) {
    this.brand = brand;
    this.model = model;
    this.size = size;
    Shoe.count += 1;
  }
  static createdAny() { return Shoe.count > 0; }
  equals(obj) {
    return obj instanceof Shoe &&
      this.brand === obj.brand &&
      this.model === obj.model &&
      this.size === obj.size;
  }
  toString() {
    return this.brand + ' ' + this.model +
      ' in size ' + this.size;
  }
}
Shoe.count = 0;

let s1 = new Shoe('Mizuno', 'Precision 10', 13);
let s2 = new Shoe('Nike', 'Free 5', 12);
let s3 = new Shoe('Mizuno', 'Precision 10', 13);
console.log('created any?', Shoe.createdAny()); // true
console.log('count =', Shoe.count); // 3
console.log('s2 = ' + s2); // Nike Free 5 in size 12
console.log('s1.equals(s2) =', s1.equals(s2)); // false
console.log('s3.equals(s3) =', s3.equals(s3)); // true
```

class method

not a standard JS method

class property

… Classes …

- Inherit with **`extends`** keyword

```
class RunningShoe extends Shoe {
  constructor(brand, model, size, type) {
    super(brand, model, size);
    this.type = type;
    this.miles = 0;
  }
  addMiles(miles) { this.miles += miles; }
  shouldReplace() { return this.miles >= 500; }
}

let rs = new RunningShoe(
  'Nike', 'Free Everyday', 13, 'lightweight trainer');
rs.addMiles(400);
console.log('should replace?', rs.shouldReplace()); // false
rs.addMiles(200);
console.log('should replace?', rs.shouldReplace()); // true
```

value after **`extends`** can be an expression that evaluates to a class/constructor function

inherits both instance and static methods

inside **`constructor`**, **`super(args)`** calls the superclass constructor; can only call **`super`** like this in a constructor and only once

inside a method, **`super.name(args)`** calls the superclass method ***`name`***

- In subclasses, **`constructor`** **must** call **`super(args)`** and it must be **before** **`this`** is accessed because the highest superclass creates the object

`this` is not set until the call to **`super`** returns

… Classes

- In a class with no **`extends`**,
  omitting **`constructor`** is the same as specifying
  `constructor() {}`
- In a class with **`extends`**,
  omitting **`constructor`** is the same as specifying
  `constructor(...args) { super(...args); }`

- Can extend builtin classes like **`Array`** and **`Error`**
  - requires JS engine support; transpilers cannot provide
  - instances of **`Array`** subclasses can be used like normal arrays
  - instances of **`Error`** subclasses can be thrown like provided **`Error`** subclasses

- Precede method names with "**`*`** " for generators (discussed later)

Getters and Setters

- ES5 supports these using `Object.defineProperty`/`defineProperties`
- ES6 supports `get` and `set` keywords in class definitions

```
class Shoe {
  ...
  get size() {
    return this._size;
  }
  set size(size) {
    this._size = size;
  }
  ...
}
let s = new Shoe();
s.size = 13; // invokes setter
console.log(s.size); // invokes getter
```

can do more here

using `size` instead of `_size` for the "backing field" would cause a `ModuleEvaluationError` with message "Maximum call stack size exceeded"

```
class Person {
  constructor(name) {
    this._name = name;
  }
  get name() {
    return this._name;
  }
}
let p = new Person('Mark');
console.log('name is', p.name); // Mark
p.name = 'Jason';
// throws ModuleEvaluationError
// with message "Cannot set property name
// of #<Person> which has only a getter
```

can use a `Symbol` in place of `_size` and `_name` to make them a non-enumerable properties

- ES5 also allows use `get` and `set` in object literals, but that seems less useful

ES5 vs. ES6 Functions

	ES5	ES6
normal function	`function`	`function` or arrow function
method	`function` on prototype	method in `class`
constructor	`function`	`constructor` in `class`

New `Math` Functions

- `Math.fround(number)` - returns nearest single precision floating point number to *`number`*
- `Math.sign(number)` - returns sign of *`number`*; -1, 0 or 1
- `Math.trunc(number)` - returns integer part of *`number`*
- `Math.cbrt(number)` - returns cube root of *`number`*
- `Math.expm1(number)` - returns `exp(number) - 1`;
  - `Math.exp` returns e (Euler's constant) raised to *`number`* power
- `Math.hypot(x, y, ...)` - returns square root of sum of squares of arguments
- `Math.imul(n1, n2)` - multiplies two 32-bit integers; for performance
- logarithmic functions - `Math.log1p(number)`, `Math.log10(number)`, `Math.log2(number)`
  - `Math.log1p` returns `Math.log(1 + number)`
- hyperbolic trig functions - `Math.asinh(number)`, `Math.acosh(number)`, `Math.atanh(number)`

New `Number` Functions

- **`Number.isFinite(n)`** - returns boolean indicating whether ***`n`*** is a **`Number`** and is not **`NaN`**, **`Infinity`** or **`-Infinity`**
- **`Number.isInteger(n)`** - returns boolean indicating whether ***`n`*** is an integer and not a float, **`NaN`**, **`Infinity`** or **`-Infinity`**
- **`Number.isNaN(n)`** - returns boolean indicating whether ***`n`*** is the special **`NaN`** value
- **`Number.isSafeInteger(n)`** - returns boolean indicating whether ***`n`*** can be represented exactly in a double (within 53 bits)
  - also new constants **`Number.MIN_SAFE_INTEGER`** and **`Number.MAX_SAFE_INTEGER`**
- **`Number.toInteger(n)`** - converts a number to an integer
- **`Number.parseInt(string)`** - parses a string into an integer; same as the global function
- **`Number.parseFloat(string)`** - parses a string into a double; same as the global function

note how some of these are functions on other objects in ES5

Numeric Literals

- Hexadecimal
  - preceded with zero and **`x`**
  - **`0xa === 10`**
  - supported before ES6
- Octal
  - preceded with zero and **`o`**
  - **`0o71 === 57`**
- Binary
  - preceded with zero and **`b`**
  - **`0b1101 === 13`**
- When used in strings,
  all of these can be parsed with **`Number(s)`**

New `String` Methods

- ***s1*.startsWith(*s2*)** - determines if starts with given characters
- ***s1*.endsWith(*s2*)** - determines if ends with given characters
- ***s1*.includes(*s2*)** - determines if includes given characters
- ***s*.repeat(*count*)** - creates new string by copying ***s count*** times
- JavaScript uses UTF-16 characters
  - each occupies two or four bytes
  - **length** property of JavaScript strings, as well as **charAt** and **charCodeAt** methods assume two bytes per character
    - to get length in code points, **[...*string*].length**
  - no easy way to get or create 4-byte characters in ES5
  - ***string*.codePointAt(*pos*)**
    gets UTF-16 integer value at a given position
    - to convert to hex, call **toString(16)** on this value
  - **String.fromCodePoint(*int1*, ..., *intN*)**
    returns string created from any number of UTF-16 integer values

can specify starting position of test for each of these

ES7 may add **trimLeft** and **trimRight** methods

use of 4-byte UTF-16 characters is somewhat rare (ex. Egyptian Hieroglyphs), so this is often not a problem

new Unicode escape syntax inside literal strings for specifying a code point
\u{*code*}
(really include the braces)

Template Strings

- String interpolation
- Surrounded by backticks
- Can contain newline characters for multi-line strings

```
let greeting = `Hello,
World!`;
```

- Can contain any number of embedded expressions
  - `${expression}`

```
console.log(`${x} + ${y} = ${x + y}`);
```

Tagged Template Strings ...

- Preceded by a function name that will produce a customized result
  - examples include special escaping (ex. HTML encoding), language translation, and DSLs
- Passed array of template strings outside expressions ("raw") and expression values as individual parameters ("cooked")

```
function upValues(strings, ...values) {
  let result = strings[0];
  values.forEach((value, index) =>
    result += value.toUpperCase() + strings[index + 1]);
  return result;
}
let firstName = 'Mark';
let lastName = 'Volkmann';
console.log(upValues `Hello ${firstName} ${lastName}!`);
// Hello MARK VOLKMANN!
```

In this example `strings` is `['Hello ', ' ', '!']` and `values` is `['Mark', 'Volkmann']`

JSHint doesn't support tagged template strings yet

- Provided template function `String.raw`
  - treats characters like `\n` as separate `\` and `n` characters

... Tagged Template Strings

```
function dedent(strings, ...values) {
  let last = strings.length - 1, re = /\n\s+/g, result = '';
  for (let i = 0; i < last; i++) {
    result += strings[i].replace(re, '\n') + values[i];
  }
  return result + strings[last];
}

let homeTeam = 'Cardinals';
let visitingTeam = 'Cubs';
console.log(dedent `Today the ${homeTeam}
                    are hosting the ${visitingTeam}.`);
// Outputs
// If template starts with an expression, strings will start with ''.
// If template ends with an expression, strings will end with ''.
console.log(dedent `${homeTeam}
                    versus
                    ${visitingTeam}`);
```

Output

```
Today the Cardinals
are hosting the Cubs.
Cardinals
versus
Cubs
```

New `Array` Functions

- **`Array.of(values)`** - creates an `Array` from it's arguments
  - can use literal array syntax instead
- **`Array.from(arrayLikeObj, [mapFn])`** - creates an `Array` from an `Array`-like object
  - ***`mapFn`*** is an optional function that is called on each element to transform the value

New `Array` Methods

- ***arr*.copyWithin(*targetIndex*, *srcStartIndex*, [*srcEndIndex*])** - copies elements from ***srcStartIndex*** to ***srcEndIndex*** **- 1**, or to the end of the array, to ***targetIndex***, replacing existing elements
  - indexes can be negative to count from end
- ***arr*.find(*predicateFn*)** - returns first element in ***arr*** that satisfies a given predicate function
  - ***predicateFn*** is passed element, index, and ***arr***
  - if none satisfy, **undefined** is returned
- ***arr*.findIndex(*predicateFn*)** - same as **find**, but returns index instead of element
  - if none satisfy, -1 is returned
- ***arr*.fill(*value*, [*startIndex*], [*endIndex*])** - fills ***arr*** with a given value
  - ***startIndex*** defaults to 0; ***endIndex*** defaults to the array length
- ***arr*.entries()** - returns an iterator over the **[*index*, *value*]** pairs of ***arr***
- ***arr*.keys()** - returns an iterator over the indices of ***arr***
- ***arr*.values()** - returns an iterator over the values in ***arr***

New `Object` Functions ...

- **`Object.assign(target, src1, ... srcN)`**
  - copies properties from src objects to target, replacing those already present
  - returns ***`target`***
  - can use to create a shallow clone an object

```
let copy = Object.assign({}, obj);
```

  - to create a clone with the same prototype

```
function clone(obj) {
  let proto = Object.getPrototypeOf(obj);
  return Object.assign(
    Object.create(proto), obj);
}
let copy = clone(obj);
```

  - can use in constructors to assign initial property values

```
class Shoe {
  constructor(brand, model, size) {
    this.brand = brand;
    this.model = model;
    this.size = size;
    // or
    Object.assign(this,
      {brand, model, size});
  }
  ...
}
```

uses enhanced object literal

  - can use to add default values to an object

```
const DEFAULTS = {
  color: 'yellow',
  size: 'large'
};
let obj = {size: 'small'};
obj = Object.assign({}, DEFAULTS, obj);
```

order is significant!

... New `Object` Functions

- `Object.is(value1, value2)`
  - determines if value1 and value2 are the same
    - values can be primitives or objects; objects are the same only if they are the same object
    - unlike `===`, this treats `Number.NaN` as the same as `Number.NaN`
    - google "MDN JavaScript Object" for more detail
- `Object.setPrototypeOf(obj, prototype)`
  - changes prototype of an existing object
  - use is discouraged because it is slow and makes subsequent operations on the object slow
- `Object.getOwnPropertySymbols(obj)`
  - returns array of symbol keys
  - alternative to existing `Object.keys` and `Object.getOwnPropertyNames` functions
  - also see functions on `Reflect` object (described next)

`Reflect` Functions

supported by Babel, but not Traceur

- `get(obj, propName)` - alternative to `obj[propName]`
- `set(obj, propName, value)` - alternative to `obj[propName] = value`
- `has(obj, propName)` - alternative to `propName in obj`
- `deleteProperty(obj, propName)` - alternative to `delete obj[propName]`

- `construct(ctorFn, args)` - alternative to using `new ctorFn(...args)`
- `apply(fn, thisValue, args)` - alternative to using `fn.apply(thisValue, args)`

- `getOwnPropertyDescriptor(obj, propName)` - similar to same function in `Object`
- `defineProperty(obj, propName, propAttrs)` - similar to same function in `Object`

- `getPrototypeOf(obj)` - same as function in `Object`
- `setPrototypeOf(obj, prototype)` - changes prototype of `obj`

- `ownKeys(obj)` - returns an array of string and symbol keys
- `enumerate(obj)` - returns an iterator over all string keys (not symbols) including those in prototype chain

---

- `isExtensible(obj)` - same as function in `Object`
- `preventExtensions(obj)` - similar to same function in `Object`

Getting Object Keys

	string keys	symbol keys	only own	only enumerable
`Object.keys`	√		√	√
`Object.getOwnPropertyNames`	√		√	
`Object.getOwnPropertySymbols`		√	√	
`Reflect.ownKeys`	√	√	√	
`Reflect.enumerate`	√			√

for-of Loops

- New way of iterating over elements in an "iterable"
  - for arrays, this is an alternative to for-in loop and `Array` `forEach` method
- Iteration variable is scoped to loop
- Value after `of` can be anything that is iterable such as an array
  - iterators are described later
- Example

```
let stooges = ['Moe', 'Larry', 'Curly'];
for (let stooge of stooges) {
  console.log(stooge);
}
```

Collections

- New collection classes include
  - `Set`
  - `Map`
  - `WeakSet`
  - `WeakMap`

`Set` Class ...

- Instances hold collections of unique values
  - when values are objects, they are compared by reference
- Values can be any type including objects and arrays

could store references to DOM nodes

- To create, `let mySet = new Set()`
  - can pass iterable object (such as an array) to constructor to add all its elements
- To add an element, `mySet.add(value);`

can chain to add multiple values

- To test for element, `mySet.has(value)`
- To delete an element, `mySet.delete(value)`
- To delete all elements, `mySet.clear()`

... `Set` Class

- **`size`** property holds number of keys
- **`keys`** method returns iterator over elements
- **`values`** method returns iterator over elements
  - used by default in for-of loop
- **`entries`** method returns iterator over [element, element] pairs
- **`forEach`** method is like in that in **`Array`**, but passes ***`value`***, ***`value`*** and the set to callback

these iterate in insertion order

methods for **`Set`** iteration treat sets like maps where corresponding keys and values are equal for API consistency

iterators are described later

Common `Set` Operations

- All of these work by creating `Array`s from `Set`s, operating on them, and creating a new `Set`
- Map
```
let newSet = new Set([...set].map(elem => some-code));
```
- Filter
```
let newSet = new Set([...set].filter(elem => some-code));
```
- Union
```
let union = new Set([...set1, ...set2]);
```
- Intersection
```
let intersection = new Set([...set1].filter(elem => set2.has(elem)));
```
- Difference
```
let union = new Set([...set1].filter(elem => !set2.has(elem)));
```
- Remove duplicates from an array
```
let newArr = [...new Set(arr)];
```

Thanks Dr. Axel Rauschmayer

`Set` Example

```
let colors = new Set();
colors.add('red');
colors.add('green');
colors.add('blue');
colors.add('red');

// Another way to populate a Set
let arr = ['red', 'green', 'blue', 'red'];
colors = new Set(arr);

console.log(colors.size); // 3
console.log(colors.has('red')); // true
console.log(colors.has('pink')); // false

console.log('\nkeys are:');
colors.forEach(key => console.log(key));
// red green blue
```

```
console.log('\nvalues are:');
for (let value of colors.values()) {
  console.log(value); // red green blue
}
for (let value of colors) { // same
  console.log(value); // red green blue
}

console.log('\nentries are:');
for (let entry of colors.entries()) {
  console.log(entry);
  // ['red', 'red']
  // ['green', 'green']
  // ['blue', 'blue']
}

colors.delete('red');
console.log(colors.size); // 2
console.log(colors.has('red')); // false
```

`Map` Class ...

- Instances hold key/value pairs where keys are unique
  - when keys are objects, they are compared by reference
- Keys and values can be any type including objects and arrays
  - differs from JavaScript objects in that keys are not restricted to strings
- To create, `let myMap = new Map()`
  - can pass iterable object to constructor to add all its pairs (ex. array of `[key, value]`)
- To add or modify a pair, `map.set(key, value)`
- To get a value, `myMap.get(key);`
  - returns `undefined` if not present
- To test for key, `myMap.has(key)`
- To delete a pair, `myMap.delete(key)`
- To delete all pairs, `myMap.clear()`
- `size` property holds number of keys

could use DOM nodes as keys or values

can chain to add/modify multiple values

… Map Class

- **`size`** property holds number of keys
- **`keys`** method returns iterator over keys
- **`values`** method returns iterator over values
- **`entries`** method returns iterator over array of **`[key, value]`** arrays
  - used by default in for-of loop
- **`forEach`** method is like in Array, but passes ***`value`***, ***`key`*** and ***`map`*** to callback

these iterate in insertion order

Common `Map` Operations

- Map

an array of key/value arrays

```
let newMap = new Map([...map].map(
  ([key, value]) => [new-key-expr, new-value-expr]));
```

- Filter

```
let newMap = new Map([...map].filter(
  ([key, value]) => boolean-expr]));
```

Thanks Dr. Axel Rauschmayer

Map Example

```
let teams = new Map();
teams.set('Chicago', 'Cubs');
teams.set('Kansas City', 'Royals');
teams.set('St. Louis', 'Cardinals');

// Another way to populate a Map
let arr = [
  ['Chicago', 'Cubs'],
  ['Kansas City', 'Royals'],
  ['St. Louis', 'Cardinals']
];
teams = new Map(arr);

console.log(teams.size); // 3
console.log(teams.has('St. Louis')); // true
console.log(teams.has('Los Angeles')); // false
console.log(teams.get('St. Louis')); // Cardinals

console.log('\\nkeys are:');
teams.forEach((value, key) => console.log(key));
// Chicago, Kansas City, St. Louis

// Another way to iterate over keys
for (let key of teams.keys()) {
  console.log(key);
  // Chicago, Kansas City, St. Louis
}
```

```
console.log('\\nvalues are:');
for (let value of teams.values()) {
  console.log(value);
  // Cubs, Royals, Cardinals
}

console.log('\\nentries are:');
for (let entry of teams.entries()) {
  console.log(entry);
  // ['Chicago', 'Cubs']
  // ['Kansas City', 'Royals']
  // ['St. Louis', 'Cardinals']
}
for (let [city, team] of teams) { // same
  console.log(
    'The', team, 'plays in', city);
}

teams.delete('Chicago');
console.log(teams.size); // 2
console.log(teams.has('Chicago')); // false
```

`WeakSet` Class

supported by Babel, but not Traceur

- Similar API to `Set`, but differs in that
  - values must be objects
  - values are "weakly held",
    i.e. can be garbage collected if not referenced elsewhere
  - don't have a `size` property
  - can't iterate over values
  - no `clear` method to remove all elements

`WeakMap` Class

supported by Babel, but not Traceur

- Similar API to `Map`, but differs in that
  - keys must be objects
  - keys are "weakly held",
    i.e. a pair can be garbage collected if the key is not referenced elsewhere
    - at that point the value can be garbage collected if not referenced elsewhere
  - don't have a `size` property
  - can't iterate over keys or values
  - no `clear` method to remove all pairs

Promises ...

- Proxy for a value that may be known in the future after an asynchronous operation completes
- Create with `Promise` constructor, passing it a function that takes `resolve` and `reject` functions
- Register to be notified when promise is **resolved** or **rejected** with `then` or `catch` method
  - `then` method takes success and failure callbacks and returns a `Promise` to support chaining

    call omit one callback
  - `catch` method only takes failure callback
  - "success callback" is passed a value of any kind
  - "failure callback" is passed a "reason" which can be an `Error` object or a string
- Can call `then` on a promise after it has been resolved or rejected
  - the success or failure callback is called immediately
- Three possible states: pending, fullfilled, and rejected
  - once state is fullfilled or rejected, can't return to pending

... Promises ...

```
function asyncDouble(n) {
  return new Promise((resolve, reject) => {
    if (typeof n === 'number') {
      resolve(n * 2);
    } else {
      reject(n + ' is not a number');
    }
  });
}

asyncDouble(3).then(
  data => console.log('data =', data), // 6
  err => console.error('error:', err));
```

in real usage, some asynchronous operation would happen above

- Static methods
  - `Promise.resolve(value)` returns promise that is resolved immediately with given value
  - `Promise.reject(reason)` returns promise that is rejected immediately with given reason
  - `Promise.all(iterable)` returns promise that is resolved when all promises in `iterable` are resolved
    - resolves to array of results in order of provided promises
    - if any are rejected, this promise is rejected
  - `Promise.race(iterable)` returns promise that is resolved when any promise in `iterable` is resolved or rejected when any promise in `iterable` is rejected

… Promises …

- Supports chaining to reduces code nesting

```
asyncDouble(1).
  then(v => asyncDouble(v)).
  then(v => asyncDouble(v)).
  //then((v) => asyncDouble('bad')).
  then(v => console.log('success: v =', v)).
  catch(err => console.error('error:', err));
```

`asyncDouble` returns a `Promise`

Output

```
success: v = 8
```

- Some fine print
  - if a success callback returns a non-`Promise` value,
    it becomes the resolved value of the `Promise` returned by `then`
  - if a success callback returns a `Promise` value,
    it becomes the `Promise` returned by `then`
  - if any `Promise` in the chain is rejected or throws,
    the next failure callback in the chain receives it
  - if a failure callback returns a value,
    it becomes the resolve value for the next success callback in the chain

… Promises

- If an error is thrown inside a success or failure callback the promise returned by **then** is rejected

```
let p = asyncDouble(3).then(
  v => {
    // This causes the promise returned by
    // the call to then above to be rejected.
    throw 'Did you see this?';
  },
  err => console.error('error:', err)); // not reached

p.then(
  value => console.log('resolved with', value),
  reason => console.log('rejected with', reason));
// Output is "rejected with Did you see this?"
```

Modules

- A JavaScript file that is imported by another is treated as a "module"
  - defined by a single, entire source file
  - contents are not wrapped in any special construct
  - also code in an HTML **`<module>`** tag is treated as a "module" (will anyone use this?)
- Modules typically export values to be shared with other files that import it
- Top-level variables and functions that are not exported are not visible in other source files (like in Node.js)
- Module code is evaluated in strict mode by default
  - no need to specify **`'use strict';`**
- Supports cyclic module dependencies
- Enables APIs to be defined in modules instead of global variables
  - eliminates need to use objects for namespaces - ex. **`JSON`** and **`Math`**
  - future versions of jQuery **`$`** and Underscore **`_`** will be defined using modules

Modules - Exporting

- Can export any number of values from a module
  - values can be any JavaScript type including functions and classes
  - can optionally specify a default export
    which is actually a named export with the name "default"
- To export a value
  - `export let name = value;`
  - `export function name(params) { ... }`
  - `export class name { ... }`
- To export multiple, previously defined values
  - `export {name1, name2 as other-name2, ...};`

note ability to export a value under a different name

- To specify a default export
  - `export default expr;`
  - `export {name as default};`

same as previous line if value of *name* is *expr*

  - `export default function (params) { ... };`
  - `export default class { ... };`

Modules - Importing

- Can import values from other modules
- To import all exports into a single object
  - `import * as obj from 'module-path';`
  - *obj* is read-only
- To import specific exports
  - `import {name1, name2 as other-name, ...} from 'module-path';`
- To import the default export
  - `import name from 'module-path';`
  - `import {default as name} from 'module-path';`
- To import the default export and specific exports
  - `import default-name, {name1, name2, ...} from 'module-path';`
- To import a module only for its side effects
  - `import 'module-path';`

module paths **do not** include `.js` file extension;
relative to containing file;
can start with `./` (the default) or `../`

note ability to import a value under a different name

same as previous line

bindings from imports are read-only

More on Modules

- A module can export values from another module without first importing them
  - adds to its own exports
  - `export * from 'module-path';` exports everything exported by the given module
  - `export {name1, name2 as other-name} from 'module-path';`

- Module Loader API
  - supports conditionally loading modules
  - allows customized resolving of `'module-path'` strings (see `Reflect.Loader`)

```
System.import('module-path').
  then(theModule => { ... }).
  catch(err => { ... });
```

  - `System.import` returns a promise
    - can use `Promise.all` to wait for multiple modules to be loaded
  - there is much more to this!

Modules in Traceur ...

- To transpile ES6 files that use modules
  - transpile just main file to generate a single ES5 file that contains all required code
  - `traceur --out main.js --source-maps main6.js`
- Traceur generated source maps support modules
  - can step through each of the original ES6 files
    that make up a single generated ES5 file
- Use in browsers requires `traceur-runtime.js`
  - if Traceur was installed using `npm install -g traceur`,
    determine where global modules are installed with `npm -g root`
    and copy `traceur-runtime.js` from `traceur/bin` below that directory
  - add `script` tag for this in main HTML file

... Modules in Traceur

bar6.js

```
export let bar1 = 'the value of bar1';

export function bar2() {
  console.log('in bar2');
}
```

foo6.js

```
import {bar1, bar2} from './bar6';

export let foo1 = 'the value of foo1';
console.log('foo6: bar1 =', bar1);

export function foo2() {
  console.log('in foo2');
  bar2();
}
```

main6.js

```
import {foo1, foo2} from './foo6';
console.log('in main');
console.log('foo1 =', foo1);
foo2();
```

index.html

```
<html>
  <head>
    <title></title>
    <script src="lib/traceur-runtime.js"></script>
    <script src="gen/main.js"></script>
  </head>
  <body>
    See console output.
  </body>
</html>
```

To run from command-line:

```
traceur main6
```

To generate ES5 and source map:

```
traceur --out gen/main.js \
--source-maps main6.js
```

Output:

```
foo6: bar1 = the value of bar1
in main
foo1 = the value of foo1
in foo2
in bar2
```

Guy Bedford Rocks!

- **ES6 Module Loader** - https://github.com/ModuleLoader/es6-module-loader
  - "dynamically loads ES6 modules in browsers and NodeJS"
  - will track "JavaScript Loader Standard" at https://github.com/whatwg/loader
- **SystemJS** - https://github.com/systemjs/systemjs
  - "universal dynamic module loader - loads ES6 modules (using **ES6 Module Loader**), AMD, CommonJS, and global scripts (like jQuery and lo-dash) in the browser and NodeJS."
  - dependency management handles circular references and modules that depend on different versions of the same module (like Node.js does)
  - supports "loading assets ... such as CSS, JSON or images"
- **jspm** - http://jspm.io and https://github.com/jspm 
  - JavaScript Package Manager for **SystemJS**
  - "load any module format (ES6, AMD, CommonJS, and globals) directly from any endpoint such as **npm** and **GitHub**"
  - "custom endpoints can be created"
  - "for development, load modules as separate files with ES6"
  - "for production, optimize into a bundle ... with a single command"

all of these support Traceur and Babel

Using jspm ...

- **To install and configure jspm**
  - `npm install -g jspm`
  - `jspm init`
    - prompts and creates `package.json` and `config.js`
    - can accept all defaults
  - create `index.html`
  - setup a local file server
    - a good option is live-server
    - `npm install -g live-server`
    - `live-server`
  - browse localhost:8080
  - automatically transpiles using Traceur (default) or Babel
  - automatically generates sourcemaps

- **To install modules**

lesser used modules require jspm configuration before they can be installed

  - for packages in npm
    - `jspm install npm:`*`module-name`* (ex. jsonp)
    - by default, installs in `jspm_packages/npm`
  - for packages in GitHub
    - `jspm install github:`*`module-name`*
    - by default, installs in `jspm_packages/github`
  - for well-known packages
    - `jspm install `*`module-name`*
    - includes angularjs, bootstrap, d3, jquery, lodash, moment, and underscore
    - see list at https://github.com/jspm/registry/blob/master/registry.json
  - adds dependencies to `package.json`
  - adds `System.config` call in `config.js`

… Using jspm

- **To reinstall dependencies**
  - similar to npm, run **`jspm install`**
  - recreates and populates **`jspm_packages`** directory
  - recreates **`config.js`** if it is missing
- **To make your own packages compatible with jspm**
  - see https://github.com/jspm/registry/wiki/Configuring-Packages-for-jspm
  - can publish in npm or GitHub
  - allows others to install them using jspm
- **To bundle for production**
  - **`jspm bundle-sfx --minify`** ***`main`***
  - removes all dynamic loading and transpiling
  - generates **`build.js`** and **`build.js.map`**
  - replace all script tags in main HTML file with one for **`build.js`**
  - if using Traceur, add
    ```
    <script src="jspm_packages/traceur-runtime.js">
    </script>
    ```
  - there are other bundling options, but this seems like the best
  - won't be necessary in the future when browsers support HTTP2
    - will be able to download many files efficiently
    - today browsers limit concurrent HTTP requests to the same domain to 6 or 8

sfx is short for "self executing"

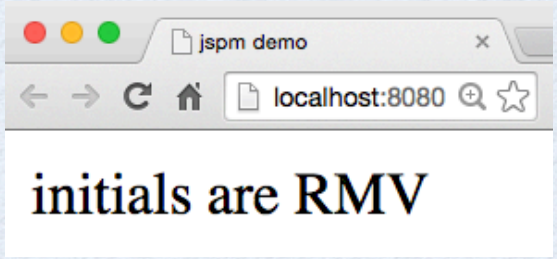
jspm Example #1

the basics plus a little jQuery

```
jspm install jquery
```

index.html

```
<!DOCTYPE html>
<html>
  <head>...</head>
  <body>
    <div id="content"></div>

    <!-- Enable ES6 module loading and more. -->
    <script src="jspm_packages/system.js"></script>

    <!-- Enable loading dependencies
         that were installed with jspm. -->
    <script src="config.js"></script>

    <!-- Load the main JavaScript file
         that can import others.  In this
         example, main.js is in same directory.
         Can also specify a relative directory path. -->
    <script>System.import('main');</script>
  </body>
</html>
```



main.js

```
import $ from 'jquery';
import * as strUtil from './str-util';

$('#content').text('initials are ' +
  strUtil.initials(
    'Richard Mark Volkmann'));
```

str-util.js

```
export function initials(text) {
  return text.split(' ').
    map(word => word[0]).
    join('');
}
```

jspm Example #2

adds Bootstrap and more jQuery

```
jspm install bootstrap
```

index.html

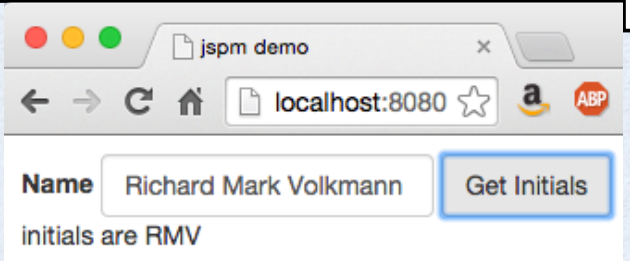
```
<!DOCTYPE html>
<html>
  <head>
    <title>jspm demo</title>
    <meta charset="utf-8">
    <link rel="stylesheet" href="main.css">
    <script src="jspm_packages/system.js"></script>
    <script src="config.js"></script>
    <script>System.import('main');</script>
  </head>
  <body>
    <label>Name</label>
    <input id="name-input"
      class="form-control"
      value="Richard Mark Volkmann">
    <button id="get-initials-btn"
      class="btn btn-default">
      Get Initials
    </button>
    <div id="content"></div>
  </body>
</html>
```

main.css

```
body {
  display: none;
  padding: 10px;
}

input.form-control {
  display: inline-block;
  vertical-align: middle;
  width: 180px;
}
```

main.js

```
import 'bootstrap';
import $ from 'jquery';
import * as strUtil from './str-util';

$('#get-initials-btn').click(() => {
  let name = $('#name-input').val();
  let initials = strUtil.initials(name);
  $('#content').text(
    'initials are ' + initials);
});

$('body').show();
```



str-util.js

```
export function initials(text) {
  return text.split(' ').
    map(word => word[0]).
    join('');
}
```

Iterators and Iterables

- Iterators are objects that can visit elements in a sequence
  - not created with a custom class; can be `Object`
  - have a `next` method and optional `return` and `throw` methods
    - described on next slide
- Iterables are objects that have a method whose name is the value of `Symbol.iterator`
  - this method returns an iterator

Iterator Methods

Why return a new object from `next` method instead of returning the same object with modified `value` and `done` properties?
It is possible for an iterator to be used by more than one consumer and those consumers could access the object returned by `next` asynchronously.
If each call doesn't return a new object, its properties could be modified after the object is received, but before it checks the properties.
While this is a rare situation, implementers of iterators can't be sure how they will be used.

- **`next`** method
  - gets next value in sequence
  - takes optional argument, but not on first call
    - specifies value that the **`yield`** hit in this call will return at the start of processing for the next call
  - returns a **new object** with **`value`** and **`done`** properties
  - **`done`** will be true if end of sequence has been reached; can omit if false
  - when **`done`** is true, **`value`** is not valid; typically **`undefined`**; can omit
- **`return`** method (optional)
  - called if iteration ends before iterator returns **`done: true`**
  - can end iteration with **`break`**, **`return`**, **`throw`**, and **`continue`** (with label of outer loop; rarely used)
  - allows iterator to clean up (ex. close files)
- **`throw`** method (optional)
  - takes error argument and throws it inside generator function that created the iterator
  - can catch inside generator function

`yield` and generators will be discussed soon

Iterable Objects ...

- Objects from these builtin classes are iterable
  - `Array` - over elements
  - `Map` - over key/value pairs as `[key, value]`
  - `Set` - over elements
  - DOM `NodeList` - over `Node` objects (coming soon)
- Primitive strings are iterable
  - over Unicode code points
- These methods on `Array` (including typed arrays), `Map`, and `Set` return an iterable
  - `entries` - over key/value pairs as `[key, value]`
  - `keys` - over keys
  - `values` - over values
- Custom objects can be made iterable
  - by adding `Symbol.iterator` method

for arrays, keys are indices;
for sets, keys are same as values

… Iterable Objects

- To get an iterable represention of an array-like object
  - `let iterable = Array.from(arrayLike)`
- **Ordinary objects** such as those created from object literals are **not iterable**
  - when this is desired, use new `Map` class instead **or** write a function like the following

```
function objectEntries(obj) {
  let index = 0;
  let keys = Reflect.ownKeys(obj); // gets both string and symbol keys
  return { // note how the iterable and iterator can be same object
    [Symbol.iterator]() { return this; },
    next() {
      if (index === keys.length) return {done: true};
      let k = keys[index++], v = obj[k];
      return {value: [k, v]};
    }
  };
}

let obj = {foo: 1, bar: 2, baz: 3};
for (let [k, v] of objectEntries(obj)) {
  console.log(k, 'is', v);
}
```

Iteratable Consumers

- **`for-of`** loop
  - `for (let value of someIterable) { ... } // iterates over all values`
- spread operator
  - can add all values from an iterable into a new array
    - `let arr = [firstElem, ...someIterable, lastElem];`
  - can use all values from iterable as arguments to a function, method, or constructor call
    - `someFunction(firstArg, ...someIterable, lastArg);`
- destructuring to an array
  - `let [a, b, c] = someIterable; // gets first three values`
- **`Map`** constructor takes an iterable over key/value pairs
- **`Set`** constructor takes an iterable over elements
- **`Promise`** methods **`all`** and **`race`** take an iterable over promises
- In a generator, **`yield*`** yields all values in an iterable one at a time

Iterator Example #1

```
let fibonacci = {
  [Symbol.iterator]() {
    let prev = 0, curr = 1;
    return {
      next() {
        [prev, curr] = [curr, prev + curr];
        return {value: curr};
      }
    };
  }
};

for (let n of fibonacci) {
  if (n > 100) break;
  console.log(n);
}
```

iterators can also be implemented with generators - see slide 89

```
1
2
3
5
8
13
21
34
55
89
```

stops iterating when **done** is true which never happens in this example

Iterator Example #2

```
let arr = [1, 2, 3, 5, 6, 8, 11];
let isOdd = n => n % 2 === 1;

// This is less efficient than using an iterator because
// the Array filter method builds a new array and
// iteration cannot begin until that completes.
arr.filter(isOdd).forEach(n => console.log(n)); // 1 3 5 11

// This is more efficient, but requires more code.
function getFilterIterator(arr, filter) {
  let index = 0;
  return {
    [Symbol.iterator] = () => ({
      next() {
        while (true) {
          if (index >= arr.length) return {done: true};
          let value = arr[index++];
          if (filter(value)) return {value};
        }
      }
    })
  };
}

for (let v of getFilterIterator(arr, isOdd)) {
  console.log(v); // 1 3 5 11
}
```

Generators

- **Generator functions**
  - implicitly return a **generator** which is a special kind of **iterator**
  - have multiple return points, each specified using `yield` keyword
  - each `yield` is hit in a separate call to the iterator `next` method
- Can obtain values from a sequence one at a time
  - supports lazy evaluation and infinite sequences
- Defined with `function* name(params) { code }`
  - *`code`* uses `yield` keyword to return each value in sequence, often inside a loop
  - ends when generator function exits
    - can exit using `return` keyword; value returned is not yielded
- Can create generator methods in class definitions
  - preceded method name with `*`
  - ex. to make instances iterable, `* [Symbol.iterator]() { ... }`

Steps to Use Generators

- 1) Call generator function to obtain generator
- 2) Call generator `next` method to request next value
  - optionally pass a value that iterator can use to compute the subsequent value
  - after iterator "yields" next value, its code is "suspended" until next request
- 3) Process value
- 4) Repeat from step 2

When an iterator is used in a `for-of` loop it performs steps 2 and 4.
Step 3 goes in loop body.

```
for (let v of someGenerator()) {
  // process v
}
```

Generator `yield`

- To return a "normal" value
  - `yield value;`

```
function* fibonacci() {
  let [prev, curr] = [0, 1];
  while (true) {
    [prev, curr] = [curr, prev + curr];
    yield curr;
  }
}

for (let value of fibonacci()) {
  if (value > 100) break;
  console.log(value);
}
```

compare to slide 85

```
1
2
3
5
8
13
21
34
55
89
```

```
// Iterables can be
// implemented with generators.
let fib = {
  * [Symbol.iterator]() {
    let [prev, curr] = [0, 1];
    while (true) {
      [prev, curr] = [curr, prev + curr];
      yield curr;
    }
  }
};

for (let n of fib) {
  if (n > 100) break;
  console.log(n);
}
```

- To yield each value returned by an iterable one at a time
  - `yield* some-iterable;`
  - can obtain an iterable by calling another generator function - `otherGenerator(params);`
  - not commonly used

More Generator Examples

```
function* gen1() {
  yield 'foo';
  yield 'bar';
  yield 'baz';
}

for (let value of gen1()) {
  console.log(value);
}
```

```
function* gen2(v) {
  try {
    v = yield 'foo' + v;
    v = yield 'bar' + v;
    yield 'baz' + v;
  } catch (e) {
    console.error('caught', e);
  }
}

let iter = gen2(1); // can pass value to generator function,
let result = iter.next(); // but can't pass in first call to next
console.log(result.value); // foo1; result.done is false

result = iter.next(2);
console.log(result.value); // bar2; result.done is false

//iter.throw('stop now'); // triggers catch in gen2

result = iter.next(3);
console.log(result.value); // baz3; result.done is false

result = iter.next(4);
console.log(result.done ? 'done' : result.value); // done
```

Generators For Async ...

workflow.js

```
function double(n) {
  return new Promise(resolve => resolve(n * 2));
}

function triple(n) {
  return new Promise(resolve => resolve(n * 3));
}

function badOp(n) {
  return new Promise((resolve, reject) => reject('I failed!'));
}

function async(generatorFn) {
  let iter = generatorFn();
  function success(result) {
    let next = iter.next(result);
    // next.value is a promise
    // next.done will be true if iter.next is called after
    // the last yield in workflow (on next slide) has run.
    if (!next.done) next.value.then(success, failure);
  }
  function failure(err) {
    let next = iter.throw(err);
    // next.value is a promise
    // next.done will be false if the error was caught and handled.
    if (!next.done) next.value.then(success, failure);
  }
  success();
}
```

multiplies a given number by 2 asynchronously

multiplies a given number by 3 asynchronously

The magic! This obtains and waits for each of the promises that are yielded by the specified generator function.
It is a utility method that would only be written once.

called on next slide

BUT DON'T DO THIS!
See **async** and **await** keywords ahead.

compare to slide 98

... Generators for Async

Call multiple asynchronous functions in series
in a way that makes them appear to be synchronous.
This avoids writing code in the pyramid of doom style.

```
async(function* () { // passing a generator
  let n = 1;
  try {
    n = yield double(n);
    n = yield triple(n);
    //n = yield badOp(n);
    console.log('n =', n); // 6
  } catch (e) {
    // To see this happen, uncomment yield of badOp.
    console.error('error:', e);
  }
});
```

These yield promises that the **async** function waits on to be resolved or rejected.

This can be simplified
with new ES7 keywords!

Proxies ...

- Can intercept all operations whose names match functions on the `Reflect` object
  - see slide 51
  - can provide additional or alternate functionality
- Uses new `Proxy` class
  - constructor takes "target" (the object for which operations are to be intercepted) and "handler" (an object that defines alternate handling)
- Must use proxy object instead of target object or interceptions won't occur!
- Methods called on proxy that aren't defined there are forwarded to the target object
- Can create proxies that can be later turned off (revoked)
  - after being revoked, calls on proxies object are just forwarded to target
- Proxies can be the prototype of other objects
- Support - currently only Firefox; no transpilers

… Proxies

```
var obj = {
  p1: 'some value',
  m1: () => 'm1 result',
  m2: () => 'm2 result'
};

var proxy = new Proxy(obj, {
  get: (target, key) => {
    console.log('intercepted get for key =', key);
    var value = target[key];
    return value === undefined ? () => 'missing method ' + key :
      typeof value === 'string' ? value.toUpperCase() :
      value;
  },
  set: (target, key, value) => {
    console.log('intercepted set for key =', key);
    target[key] = value;
  }
});

// Replace a method on obj with a proxy for it.
obj.m1 = new Proxy(obj.m1, {
  apply: (fn, target, args) => {
    console.log('intercepted call to function', fn);
    var result = fn.apply(target, args);
    return typeof result === 'string' ? result.toUpperCase() : value;
  }
});

proxy.p1 = 'other value';
console.log('proxy.p1 =', proxy.p1);
console.log('obj.p1 =', obj.p1);

console.log('proxy.m1() =', proxy.m1()); // has a proxy
console.log('proxy.m2() =', proxy.m2()); // doesn't have a proxy

console.log(proxy.makeMeUpOnTheFly());
```

At the time this was written, only Firefox supported proxies. However, there were other ES6 features it did not yet support such as "let" and enhanced object literals.

Proxies **can't distinguish** between gets for **property lookup** and gets for **method calls**, so "method missing" can only be implemented if it can be assumed that all missing property lookups should provide a method. It could only supply methods for key names that match a certain pattern.

This works because functions are objects.

Output

```
intercepted set for key = p1
intercepted get for key = p1
proxy.p1 = OTHER VALUE
obj.p1 = other value

intercepted get for key = m1
intercepted call to function function obj.m1()
proxy.m1() = M1 RESULT

intercepted get for key = m2
proxy.m2() = m2 result

intercepted get for key = makeMeUpOnThFly
missing method makeMeUpOnTheFly
```

Tail Call Optimization

- Makes it possible to avoid growing the call stack when making recursive calls or invoking callback functions
  - otherwise could exceed maximum call stack allowed
  - alternative to recursion is using loops
- Possible when the last operation in a function is a function call

```
function fac(n, acc) {
  return n == 0 ? acc : fac(n - 1, acc * n);
}
function factorial(n) {
  return fac(n, 1);
}
```

  - translates to

```
// This version can't use TCO because
// multiplication occurs AFTER the recursive call.
function factorial(n) {
  return n <= 1 ? n : n * factorial(n - 1);
}
```

- Support - currently only Babel; no browsers

continuation passing style (CPS)

```
"use strict";

function fac(_x, _x2) {
  var _again = true;

  _function: while (_again) {
    _again = false;
    var n = _x,
        acc = _x2;
    if (n == 0) {
      return acc;
    } else {
      _x = n - 1;
      _x2 = acc * n;
      _again = true;
      continue _function;
    }
  }
}

function factorial(n) {
  return fac(n, 1);
}
```

a label

why not drop the `_again` flag, label, and `continue` and change the loop condition to `true`?

What's Next?

- The next version is always referred to as "JS-next"
- Currently that is ES7
- Will include
  - `async` and `await` keywords
  - type annotations
  - new `Object` instance method `observe`
  - array comprehensions
  - generator comprehensions
  - value objects - immutable datatypes for representing many kinds of numbers
  - more

`async` and `await` ...

- Keywords to be added **in ES7**
  - already implemented in Traceur as an experimental feature
  - JSHint doesn't recognize these yet
- Hide use of generators for managing async operations, simplifying code
- Replace use of **`yield`** keyword with **`await`** keyword to wait for a value to be returned asynchronously
  - **`await`** can be called on any function
  - not required to be marked as **`async`** or return a **`Promise`**
- Mark functions that use **`await`** with **`async`** keyword
- Works in Traceur and Babel now in experimental mode

... async and await

```
function sleep(ms) {
  return new Promise(resolve => {
    setTimeout(resolve, ms);
  });
}

async function double(n) {
  await sleep(50);
  return n * 2;
}

function triple(n) {
  return new Promise(resolve => resolve(n * 3));
}

function quadruple(n) {
  return n * 4;
}

function badOp() {
  return new Promise(
    (resolve, reject) => reject('I failed!'));
}
```

compare to slides 91-92

async function

function that returns a promise

"normal" function

Call multiple asynchronous functions in series in a way that makes them appear to be synchronous. This avoids writing code in the pyramid of doom style.

```
async function work() {
  let n = 1;
  try {
    n = await double(n);
    n = await triple(n);
    //n = await badOp(n);
    n = await quadruple(n);
    console.log('n =', n); // 24
  } catch (e) {
    // To see this happen,
    // uncomment await of badOp.
    console.error('error:', e);
  }
}

work();
```