Javascript
Because ECMAScript sounds horrible
Javascript

Javascript is a general purpose programming language

• It usually runs within a browser
  • Node.js runs Javascript in a server / application context

• Developed in the mid nineties as a simple way to provide interactivity to web pages.

• Originally developed by Brendan Eich working at Netscape

• Submitted to ECMA standards body in 1996

• ECMAScript 5.1 released in 2011
Javascript In A Browser

- REPL
  - Read-Eval-Print Loop
- All major browsers have a Javascript REPL system in the console
Javascript In A Browser

```javascript
> 1 + 2
3

> a = "hello"
> "hello"

> b = ['a', 'b', 'c', 'd']
>  
> b[2]
>  "c"

> o = {name: 'Mark', class: 'CS337'}

> o.name
> "Mark"

> document
>  
>  ▼#document
>  
>  <!DOCTYPE html>
>  
>  <html>
>  
>  <head>...
>  </head>
>  
>  <body>...
>  </body>
>  
>  </html>
```
Documentation

http://ecma262-5.com/ELS5 HTML.htm

Data Types
Basic Data Types

- number
- boolean
- string
- function
- object
Data Types

typeof

- typeof unary operator
- lets us know what we’re dealing with
- If you’re evaluating a complex operation, you need parenthesis. Not because typeof is a function, but to make sure that there’s only one argument to typeof
Numbers

- Javascript has a single number datatype to deal with all numbers.
- No distinction between integers, floats, doubles, etc.
- All numbers are represented as floating point numbers, but if the fractional part is zero, they’re shown as integers.
Numbers

- Numbers stored in variables are converted objects when needed, to have methods and properties
- `Number.toString()`
- `Number.toPrecision()`

Strings

- A series of zero or more characters.
- Unicode support is pretty good.
Strings

• String variables are also converted to objects as needed.

• String.toUpperCase()

• String.substring(start, end)

• Note the difference between .substring() and .length

• One is a method, one is a property

Boolean

- Boolean for `true` and `false`.
- Comparisons
- Coerce other datatypes into Boolean.
- Note the behavior of the Boolean value for strings.
  - Empty string is `false`
  - Other strings are `true`. Even “false”!
Variables

- Variable names can be any combination of letters, numbers, an underscore (_), or $.
- Variable names cannot start with a number.
- Variables do not need to be declared.
- The `var` keyword can be used to declare and scope variables.

Variables

- Variables have global scope unless `var` is used to declare a variable.
Arrays

- Collection of values
- Created with \([n, \, n+1, \ldots k-1]\) syntax
- Array access with brackets: \(n[\ ]\)
- Length property
- Standard Zero based indexing
Arrays

- Arrays can be collections of many different datatypes.
Arrays From Strings

- String.split() to create an array from a string.
Array Methods

- Lots of useful array methods.
  - `.contains(<some value>)` // returns true or false
  - `.join(<glue string>)` // joins all elements together with glue and returns a string.
  - `.toString()` // Quick string representation of the array
  - `.pop()` .`.push()` .`.shift()` .`.unshift()` // Standard array methods
  - `.sort()` // Sorts elements according to criteria
  - `.splice()` // Adds or removes elements from an array

Array Assignment

- Assigning an array to another variable assigns a reference of the array to the variable, not a copy.
Array Assignment

- To make a copy of an array, use the `.slice(0)` method.
undefined


• Javascript has a special value for things that are not defined: undefined

• Out of bounds requests

• Un-initialized variables

• undefined is a property of the global object. Its type is undefined.
Objects

- Objects are very flexible data structures.
- A basic object:

  ```
  o = {id: 1, name: "an object", counter: 10};
  ```

- Create property names and values using **key: value** syntax.
- Separate multiple properties by commas.
Objects

• Access properties via dot syntax

```javascript
o = {id: 1, name: "an object", counter: 10};
```
Objects

- Act as “Associative Arrays” or “Key / Value” arrays, or “Dictionary” array
- `arr["key"]` syntax

```
o = {id: 1, name: "an object", counter: 10};
```
Objects

• Assigning to undefined properties creates them
null


- Null is a literal value representing an “empty” or non-existent value.
Operators

- **Arithmetic Operators**: + − / * % ++ --
- **String concatenation**: +
- **Logical Operators**: && || !
- **Comparisons**: < > <= >=
- **Ternary Operator**: condition ? true expr : false expr
- **Bitwise Operators**: << >> ^ ~
Control Structures

• if (condition) { stmt1 } else { stmt2 }
• while (condition) { statements }
• for (i = 0; i < 10; i++) { statements }
• Pretty much work like every other C or Java style language
Control Structures: forEach

• Arrays have a special **forEach** method for performing some action relating to each element of the array.

• The **forEach** method takes a *function* as an argument.

```javascript
a = ["one", "two", "three"];  
a.forEach(function(element, index, arr) {
    console.log(element.toUpperCase());
});
```
Basic I/O

- Alerts
- Log to Console
- Confirms
- Prompt
- DOM Manipulation
- Debugger
- No Direct Local File I/O!
alert( )

• Display a modal dialog box with the specified text.

• Pauses execution of Javascript until dialog is dismissed.

alert("Hello World");
console.log( )

• Quick way to get some debugging out.
• Doesn’t block execution, so usually a better choice for debugging and testing than alert().

```javascript
console.log("Hello World");
```
Debugger

• Most browsers have a full featured interactive debugger built in.

• Breakpoints, watched expressions, step through execution, etc.

• Example.
Functions

• Multiple ways to define a function

```javascript
function echo(a) {
    return a;
}

echoTwo = function(a) {
    return a;
}

var echoThree = function(a) {
    return a;
}

console.log( echo("one") );
console.log( echoTwo("two") );
console.log( echoThree("three") );
```
Functions

- Declares a named function without requiring assignment
  ```javascript
  function echo(a) {
    return a;
  }
  ```

- Declares a `global` variable `echoTwo` and assigns an anonymous function to it
  ```javascript
  echoTwo = function(a) {
    return a;
  }
  ```

- Declares a `local` variable `echoThree` and assigns an anonymous function to it
  ```javascript
  var echoThree = function(a) {
    return a;
  }
  ```

- Logs the output of each function
  ```javascript
  console.log( echo("one") );
  console.log( echoTwo("two") );
  console.log( echoThree("three") );
  ```
Functions

• Does any of this matter?
• What if we call the functions before they’re declared?

```javascript
function echo(a) {
  return a;
}

echoTwo = function(a) {
  return a;
}

var echoThree = function(a) {
  return a;
}

console.log( echo("one") );
console.log( echoTwo("two") );
console.log( echoThree("three") );
```
Functions

```javascript
console.log( echo("one") );
console.log( echoTwo("two") );
console.log( echoThree("three") );

function echo(a) {
    return a;
}

echoTwo = function(a) {
    return a;
}

var echoThree = function(a) {
    return a;
}
```

Uncaught ReferenceError: echoTwo is not defined
Functions

- The first style has a symbol table entry created for it at parse time. So it can be referenced immediately during runtime.

- The other two have symbol table entries created at runtime, so aren’t available until after they’ve been executed.

```javascript
function echo(a) {
    return a;
}

function echoTwo(a) {
    return a;
}

var echoThree = function(a) {
    return a;
}

console.log(echo("one"));
console.log(echoTwo("two"));
console.log(echoThree("three"));
```

[javascriptweblog.wordpress.com/2010/07/06/function-declarations-vs-function-expressions/]
Functions

- So should we always use Function Declarations?
  - Well, it depends…

```javascript
// Function Declaration
function add(a,b) {return a + b};
// Function Expression
var add = function(a,b) {return a + b};
```
Functions

• What is the console output here?

```javascript
function echo(a) {
    return a;
}

console.log( echo("one") );

function echo(a) {
    return a.toUpperCase();
}

console.log( echo("one") );
```
Functions

• Hmm, maybe not what we were expecting.

• Function Declarations are ‘hoisted’ to the top at parse time, so when executed, the last declared version wins.
Function Declarations

- Can only appear as block level elements.
- Are ‘hoisted’ to the top at parse time, before run time.
- Cannot be nested within non-function blocks.
- Are scoped by where they are declared, like `var`
Function Expressions

- Can be used anywhere an expression is valid.
  - Can be more flexible because of this.
- Are evaluated and assigned at run time.
Function Expressions

• Recall that functions are first-class data types in JavaScript. This means that anywhere in the language you can use an expression, you can substitute a function.

```javascript
function logWithFormat(message, formatter) {
  let formattedMessage = formatter(message)
  console.log(formattedMessage)
}
logWithFormat("Hello", function(s) { return s.toUpperCase() })
// prints "HELLO" to the console
```
Arrow Functions

- Many of these “callback” style functions require the same format.
- Of course programmers developed a shorter way to write them

```javascript
logWithFormat("Hello", function(s) { return s.toUpperCase() })
logWithFormat("Hello", (s) => s.toUpperCase())
```
Arrow Functions

- Arrow functions are anonymous. There’s no named symbol to reference anywhere else.

- If the function body is simple, you can omit the `{ }` and the statement will automatically be returned.

- If your function body is more complex, you must explicitly return a value.

- Arrow functions have other benefits.

Objects and Functions

- Functions can be added to objects as property variables.
- Object “methods” are really properties with functions assigned to them.
var doubleMe = function(x) {
    return 2 * x;
}

var halveMe = function(x) {
    return x/2;
}

var myLib = {
    version: 0.3,
    name: "My Test Library",
    double: doubleMe,
    half: halveMe
}

console.log( myLib.double(3) );
console.log( myLib.half(10) );
Objects and Functions

• Using anonymous function expressions instead.
• Arrow functions are especially popular in this situation.

```javascript
var myLib = {
    version: 0.4,
    name: "My Test Library",
    double: function(x) { return 2 * x; },
    half: function(x) { return x/2; }
}
console.log( myLib.double(3) );
console.log( myLib.half(10) );
```

```javascript
var myLib = {
    version: 0.4,
    name: "My Test Library",
    double: (x) => 2 * x,
    half: (x) => x/2
}
console.log( myLib.double(3) );
console.log( myLib.half(10) );
```
Javascript in HTML

• Where does our Javascript live?
• Inline in an HTML document inside a `<script>` element
• Included in an external file via a `<script>` element.
Javascript in HTML

- The `<script>` element with inline content
- Within the `<script>` element, we’re parsing Javascript, not HTML

```html
<!doctype html>
<head>
  <title>js/jstest.html</title>
  
  <script>
    var answer = 42;
    function calculateAnswer() {
      return answer;
    }
    console.log( calculateAnswer() );
  </script>
</head>

<body>
  <div></div>
  <div></div>
</body>
</html>
```
Javascript in HTML

- The `<script>` element with `src` attribute.
- Includes an external file with Javascript in it.
- No wrapping `<script>` tags within external files.

```html
<!doctype html>
<html>
<head>
  <title>js/jstest.html</title>
  <script src="jstest.js"></script>
</head>
<body>
  <div></div>
</body>
</html>

var answer = 42;
function calculateAnswer() {
  return answer;
}
console.log( calculateAnswer() );
```
The document Object

This is all well and good, but how about something involving a web page?
The document Object

- The document object is **NOT** part of the Javascript language.
- You won’t find it in server contexts such as `node.js` for example.
- It is an API defined by the W3C to interact with HTML and XML documents.

The **document Object**

- Browsers parse the HTML and CSS of a page, and build an object model in memory.
- The browser exposes this object to us for use with our Javascript as the **document object**.
The **document Object**

```html
<!DOCTYPE html>
<html>
  <head>
    <title>A Page</title>
  </head>
  <body>
    <h1>A Basic HTML Page</h1>
  </body>
</html>
```
The document Object

- Document elements are objects, so accessing their properties is done with the dot syntax.
- `document.property`
- `html.innerHTML` for example
DOM Selection

- Starting with the `document` root and drilling down via `.children` is tedious. Can we get at elements some other way?

- `document.getElementById("main")`

- `document.getElementsByTagName("p")`

- `document.getElementsByClassName("error")`
getElementsByld

- Gets an HTML Element object from the document based on an ID.
- Since ID must be unique, this method returns a single element, not an array of elements.
getElementsByOld

```html
<!doctype html>
<head>
  <title>js/getElementById.html</title>
  <link rel="stylesheet" type="text/css" href="getElements.css" />
</head>

<body>
  <div id="main">
    <div id="first" class="item">
      First Block
    </div>
    <div id="second" class="item">
      Second Block
    </div>
    <div id="third" class="item selected">
      Third Block
    </div>
  </div>
</body>
</html>
```
Updating the DOM

• Now that we can get an element, can we do something with it?

```html
<!doctype html>
<head>
  <title>js/getElementById.html</title>
  <link rel="stylesheet" type="text/css" href="getElements.css" />
  <script src="getElementById.js"></script>
</head>

<body>
  <div id="main">
    <div id="first" class="item">First Block</div>
    <div id="second" class="item">Second Block</div>
    <div id="third" class="item">Third Block</div>
  </div>
</body>
</html>

d2 = document.getElementById('second');
d2.classList.add("selected");
```
Updating the DOM

- Hmm nothing happened. Why? Check the console.
Updating the DOM

- Uncaught TypeError: Cannot read properties of null?? But how can `d2` be null?

```javascript
d2 = document.getElementById('second');
d2.classList.add("selected");
```
Waiting for the DOM to load

- The browser waits for no DOM
- The browser parses the file, loads the `getElementById.js` file, and executes it all before the rest of the HTML is parsed and the DOM is created.
Waiting for the DOM to load

- What if we just move the `<script>` element down to the bottom?

```html
<!doctype html>
<head>
  <title>js/getElementById.html</title>
  <link rel="stylesheet" type="text/css" href="getElements.css" />
</head>
<body>
  <div id="main">
    <div id="first" class="item">First Block</div>
    <div id="second" class="item">Second Block</div>
    <div id="third" class="item">Third Block</div>
  </div>
  <script src="getElementById.js"></script>
</body>
</html>
```
Waiting for the DOM to load

• Works!
Waiting for the DOM to load

• That seems... hackish. Isn’t there a “right” way to do this?

• Well, it's perfectly valid. `<script>` elements do not have to go in the `<head>`, although they frequently do.

• However, `<script>` elements that aren’t in the `<head>` tend to get overlooked later, so we try to put them there if we can.
Events

• The web browser is an Event Driven application.

• Documents load, links are clicked, HTTP requests are made and completed.

• Each of these is an event, and we can register event listeners (functions) which will be called as these events occur.

• These are called *callbacks*.
Events

- `object.addEventListener('event', callback);`

- The object can be any object that responds to event listeners, such as an Element, the Document, or maybe the Window.
Events

• A basic example of a ‘click’ event handler.

```html
<!doctype html>
<head>
  <title>js/events.html</title>
  <link rel="stylesheet" type="text/css" href="getElements.css" />
</head>
<body>
  <div id="main">
    <div id="first" class="item">First Block</div>
    <div id="second" class="item">Second Block</div>
    <div id="third" class="item">Third Block</div>
  </div>
  <script>
    clickCount = 0;
    d1 = document.getElementById('first');
    d1.addEventListener('click', function() {
      console.log("Clicked " + ++clickCount + " times.");
    });
  </script>
</body>
</html>
```
Window Load Event

- There’s also a `window` object that the DOM API provides for us.
- The Window object supports the `load` event, and we can register our own callback with this.
- The `load` event fires once the DOM has completed loading.
window load Event

```html
<!doctype html>
<head>
  <title>js/window-load.html</title>
  <link rel="stylesheet" type="text/css" href="getElements.css" />
  <script src="window-load.js"></script>
</head>

<body>
  <div id="main">
    <div id="first" class="item">First Block</div>
    <div id="second" class="item">Second Block</div>
    <div id="third" class="item">Third Block</div>
  </div>

  window.addEventListener('load', function() {
    d2 = document.getElementById('second');
    d2.classList.add('selected');
  });
</body>
</html>```
window load Event

- Works!
window load Event

- IE 8 supported a different method, the `object.attachEvent` method.

- Even older browsers only support a single “onload” property.

```javascript
var ready = function (myFunciton) {
    if (window.attachEvent) {
        window.attachEvent('onload', myFunciton);
        console.log('IE');
    } else if (window.addEventListener) {
        window.addEventListener('load', myFunciton);
        console.log('Modern');
    } else {
        console.log('Legacy');
        if (window.onload) {
            var curronload = window.onload;
            var newonload = function () {
                curronload();
                myFunciton();
            };
            window.onload = newonload;
        } else {
            window.onload = myFunciton;
        }
    }
}
```
window load Event

- IE 8 supported a different method, the `object.attachEvent` method.
- Even older browsers only support a single “onload” property.
- But none of this matters anymore because we live in the future! 🎉

```javascript
var ready = function (myFunciton) {
  if (window.attachEvent) {
    window.attachEvent('onload', myFunciton);
    console.log("IE");
  } else if (window.addEventListener) {
    window.addEventListener('load', myFunciton);
    console.log("Modern");
  } else {
    if (window.onload) {
      var curronload = window.onload;
      var newonload = function () {
        curronload();
        myFunciton();
      };
      window.onload = newonload;
    } else {
      window.onload = myFunciton;
    }
  }
};
```
Putting Pieces Together
<!doctype html>
<head>
  <title>js/click-count.html</title>
  <link rel="stylesheet" type="text/css" href="click-count.css"/>
  <script src="click-count.js"></script>
</head>

<body>
  <div id="main">
  </div>
</body>
</html>
var addCount = function(event) {
    var curCount = Number(this.textContent);
    curCount++;
    this.textContent = curCount.toString();
}

window.addEventListener('load', function() {
    var numBoxes = 9;
    main = document.getElementById('main');
    for (i = 0; i < numBoxes; i++) {
        var newBox = document.createElement("div");
        newBox.textContent = "0";
        newBox.addEventListener('click', addCount);
        main.appendChild(newBox);
    }
});
CAN YOU PASS THE SALT?

I SAID—
I KNOW! I'M DEVELOPING A SYSTEM TO PASS YOU ARBITRARY CONDIMENTS. IT'S BEEN 20 MINUTES!
IT'LL SAVE TIME IN THE LONG RUN!
Classes

Oops, sorry, there are no classes.
Class Like Thingies

- Javascript has no “Class” concept.
- Objects are based on building on a prototype.
- “Instances” are not tied to a particular static Class definition.
- function?
functions and new

- Classes are just functions!
- Create new instances with the new keyword.

```javascript
function Droid(type, name) {
  this.type = type;
  this.name = name;
}

var r2 = new Droid('astromech', 'R2D2');
var c3 = new Droid('protocol', 'C3PO');

console.log(r2);
```
• Methods can be added through the special `prototype` property of objects.

```javascript
function Droid(type, name) {
    this.type = type;
    this.name = name;
}

Droid.prototype = {
    getName: function() { return this.name },
    getType: function() { return this.type }
}

var r2 = new Droid('astromech', 'R2D2');
var c3 = new Droid('protocol', 'C3PO');

console.log(r2);
console.log(r2.getName());
```
prototypes

• Don’t like the behavior of something? Re-define it on the fly

```javascript
function Droid(type, name) {
  this.type = type;
  this.name = name;
}

Droid.prototype = {
  getName: function() { return this.name },
  getType: function() { return this.type }
}

var r2 = new Droid('astromech', 'R2D2');
var c3 = new Droid('protocol', 'C3PO');

console.log(r2.getName());

Droid.prototype.getName = function() {
  return this.name.toLowerCase();
};

console.log(r2.getName());
```
Asynchronous JavaScript

The JavaScript Event Loop

• The JavaScript Event Loop allows for asynchronous operation

• Required for the event driven architecture

• Browser can still process events like scrolling and mouse clicks while it waits for an external network call to complete

• Two main ways to deal with events that happen over time, typically I/O operations
  • Callbacks
  • Promises
Asynchronous JavaScript

Callbacks

- Register a callback function to be executed when an event occurs.

```javascript
window.addEventListener('load', function() {
  console.log("Page has loaded")
});
```

```javascript
window.addEventListener('load', () =>
  console.log("Page has loaded")
);
```
Asynchronous JavaScript

Callbacks

• Register a callback function to be executed when an event occurs.

• JavaScript stores the anonymous function on the stack, and links it to the load event. When the window finishes loading, the JavaScript engine calls all registered callback functions for that event.

() => console.log("Page has loaded")
Asynchronous JavaScript

Callbacks

• This model works well for simple workflows, but has problems when you need to perform multiple asynchronous tasks in a specific order.

• This quickly becomes cumbersome and has come to be known as “callback hell” or “the dreaded callback pyramid”

```javascript
window.addEventListener('load', function() {
    callExternalAPI(apiURL, function(response) {
        console.log(response.json());
    });
});
```
Asynchronous JavaScript
Promises

• Promises arose to combat this model, and fix many of its shortcomings

• A Promise object wraps an asynchronous operation to manage its eventual completion or failure

• Essentially, a promise is a returned object to which you attach callbacks, instead of passing callbacks into a function.

callExternalAPI(apiURL)
  .then((result) => callAnotherAPI(api2URL, result))
  .then((response) => console.log(response.json()))

Asynchronous JavaScript
Promises

• Newer APIs such as the `fetch` API, support Promises by default, but many older ones don’t. For example the `window.addEventListener` method.

• Can wrap these functions in a new Promise object

• Useful for combining new Promise code with older APIs

```javascript
const windowEvent = (e) =>
  new Promise((resolve) => window.addEventListener(e, resolve))

windowEvent('load')
  .then(() => console.log("Page Load Promise Resolved"))
```
AJAX
Talking Behind the Browser’s Back
AJAX

- Asynchronous
- Javascript
- And
- XML
AJAX

• Fortunately, almost no one uses XML anymore
• JSON is far more popular now as the format for asynchronous data
• JavaScript Object Notation
XMLHttpRequest

• Concept First proposed by Microsoft
• First appeared in IE 5 as an ActiveX component
• Mozilla Adopted the idea and created a Javascript implementation of it as nsIXMLHttpRequest. Appeared in Gecko engine in 2002
• Became the de facto standard when WebKit implemented it in 2004
• W3C formally standardized it in 2006
Web Server

Browser

Initial Page Request

New Page Displayed

HTML Returned

Request made via Javascript
using XMLHttpRequest()

No New Page Displayed!

Web Server

Python

MySQL

JSON Returned

New Page Displayed!
XMLHttpRequest Demo

https://www2.cs.arizona.edu/classes/cs346/fall22/docs/examples/ajax-demo/
New fetch API
So much simpler

- We can finally put together all our function and Promise knowledge

```javascript
fetch(apiURL)
  .then((responsePromise) => responsePromise.json())
  .then((responseObj) => process(responseObj))
```
Now we know enough to be dangerous