JavaScript

PIC 40A, UCLA

JavaScript

JavaScript is a programming language that is used heavily in web development. Most websites that enable interactivity in responding to a user's inputs use JavaScript to manage events. It also has many uses in generating more complicated webpages that would be a huge hassle to write with raw HTML.

Most JavaScript runs through a web browser, in a **window**. But JavaScript can also function as a standalone language, such as the case of **NodeJS** where it can run on the server.

JavaScript

JavaScript is a **high level** programming language. It is high level in that many elements that are present and may require attention in languages like C or C++ - including pointers, memory management, variable typing, etc. - are abstracted away.

It is an **interpreted language**: code that is written in JavaScript is parsed by another program, a JavaScript engine in the case of JavaScript, and this other program determines which instructions to carry out. This happens every time the program is run. This differs from a **compiled language**, such as C++, whereby a program can be converted to very efficient machine instructions and run ever after.

Fun fact: the Chrome V8 JavaScript Engine is written in C++!

JavaScript

JavaScript is also a **scripting language.** The term refers to the programs being written as a series of commands/statements that are not compiled, which goes hand-in-hand with it being an interpreted language.

ECMAScript is an international standard for scripting languages. JavaScript is a language that conforms to these standards, but it is not the only such language. The current **ECMA 6 Specifications can be found here.**

Writing JavaScript

JavaScript can be included in the **head** of a document. For most of the early examples, we will make use of the JavaScript debugging tools in the web browsers and can use an HTML document structure:

```
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <script src="some_file.js" defer ></script>
</head>
<body>
</body>
</html>
```

Then code can be written in that **some_file.js** file. Of course the **src** can be a full URL as well, not just a relative path.

Writing JavaScript

There are many other ways to include JavaScript. The approach on the previous slide is, by current standards, the best, for reasons we shall elaborate upon.

JavaScript should be included inside of a **<script>...</script>** pair of tags, or it should be provided as an external resource with **src**.

In HTML4, the **script** elements required **type="text/javascript"**, but this is not required in HTML5.

Writing JavaScript

There is a difference between **src** and **href**. Notice the patterns

```
<a href="...">...</a>
<link href="..." />

<img src="..." />
<script src="...">...</script>
```

In general with **href**, a link is established to the other resource but the page continues to parse the HTML. With **src**, the resource is acquired and the page does not parse any more HTML until the resource is acquired, thus slowing down the page loading.

Writing JavaScript

The old school fix was to include the **script** tags just before the closing body tag.

With HTML5, two new boolean attributes were introduced, **async** and **defer**. Both allow for the HTML to be parsed concurrently with downloading the scripts. With **async**, if multiple scripts are included, the second may be fully loaded before the first; with **defer**, if multiple scripts are present, they are loaded in the order in the code.

JavaScript Overview

In order to be productive with JavaScript, it is important to understand it as a language in its own right, rather than as a bunch of scripts that come out of nowhere. Roughly speaking, amidst seeing some applications, we will consider:

- data types: primitives vs object
- type coercion
- arrays, functions, and other objects
- variables, copies, and references
- Document Object Model
- hoisting (initialization)
- this and closures
- control flow
- Math and Date objects
- events, timers, and asynchronous JavaScript
- cookies
- object oriented design
- libraries (jQuery)

Data Types

In JavaScript there are 6 **primitive types**:

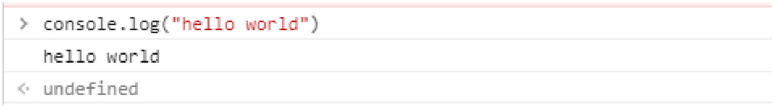
- **undefined**
- **null**
- **Boolean**
- **Number**
- **String**
- **Symbol**

Everything else, including **Arrays**, functions, and classes are **objects.**

All functions are objects in JavaScript. Think of this like the lambda expressions in C++: they are callable objects/classes.

Directly Writing JavaScript

To explore JavaScript code without focusing upon a website, through most web browsers, one can *inspect* an empty tab and go to the *console* view.



```
> console.log("hello world")
  hello world
<· undefined
```

console.log is a useful way to print things for debugging. In this *console* option, some browsers will append extra *undefined* statements indicating that a function/statement does not return a value.

console.log is like std::cout $<<$ in C++.

Data Types: undefined

In JavaScript, a variable can be defined with the **var**, **let**, or **const** keywords.

```
let x;
```

This says that **x** is a variable. The first time a variable comes into existence if it is not assigned a value, the JavaScript engine gives it the value **undefined**. So **undefined** is a value signifying it has not been set yet.

Remark: JavaScript will not give an error if you use a variable that is undefined. Your code will just behave badly...

In C++ terms this undefined value corresponds to when a variable has been defined but not explicitly initialized, often erroneously called "declared but not defined" by the uninitiated.

Data Types: null

If a variable should not have a value after it has already been in use, the programmer may choose to set the variable to **null**:

```
x = null; // now x is null
```

Yes, JavaScript comments are similar to C++ comments with // for single line and /* **...** */ for multi-line comments**.**

There is only one value that is null. This is like nullptr in C++ that is the only instance of std::nullptr_t.

Data Types: Boolean

These correspond to the typical **true** and **false** values of other programming languages. They are useful in control flow.

```
x = true;
x = false;
x = !false; // now true
```

! is logical negation.

Data Types: Number

In JavaScript there is only one data type for numbers, be they integers or floating type. The **Number** data type corresponds to a 64-bit floating point number.

```
let y = 1234567890; // y is a Number
let z = 3.14159265; // z is a Number
```

Data Types: Number

The arithmetic operations for Numbers behave the same in JavaScript as in C++ with: **+, -, *, /, %, +=, -=, *=, /=, %=**, assignment **=**, and prefix/postfix **++** and **- -**.

```
let x = 3, y = 3;
y = y + 1; // y is now 4, returns value 4
x *= y; // x is now 12, returns value 12
++x; // x is now 13, returns value 13
y- -; // y is now 3, returns value 4
```

Note: we can define multiple variables on a single line.

Data Types: String

The **String** datatype should be used to store textual information. A **String** can be declared with either single ’ or double **"** quotes.

```
let msg1 = "hello";
let msg2 = ’world’;
let msg3 = msg1 + " " + msg2; // will be string "hello world"
msg3 += ’!’; // will be string "hello world!"
```

As with C++, the + (and +=) can be used for string concatenation.

Data Types: String

JavaScript supports escape characters:

\n for a new line,
\t for a tab,
\\\\ for a backslash,
\\’ for a single quote,
\**"** for a double quote,
\b for a backspace.

Data Types: String

In JavaScript, **String**s are immutable. The **String** contents themselves cannot be modified (but of course reassignment is allowed).

```
// msg3 was "hello world!"
msg3[0] = 'H'; // does nothing
```

Data Types: String

Here are a few useful things we can do within strings:

```
"hello".length; // extract length property, value is 5

let message = "hello world";
let pos = message.indexOf("world"); // 6, index of "world"

let x = message.substr(0,5); // "hello"
```

length is a property, so we do not call a function upon it.
indexOf returns the index where a substring is found, -1 if not found.
substr behaves the same as in C++: the first value is the index where the substring begins and the second value is the length.

Remark: many other functions exist with similar functionalities, but we won’t go into them.

Data Types: Symbol

The newest type introduced in the ECMA 6 Standard is **Symbol**. It effectively makes something that is unique in value. It can be used to allow functions to mark objects without interfering with program logic and to give **private**-like features to objects.

```
let x = Symbol("a"); // x and y are constructed the same way
let y = Symbol("a"); // but they are distinct and not equal
```

Alert, Confirm, Prompt

In JavaScript, we can display a message to the screen with an alert box. The syntax is:

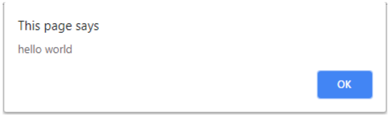
alert(some_message);

where **some_message** could be a string or some other variable.

With a script

```
let msg = 'hello world';
alert(msg);
```

we are greeted with an alert box:


This page says

hello world

Alert, Confirm, Prompt

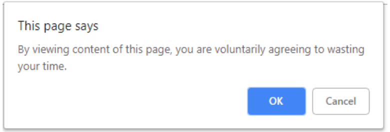
In JavaScript, the **confirm** function makes the user read a message and click **OK** or **Cancel**. It returns the value **true** if they clicked "OK" and false otherwise.

They cannot view other parts of the page until they have clicked OK/Cancel.

With a script

```
let decision = confirm("By viewing content of this page, you are voluntarily agreeing to
     wasting your time.");
```

we are greeted with a confirmation box:


This page says

By viewing content of this page, you are voluntarily agreeing to wasting your time.

decision will be **true** or **false**.

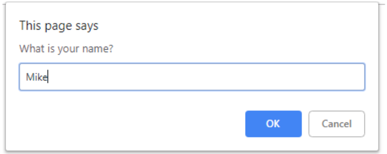
Alert, Confirm, Prompt

The **prompt** function prompts a user for a piece of information. It takes arguments of the prompt text, a default value of the response, and it returns their answer.

With a script

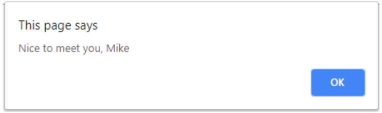
```
let name = prompt("What is your name?", "");
alert("Nice to meet you, " + name);
```

we can be greeted and welcomed


This page says

What is your name?

Mike


This page says

Nice to meet you, Mike

Data Types: Weakly Typed

JavaScript is weakly typed. Variables can be transformed from one type to another without any problems.

```
let x = 14; // x is a Number
x = 'foo'; // now it is a String
x = false; // now a Boolean
```

Data Types: Coercion

If JavaScript needs to operate on two values of different type, it may apply **coercion** to convert one data type into the other. This can be confusing!

Some of the conventions are familiar:

```
let x = 7, y = true;
x += y; // true converted to 1, x now 8
```

When needed, **Boolean** can be converted to **Number** with **true** becoming 1 and **false** becoming 0.

Data Types: Coercion

JavaScript does more, however...

The following values all are converted to **false** during coercion:

- 0 (the Number)
- ” or "" (the empty String)
- null
- undefined
- NaN (flag when a Number is not valid such as from division by 0)

Everything else is converted to **true** during coercion including things like:

- ’0’
- "false"
- [] (an empty array)
- {} (an empty object)

Data Types: Coercion

As a few examples of these coercions, consider a simple if-statement. The syntax is the same as in C++:

```
if("false") {
   console.log("hello"”);
}

let x = 0/0; // so NaN

if(x) {
   console.log("hello again”);
}
```

Only the first statement prints.

Data Types: Coercion

This also makes "math" somewhat confusing:

```
3 * "7"; // === 21
"12" - 9; // === 3
5 / "4"; // === 1.25
5 / "4 and some extra stuff"; // === NaN
4 + "3"; // === "43"
1 + 2 + "3"; // === "33"
1 + "2" + 3; // === "123"
```

When using **+**, JavaScript will concatenate Numbers and Strings. For **-**, *****, /, it will convert the String to a Number if it can or return **NaN** (not a number).

As with all programming languages, operators have precedence and associativity (direction). The **+** is a left-to-right operator so 1+2+"3" is first seen as (1+2)+"3"; whereas 1+"2"+3 is first seen as (1+"2")+3.

Data Types: Coercion

Other rules exist, too, but we won’t get into them. It is important to be aware of the consequences of being weakly typed and allowing so many coercions!

The two most efficient ways to convert a Number to a String:

```
let n = -3;
let x = n + ""; // add empty string
y = n.toString(); // call toString method
```

Simple ways to convert a String to a Number:

```
let z = x * 1; // just mutiply by 1... or subtract 0... or divide by 1
let w = Number(y); // invoke the Number function
```

Control Flow

We’ll go through a series of basic control flow structures before looking into objects. Note that in JavaScript, we have the following logical operators:

|| for or
&& for and
! for logical negation.

Control Flow: if, else I

The syntax for **if** and **else** is the same as for C++:

```
if(statement) {
   // what to do
}

if(statement) {
   // what to do here
}
else {
   // what to do here
}

if(statement1) {
   // what to do here
}
else if(statement2) {
```

Control Flow: if, else II

```
   // what to do here
} else {
   // what to do here
}
```

As in C++, grammatically, for if/else and loops, the braces are not required if only a single statement follows, *but they should always be included for code robustness*.

As a further stylistic requirement for code documentation, *every branch of control flow should have its own documentation*.

Control Flow: if, else

Here is a simple example of using **if**/**else**:

```
let x = 277;

if( (x % 2) === 0) { // no remainder when divided by two
  console.log("even number");
} else { // then has a remainder and is odd
  console.log("odd numer");
}
```

Control Flow: if, else

Beware coercsions!

```
let x = "0";

if( x ) { // if x is true...
  console.log("gets printed!");
}
```

Data Types: Objects - Arrays

An object is any data that is not a primitive type. We first consider an **Array**.

In JavaScript, arrays are specified with **[...]** square brackets. They can then contain a (possibly empty) comma separated list of values *of any type!!!*.

Some useful methods and properties of an array include:

- Subscript operator [], indexed from 0, returning the variable at the given index
- **concat**: joins two or more arrays and returns a copy of the joined arrays
- **pop**: removes the last element of the array and returns it
- **push**: adds one or more elements to the array and returns the new length
- **length**: a number corresponding to the array length

Data Types: Objects - Arrays

```
let a = [2,4,6];
let b = [false,'hello',26];
let c = [];
let d = [a,111.111]; // okay: d is an array

d[0].pop(); // now a is [2,4], and d is [ [2,4], 111.111]
```

Warning: in this context, **d** is storing a reference to **a**!

Data Types: Objects - Arrays

```
a = [1,2,false];
b = ['cat','dog','fish'];
c = [];
a[2] = true; // now a is [1,2,true]
d = a.concat(b,c); // d is [1,2,true,'cat','dog','fish'];
c.push('hi','bye'); // returns 2, the new size, and c is ['hi','bye']
a.pop(); // returns true and now a is [1,2]
a.length; // 2, note this is not a member function! no parentheses
```

Remarks: functions such as **concat** and **push** can take more than one argument! And **length** is a property of the array so it does not get invoked as a function.

In C++ terms, the length property could be thought of as a public member variable of the Array class. And the functions accepting arbitrary numbers of input arguments could be viewed as variadic functions.

Control Flow: for

The **for** loop is nearly identical to C++. It follows:

```
for(initialization statement(s); condition; steps after body) {
   // ...
}
```

```
let arr = ["hello", " world"];
let msg = "";
for (let i = 0; i < arr.length; ++i) { // go through each word
   // and add it to the HTML
   msg += arr[i];
}

console.log(msg); // logs "hello world"
```

Control Flow: while and do

While and do also behave the same as C++, with format

```
while(condition) {
   // stuff to do
}

do {
   // stuff
} while(condition);
```

Control Flow: break and continue

There are also **break** statements to break out of the immediately enclosing loop and **continue** statements to skip the remaining steps of a loop iteration before moving to the next iteration.

Data Types: Objects - Functions

Functions in JavaScript are objects. They can appear as either **function declarations** or **function expressions**.

A **function declaration** uses the **function** keyword to create a function object of a given name:

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

The function above takes in two arguments, called **a** and **b**, and returns the two values with + acting between them.

Functions that return values use a **return** statement. For functions that do not return values, the **return;** is optional.

Data Types: Objects - Functions

As in other programming languages, function documentation is important. The format we adopt is illustrated below:

```
/**
This function adds its two inputs.

@param {Number} a the first number.
@param {Number} b the second number.

@return {Number} the sum.
*/
function add(a,b){
  return a+b;
}
```

All function documentations begin with /** and end with */. They begin with a description.
Then for each input, there is a list
@param {ITS DATA TYPE IN BRACES} its_name a_desciption.
Then for the output, if there is one,
@return {ITS DATA TYPE IN BRACES} a_descrption.

Since JavaScript is loosely typed, listing the expected input/output types is even more important!

Data Types: Objects - Functions

JavaScript also suppots default arguments for functions. As with C++, these arguments can be supplied from right to left, and function arguments are assigned left to right.

```
function f(a,b=3) {
   return a+b;
}

function g(a=9,b=3) {
   return a+b;
}

f(1,8); // 9
f(7); // 10
g(4,4); // 8
g(4); // 7
g(); // 12;
```

Data Types: Objects - Functions

Due to the weakly typed nature of the language, functions **cannot be overloaded** like other languages.

In addition to this, each function is, in C++ terms, "variadic", accepting arbitrary numbers of arguments. Implicitly there is an **arguments** variable local to a function that behaves *like an array* storing all the input arguments. It isn’t an actual array.

We can even choose to lump the final arguments of a function into a single array variable.

Data Types: Objects - Functions

For example:

```
foo(3,4,'hello','world');

function foo(a,b,...c){
  console.log(a); // 3
  console.log(b); // 4
  console.log(c); // ['hello', 'world']
  console.log(arguments.length); // 4
  console.log(arguments[0]); // 3
  console.log(arguments[1]); // 4
  console.log(arguments[2]); // hello
  console.log(arguments[3]); // world
}
```

In C++, this would be kind of like:

```
template<typename A, typename B, typename ... Types>
auto foo(A&& a, B&& b, Types&&... c){
  // do stuff
}
```

Data Types: Objects - Functions

A **function expression**, called **anonymous functions** or **lambdas** in other languages, is one that evaluates to a function but is not named. We can choose to store the function in a variable if we want.

```
let add2 = function(a,b) {
   return a+b;
};
```

The right-hand-side of the above code is a function expression. It evaluates to a function that we refer to as **add2**.

In either case, we get behaviour we expect:

```
add(3,4); // 7
add2(3,4) // 7
```

We created a variable that stores a function, similar to if we had written **let foo = 7;** where we create a variable that stores a number.

Data Types: Objects - Functions

JavaScript uses a lot of function expressions because functions can be created for "one off" events where a function is needed on the fly. They also arise in **immediately invoked function expressions (IIFEs)**. We'll see these later, but here's a baby example:

```
(function(a,b){ return a+b; })(3,4); // evaluates to 7
```

The expression in the parentheses is a function expression which can receive two inputs, which is fed the values 3 and 4.

In C++ terms, function expressions are like lambdas. Our add2 function could be thought of as:

```
auto add2 = [](double a, double b)
  ->double{return a+b;};
```

Data Types: Objects - Functions

We can also use anonymous functions to sort arrays. Arrays have a sort function that by default sorts elements *alphabetically!*. It turns numbers to strings and sorts that way.

```
let arr = [2,100,199];
arr.sort(); // [100,199,2] - - clearly not good
```

But we can provide a binary compare function, being negative if the first argument is "less than" the second, 0 if they are "equal", and positive if the first is "greater than" the second. This also allows arbitrary sorting.

Data Types: Objects - Functions

We change our sorting:

```
arr.sort( function(x,y) { return x - y; }); // [2,100,199]
arr.sort( function(x,y) { return y-x; } ); // [199,100,2]
```

In C++, it works the same. If values is any random access container like a std::vector<int>, say, we can have items sorted in decreasing order:

```
std::sort(std::begin(values), std::end(values),
  [](int x, int y)->bool{
    return y>x;
});
```

Data Types: Objects - Functions

We use the term **execution context** to describe the environment in which code is being run. This could be the **global execution context**, which is where everything lives by default, or it could be a **function execution context**, which is the same thing as the global, but restricted to the body of the function.

Data Types: Objects - General

In general an object in JavaScript uses the brace syntax. Members (variables/functions) and their values appear in **name: value** pairs, separated by commas.

```
let x = { }; // x is an empty object

let pic40a = { // has a time (Number), room (String), and function
   start_hour: 8,
   room: ’MS 2000’,
   chant: function() { console.log("Go Bruins!"); }
};
```

console.log is a function that logs things. The outputs can be viewed by looking for the console output with web browser development tools. The outputs are not rendered to the webpage.

Data Types: Objects - General

We can now use **pic40a** as a class object.

```
let end_hour = pic40a.start_hour + 1;
pic40a.chant(); // logs "Go Bruins!"
```

Members are accessed with the **.** syntax.

In C++ terms, pic40a is an instance of a class with all public members. It has member variables start_hour and room, of type int and std::string, respectively. It has a member function chant that can display the message.

Data Types: Objects - General

Remember how **x** was an empty object? Well, in JavaScript, more members can be added.

```
x.i = 7; // x now has a member i of value 7
x.foo = function() { }; /* x now has a member foo, a function, that does
   nothing */

x["p"] = false; // x now has a member p of value false
```

Members can be added through the **.** operator or through the subscript operator with a string argument. Members can even be accessed through the subscript.

The most common convention is to use **.** - and that’s probably good advice to avoid confusion.

Data Types: Objects - General

Functions are just objects that can be called with **()**. A function internally stores a reference to the instructions to follow when called. But it can store more...

```
function f(name) {
   console.log('hello ' + name);
}

f.a = 7;
```

The variable **f** can be called as in **f("Alice")** but also has a member called **a** with value 7... Yes, this is a little weird, but this comes down to all non-primitives being objects.

Data Types: Objects - General

The **typeof** function returns the type of its argument: for primitive types (except null) it returns their type, for all other inputs it returns "object".

```
typeof(true); // "boolean"
typeof(888); // "number"

let x;
typeof(x); // "undefined"

x = null;
typeof(x); // "object"

typeof({}); // "object"
```

The peculairity with **null** relates historically to how the language was developed and the need to preserve backwards compatability for programs that relied on this quirk before it could be remedied.

Data Types: Comparison

Due to coercions, there are actually two types of equality comparisons and two types of inequality comparisons.

In general we can say **A == B** if, after a possible coercion, **A** and **B** are equal; and **A != B** if, after a possible coercion, **A** and **B** are not equal. This gray area, which can get a lot more complicated, is often termed **truthy** and **falsy**.

In JavaScript there are also **===** and **!==**. We write **A === B** if **A** and **B** are equal and of the same type; and **A !== B** if either **A** and **B** differ in type or differ in value but have the same type.

Remark: it is almost always ill-advised to use **==** or **!=**. Just use **===** and **!==**.

Data Types: Comparison

JavaScript supports the usual comparison operators as C++: **<** (less than), **<=** (less than or equal), **>** (greater than), and **>=** (greater than or equal).

When comparing a string and a number, the string is converted to a number.

```
3 < "10"; // true
"500" <= 500; // true
```

When comparing two strings, the comparison is done lexicographically, i.e. like a dictionary, as in C++:

```
"apple" >= "coffee"; // false
"zebra" < "goldfish"; // false
```

Data Types: Comparison

As in C++, when an expression is placed as an argument for a control flow structure, an explicit conversion to **boolean** must be made before continuing.

Consider the JavaScript:

```
if(something) { /* do stuff */ }
```

If **something** is a **boolean** no conversion is necessary. Otherwise, if **something** is ...

- **null** or **undefined**, it is **falsey**;
- a **number** of value **0** or **NaN** it is **falsey** and all other numbers make it **truthy**;
- an empty **string** it is **falsey** and all other strings make it **truthy**;
- an **object** then it is **truthy**.

Data Types: Comparison

With the **==** operator, the rules are a lot more complicated. Generally, the JS engine will try to convert one or both of the arguments to a number.

null and **undefined** are equal to each other and themselves under **==** but otherwise are **!=** to other types.

```
undefined == null; // true
"1" != true; // becomes 1 != 1, which is false
null == false; // false
```

Just use the **===** and **!==** and you’ll be safe.

Switch

JavaScript has switch statements, too. The syntax is similar to C++:

```
switch(value){
   case first_value:
      // do stuff
      break;
   case second_value:
      // do stuff
      break;
   default:
      // do stuff
}
```

Switch statements use strict equality **===** to test their cases. Unlike C++, the values being tested need not be of integer type.

Warning: beware to include the **break** statements at the end of each non-default case!

Variables

In JavaScript, a variable can be defined with the **var**, **let**, **const** keywords - even none (should be avoided).

In modern JS, only **let** and **const** should be used. In a nutshell:

- **var**: defines a variable either globally if it is defined globally or throughout an entire **function execution context** if defined within a function. **var** gives no warning if a variable is redefined with the **var** keyword.
- **let**: defines a variable only within the given scope, i.e. set of braces { }, or globally if it is defined in the global execution context. An error is generated if a variable defined again after its first **let**.
- **const**: does the same thing as **let** but also keeps the variable constant and protects against mutation.
- defining a variable without a keyword could either define a new global variable or modify a global variable.

Variables

Remark: when used in global contexts, **let** and **const** do not add properties to the global **window** object but **var** does.

```
// in the global execution context

x = 5; // now window.x === 5

var y = 6; // now window.y === 6

const z = 43; // there is z === 43 but no window.z
```

Variables

Remark: in JavaScript many variables are **global**, meaning they can be accessed everywhere in the program, but there are various means of **encapsulation** and avoiding naming conflicts by wrapping variables up inside of objects or using **IIFE**s.

Valid variable names begin with either a letter or $ or _, then contain letters, digits, $'s, or _'s. Variable names are **case sensitive**.

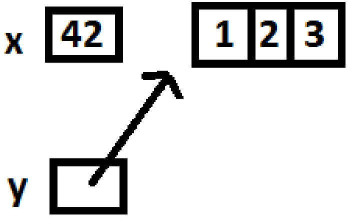
Variables

Any variable that is a primitive type can be thought of as storing its corresponding value.

```
let x = 42;
```

On the other hand, a variable that is an object *only stores a reference* (pointer) to the object: the value is stored elsewhere in memory.

```
let y = [1,2,3]; // an Array - all Arrays are objects
```



Passing by Value vs Reference

The preceding facts have serious ramifications. When variables are reassigned, it is only the data stored within the variable itself, not necessarily its value, that gets reassigned.

```
let x = 42;
let y = x; // y is also 42
x = 27; // y is still 42

let foo = [1,2,3,4]; // foo references [1,2,3,4]
let bar = foo; // so does bar
bar.pop(); // foo and bar BOTH reference [1,2,3]
```

Above, **foo** and **bar** both wind up referencing the same block of memory with the array values. By changing either through a member function, the array values in memory are modified, so **foo** and **bar** are changed!

Passing by Value vs Reference

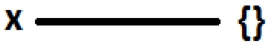
But during assignment, new objects could be created...

```
let x = { };
let y = x; // both reference the empty object

x = { snack: "walnuts and dates" };
```

In the case above, **y** still references the empty object in the end but **x** references the object with **snack**.

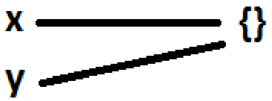
Passing by Value vs Reference

```
let x = {};
```



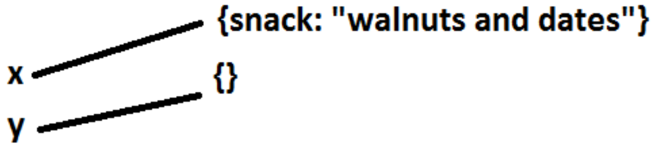
Passing by Value vs Reference

```
let y = x;
```



Passing by Value vs Reference

```
x = { snack: "walnuts and dates" };
```



Passing by Value vs Reference

Functions behave no differently in this regard.

```
function foo(arg1, arg2) {
   // do stuff
   // maybe return stuff
}

foo(x,y);
```

is effectively the same thing as:

```
let arg1=x, arg2=y;
// do stuff
// maybe get a value
```

Primitive variables will be passed by value to a function, objects will be passed by reference.

Document Object Model

Before focusing more upon the JavaScript language, we can look at a few applications of the topics so far. We will study the **Document Object Model (DOM).** This is the organizational scheme used by web browsers to place and style elements and their content. Most of JavaScript interactivity pertains to modifying the DOM.

In the DOM, everything is represented as a tree with nodes. **document** refers to the overall document storing everything.

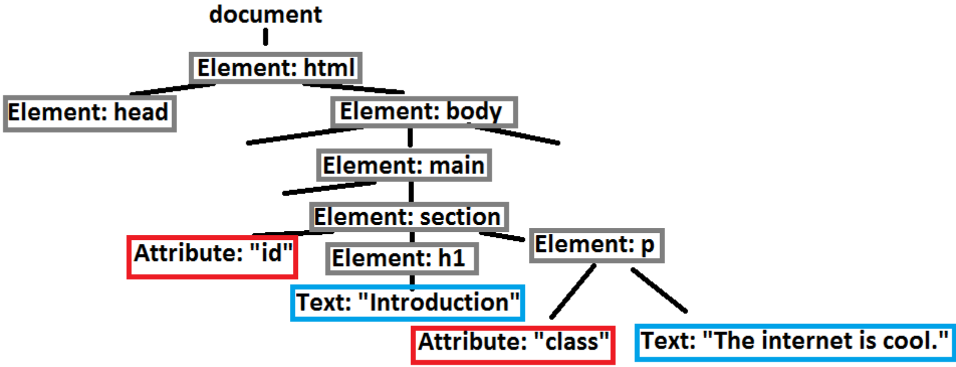
A **node** can be an **element node** (such as p, section, b, etc.), a **text node** (the actual text content), a **comment node**, or an **attribute node** (such as an href, src, etc.).

Danger: any white space is considered a text node!

Document Object Model

Consider

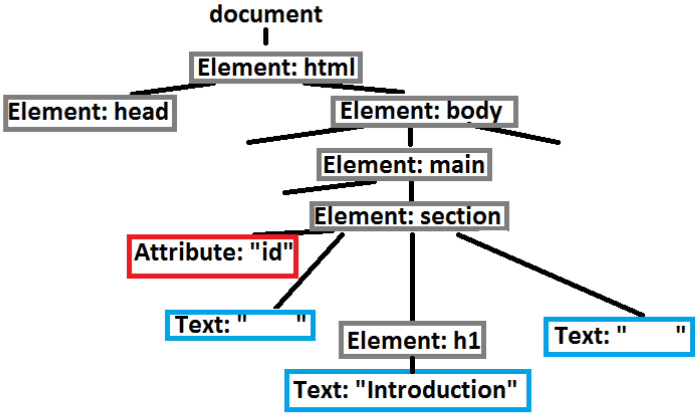
```
<section id="intro"><h1>Introduction</h1><p class="first">The internet is cool.</p></section
    >
```



Document Object Model

We added some white space...

```
<section id="intro">
  <h1>Introduction</h1>
</section>
```



Document Object Model

When JavaScript runs, there is a global variable, **document**, and we can retrieve elements of the DOM by invoking member functions upon it.

The **getElementById** method retrieves the element of the given ID.

The **getElementsByName** method retrieves all elements with a given **name** attribute as an array.

The **getElementsByTagName** method retrieves all the elements of a given type and returns them as an array. An argument of "*" can be used to retrieve all elements.

The **getElementsByClassName** retrieves all elements of a given class value and returns them as an array.

Document Object Model

innerHTML is a member of each element object and the HTML within an element can be (re)set by setting this member.

An element's attribute can be (re)set with the **setAttribute** member function taking the attribute and value as arguments.

We can also retrieve the value of an attribute with the **getAttribute** function, accepting an argument of what attribute value to find.

Warning: writing **document.getElementById("some_input").getAttribute("value")** will only give the value originally placed in the HTML. To get the "live" value, instead write **document.getElementById("some_input").value**.

Document Object Model

onclick is an HTML attribute that can specify what JavaScript method/function to call when it is clicked on.

We can also add **onclick** events to elements in JS. If we have selected the element **e** then:

```
e.onclick = function() { alert('hi'); };
```

adds an onclick method to **e**.

Document Object Model

Consider the HTML

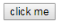
```
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <input type="button" value = "click me" onclick="change();" />
    <p id="first">
    </p>
  </main>
</body>
</html>
```

with **demo.js**

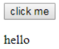
```
function change(){
  document.getElementById("first").innerHTML = "hello";
}
```

Document Object Model

Before clicking the button:



After clicking the button:



Document Object Model

Consider the HTML

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <link rel="stylesheet" href="style.css" />
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <input type="button" value = "click me" onclick="change();" />
    <p>
      Hi
    </p>
    <p>
      Bye
    </p>
  </main>
</body>
</html>
```

with **style.css**

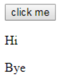
```css
.special{
  font-size: 2em;
  color: red;
}
```

and with **demo.js**

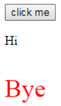
```javascript
function change(){
  document.getElementsByTagName("p")[1].setAttribute("class", "special");
}
```

Document Object Model

Before clicking the button:



After clicking the button:



The **getElementsByTagName** returns an array of all the **p** elements. We then set the **class** attribute of the second paragraph to **special**, which the CSS styles.

Document Object Model

We can set the CSS directly. Given an element node **obj**:

obj.style.property = "value";

where **property** is the CSS property being set and **value** is the new value.

In general CSS properties that used to have - between words become camel-cased: **font-family** becomes **fontFamily**, for example.

Document Object Model

Consider the HTML

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <input type="button" value = "click me" onclick="change();" />
    <p>
      Hi
    </p>
    <p>
      Bye
    </p>
  </main>
</body>
</html>
```

with **demo.js**

```javascript
function change(){
  document.getElementsByTagName("p")[1].style.fontSize = "2em";
  document.getElementsByTagName("p")[1].style.color = "red";
}
```

When clicked, the font size of the second paragraph will double and the font will be red.

Document Object Model

Each node also stores references to some other nodes as members:

- **parentNode** (its parent)
- **children** (all element children as array)
- **firstChild** (an element's first child)
- **firstElementChild** (an elements first element child)
- **lastChild** (an element's last child)
- **lastElementChild** (an elements last element child)
- **nextSibling** (next node that is not a descendent)
- **nextElementSibling** (next element that is not a descendent)
- **previousSibling** (previous node that is not a parent)
- **previousElementSibling** (previous element that is not a parent)

In the preceding example:

```
// references the main
document.getElementsByTagName("p")[0].parentNode;
```

Document Object Model

If **e** is a reference to a radio button or checkbox, **e.checked** is a boolean value. It is true/false when the button has/hasn't been selected.

The selection can also be set by assigning to **e.checked**.

Document Object Model I

We can build a simple countdown printout with HTML

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <p id="counter">
    </p>
  </main>
</body>
</html>
```

and **demos.js**

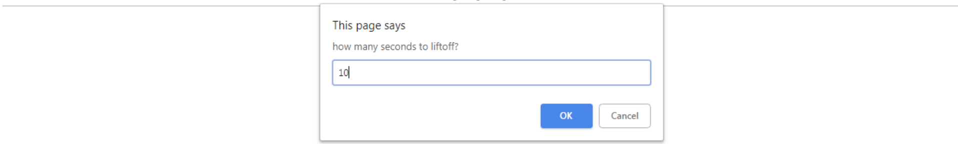
```javascript
/**
This function prints a countdown message for how many seconds until liftoff

@param {Number} time the number of seconds
*/
function run(time){
  let line = "";
  while(time>0){ // until the time is 0
    if(time !== 1){ // if not 1 second, seconds is plural
      line = (time--) + " seconds<br/>";
    }
    else{ // if 1 second, use singular
      line = (time--) + " second<br/>";
```

Document Object Model II

```
    }
    document.getElementById("counter").innerHTML += line;
  }
    document.getElementById("counter").innerHTML += "liftoff!";
}

let input = prompt("how many seconds to liftoff?", "");
run(input);
```

we have a simple page

Before:

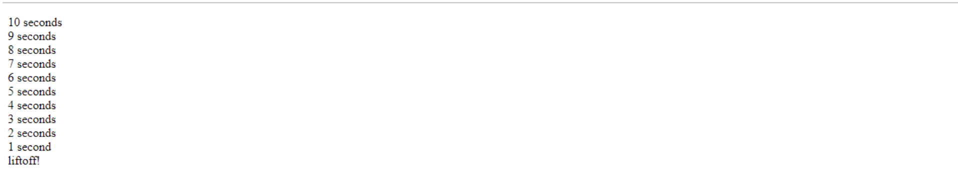

This page says

how many seconds to liftoff?

10

Document Object Model III

After:



```
10 seconds
9 seconds
8 seconds
7 seconds
6 seconds
5 seconds
4 seconds
3 seconds
2 seconds
1 second
liftoff!
```

Query Strings to Prevent Caching

To prevent a web browser from caching files, we can append a **query string** to the end of the file we are including. Then we can update the number each time we update the JavaScript file, just to force the browser to download the file again. This amounts to

```
<script src="demos.js?v=1" defer></script>
<script src="demos.js?v=2" defer></script>
<script src="demos.js?v=3" defer></script>
```

etc.

The **?v=1** is an example of a query string. In this context, it has no effect on the file being downloaded but the browser “thinks” it is different. A query string begins with a **?** and includes **name=value** pairs.

JavaScript Hoisting

Before a JavaScript program begins to run, the JavaScript engine does something called **hoisting.** It secretly moves declarations made with **var** and functions to the top of the execution context.

```
var x = 11;

print(x);
print(y);

var y = 22;

print(y);

function print(a){
  console.log(a);
}
```

The logged output is:

```
11
undefined
22
```

JavaScript Initialization (Hoisting)

Within each execution context, during the **hoisting** phase, all variables declared with **var** are collected and given the value **undefined.** All functions are collected and their instructions are moved to the code memory, which they have access to. Then the program runs.

So, in the preceding example:

1. The engine sets **x** and **y** to **undefined.** *
2. The engine creates instructions to run when **print** is called and **print** references those instructions. *
3. **x** is set to **11**.
4. **print** can print that value.
5. **print** has to print **y**, but that value is still **undefined**.
6. **y** is set to **22**.
7. **print** can print y as **22** now.

*: it might not be specified which of (1) or (2) happens first, but they both happen before the other steps.

JavaScript Initialization (Hoisting)

The *identical concept* applies to all execution contexts. If we ran the same code inside an IIFE, we would get the same output.

```
(function(){
  var x = 11;

  print(x);
  print(y);

  var y = 22;

  print(y);

  function print(a){
    console.log(a);
  }
}
)();
```

JavaScript Initialization (Hoisting)

This is a reason why **let** and **const** are better. You can actually get errors, not strange bugs, when you use such variables before they have been initialized.

```
(function(){
  let x = 11;

  print(x);
  print(y);

  let y = 22;

  print(y);

  function print(a){
    console.log(a);
  }
}
)();
```

We get an error because we used **y** before it was initialized. **y** did not get hoisted.

let and const vs var in Loops

The variables **let** and **const** behave very differently in control flow than **var**.

When **var** is used, there is the usual hoisting so the loop variables created with **var** gain global/function execution context.

When **let** and **const** are used, those variables are only local to the lexical scope, i.e., set of braces { }. In loops with **let** and **var**, for each iteration, a brand new lexical environment is created and a copy of the loop variable is used.

let and const vs var in Loops I

The code:

```
for(var i=0; i < 2; ++i) {
   /* stuff with i, etc. */
}

console.log(i);
```

let and const vs var in Loops II

amounts to:

```
var i; // i is hoisted to entire execution context
{
   i = 0;
   /* stuff */
}
++i;
{
   /* stuff */
}
++i;
console.log(i);
```

let and const vs var in Loops I

The code:

```
for(let i=0; i < 2; ++i) {
   /* stuff with i, etc. */
}
```

let and const vs var in Loops II

amounts to:

```
{
   let i = 0; // only copies of i are used within the loop body!
   {
      let icopy = i;
      /* stuff with icopy when i is being stored/referenced */
      /* stuff with i if i is being modified */
   }
   ++i;
   {
      let icopy = i;
      /* stuff with icopy when i is being stored/referenced */
      /* stuff with i if i is being modified */
   }
   ++i;
} // i ceases to exist outside of loop scope
```

Garbage Collection

In lower-level languages, memory management is often the responsibility of the programmer. In languages like C++, stack memory is managed with a last-in-first-out policy and heap memory management requires the programmer, either directly (by using **new** and **delete expressions** or lower level operations) or indirectly (through using containers of the Standard Library that manage dynamic memory), ensure no memory is being wasted, holding up resources, but not being used.

JavaScript and other higher level langauges like Python and Java have what is called **garbage collection.** This process happens outside of the programmer's control.

Garbage Collection

Periodically, the JavaScript engine runs a garbage collection cycle. It looks for variables and objects that cannot be reached from the global **window** object. Any variables/objects that cannot be reached are destroyed and the memory is freed up.

We consider the code snippet below with 3 places where garbage collection could take place.

```
let person = {
  name: "Peter",
  fav_nums: [17,22];
};

// place 1

(function(){
  let str = person.name;
  let nums = person.fav_nums;
  // place 2
})();

person.fav_nums = [1,2,3];
// place 3
```

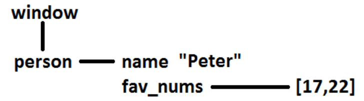
Garbage Collection

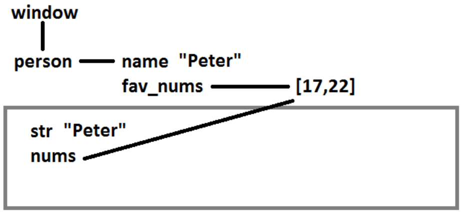
We have the three panels diagramming the memory structure at different points. At first, **person** is the only object. It has a string and array as members. Recall that arrays are objects, which reference their values.

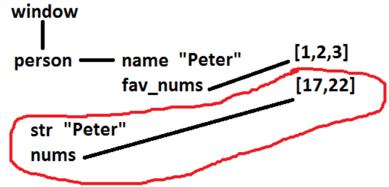
Within the function, we create the new variables **str** and **nums** but since the function is in-use, we don’t destroy them.

After the last line of code, **str** and **nums** cannot be reached. And the values originally referenced by **person.fav_nums** cannot be reached. So garbage collection could free them, circled in red.

Garbage Collection







noscript

JavaScript is wonderful to use but some browsers may not support it or else they may not allow its use. We can use the **noscript** tag to display a message in that case.

```html
<!-- DOCTYPE, html, head stuff -->
<body>
<noscript>
Your browser does not support JavaScript. Parts of this page may not work for you as
     intended.
</noscript>
<!-- other stuff -->
</body>
</html>
```

this

In JavaScript, **this** is a reserved keyword that can mean different things, depending where it appears. It always references an object, possibly the global **window** object, possibly another object.

When it appears globally, it references **window**.

```
this.foo = "bar"; // adds foo property to window, value = bar
console.log(this); // same as console.log(window)

var x; // adds x property to window
let y; // does not add y property to window
```

When a variable is declared globally with **var**, it is added to the **window** object. This does not happen with **let**.

this

When **this** sits directly inside a method (member function), it is a reference to that object.

```javascript
let person = {
  name: 'Alice',
  friend: 'Bob',
  change_friend: function(new_friend){
    this.friend = new_friend;
  }
}

person.change_friend("Connie"); // now person.friend is "Connie"
```

But when **this** sits directly inside a free function, it references the global object.

```javascript
function display_window(){
  console.log(this); // logs the window
}
```

this

This actually causes a lot of confusion and a lot of programmers consider behaviour like this a bug (as opposed to a feature...).

```javascript
let obj = {
  x: 0, // obj.x will be a special value
  update: function(){
    // setTimeout can take a function as an argument
    // in 1000 ms, we intend for obj.x to be 42...
    setTimeout( function() { this.x = 42}, 1000 );
  }
};
```

We will discuss **setTimeout** shortly. But the function argument it accepted is supposed to change **obj.x** to **42**. Instead, we added a variable **x** to the global **window** environment at set it to 42!

this

A workaround many programmers use is to create a **self** variable within a function and use that instead of **this**.

```
let obj = {
  x: 0, // obj.x will be a special value
  update: function(){
    let self = this; // so self means obj...
    setTimeout( function() { self.x = 42}, 1000 );
  }
};
```

The variable **self** is defined directly inside the method rather than inside the anonymous function and where it is defined **this** does still mean the object.

The Scope Chain

The global environment, the body of each function, and the contents within braces {} form what are called **lexical environments.** When a variable name is used, the local environment is searched first for that variable; if it is not found, JavaScript looks for the variable in the enclosing environment; if not found there, it goes to the enclosing environment, etc., etc. etc. If the variable is not found at all then we have an error.

```
let a = 7;
let b = 70;
let c = 700;

function foo(){
  let b = 8;
  let c = 80;
  function bar(){
    let c = 9;
    console.log(c); // finds the c in bar
    console.log(b); // finds the b in foo
    console.log(a); // finds the global a
    console.log(w); // will not find w
  }
  if(true){ // execute body since true is true :)
    let w = 10; // only local with let and no hoisting!
  }
  bar();
}

foo(); // prints 9, 8, 7, then gives error
```

Closures and this

A **closure** is a way for a function object to preserve its environment, even when those environment values cannot be reached by other parts of a program.

```javascript
function greet(salutation, name){
  let message = salutation + " " + name;
  return function(){
    alert(message);
  };
}

// both variables are functions
let greet_john = greet('howdy', 'John');
let greet_jane = greet('heya', 'Jane');

greet_john(); // alerts "howdy John"
greet_jane(); // alerts "heya Jane"
```

Closures and this

There are some conceptual hurdles here. First of all, remember that functions are objects. It’s perfectly legit to return a function object from **greet**. That function object alerts a greeting.

More fundamentally, though, notice that **message** is created local to the **greet** function, each time it is called. And the anonymous function returned is supposed to use **message** in the alert box. So how does that work?...

The answer is **closures**. Although **message** cannot be referenced outside of **greet**, the function returned by **greet** keeps a reference to the spot in memory where the greeting is stored. So everything just works.

Syntax

The JavaScript syntax can be quite forgiving.

In JavaScript, a semicolon is not required to end a statement. Because the language is interpreted, when the JavaScript engine encounters a new line in the code, it may/may not insert a semicolon, depending on whether it thinks one belongs.

When, as the program is parsed from left to right, a token (called the offending token) is encountered that is not allowed by any production of the grammar, then a semicolon is automatically inserted before the offending token if one or more of the following conditions is true: The offending token is separated from the previous token by at least one LineTerminator [...,] The offending token is } [... or] The previous token is) and the inserted semicolon would then be parsed as the terminating semicolon of a do-while statement ~ECMAScript Language Specification

Syntax

```
function get_best_number_ever(){
  return
  22;
}

console.log( get_best_number_ever() ); // undefined
```

With this code, a semicolon is inserted after the return statement.

Remark: just as a programming practice, it is best to include the semicolons to make statement intents clearer. Seldom does the semicolon insertion actually lead to a bug.

More DOM Manipulations I

JavaScript allows us to create new elements and text nodes with **createElement** and **createTextNode**.

```
let new_p = document.createElement("p"); // make a new p element

// new text node
let p_words = document.createTextNode("paragraph text");
```

The **appendChild** function adds a new child node to a given node.

```
let some_article = document.getElementById("the_article");
some_article.appendChild(new_p);
new_p.appendChild(p_words);
```

More DOM Manipulations I

There are also **insertBefore** to insert one node (first argument) before another (second argument) and **replaceChild** to overwrite the node specified as second argument by the node specified by the first argument.

```
let newer_p = document.createElement("p");
let more_words = document.createTextNode("words that come before");

some_article.insertBefore(newer_p, new_p);
newer_p.appendChild(more_words);
```

More DOM Manipulation I

Here’s an example using this new syntax.

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <input type="button" value = "click me" onclick="change();" />
    <div></div>
  </main>
</body>
</html>
```

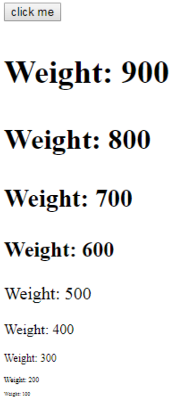
and **demos.js**

```javascript
function change(){
  // get the only one
  let div_node = document.getElementsByTagName("div")[0];

  // i represents font weights and scaled font sizes
  for(let i=100; i <= 900; i+=100){ // let it range from 100 to 900
    let new_p = document.createElement("p");
    let label = document.createTextNode("Weight: " + i);

    new_p.appendChild(label);
    new_p.style.fontWeight = i;
    new_p.style.fontSize = (i/400) + "em";

```

More DOM Manipulation II

```
    let first_child = div_node.firstChild;

    if(first_child === null){ // if div has no children
      div_node.appendChild(new_p); // add the child
    }
    else{ // if it has children
      div_node.insertBefore(new_p, first_child); // make this new first
    }
  }
}
```

More DOM Manipulation III



Weight: 900

Weight: 800

Weight: 700

Weight: 600

Weight: 500

Weight: 400

Weight: 300

Weight: 200

Weight: 100

Control Flow: for ... of

For iterable containers such as arrays, strings, etc., we can iterate through the containers with the **for ... of** loop.

```
let arr = [2,'hello',3.14];
for (let e of arr) { // for every element e of arr
   console.log(e);
}
```

We go through each element of the array, call it **e** (or some other name) temporarily, and log it.

In C++, it is the same thing as the range-for loops:

```
// suppose container is a set/vector/array/etc.
for( const auto& e : container) {
  std::cout << e << '\n';
}
```

Control Flow: for ... of

Remark: it is a little different for containers with key-value pairs. The **for ... of** would take the form:

```
for(let [key_name, value_name] of the_map) { ... }
```

Control Flow: for ... in

Warning: there is also a **for... in** loop in JavaScript, but it is not suitable for iterating over values of a container. Do not confuse the two or strange things can happen.

for ... in goes through all properties; **for ... of** goes through iterables.

```
let arr = ['foo', 'bar'];
arr.x = 9;

// prints iterable elements
for(let i of arr) {
   console.log(i); // prints 'foo'and 'bar'
}

// prints the properties: indices 0, 1, and x
for(let i in arr) {
   console.log(i); // prints 0, 1, x '
}
```

Other Useful Classes

JavaScript has **Set**s, **Map**s, and other structures. They are similar conceptually to those in C++, having unique values and keys, respectively, but these containers are not sorted by value/key: they are sorted by the insertion order.

They are worth looking up if needed. Here's just a preview of some of their syntax/functions:

```
// start empty (or put array in parentheses to give values)
let s = new Set();

s.add(3);
s.add('hello'); // stores two elements now
s.has(7); // false, not in the set
s.delete(3); // now 3 is gone
s.size; // 1
```

Other Useful Classes

```
// m has ’a’==>9, ’b’==>11 as key==>value pairs
let m = new Map([[’a’,9],[’b’,11]]);

m.get(’a’); // 9, get the value
m.delete(’a’); // ’a’==9 gone
m.size; // 1

for( let [key, val] of m ) { // print everything
   console.log( key + ': ' + val );
}
```

The loop prints:

```
b:  11
```

Math

Math is a global object with many useful member functions. The following functions are found within **Math**:

- **abs** (absolute value)
- **sin, cos, tan** (sine, cosine, tangent)
- **exp, log** (natural exponential, natural logarithm)
- **pow** (raises first argument to power of second argument)
- **random** (takes no arguments, returns value on $[0, 1)$ - 0 included but 1 not)
- **round** (rounds to nearest integer)
- **ceil, floor** (integer ceiling and floor functions)

For example:

```
let x = Math.random(); // will be between 0 and 1
let die_roll = 1 + Math.floor(6*x); // will be 1,2,3,4,5, or 6
```

new

In JavaScript, the **new** keyword can be used in conjunction with a function call. In such cases, we are invoking the function as a constructor to create a new object.

Unless **new** is used, the function may not return an object.

new

In programming, a **constructor** is a function that makes an object.

When a function is called with the **new** keyword, it becomes a constructor for an object. An empty object is created and passed to the function with the special name of **this**.

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

let joe = new Person("Joe"); // joe.name === "Joe"
```

Within the function, because **new** was used, there is an object called **this** that starts empty and has a **name** property added. This object is returned.

Date

In JavaScript, there are **Date** objects that can be constructed by invoking the **Date** constructor.

Internally, JavaScript stores dates in milliseconds since January 1, 1970, 00:00. Here are a few ways to construct dates:

```
let now = new Date(); // no arguments, get current date+time
let start = new Date(0); // one argument = number of milliseconds
let new_year = new Date(2019,0,1);
```

By supplying more than one argument, we specify the **year**, **month**, **day**, **hour**, **minute**, **second**, and number of extra **milliseconds**, with defaulted values of 0 supplied.

Months are indexed mod 12 from 0 = January to 11 = December!

Date

Dates can also be constructed with an International Organization for Standaridization (oddly abbreviated ISO) date: "yyyy-mm-dd":

```
let solstice = new Date("2018-11-21");
```

There are also getting and setting methods:

- **setDate** sets day value
- **setMonth** sets month value (0-11 for Jan-Dec!)
- **setFullYear** sets year value
- **setHours** sets hours
- **setMinutes** sets minutes
- **setSeconds** sets seconds
- **setMilliseconds** sets milliseconds
- **setTime** sets milliseconds since Jan 1, 1970, 00:00

Likewise, there are **getDate**, etc., versions.

```
solstice.setHours(16); // at 4 pm
```

Other Useful Classes

Remark: primitives like string, number, and boolean are not objects. There are, however String, Number, and Boolean wrapper objects. These are classes that wrap around the primitives and give them different functionality.

Most of the time, we should avoid using these wrapper objects because they can make code more error prone and less efficient. But for conceptual completeness, code lines like those below implicitly created objects for us:

```
"hello".length; // makes a String objects from "hello" so it has a length

let a = "12";
let b = Number(a);

let c = b.toString(); // make b into a Number object to call function
```

Timers

With JavaScript, we can set a process to run/be repeated after/every some time in milliseconds. For this, we use **setTimeout** and **setInterval**, respectively.

Both of these functions take two arguments: a function object for the process to run and the time interval in milliseconds. They both return an id of the event.

There are also **clearTimeout** and **clearInterval** functions that accept an event id and cancel the process(es).

Timers I

With HTML

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>JS Demos</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <p id = "text">
      This text will change in size every so often.
    </p>
    <form>
      <fieldset>
        <label for="sec">Time in seconds: </label>
        <input type="text" id="sec" value="" />
      </fieldset>
      <fieldset>
        <input type="button" value="start" onclick="start_changing();" />
        <input type="button" value="stop" onclick = "stop_changing();" />
      </fieldset>
    </form>
  </main>
</body>
</html>
```

and **demo.js**

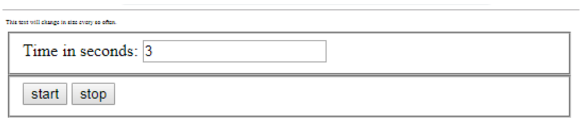
Timers II

```
// params acts as a namespace for properties
let params = {
  event_id: null,
  millisec_per_sec: 1000,
  scale_range: 5
};

function start_changing(){
 if(params.event_id){ // do not double-up on event timers
   clearTimeout(params.event_id);
 }

  let interval = document.getElementById("sec").value * params.millisec_per_sec;

  // does the resizing
  function to_repeat(){
    let scale = Math.random()*params.scale_range;
    document.getElementById("text").style.fontSize = scale + "em";
    call_back();
  }

  function call_back(){
    // call the resizing function
    params.event_id = setTimeout(to_repeat, interval);
  }

  call_back(); // start the process
}

function stop_changing(){
  if(params.event_id){ // make sure event has been set, null becomes false
    clearTimeout(params.event_id);
```

Timers III

```
        }
    }
```

we have a page where the size of the text changes to a random scaled value from 0-5 with a period in seconds specified by the user.



This text will change in size every so often.

Time in seconds: 3

Timers

Due to the possibility of a function call causing an error or time-intensive processes being called more often than necessary (when they should, ideally, wait for another process), **setTimeout** is considered better practice than **setInterval.**

One can always bring about the desired effect by a function calling itself or another function that calls it using **setTimeout.**

Note how we avoided multiple global variables by encompassing the variables in a single object called **params** that serves as a namespace.

Synchronous vs Asynchronous

The term **synchronous** refers to carrying out one task at a time, in the order received, whereas **asynchronous** refers to carrying out multiple tasks/processes at once.

Fundamentally, JavaScript is synchronous. Each time it processes an event, it loads all the necessary functions onto the call stack (how programs keep track of what to do next) and runs those processes to completion, leaving the call stack empty. Then it can process another event. It happens one at a time!

However, the language has features that give it asynchronous behaviour, too.

Synchronous vs Asynchronous

Functions such as **setTimeout** and **setInterval** are given a **callback** function and a time delay/period. Their callback functions are only invoked when the call stack is empty and when the timer has queued up the callback. This means that the time interval we specifiy is a minimum time to wait for/between callbacks, not the precise time.

Consider the HTML paragraph

```html
<p id="msg"></p>
```

with a JavaScript program as follows:

```javascript
(function(){

  setTimeout( function(){
    document.getElementById("msg").innerHTML += "one<br/>";
    }, 0);

  for(let i=1; i <= 1000; ++i){
    // do nothing, just waste time...
  }

  document.getElementById("msg").innerHTML += "two<br/>";

})();

document.getElementById("msg").innerHTML += "three<br/>";
```

Synchronous vs Asynchronous

At the end of the day, the paragraph will store:

```
two
three
one
```

Even though we specified a timeout of 0 seconds with a request of adding "one" to the paragraph, followed by a long loop, and then later requested to add the "two".

Within the IIFE, the **setTimeout** function was called, and it made a record of the callback function and the time.

At this point, the call stack is not empty. So JavaScript runs the loop and also adds "two" to the paragraph. Even after the IIFE, the call stack is still not empty so the "three" gets added.

Finally, the call stack is empty so the callback function runs, adding "one".

Events

In JavaScript we can specify what events are to take place when the page has loaded by giving a value to the **window.onload** variable. Assigning a function to this member ensures that function is executed once the page has been rendered, the images are in place, etc.

Here is a simple JavaScript program:

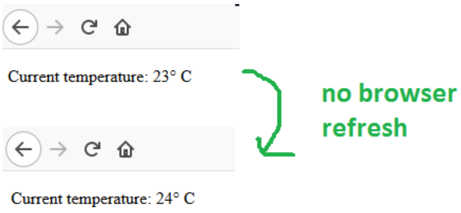
```
window.onload = function(){
  alert("hello");
}
```

AJAX

Asynchronous Java Script and XML (AJAX) is a way of extracting information from files and other resources while a user is on a page. As the desired data are updated, this can be reflected on the page they visit, without a need for them to refresh.

We'll consider a very simple case study. Imagine we have a website that is supposed to tell the visitors the current temperature. There is a text file that gets updated periodically with the temperature. We want the visitors to see the temperature displayed on the webpage update when/if that text file gets updated...

AJAX


Current temperature: 23° C

Current temperature: 24° C

AJAX I

Here is our HTML (super simple):

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>AJAX Demo</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <p id="msg">
      Current temperature: <span id="temp"></span>&deg; C
    </p>
  </main>
</body>
</html>
```

---

and the JavaScript file:

```javascript
/**
This function creates an object to manage updates to the temperature file
@param {string} file the name of the file
@param {string} element the id of the element to update
@return an object that tracks the file name, element id, current temperature, and length
for the timeout to wait
*/
function Temperature(file,element){
  this.file_name = file;
  this.element_id = element;
  this.temp = null;
  this.interval = 5000; // so 5 sec intervals
```

AJAX II

```
}

/**
This function performs an AJAX call to update part of the HTML page
@param {object} updater a Temperature object
*/
function read_text(updater){
  let xhttp = new XMLHttpRequest(); // object to do ajax with

  // when the operation is complete (readyState 4) and it is successful ( status 200)
  xhttp.onreadystatechange = function() {
    if (this.readyState === 4 && this.status === 200) {
      // change HTML to store what came back
      set_value(updater.element_id, this.responseText);
      setTimeout(read_text, updater.interval, updater);
    }
  };

  // set GET request to read from the file, doing it 'asynchronously'
  xhttp.open("GET", updater.file_name + "?v=" + Math.random() , true);
  xhttp.send(); // do it!
}

/**
This function changes the value of the text within an element
@param {string} id the id of an element
@param {string} value the value to place inside
*/
function set_value(id, value){
  document.getElementById(id).innerHTML = value;
}

```

AJAX III

```
// when the window loads
window.onload = function(){
  let updater = new Temperature("temp.txt","temp");
  setTimeout(read_text, updater.interval, updater);
};
```

Here's what we did: we created a global object, **Temperature**, effectively serving as a namespace, to store the timer's event ID, the file to read from, the ID of the element we want to change, and the current temperature.

When the page loads, we perform two processes: we make a **Temperature** variable to store relevant data and set **read_text** as a callback.

read_text sets itself as a callback so that it will be repeated. Both **setInterval** and **setTimeout** can be given third, fourth, ... arguments. The extra arguments beyond the second are used as inputs to the callback function.

AJAX IV

The **set_value** function just looks up an element by ID and inserts the text directly there.

The bulk of the work happens in the **read_text** function. For that we need to discuss the **XMLHttpRequest** object type...

AJAX

From what we see in the example, an **XMLHttpRequest** object has a member, **onreadystatechange**, a callback, that gets called whenever the ready state changes.

When the state changes, provided retrieving the data was successful, we update **data.temp** with the response of the request, stored in the **responseText** member of the **XMLHttpRequest** object.

The **status** member will be 200 if successful.
The **readyState** will be 4 when it is done (3 = in progress, 2 = send has been called, 1 = open has been called, 0 = open not yet called).

AJAX

We call the **open** function to ask the object to perform a **get** request (recall there are different types of requests) from the file **data.file**, and we want the process to occur asynchronously (so other processes can go on). The query string in the file name prevents the browser from caching the results of an old file.

Calling **send** sends the request.

Events

We can also add **event listeners** so various processes are run based on the user triggering them, such as by them mousing over a paragraph, clicking a button, pressing a character on the keyboard.

The syntax is:

element.addEventListener("event", callback);

where "event" is the event with common values "click" (when clicked), "mouseover" (when the mouse moves over the element), "mouseout" (when the mouse moves off the element); and **callback** is a function object.

Events

To listen for keys that are pressed, we add an event listener to the **window.document** variable (or just "document").

```
document.addEventListener('keypress',
  function(event){
    alert(event.key + " was pressed")
  }
);
```

The key pressed will be stored as a member variable **key.**

Danger: keydown occurs when a key is pressed down, **keyup** occurs when a key is released, and **keypress** occurs with down and up together.

The arrow keys (up/down/left/right) are only triggered with **keydown**!

Cookies

A **cookie** is a small text file your browser stores when you visit a webpage. When you next visit the page, you may be "remembered" and find your name can still be automatically filled in, etc.

Cookies are created with the syntax:

document.cookie = "name=value; expires=Date of expiry; path=relative path";

where **name** is a property and **value** is its value, **expires** specifies when the cookie is forgotten, and **path** specifies the relative directories in the website where the cookie is valid.

Cookies

By default, **expires** is set to when the browser is closed. By default **path** is set to "/".

If "/" is given for a path, the cookie is valid throughout the entire website; if "/folder" is given, it is valid in "/folder" and all subfolders, etc.

The current working directory can be obtained from **window.location.pathname**. Using this as the path ensures the cookie is only valid in the subfolder (and folders below) in which it is found.

Cookies

Multiple name-value pairs can be stored within the **document.cookie**: it is not a regular string! Each time we assign to it, it could store more and more information.

To delete a cookie, we assign to the **document.cookie** a value for name (can be anything or blank) and an **Date** object for expiry in the past.

Warning: do not ever use **Date(0)** for an expiry time. Some browsers use this as the default expiry (when the browser closes). The cookie may not expire!!!

Cookies

In working with cookies, the **split** method of **String** is quite useful. A string object can be broken into an array at a designated splitting character.

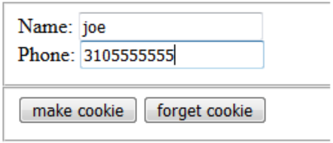
```
let str = "name=John; phone=3105555555;";
let arr = str.split(';'); // arr == ["name=John", " phone=3105555555", ""];
```

Cookies

We will consider a simple case study: a form that can track a user's name and phone number. There are buttons that can toggle between remembering the information and forgetting it.

The user can enter their name and phone and ask for this to be remembered.

When the page loads, if the cookie is being remembered, the name and phone fields get filled in automatically. If the cookie has expired (after 1 minute) or the user asks for the information to be forgotten, the next reloading of the page will find those fields empty.



Name: joe
Phone: 3105555555

Cookies I

Here is our HTML:

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>Cookie Demo</title>
  <script src="demos.js" defer></script>
</head>
<body>
  <main>
    <form>
      <fieldset>
        <label for="name">Name: </label> <input type="text" id="name" /> <br/>
        <label for="name">Phone: </label> <input type="tel" id="phone" /> <br/>
      </fieldset>
      <fieldset>
        <input type="button" onclick="make_cookie();" value="make cookie" />
        <input type="button" onclick="forget_cookie();" value="forget cookie" />
      </fieldset>
    </form>
  </main>
</body>
</html>
```

and here is our JavaScript:

Cookies II

```
/**
This function makes a cookie out of the user data.
It expires in one minute.
*/
function make_cookie(){
  let user_name = document.getElementById("name").value;
  let cookie_name = "name=" + user_name + ";";
  let user_phone = document.getElementById("phone").value;
  let cookie_phone = "phone=" + user_phone + ";";

  let now = new Date(), expires = now;
  expires.setMinutes(expires.getMinutes()+1);
  let cookie_expires = "expires=" + expires.toUTCString() + ";";

  let cookie_path = "path=" + window.location.pathname;

  document.cookie = cookie_name + cookie_expires + cookie_path;
  document.cookie = cookie_phone + cookie_expires + cookie_path;
}

/**
The user info is removed from the cookie.
*/
function forget_cookie(){
  let past = new Date(1); // 1 ms since the "beginning of time"
  past = past.toUTCString();
  document.cookie = "name=; expires=" + past + "; path=" + window.location.pathname;
  document.cookie = "phone=; expires=" + past + "; path=" + window.location.pathname;
}

window.onload = function(){
  let fields = ["name", "phone"];
```

Cookies III

```
    let cookie = document.cookie.split(';');

    for(let field of fields){ // go through each field to populate
      for(let part of cookie){ // look at all parts of the cookie
        let pieces = part.split('='); // split that, the right part

        if(pieces.length===2){ // so enough parts

          while(pieces[0][0] === ' '){ // while whitespace at start
            pieces[0] = pieces[0].substr(1); // remove it!
          }

          if(pieces[0] === field){ // if field found within part
            document.getElementById(field).value = pieces[1];
            break;
          }
        }
    }
  }
```

Cookies

Before panicking about security, it is important to note that most websites **do not** store passwords in a cookie!

After a user logs in, a cookie with an identification number attribute may be given to that user. Valid id numbers such that a user should still be "logged in" are stored in a database that the outside world should not have access to.

Warning: some browsers such as **Chrome** strictly interpret **Date**s as UTC Strings. As an extra step we had to convert the value of **expires** to a UTC String time otherwise it will not work in Chrome.

Redirect

If we want to redirect someone, we simply set the **window.location** property:

To redirect to external link, provide full URL with **http:**

```
window.location = "http://www.math.ucla.edu";
```

To redirect to relative directory/page:

```
window.location = "imgs/cat.png";
```

Object Oriented Programming

JavaScript can be implemented as an object oriented language. Here we’ll look at more specifics of creating constructors and classes.

JavaScript adheres to **prototypal inheritance**, which is different to the **classical inheritance** of languages like C++, Java, and Python.

With classical inheritance, we have the notion of a class, which is more abstract and distinct from instances of a class.

In prototypal inheritance, there are no such thing as "classes": everything is an object (even functions, remember!). All objects have a prototype object that in turn can reference another object as its prototype. An object has access to all of its own properties, plus any that can be reached by looking to its prototype, or its prototype’s prototype, etc.

Remark: it really is "prototypal inheritance", not "prototypical inheritance"!

Object Oriented Programming

Recall our example of writing a **Person** constructor.

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

We will now consider adding methods.

Object Oriented Programming

Member functions could be handled in a similar way as adding properties to an object by having a **this.function_name = some_function_object;** in the constructor. But that would be inefficient and not make use of the power of prototypal inheritance.

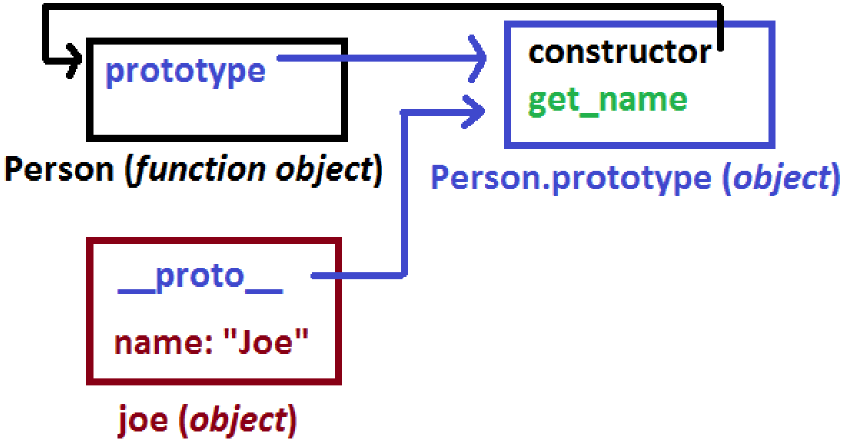
Instead, we add a property to the object's prototype. Remember that **Person** is an object...

```
Person.prototype.get_name = function() {
   return this.name;
}
```

Now we can extract the **name** of **joe** via **joe.get_name();**.

Object Oriented Programming

All non-function objects have a **__proto__** property and it corresponds to the prototype of the constructor that created the object.



Object Oriented Programming

To allow for an object **B** to inherit from **A**, i.e., have as its prototype, the prototype of object **A**, we use:

```
B.prototype = Object.create(A.prototype);
```

This creates an empty object whose prototype is that of **A**’s prototype, and this object serves as the prototype for **B**. This should take place before any prototype values of **B** are added.

This will make the B’s prototype’s constructor to be **A** so we overwrite this with:

```
B.prototype.constructor = B;
```

Object Oriented Programming

Within the **B** constructor function, to call the **A** constructor, i.e., to add **A** properties to the **this** of **B**, we write

A.call(this, list of arguments);

We'll look at an example with Squares and ColouredSquares...

Object Oriented Programming I

We'll write the JavaScript "equivalent" of the C++ classes below:

```
struct Square{
 double length;
 Square(double _length) : length(_length) {} // (A)
 double get_area() const {return length*length;} //(B)
};

struct ColouredSquare : public Square{ // (C)
 std::string colour;
 ColouredSquare(double _length, std::string _colour):
  Square(_length), colour(std::move(_colour)){} // (D)
 void display() const { // (E)
  std::cout << colour + " square of area "
   << get_area() << '\n';
 }
};
```

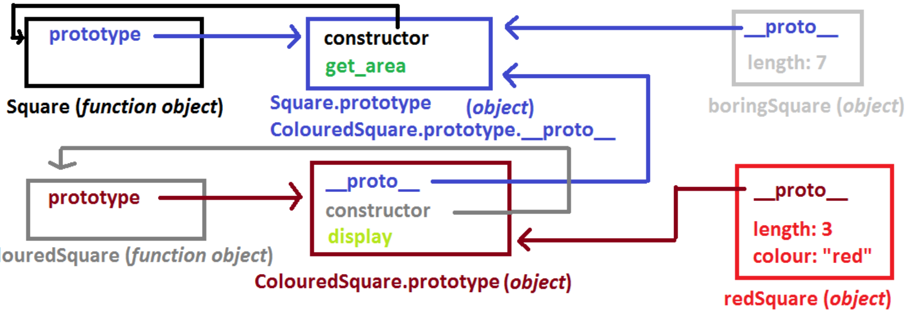
Object Oriented Programming I

Note the correspondences between the marked points (A)-(E) in the two languages.

```
function Square(_length){ // (A): define Square constructor
  this.length = _length; // add property
}

function ColouredSquare(_length, _colour){ // (D): define ColouredSquare constructor
  Square.call(this,_length); // initialize Square properties
  this.colour = _colour; // add ColouredSquare properties
}

Square.prototype.get_area = function(){ // (B): define member function
  return this.length*this.length;
};

ColouredSquare.prototype = Object.create(Square.prototype); // (C): inherit Square methods
ColouredSquare.prototype.constructor = ColouredSquare; // constructor is ColouredSquare

ColouredSquare.prototype.display = function(){ // (E): add ColouredSquare member function
  console.log(this.colour + " square of area " + this.get_area());
};

let boringSquare = new Square(7);
console.log(boringSquare.get_area()); // 49
let redSquare = new ColouredSquare(3,"red");
redSquare.display(); // "red square of area 9"
```

Object Oriented Programming I

Here's a diagram of what we have done.


prototype
constructor
get_area
__proto__
length: 7
Square (*function object*)
Square.prototype (*object*)
ColouredSquare.prototype.__proto__
boringSquare (*object*)
prototype
__proto__
constructor
display
__proto__
length: 3
colour: "red"
ColouredSquare (*function object*)
ColouredSquare.prototype (*object*)
redSquare (*object*)

When we call **redSquare.display()**, such a property is not part of **redSquare** so JS looks to its prototype object, which does. When we call **redSquare.get_area()**, such a property is not part of **redSquare** so JS looks to its prototype object. The prototype does not have this method so JS looks at its prototype object which does have **get_area**.

Object Oriented Programming

Remark: the ES6 did introduce the **class** keyword in JavaScript giving programmers the syntactic sugar of writing classes like other programming languages. But it does not change what is going on "under the hood". The preceding presentation of inheritance was done in an effort to keep the concept as clear as possible, without glossing over those important details.

Symbols for Privacy I

Symbols can be used to add privacy to an object. To do this properly, **proxy** objects are required. We won't get into that. Here's just a simple illustration:

```
let person = {
  name: 'Jasmine'
};

{ // p is local to this scope
  let p = Symbol('password');

  person[p] = 'foo';
}

for (let i in person){
  console.log(i + ': ' + person[i] ); // no password!
}
```

In the example above, there are still means of accessing the symbol. But it is harder because symbols do not show up in **for ... in** loops.

JavaScript Coding

Before some the final topic, we will look at a number of important style points for JavaScript programming. Many of these points apply to all programming languages, but this list concisely summarizes "good practice".

For readability...

- Comment code.
- Comment every branch of control flow.
- Document functions in the prescribed manner.
- Use descriptive variable names.
- Avoid "magic numbers" and define those values as variables.
- Space out the code nicely.

JavaScript Coding

For robustness and efficiency:

- Always use the semicolons.
- Include braces for all control flow.
- Use === and !==, not == or !=.
- Use an object to serve as a namespace instead of polluting the global environment.
- Use an IIFE to avoid polluting the global environment.
- Use **const** and **let** instead of **var** to avoid hoisting variables to the lexical scope.
- Avoid objects such as **new Number**, **new Boolean**, etc.: use the primitives instead.
- Debug code! Ensure it works.
- Use **defer** for the script tags.

jQuery

A useful JavaScript library is **jQuery.** It makes a lot of operations and syntax from regular "pure" JavaScript a lot shorter and simpler. In addition, it makes writing functional code across web browsers simpler because it manages "edge cases" like what to do for Internet Explorer...

It is JavaScript, however!

This is a very brief overview of some of its features since JavaScript has already been introduced.

jQuery

To access jQuery, one needs to link to the library:

```html
<!DOCTYPE html>
<html>
<head>
  <meta charset="utf-8" />
  <title>JQuery Demo</title>

  <script
  src="https://code.jquery.com/jquery-3.3.1.min.js"
   defer></script>
  <!-- other stuff -->
```

This may take some searching for "most current JQuery library link". It is best to choose the "minified" version so it can be downloaded faster.

jQuery - Selectors

In jQuery, there is a friendly object called **$.** Here are some things we can do with it:

$('foo'): references ALL elements with tag of **foo**, not just an awkward array

$('#bar'): references ALL elements (should just be one) with id **bar**

$('.baz'): references ALL elements of the class **baz**

$("quuz[name='blarg']"): references ALL quuz elements with name **blarg**

jQuery - Events

$(function_object): invokes the function **function_object** when the document has loaded, much like specifying the **window.onload.**

We can add click event listeners:

$(’#id’).click(function_object);

or what to do as a mouse moves over and off an element with the **hover**:

$(’#id’).hover(function_move_in, function_move_out);

jQuery - Edits

If **e** is a node (or group of them) then with JQuery:

e.html(); // returns the html an element
e.html(’blah’); // sets the html within all to blah

e.attr(’foo’); // returns the value of the foo attribute of element
e.attr(’foo’,’bar’); // sets the value of the foo attribute to bar for all

e.css(’property’); // returns value of given CSS property of element
e.css(’property’, ’value’); // sets the value of the CSS property for all

e.val(); // gives the value in e if it is an input field, say
e.val(’foo’); // sets the value in e to foo

e.eq(n) // returns a reference to the element at index n of e

jQuery Example I

With the HTML file

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>jQuery Demo</title>
  <script src="https://code.jquery.com/jquery-3.3.1.min.js" defer></script>
  <script src="demos.js" defer></script>
</head>
<body>
  <main id="the_main">
    <p id="p1">first</p>
    <p id="p2">second</p>
    <p id="p3"></p>
  </main>
</body>
</html>
```

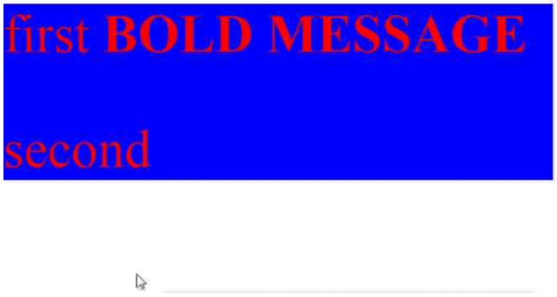
and JavaScript file

jQuery Example II

```
$(
function(){
  $('p').css('color','red'); // all p's are red
  $('#the_main').css('background-color','blue'); // main background color

  let p1 = $('#p1'); // insert more into the p1
  p1.html(p1.html() + " <b>BOLD MESSAGE</b>");

  $('#the_main').hover(
    function(){ // when the mouse moves over
      $('#p2').html("mousing over");
    },
    function(){ // when the mouse moves out
      $('#p2').html("mousing out");
    }
  );
}
);
```

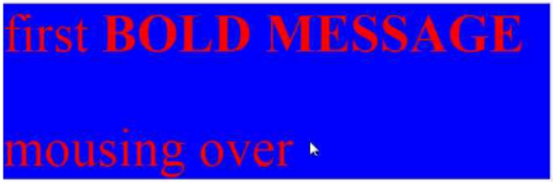
we have the simple functionality illustrated:

jQuery Example III


first **BOLD MESSAGE**

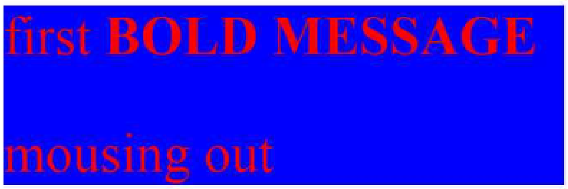
second

jQuery Example IV


first **BOLD MESSAGE**

mousing over

jQuery Example V


first **BOLD MESSAGE**

mousing out

jQuery - AJAX

It even makes AJAX calls easier:

```
$.ajax({
  url : "file.txt",
  dataType: "text",
  success : function (data) {
    $("#my_element").text(data);
  }
});
```

We call the **ajax** function of **$** and pass it an object.

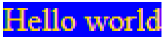
The object has a **url** property for where to look for data, a **dataType** property for what data it will receive, and a **success** property, a callback, for what to do when there is success. In this case, it sets the HTML of the element of ID **my_element** to the text within the file.

Much More: Custom Elements

This was barely an introduction to JavaScript. It is a very deep language with many more features. It can even do the back-end work in the form of **Node.js** as an alternative to PHP (next topic).

We could make our own HTML elements. Such elements must contain a dash in their name:

```
let SpecialQuote = document.registerElement('special-quote');
let quote = new SpecialQuote();
quote.style.backgroundColor = 'blue';
quote.style.color = 'gold';
quote.innerHTML = 'Hello world';
document.getElementsByTagName('body')[0].appendChild(quote);
```


Hello world

Much More: Custom Elements

The **document.registerElement** function that returns an element constructor is about to be deprecated by a **customElements.define** function. Unfortunately the new function is harder to use and many web developers feel it is a step backwards.

Much More: String Interpolation

By enclosing a string in **backtics** (tick mark on tilde key), prepending a variable with **$** and enclosing it in braces, a variable can be interpolated as a string.

```
let x = 111;
let y = `The value of x is ${x}.`;
alert(y); // alerts: "The value of x is 111."
```

PHP will do similar things when we study it.

Much More: Regular Expressions

JavaScript supports regular expressions. A regular expression object is created within /'s. They have a **test** function that accepts a string to determine if it meets the condition.

```
let reg = /\d{3,}/;
reg.test('14'); // false
reg.test('55555555'); // true
```

Much More: Canvas I

HTML5 supports a **canvas** element that works well with JavaScript. It allows for drawing and animations.

Consider HTML:

```html
<!-- ... -->
<body>
  <section id="canvas_area">
    <canvas id="drawing"></canvas>
  </section>
</body>
<!-- ... -->
```

Then with JS:

```javascript
function Drawing(){
  // set up for drawing
  this.can = document.getElementById('drawing');
  this.can.width = window.innerWidth;
  this.can.height = window.innerHeight;
  this.can.style.border = "4px solid black";

  // a drawing context
  this.ctx = this.can.getContext("2d");

  this.start();
}

Drawing.prototype.start = function () {
```

Much More: Canvas II

```
    let self = this;

    // when its canvas is clicked
    this.can.addEventListener('click',
      function(e){ // call the event 'e'
        let rect = self.can.getBoundingClientRect();

        // find coordinates from mouse and draw
        let xpos = e.clientX - rect.left;
        let ypos = e.clientY - rect.top;

        self.ctx.fillRect(xpos,ypos,2,2);
      }
    );
  }

  let drawing = new Drawing();
```

we have an HTML page that responds to user’s clicks, drawing small boxes where the user clicks.

Much More: Canvas III