UNIVERSITY OF
Southampton

# Web APIs and WebAssembly

COMP3220 Web Infrastructure

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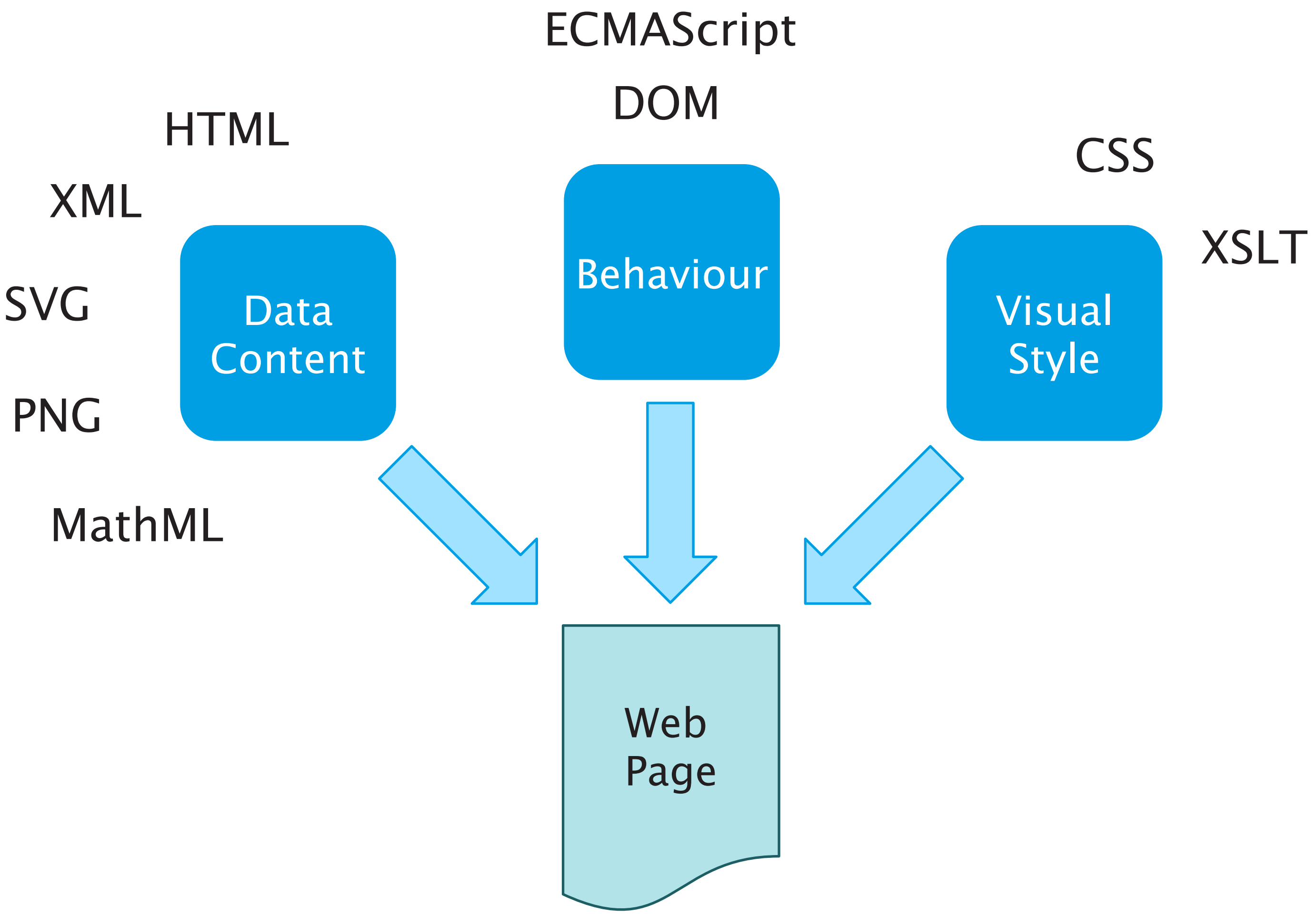
# Content, Behaviour, Presentation



# HTML as application platform

Web APIs fall into three broad classes:

1. Document content
    - Document Object Model, Canvas
2. Browser services
    - XMLHttpRequest, Fetch, WebSockets
    - Web Storage, IndexedDB
    - Web Workers, Service Workers
3. Hardware access
    - Geolocation, Media Capture, Vibration, Battery Status

# A word on standardisation

Status of APIs is highly variable

- Some are W3C recommendations
- Some are WHATWG "living standards"
- Some are both (but equivalent)
- Some are both (but differ)
- Some are neither (e.g. WebGL)

Browser support is variable

- Write defensive code – check for API support before calling it

# Document Object Model

# Document Object Model (DOM)

Standard API for accessing and manipulating XML and HTML

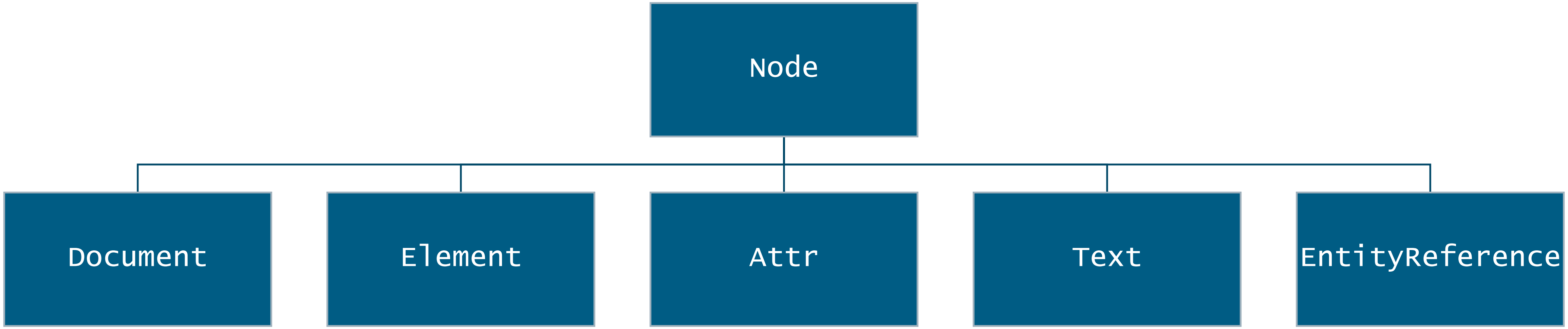
- Document represented as a hierarchy of objects of type `Node`
- Root of hierarchy is an object of type `Document`

`Node` interface is the key to understanding DOM

- Methods for basic access and manipulation of hierarchy
- Other types derived from `Node` add further methods

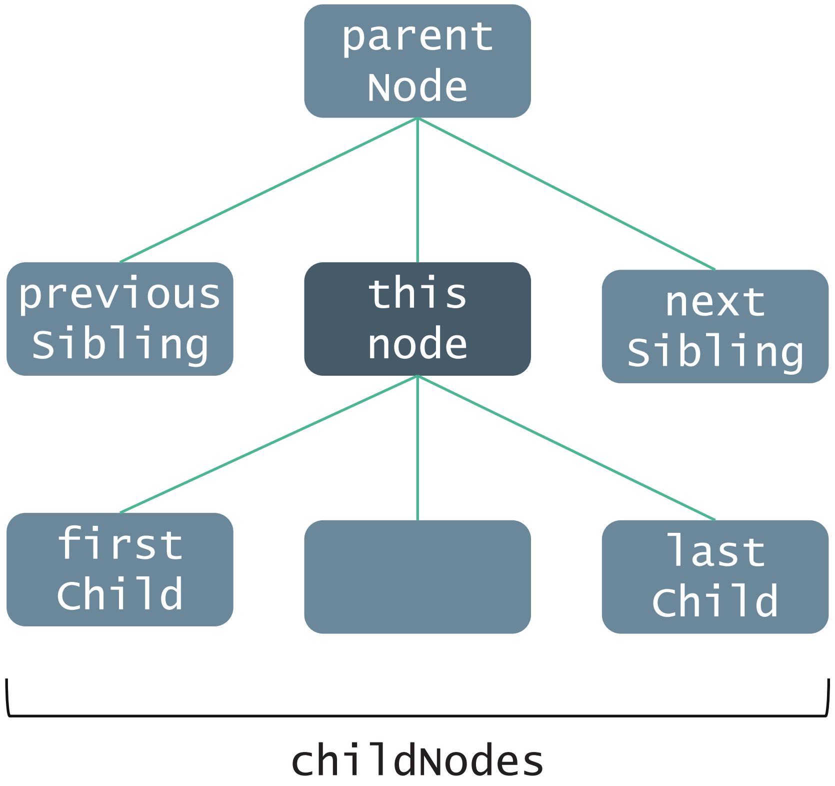
WHATWG (2020) *DOM Living Standard*. Available at: https://dom.spec.whatwg.org/

# Selected Node type hierarchy



# Node interface – attributes

- parentNode
- childNodes
- firstChild
- lastChild
- previousSibling
- nextSibling
- attributes



# Node interface – methods

`insertBefore(newChild, refChild)`

- Inserts `newChild` into list of children after `refChild`

`replaceChild(newChild, oldChild)`

- Replaces `oldChild` in list of children with `newChild`

`removeChild(oldChild)`

- Removes `oldChild` from list of children

`appendChild(newChild)`

- Adds `newChild` to the end of the list of children

`cloneNode(deep)`

- Returns a duplicate of the node (which may be a deep copy)

# Document interface – methods

`getElementsByTagName(tagname)`

- Get a list of all elements with the given tag name

`getElementById(elementId)`

- Get the element with the given ID

`createElement(tagName)`

`createAttribute(name)`

`createTextNode(data)`

`createEntityReference(name)`

# `Element` interface – methods

`getAttribute(name)`

- Returns value of named attribute

`setAttribute(name, value)`

- Sets value of named attribute

`getElementsByTagName(name)`

- Get a list of all descendant elements with the given tag name

# Canvas

# Canvas 2D Context

API for drawing graphics via JavaScript

- Uses <canvas> element as container for 2d context
- Animation via JavaScript
  (compare with declarative animation in SVG)

# Canvas example – `canvas.html`

```
<!DOCTYPE html>
<html>
  <head>
    <title>Canvas example</title>
  </head>
  <body>
    <canvas id='canvas' width='600' height='300'>
      Canvas not supported
    </canvas>
    <script src='canvas.js'></script>
  </body>
</html>
```

fallback content

external script

# Canvas example – canvas.js

```
var canvas = document.getElementById('canvas');
var context = canvas.getContext('2d’);

context.fillStyle = 'red';
context.fillRect(10,10,110,60);
context.font = '32pt Lucida Sans';
context.strokeStyle = 'blue';
context.strokeText("Lorem Ipsum", 40, 40);
```

# WebGL

Low-level 3D graphics API based on OpenGL

Defined as an additional context for the canvas element

```
var canvas = document.getElementById('canvas’);
var context = canvas.getContext('webgl’);
```

Jackson, D. and Gilbert, J. (2020) *WebGL Specification*. Beaverton, OR: Khronos Group.
Available at: https://www.khronos.org/registry/webgl/specs/latest/1.0/

# XMLHttpRequest and Fetch

# XMLHttpRequest

API for fetching representations of resources

Asynchronous

- Register `onload` handler function for response
- AJAX – Asynchronous JavaScript and XML

WHATWG (2020) *XMLHttpRequest Living Standard*. Available at: https://xhr.spec.whatwg.org/

# XMLHttpRequest example

```
function handler() {
  if (this.status == 200 && this.response != null {
    // do something with the resource
  } else {
    console.error("Request failed: HTTP status: " + this.status);
  }
}

var client = new XMLHttpRequest();
// Register handler
client.onload = handler;
// Construct request
client.open("GET", ”http://example.org/picture.png");
// Send request
client.send();
```

# Fetch

Modern replacement for XMLHttpRequest

- Makes extensive use of promises for handling asynchrony

`fetch(` *`resource`*`,` *`init`* `)`

`init` is an optional object containing custom settings:

- `method` – GET, POST, etc
- `headers` – headers to be added to request
- `body` – request body
- `mode` – cors, no-cors, same-origin

WHATWG (2020) *Fetch Living Standard*. Available at: https://fetch.spec.whatwg.org/

# Fetch example

```
fetch("http://example.org/picture.png")
  .then(response => {
    if (!response.ok) {
      throw new Error("HTTP Status: " + response.status);
    }
    return response.blob();
  })
  .then(blob => {
    // do something with the fetched resource
  })
  .catch(error => {
    console.error("Fetch failed:", error);
  });
```

# Web Sockets

# Web Sockets

Three issues with `XMLHttpRequest`:

1. Connection is not persistent
   Repeated requests require TCP setup and teardown
2. Communication always initiated by client
   No pushing of messages from the server
3. Bound only to HTTP/HTTPS

Web Sockets is a modern replacement for `XMLHttpRequest`

- Supports multiple transport protocols

Fette, I. and Melnikov, A. (2011) *The Web Socket Protocol.* RFC6455. Available at: https://tools.ietf.org/html/rfc6455
WHATWG (2020) *HTML Living Standard: Web Sockets*. Available at: https://html.spec.whatwg.org/multipage/web-sockets.html

# Web Sockets example

```
var connection = new WebSocket('ws://example.org/srv',
                               [‘http', 'xmpp']);

connection.onmessage = function (e) {
  console.log('Server: ' + e.data);
};

connection.send('...data...');
```

# Web Storage

# Web Storage

Cookies used to store key-value data in the browser

- HTTP-based mechanism (`Cookie:` header)
- Breaks stateless nature of HTTP

Web Storage is a more principled replacement

- Separate storage area for each origin (web page)
- Non-persistent storage (`Window.sessionStorage`)
- Persistent storage (`Window.localStorage`)

WHATWG (2020) *HTML Living Standard: Web Storage*. Available at: https://html.spec.whatwg.org/multipage/webstorage.html

# Web Storage example

```
localStorage.setItem('email', 'fred@example.org');
localStorage.getItem('visitCount');

sessionStorage.getItem('query');
```

# IndexedDB

# IndexedDB

Web Storage API only useful for key-value data

IndexedDB is a more sophisticated web browser database:

- Asynchronous
- Transaction support
- Structured (JSON) data (c.f. CouchDB, MongoDB, etc)

Alabbas, A. and Bell, J. (2018) *Indexed Database API 2.0*. W3C Recommendation. Available at: https://www.w3.org/TR/IndexedDB-2/

# IndexedDB example

```
var db;
var request = indexedDB.open("books");

request.onsuccess = function() {
  db = request.result;
};

var trans = db.transaction("books", "readwrite");
var store = trans.objectStore("books");

store.put({title: "HTML5 for Dummies", isbn: 123456});
store.put({title: "Starting HTML5", isbn: 234567});
store.put({title: "HTML5 Revealed", isbn: 345678});

trans.oncomplete = function() {
  // Called when all requests have succeeded
  // (the transaction has committed)
};
```

# Web Workers and Service Workers

# Web Workers

Trend in Web scripting is towards asynchrony

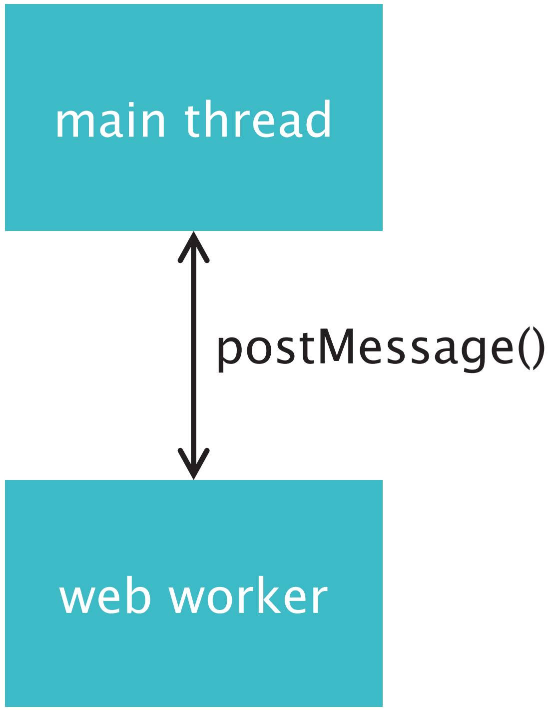
- XMLHttpRequest
- Web Sockets
- Web Storage

JavaScript browser environment is single-threaded

- Compute-intensive tasks affect responsiveness of scripts

Web Workers provides multi-threading for JavaScript

- Asynchronous handling of results




WHATWG (2020) *HTML Living Standard: Workers*. Available at: https://html.spec.whatwg.org/multipage/workers.html

# Web Workers example

```
// Main thread:

const searcher = new Worker('searcher.js');
searcher.onmessage = function (event) {
  // process response from the worker thread
};

// send message to worker
searcher.postMessage(query);
```

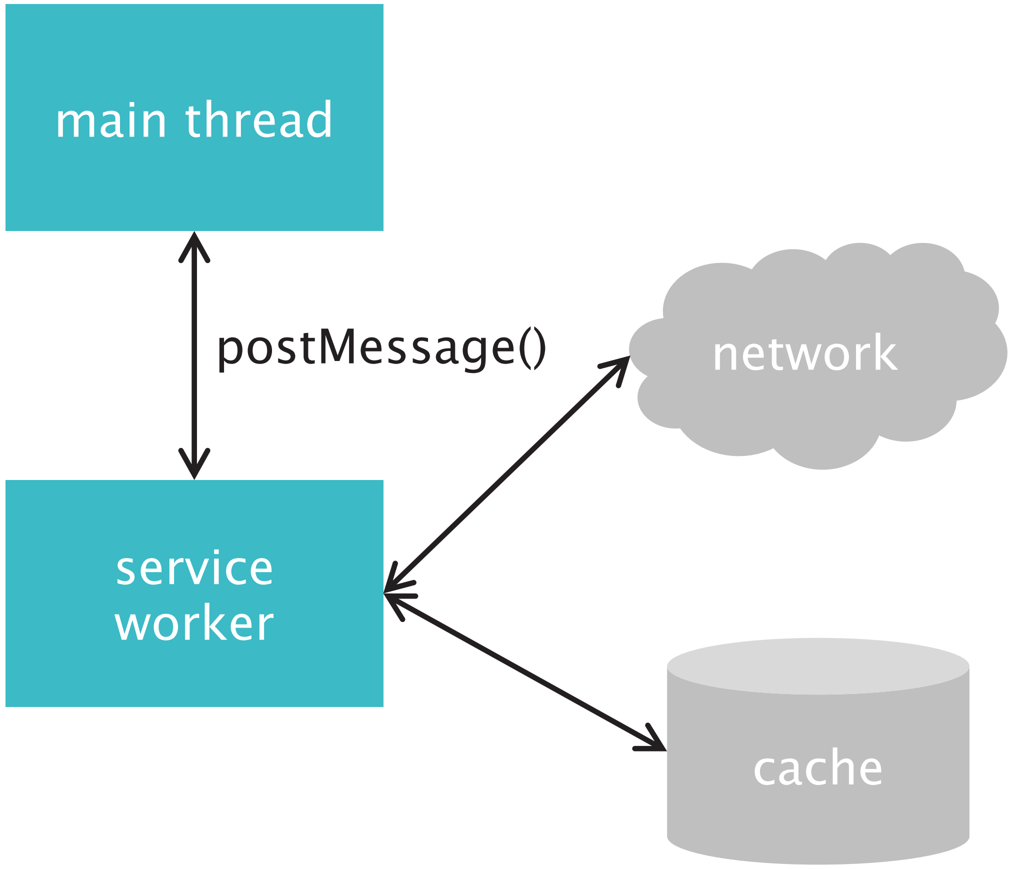
```
// searcher.js:

onmessage = function (event) {
  // process message received from the main thread

  // send response to main thread
  self.postMessage();
};
```

# Service Workers

Background script similar to Web Workers

Designed to proxy fetch requests

- Service workers registered with a scope
- fetch requests for resources within that scope are passed to the worker




Russell, A. at al (2019) *Service Workers*. W3C Candidate Recommendation. Available online at: https://www.w3.org/TR/service-workers/

# Service Workers example

```
//main.js

navigator.serviceWorker.register("/worker.js")
  .then(reg => { console.log("Registration succeeded for scope:", reg.scope); })
  .catch(err => { console.error("Registration failed:", err});


// worker.js

self.addEventListener("install", event => {
  // code that runs when the service worker is registered (set up cache, etc)
});

self.addEventListener("fetch", function(event) {
  // code that runs when a fetch is executed in the scope of this service worker
  // (return cached resource if available, otherwise execute fetch)
});
```

# Geolocation

# Geolocation

Allows a script to determine client location

- One-off (`getCurrentPosition()`)
- Ongoing (`watchPosition()`)

Location information service independent

- GPS, GSM/CDMA, Wi-Fi

```
navigator.geolocation.getCurrentPosition(success);

function success(pos) {
  console.log("Latitude: " + pos.coords.latitude);
  console.log("Longitude: " pos.coords.longitude);
}
```

Popescu, A. (2018) *Geolocation API Specification 2nd Edition*. W3C Recommendation. Available at: https://www.w3.org/TR/geolocation-API/

# Further reading

WHATWG (2020) *DOM Living Standard*.
https://dom.spec.whatwg.org/

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https://www.khronos.org/registry/webgl/specs/latest/1.0/

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https://xhr.spec.whatwg.org/

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https://fetch.spec.whatwg.org/

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https://www.w3.org/TR/IndexedDB-2/

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Russell, A. at al (2019) *Service Workers*. W3C Candidate Recommendation.
https://www.w3.org/TR/service-workers/

Popescu, A. (2018) *Geolocation API Specification 2nd Edition*. W3C Recommendation.
https://www.w3.org/TR/geolocation-API/

# asm.js and WebAssembly

# A little history of Web scripting

Client-side web scripting first investigated by Netscape in 1995

- Licence Java from Sun Microsystems (i.e. Java applets)
- Use Scheme as a scripting language (simple language in the Lisp family)

Brendan Eich of Netscape chose a third option: create a new language

- C-like syntax
- Weak, dynamic typing
- Object-oriented with prototype-based inheritance
- Multiparadigm – supports functional programming as well as imperative

(and on the tenth day he rested)

# A little history of Web scripting

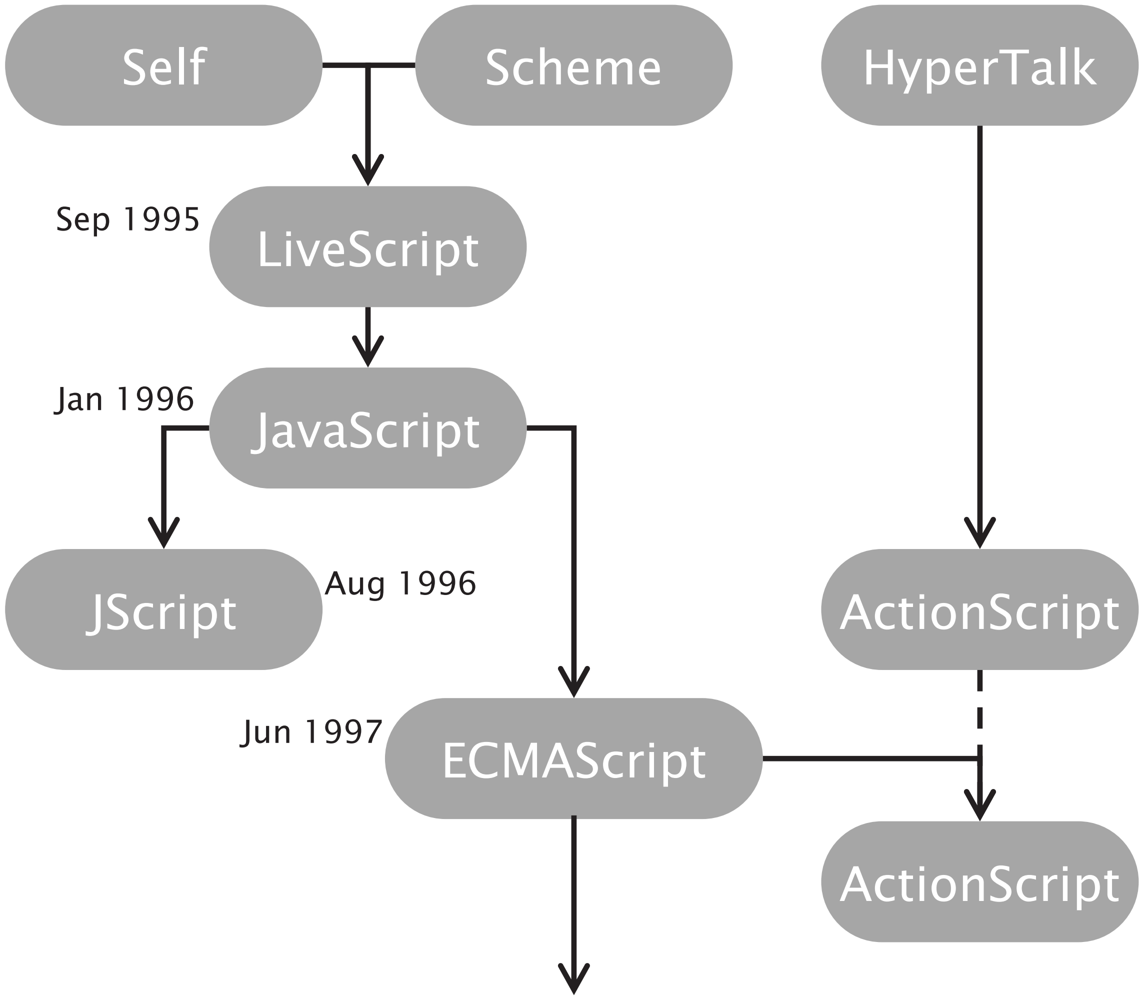
JavaScript released in Netscape 2 in 1996

Reverse engineered by Microsoft as JScript

Submitted to ECMA for standardisation

ECMA-262 published in 1997

JavaScript, JScript and ActionScript as implementations of ECMAScript



# A little history of Web scripting

As originally designed, JavaScript allowed only very simple page manipulation

- Event handlers only for forms - `onClick()`, etc
- Early versions predate DOM – `document.write()`

Introduction of XMLHttpRequest in Gecko in 2000 led to growth of AJAX

- Increasingly complex single-page applications
- Efficiency of executing JavaScript as limiting factor

Google's V8 engine introduced JIT compilation of JavaScript in 2008

- Significant performance improvements – compile to intermediate bytecode or native code
- JavaScript for server-side programming (node.js)

Garrett, J.J. (2005) *AJAX: A New Approach to Web Applications*. Available online at: https://web.archive.org/web/20150910072359/http://adaptivepath.org/ideas/ajax-new-approach-web-applications/

# asm.js

Strict subset of ECMAScript 2015 (ES6) used as target for source-to-source compilers

- Write in C, compile to asm.js, run in any browser
- Allows APIs such as OpenGL and SDL to be used within web pages
- No garbage collection (typed array for memory), static typing (enabling AOT compilation)

Typically runs at ~2/3 the speed of native code

Compiler implementation (emscripten) as LLVM backend

- Straightforward support for other languages: compile to LLVM IR, compile LLVM IR to asm.js

http://asmjs.org/
Zakai, A. (2013) *Big Web app? Compile it!* Available at: https://kripken.github.io/mloc_emscripten_talk/

# Web Assembly

asm.js improves runtime performance, but parsing JavaScript syntax is costly

The solution: adopt a standard bytecode

WebAssembly is a bytecode for a stack-based virtual machine

- cf. the stack-based machine used by SeaMonkey or the register machine used by V8

Compile $LANGUAGE to .wasm using emscripten, as for asm.js

Eich, B. (2015) *From asm.js to WebAssembly*. Available at: https://brendaneich.com/2015/06/from-asm-js-to-webassembly/

# C function...

```
#include <emscripten.h>


int EMSCRIPTEN_KEEPALIVE gcd(int a, int b) {
  while(a != b) {
    if (a > b) {
      a -= b;
    } else {
      b -= a;
    }
  }
  return a;
}
```

tells emscripten to export this function as wasm

# ...called from JavaScript

name of C function

```
gcd = Module.cwrap('gcd', 'number', ['number', 'number']);

window.alert( gcd(432,78) );
```

type of return value

types of parameters

# Further Reading

ECMA-262 (ECMAScript standard)

- https://www.ecma-international.org/publications/standards/Ecma-262-arch.htm

asm.js Specification

- http://asmjs.org/

emscripten compiler

- https://github.com/emscripten-core/emscripten

WebAssembly Specification

- https://webassembly.org/

WebAssembly Binary Toolkit ("wabbit")

- https://github.com/WebAssembly/wabt

# Next Lecture: CSS and XSLT