CS193X: Web Programming Fundamentals

Spring 2017

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Schedule

Today:

- Servers, generally
- NodeJS
- NPM
- Express
- `fetch()` to localhost

If we have time:

- Single-threaded asynchrony
  - JS Event loop

Lecture code

All lecture code is in this git repository:
https://github.com/yayinternet/lecture19

You will need to run the commands we show in lecture to run the server code!

Servers

Server-side programming

The type of web programming we have been doing so far in 193x is called "**client-side**" programming:

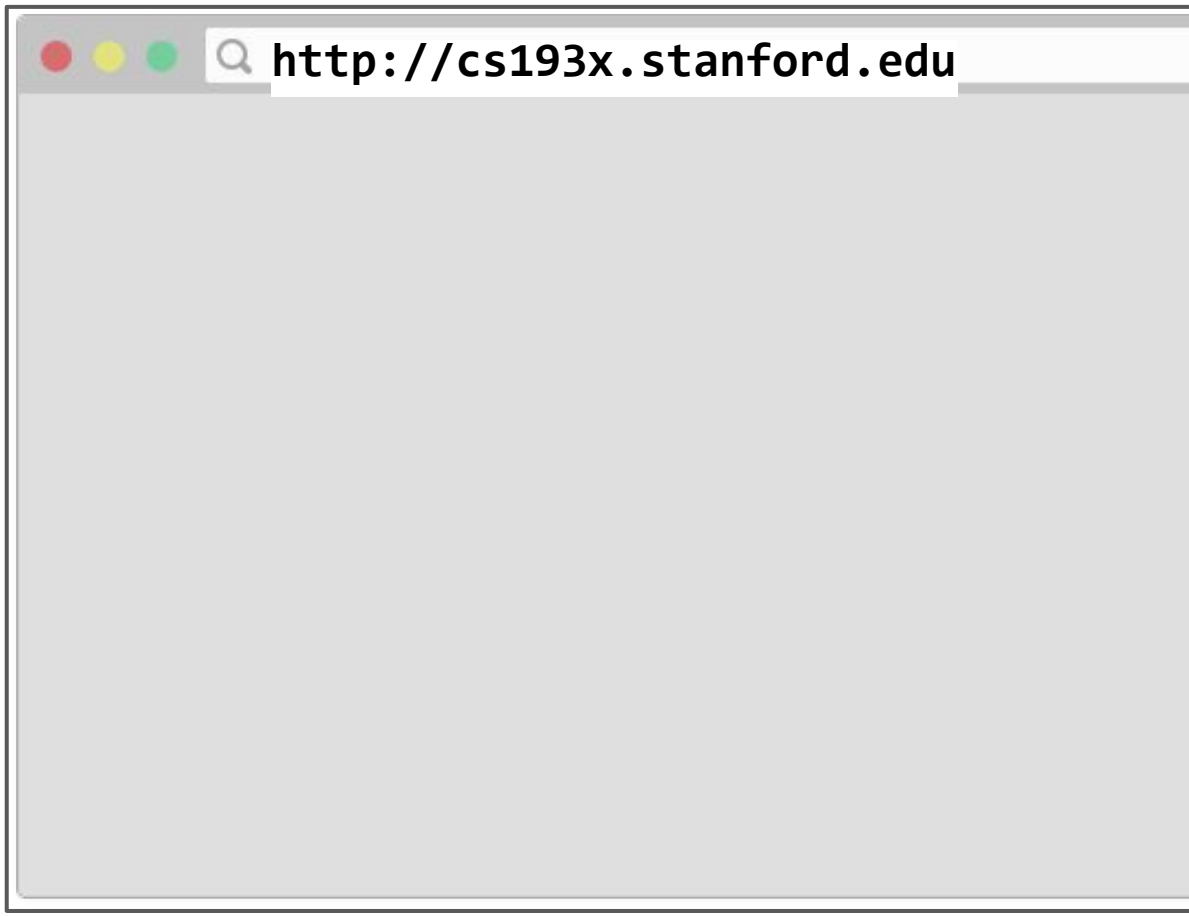
- The code we write gets run in a browser on the user's (client's) machine

Today we will begin to learn about **server-side** programming:

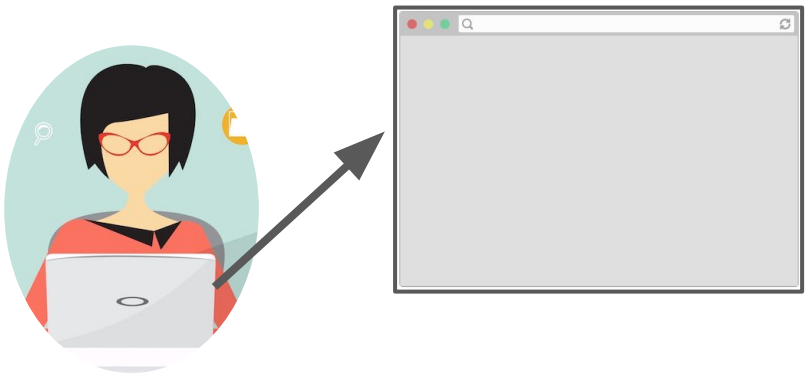
- The code we write gets run on a server.
- Servers are computers run programs to generate web pages and other web resources.

Let's take another look
at how clients and servers work...

CLIENT: You type a URL in the address bar and hit "enter"



Browser sends an HTTP GET request saying "Please GET me the index.html file at http://cs193x.stanford.edu"



Let's take a deeper look at this process...

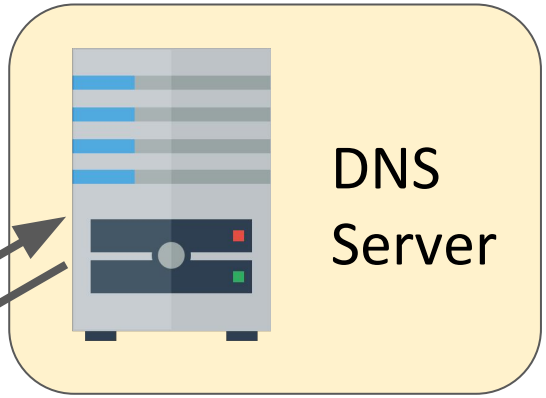
```
▼ Request Headers      view parsed
  GET /class/cs193x/ HTTP/1.1
  Host: web.stanford.edu
  Connection: keep-alive
  Cache-Control: max-age=0
  Upgrade-Insecure-Requests: 1
  User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_11_6) A
  Accept: text/html,application/xhtml+xml,application/xml;q=0.9
  Accept-Encoding: gzip, deflate, sdch
  Accept-Language: en-US,en;q=0.8
```

Browser C++ code creates an array of bytes that is formatted in using HTTP request message format

Browser asks operating system, "Hey, can you send this HTTP Get request message to http://cs193x.stanford.edu"?

Operating system sends a **DNS** query to look up the **IP address** of "http://cs193x.stanford.edu"

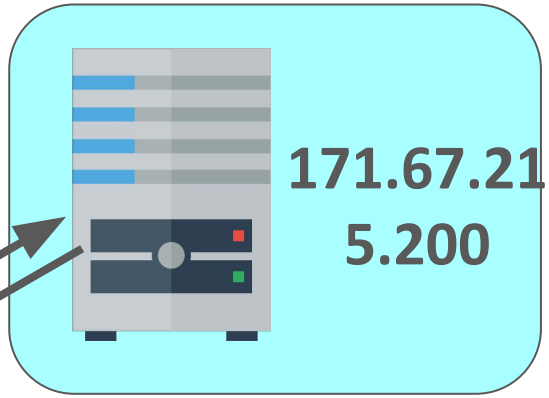
(Routing, etc…)

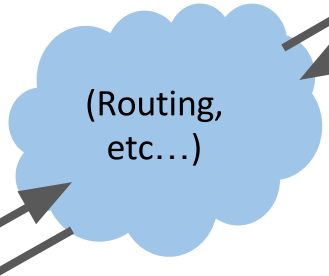


DNS server replies with the **IP address**, e.g. 171.67.215.200

- **DNS**: Domain Name System: Translate domain names to **IP address** of the computer associated with that address.
- **IP address**: Numerical unique identifier for every computer connected to the internet.

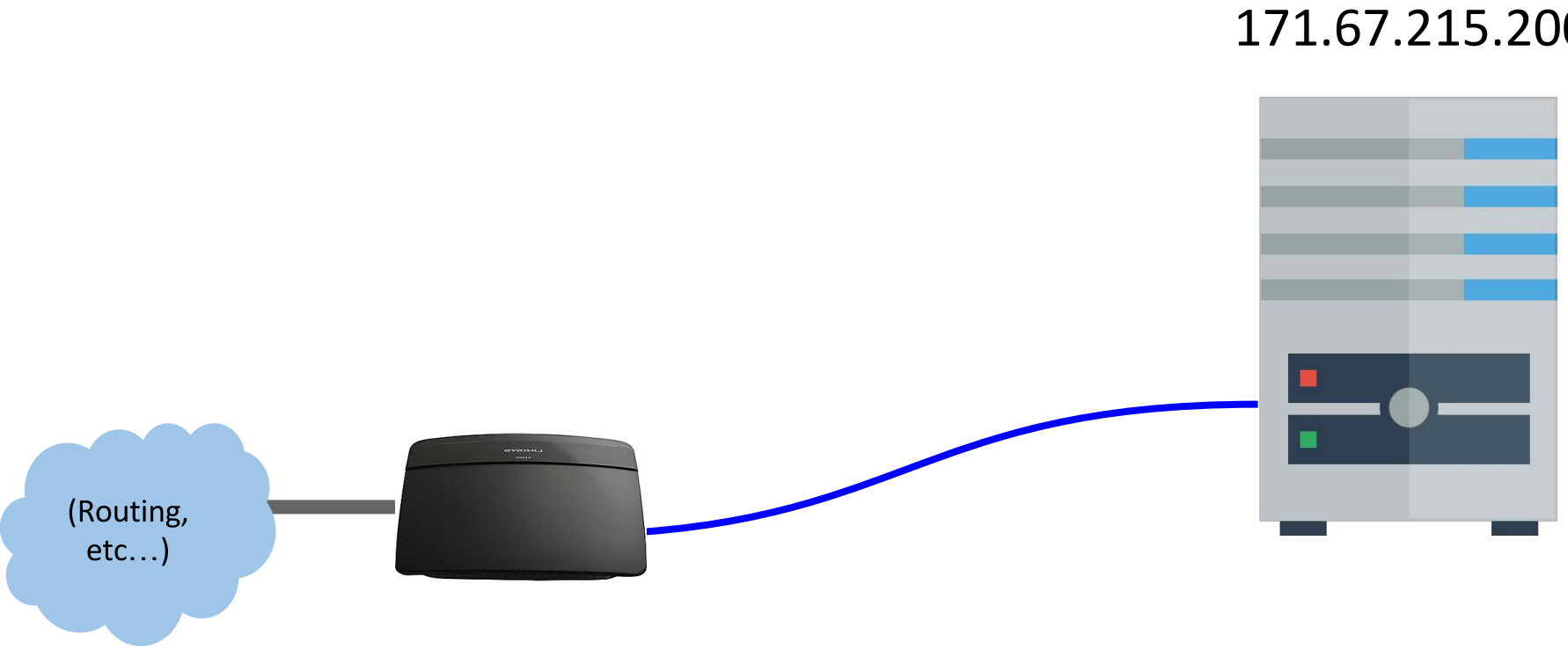
Operating system opens a **TCP** connection with the computer at 171.67.215.200





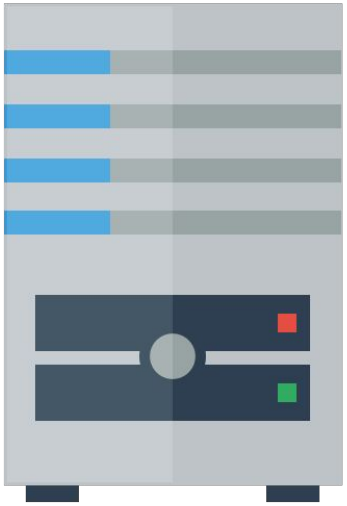
After the **TCP** connection is established, the OS can send the HTTP message to 171.67.215.200 ***through*** the **TCP** connection.

- **TCP**: Transmission Control Protocol, defines the data format for sending information over the wire. (Can be used for HTTP, FTP, etc)



SERVER: There is a computer that is connected to the internet at IP address 171.67.215.200.

171.67.215.200



On this computer is a **web server program**:

- The web server program is **listening** for incoming messages that are sent to it.
- The web server program can **respond** to messages that are sent to it.

Node: The platform we will use to create a web server program that will receive and respond to HTTP requests.

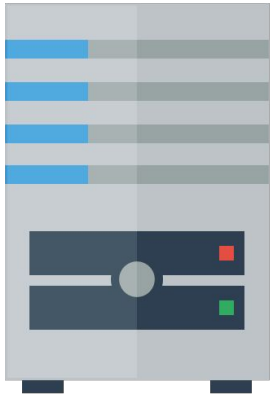
- Also known as "**NodeJS**"; these terms are synonyms

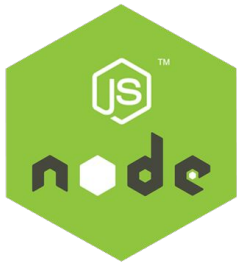
Aside: "Server"

The definition of **server** is overloaded:

- Sometimes "server" means the machine/computer that runs the server software.
- Sometimes "server" means the software running on the machine/computer.

You have to use context to know which is being meant.





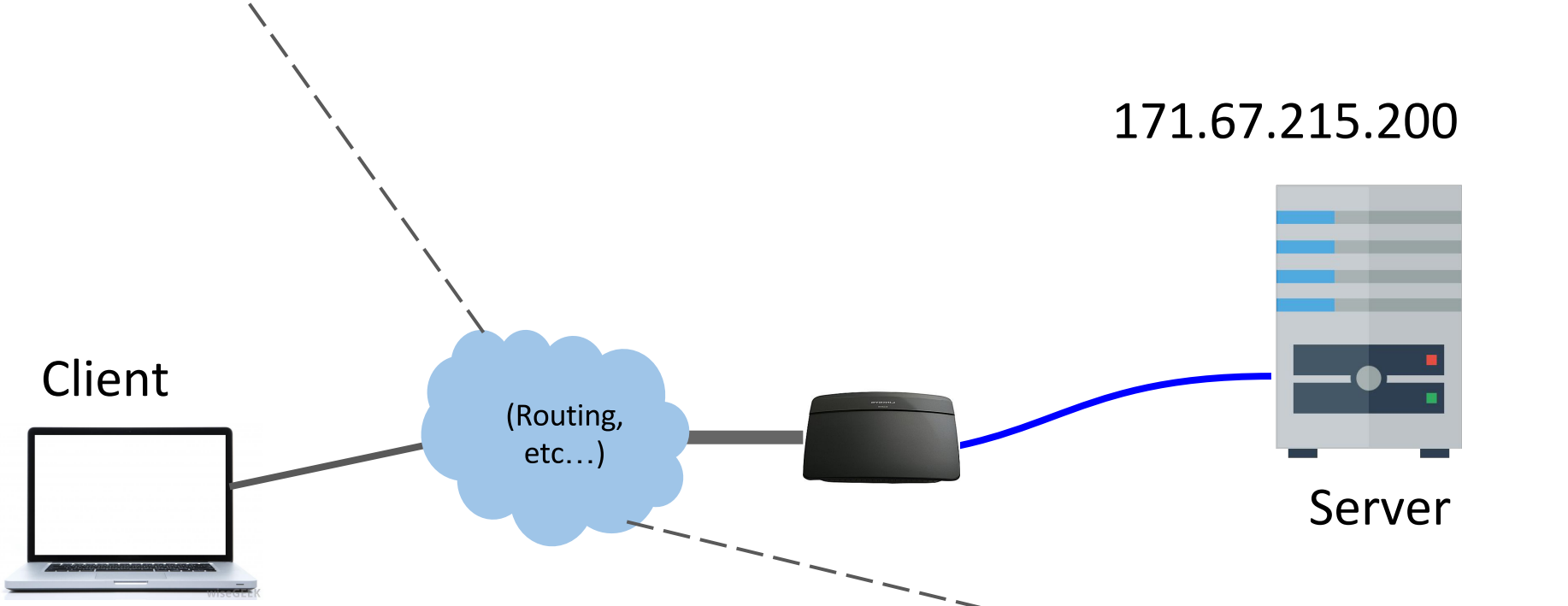
Aside: Sockets

Q: What does it mean for a program to be "listening" for messages?

When the server first runs, it executes code to create a **socket** that allows it to receive incoming messages from the OS.

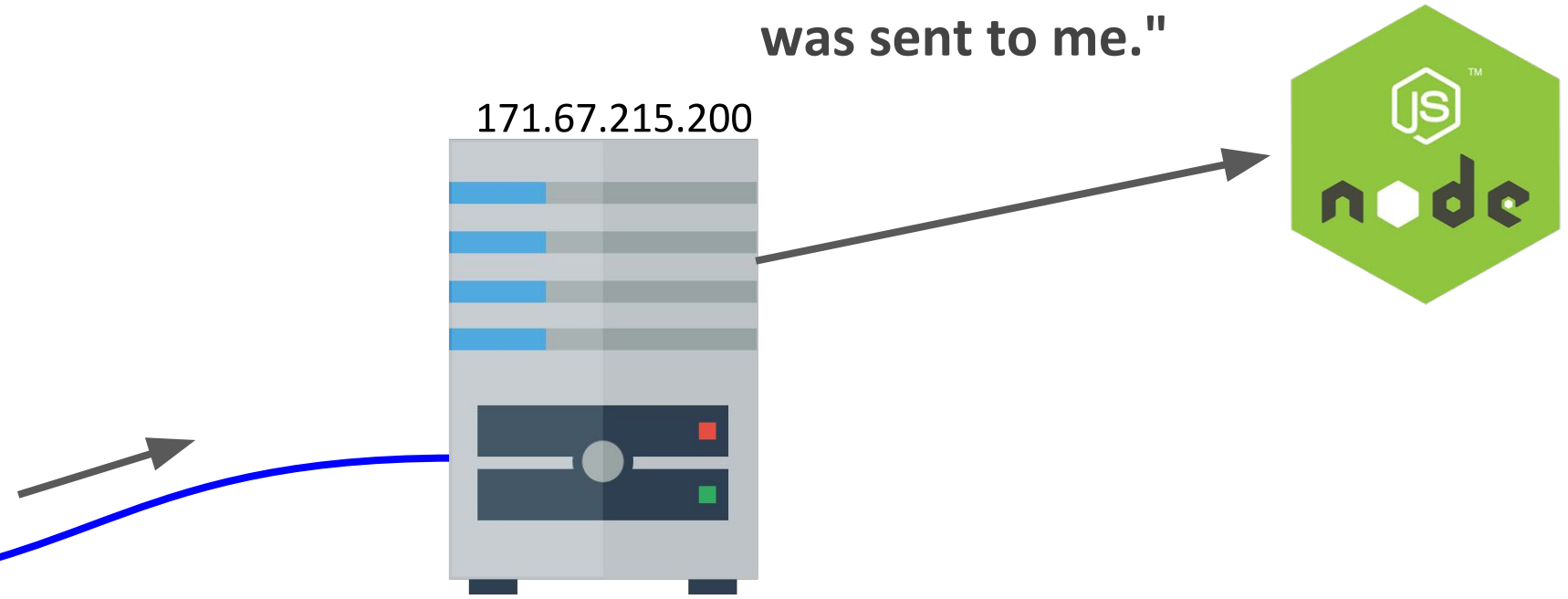
A **socket** is one end of a communication channel. You can send and receive data on sockets.

However, NodeJS will abstract this away so we don't have to think about sockets.

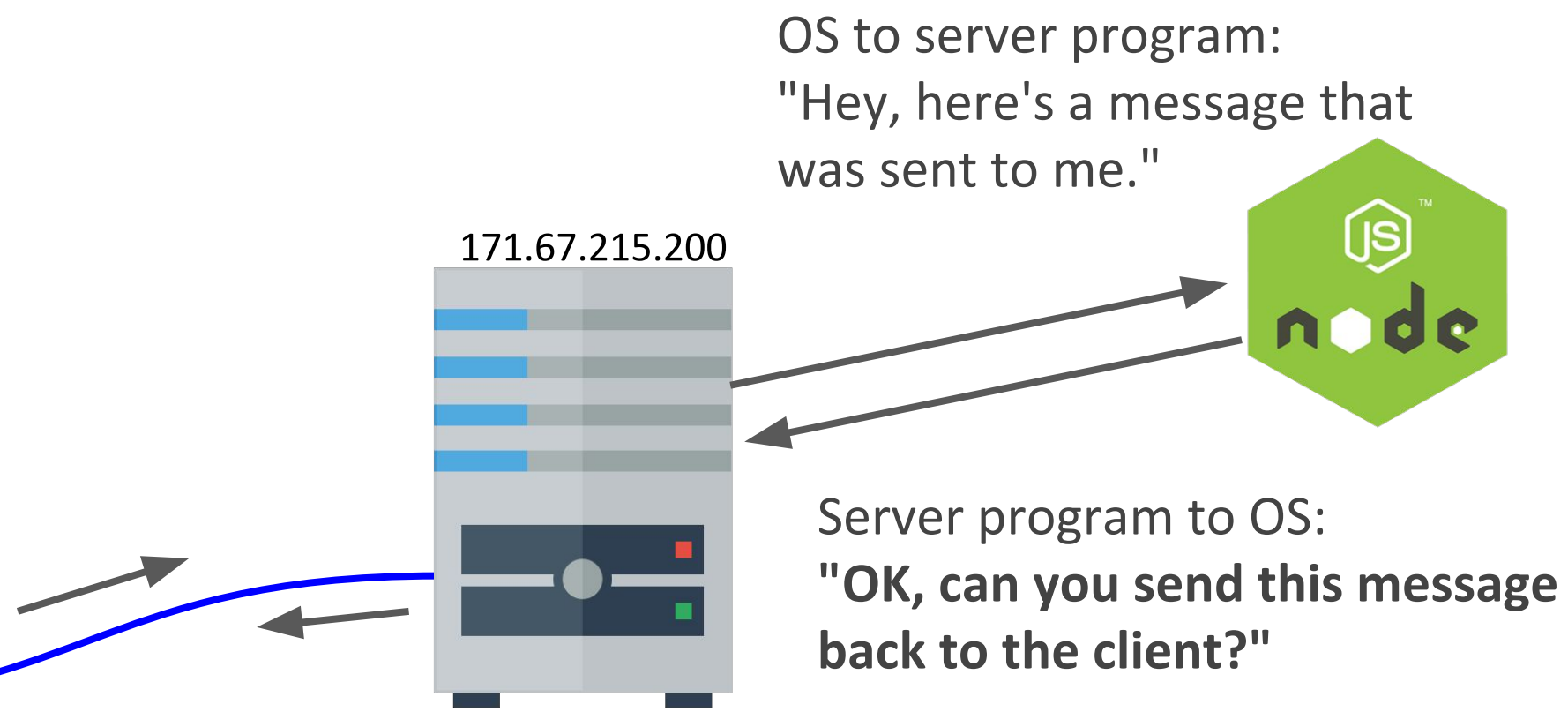


A TCP connection is established between the client and the server, so now the client and server can send messages directly to teach other.

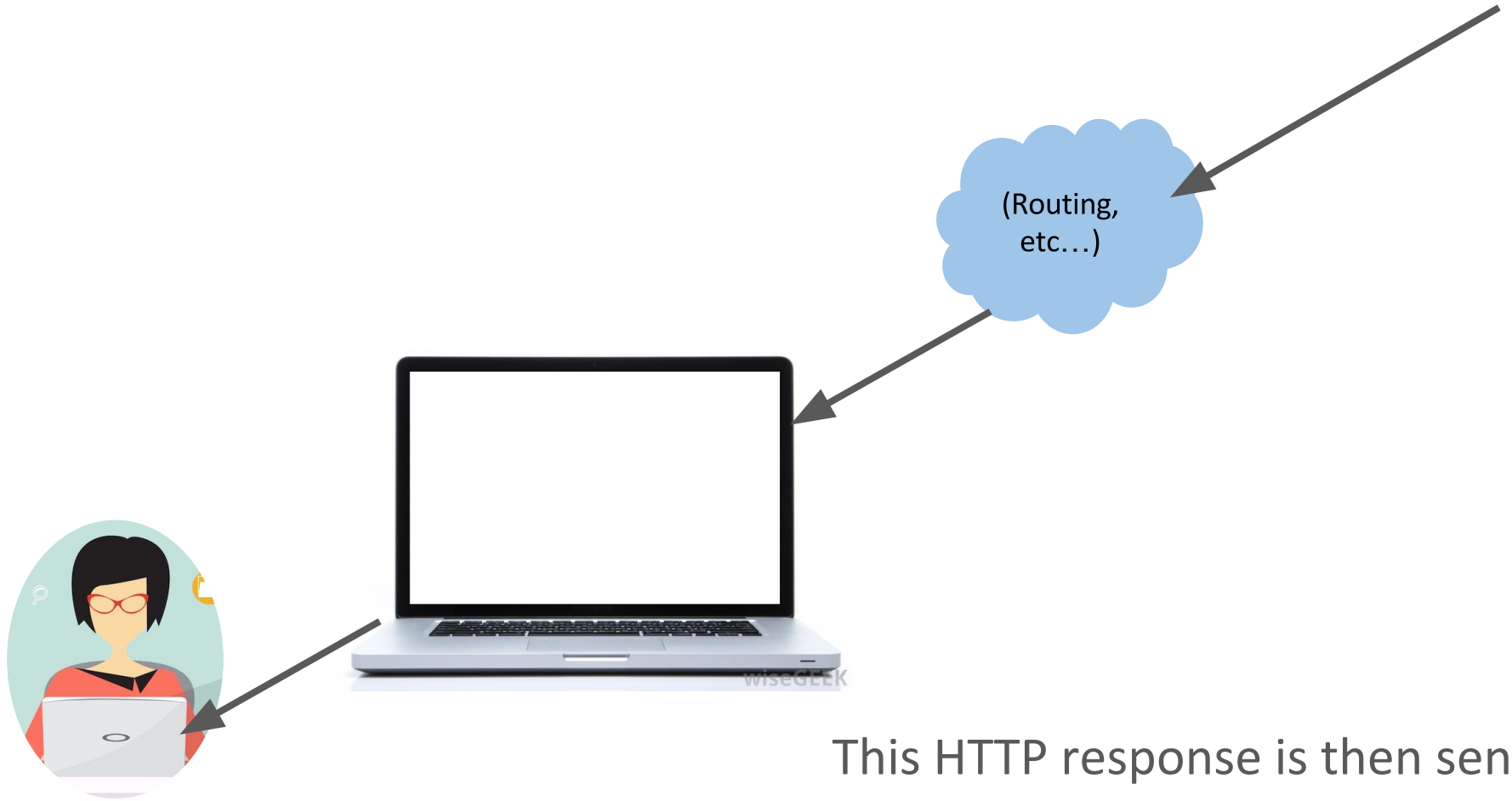
OS to server program:
"Hey, here's a message that was sent to me."

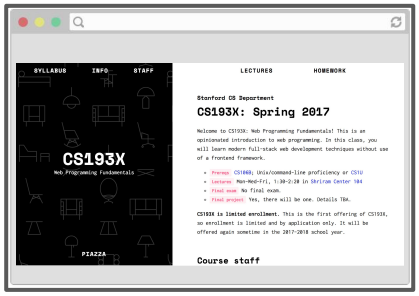


Now the operating system is receiving TCP packets from the wire, and the operating system begins sending the contents of the request to the server program.



The server software parses the HTTP request and then decides what message it wants to send in response. It formats this message in HTTP, then asks the OS to send this response message over TCP back to the sender.





This HTTP response is then sent back to the client's OS, which notifies the browser of the HTTP response, and then the browser displays the web page.

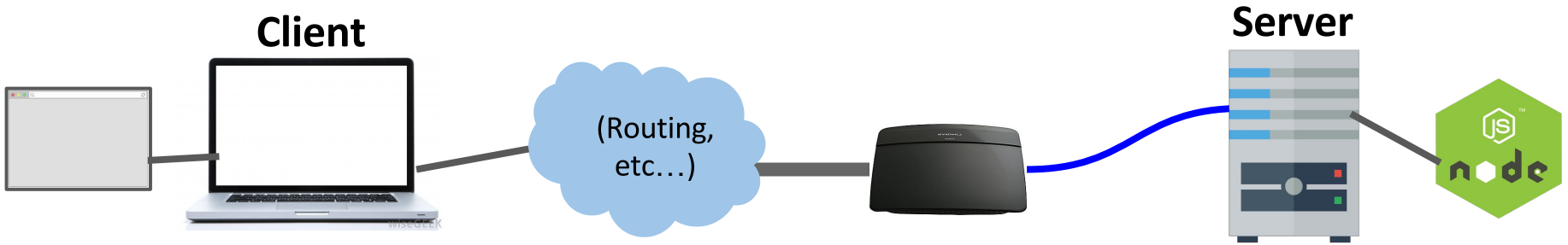
Summary

When you navigate to a URL:

- Browser creates an HTTP GET request
- Operating system sends the GET request to the server over TCP

When a server computer receives a message:

- The server's operating system sends the message to the server software (via a socket)
- The server software then parses the message
- The server software creates an HTTP response
- The server OS sends the HTTP response to the client over TCP



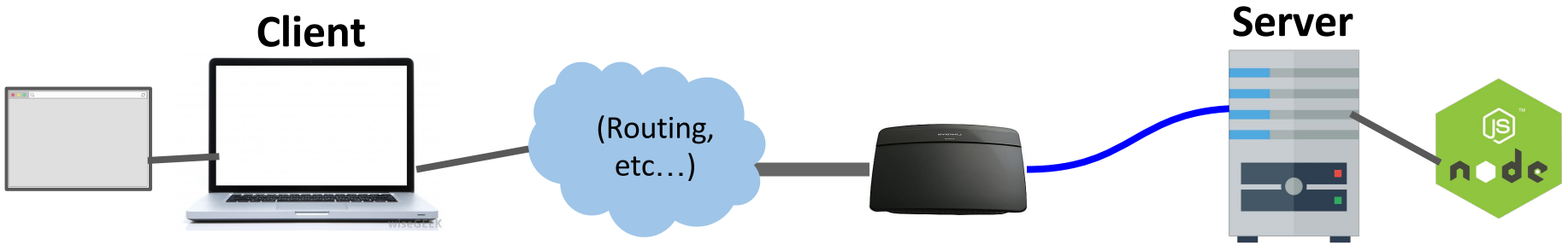
Learn more

For more on basic server design, sockets and TCP/IP:

- CS110: Principles of Computer Systems

For more on computer networks:

- CS144: Introduction to Computer Networking *(Prereq: CS110)*



NodeJS

NodeJS

NodeJS:

- A JavaScript runtime written in C++.
- Can interpret and execute JavaScript.
- Includes support for the NodeJS API.

NodeJS API:

- A set of JavaScript libraries that are useful for creating server programs.

V8 (from Chrome):

- The JavaScript interpreter ("engine") that NodeJS uses to interpret, compile, and execute JavaScript code

NodeJS

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Q: What does this mean?

NodeJS API:

- A set of JavaScript libraries that are useful for creating server programs.

V8 (from Chrome):

- The JavaScript interpreter ("engine") that NodeJS uses to interpret, compile, and execute JavaScript code

First: Chrome

Chrome:

- A browser written in C++.
- Can interpret and execute JavaScript code.
- Includes support for the DOM APIs.

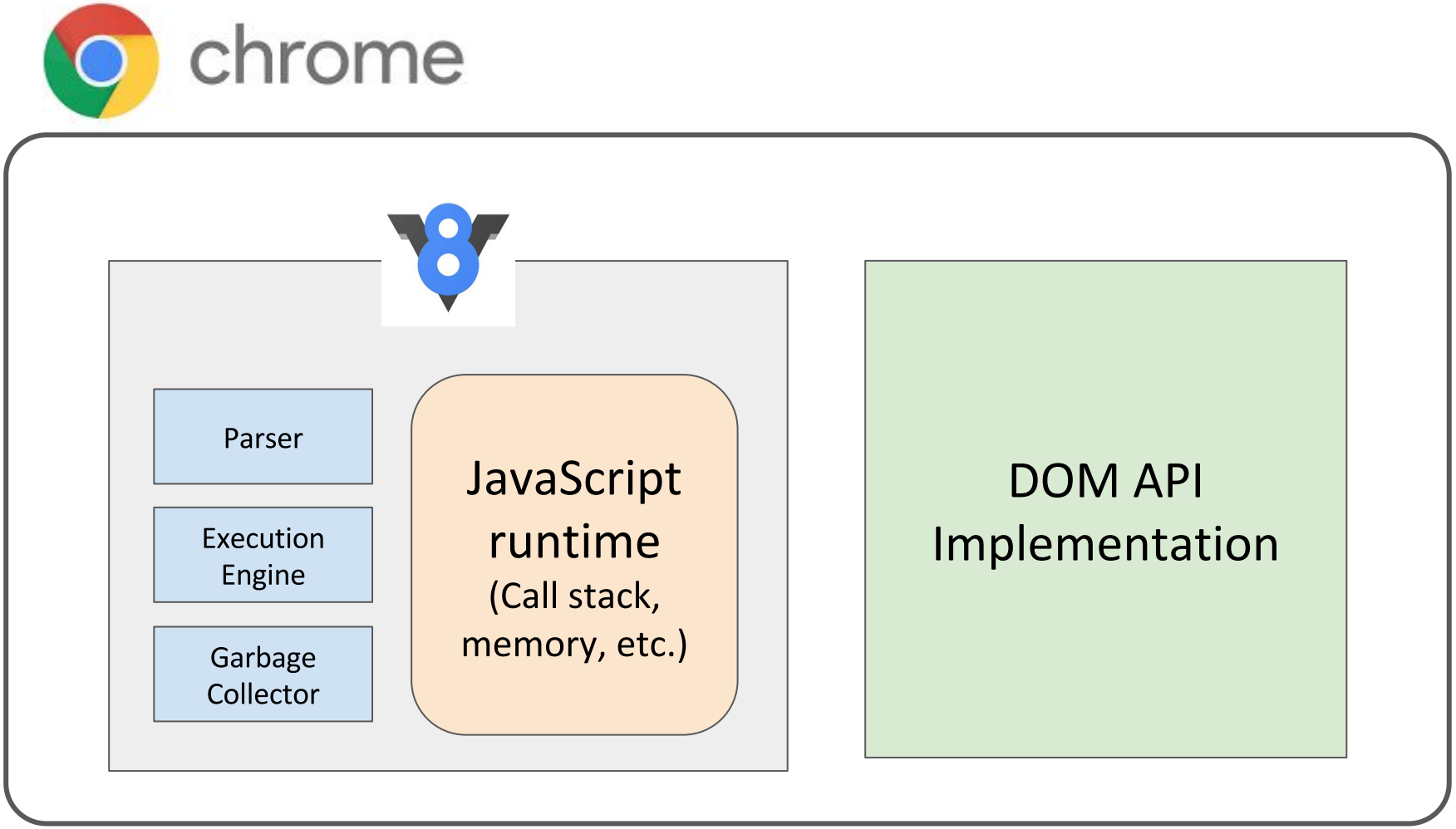
DOM APIs:

- JavaScript libraries to interact with a web page

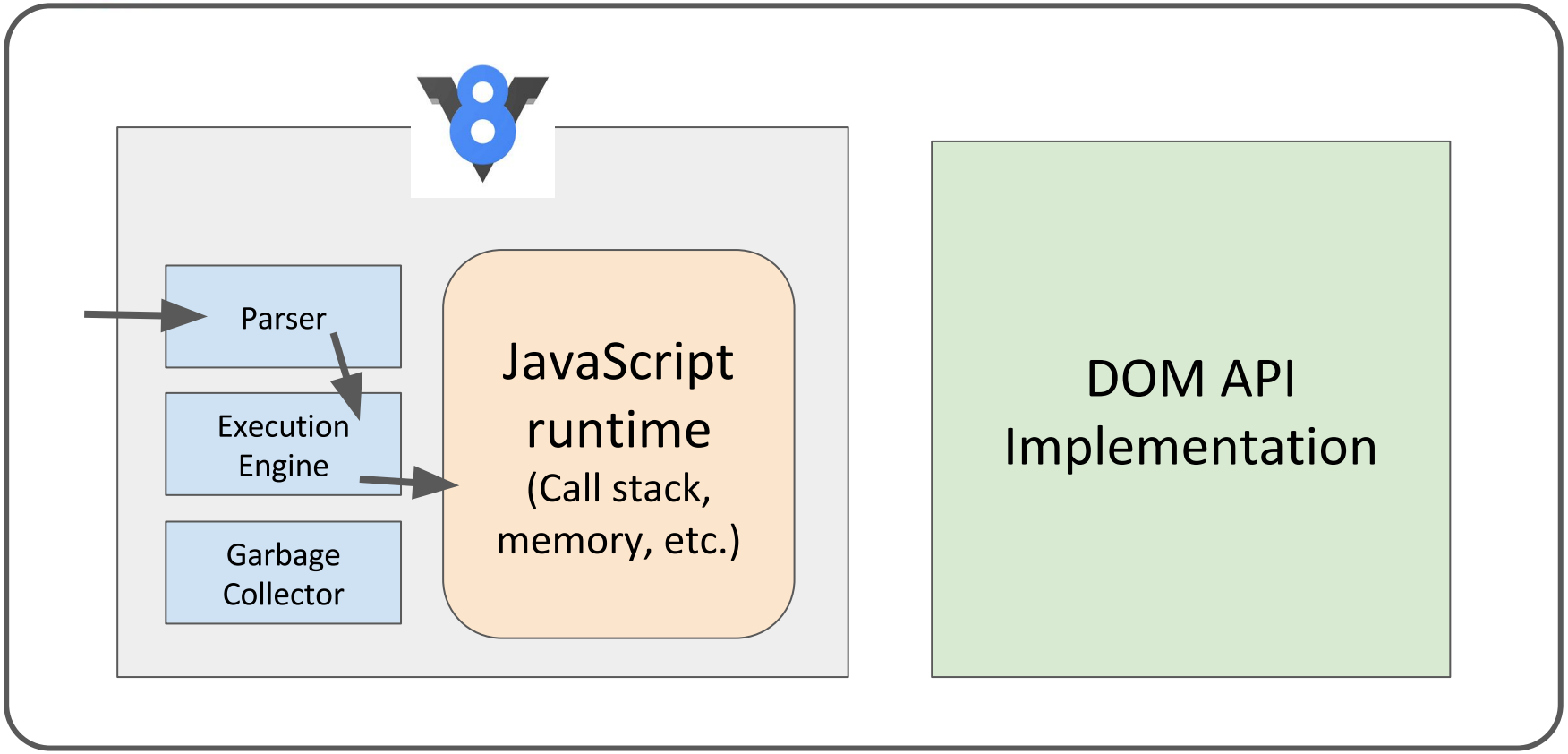
V8:

- The JavaScript interpreter ("engine") that Chrome uses to interpret, compile, and execute JavaScript code

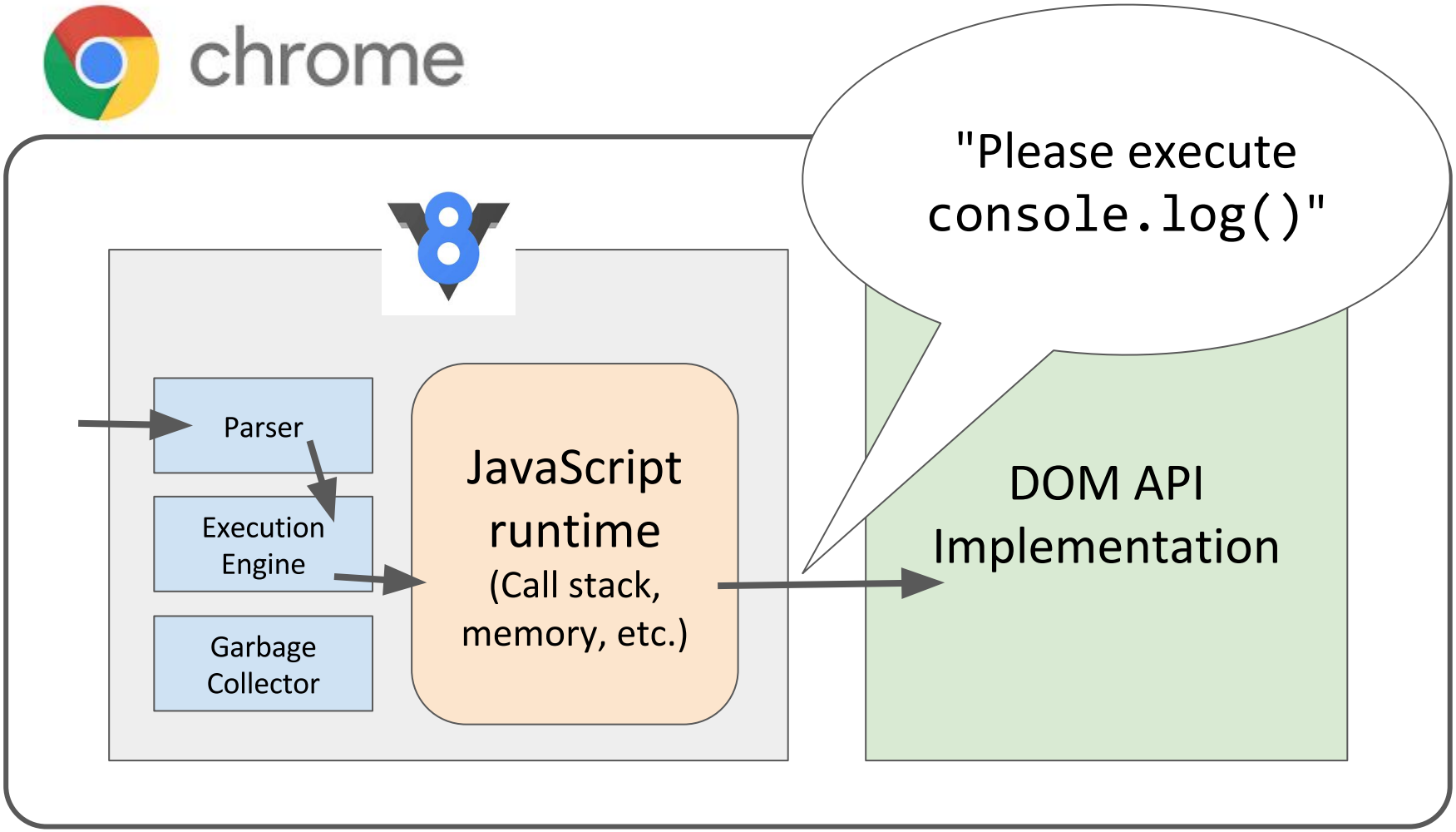
Chrome, V8, DOM



chrome

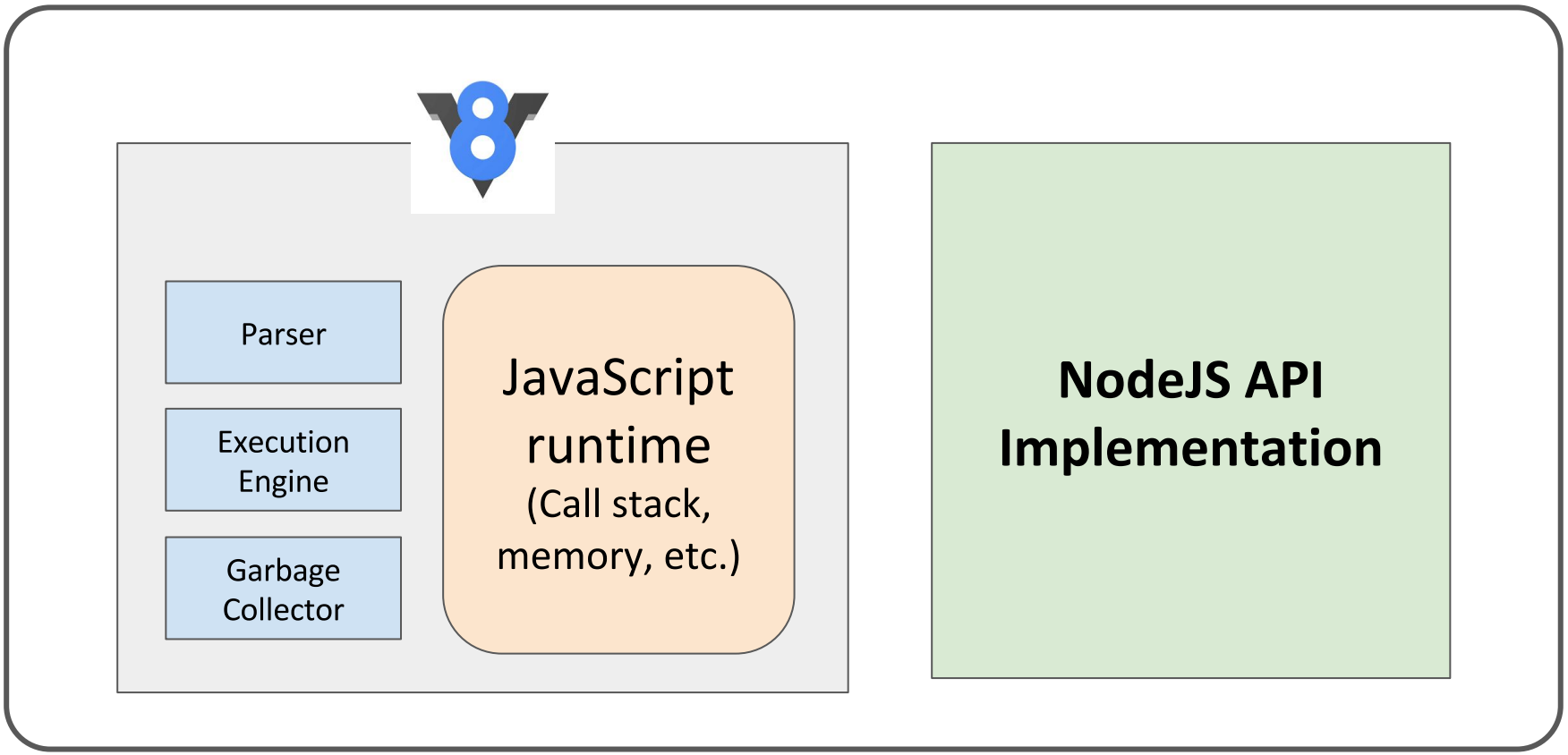


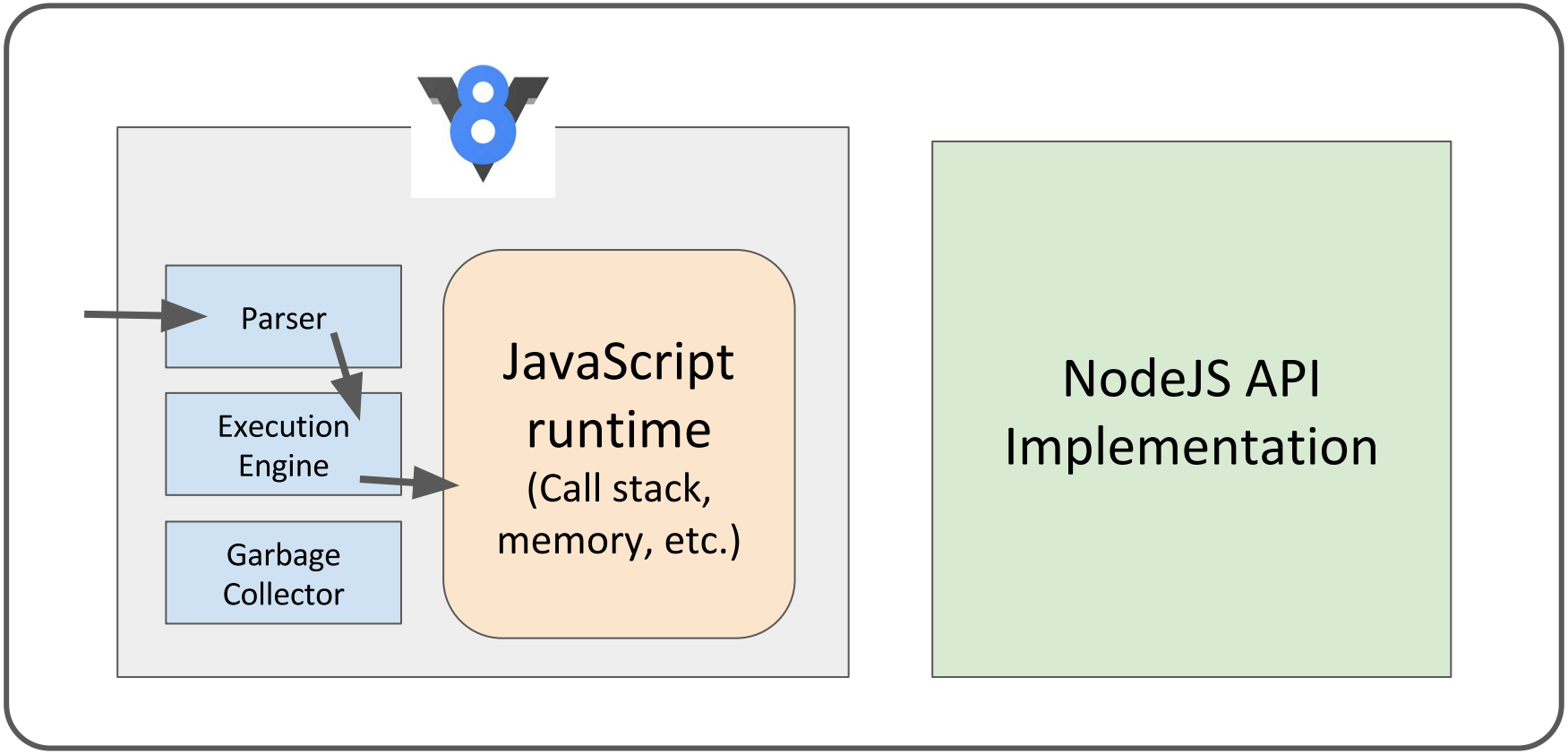

```
const name = 'V8';
```



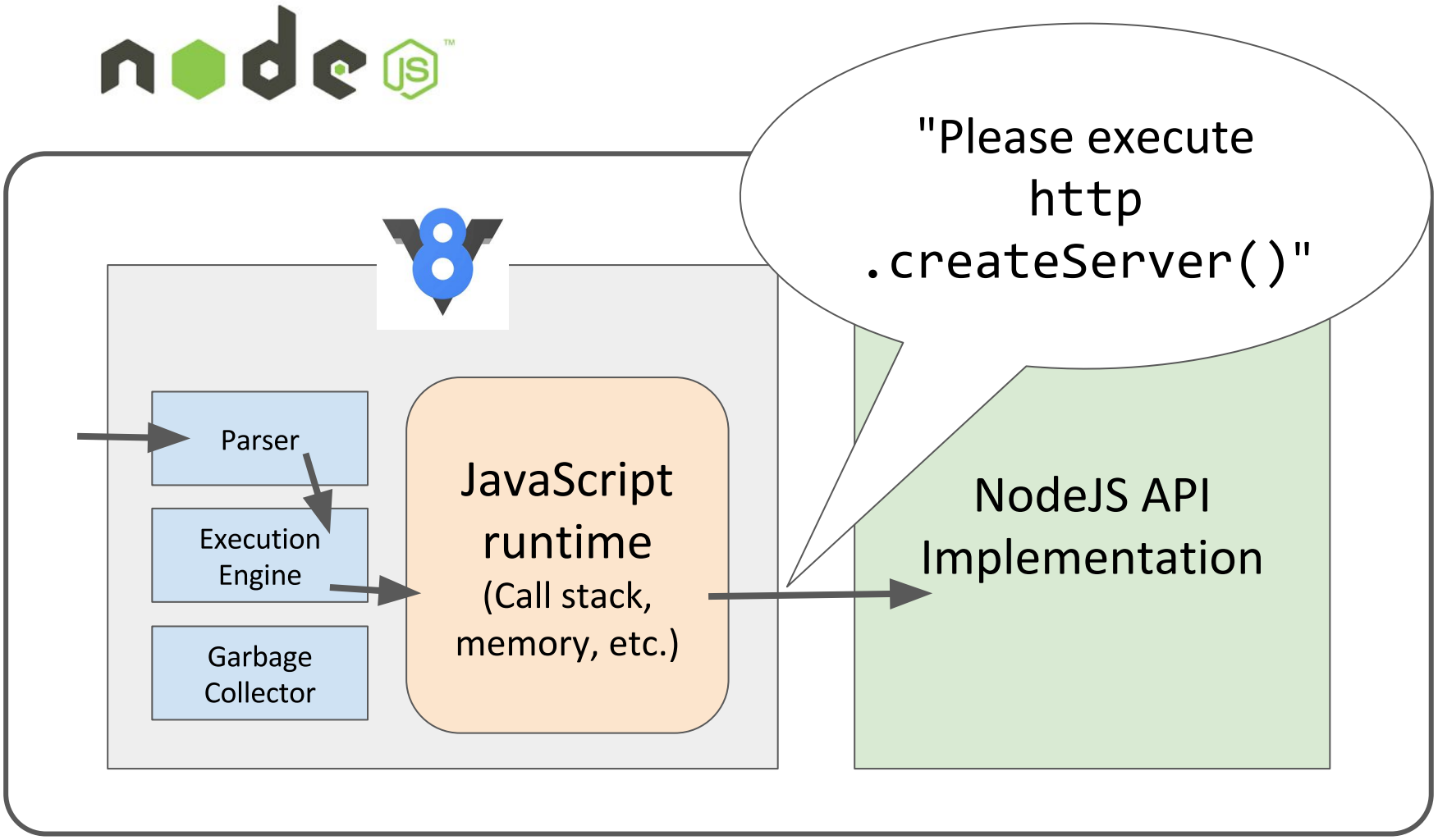

```
console.log('V8');
```

NodeJS, V8, NodeJS APIs

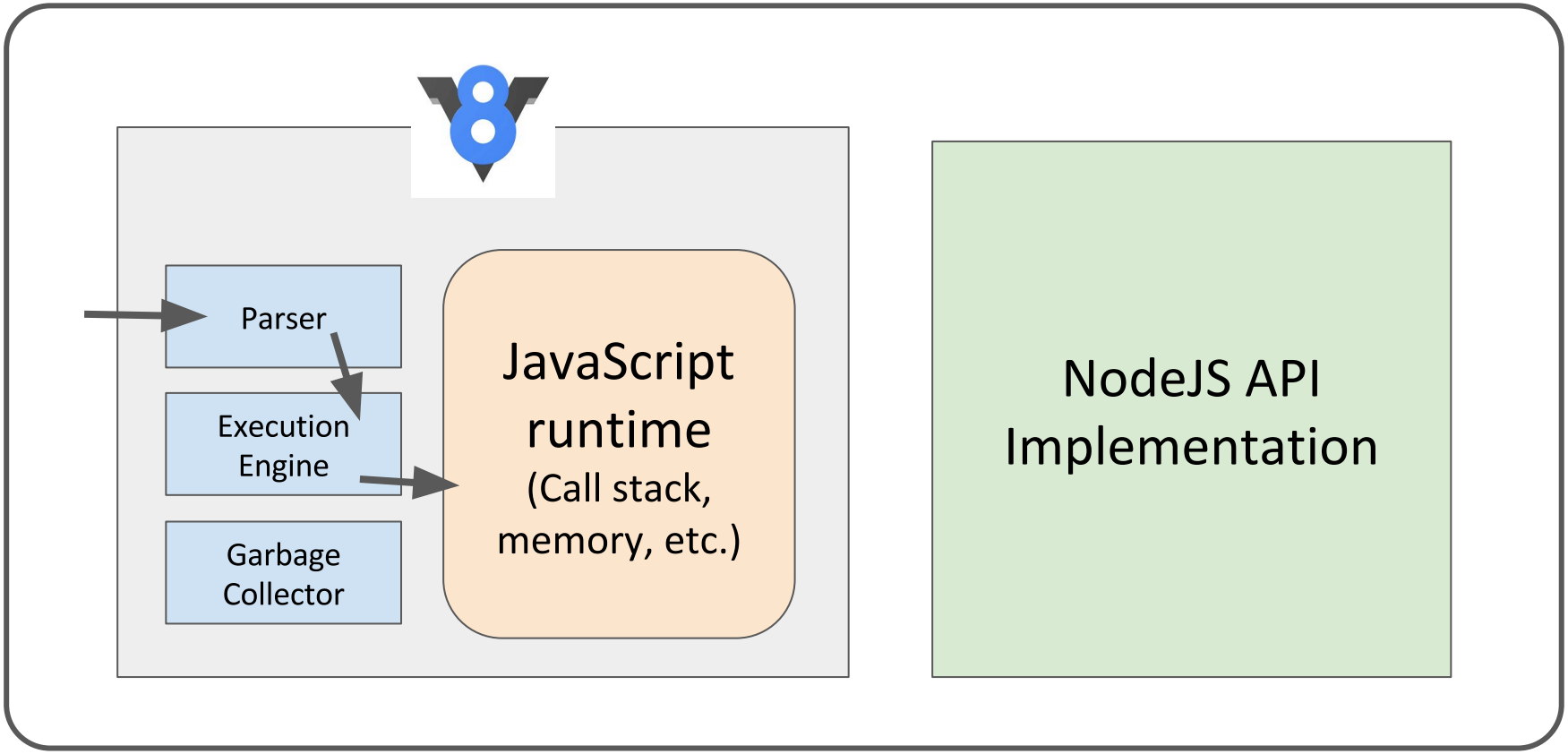



Parser
Execution Engine
Garbage Collector
JavaScript runtime
(Call stack, memory, etc.)
NodeJS API Implementation

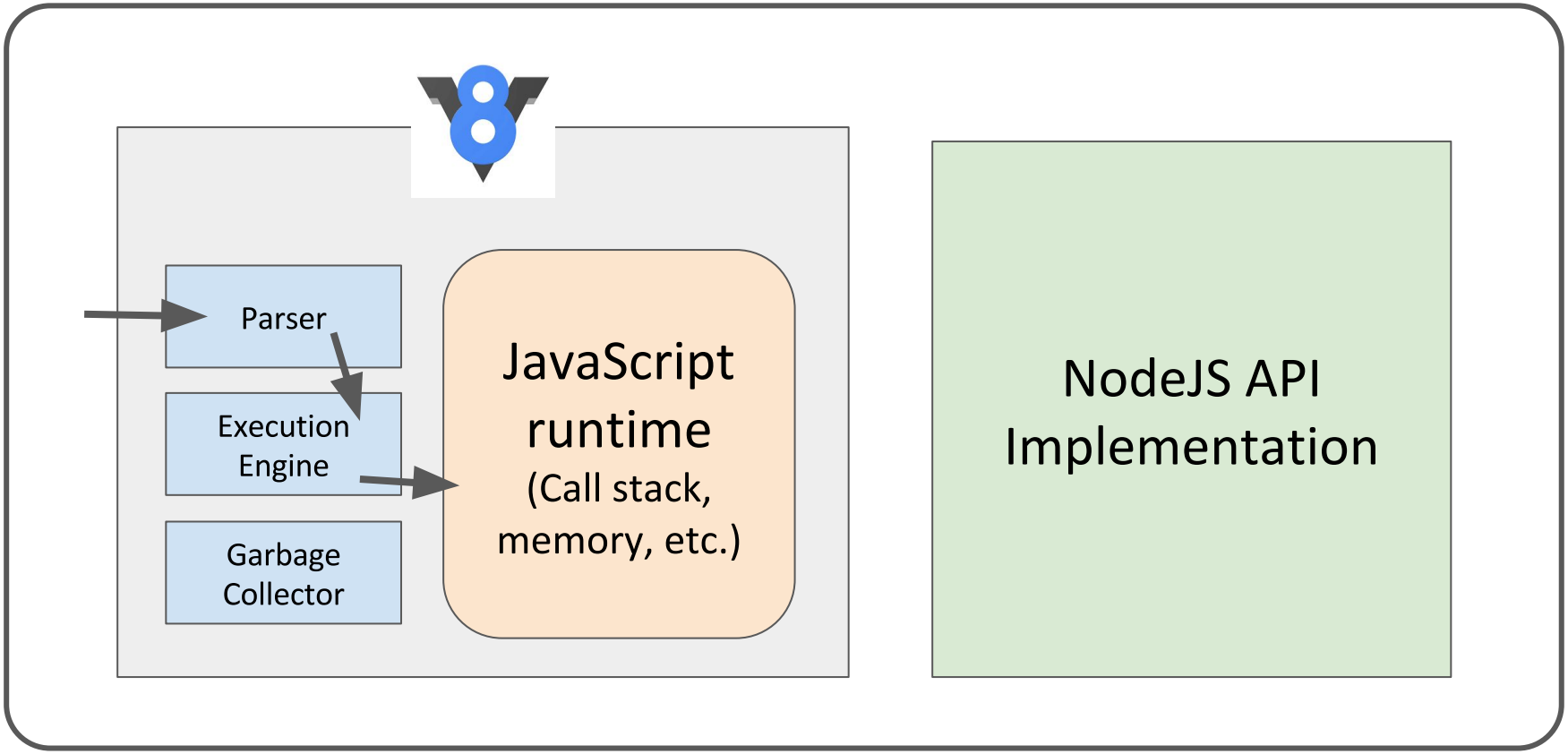
```
const x = 15;
x++;
```




```
http.createServer();
```

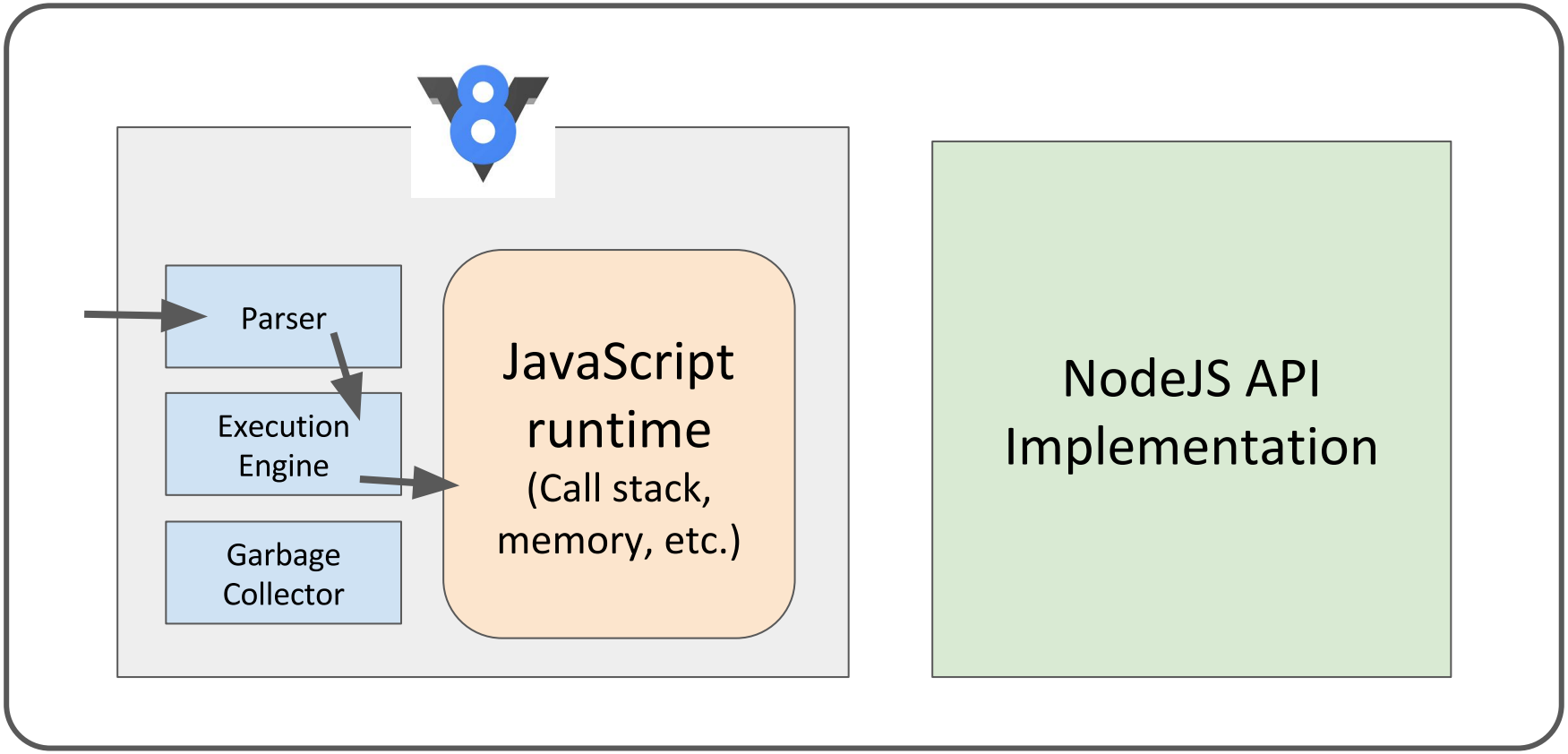


What if you tried to call
`document.querySelector('div');`
in the NodeJS runtime?

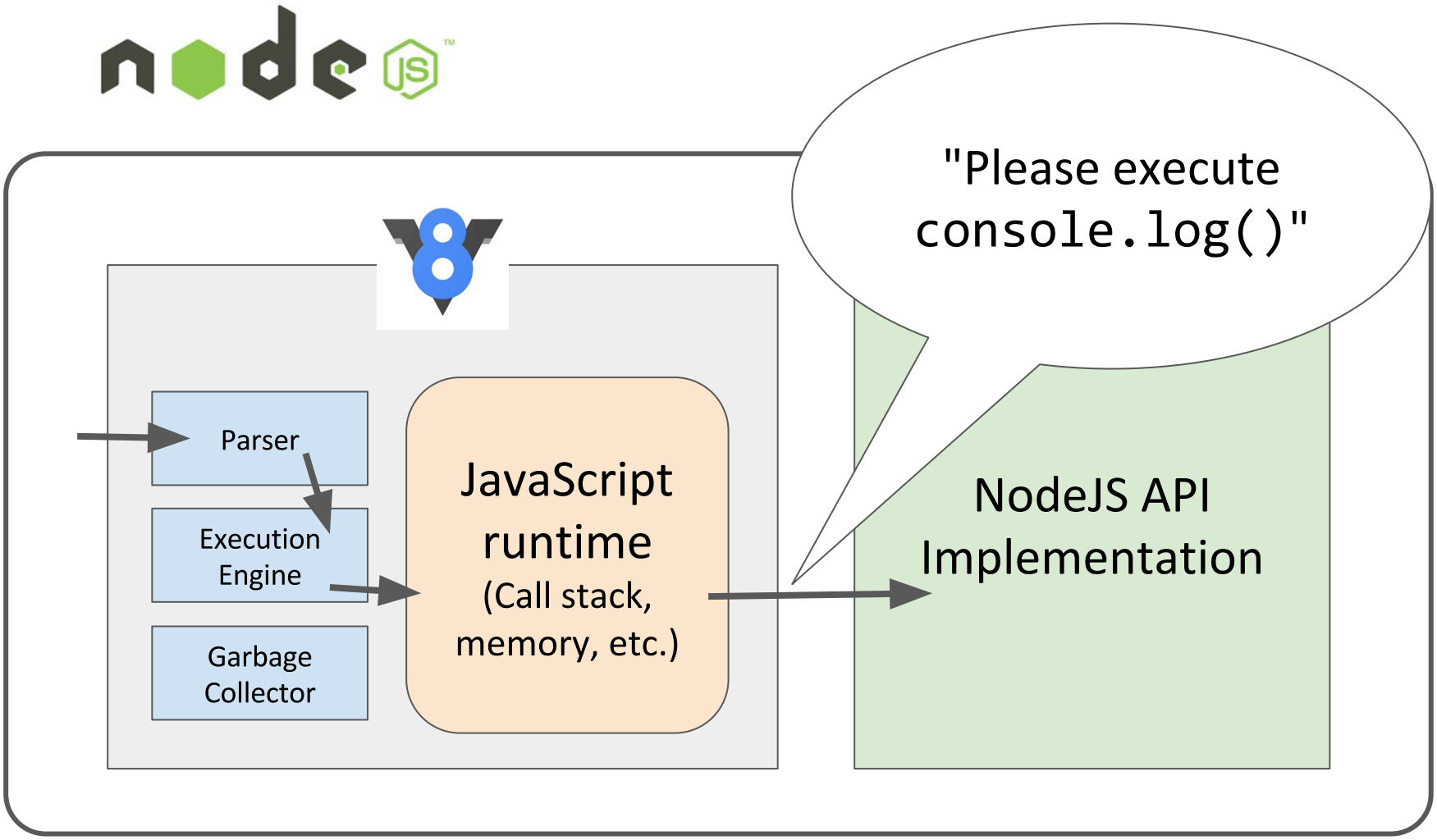



```
document.querySelector('div');
```

ReferenceError: document is not defined



What if you tried to call `console.log('nodejs');` in the NodeJS runtime?




```
console.log('nodejs');
```

(NodeJS API implemented their own `console.log`)

NodeJS

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NodeJS API:

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V8 (from Chrome):

- The JavaScript interpreter ("engine") that NodeJS uses to interpret, compile, and execute JavaScript code

Installation

NOTE: The following slides assume you have already installed NodeJS.

We will have NodeJS installation instructions linked on the course web page.

node command

Running node without a filename runs a REPL loop

- Similar to the JavaScript console in Chrome, or when you run "python"

```
$ node
> let x = 5;
undefined
> x++
5
> x
6
```

NodeJS

NodeJS can be used for writing scripts in JavaScript, completely unrelated to servers.

simple-script.js

```
function printPoem() {
  console.log('Roses are red,');
  console.log('Violets are blue,');
  console.log('Sugar is sweet,');
  console.log('And so are you.');
  console.log();
}

printPoem();
printPoem();
```

node command

The node command can be used to execute a JS file:

$ node ***fileName***

```
$ node simple-script.js
Roses are red,
Violets are blue,
Sugar is sweet,
And so are you.

Roses are red,
Violets are blue,
Sugar is sweet,
And so are you.
```

Node for servers

Here is a very basic server written for NodeJS:

```
const http = require('http');

const server = http.createServer();

server.on('request', function(req, res) {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello World\n');
});

server.on('listening', function() {
  console.log('Server running!');
});

server.listen(3000);
```

(WARNING: We will not actually be writing servers like this!!!

We will be using ExpressJS to help, but we haven't gotten there yet.

require()

```
const http = require('http');
const server = http.createServer();
```

The NodeJS `require()` statement loads a module, similar to `import` in Java or `include` in C++.

- We can `require()` modules included with NodeJS, or modules we've written ourselves.
- In this example, `'http'` is referring to the HTTP NodeJS module

require()

```
const http = require('http');

const server = http.createServer();
```

The `http` variable returned by `require('http')` can be used to make calls to the HTTP API:

- `http.createServer()` creates a Server object

Emitter.on

```
server.on('request', function(req, res) {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello World\n');
});

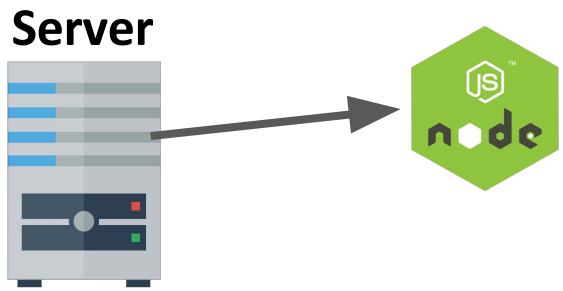
server.on('listening', function() {
  console.log('Server running!');
});
```

The on() function is the NodeJS equivalent of `addEventListener`.

Emitter.on

```
server.on('request', function(req, res) {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello World\n');
});
```

The `request` event is emitted each time there is a new HTTP request for the NodeJS program to process.



Emitter.on

```
server.on('request', function(req, res) {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello World\n');
});
```

The `req` parameter gives information about the incoming request, and the `res` parameter is the response parameter that we write to via method calls.

- `statusCode`: Sets the HTTP status code.
- `setHeader()`: Sets the HTTP headers.
- `end()`: Writes the message to the response body then signals to the server that the message is complete.

listen() and listening

```
server.on('listening', function() {
  console.log('Server running!');
});

server.listen(3000);
```

The `listen()` function will start accepting connections on the given **port number**.

- The `listening` event will be emitted when the server has been bound to a port.

Q: What's a port? What is binding?

Ports and binding

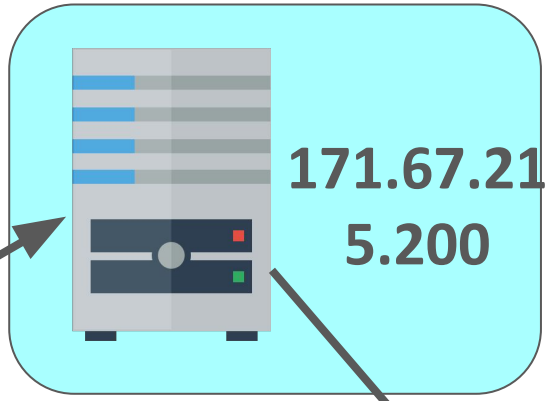
port: In the context of networking, a "logical" (as opposed to a physical) connection place

- A number from 0 to 65535 (16-bit unsigned integer)

When you start running a server process, you tell the operating system what port number to associate with it. This is called **binding**.

Operating system opens a TCP connection on port **80** of the computer at 171.67.215.200.

(Routing, etc…)



The server process running on port **80** Is responding to requests.

A TCP connection requires an IP address **and** a port number.

- If no port number is specified, 80 is the default for HTTP requests.

Ports defaults

There are many **well-known ports**, i.e. the ports that will be used by default for particular protocols:

21: File Transfer Protocol (FTP)
22: Secure Shell (SSH)
23: Telnet remote login service
25: Simple Mail Transfer Protocol (SMTP)
53: Domain Name System (DNS) service
80: Hypertext Transfer Protocol (HTTP) used in the World Wide Web
110: Post Office Protocol (POP3)
119: Network News Transfer Protocol (NNTP)
123: Network Time Protocol (NTP)
143: Internet Message Access Protocol (IMAP)
161: Simple Network Management Protocol (SNMP)
194: Internet Relay Chat (IRC)
443: HTTP Secure (HTTPS)

Development server

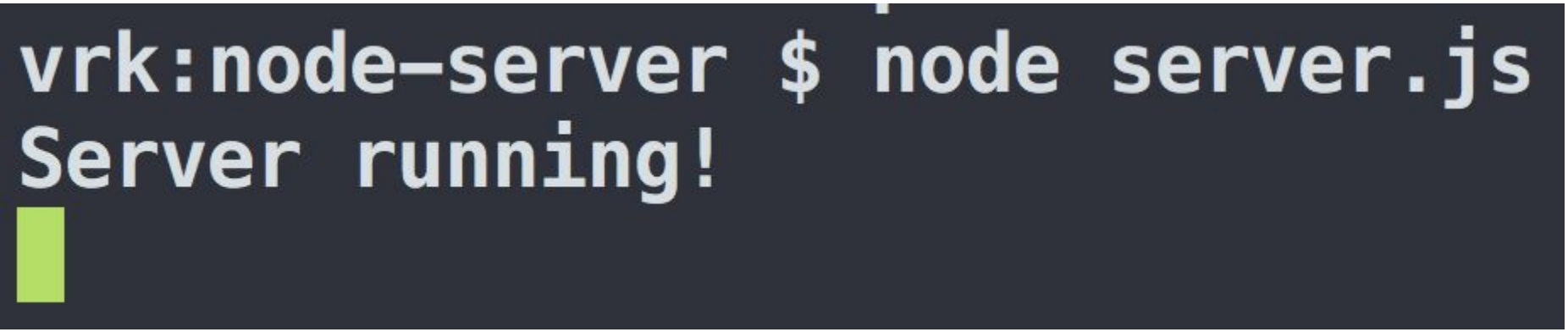
```
server.on('listening', function() {
  console.log('Server running!');
});

server.listen(3000);
```

For our development server, we can choose whatever port number we want. In this example, we've chosen 3000.

Running the server

When we run node `server.js` in the terminal, we see the following:



The process does not end after we run the command, as it is now waiting for HTTP requests on port 3000.

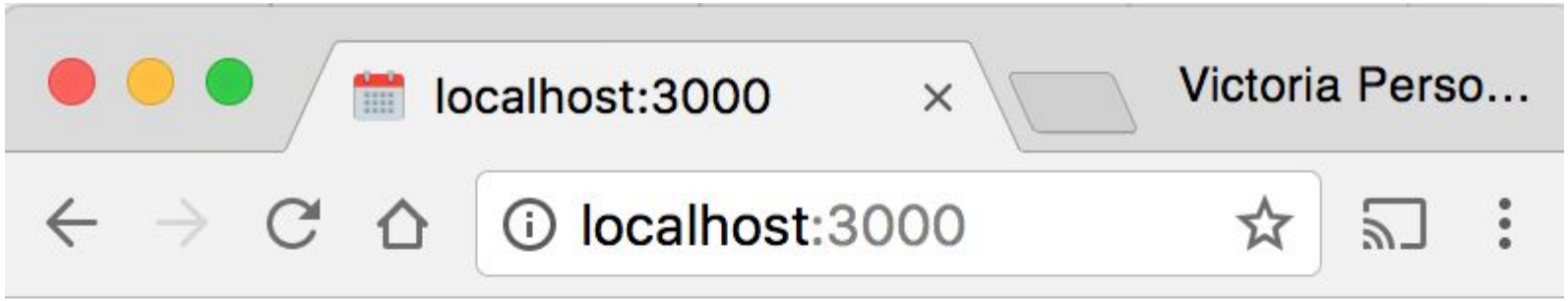
Q: How do we send an HTTP request on port 3000?

Localhost

We can send an HTTP GET request running on one of the ports on the local computer using the URL:

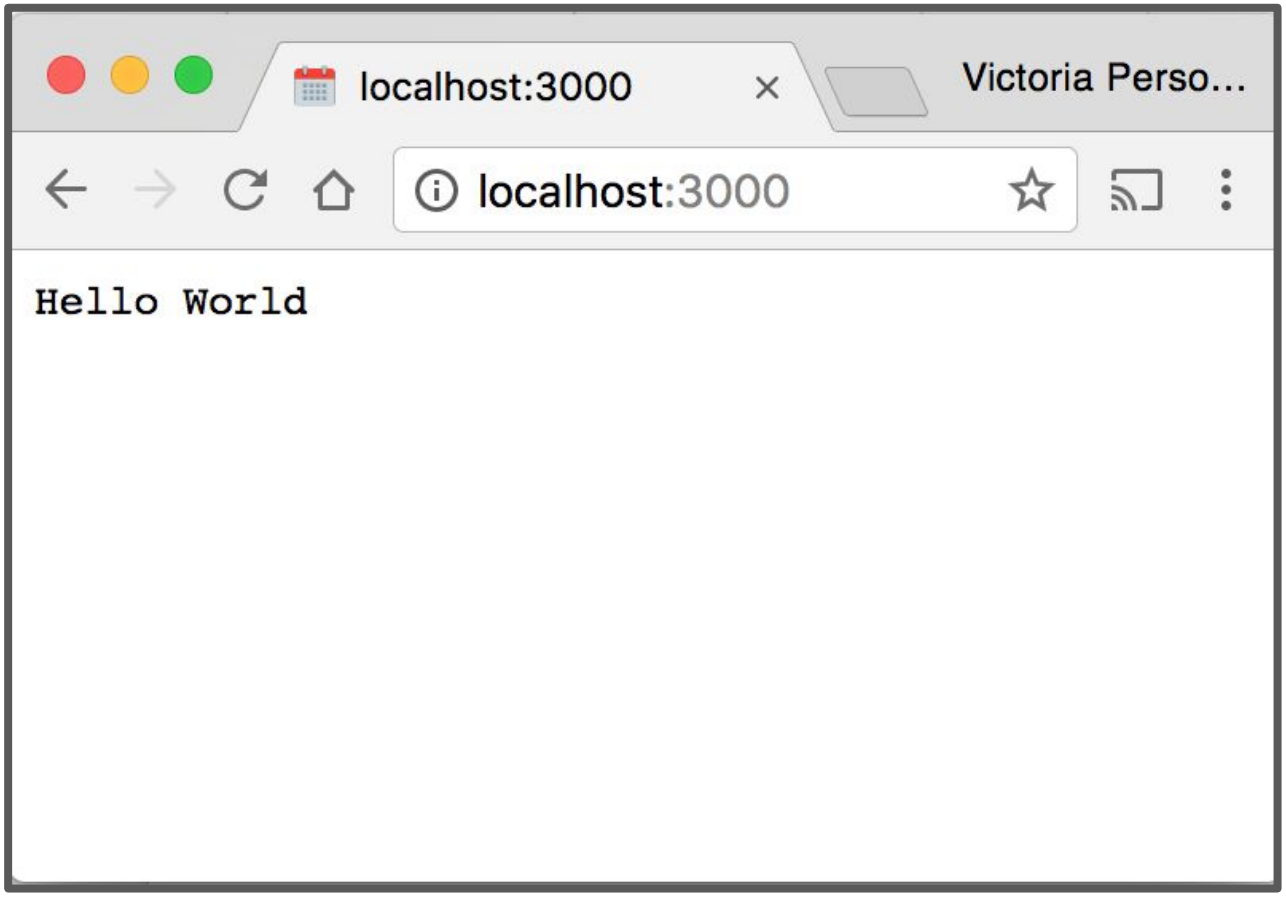
`http://localhost:`*portNumber*, e.g.
`http://localhost:3000`

Localhost is a hostname that means "this computer."



Server response

Here is the result of the request to our HTTP server:



Node for servers

This server returns the same response no matter what the request is.

```
const http = require('http');

const server = http.createServer();

server.on('request', function(req, res) {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello World\n');
});

server.on('listening', function() {
  console.log('Server running!');
});

server.listen(3000);
```

Node for servers

The NodeJS server APIs are actually pretty low-level:

- You build the request manually
- You write the response manually
- There's a lot of tedious processing code

```
var http = require('http');

http.createServer(function(request, response) {
  var headers = request.headers;
  var method = request.method;
  var url = request.url;
  var body = [];
  request.on('error', function(err) {
    console.error(err);
  }).on('data', function(chunk) {
    body.push(chunk);
  }).on('end', function() {
    body = Buffer.concat(body).toString();
    // BEGINNING OF NEW STUFF

    response.on('error', function(err) {
      console.error(err);
    });

    response.statusCode = 200;
    response.setHeader('Content-Type', 'application/json');
    // Note: the 2 lines above could be replaced with this next one:
    // response.writeHead(200, {'Content-Type': 'application/json'})

    var responseBody = {
      headers: headers,
      method: method,
      url: url,
      body: body
    };
```

ExpressJS

We're going to use a library called ExpressJS on top of NodeJS:

```
const express = require('express');
const app = express();

app.get('/', function (req, res) {
  res.send('Hello World!');
})

app.listen(3000, function () {
  console.log('Example app listening on port 3000!');
})
```

Express routing

ExpressJS

However, Express is not part of the NodeJS APIs.

If we try to use it like this, we'll get an error:

```
const express = require('express');
const app = express();
```

```
module.js:327
    throw err;
    ^

Error: Cannot find module 'express'
    at Function.Module._resolveFilename
```

We need to install Express via npm.

npm

When you install NodeJS, you also install `npm`:

- **npm**: Node Package Manager*:
  Command-line tool that lets you install **packages** (libraries and tools) written in JavaScript and compatible with NodeJS
- Can find packages through the online repository:
  https://www.npmjs.com/

*though the creators of "npm" say it's not an acronym (as a joke -_-)

npm install and uninstall

`npm install` ***package-name***

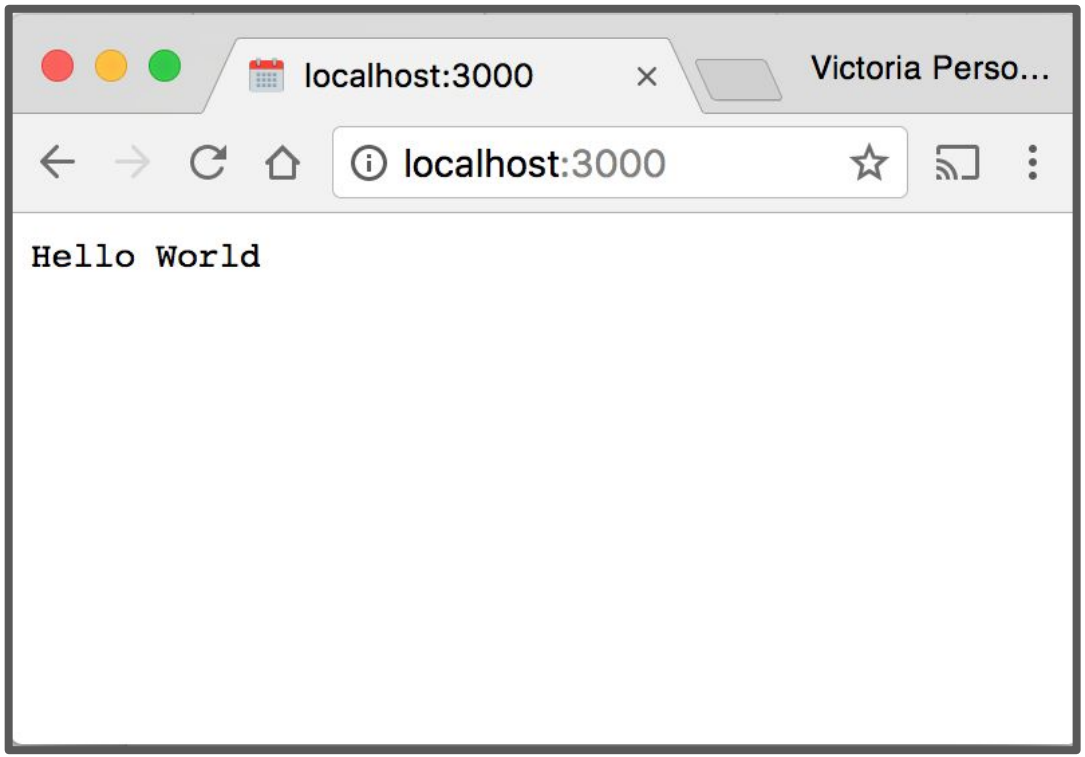
- This downloads the *package-name* library into a `node_modules` folder.
- Now the *package-name* library can be included in your NodeJS JavaScript files.

`npm uninstall` ***package-name***

- This removes the *package-name* library from the `node_modules` folder, deleting the folder if necessary

Express example

```
$ npm install express
$ node server.js
Example app listening on port 3000!
```



Express routes

You can specify routes in Express:

```
app.get('/', function (req, res) {
  res.send('Main page!');
});

app.get('/hello', function (req, res) {
  res.send('GET hello!');
});

app.post('/hello', function (req, res) {
  res.send('POST hello!');
});
```

Express routes

```
app.get('/hello', function (req, res) {
  res.send('GET hello!');
});
```

app.***method***(***path***, ***handler***)

- Specifies how the server should handle HTTP ***method*** requests made to URL/***path***
- This example is saying:
  - When there's a GET request to http://localhost:3000/hello, respond with the text "GET hello!"

Handler parameters

```
app.get('/hello', function (req, res) {
  res.send('GET hello!');
});
```

Express has its own `Request` and `Response` objects:

- req is a Request object
- res is a Response object
- `res.send()` sends an HTTP response with the given content
  - Sends content type "text/html" by default

Querying our server

Here are three ways to send HTTP requests to our server:

1. Navigate to http://localhost:3000/<path> in our browser
    a. Can only do GET requests

2. Call `fetch()` in web page
    a. We've done GET requests so far, but can send any type of HTTP request

3. `curl` command-line tool
    a. Debug tool we haven't seen yet

curl

`curl`: Command-line tool to send and receive data from a server (Manual)

`curl --request` ***METHOD url***

e.g.

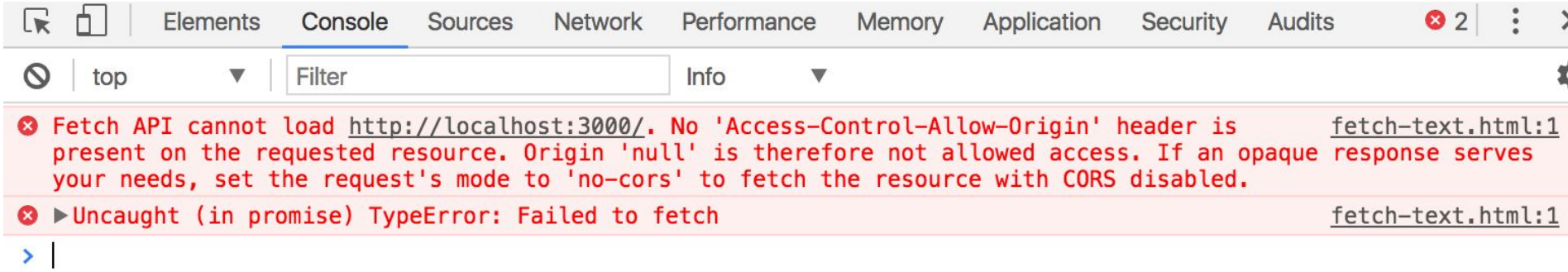
```
$ curl --request PUT http://localhost:3000/hello
```

fetch() to localhost

If we try fetching to localhost from file://

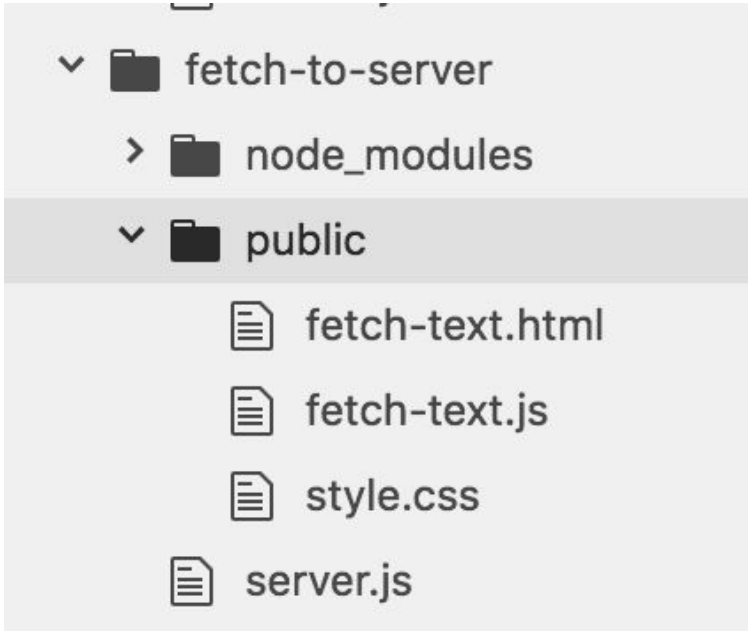
```
fetch('http://localhost:3000')
    .then(onResponse)
    .then(onTextReady);
```

We get this CORS error:



Server static data

We can instead serve our HTML/CSS/JS **statically** from the same server:




```
const express = require('express');
const app = express();

app.use(express.static('public'))

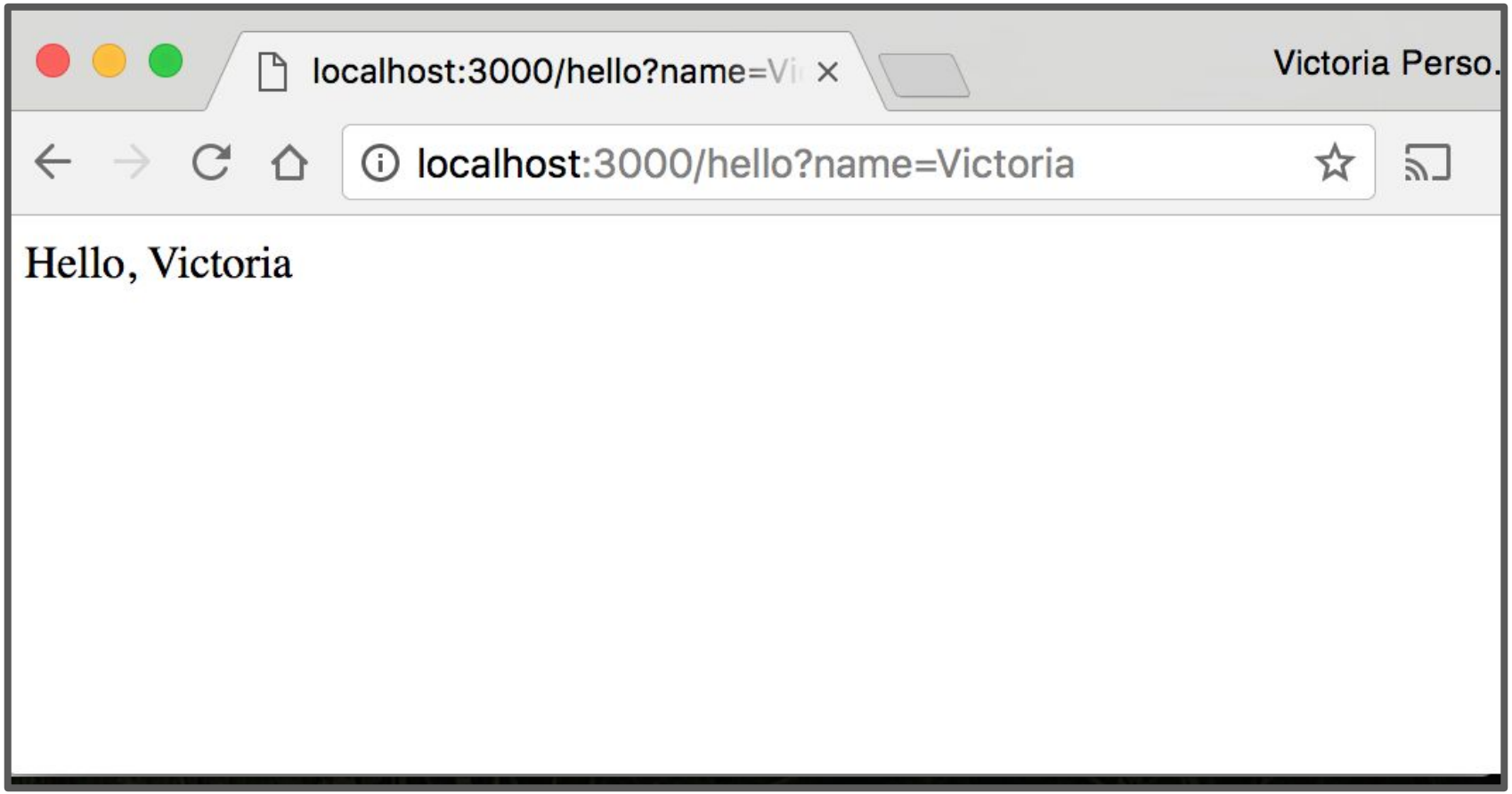
app.get('/', function (req, res) {
  res.send('Main page!');
});
```

GET query params in Express

```
app.get('/hello', function (req, res) {
  const queryParams = req.query;
  console.log(queryParams);
  const name = req.query.name;
  res.send('Hello, ' + name);
});
```

Query parameters are saved in **`req.query`**.

GET query params in Express



`fetch()` with POST

```
app.post('/hello', function (req, res) {
  res.send('POST hello!');
});
```

On the server-side, you define your handler in `app.post()` to handle POST requests.

fetch() with POST

```
function onTextReady(text) {
  console.log(text);
}

function onResponse(response) {
  return response.text();
}

fetch('/hello', { method: 'POST' })
    .then(onResponse)
    .then(onTextReady);
```

fetch() with POST

```
function onTextReady(text) {
  console.log(text);
}

function onResponse(response) {
  return response.text();
}

fetch('/hello', { method: 'POST' })
    .then(onResponse)
    .then(onTextReady);
```

Query params with POST

You can send query parameters via POST as well:

```
function onTextReady(text) {
  console.log(text);
}

function onResponse(response) {
  return response.text();
}

fetch('/hello?name=Victoria', { method: 'POST' })
    .then(onResponse)
    .then(onTextReady);
```

(WARNING: We will not be making POST requests like this!

We will be sending data in the body of the request instead of via query params.)

Query params with POST

These parameters are accessed the same way:

```
app.post('/hello', function (req, res) {
  const queryParams = req.query;
  console.log(queryParams);
  const name = req.query.name;
  res.send('POST Hello, ' + name);
});
```

(WARNING: We will not be making POST requests like this!

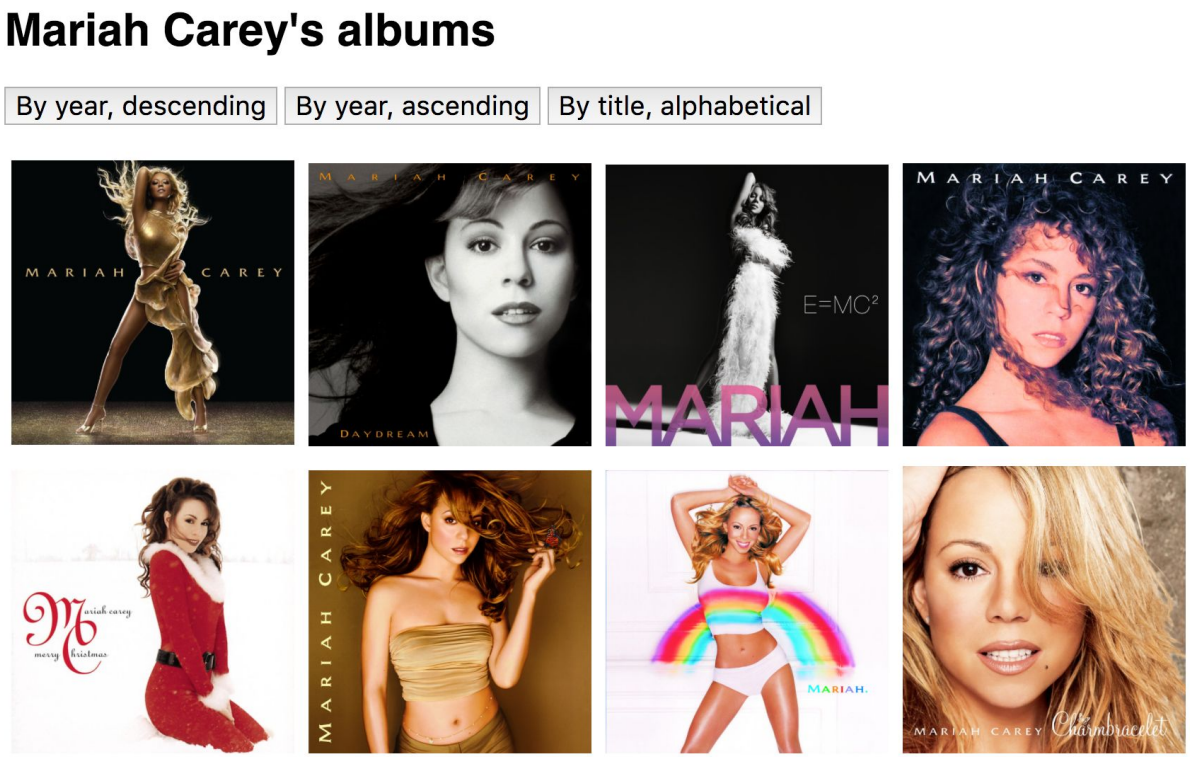
We will be sending data in the body of the request instead of via query params.)

Overflow (will cover if time)

Single-threaded asynchrony

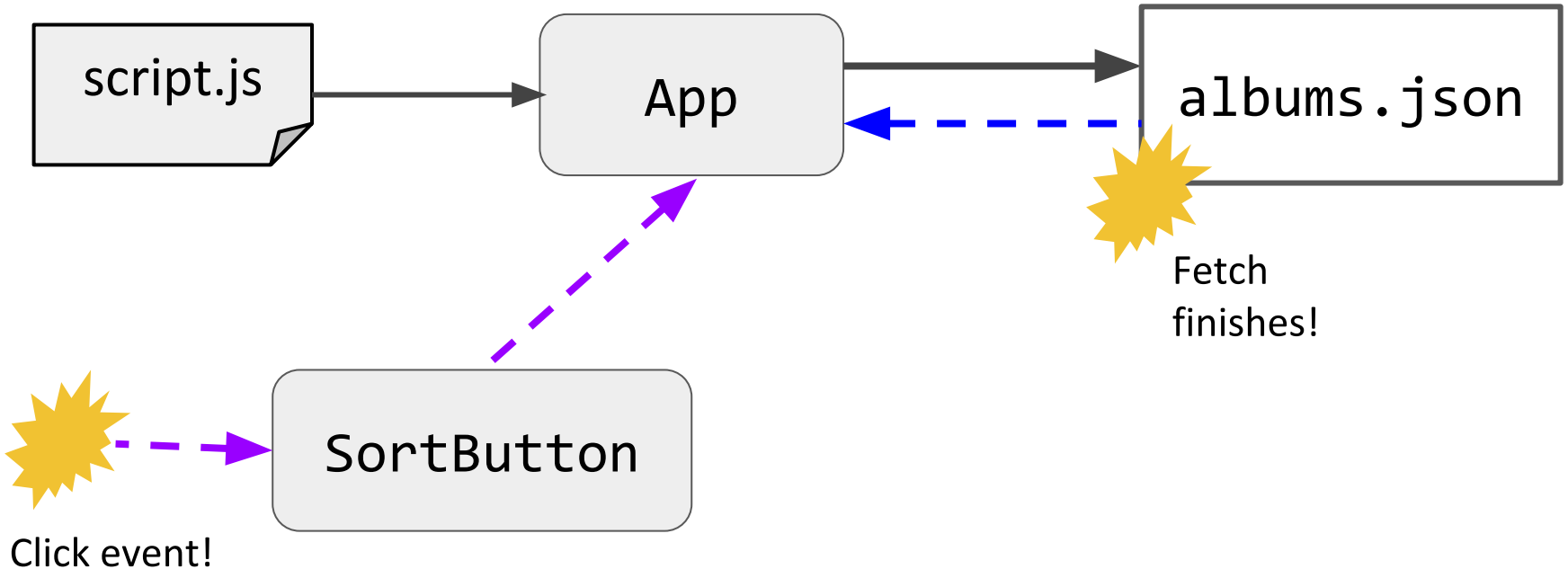
Recall: Discography page

We wrote a web page that lists the Mariah Carey albums stored in albums.json and lets us sort the albums: (CodePen / demo)



Asynchronous events

We have written our code in a way that assumes `fetch()` will complete before clicking, but on a slow connection, that's not a safe assumption.

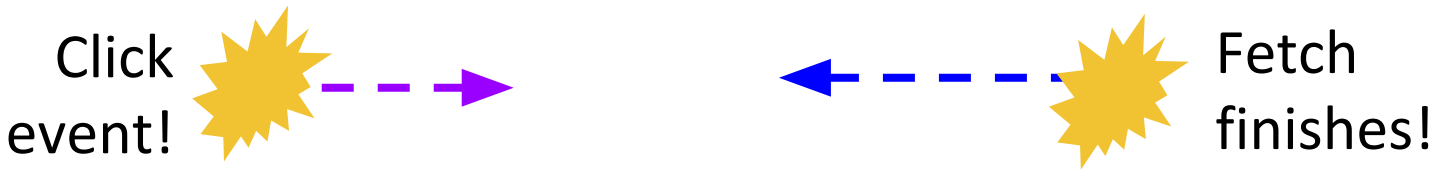


General problem

The problem stated generically:

- There are 2+ events that can occur at unpredictable times, and the two events are **dependent** on each other in some way

(Some people call this a "**race condition**", though other people reserve the term for multiple threads only.)



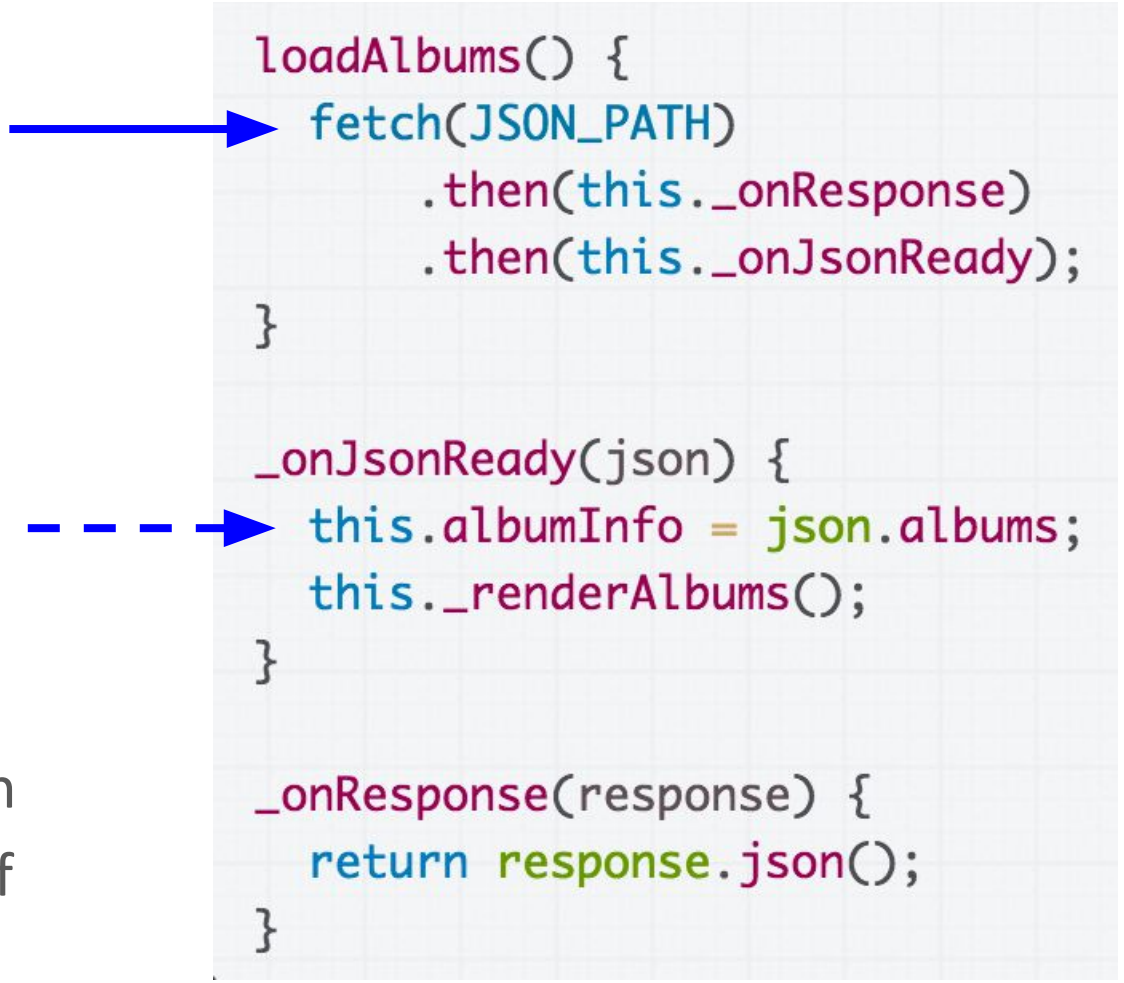
Solutions

You can either "force" loading to occur before button click, for example:

- Disable buttons until the JSON loads
- OR: Don't show buttons until the JSON loads
- OR: Don't show the UI at all until the JSON completes

Single-threaded asynchrony

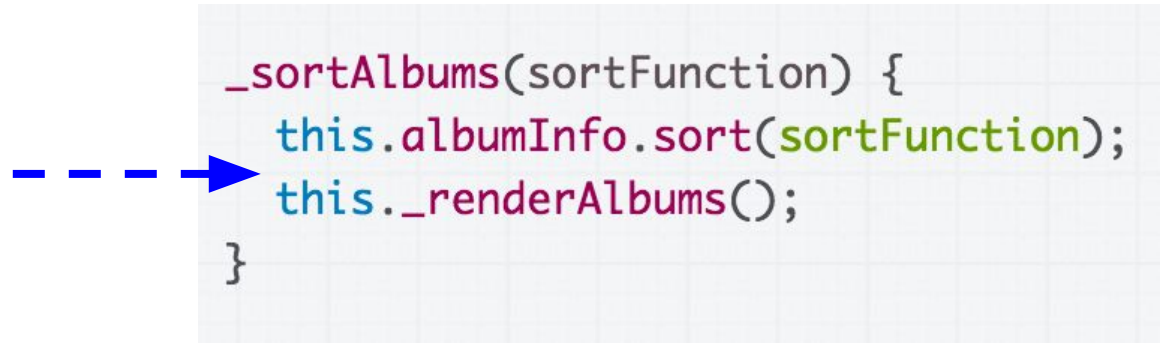
Is it possible for the _onJsonReady function to fire *in the middle* of sortAlbums?



```
loadAlbums() {
  fetch(JSON_PATH)
      .then(this._onResponse)
      .then(this._onJsonReady);
}

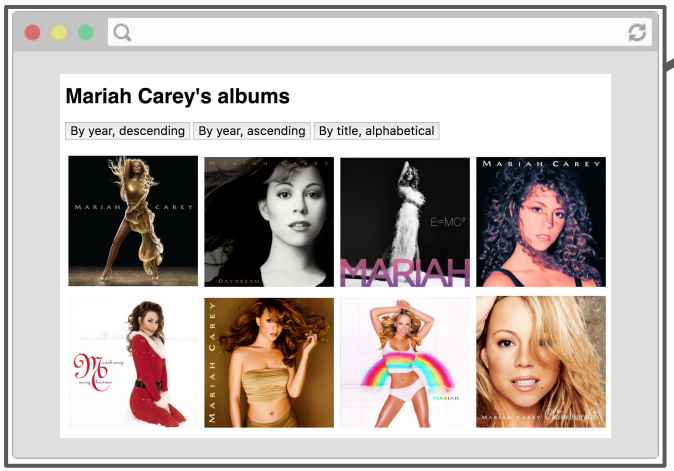
_onJsonReady(json) {
  this.albumInfo = json.albums;
  this._renderAlbums();
}

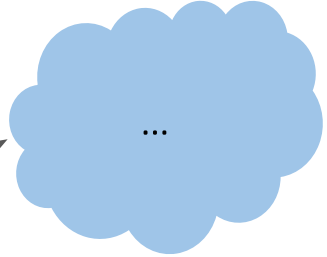
_onResponse(response) {
  return response.json();
}
```

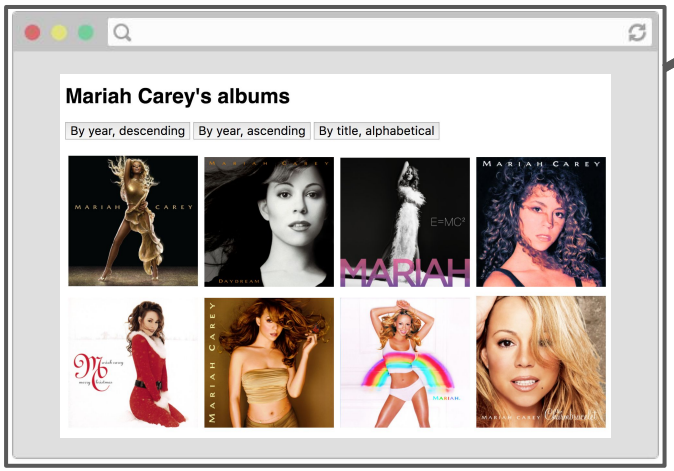


```
_sortAlbums(sortFunction) {
  this.albumInfo.sort(sortFunction);
  this._renderAlbums();
}
```

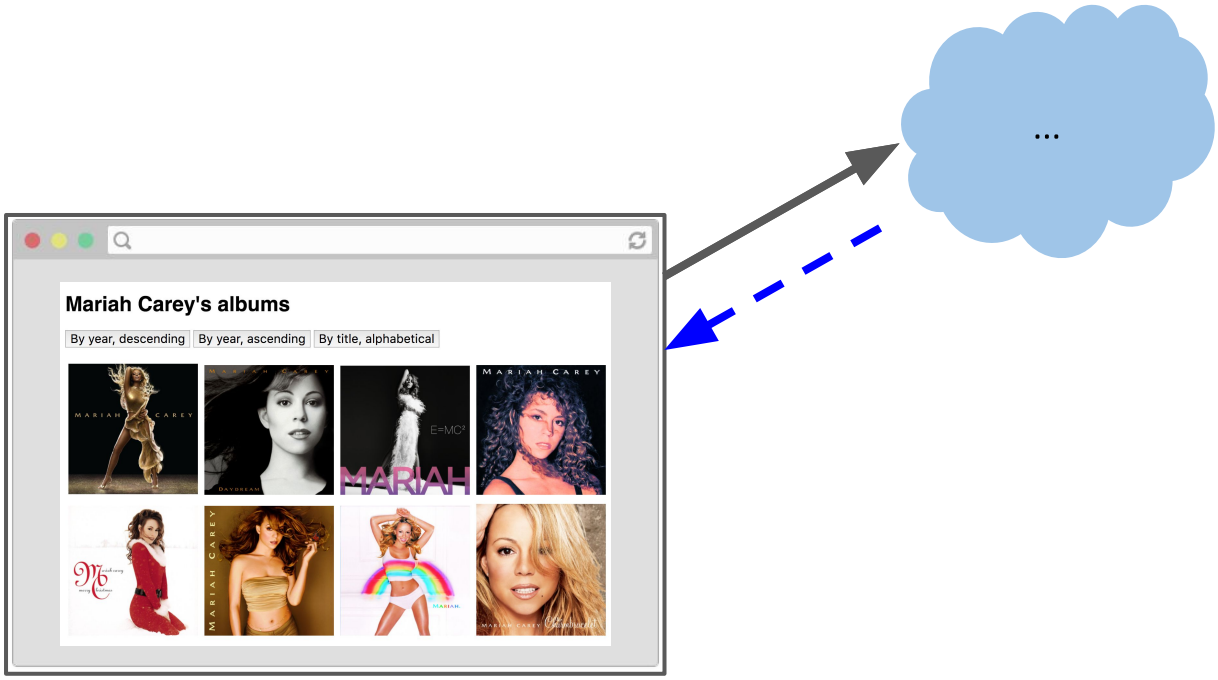
The browser is fetching `albums.json`...







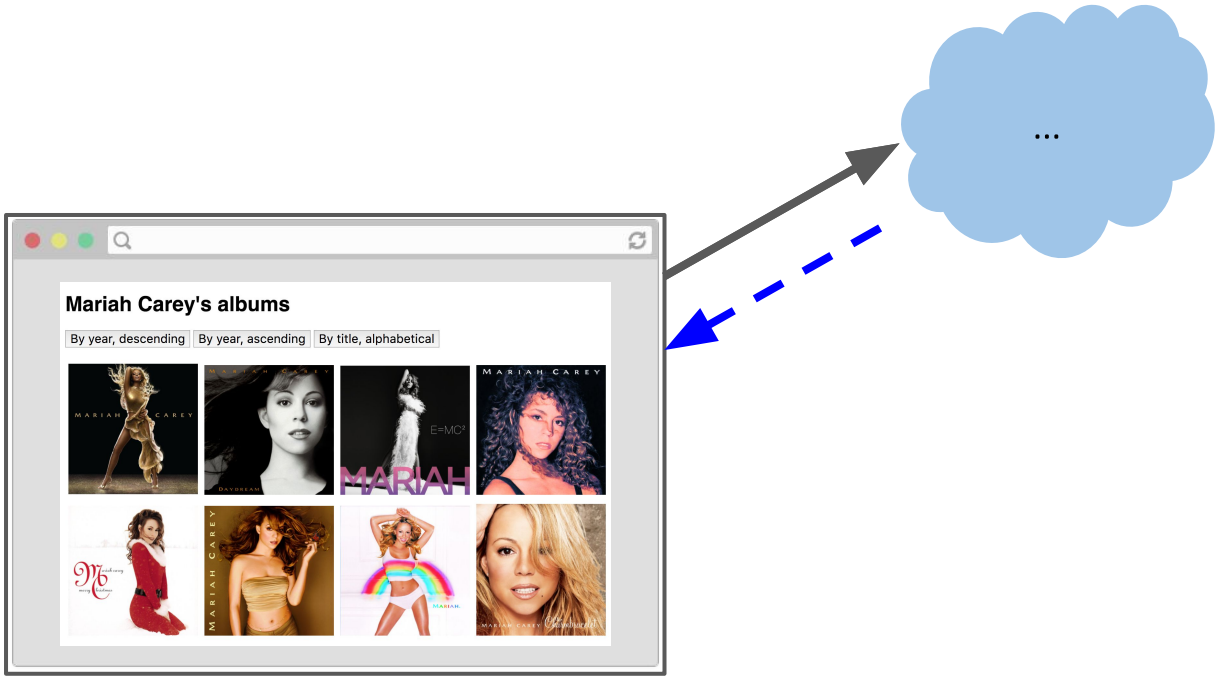
User clicks a button, so the event handler is running



Is it possible that **while** the click handler is still running (still on the call stack), the `fetch()` callback also fires?

```
_sortAlbums(sortFunction) {
  this.albumInfo.sort(sortFunction);
  this._renderAlbums();
}
```

```
_onJsonReady(json) {
  this.albumInfo = json.albums;
  this._renderAlbums();
}
```



The answer is **No**, because JavaScript is **single-threaded**.

```
_sortAlbums(sortFunction) {
  this.albumInfo.sort(sortFunction);
  this._renderAlbums();
}
```

```
_onJsonReady(json) {
  this.albumInfo = json.albums;
  this._renderAlbums();
}
```

Single-threaded?

Some hand-wavy definitions:

- **Single-threaded**:
  - When your computer processes one command at a time
  - There is one call stack
- **Multi-threaded**
  - When your computer processes multiple commands simultaneously
  - There is one call stack **per thread**

thread: a linear sequence of instructions; an executable container for instructions

Single-threaded JS

- We create a new Album for each album in the JSON file
- For each album, we create a new DOM Image

```
_renderAlbums() {
  const albumContainer = document.querySelector('#album-container');
  albumContainer.innerHTML = '';
  for (const info of this.albumInfo) {
    const album = new Album(albumContainer, info.url);
  }
}
```

Q: If in JavaScript, only one thing happens at a time, does that mean only one image loads at a time?

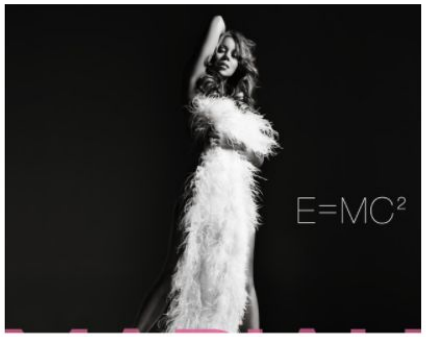
```
class Album {
  constructor(albumContainer, imageUrl) {
    // Same as document.createElement('img');
    const image = new Image();
    image.src = imageUrl;
    albumContainer.append(image);
  }
}
```

Image loading

Empirically, that doesn't seem to be the case:

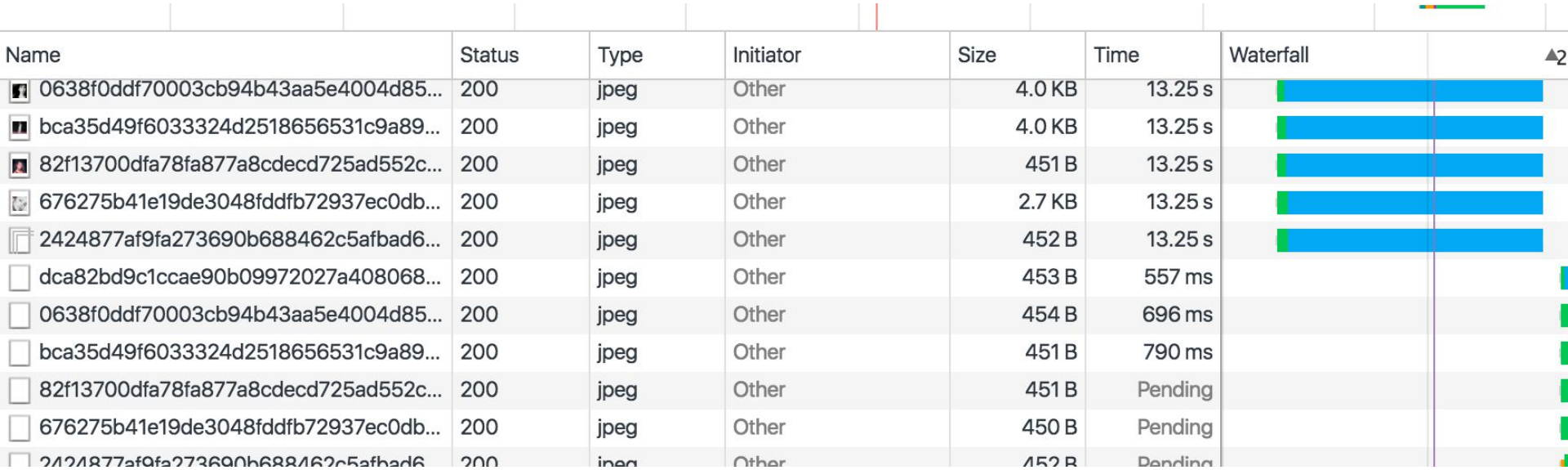
Mariah Carey's albums

By year, descending | By year, ascending | By title, alphabetical



Network tab

If we look at Chrome's Network tab, we see there are several images being loaded simultaneously:



Name	Status	Type	Initiator	Size	Time	Waterfall
0638f0ddf70003cb94b43aa5e4004d85...	200	jpeg	Other	4.0 KB	13.25 s	
bca35d49f6033324d2518656531c9a89...	200	jpeg	Other	4.0 KB	13.25 s	
82f13700dfa78fa877a8cdecd725ad552c...	200	jpeg	Other	451 B	13.25 s	
676275b41e19de3048fddfb72937ec0db...	200	jpeg	Other	2.7 KB	13.25 s	
2424877af9fa273690b688462c5afbad6...	200	jpeg	Other	452 B	13.25 s	
dca82bd9c1ccae90b09972027a408068...	200	jpeg	Other	453 B	557 ms	
0638f0ddf70003cb94b43aa5e4004d85...	200	jpeg	Other	454 B	696 ms	
bca35d49f6033324d2518656531c9a89...	200	jpeg	Other	451 B	790 ms	
82f13700dfa78fa877a8cdecd725ad552c...	200	jpeg	Other	451 B	Pending	
676275b41e19de3048fddfb72937ec0db...	200	jpeg	Other	450 B	Pending	
2424877af9fa273690b688462c5afbad6...	200	jpeg	Other	452 B	Pending	

Q: If JavaScript is single-threaded, i.e. if only one thing happens at a time, how can images be loaded in parallel?

JavaScript event loop

Note: see talk!

(For a perfectly great talk on this, see Philip Roberts' talk: https://www.youtube.com/watch?v=8aGhZQkoFbQ&t=1s

And for a perfectly great deep dive on this, see Jake Archibald's blog post: https://jakearchibald.com/2015/tasks-microtasks-queues-and-schedules/

These slides are inspired by these resources!)

`setTimeout`

To help us understand the event loop better, let's learn about a new command, `setTimeout`:

`setTimeout(`***function***, ***delay***`);`

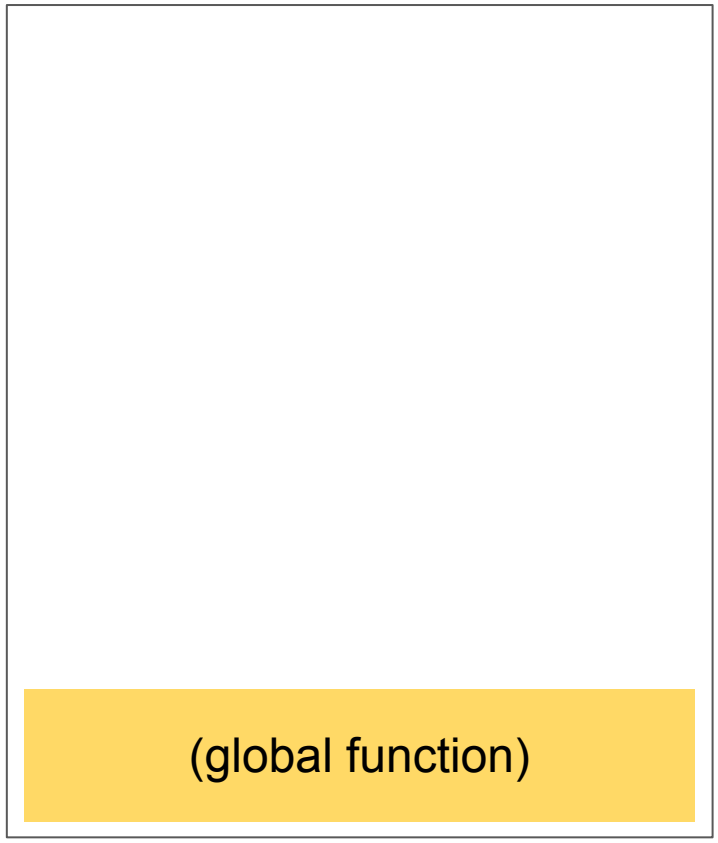
- ***function*** will fire after ***delay*** milliseconds
- CodePen example

Call stack + `setTimeout`

```
function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
  h1.textContent = 'loaded';
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack



Call stack + `setTimeout`

```
function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
  h1.textContent = 'loaded';
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack

Call stack + `setTimeout`

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function onTimerDone() {
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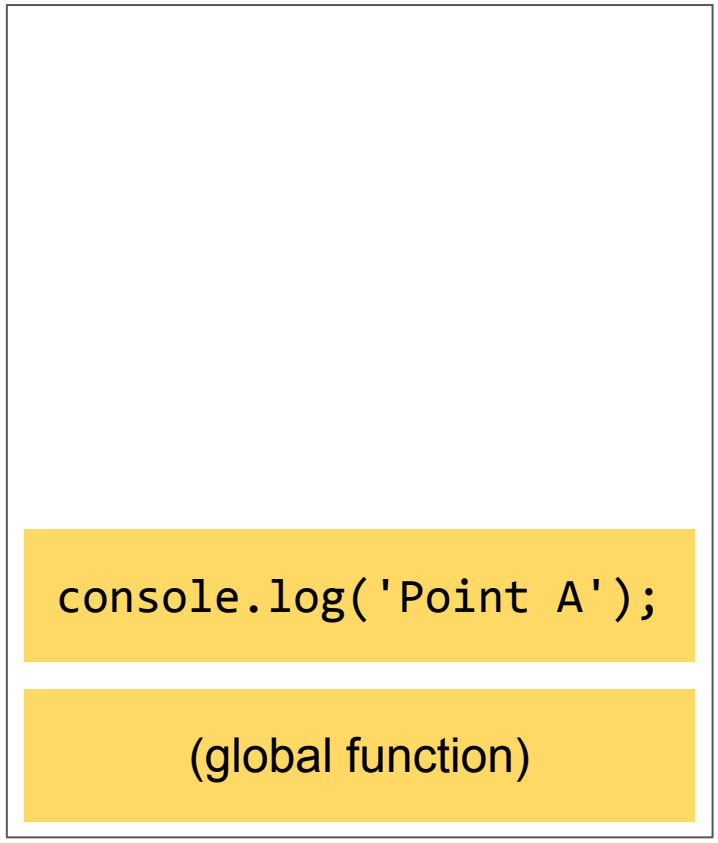
```

Call Stack



Call stack + `setTimeout`

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function onTimerDone() {
  console.log('Point C');
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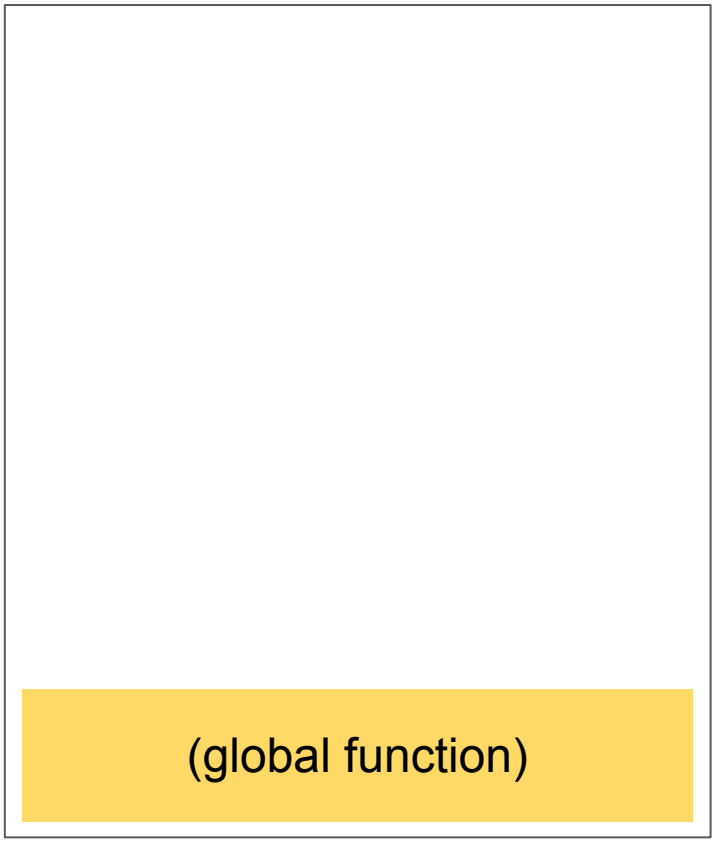
```

Call Stack



Call stack + `setTimeout`

```
function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
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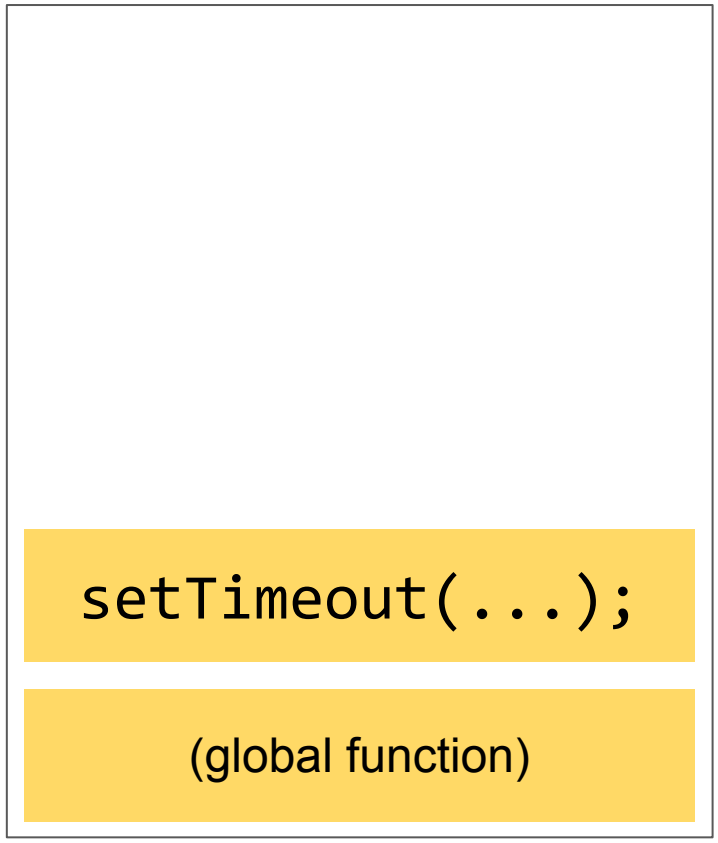
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack

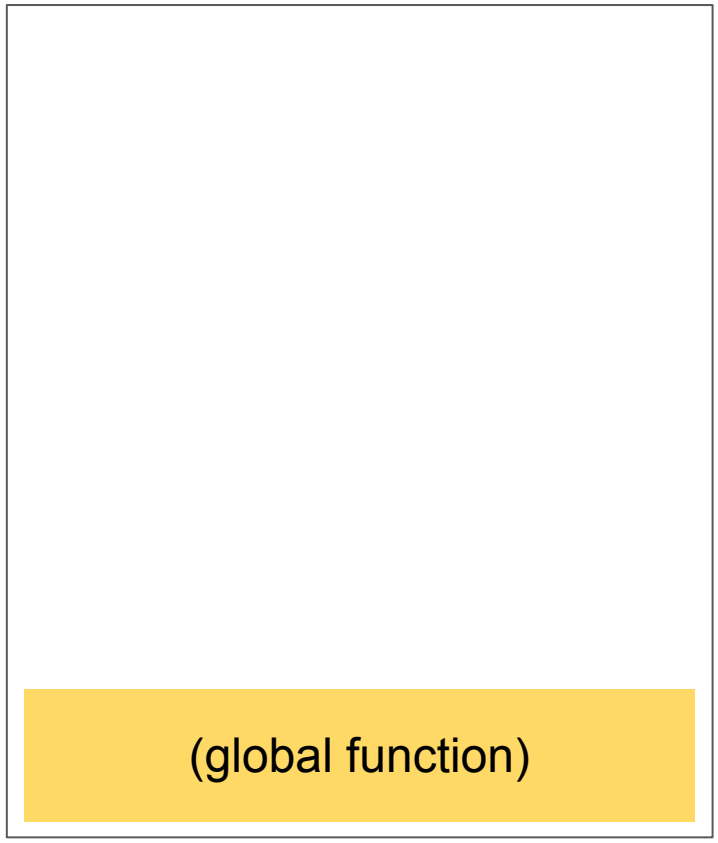


Call stack + `setTimeout`

```
function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
  h1.textContent = 'loaded';
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack

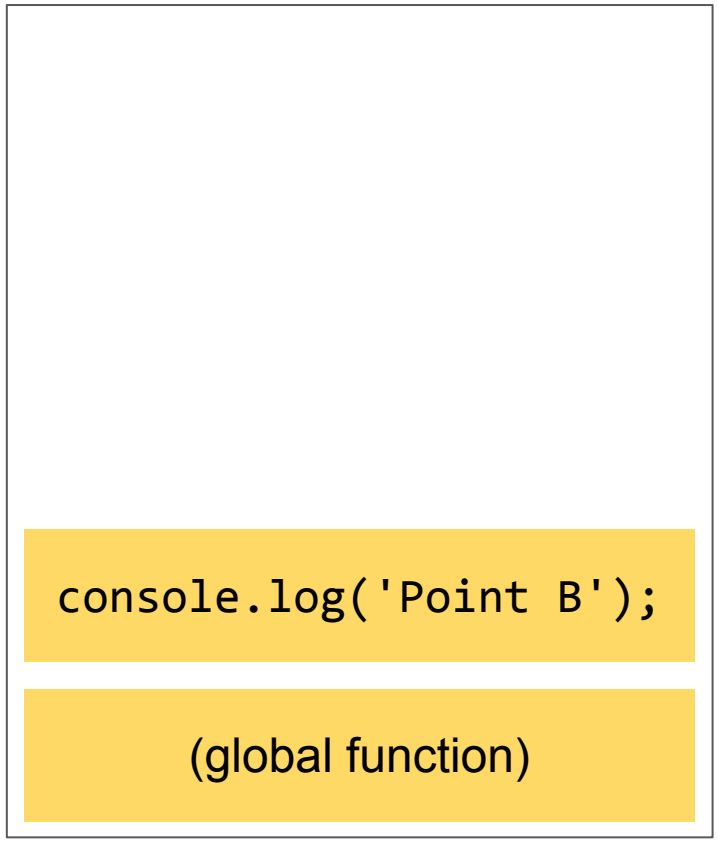


Call stack + `setTimeout`

```
function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
  h1.textContent = 'loaded';
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack



Call stack + `setTimeout`

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function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
  h1.textContent = 'loaded';
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack

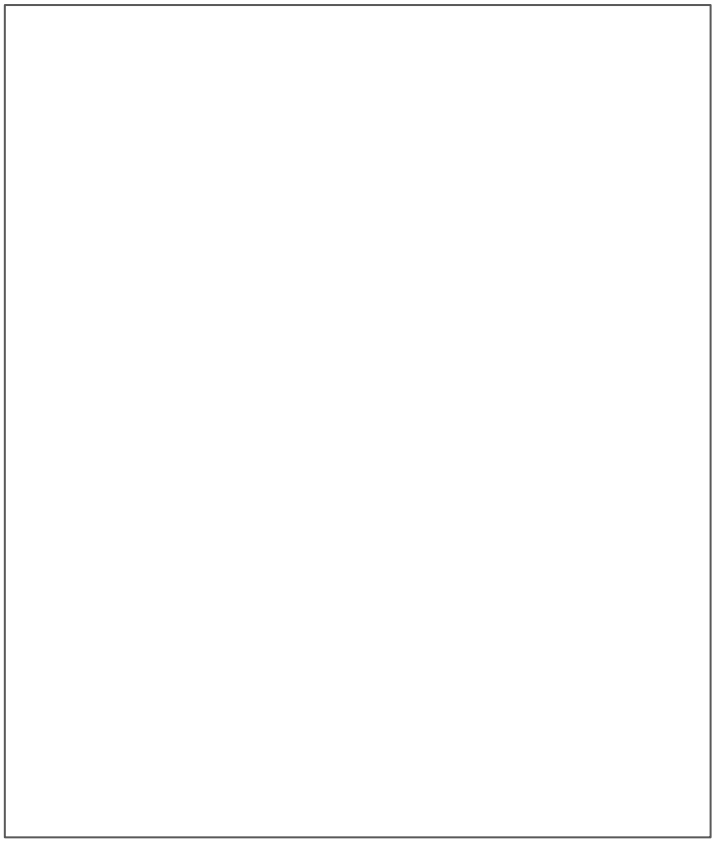
(global function)

Call stack + `setTimeout`

```
function onTimerDone() {
  console.log('Point C');
  const h1 = document.querySelector('h1');
  h1.textContent = 'loaded';
}

console.log('Point A');
setTimeout(onTimerDone, 3000);
console.log('Point B');
```

Call Stack



Call stack + `setTimeout`

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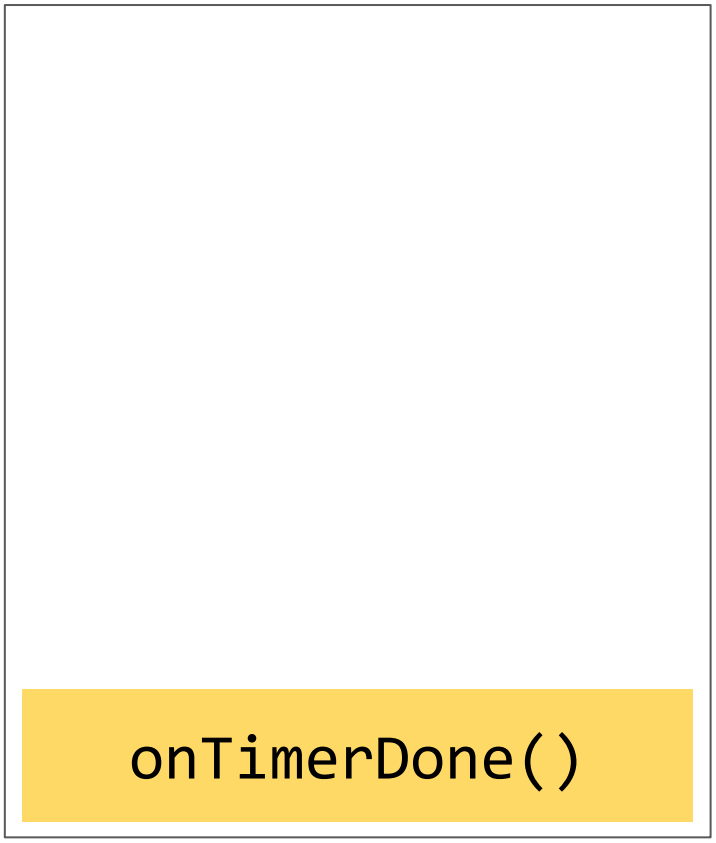

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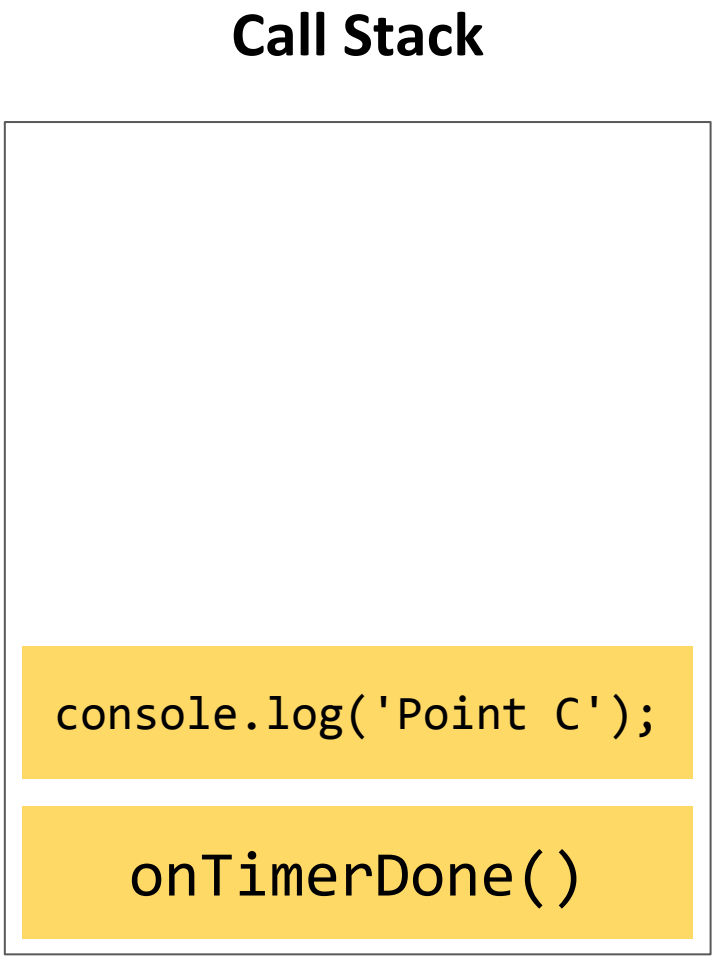

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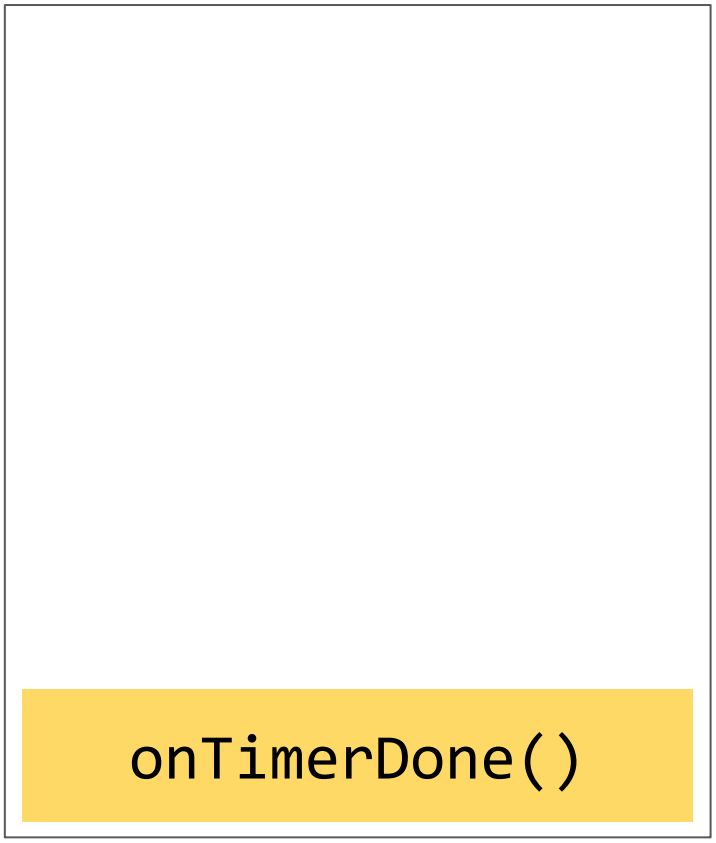

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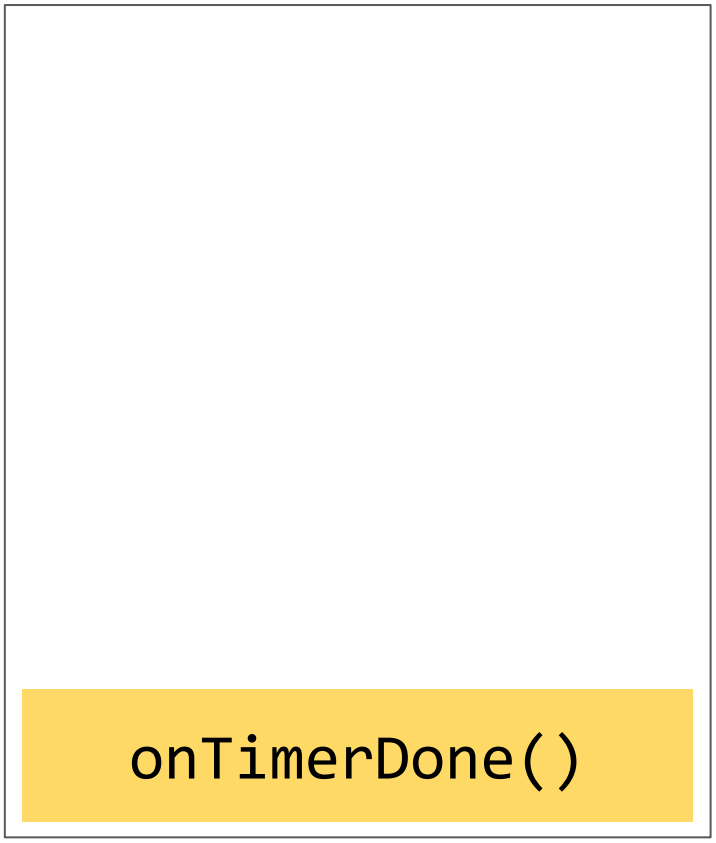

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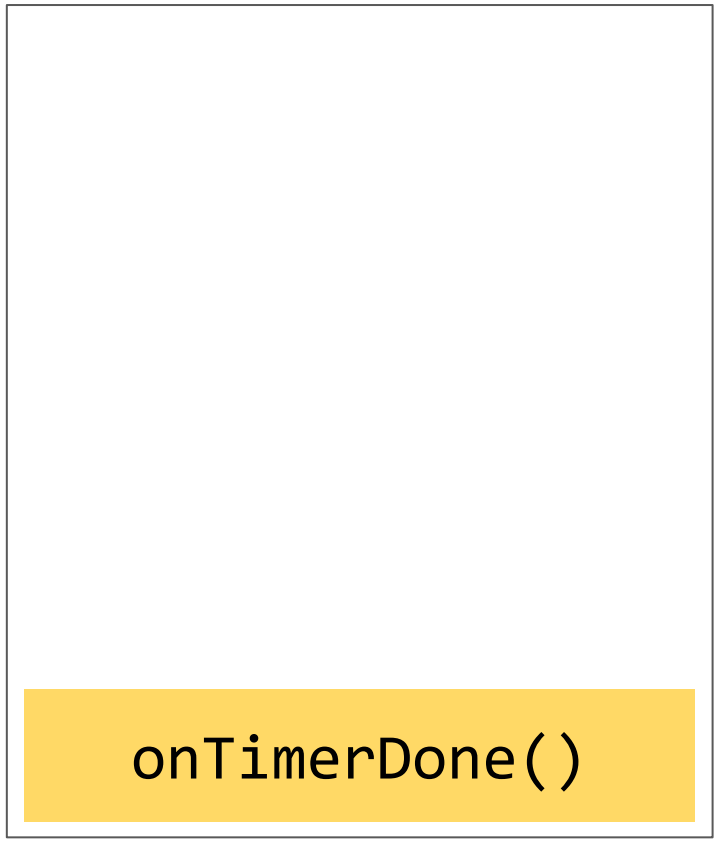

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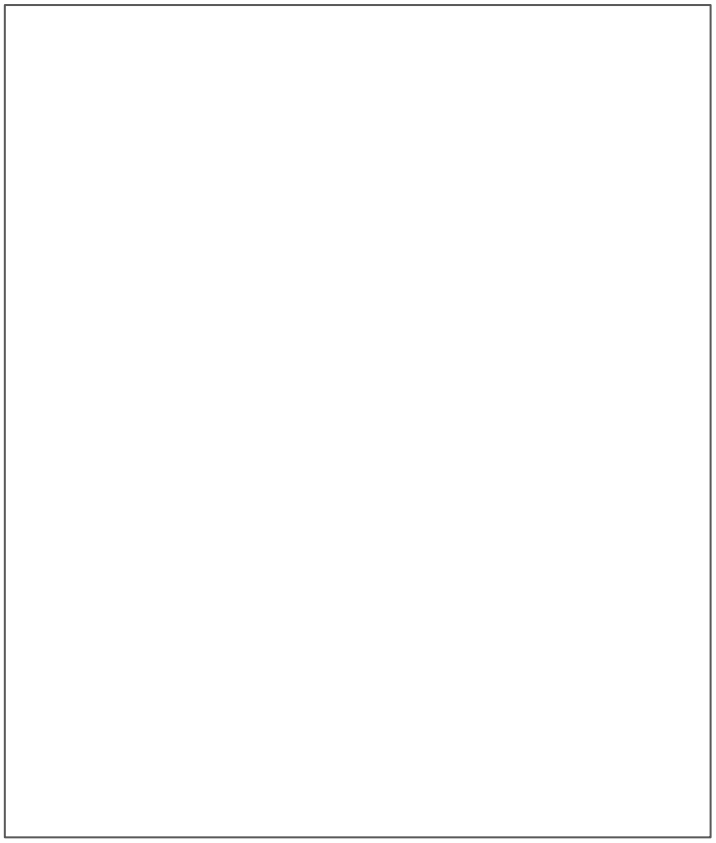

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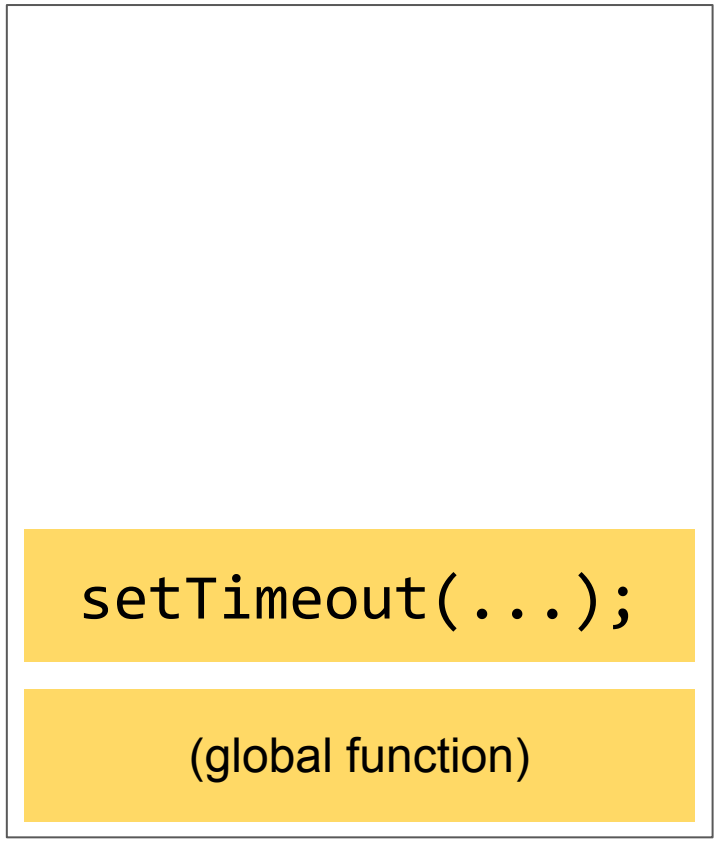
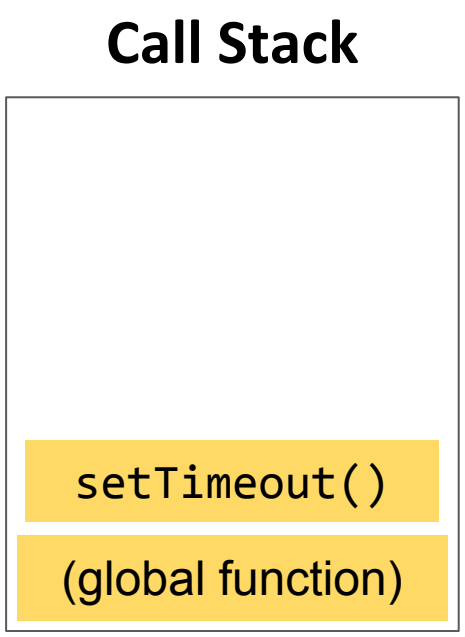
What "enqueues" onTimerDone?
How does it get fired?

Call Stack



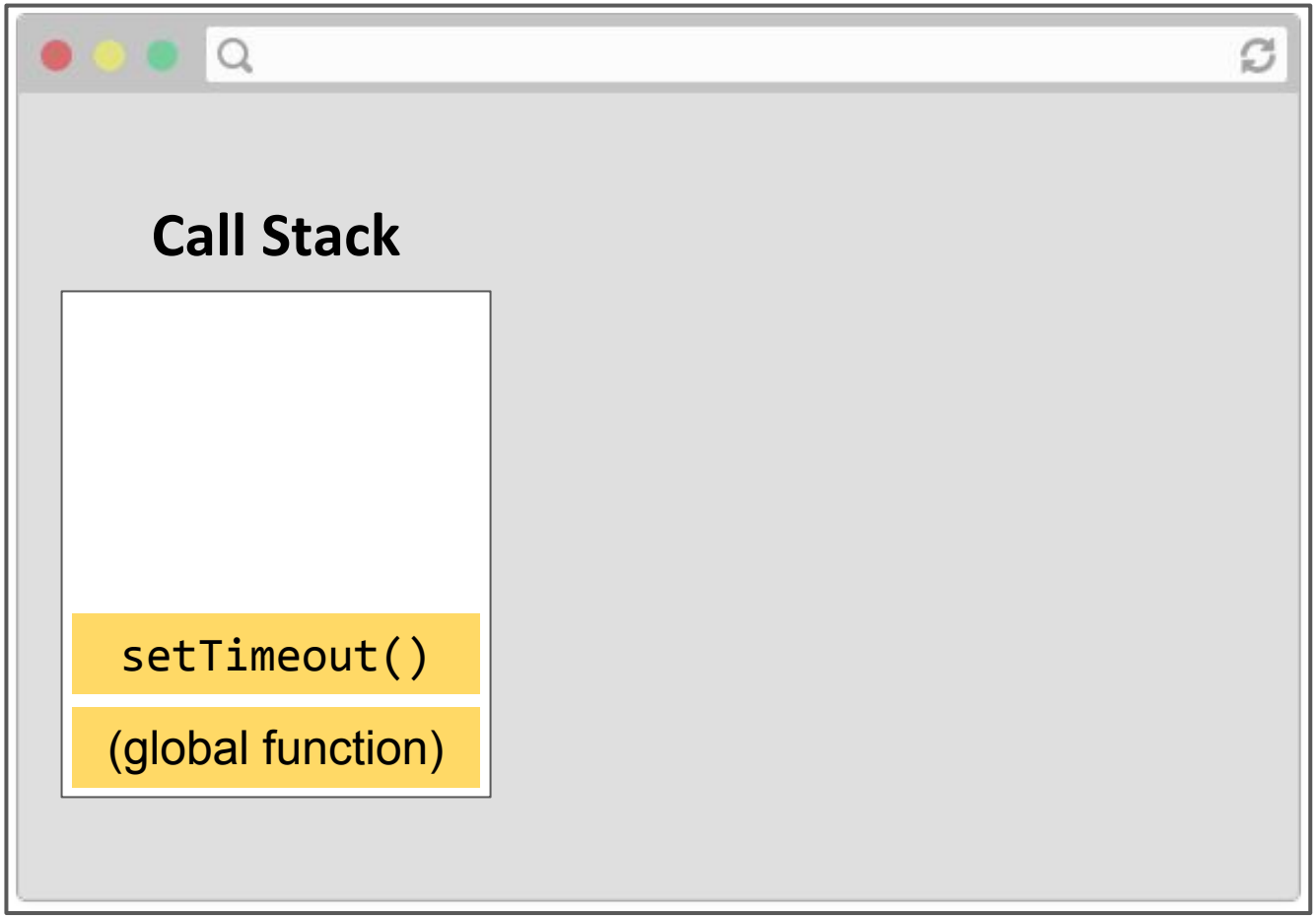
Tasks, Micro-tasks, and the Event Loop

Tasks and the Event Loop

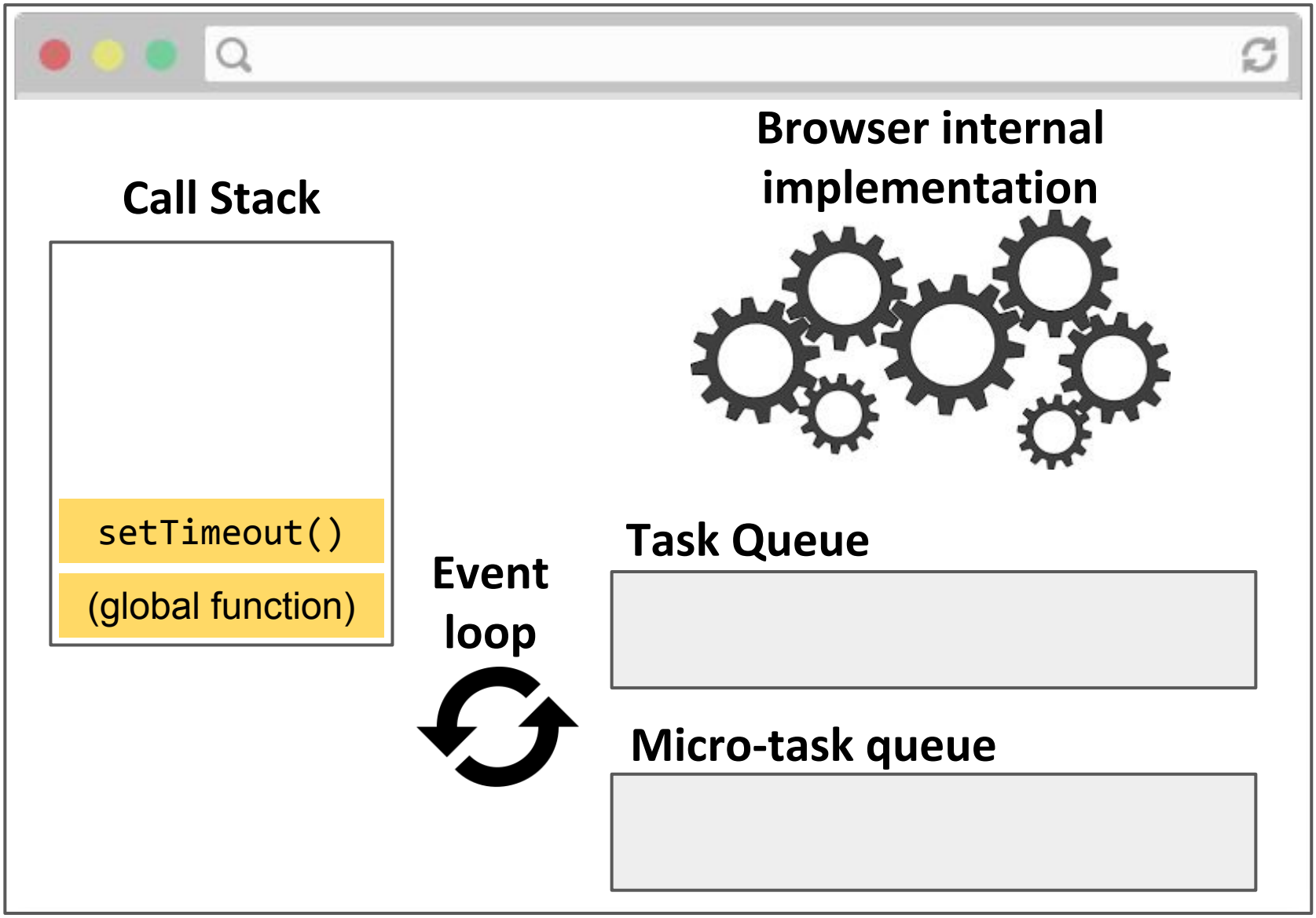


The JavaScript runtime can do only one thing at a time...

Tasks and the Event Loop

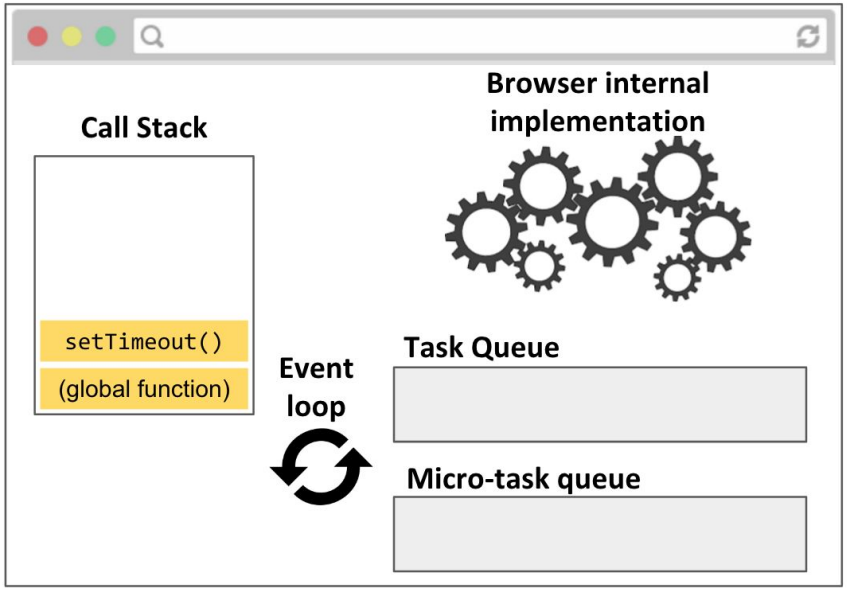


But the JS runtime runs within a browser, which can do multiple things at a time.



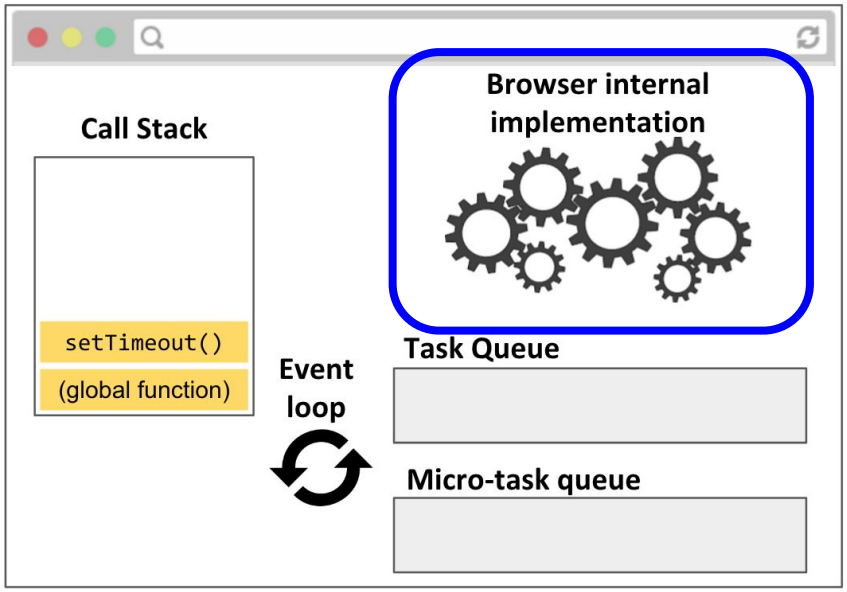
Here's a picture of the major pieces involved in executing JavaScript code in the browser.

JS execution



- **Call stack:** JavaScript runtime call stack. Executes the JavaScript commands, functions.
- **Browser internal implementation:** The C++ code that executes in response to native JavaScript commands, e.g. `setTimeout`, `element.classList.add('style')`, etc.

JS execution



The browser itself is multi-threaded and multi-process!

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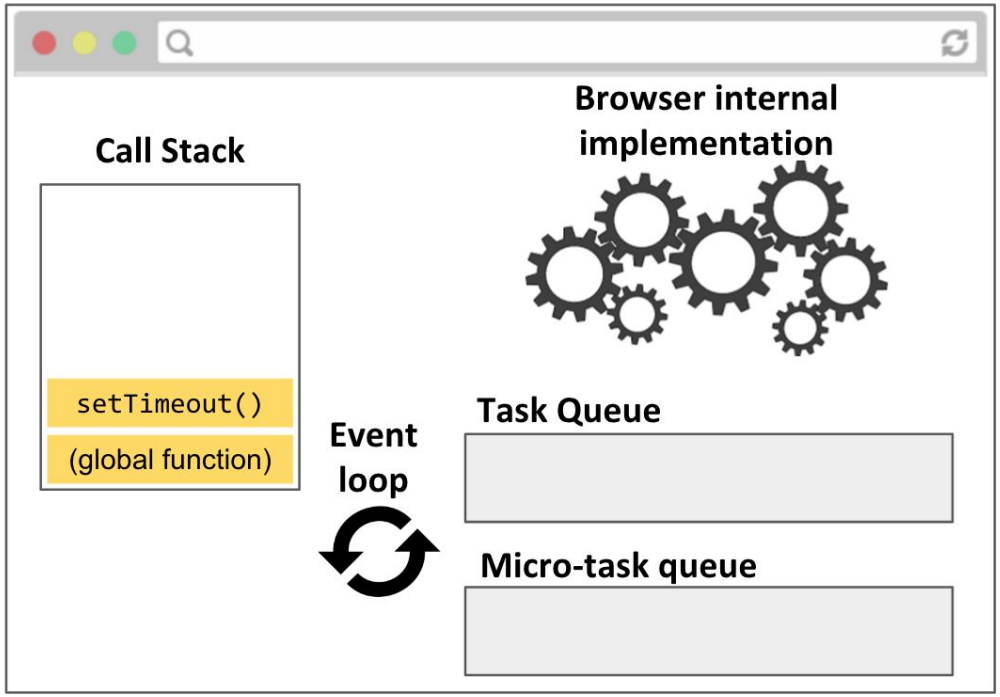
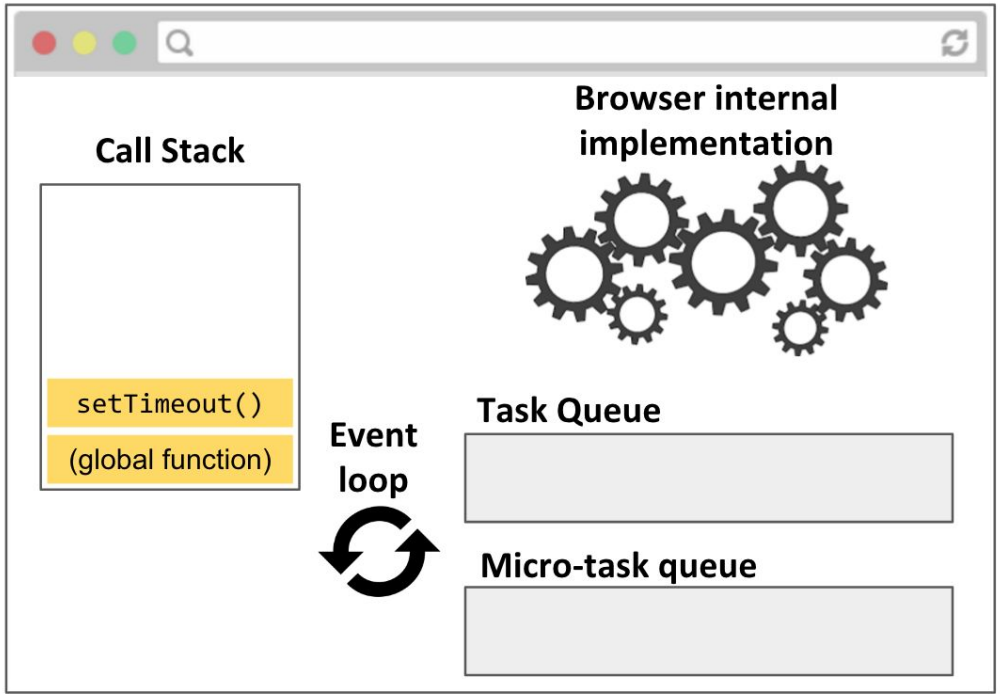
JS execution



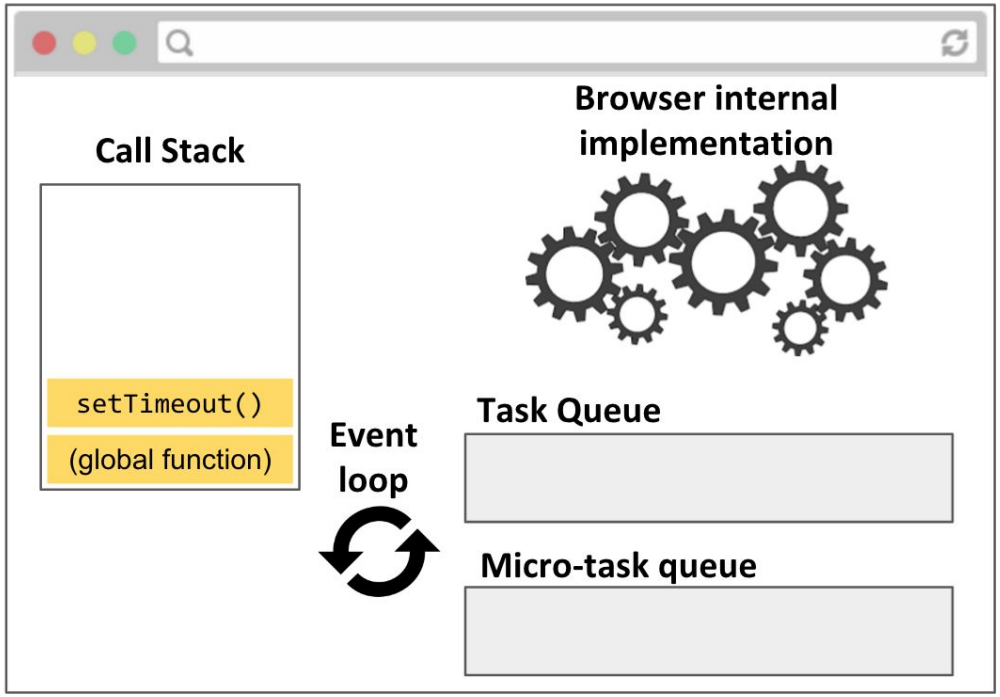
- **Task Queue:** When the browser internal implementation notices a callback from something like setTimeout or addEventListener is should be fired, it creates a Task and enqueues it in the Task Queue

JS execution



- **Micro-task Queue:** Promises are special tasks that execute with higher priority than normal tasks, so they have their own special queue. (see details here)

JS execution



Event loop: Processes the task queues.

- When the call stack is empty, the event loop pulls the next task from the task queues and puts it on the call stack.
- The Micro-task queue has higher priority than the Task Queue.

Demo

Philip Roberts wrote a nice visualizer for the JS event loop:

- setTimeout
- With click