CT313H:
Web Technologies and Services

Bùi Võ Quốc Bảo
(bvqbao@cit.ctu.edu.vn)

Cần Thơ, 2023

Credit

- The slides are inspired by the CS193X course created by Victoria Kirst

Servers

Server-side programming

“**Client-side**" programming:

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

“**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

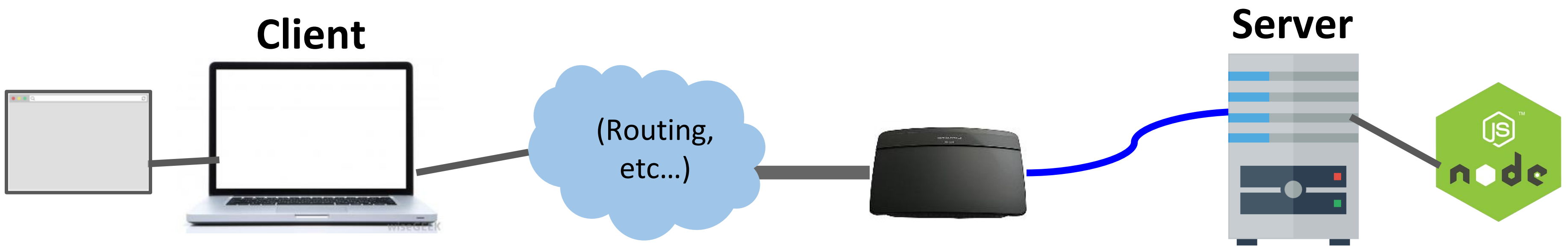
Recall...

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

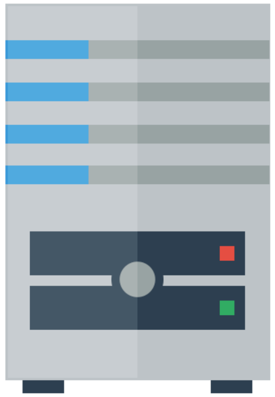


"Server"

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



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

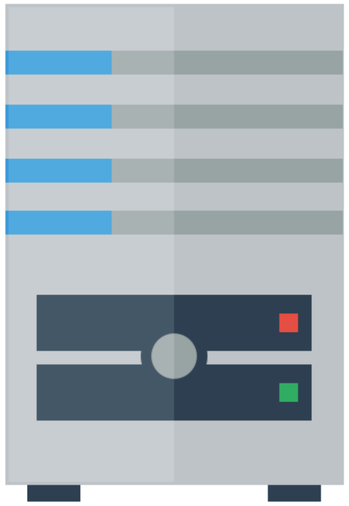
A **socket** is one end of a communication channel. You can send and receive data on sockets

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

Servers

Sometimes when you type a URL in your browser, the URL is a **path to a file** on the internet:

- Your browser connects to the host address and requests the given file over **HTTP**
- The web server software (e.g. Apache) grabs that file from the server's local file system, and sends back its contents to you



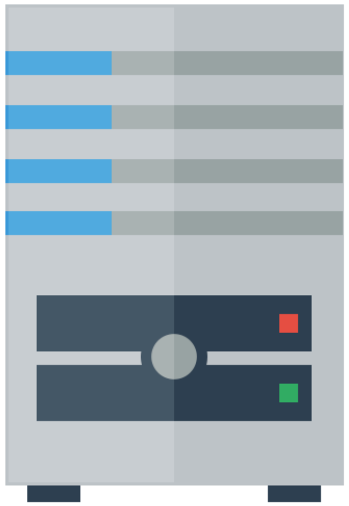
But that's not always the case

Web Services

Other times when you type a URL into your browser, the URL represents **an API endpoint**, and not a path to a file

That is:

- The web server does **not** grab a file from the local file system, and the URL is **not** specifying where a file is located
- Rather, the URL represents **a parameterized request**, and the web server dynamically generates a response to that request



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

NodeJS:

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

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

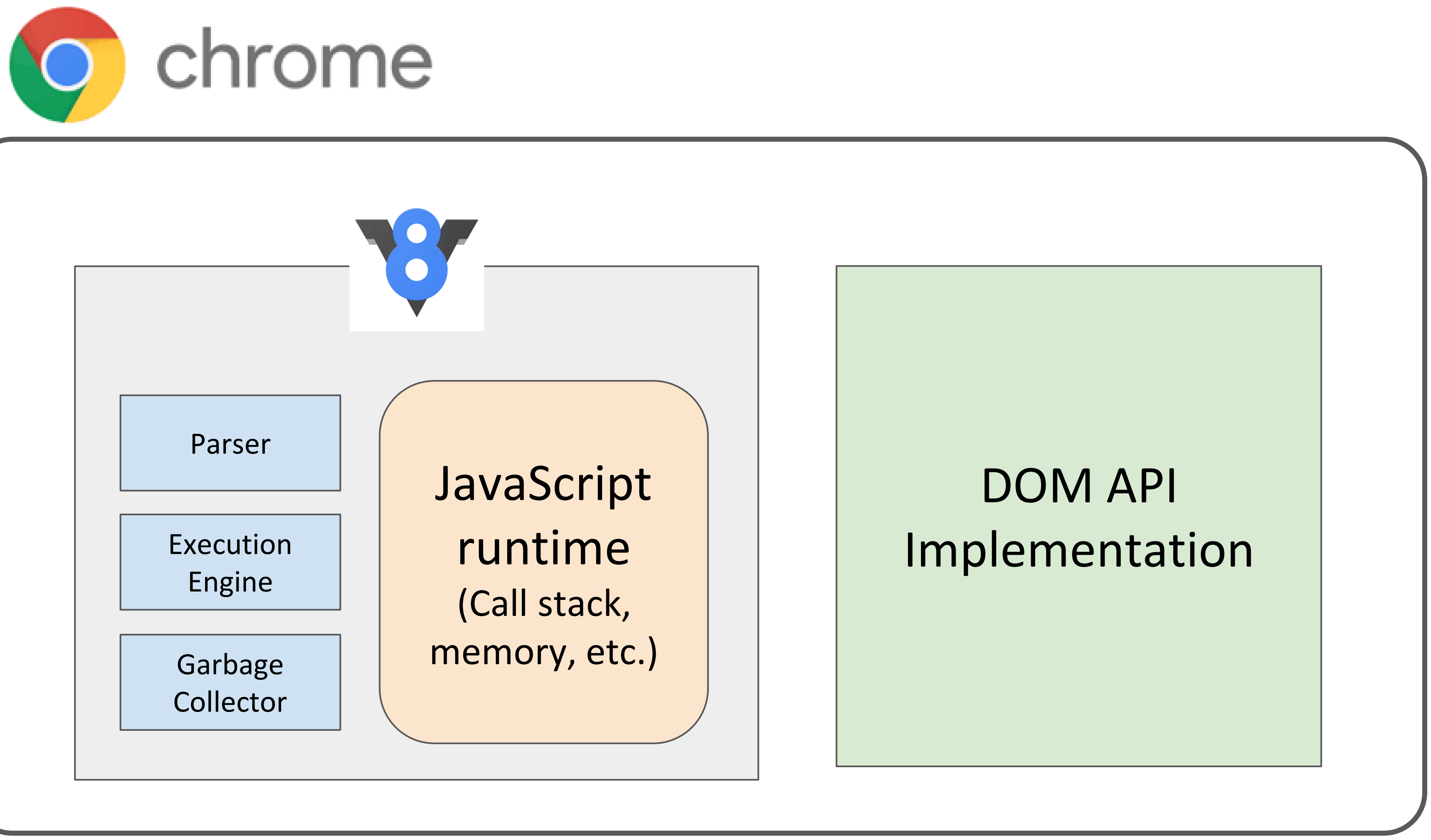
DOM APIs:

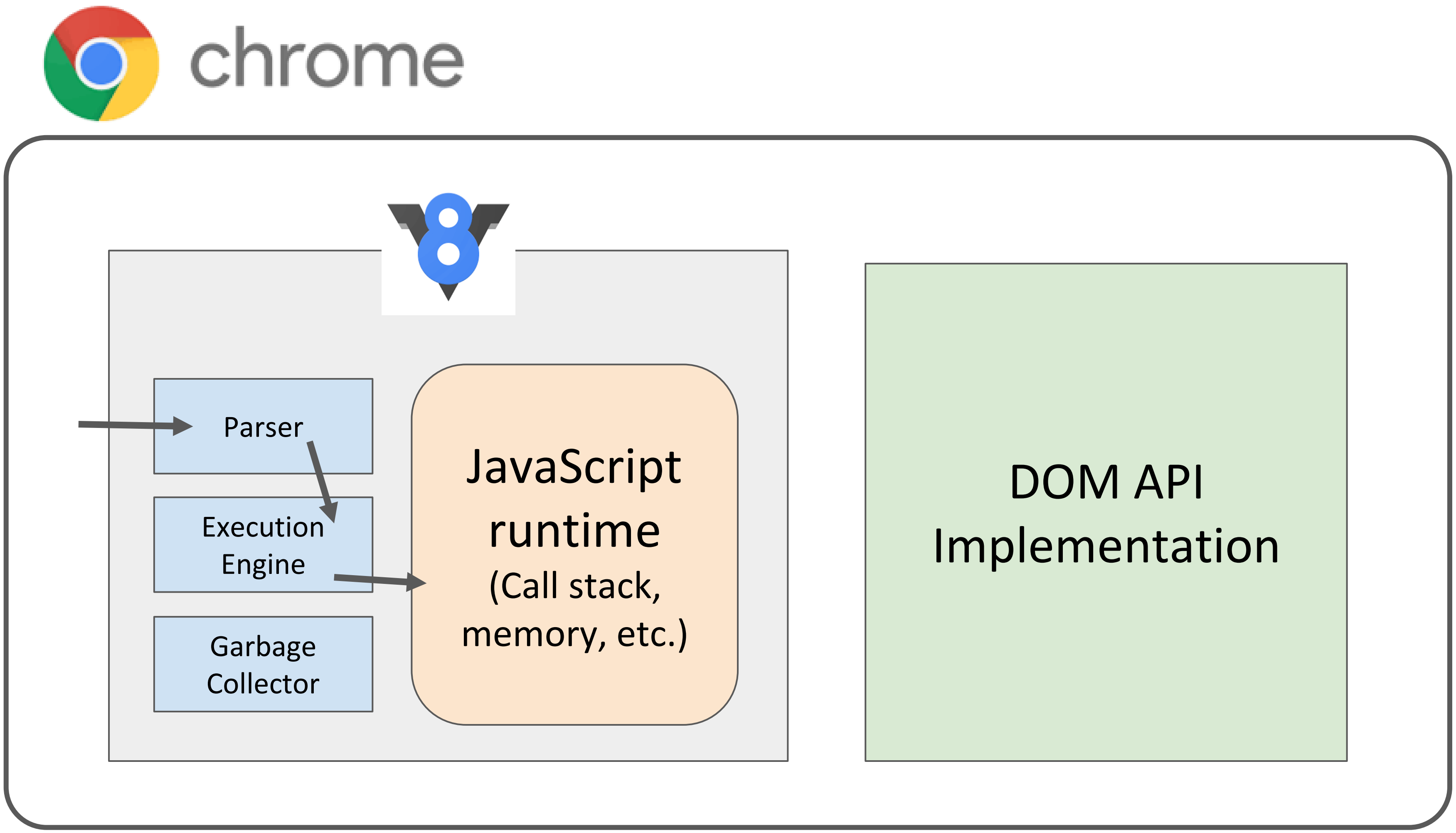
- JavaScript libraries to interact with a web page

V8:

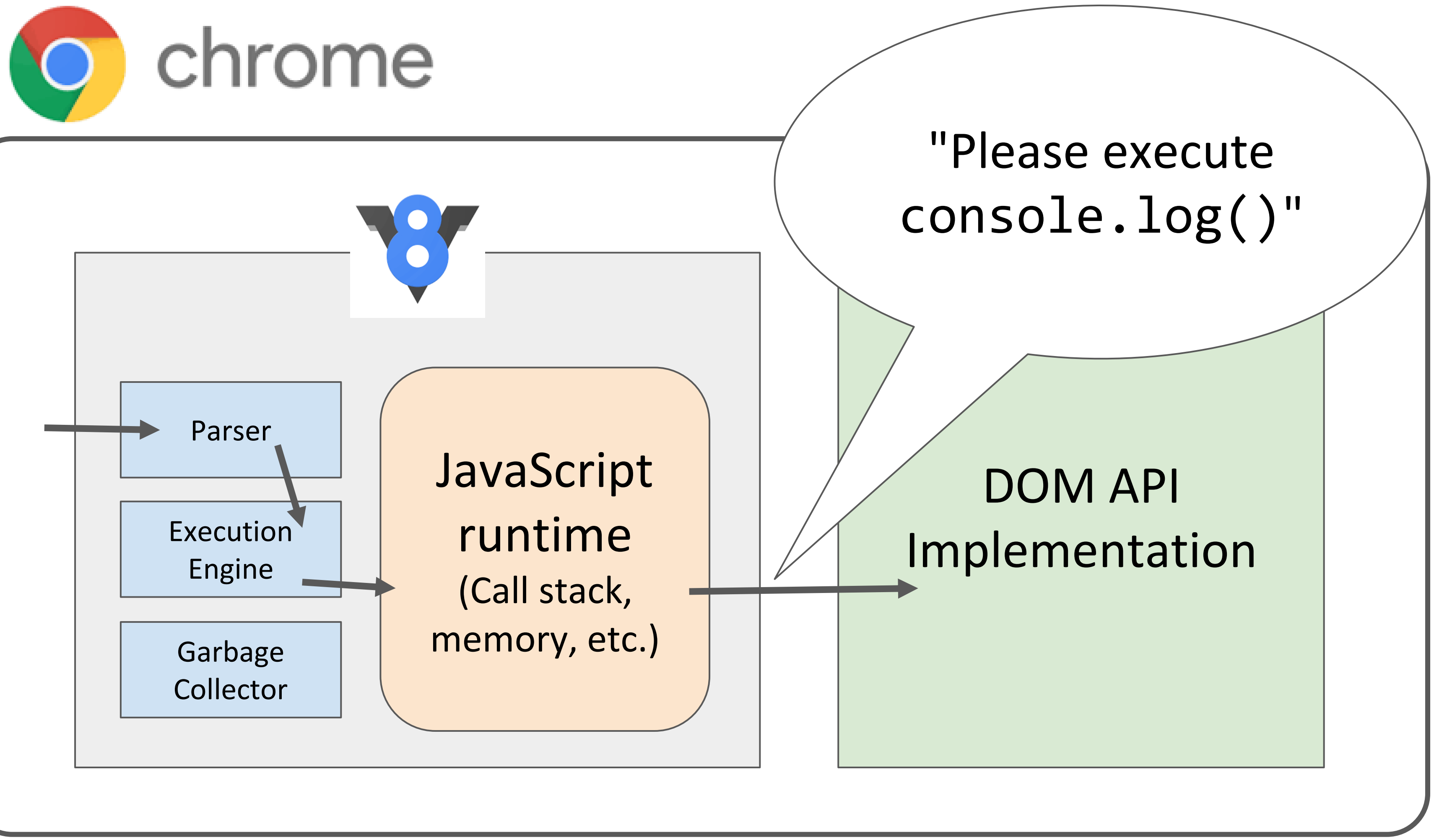
- The JavaScript interpreter ("engine") that Chrome uses to interpret, compile, and execute JavaScript code

Chrome, V8, DOM



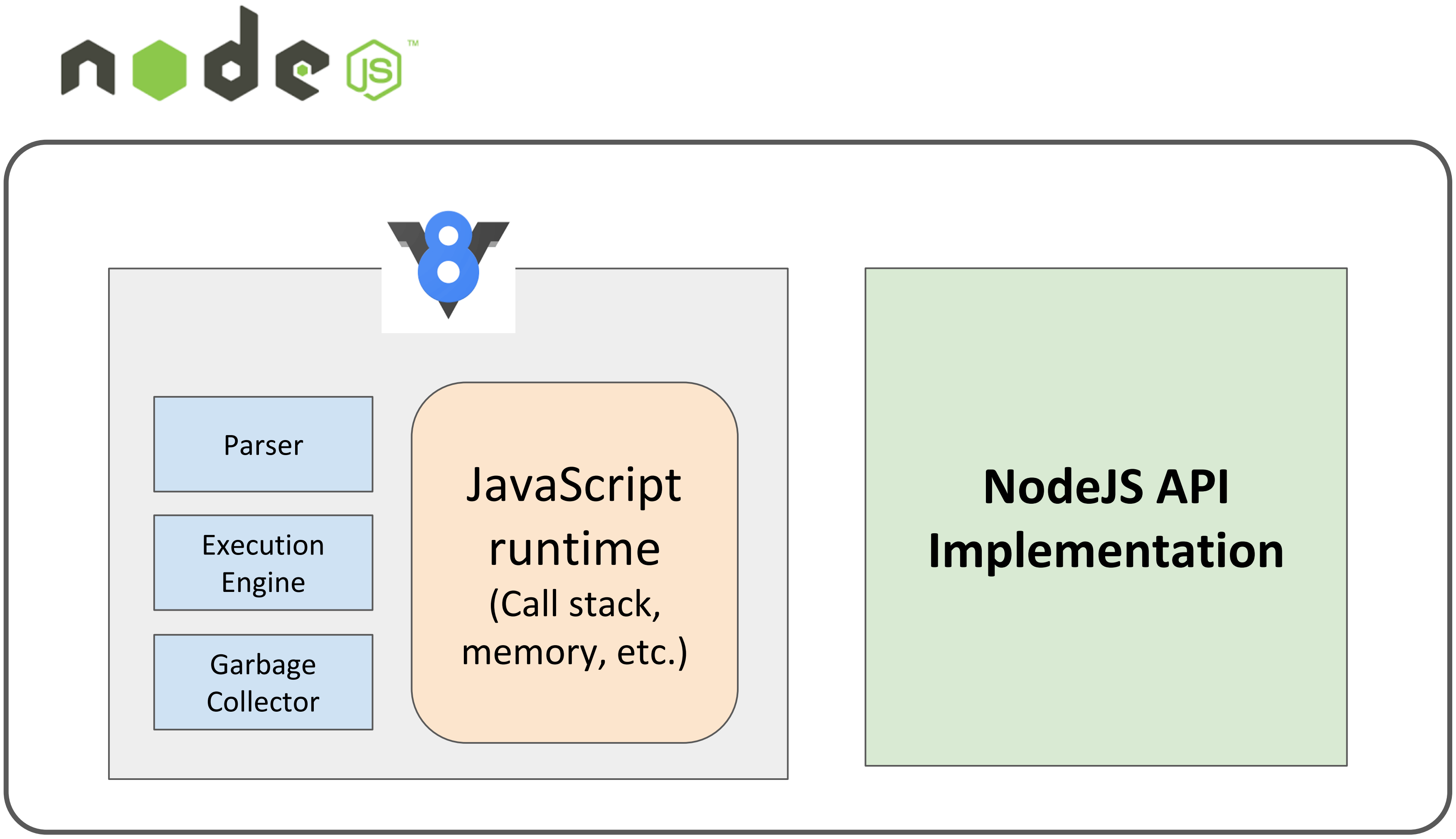


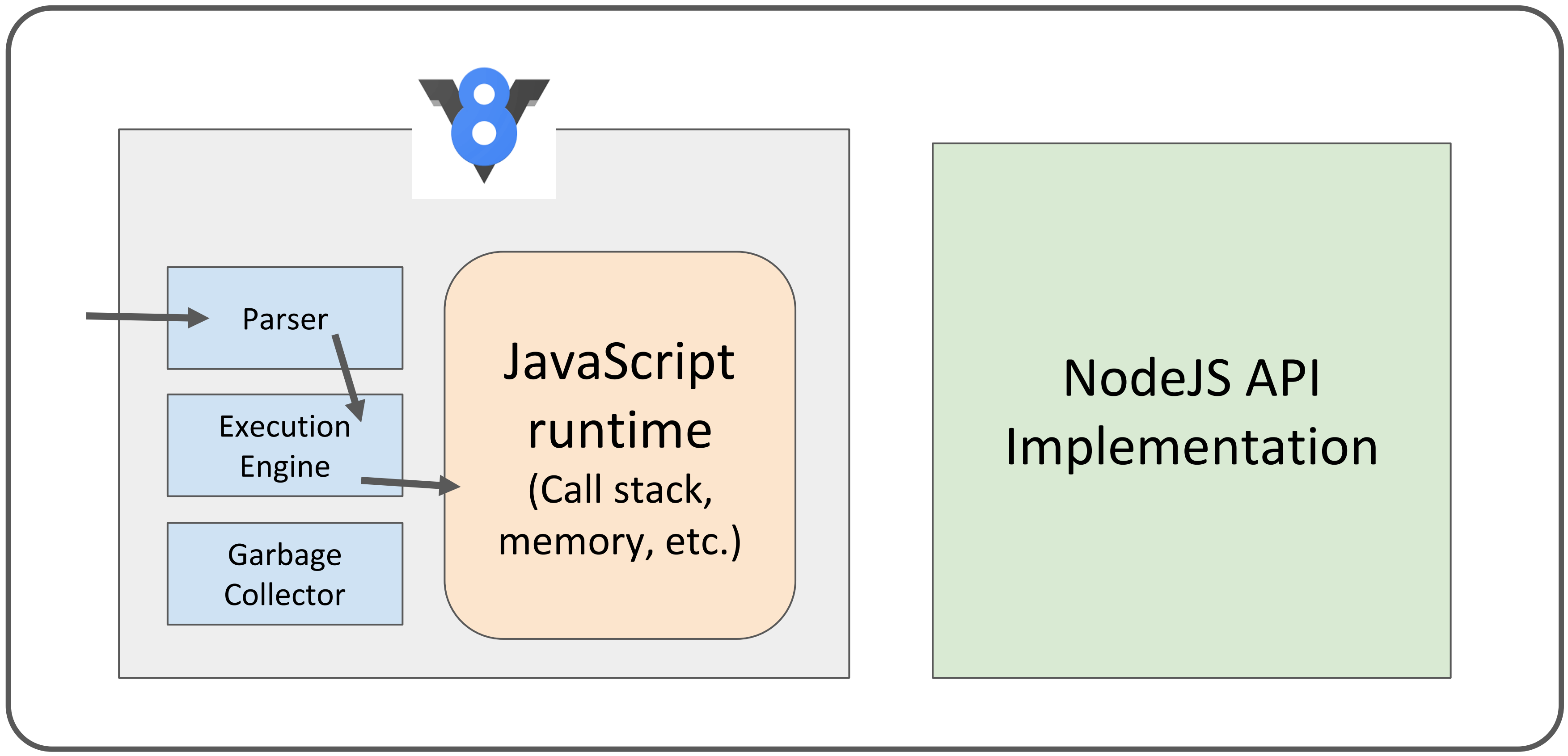
```
const name = 'V8';
```


chrome
"Please execute console.log()"
Parser
Execution Engine
Garbage Collector
JavaScript runtime (Call stack, memory, etc.)
DOM API Implementation

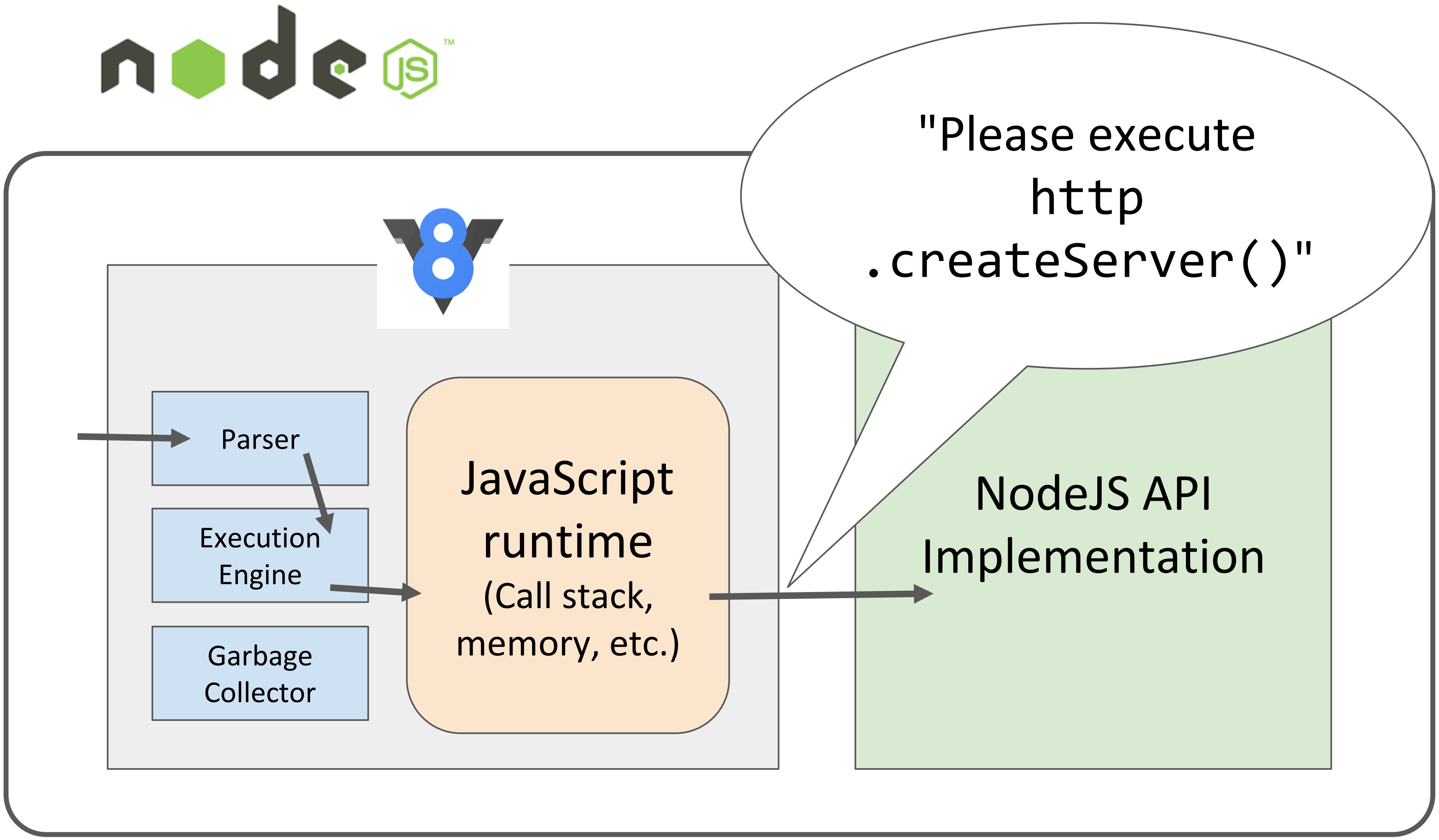
```
console.log('V8');
```

NodeJS, V8, NodeJS APIs

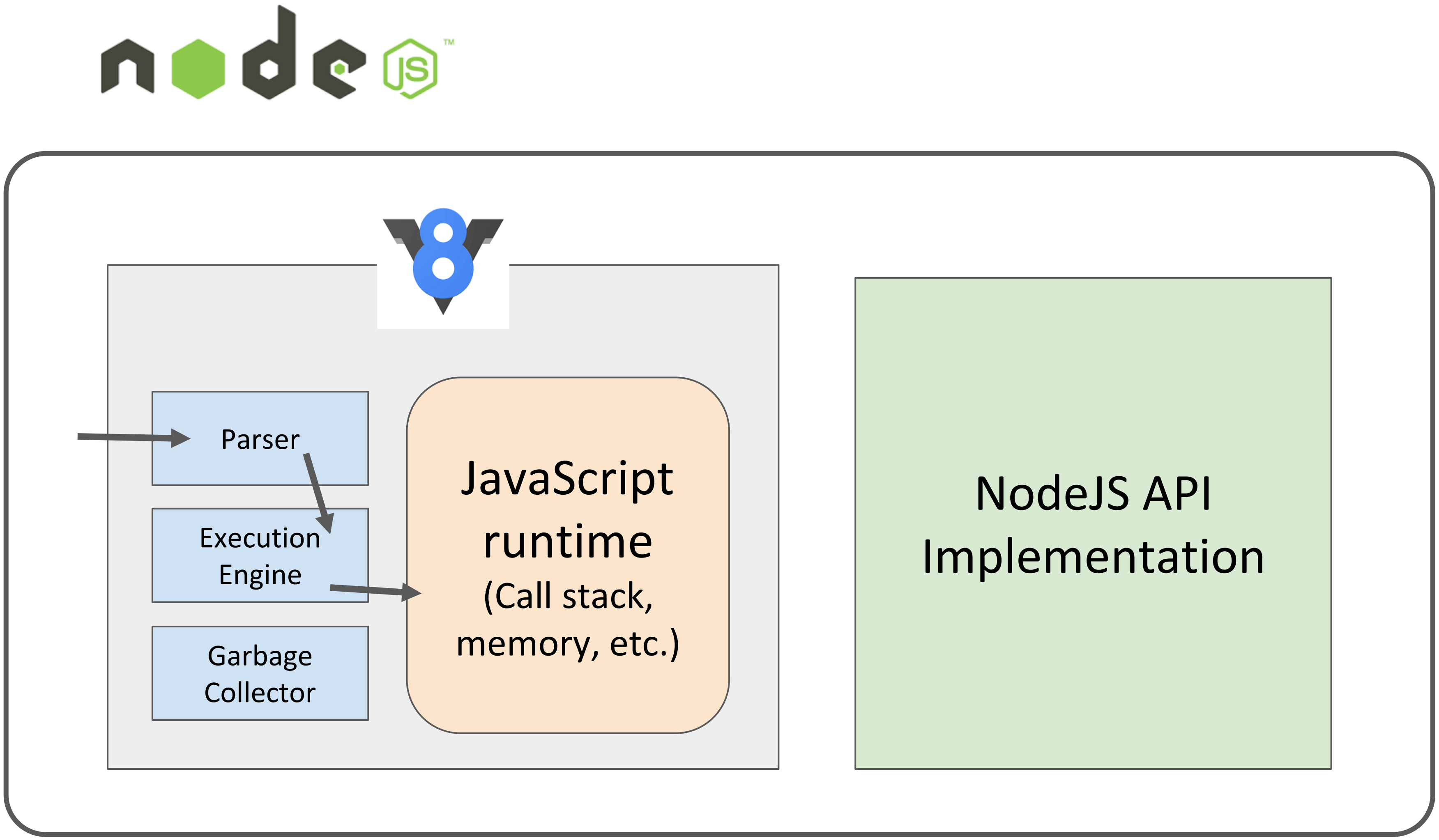



Parser
Execution Engine
Garbage Collector
JavaScript runtime
(Call stack, memory, etc.)
NodeJS API Implementation

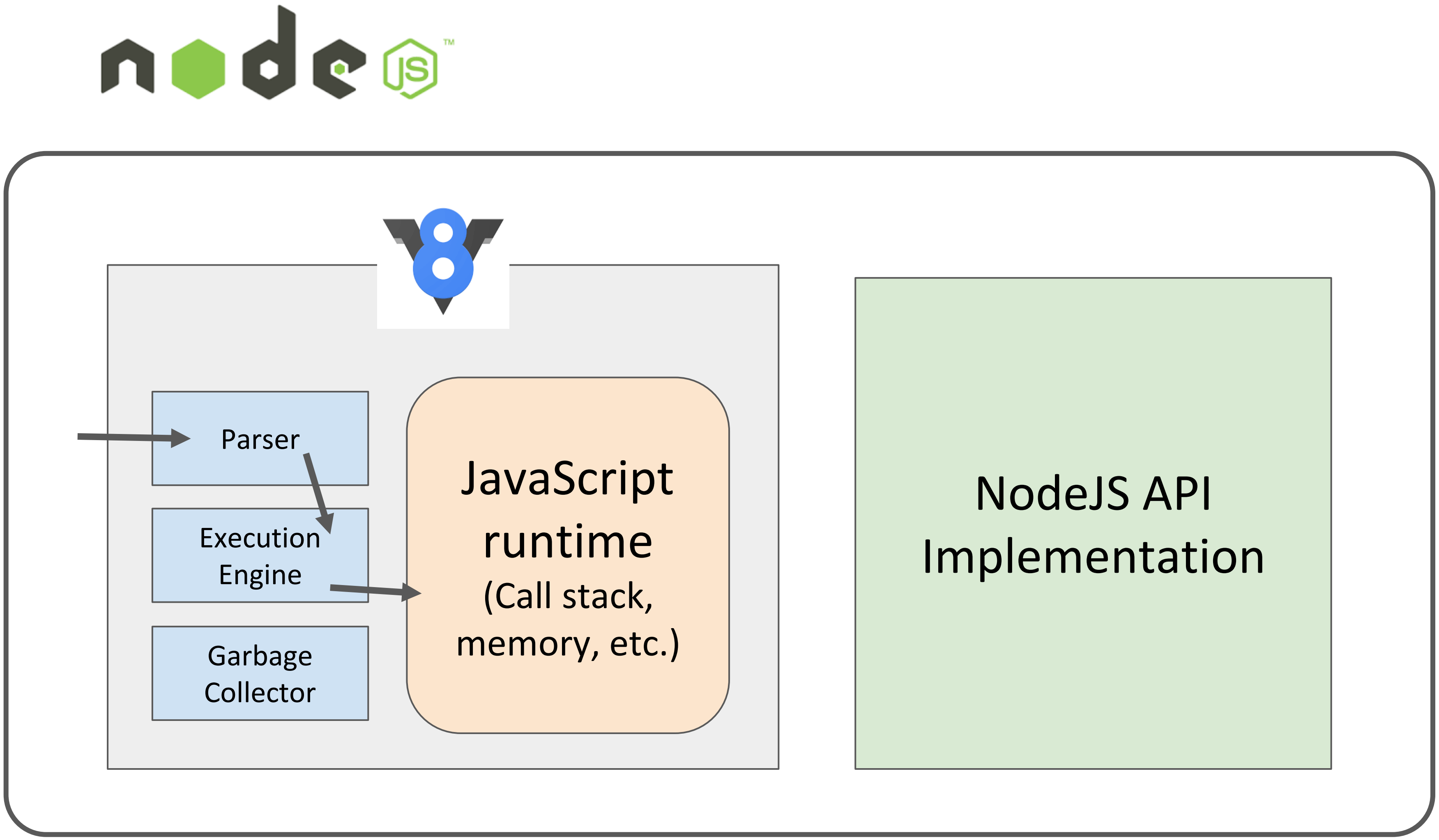
```
const x = 15;
x++;
```


Parser
Execution Engine
Garbage Collector
JavaScript runtime (Call stack, memory, etc.)
NodeJS API Implementation
"Please execute http .createServer()"

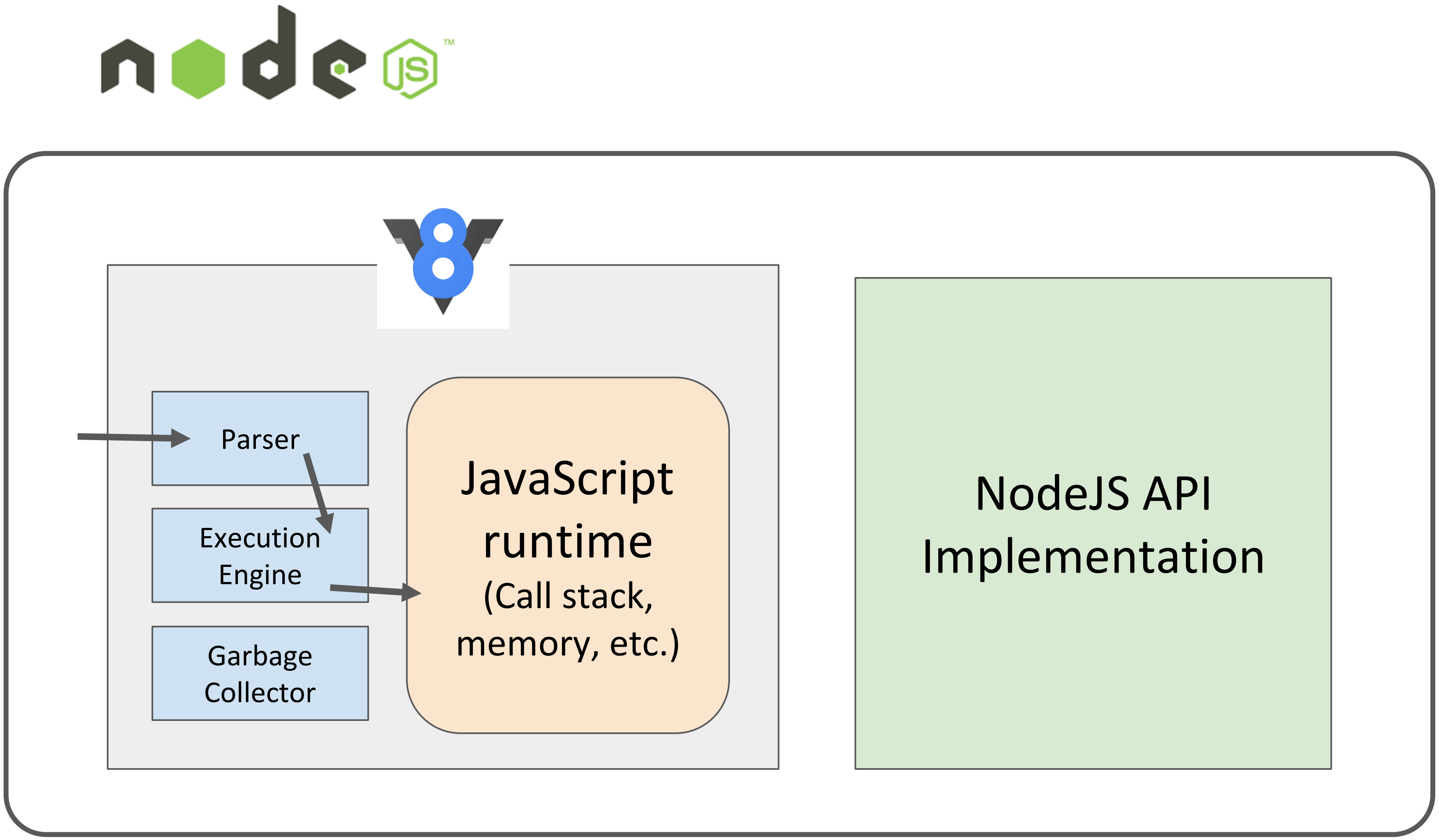
```
http.createServer();
```



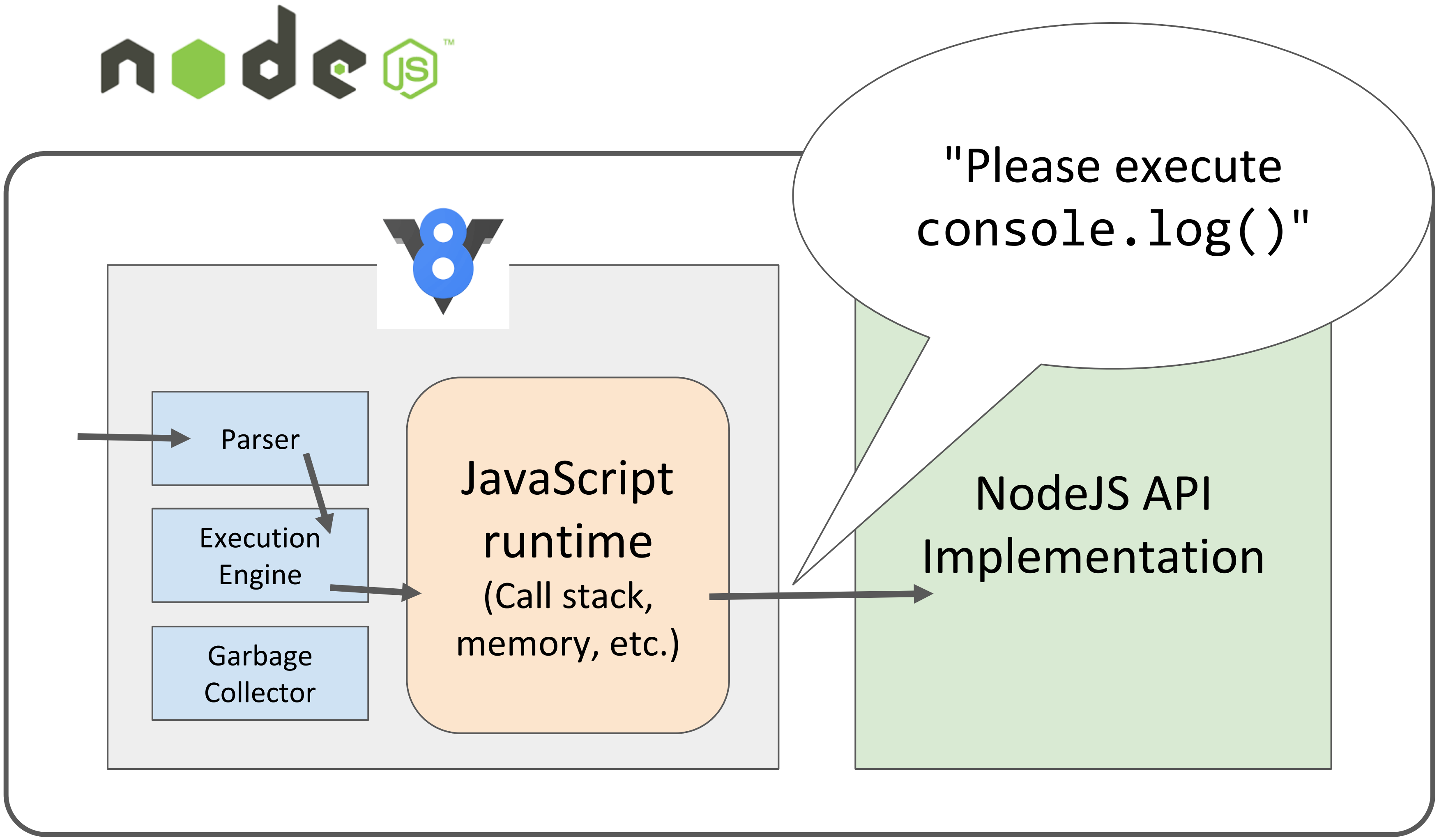
What if you tried to call `document.querySelector('div');` in the NodeJS runtime?



```
document.querySelector('div');
ReferenceError: document is not defined
```



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


"Please execute console.log()"
Parser
Execution Engine
Garbage Collector
JavaScript runtime (Call stack, memory, etc.)
NodeJS API Implementation

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

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

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

Installation

NodeJS installation:

- https://nodejs.org/en/download/
- https://github.com/nvm-sh/nvm
- https://github.com/coreybutler/nvm-windows

node command

Running node without a filename runs a read-eval-print loop (REPL)

- 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

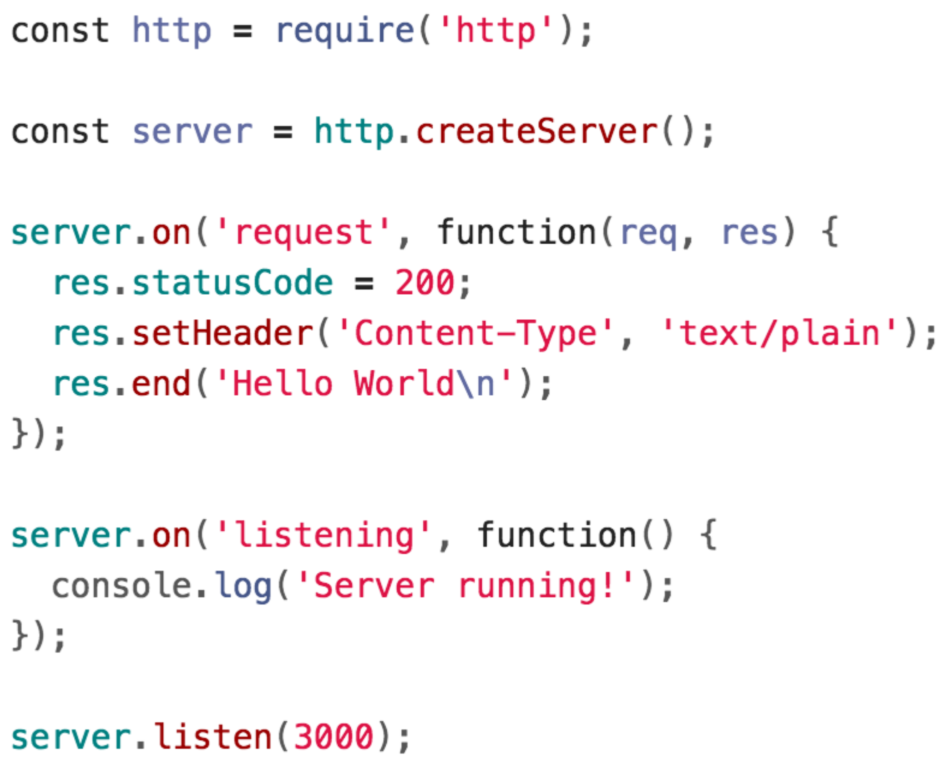
The node command can be used to execute a JS file:

$ 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/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

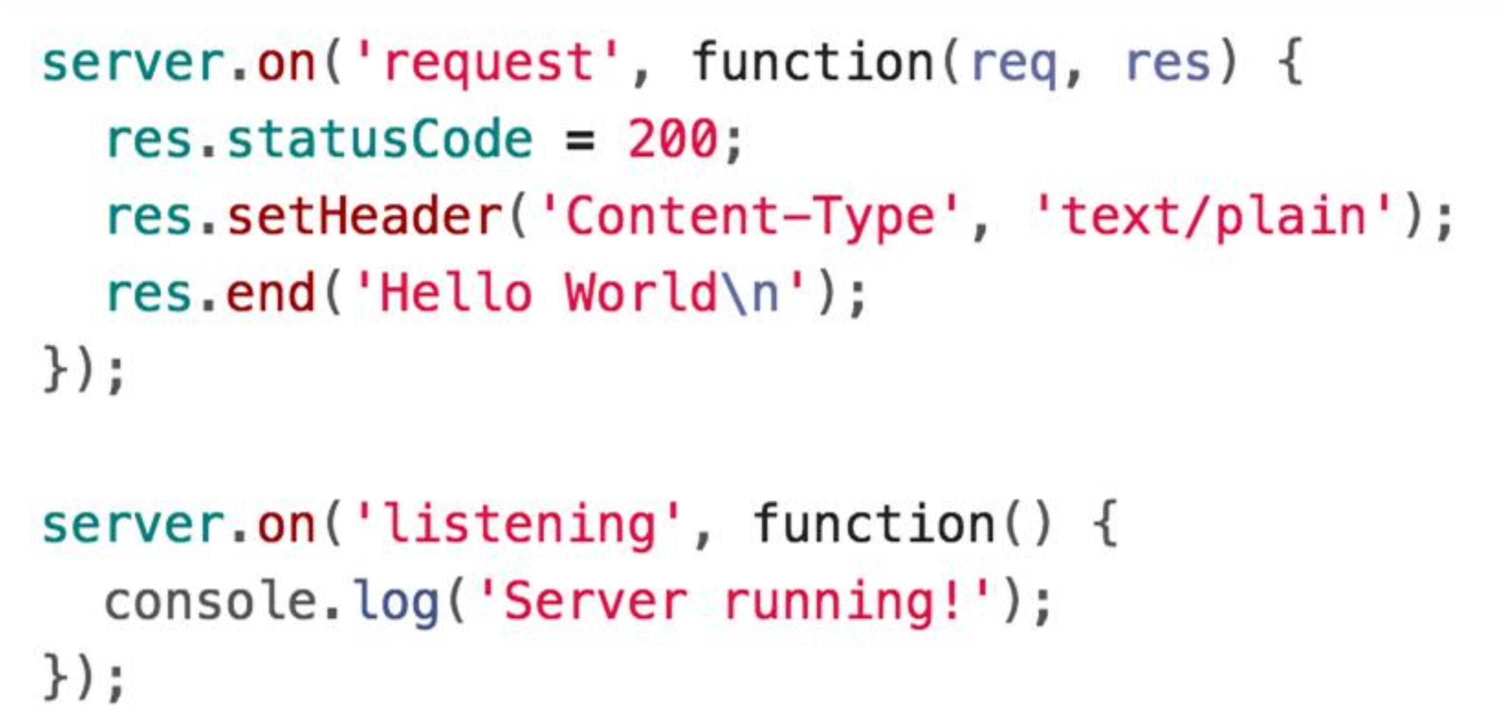
`require()`

```
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

EventEmitter.on



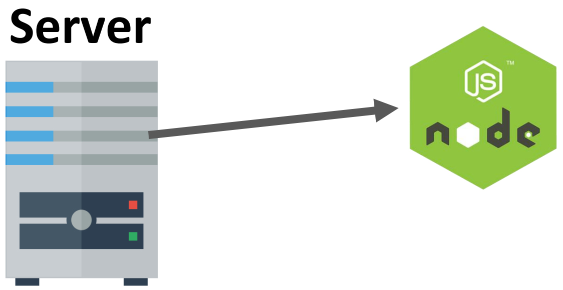
```
server.on('request', function(req, res) {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello World\n');
});

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

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

EventEmitter.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



EventEmitter.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

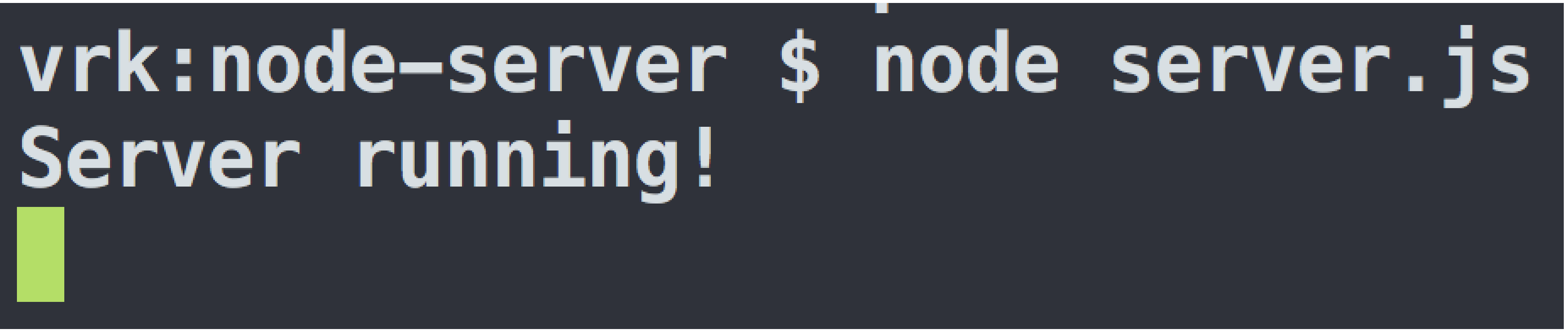
```
server.on('listening', function() {
  console.log('Server running!');
});

server.listen(3000);
```

The `listen()` function will make the program start accepting messages sent to the given **port number**

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

Running the server

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

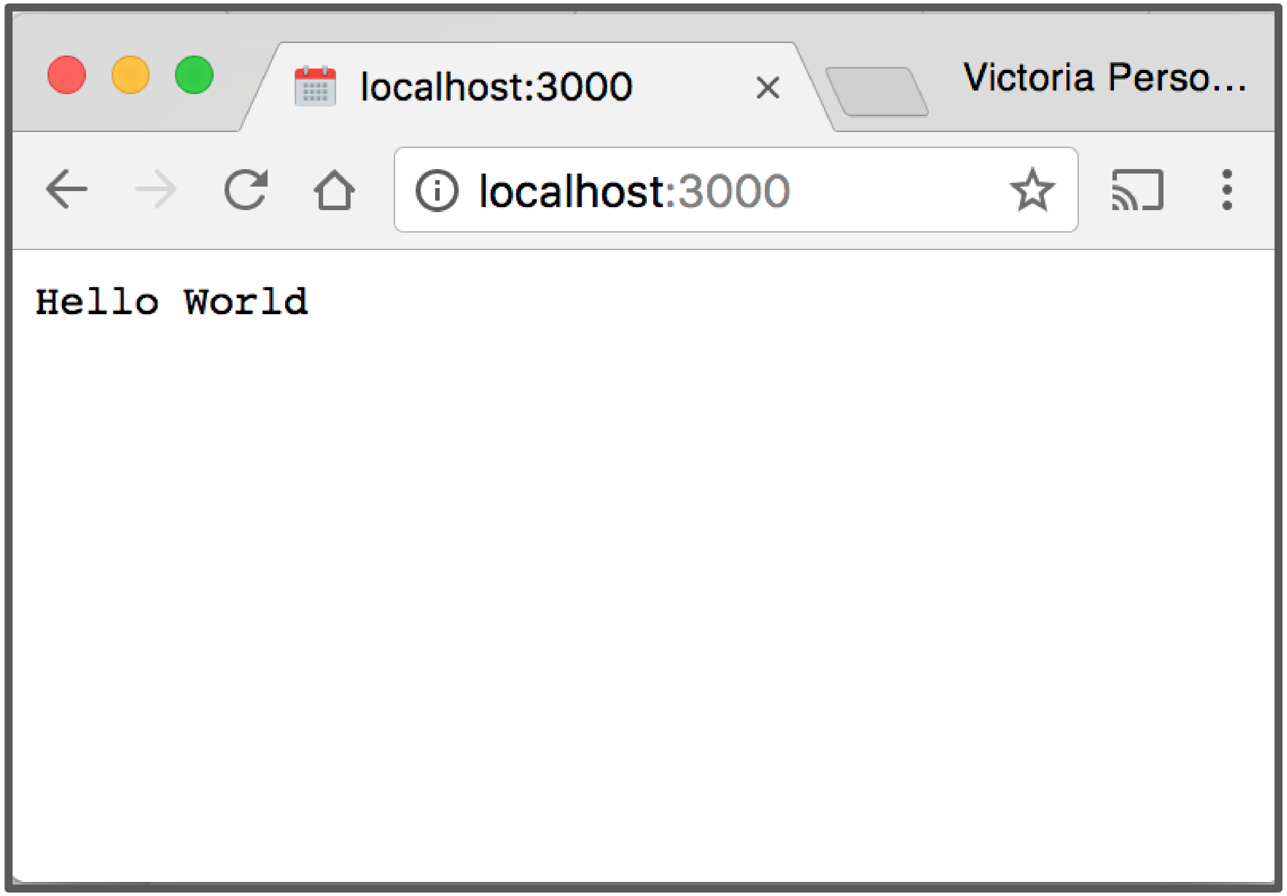


```
vrk:node-server $ node server.js
Server running!
█
```

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

Server response

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



```
Hello World
```

Node for servers

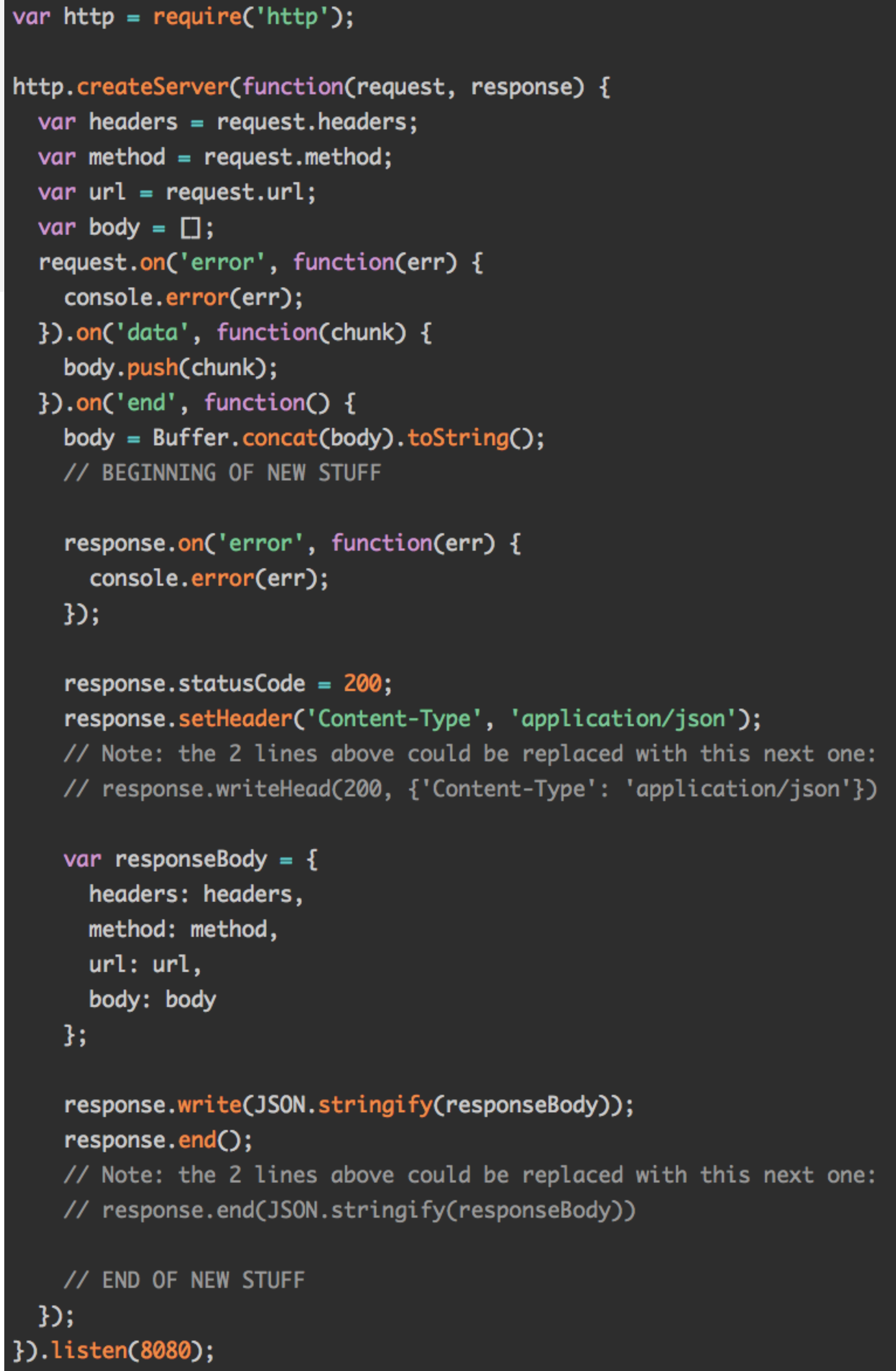
This server returns the same response no matter what the request is

```
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:

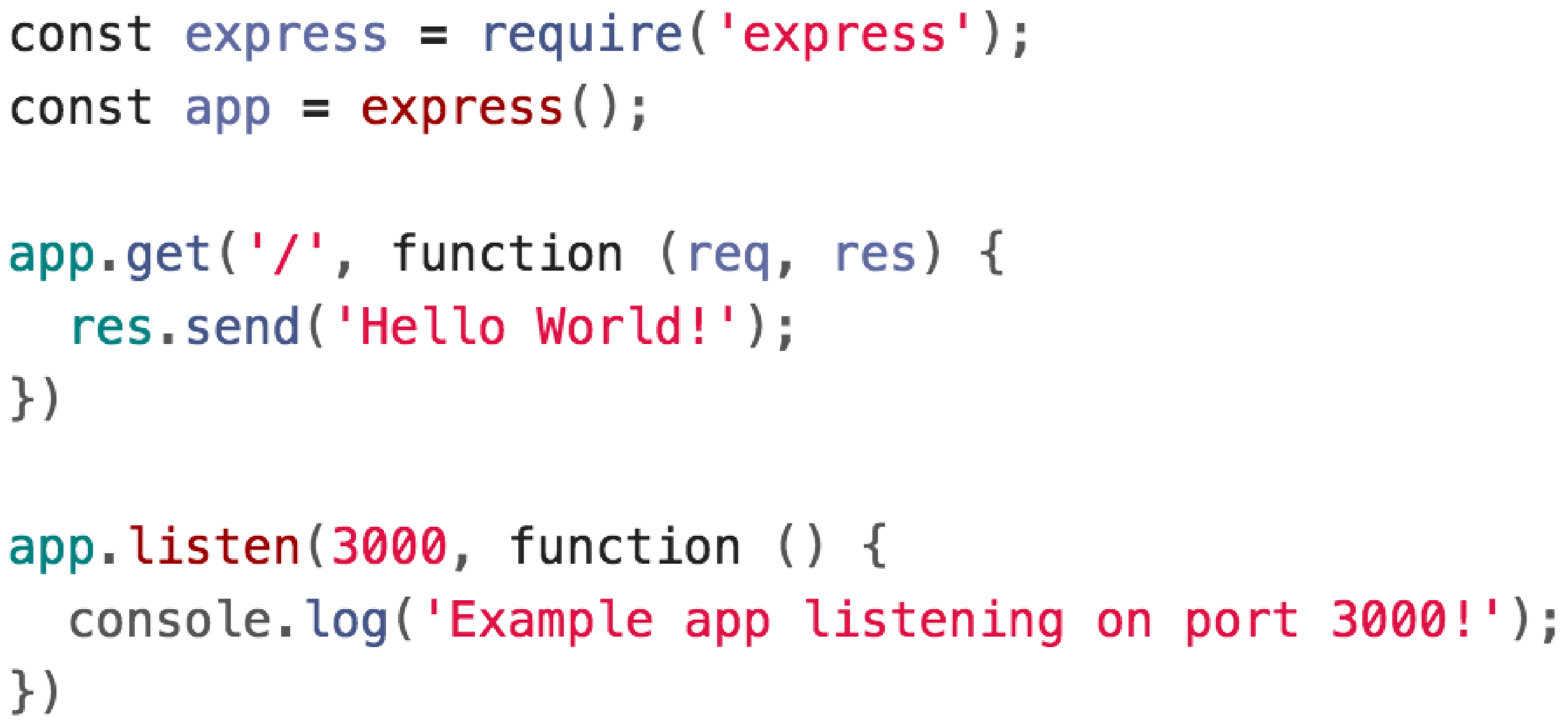
- You build the request manually
- You write the response manually
- There's a lot of tedious processing code



```
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
    };

    response.write(JSON.stringify(responseBody));
    response.end();
    // Note: the 2 lines above could be replaced with this next one:
    // response.end(JSON.stringify(responseBody))

    // END OF NEW STUFF
  });
}).listen(8080);
```

Express

We're going to use a library called Express 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!');
})
```

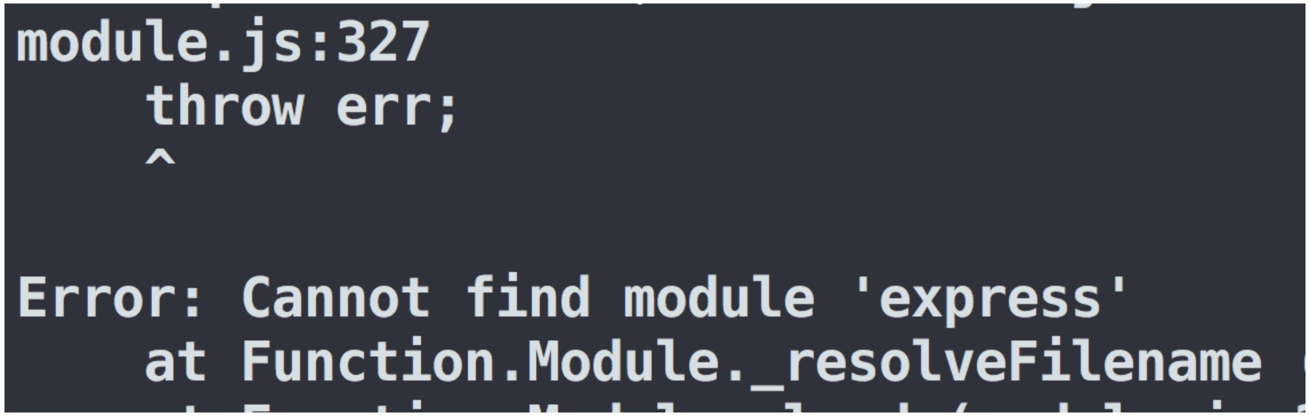
Express routing

Express

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***

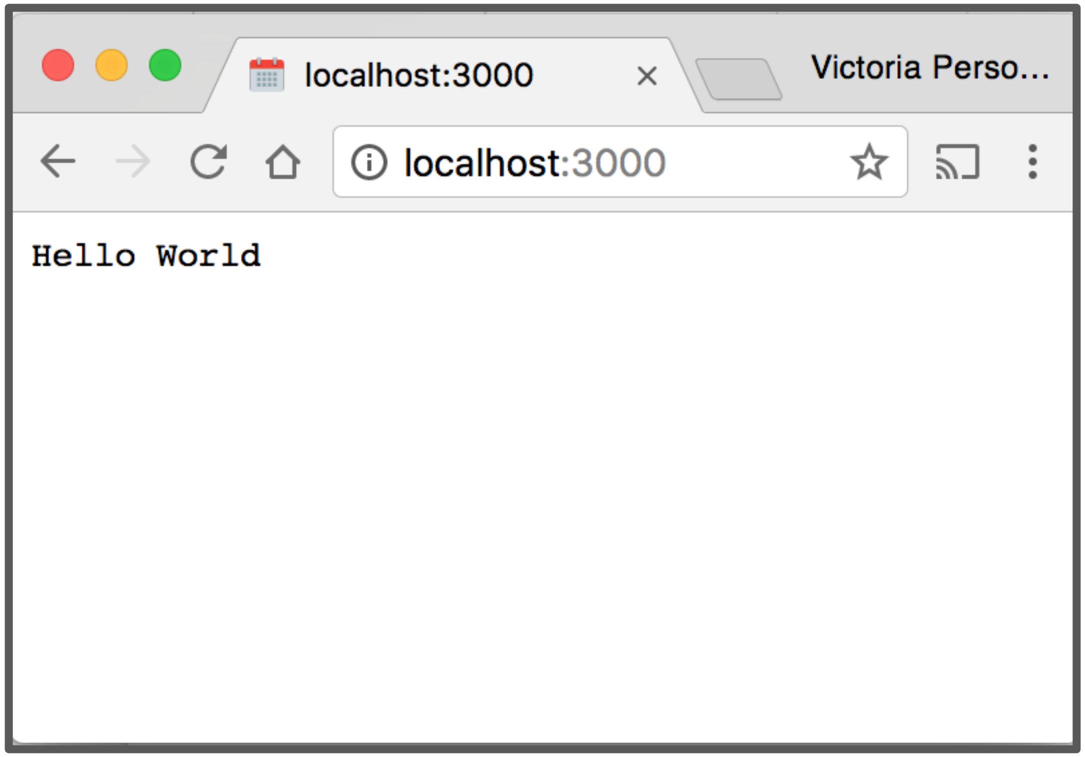
- This downloads the *package-name* library into a `node_modules` folder
- Now the *package-name* library can be included in your NodeJS JavaScript files

`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!
```



```
Hello World
```

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!');
});
```

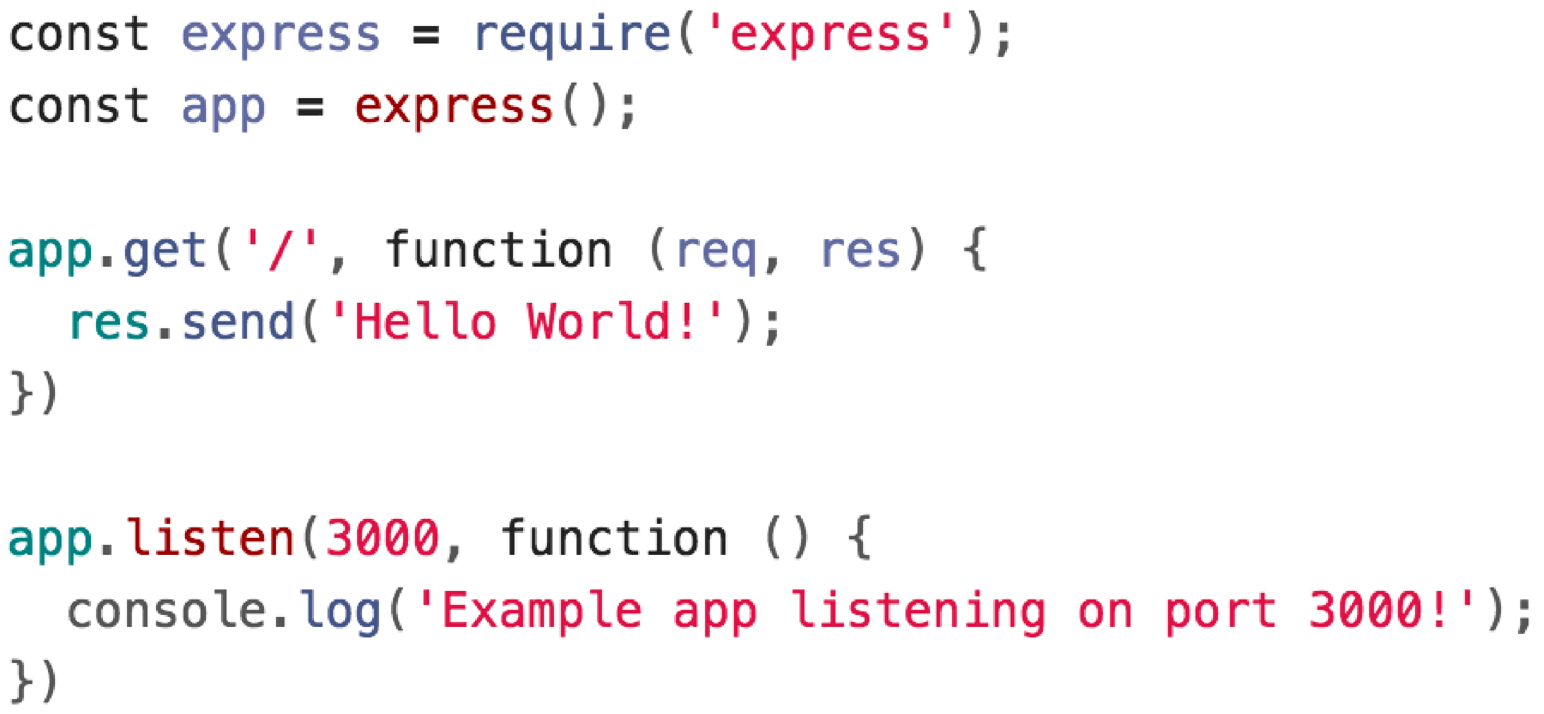
Express has its own `Request` and `Response` objects:

- 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

HTTP requests

Our server is written to respond to HTTP requests (GitHub):



```
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!');
})
```

Q: How do we sent HTTP requests to our server?

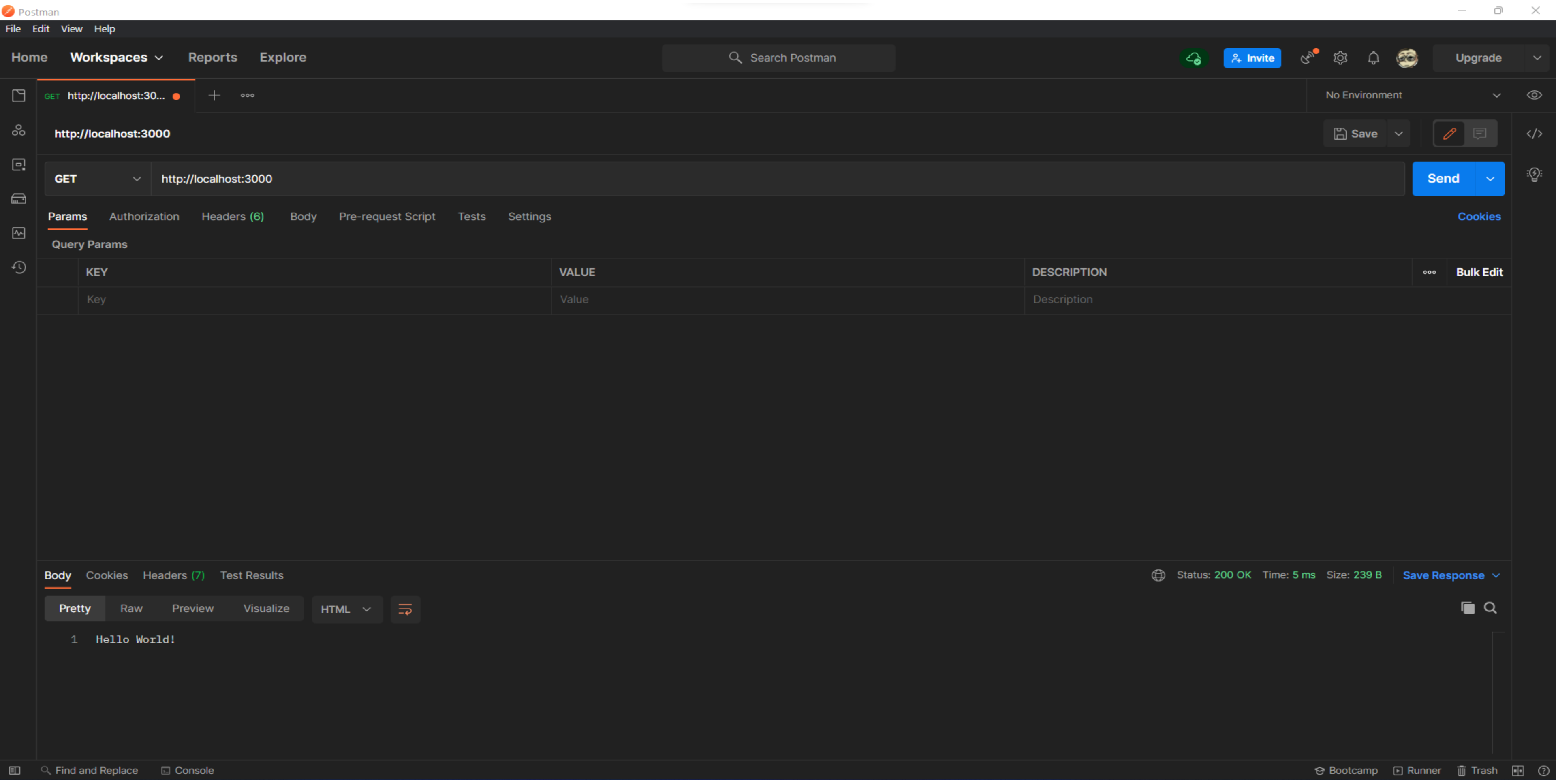
Querying our server

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

1. Navigate to http://localhost:3000/<path> in our browser
   - **Caveat:** Can only do GET requests
2. `Postman` Web/HTTP API client
3. `curl` command-line tool
4. Call `fetch()` in web page

Postman

https://www.postman.com/



Postman
File Edit View Help
Home Workspaces Reports Explore
Search Postman
Invite
Upgrade
No Environment
Save
Send
Params Authorization Headers (6) Body Pre-request Script Tests Settings
Cookies
Query Params
Bulk Edit
Body Cookies Headers (7) Test Results
Save Response
Pretty Raw Preview Visualize HTML
Find and Replace Console
Bootcamp Runner Trash

GET http://localhost:3000

KEY	VALUE	DESCRIPTION
Key	Value	Description

Status: 200 OK Time: 5 ms Size: 239 B

```
Hello World!
```

curl

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

`curl -d '…' -H '…'  -X` ***METHOD url***

e.g.

```
$ curl -X GET http://localhost:3000/
```

Querying with fetch()

JavaScript client code in a web page:

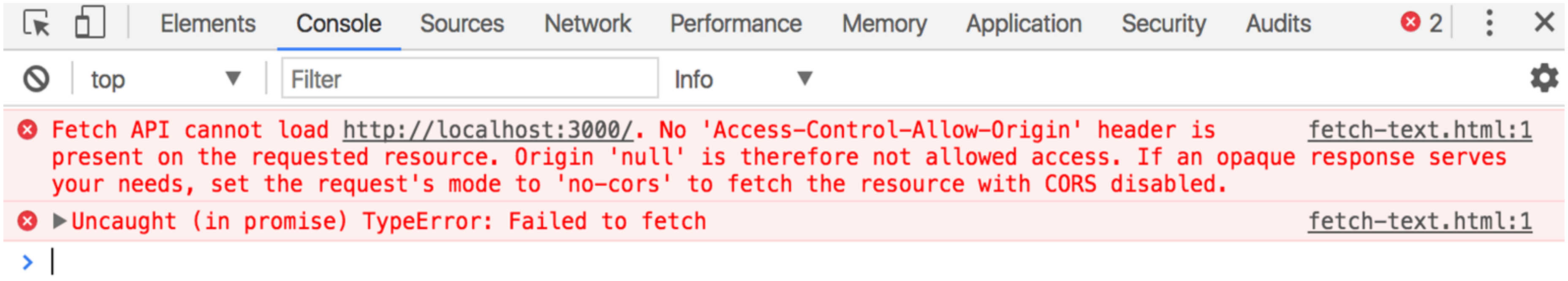
```
function onTextReady(text) {
  console.log(text);
}

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

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

`fetch()` to localhost

But if we try fetching to localhost from file://

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

We get this CORS error:



```
Fetch API cannot load http://localhost:3000/. No 'Access-Control-Allow-Origin' header is     fetch-text.html:1
present on the requested resource. Origin 'null' is therefore not allowed access. If an opaque response serves
your needs, set the request's mode to 'no-cors' to fetch the resource with CORS disabled.
▶Uncaught (in promise) TypeError: Failed to fetch                                            fetch-text.html:1
> |
```

CORS

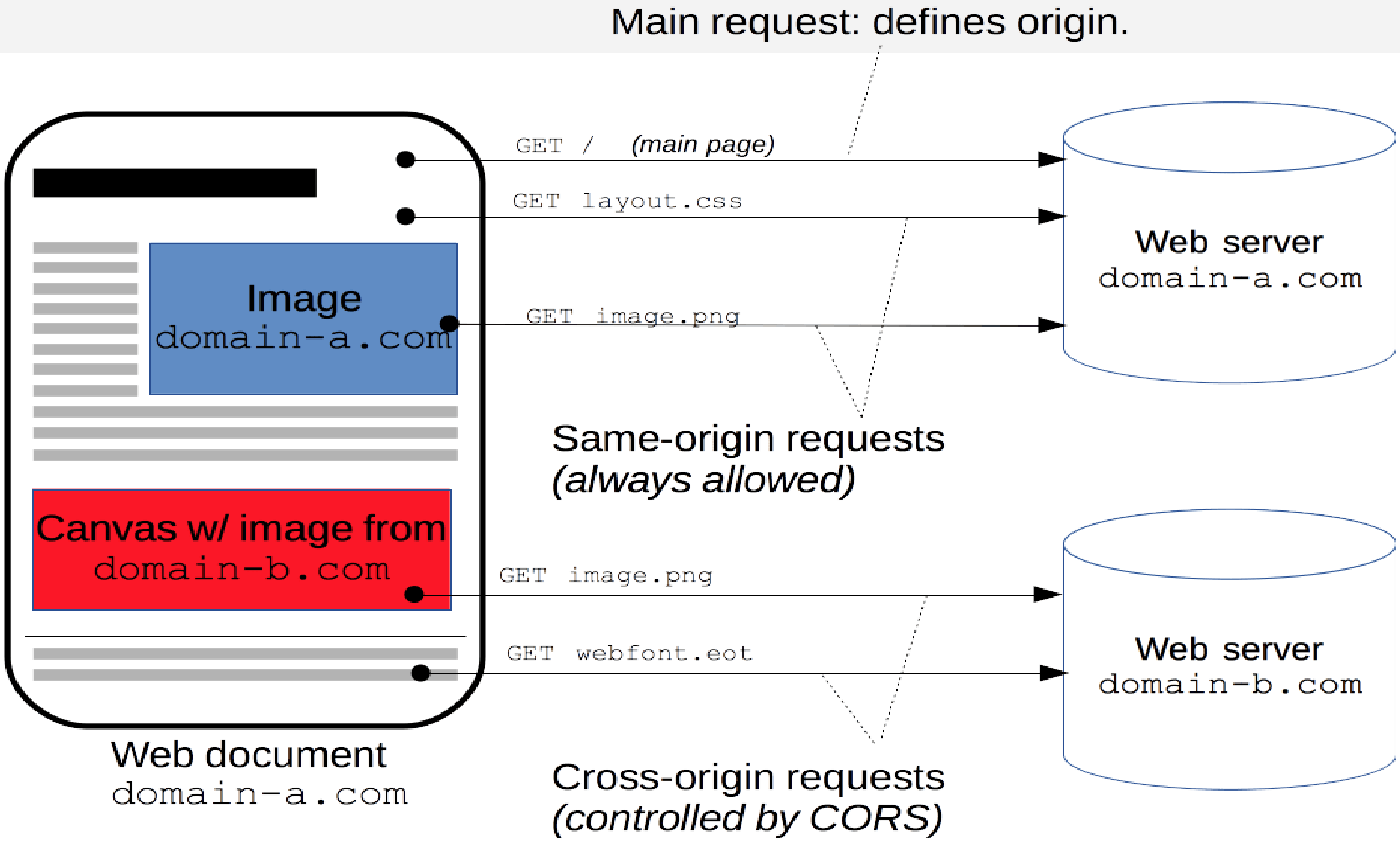
CORS: **C**ross-**O**rigin **R**esource **S**haring (wiki)

- Browser policy for what resources a web page can load
- **An origin = protocol + host + port**
- You **cannot** make cross-origin requests by default for:
    - Resources loaded via `fetch()` or XHR

The problem is that we are trying to `fetch()` **http://localhost:3000** from **file:///**

- Since the two resources have different origins, this is disallowed by default CORS policy

CORS



https://developer.mozilla.org/en-US/docs/Web/HTTP/CORS

Cross-origin solutions

The problem is that we are trying to `fetch()` **http://localhost:3000** from **file:///**

Two ways to solve this:

1. Change the server running on localhost:3000 to allow cross-origin requests, i.e. to allow requests from different origins (such as file:///)

2. **Preferred solution:** Load the frontend code statically from the same server, so that the request is from the same origin

Solution 1: Enable CORS

```
app.get('/', function (req, res) {
  res.header("Access-Control-Allow-Origin", "*");
  res.send('Main page!');
});
```

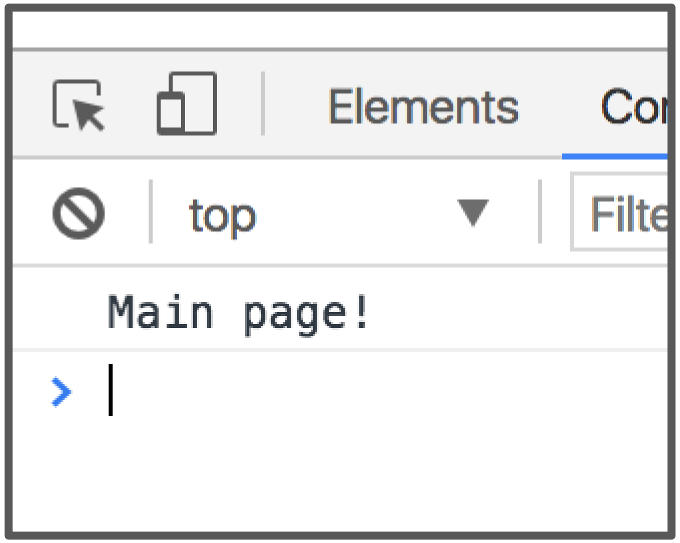
You can set an Access-Control-Allow-Origin HTTP header before sending your response

- This is the server saying to the browser in its response: "Hey browser, I'm totally fine with websites of any origin requesting this file"

Solution 1: Enable CORS

Now the fetch will succeed:

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

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

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



```
Main page!
>
```

Cross-origin solutions

However, you wouldn't have to enable CORS at all if you were making requests from the same origin

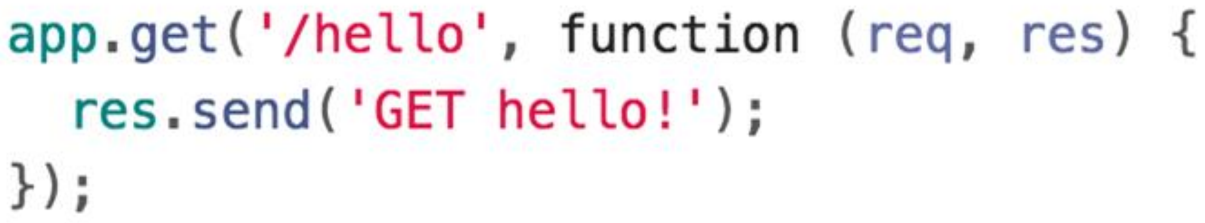
Preferred solution: Load the frontend code statically from the same server, so that the request is from the same origin

Recall: Web services

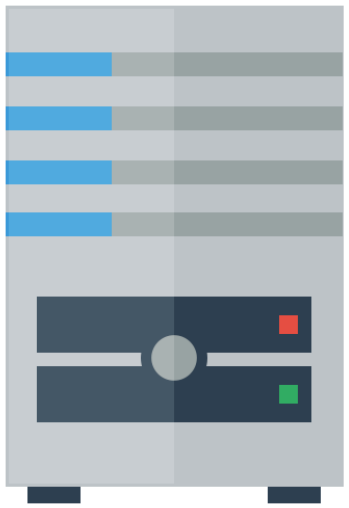
Sometimes when you type a URL into your browser, the URL represents **an API endpoint**

That is, the URL represents **a parameterized request**, and the web server dynamically generates a response to that request

That's how our NodeJS server treats routes defined like this:



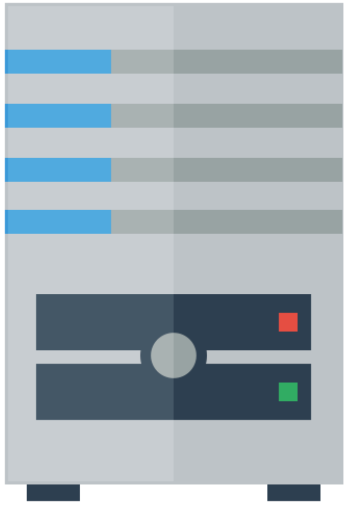
```
app.get('/hello', function (req, res) {
  res.send('GET hello!');
});
```



Recall: Servers

Other times when you type a URL in your browser, the URL is a **path to a file** on the hard drive of the server:

- The web server software grabs that file from the server's local file system, and sends back its contents to you



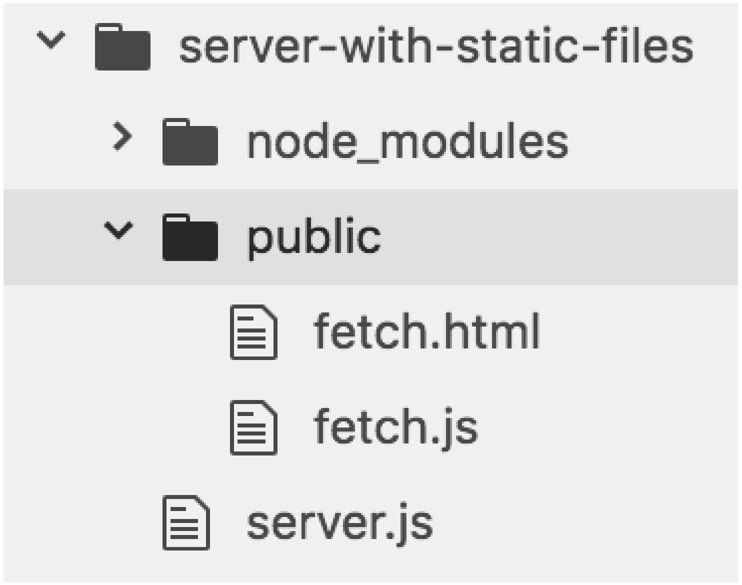
We can make our NodeJS server also sometimes serve files "statically," meaning instead of treating **all** URLs as API endpoints, some URLs will be treated as file paths

Solution 2: Statically served files

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

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

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

This line of code makes our server now start serving the files in the 'public' directory directly

Server static data



```
server-with-static-files
    node_modules
    public
        fetch.html
        fetch.js
    server.js
```

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

Now Express will serve:

http://localhost:3000/fetch.html

http://localhost:3000/fetch.js

Express looks up the files relative to the static directory, so the name of the static directory ("public" in this case) is not part of the URL

Sending data to the server

Route parameters

A parameter defined in the URL of the request is often called a "**route parameter**"

Example:

`https://jsonplaceholder.typicode.com/users/10`

The last part of the URL is a **parameter** representing the user id, which is 10

Route parameters

Q: How do we read route parameters in our server?

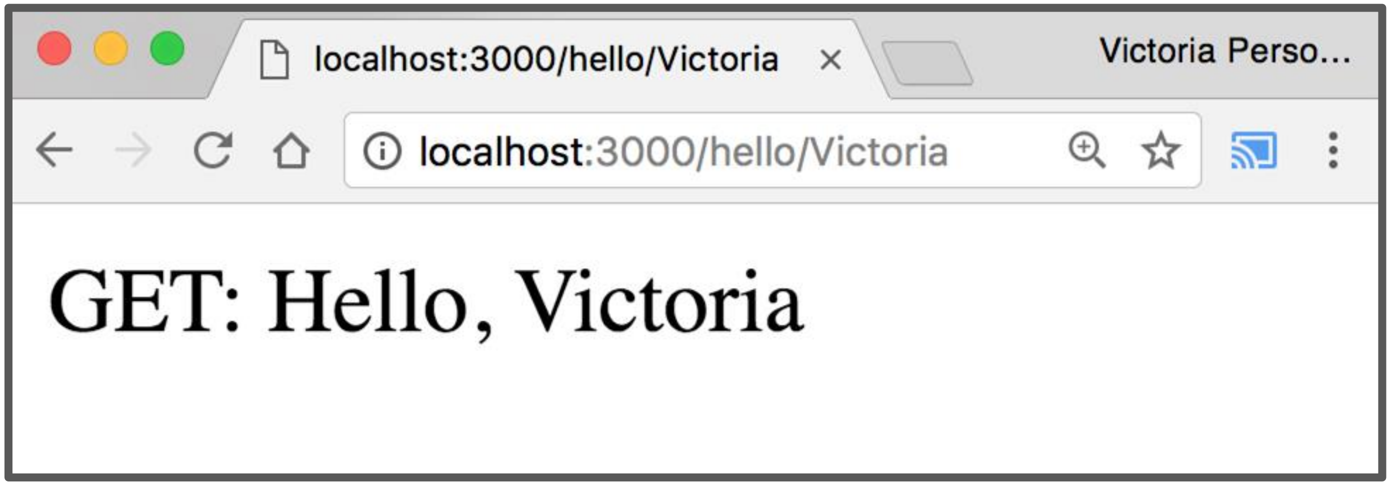
A: We can use the `:`***variableName*** syntax in the path to specify a route parameter (Express docs):

```
app.get('/hello/:name', function (req, res) {
  const routeParams = req.params;
  const name = routeParams.name;
  res.send('GET: Hello, ' + name);
});
```

We can access the route parameters via **`req.params`**

Route parameters

```
app.get('/hello/:name', function (req, res) {
  const routeParams = req.params;
  const name = routeParams.name;
  res.send('GET: Hello, ' + name);
});
```

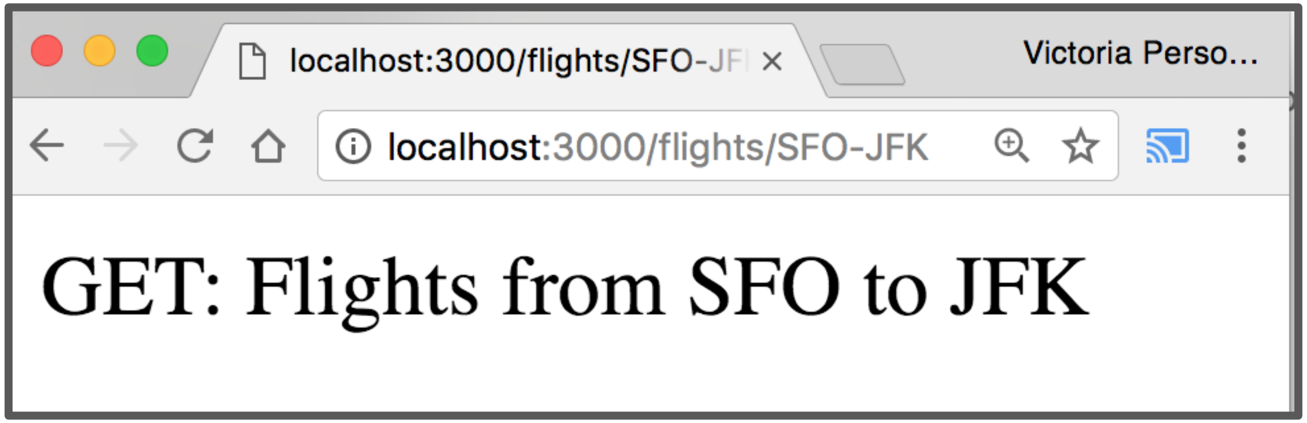


GET: Hello, Victoria

Route parameters

You can define multiple route parameters in a URL (docs):

```
app.get('/flights/:from-:to', function (req, res) {
  const routeParams = req.params;
  const from = routeParams.from;
  const to = routeParams.to;
  res.send('GET: Flights from ' + from + ' to ' + to);
});
```



localhost:3000/flights/SFO-JFK

GET: Flights from SFO to JFK

Query parameters

Example:

`https://jsonplaceholder.typicode.com/posts`**`?userId=1`**

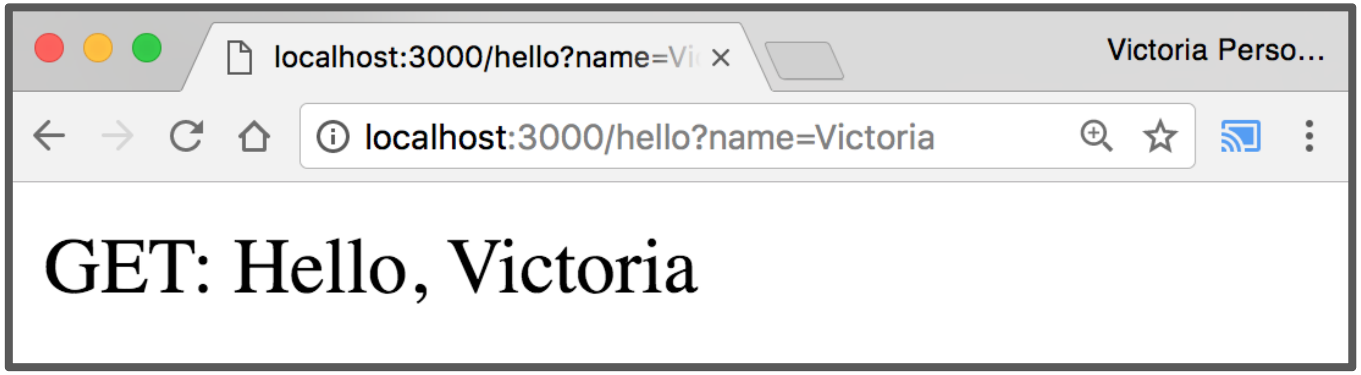
The query parameter sent to the server endpoint is userId, whose value is 1

Query parameters

Q: How do we read query parameters in our server?

A: We can access query parameters via **`req.query`**:

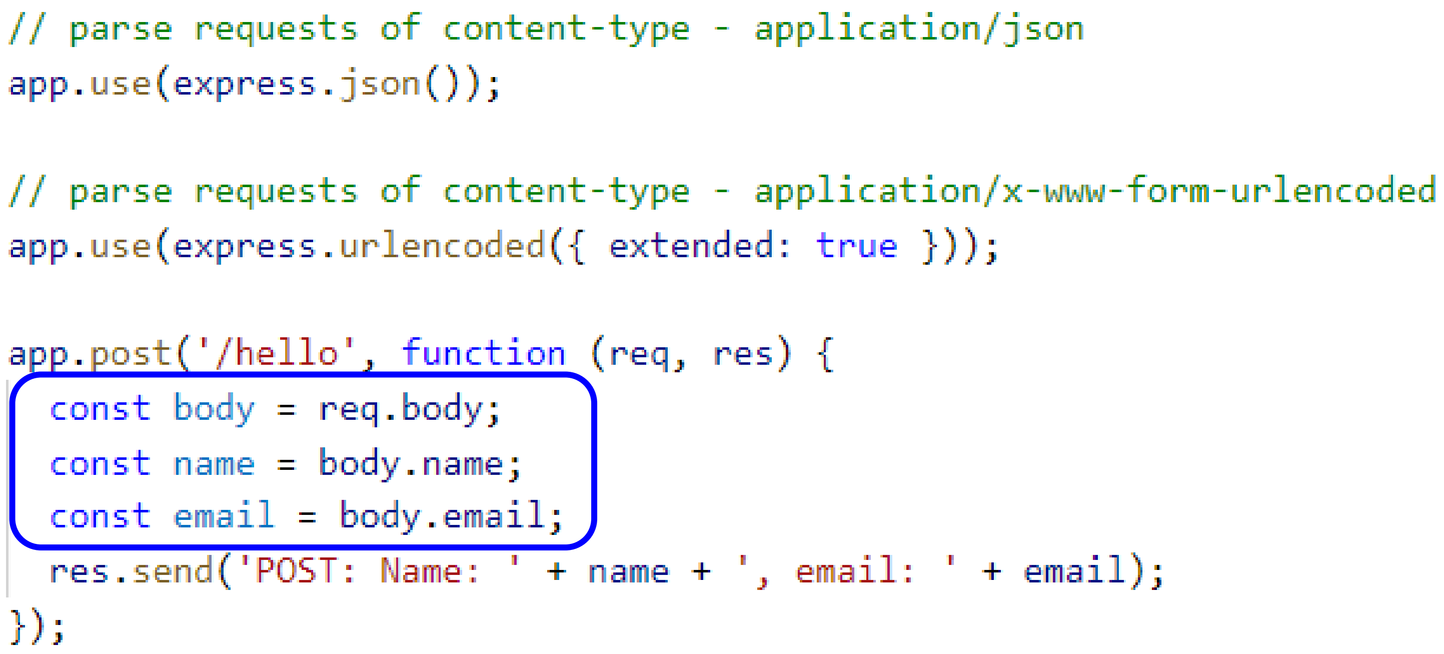
```
app.get('/hello', function (req, res) {
  const queryParams = req.query;
  const name = queryParams.name;
  res.send('GET: Hello, ' + name);
});
```



localhost:3000/hello?name=Victoria

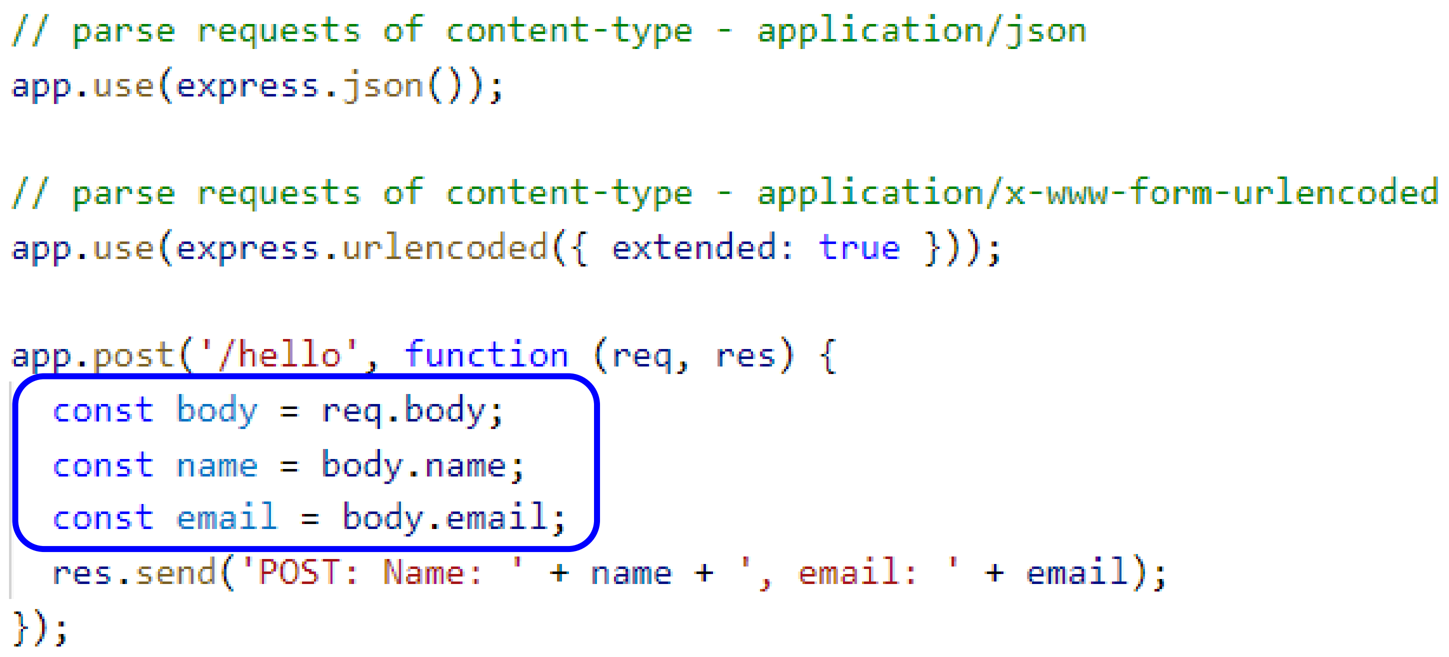
GET: Hello, Victoria

POST message body



```
// parse requests of content-type - application/json
app.use(express.json());

// parse requests of content-type - application/x-www-form-urlencoded
app.use(express.urlencoded({ extended: true }));

app.post('/hello', function (req, res) {
  const body = req.body;
  const name = body.name;
  const email = body.email;
  res.send('POST: Name: ' + name + ', email: ' + email);
});
```

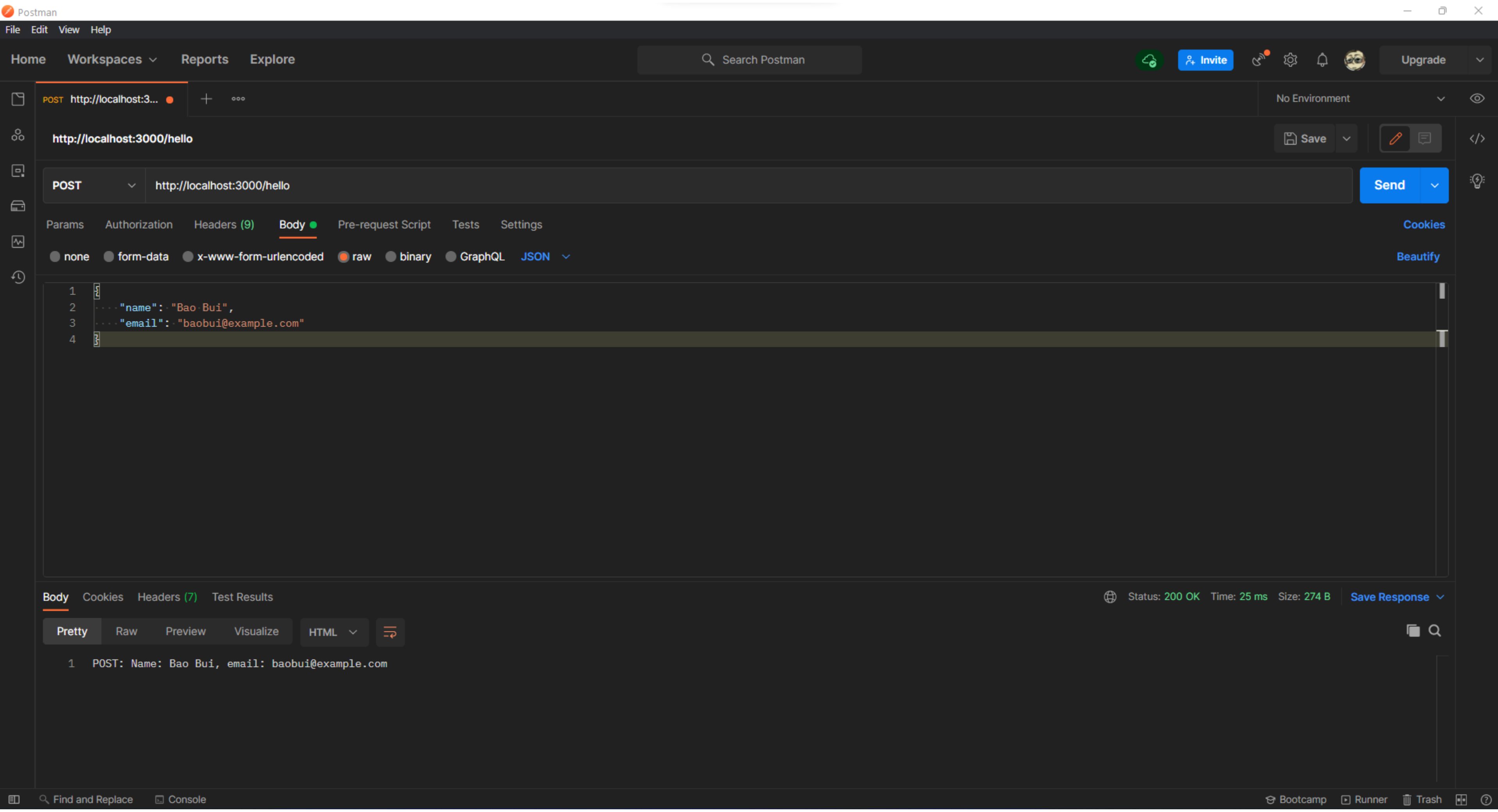
POST message body



```
// parse requests of content-type - application/json
app.use(express.json());

// parse requests of content-type - application/x-www-form-urlencoded
app.use(express.urlencoded({ extended: true }));

app.post('/hello', function (req, res) {
  const body = req.body;
  const name = body.name;
  const email = body.email;
  res.send('POST: Name: ' + name + ', email: ' + email);
});
```

```
Content-Type: application/json
{"name": "Bao Bui", "email": "bao@example.com"}

Content-Type: application/x-www-form-urlencoded
name=Bao%20Bui&email=bao%40example.com
```

POST message body


Postman
File Edit View Help
Home Workspaces Reports Explore
Search Postman
Invite Upgrade
POST http://localhost:3...
No Environment
Save
Send
Params Authorization Headers (9) Body Pre-request Script Tests Settings
Cookies
Beautify
Body Cookies Headers (7) Test Results
Save Response
Pretty Raw Preview Visualize HTML
Find and Replace Console
Bootcamp Runner Trash

http://localhost:3000/hello

POST http://localhost:3000/hello

Body: none form-data x-www-form-urlencoded [✓ raw] binary GraphQL JSON

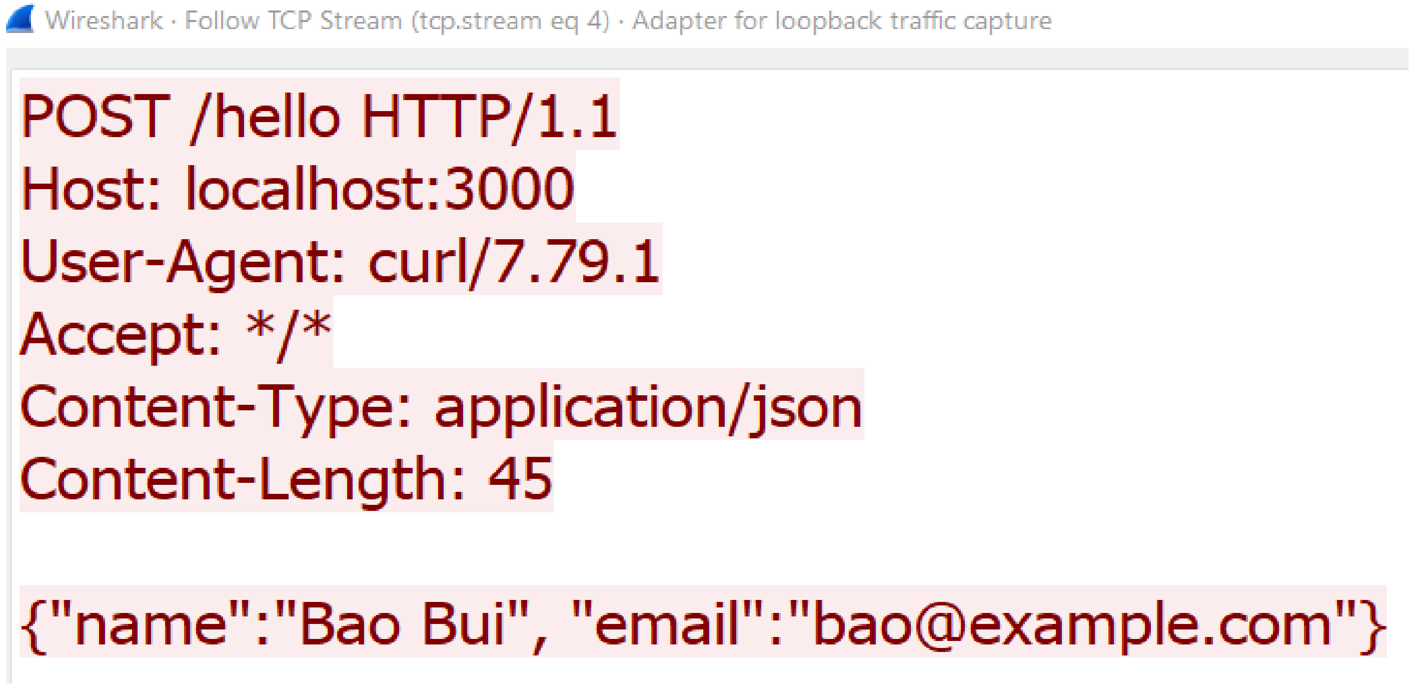
```
{
    "name": "Bao Bui",
    "email": "baobui@example.com"
}
```

Status: 200 OK Time: 25 ms Size: 274 B

```
POST: Name: Bao Bui, email: baobui@example.com
```

POST message body

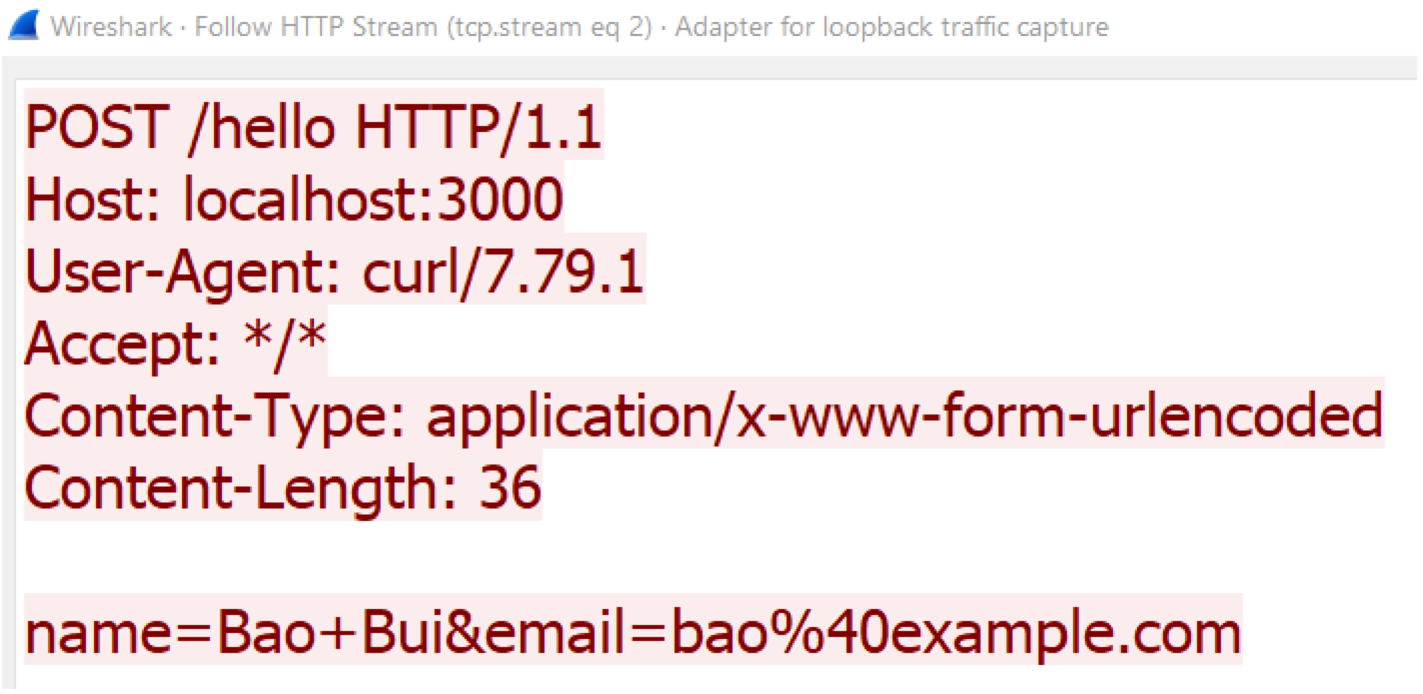
```
$ curl -d '{"name":"Bao Bui", "email":"bao@example.com"}'
-H 'Content-Type: application/json' -X POST
http://localhost:3000/hello
```


Wireshark · Follow TCP Stream (tcp.stream eq 4) · Adapter for loopback traffic capture

```
POST /hello HTTP/1.1
Host: localhost:3000
User-Agent: curl/7.79.1
Accept: */*
Content-Type: application/json
Content-Length: 45

{"name":"Bao Bui", "email":"bao@example.com"}
```

POST message body

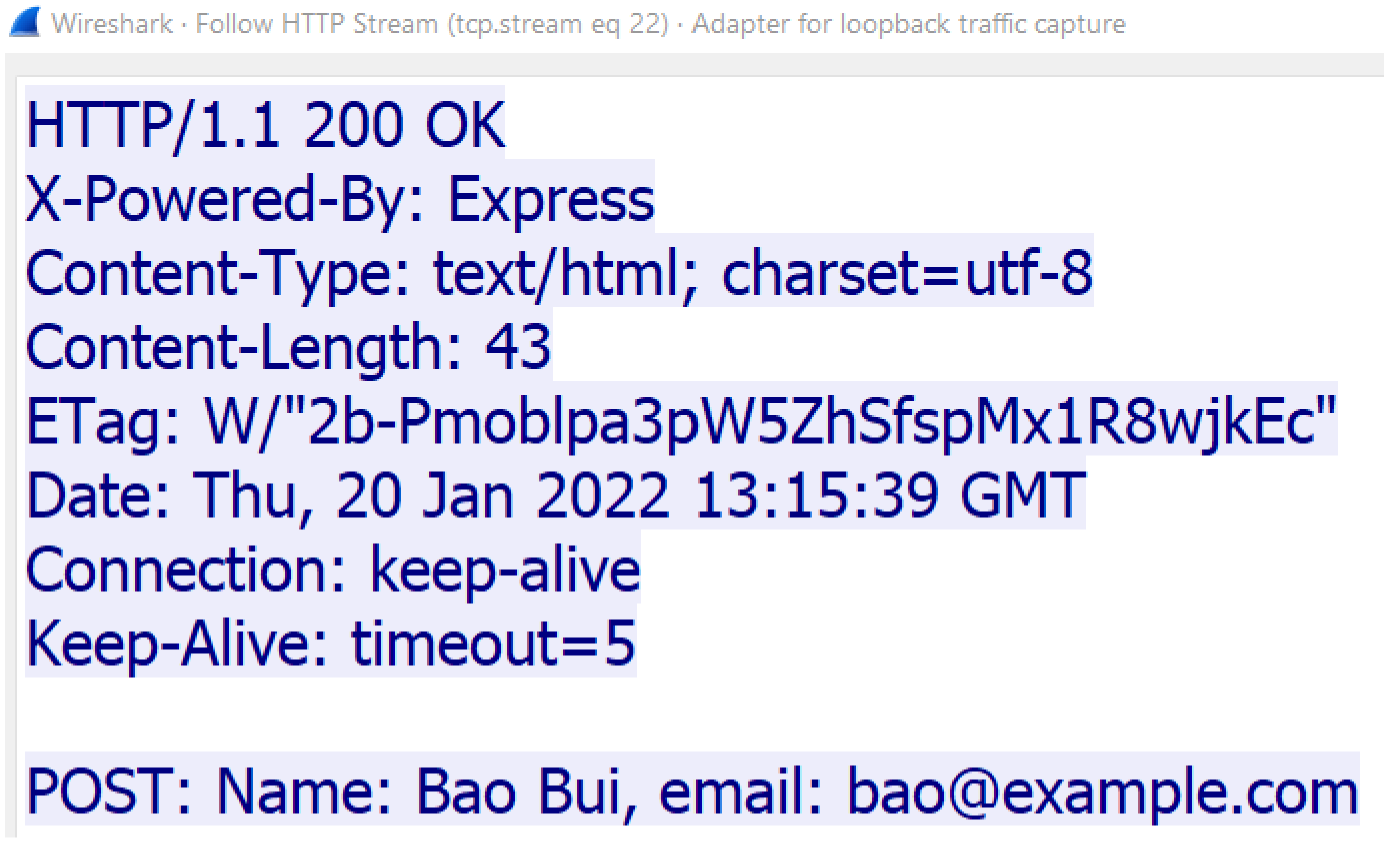
```
$ curl --data-urlencode 'name=Bao Bui' --data-urlencode 'email=bao@example.com' -H 'Content-Type: application/x-www-form-urlencoded' -X POST http://localhost:3000/hello
```


Wireshark · Follow HTTP Stream (tcp.stream eq 2) · Adapter for loopback traffic capture

```
POST /hello HTTP/1.1
Host: localhost:3000
User-Agent: curl/7.79.1
Accept: */*
Content-Type: application/x-www-form-urlencoded
Content-Length: 36

name=Bao+Bui&email=bao%40example.com
```

POST message body

HTTP Response Message


Wireshark · Follow HTTP Stream (tcp.stream eq 22) · Adapter for loopback traffic capture

```
HTTP/1.1 200 OK
X-Powered-By: Express
Content-Type: text/html; charset=utf-8
Content-Length: 43
ETag: W/"2b-Pmoblpa3pW5ZhSfspMx1R8wjkEc"
Date: Thu, 20 Jan 2022 13:15:39 GMT
Connection: keep-alive
Keep-Alive: timeout=5

POST: Name: Bao Bui, email: bao@example.com
```

Recap

You can deliver parameterized information to the server in the following ways:

1. Route parameters
2. GET request with query parameters
   (**DISCOURAGED:** POST with query parameters)
3. POST request with message body

Q: When do you use route parameters vs query parameters vs message body?

GET vs POST

- Use GET requests for retrieving data, not writing data

- Use POST requests for writing data, not retrieving data
  You can also use more specific HTTP methods:
  - PUT/PATCH: Updates the specified resource
  - DELETE: Deletes the specified resource

There's nothing technically preventing you from breaking these rules, but you should use the HTTP methods for their intended purpose

Route params vs Query params

Generally follow these rules:

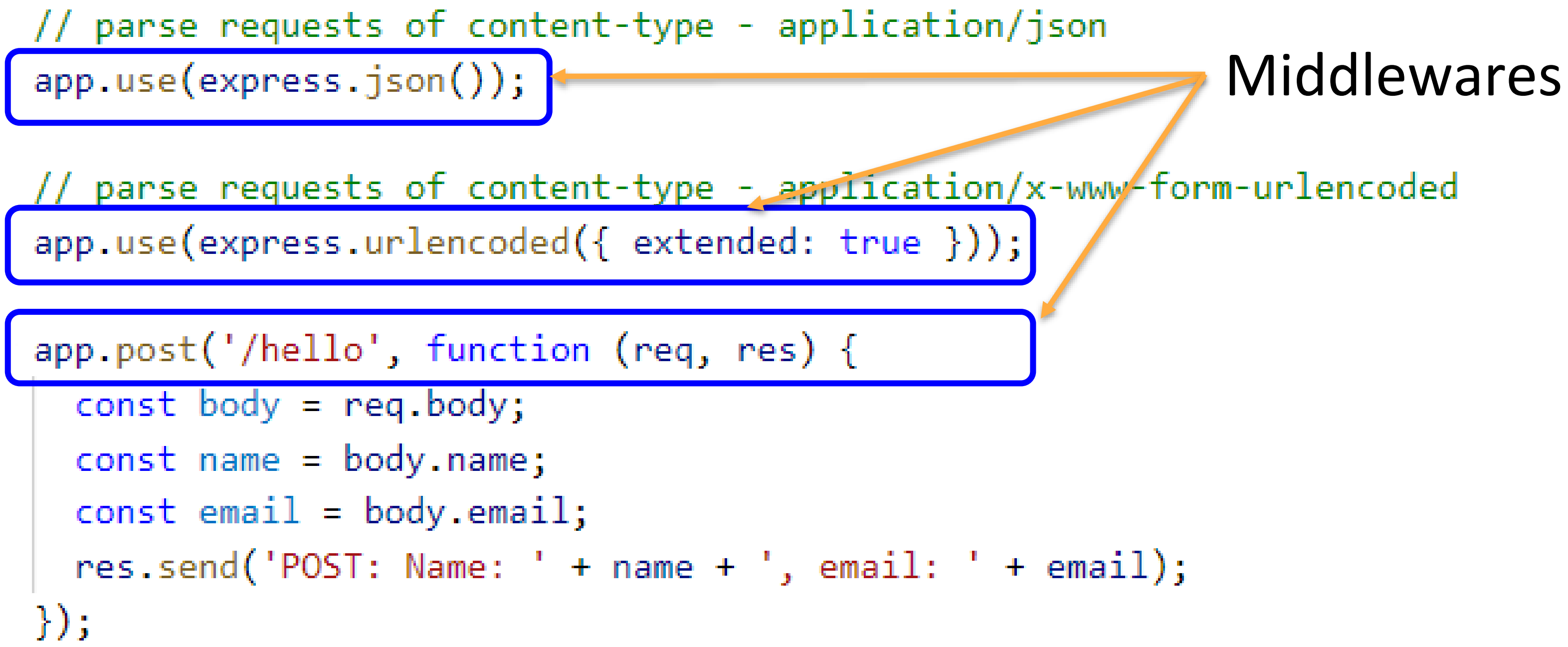
- Use **route parameters** for required parameters for the request
- Use **query parameters** for:
  - Optional parameters
  - Parameters whose values can have spaces

These are conventions and are not technically enforced, nor are they followed by every HTTP API

Also note that query and route parameters are all **strings**

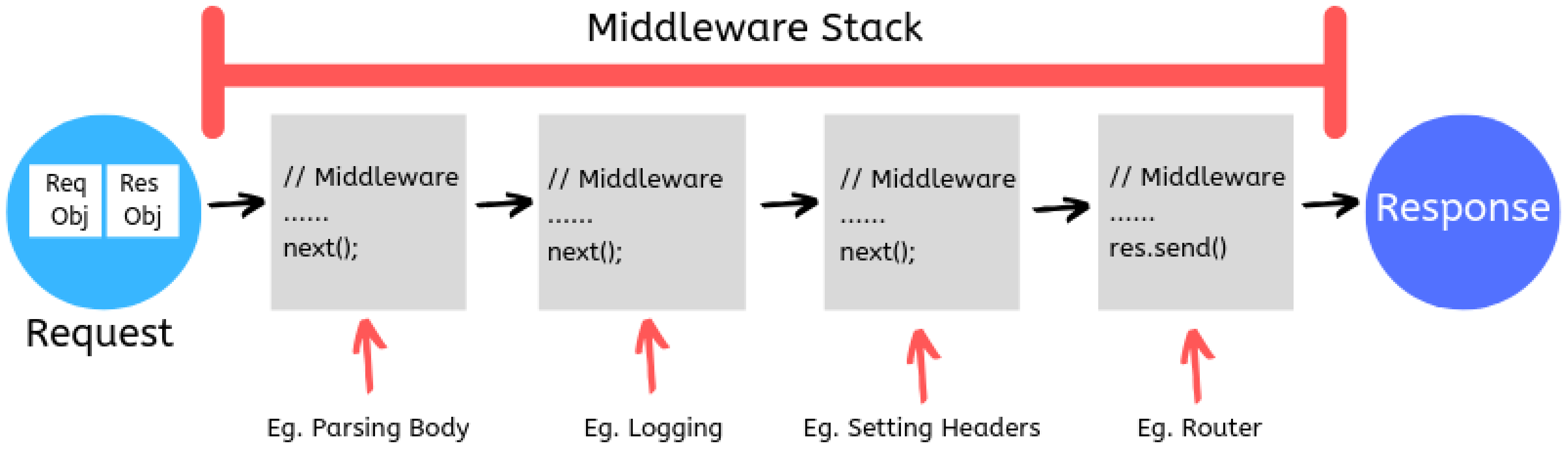
Middleware

Middleware



```javascript
// parse requests of content-type - application/json
app.use(express.json());

// parse requests of content-type - application/x-www-form-urlencoded
app.use(express.urlencoded({ extended: true }));

app.post('/hello', function (req, res) {
    const body = req.body;
    const name = body.name;
    const email = body.email;
    res.send('POST: Name: ' + name + ', email: ' + email);
});
```

Middleware



The middleware stack follows **the order of middlewares placed in the code**

*Nguồn: https://iq.opengenus.org/middlewares-in-express/

Middleware

```
function(req, res, next) { ... };
```

Middleware functions can perform the following tasks:

- Execute any code
- Make changes to the request and the response objects
- End the request-response cycle
- Call the next middleware in the stack

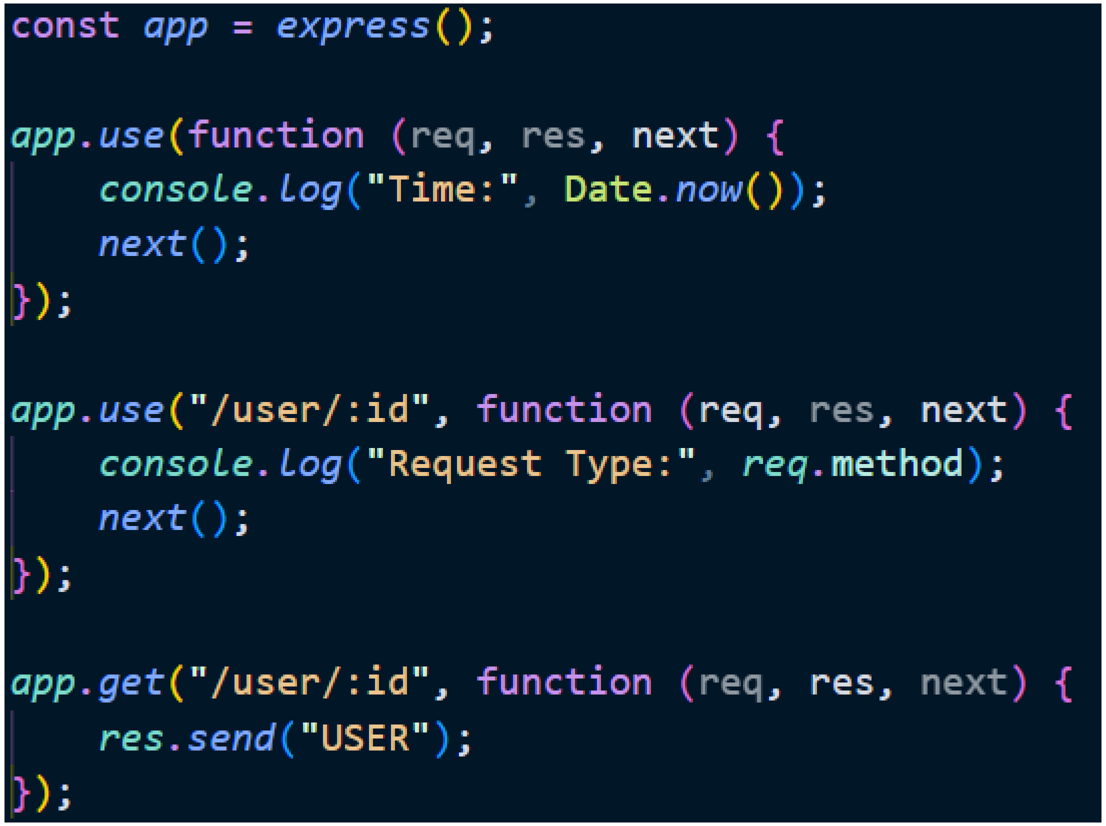
Middleware

Types of middleware:

- Application-level middleware
- Router-level middleware
- Error handling middleware
- Built-in middleware
- External middleware (requires `npm install`)

Middleware

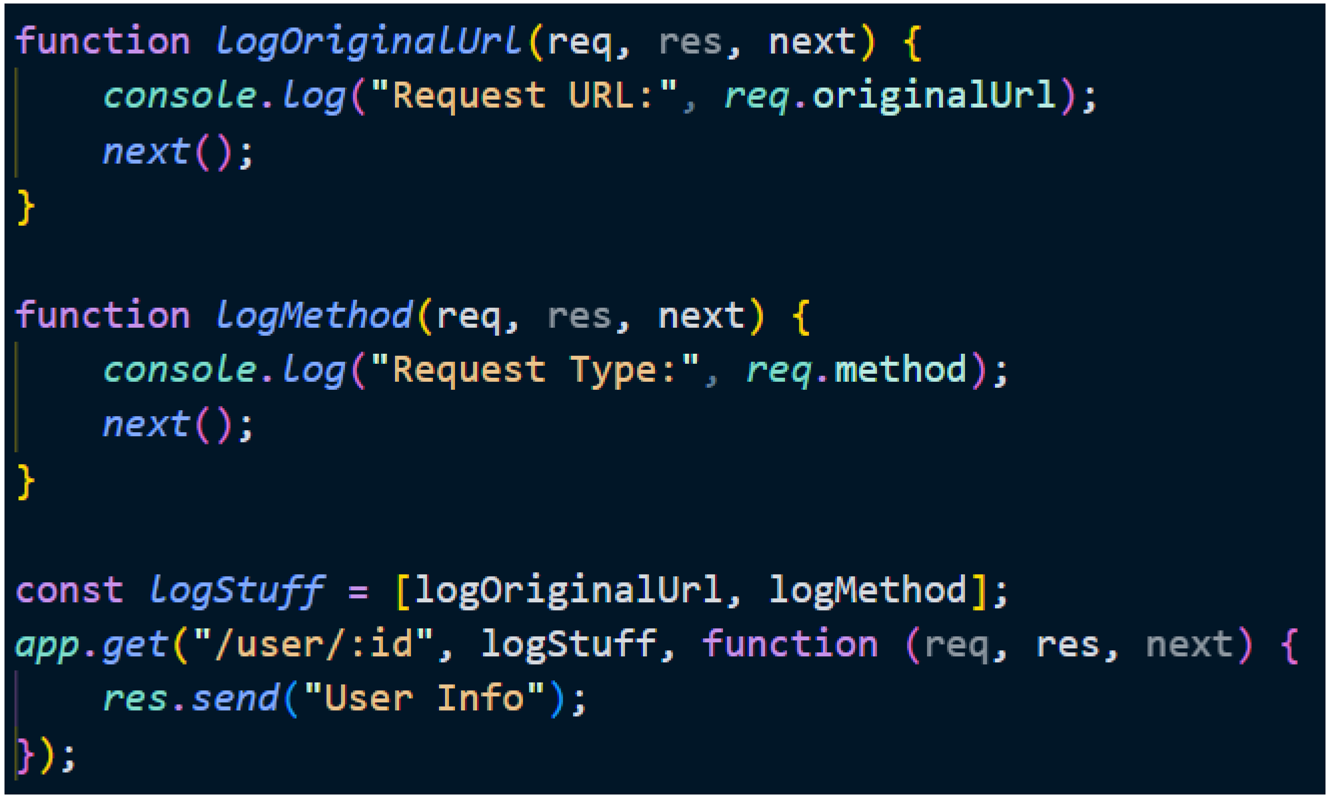
Application-level middleware: bound to the app instance by using `app.use()` or `app.METHOD()` functions



```
const app = express();

app.use(function (req, res, next) {
    console.log("Time:", Date.now());
    next();
});

app.use("/user/:id", function (req, res, next) {
    console.log("Request Type:", req.method);
    next();
});

app.get("/user/:id", function (req, res, next) {
    res.send("USER");
});
```

Middleware

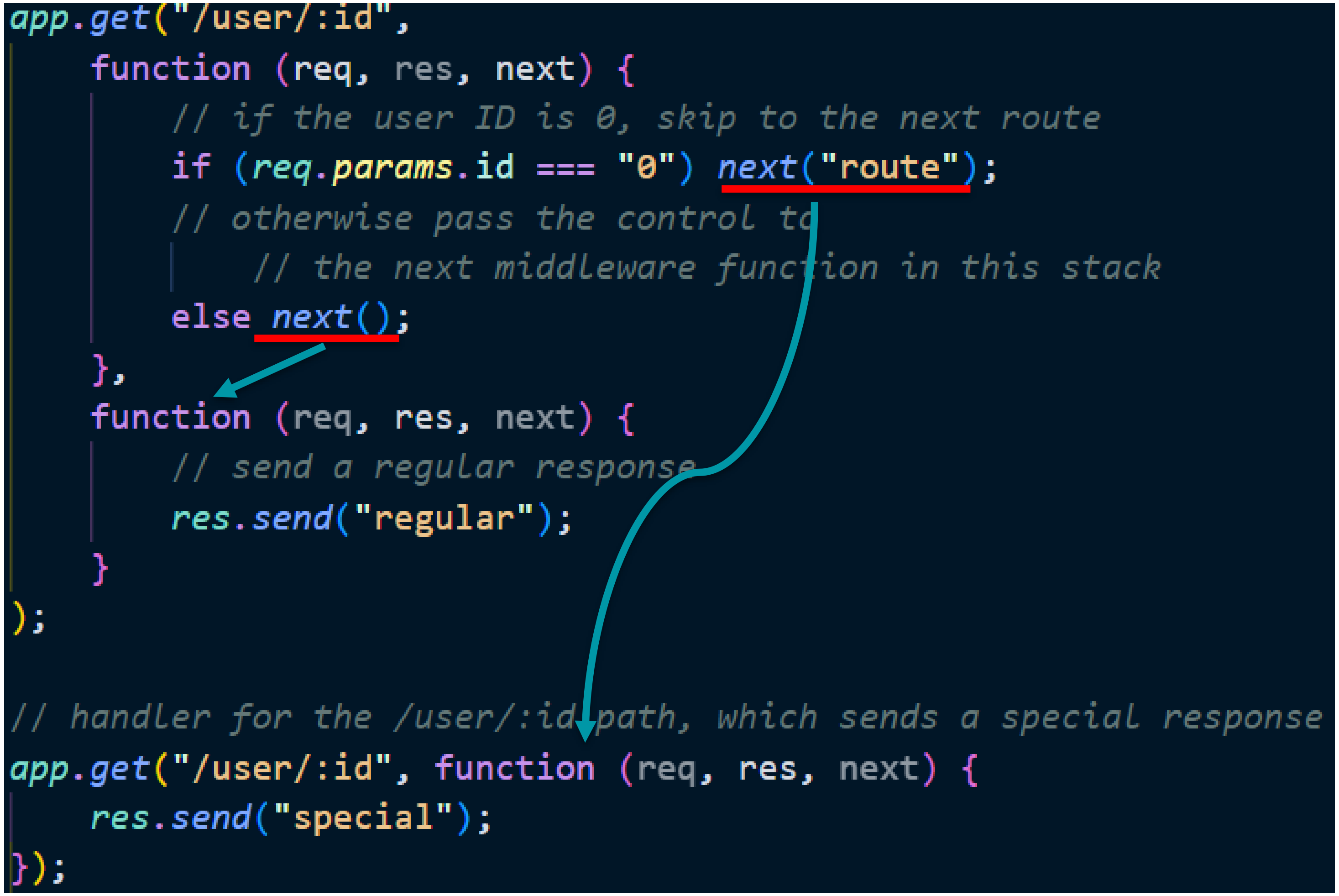
Application-level middleware: bound to the app instance by using `app.use()` or `app.METHOD()` functions



```
function logOriginalUrl(req, res, next) {
    console.log("Request URL:", req.originalUrl);
    next();
}

function logMethod(req, res, next) {
    console.log("Request Type:", req.method);
    next();
}

const logStuff = [logOriginalUrl, logMethod];
app.get("/user/:id", logStuff, function (req, res, next) {
    res.send("User Info");
});
```

Middleware

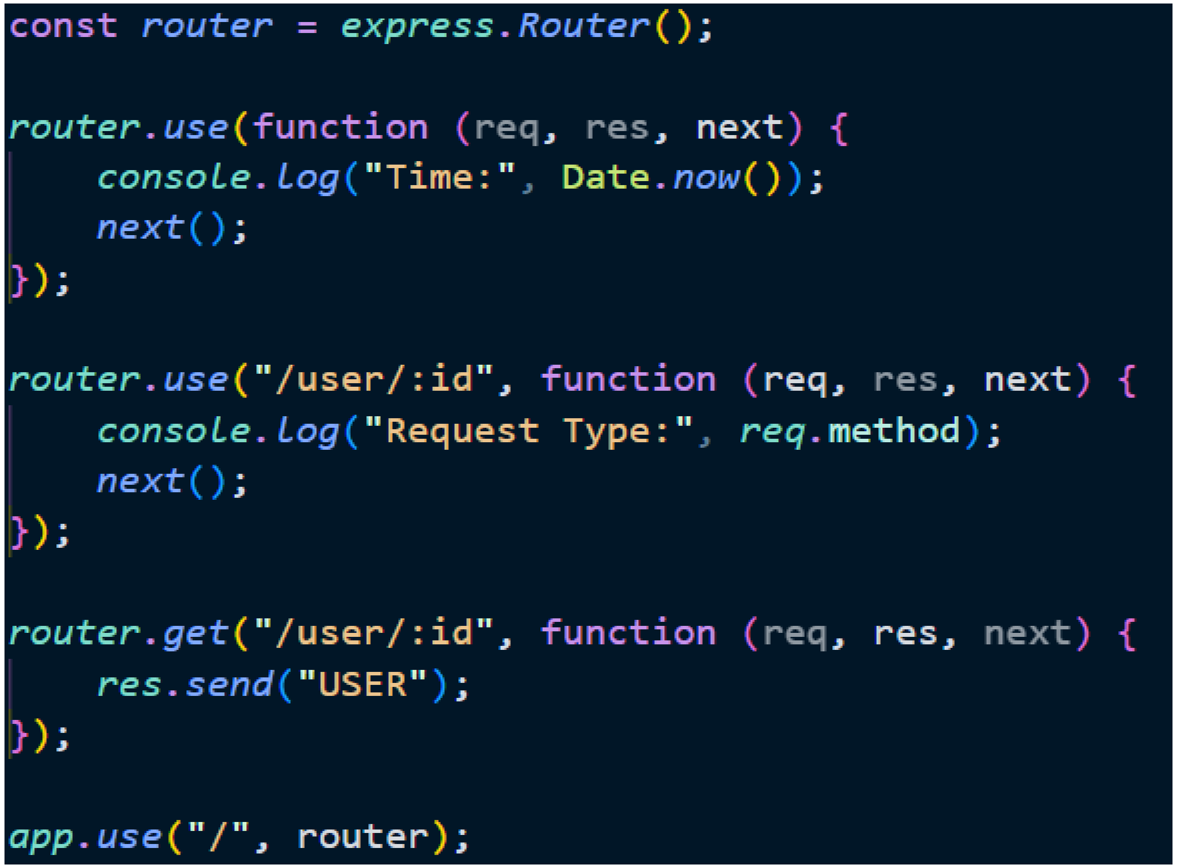
Application-level middleware



```
app.get("/user/:id",
    function (req, res, next) {
        // if the user ID is 0, skip to the next route
        if (req.params.id === "0") next("route");
        // otherwise pass the control to
            // the next middleware function in this stack
        else next();
    },
    function (req, res, next) {
        // send a regular response
        res.send("regular");
    }
);

// handler for the /user/:id path, which sends a special response
app.get("/user/:id", function (req, res, next) {
    res.send("special");
});
```

Middleware

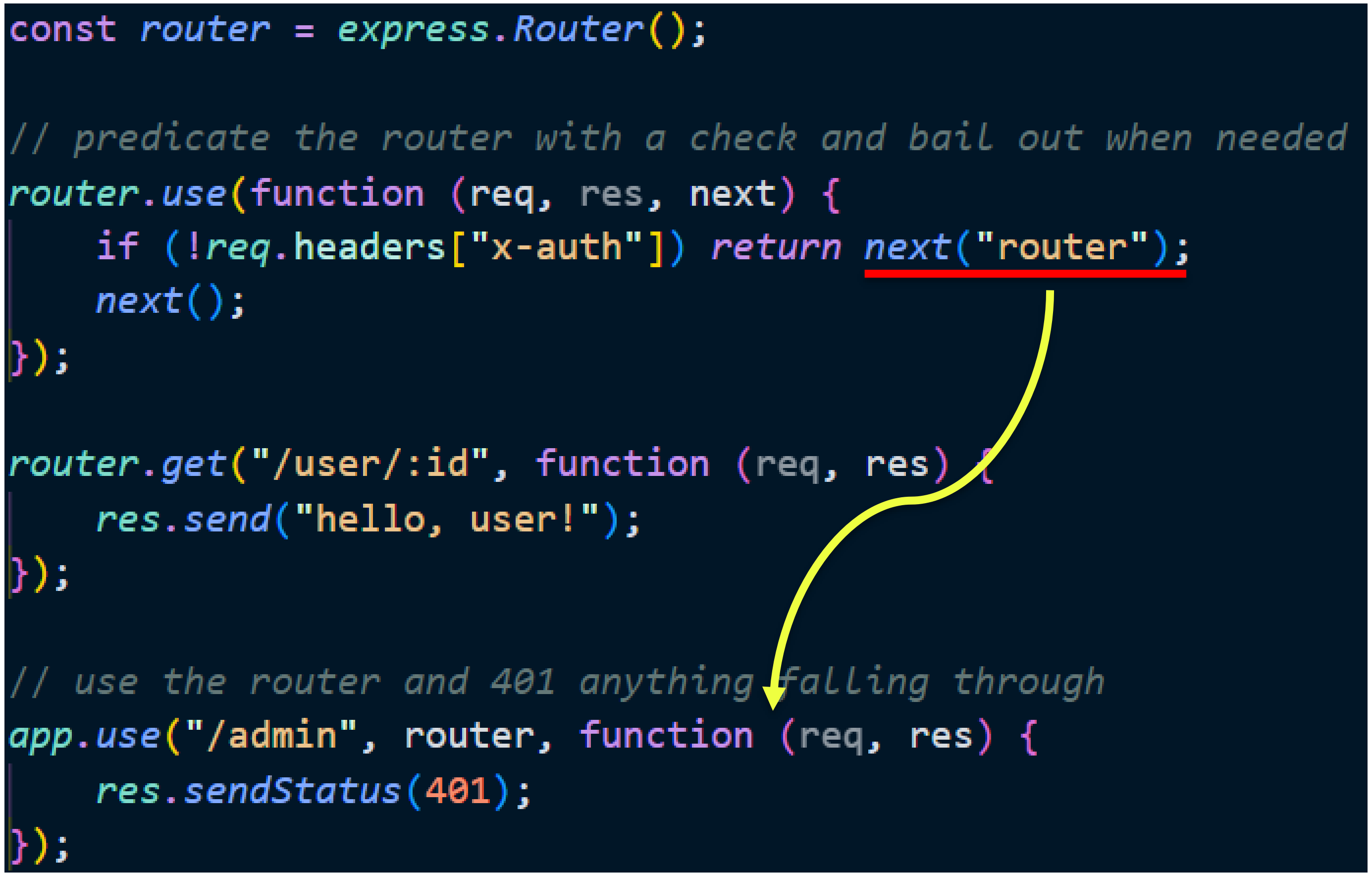
Router-level middleware: bound to an instance of express.Router()



```
const router = express.Router();

router.use(function (req, res, next) {
    console.log("Time:", Date.now());
    next();
});

router.use("/user/:id", function (req, res, next) {
    console.log("Request Type:", req.method);
    next();
});

router.get("/user/:id", function (req, res, next) {
    res.send("USER");
});

app.use("/", router);
```

Middleware

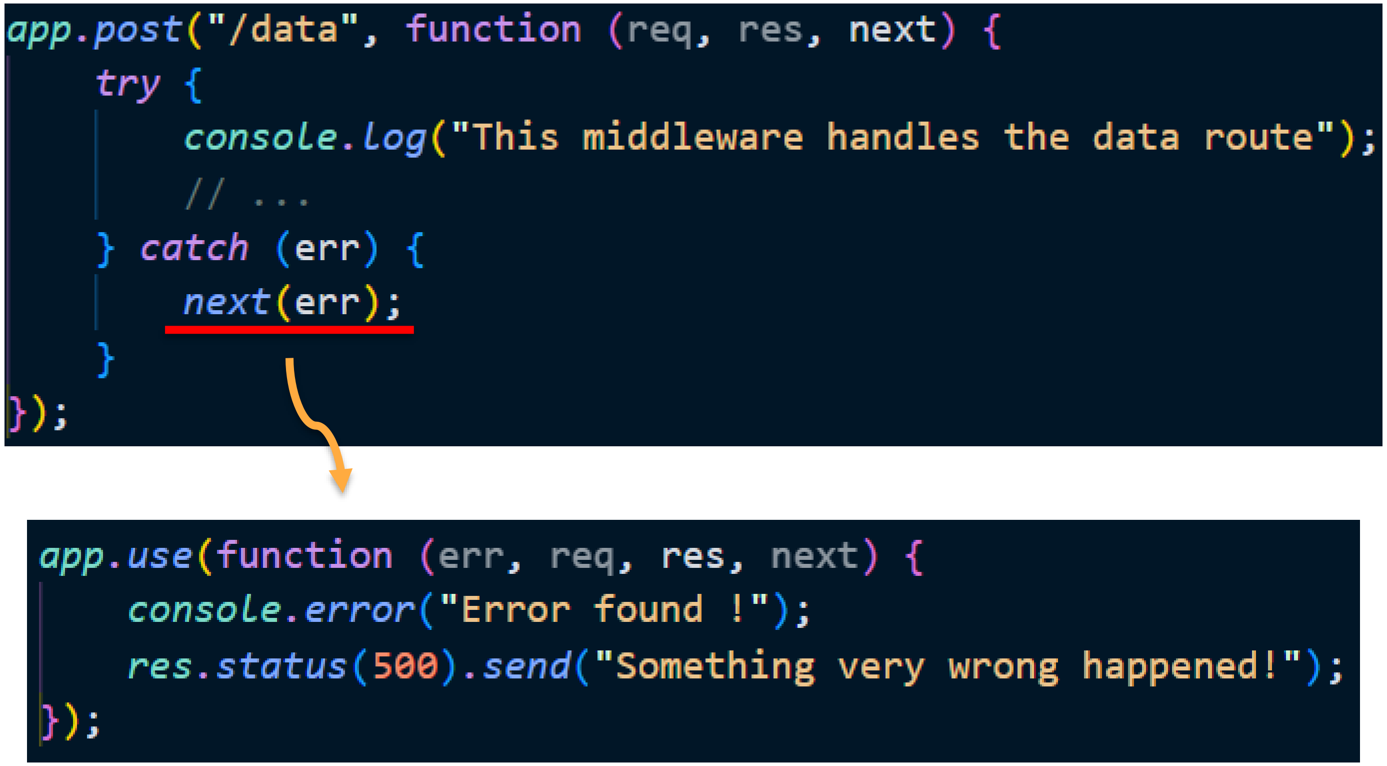
Router-level middleware: bound to an instance of express.Router()



```
const router = express.Router();

// predicate the router with a check and bail out when needed
router.use(function (req, res, next) {
    if (!req.headers["x-auth"]) return next("router");
    next();
});

router.get("/user/:id", function (req, res) {
    res.send("hello, user!");
});

// use the router and 401 anything falling through
app.use("/admin", router, function (req, res) {
    res.sendStatus(401);
});
```

Middleware

Error handling middleware: defined last, after other app.use() and routes calls



```
app.post("/data", function (req, res, next) {
    try {
        console.log("This middleware handles the data route");
        // ...
    } catch (err) {
        next(err);
    }
});
```

```
app.use(function (err, req, res, next) {
    console.error("Error found !");
    res.status(500).send("Something very wrong happened!");
});
```

Middleware

Built-in middleware

- `express.static()`: serves static assets (HTML files, images,…)
- `express.json()`: parses incoming requests with JSON payloads (Express >= 4.16.0)
- `express.urlencoded()`: parses incoming requests with URL-encoded payloads (Express >= 4.16.0)

Middleware

(Some) External middleware

- `morgan`: HTTP request logger middleware for node.js
- `cors`: middleware that can be used to enable CORS with various options
- `cookie-parser`: parses Cookie header and populates `req.cookies` with an object keyed by the cookie
- `multer`: middleware for handling `multipart/form-data` (file uploads)

Middleware

(Some) External middleware

```
npm install -D morgan
```

```
const morgan = require("morgan");
app.use(morgan("dev"));
```

package.json

Installing dependencies

In our examples, we had to install the Express npm packages

```
$ npm install express
```

These get written to the `node_modules` directory

Uploading server code

When you upload NodeJS code to a GitHub repository (or any code repository), you should **not** upload the `node_modules` directory:

- You shouldn't be modifying code in the `node_modules` directory, so there's no reason to have it under version control
- This will also increase your repo size significantly

Q: But if you don't upload the node_modules directory to your code repository, how will anyone know what libraries they need to install?

Managing dependencies

If we don't include the `node_modules` directory in our repository, we need to somehow tell other people what npm modules they need to install

npm provides a mechanism for this: [`package.json`]

package.json

You can put a file named `package.json` in the root directory of your NodeJS project to specify metadata about your project

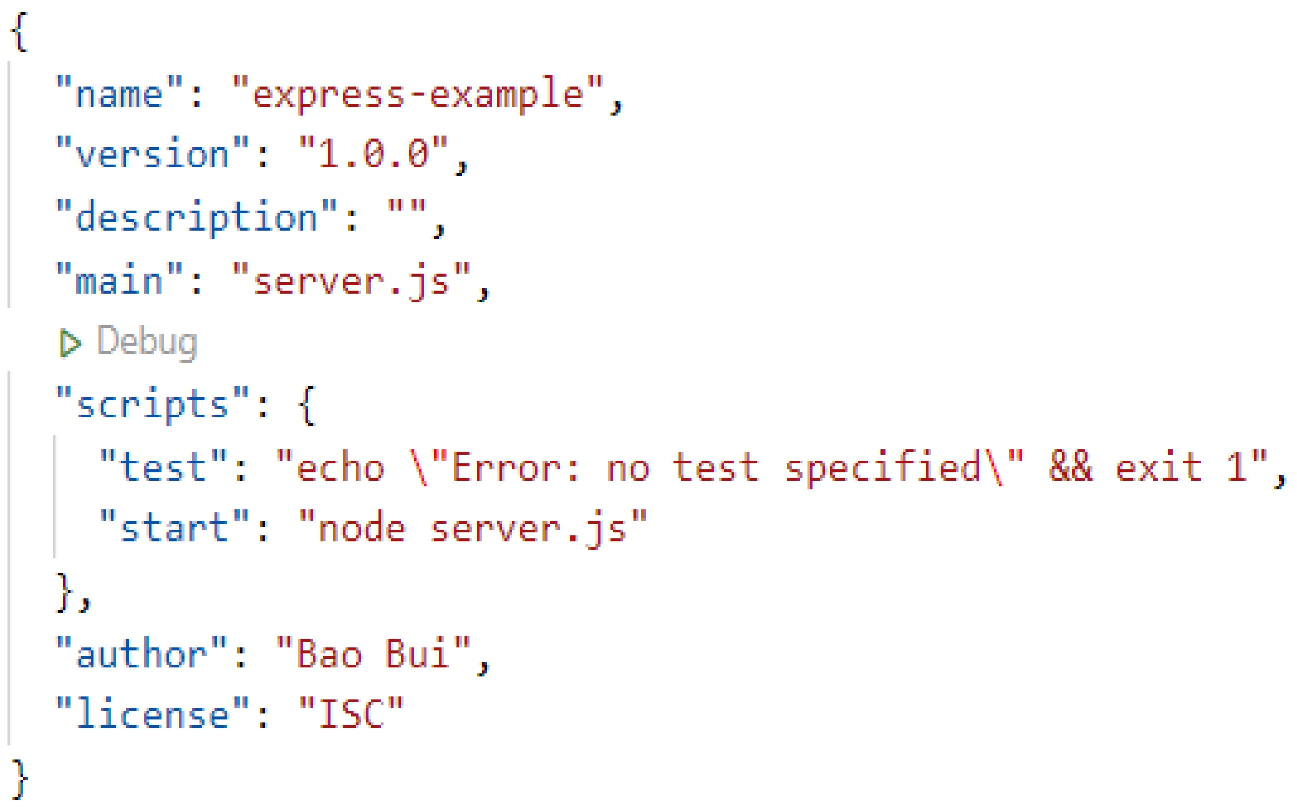
Create a `package.json` file using the following command:

```
$ npm init
```

This will ask you a series of questions then generate a `package.json` file based on your answers

- Add `-y` option to get a package.json file with default values

Auto-generated package.json



```
{
  "name": "express-example",
  "version": "1.0.0",
  "description": "",
  "main": "server.js",
  ▷ Debug
  "scripts": {
    "test": "echo \"Error: no test specified\" && exit 1",
    "start": "node server.js"
  },
  "author": "Bao Bui",
  "license": "ISC"
}
```

Saving deps to package.json

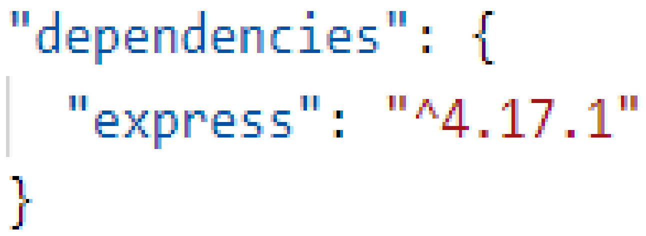
Now when you install packages:

```
$ npm install express
```

Or

```
$ npm i express
```

An entry for this library is added in package.json



```
"dependencies": {
  "express": "^4.17.1"
}
```

Saving deps to package.json

If you remove the node_modules directory:

```
$ rm -rf node_modules
```

You can install your project dependencies again via:

```
$ npm install
```

- This also allows people who have downloaded your code from GitHub to install all your dependencies with one command instead of having to install all dependencies individually

package-lock.json

package-lock.json is auto generated for any operations where npm modifies either the *node_modules* tree, or *package.json*

It describes the exact tree that was generated

npm scripts

Your package.json file also defines scripts:

```
"scripts": {
  "test": "echo \"Error: no test specified\" && exit 1",
  "start": "node server.js"
},
```

You can run these scripts using `$ npm [run]` ***scriptName***

E.g. the following command runs "node server.js"

```
$ npm start
```

nodemon

Automatically restart the node application when file changes

```
$ npm i -D nodemon
```

`-D` option: package will appear in *devDependencies* section

dependencies: packages required to run
devDependencies: only for development

`npm install`: install packages listed in both sections
`npm install --production`: only packages in *dependencies* are installed

nodemon

Automatically restart the node application when file changes

In package.json, use nodemon to start the server:

```
"scripts": {
    "start": "nodemon server.js"
}
```

Then run `$ npm start`

npx: an npm package runner

npx makes it easy to use CLI tools and other executables hosted on the registry

Using locally-installed tools without npm run-script:

```
$ npm i -D cowsay
$ npx cowsay hello!
```

Executing one-off commands:

```
$ npx cowsay hello!
```

Node.js Event Loop

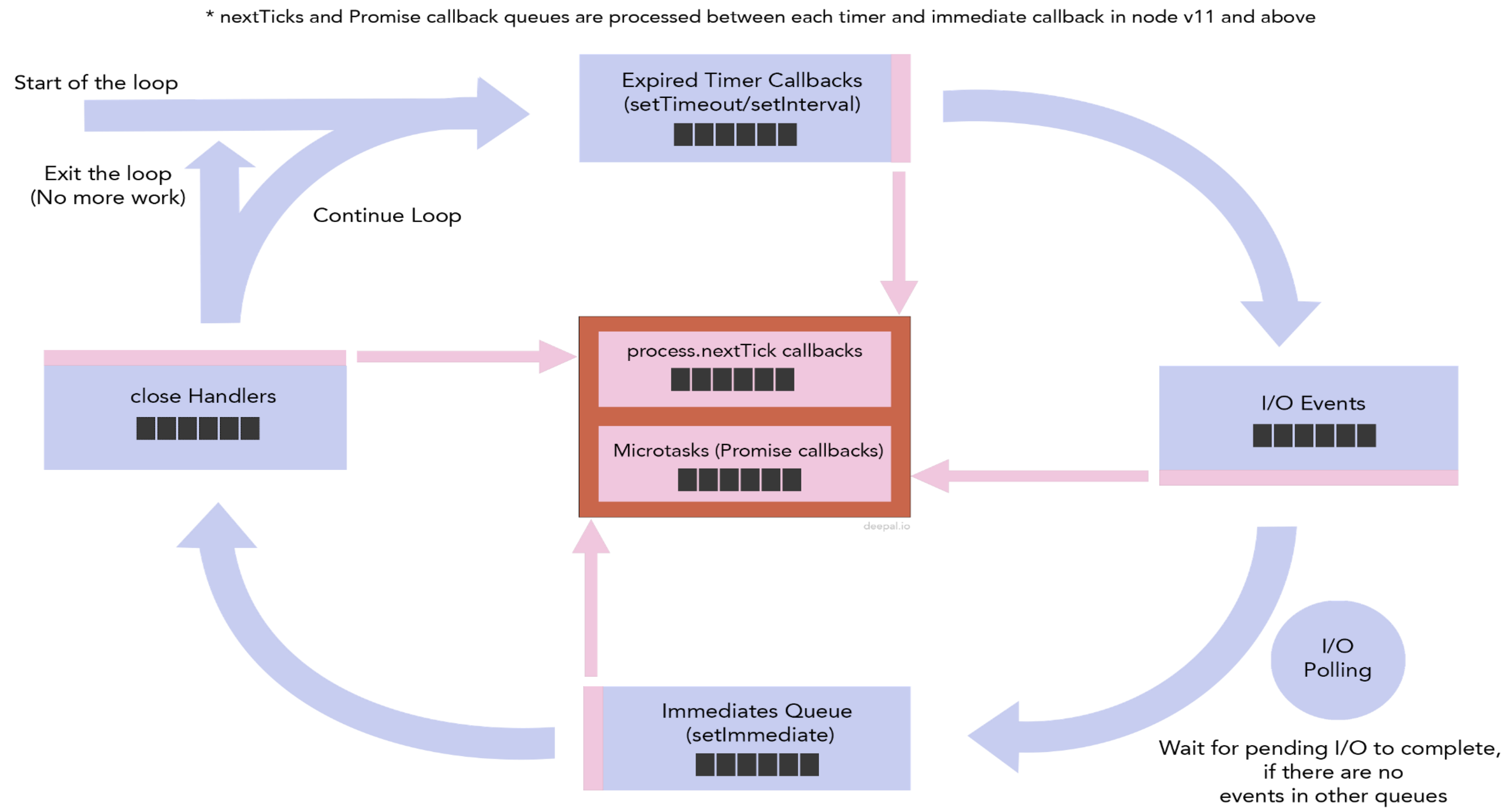
Event loop

There are two types of threads in Nodejs:

- One Event Loop (aka the main loop, main thread, event thread, etc.)
  - Responsible for callbacks and non-blocking I/O (i.e., network I/O)
  - *All incoming requests and outgoing responses pass through the Event Loop*

- A pool of k (k=4 by default) Workers in a Worker Pool (aka the threadpool)
  - Handle I/O intensive tasks (dns, file APIs) or CPU-intensive ones (crypto, zlib APIs)

Event loop


* nextTicks and Promise callback queues are processed between each timer and immediate callback in node v11 and above
Start of the loop
Expired Timer Callbacks (setTimeout/setInterval)
Exit the loop (No more work)
Continue Loop
process.nextTick callbacks
Microtasks (Promise callbacks)
close Handlers
I/O Events
deepal.io
I/O Polling
Immediates Queue (setImmediate)
Wait for pending I/O to complete, if there are no events in other queues

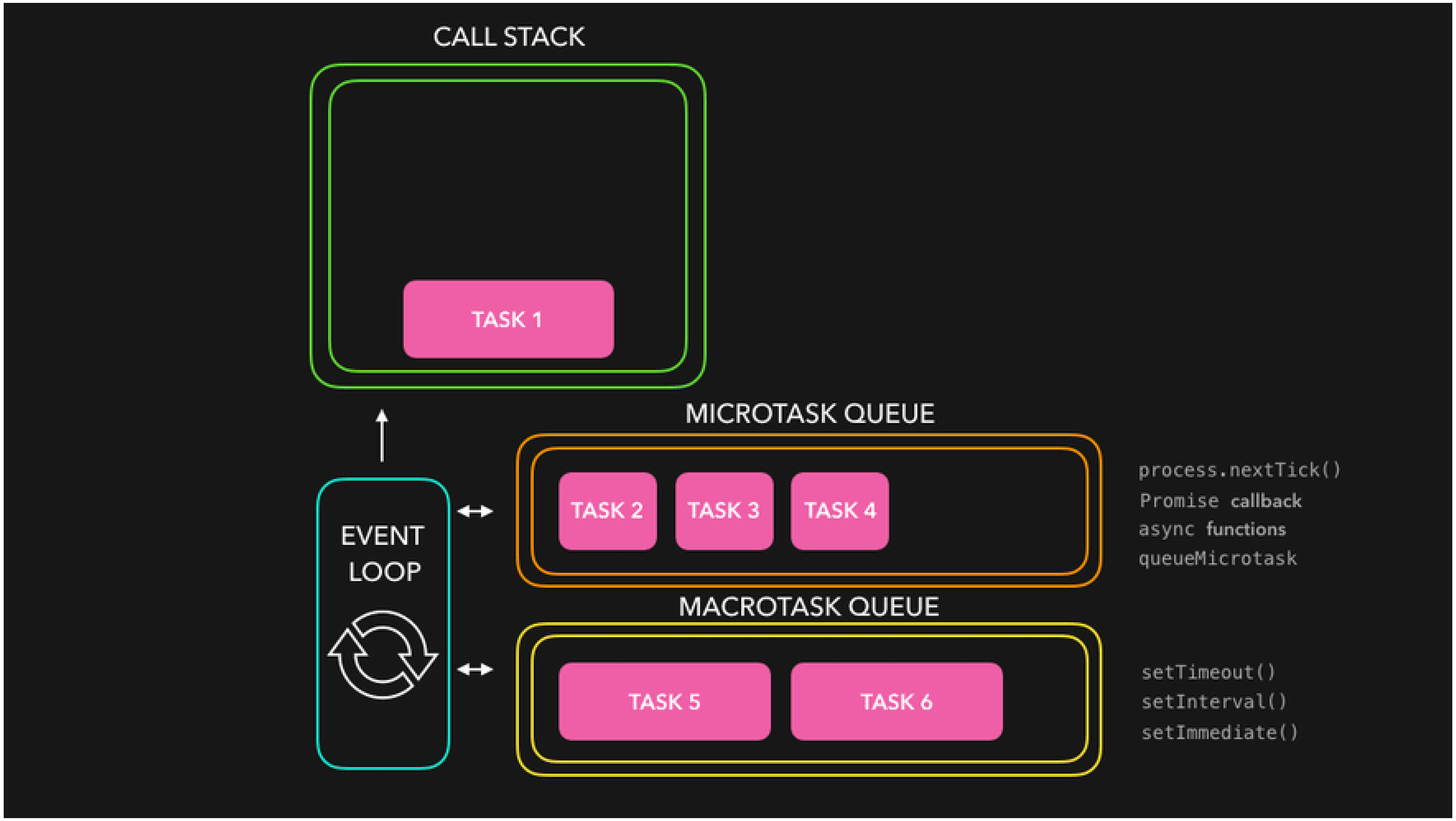
https://blog.insiderattack.net/event-loop-and-the-big-picture-nodejs-event-loop-part-1-1cb67a182810

Event loop

- All user-written ***synchronous JavaScript code*** takes priority over async code that the runtime would like to execute
  - Only after the call stack is empty does the event loop come into play

- Every microtask queue (process.nextTick, resolved Promises) is visited and emptied after every macrotask (setImmediate, setTimeout,…)

Event loop



https://techva.me/callback-functions-promises-nodejs/

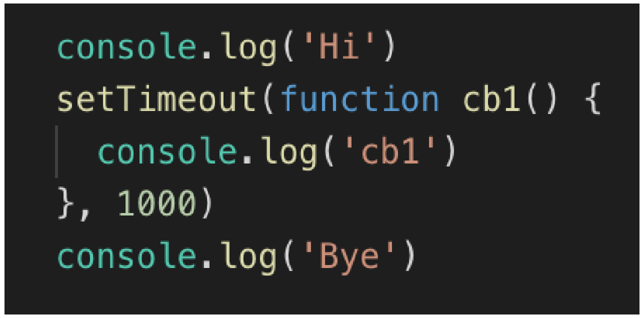
`setTimeout`

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

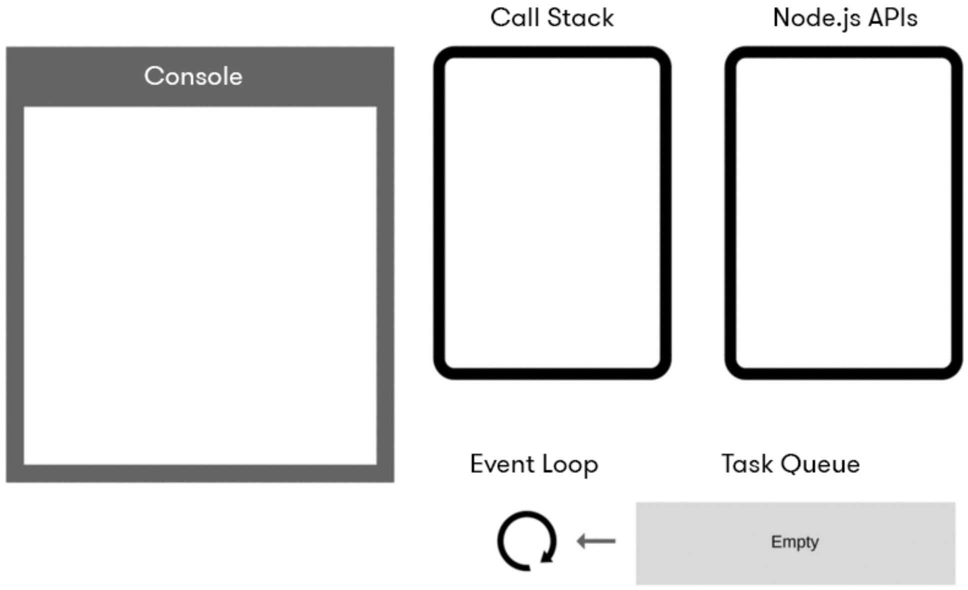
`setTimeout(`***function***`, `***delay***`);`

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

JS execution

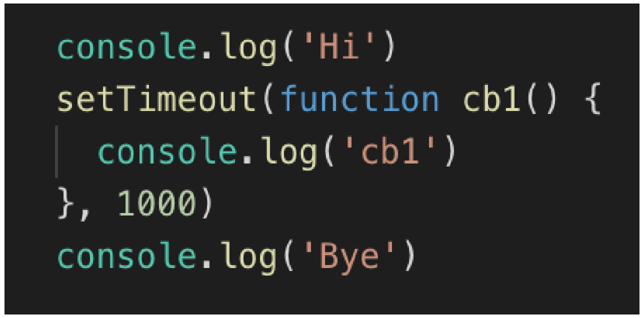


```
console.log('Hi')
setTimeout(function cb1() {
  console.log('cb1')
}, 1000)
console.log('Bye')
```

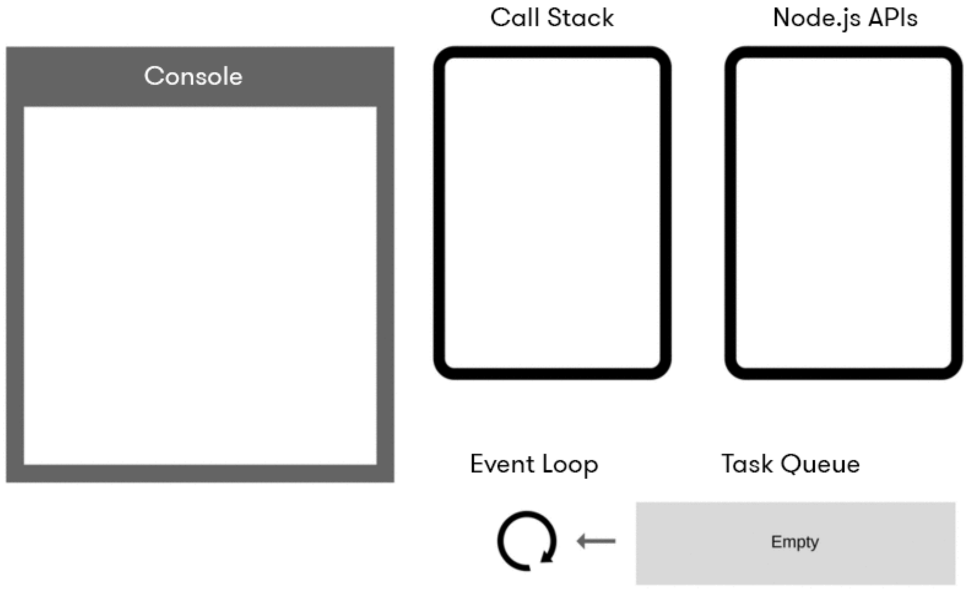


Call stack: JavaScript runtime call stack. Executes the JavaScript commands, functions

JS execution

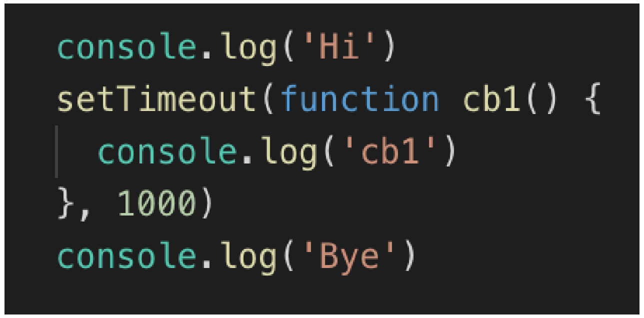


```
console.log('Hi')
setTimeout(function cb1() {
  console.log('cb1')
}, 1000)
console.log('Bye')
```

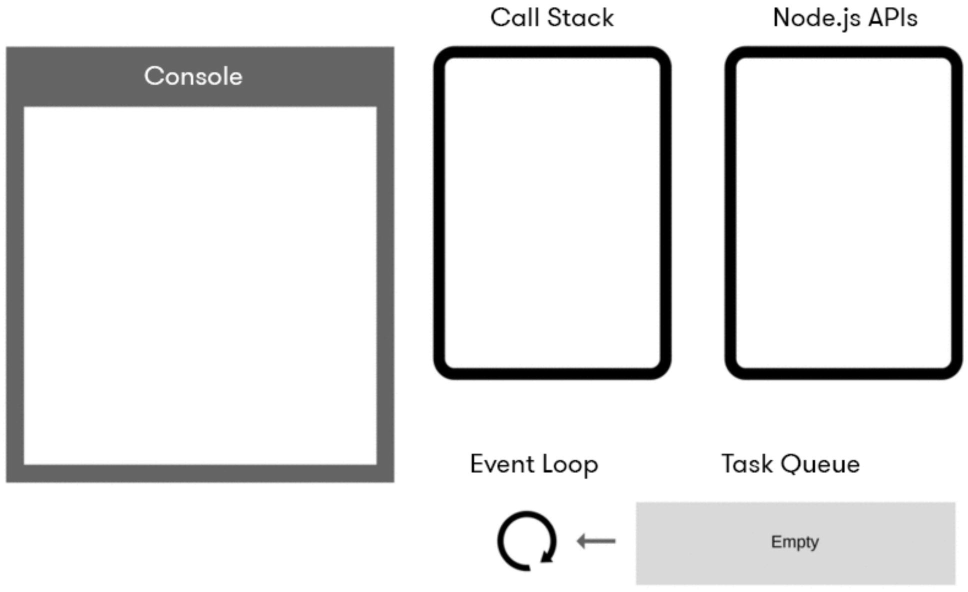


Task Queue: When Node.js APIs notice a callback from something like setTimeout should be fired, it creates a Task and enqueues it in the Task Queue

JS execution



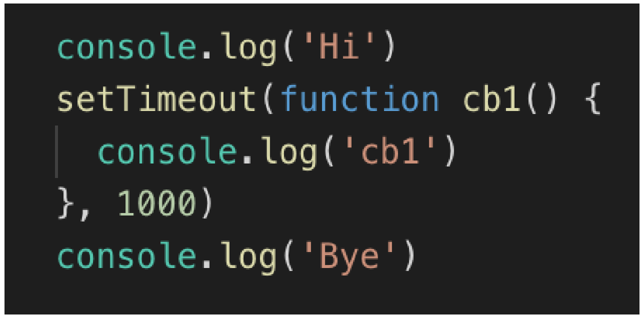
```
console.log('Hi')
setTimeout(function cb1() {
  console.log('cb1')
}, 1000)
console.log('Bye')
```



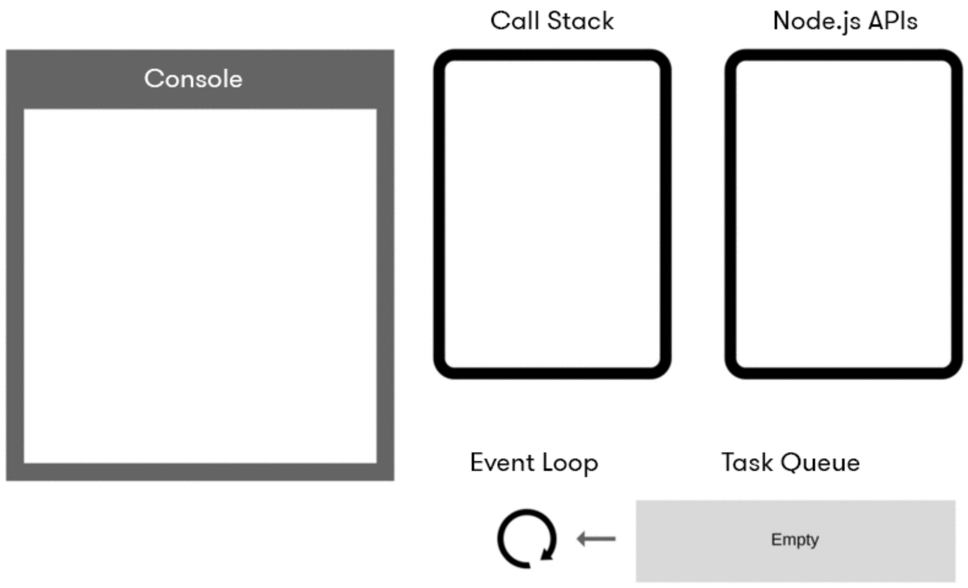
Event loop: Processes the task queues

- When the call stack is empty, the event loop pulls the next task from the task queues and puts it on the call stack

JS execution



```
console.log('Hi')
setTimeout(function cb1() {
  console.log('cb1')
}, 1000)
console.log('Bye')
```



https://symphony.is/blog/secret-life-event-loop-meetup-overview