SWE 432 -Web Application Development

Fall 2021

George Mason University

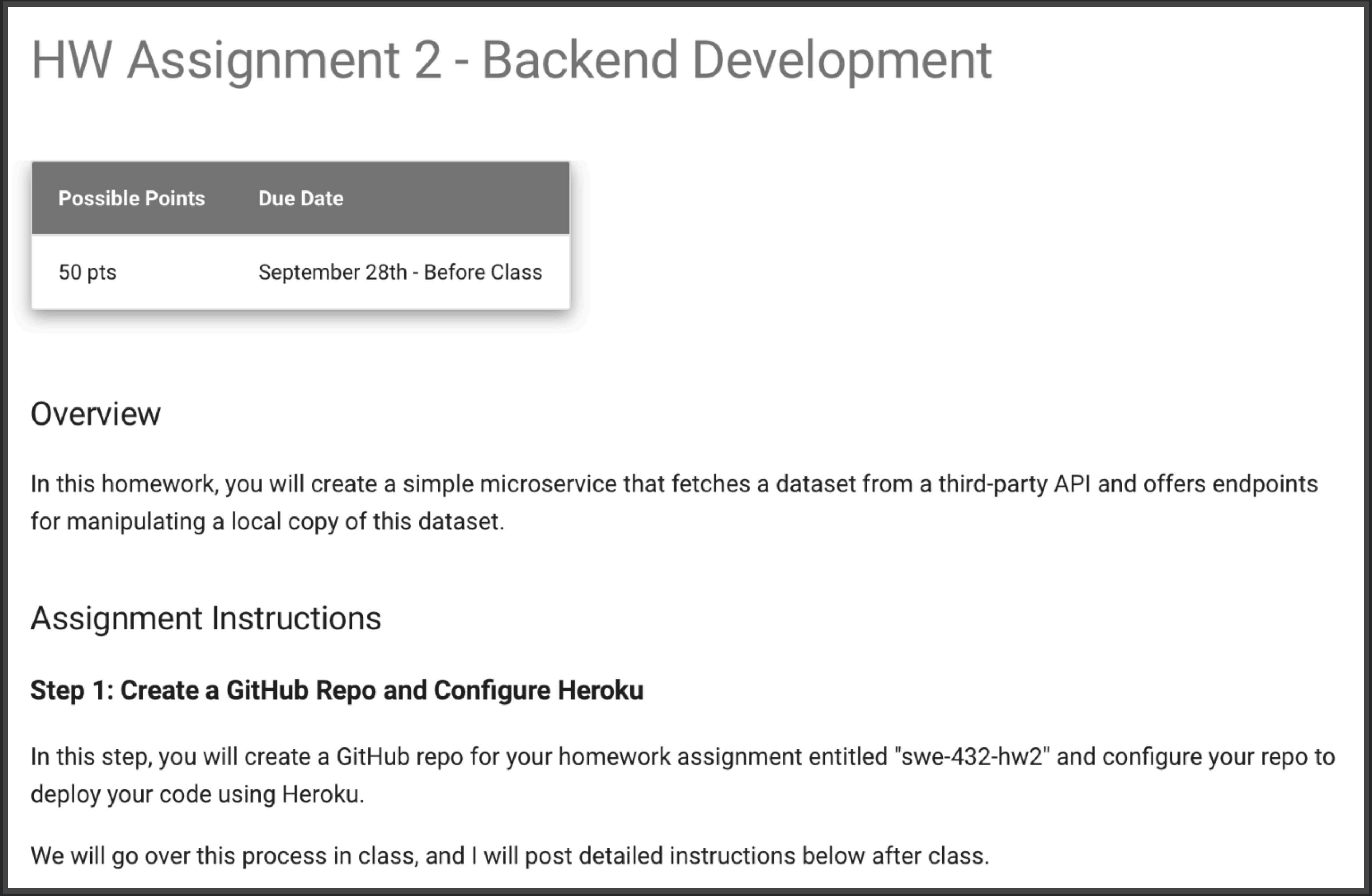
Dr. Kevin Moran

Week 4: Backend Development & HTTP Requests

Administrivia

- ***HW Assignment 1*** - Grades Available on Blackboard - Detailed Comments in Replit
- ***HW Assignment 2*** - Due September 28th Before Class

Homework Assignment #2



HW Assignment 2 - Backend Development

Possible Points	Due Date
50 pts	September 28th - Before Class

Overview

In this homework, you will create a simple microservice that fetches a dataset from a third-party API and offers endpoints for manipulating a local copy of this dataset.

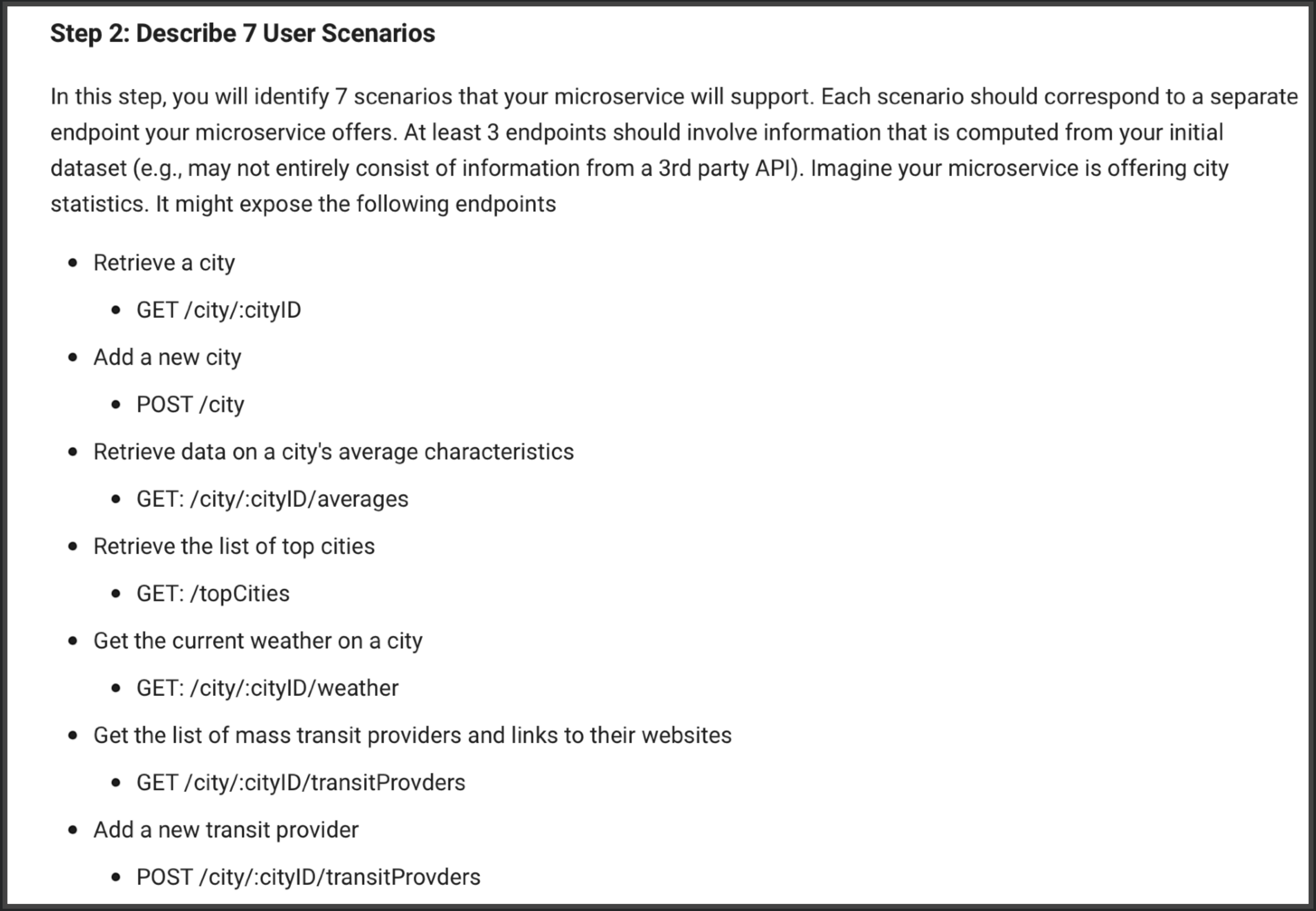
Assignment Instructions

Step 1: Create a GitHub Repo and Configure Heroku

In this step, you will create a GitHub repo for your homework assignment entitled "swe-432-hw2" and configure your repo to deploy your code using Heroku.

We will go over this process in class, and I will post detailed instructions below after class.

Homework Assignment #2

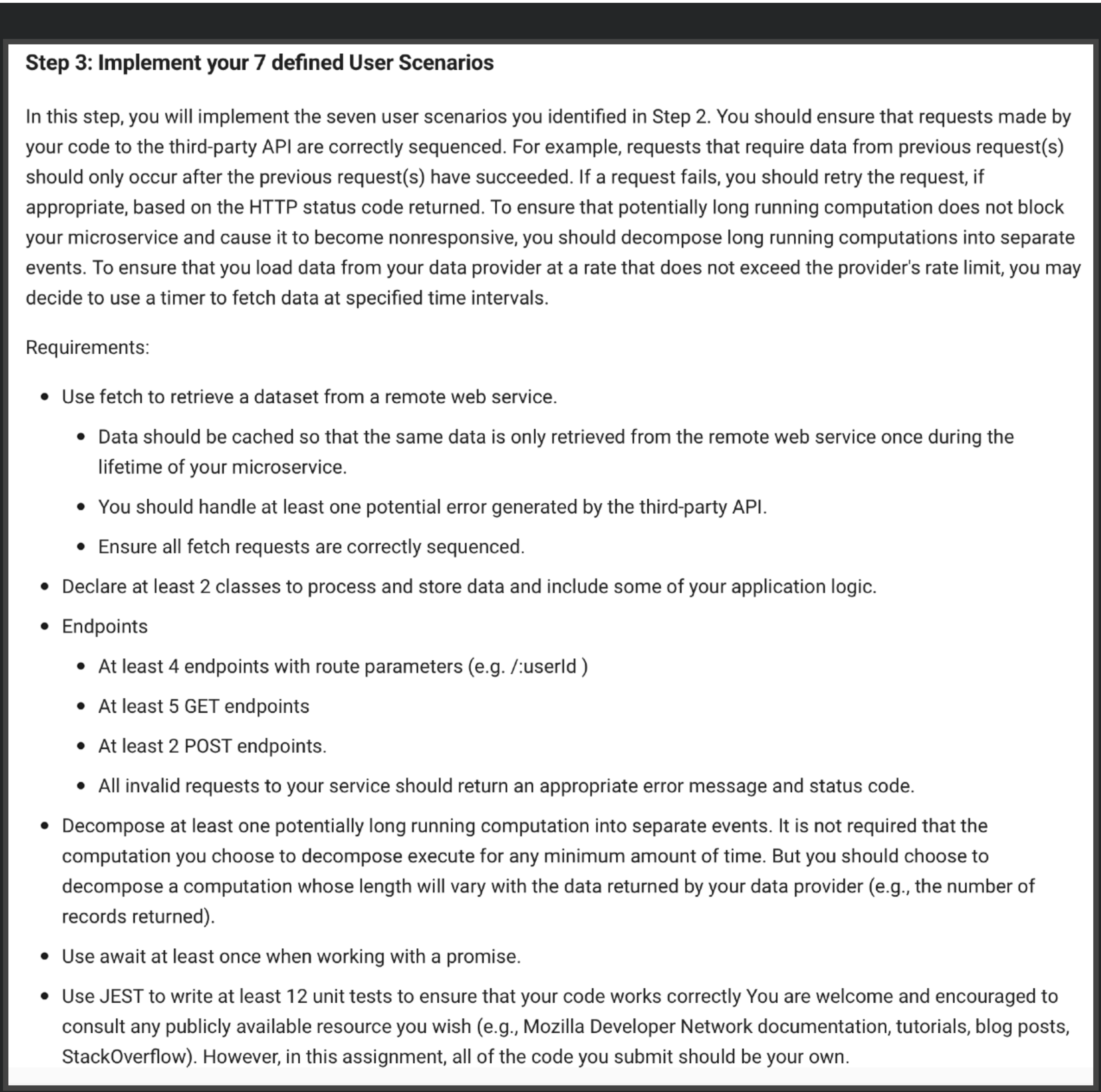


Step 2: Describe 7 User Scenarios

In this step, you will identify 7 scenarios that your microservice will support. Each scenario should correspond to a separate endpoint your microservice offers. At least 3 endpoints should involve information that is computed from your initial dataset (e.g., may not entirely consist of information from a 3rd party API). Imagine your microservice is offering city statistics. It might expose the following endpoints

- Retrieve a city
  - GET /city/:cityID
- Add a new city
  - POST /city
- Retrieve data on a city's average characteristics
  - GET: /city/:cityID/averages
- Retrieve the list of top cities
  - GET: /topCities
- Get the current weather on a city
  - GET: /city/:cityID/weather
- Get the list of mass transit providers and links to their websites
  - GET /city/:cityID/transitProvders
- Add a new transit provider
  - POST /city/:cityID/transitProvders

Homework Assignment #2



Step 3: Implement your 7 defined User Scenarios

In this step, you will implement the seven user scenarios you identified in Step 2. You should ensure that requests made by your code to the third-party API are correctly sequenced. For example, requests that require data from previous request(s) should only occur after the previous request(s) have succeeded. If a request fails, you should retry the request, if appropriate, based on the HTTP status code returned. To ensure that potentially long running computation does not block your microservice and cause it to become nonresponsive, you should decompose long running computations into separate events. To ensure that you load data from your data provider at a rate that does not exceed the provider's rate limit, you may decide to use a timer to fetch data at specified time intervals.

Requirements:

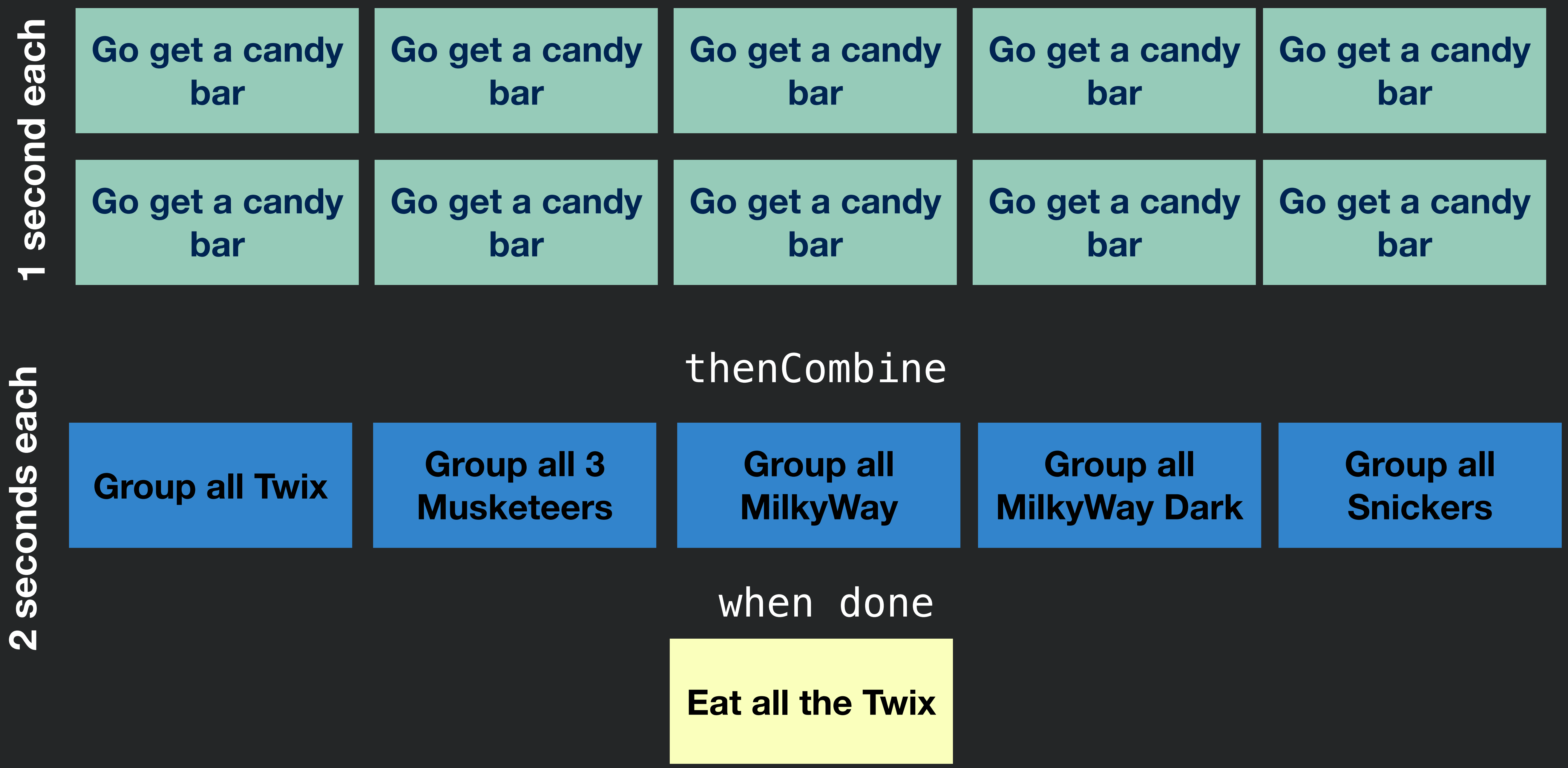
- Use fetch to retrieve a dataset from a remote web service.
  - Data should be cached so that the same data is only retrieved from the remote web service once during the lifetime of your microservice.
  - You should handle at least one potential error generated by the third-party API.
  - Ensure all fetch requests are correctly sequenced.
- Declare at least 2 classes to process and store data and include some of your application logic.
- Endpoints
  - At least 4 endpoints with route parameters (e.g. /:userId)
  - At least 5 GET endpoints
  - At least 2 POST endpoints.
  - All invalid requests to your service should return an appropriate error message and status code.
- Decompose at least one potentially long running computation into separate events. It is not required that the computation you choose to decompose execute for any minimum amount of time. But you should choose to decompose a computation whose length will vary with the data returned by your data provider (e.g., the number of records returned).
- Use await at least once when working with a promise.
- Use JEST to write at least 12 unit tests to ensure that your code works correctly You are welcome and encouraged to consult any publicly available resource you wish (e.g., Mozilla Developer Network documentation, tutorials, blog posts, StackOverflow). However, in this assignment, all of the code you submit should be your own.

Class Overview

- *Part 1 - Backend Programming:* A Brief History and Intro to Express with Node.js.
- ***10 minute Break***
- *Part 2 -Handling HTTP Requests:* Exploring HTTP and REST
- *Part 3 - In-Class Activity:* Exploring Express

Review

Review: Async Programming Example



1 second each

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

Go get a candy bar

`thenCombine`

2 seconds each

Group all Twix

Group all 3 Musketeers

Group all MilkyWay

Group all MilkyWay Dark

Group all Snickers

`when done`

Eat all the Twix

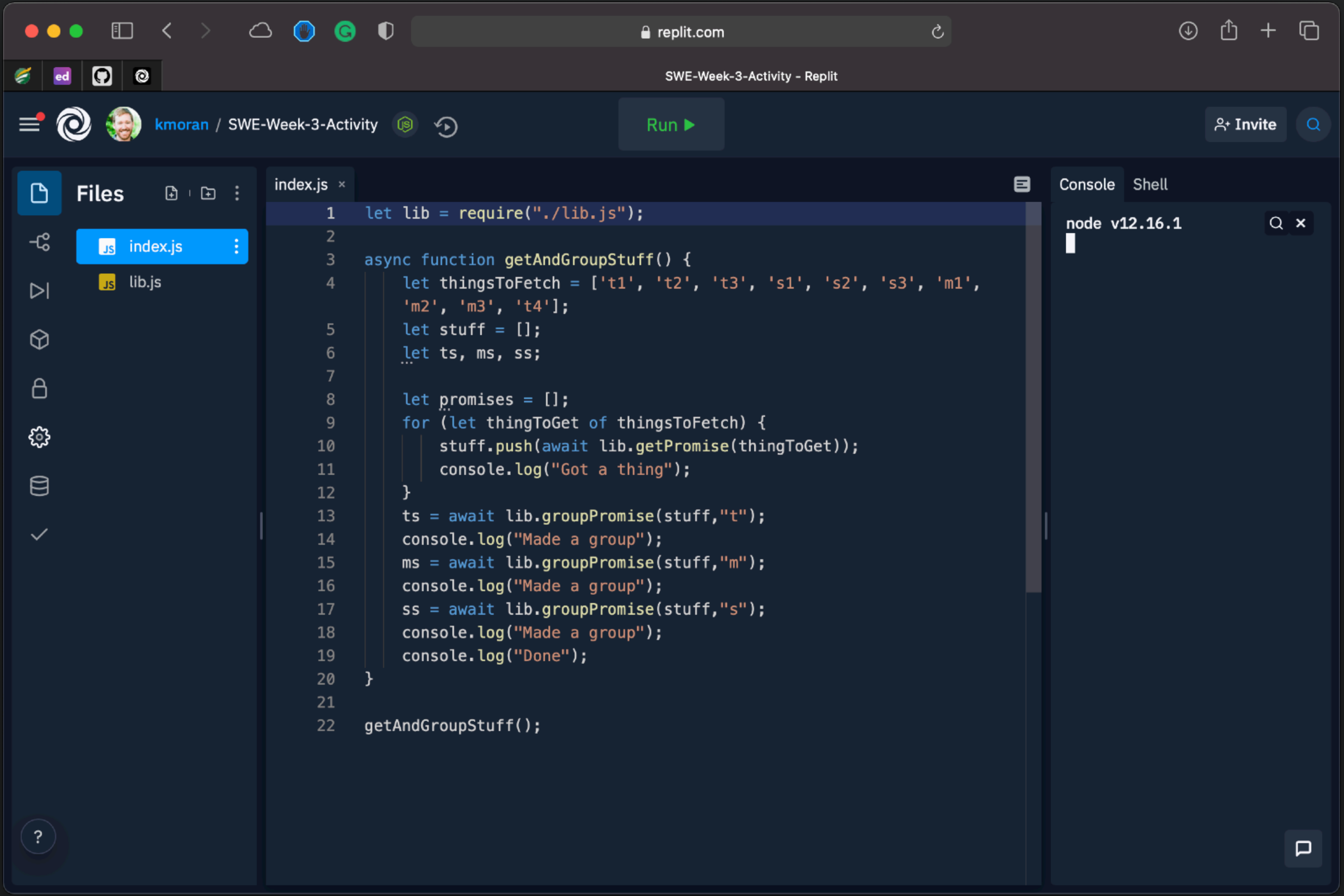
Async/Await

- Rules of the road:
    - You can only call **await** from a function that is **async**
    - You can only **await** on functions that return a **Promise**
    - Beware: await makes your code synchronous!

```
async function getAndGroupStuff() {
...
    ts = await lib.groupPromise(stuff,"t");
...
}
```

In-Class Example

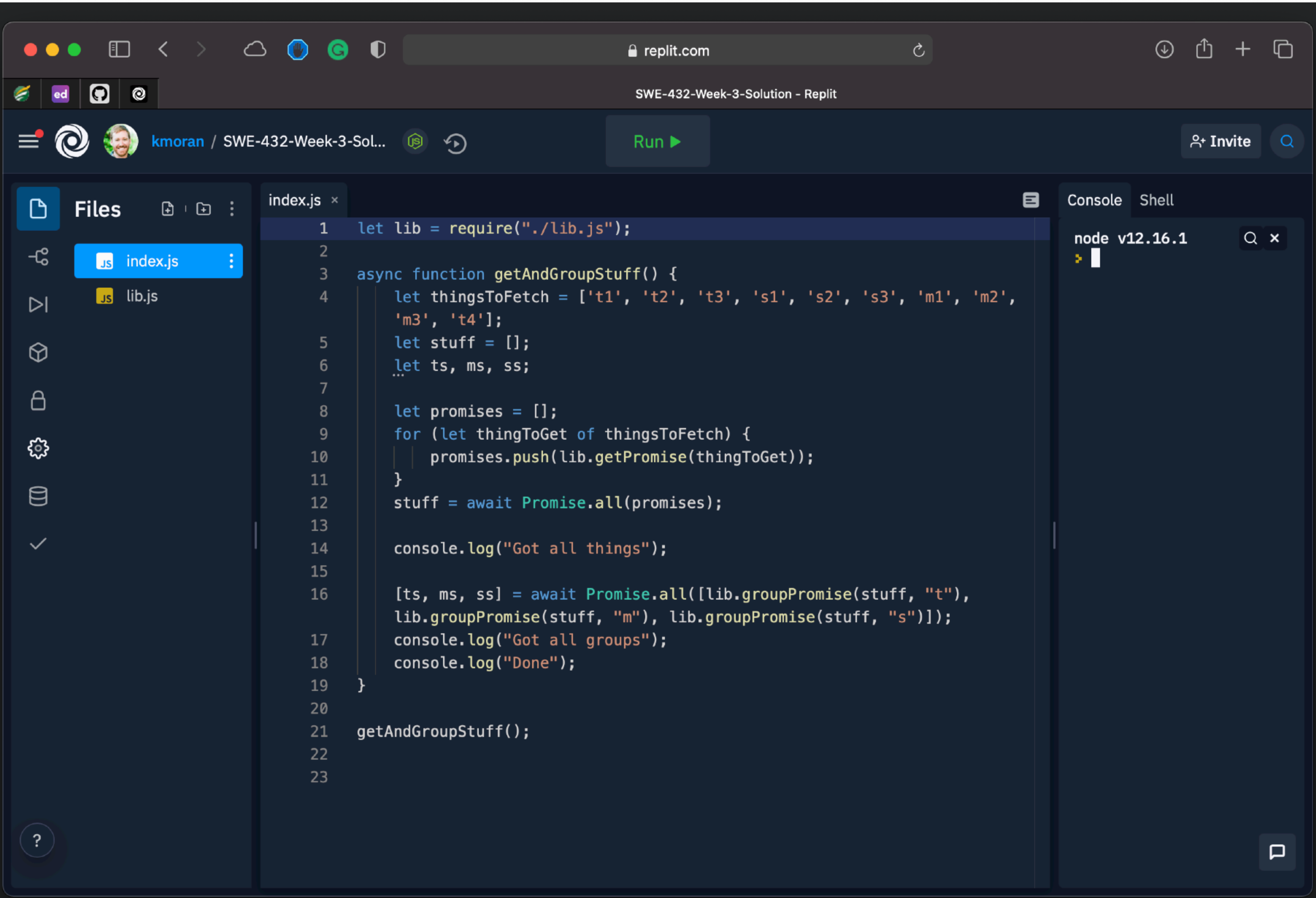
Rewrite this code so that all of the things are fetched (in parallel) and then all of the groups are collected using async/await



```javascript
let lib = require("./lib.js");

async function getAndGroupStuff() {
    let thingsToFetch = ['t1', 't2', 't3', 's1', 's2', 's3', 'm1',
    'm2', 'm3', 't4'];
    let stuff = [];
    let ts, ms, ss;

    let promises = [];
    for (let thingToGet of thingsToFetch) {
        stuff.push(await lib.getPromise(thingToGet));
        console.log("Got a thing");
    }
    ts = await lib.groupPromise(stuff,"t");
    console.log("Made a group");
    ms = await lib.groupPromise(stuff,"m");
    console.log("Made a group");
    ss = await lib.groupPromise(stuff,"s");
    console.log("Made a group");
    console.log("Done");
}

getAndGroupStuff();
```

```
node v12.16.1
```

In-Class Example



replit.com
SWE-432-Week-3-Solution - Replit
kmoran / SWE-432-Week-3-Sol...
Run ▶
Invite
Files
index.js
lib.js
Console
Shell

```javascript
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    let stuff = [];
    let ts, ms, ss;

    let promises = [];
    for (let thingToGet of thingsToFetch) {
        promises.push(lib.getPromise(thingToGet));
    }
    stuff = await Promise.all(promises);

    console.log("Got all things");

    [ts, ms, ss] = await Promise.all([lib.groupPromise(stuff, "t"), lib.groupPromise(stuff, "m"), lib.groupPromise(stuff, "s")]);
    console.log("Got all groups");
    console.log("Done");
}

getAndGroupStuff();
```

```
node v12.16.1
›
```

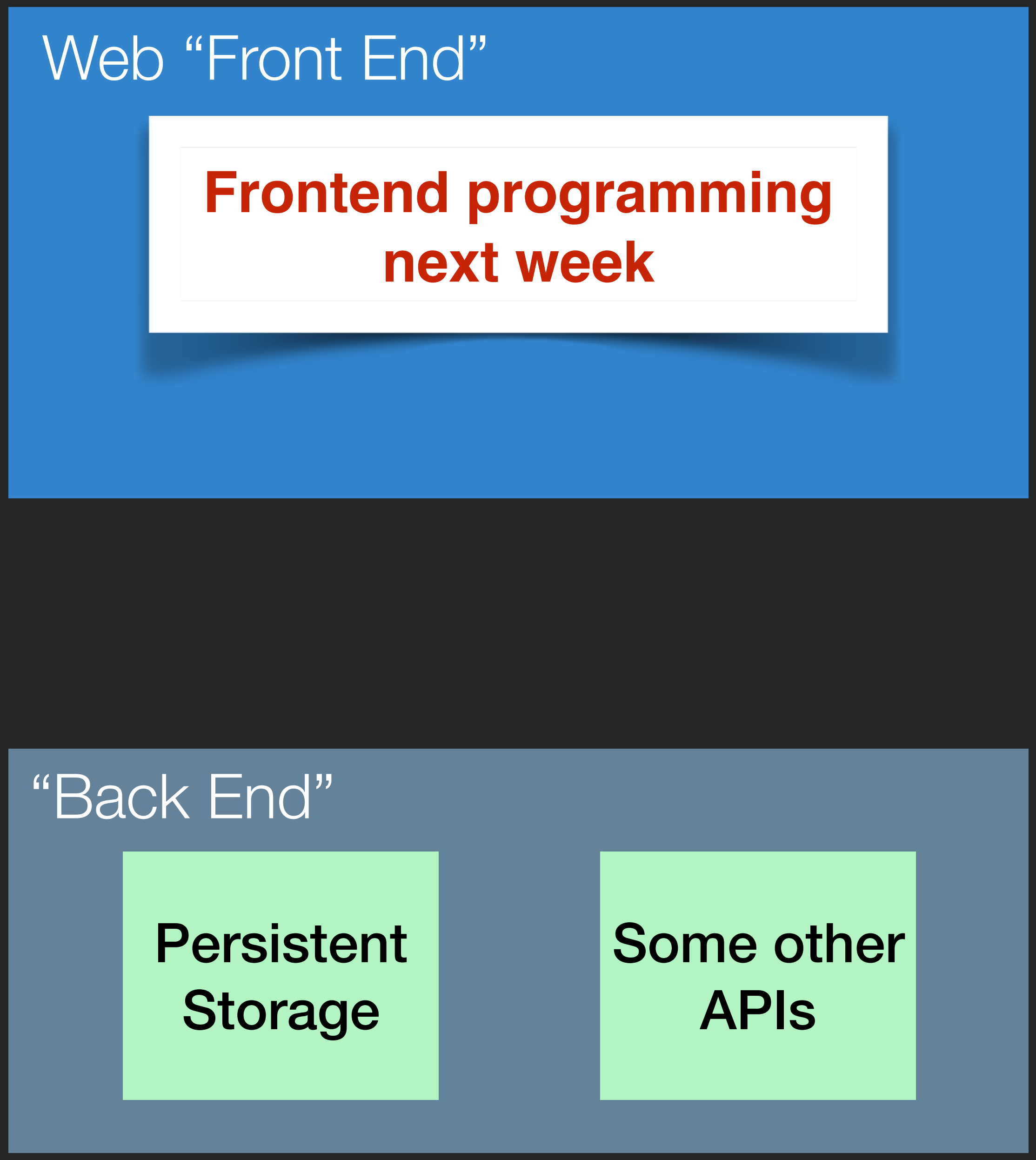
Backend Web Development

A Brief Intro and History of Backend Programming

Why We Need Backends

- Security: *SOME* part of our code needs to be "**trusted**"
  - Validation, security, etc. that we don't want to allow users to bypass
- Performance:
  - Avoid **duplicating** computation (do it once and cache)
  - Do **heavy** computation on more powerful machines
  - Do data-intensive computation "**nearer**" to the data
- Compatibility:
  - Can bring some **dynamic** behavior without requiring much JS support

Dynamic Web Apps



Web “Front End”

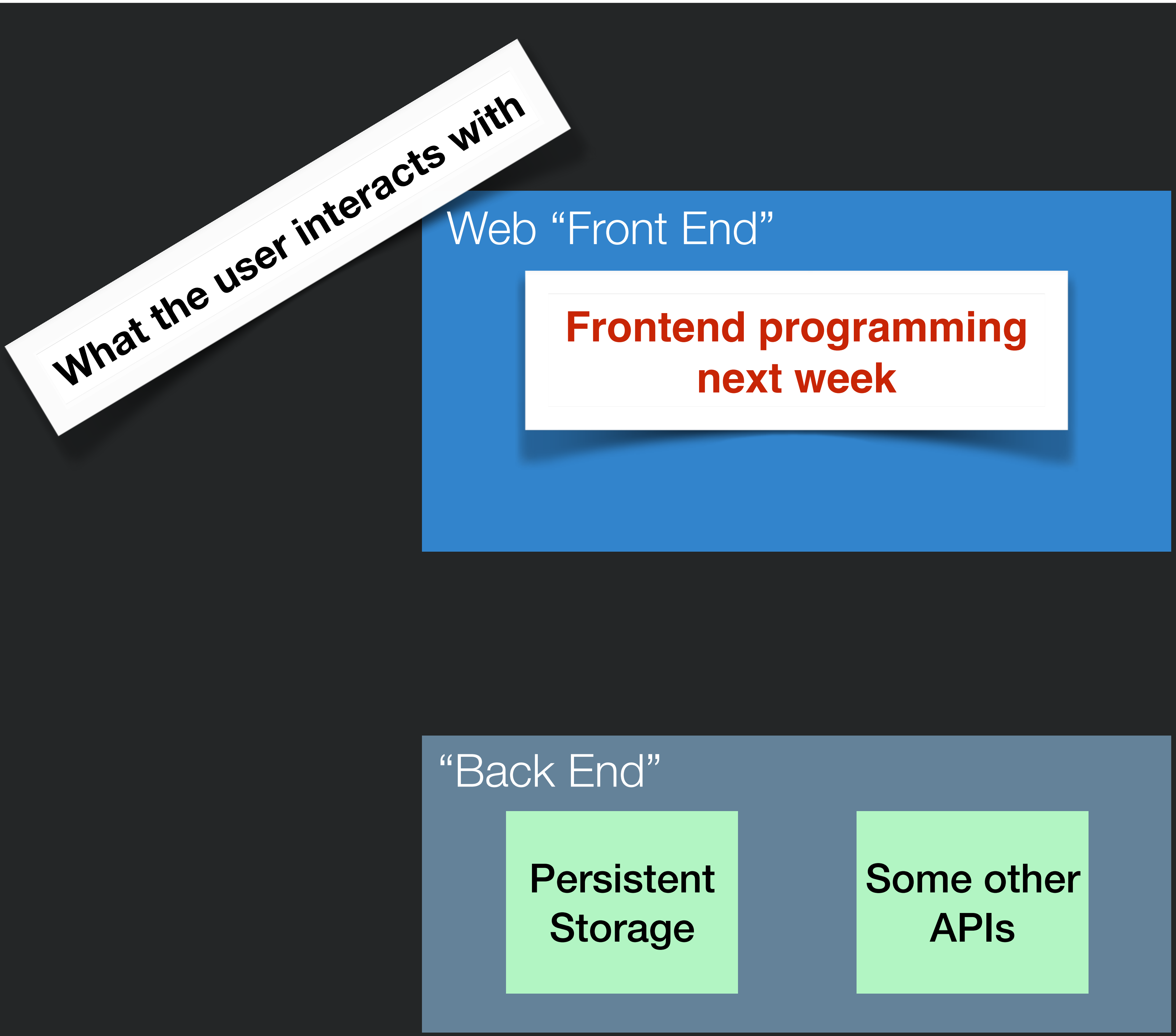
Frontend programming next week

“Back End”

Persistent Storage

Some other APIs

Dynamic Web Apps



What the user interacts with

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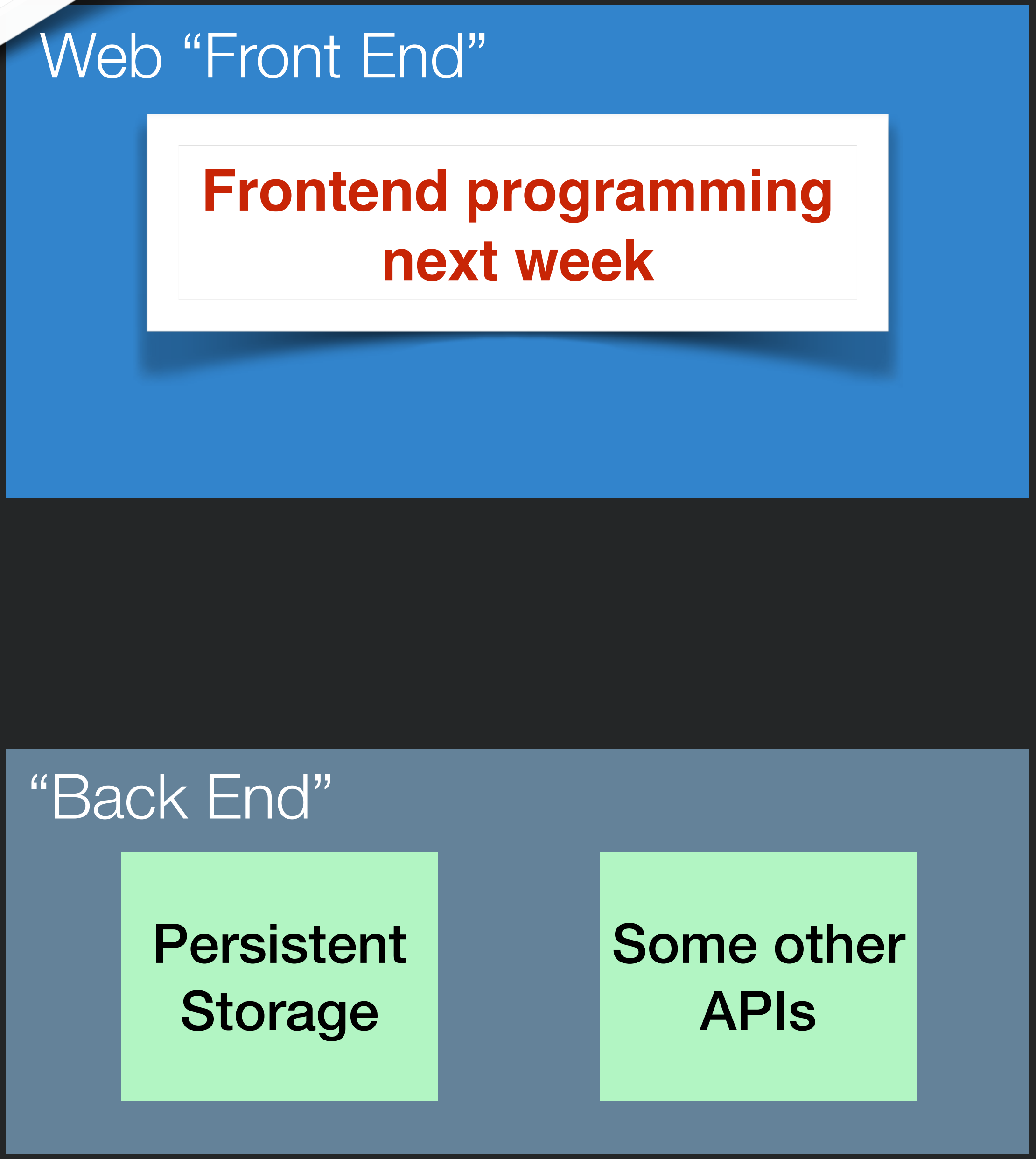

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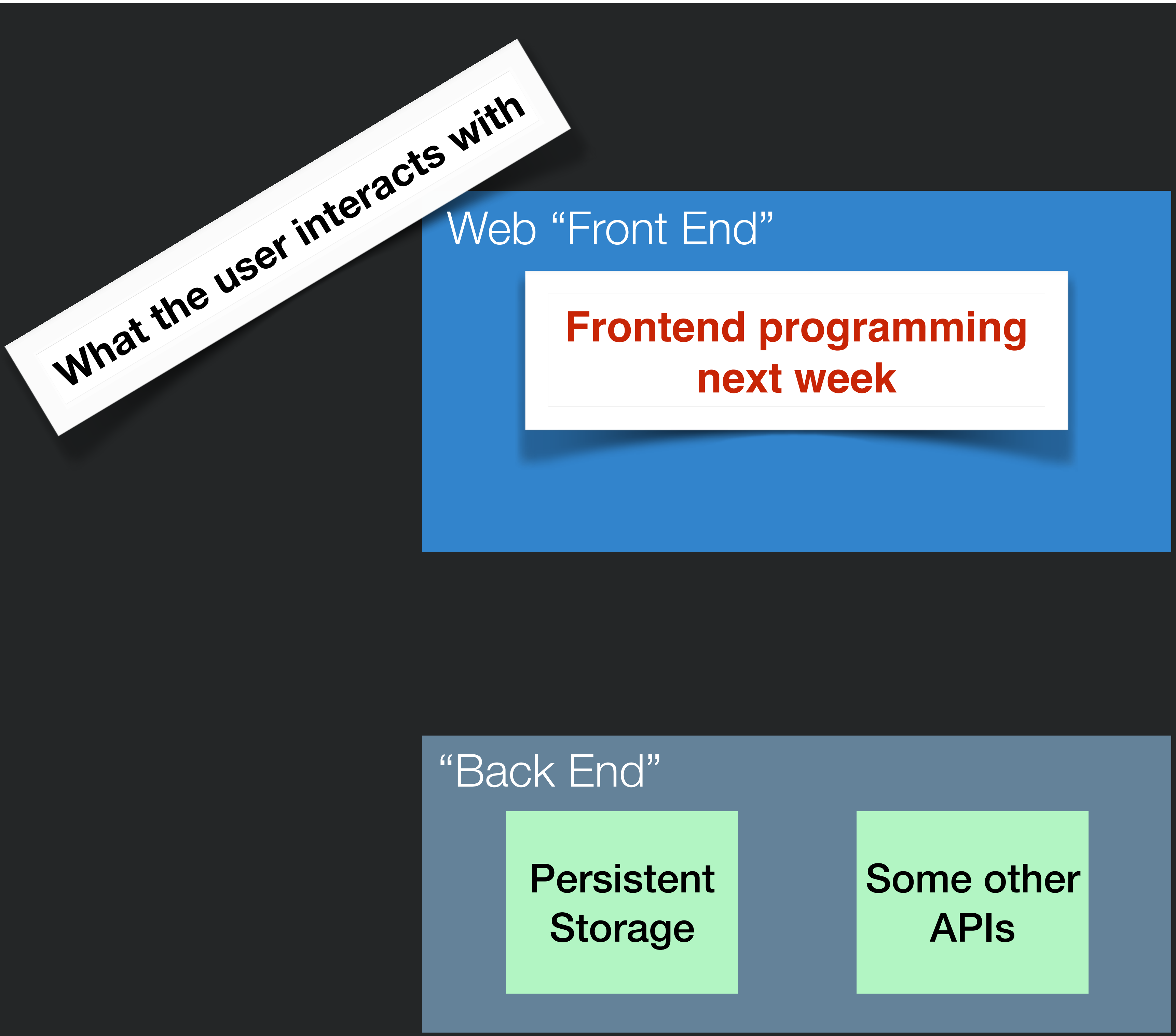
Presentation

Dynamic Web Apps



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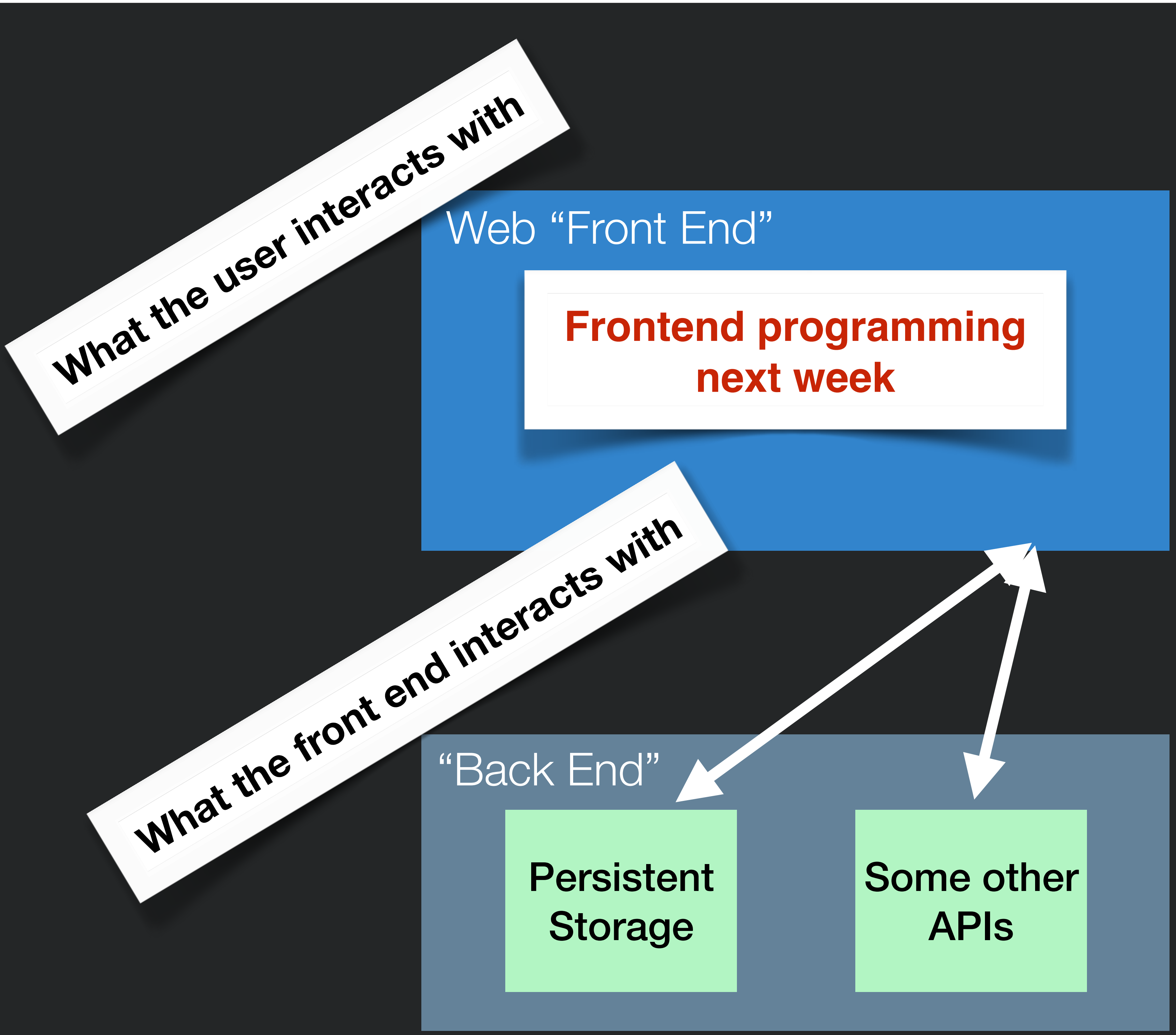
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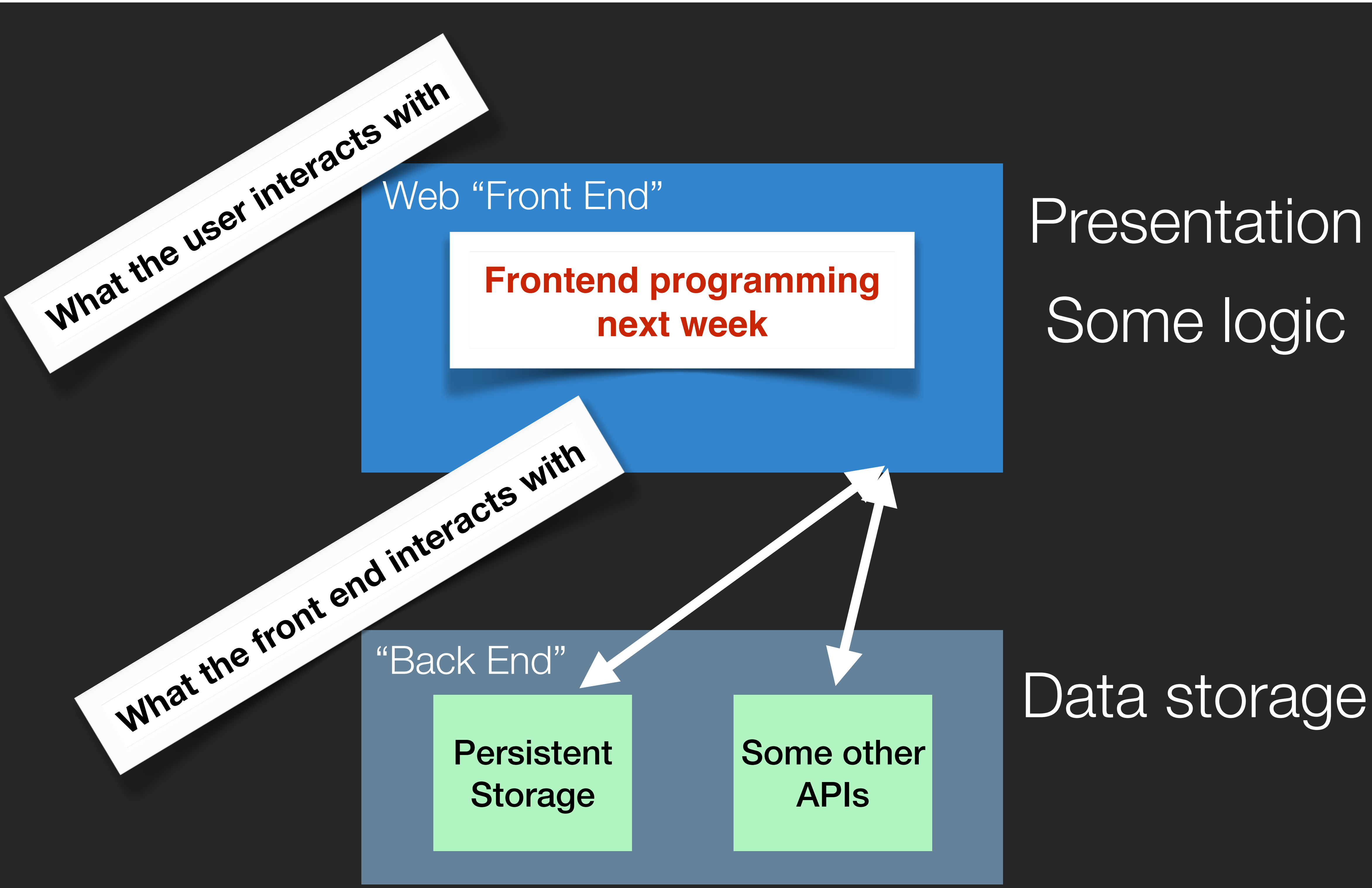

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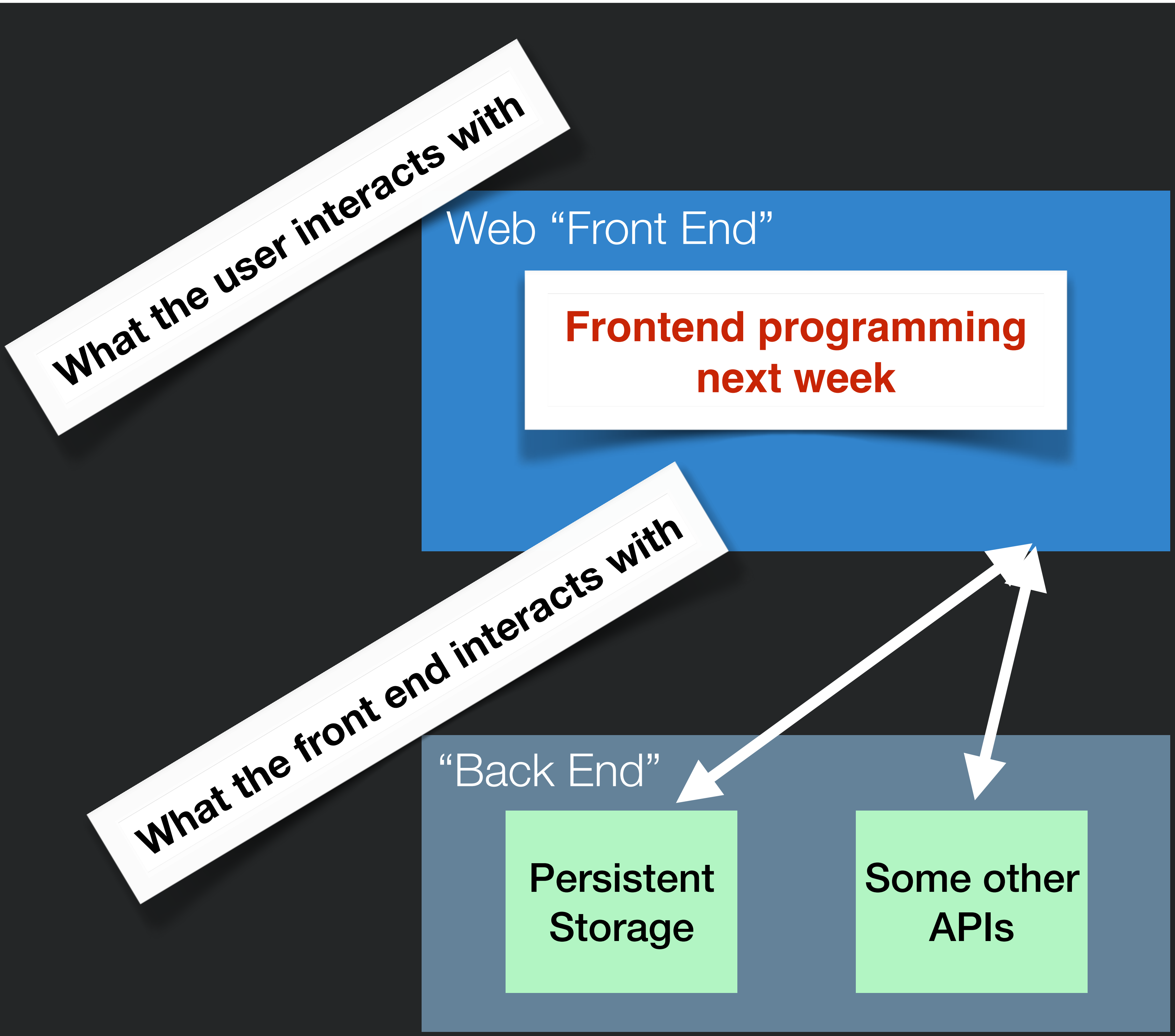


What the user interacts with

Web "Front End"

Frontend programming next week

What the front end interacts with

"Back End"

Persistent Storage

Some other APIs

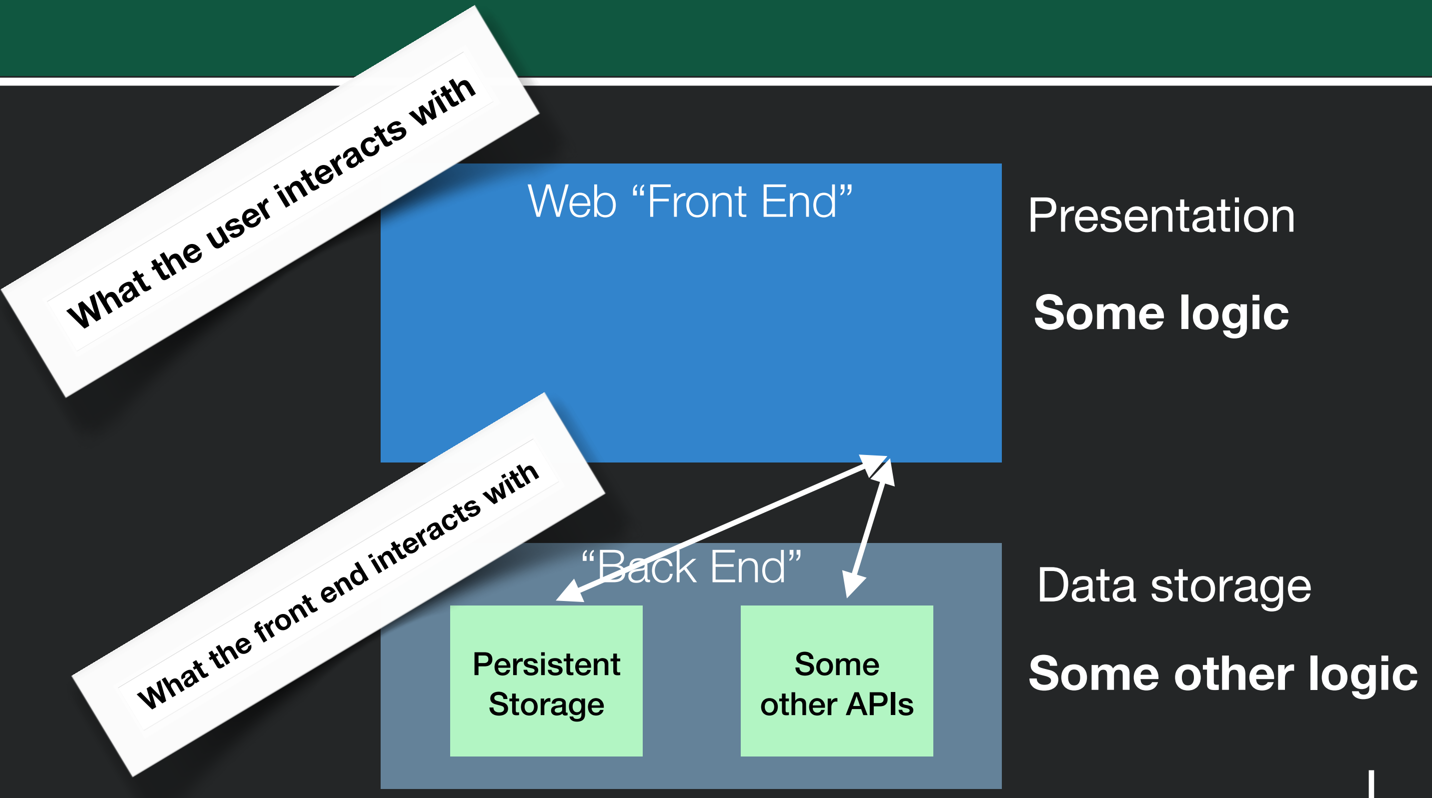
Presentation

Some logic

Data storage

Some other logic

Where Do We Put the Logic?



Frontend Pros

Very responsive (low latency)

Frontend Cons

Security

Performance

Unable to share between front-ends

Backend Pros

Easy to refactor between multiple clients

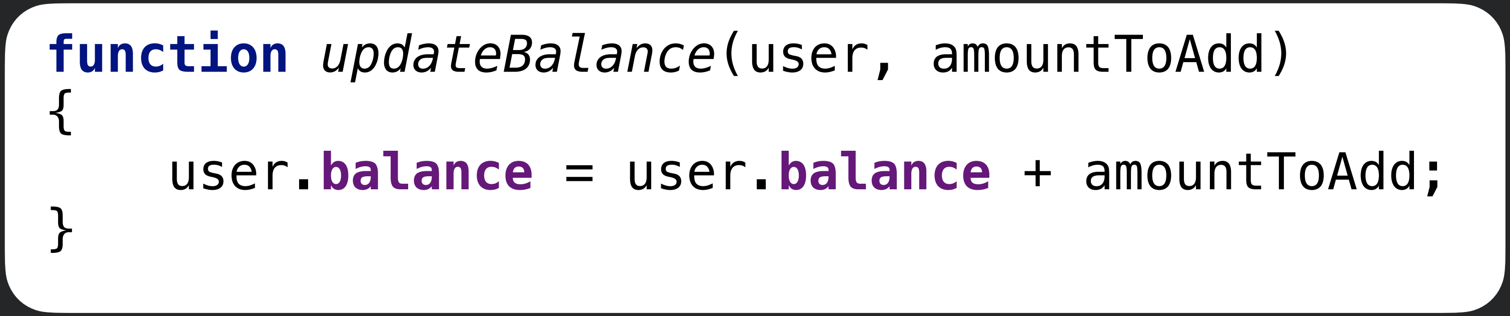
Logic is hidden from users (good for security, compatibility, etc.)

Backend Cons

Interactions require a round-trip to server

Why Trust Matters

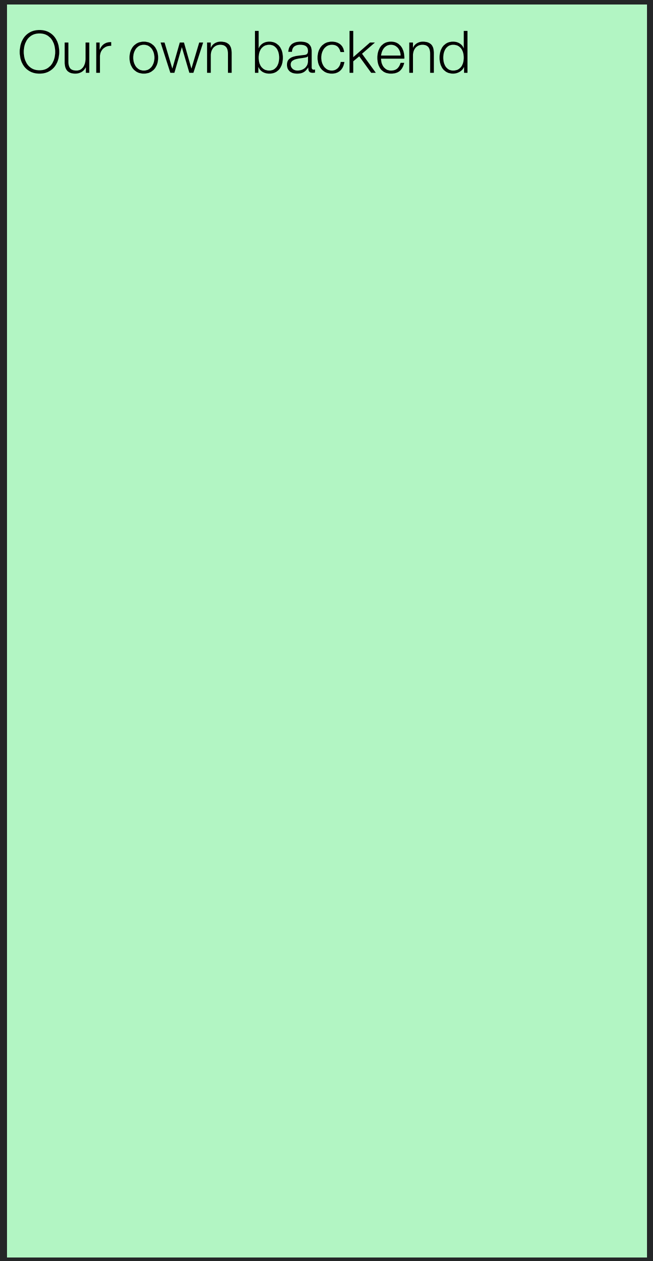
- Example: Banking app
  - Imagine a banking app where the following code runs in the browser:



```
function updateBalance(user, amountToAdd)
{
    user.balance = user.balance + amountToAdd;
}
```

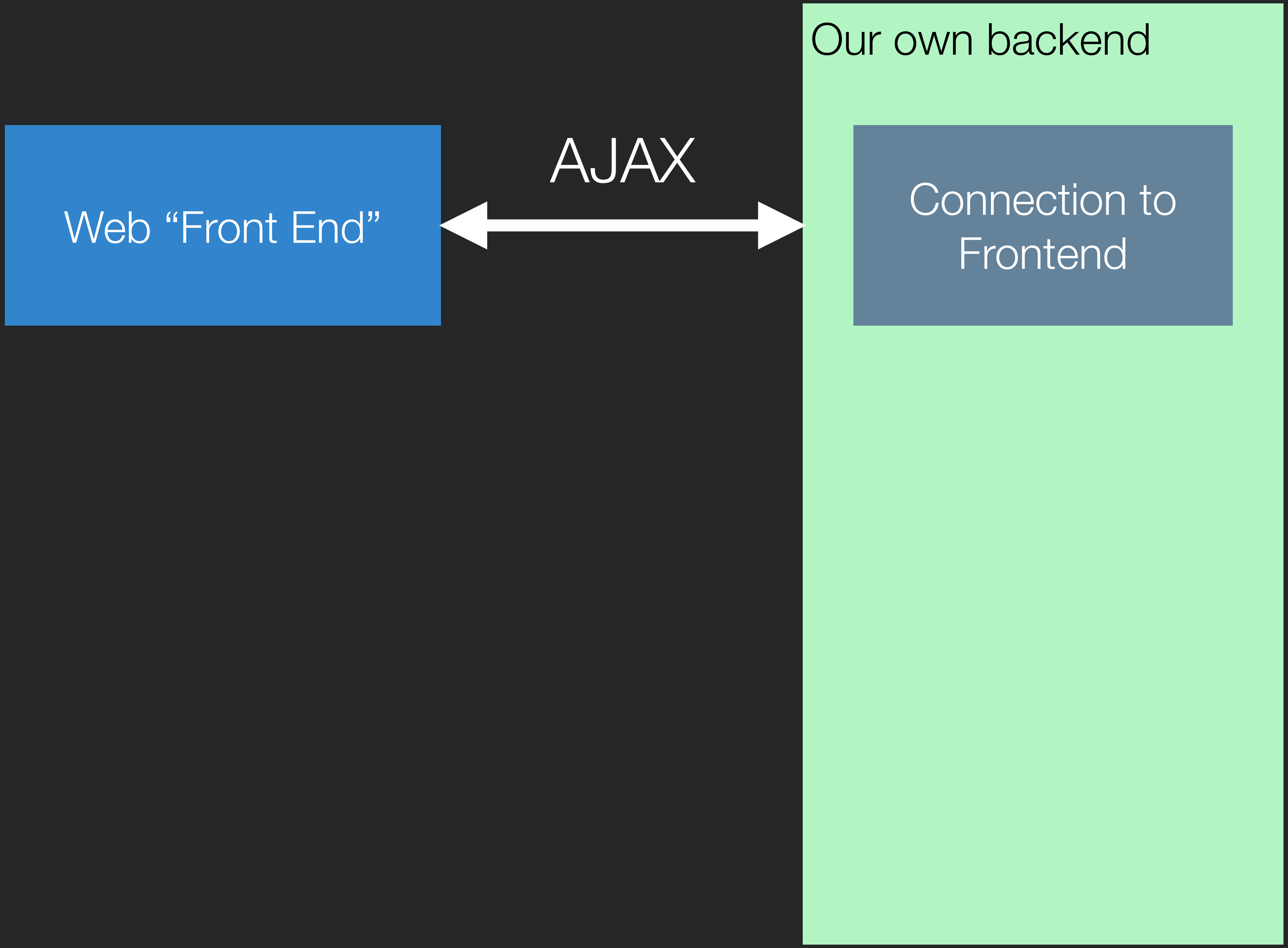
- What’s wrong?
- How do you fix that?

What Does our Backend Look Like?



Our own backend

What Does our Backend Look Like?



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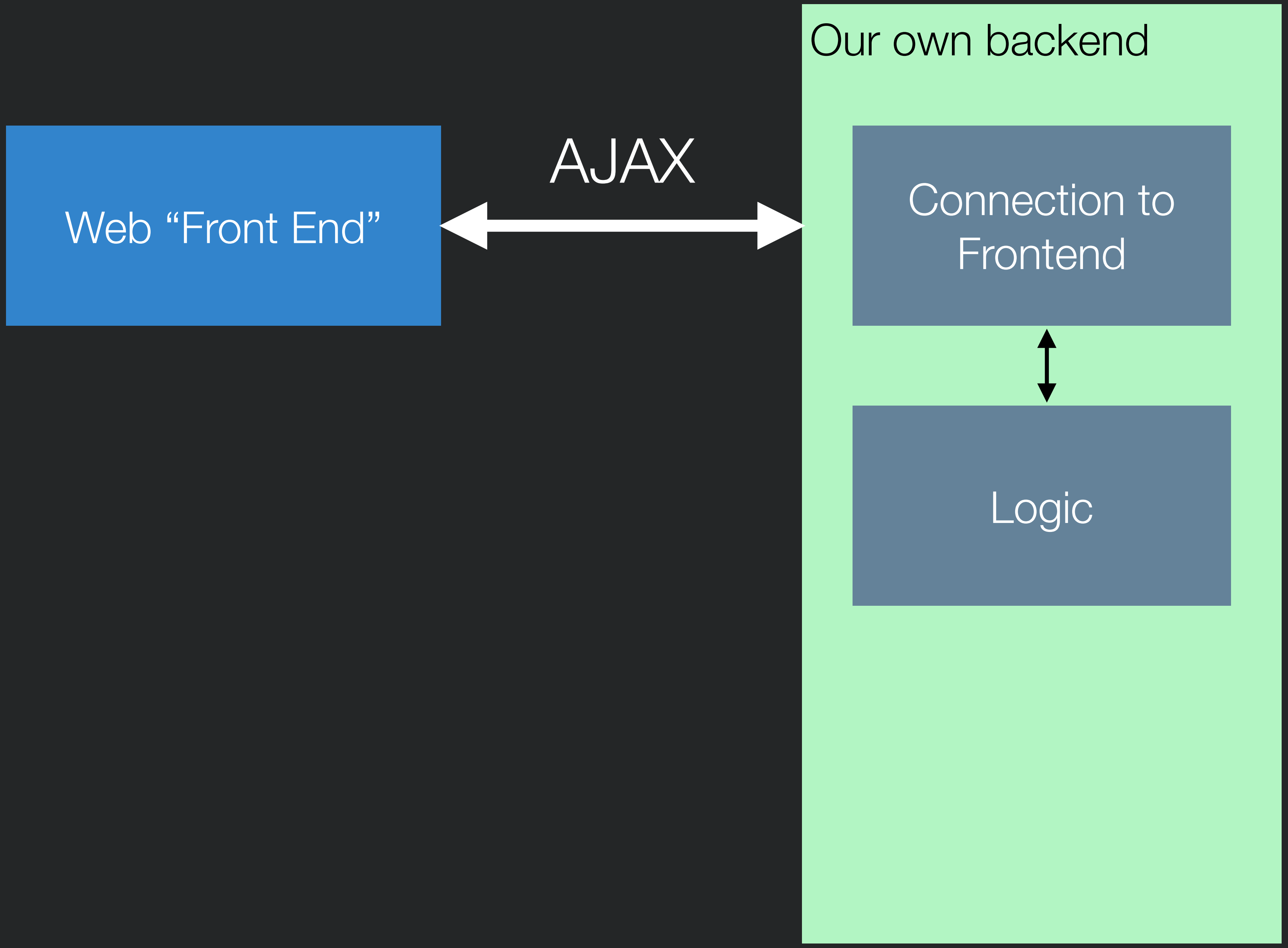

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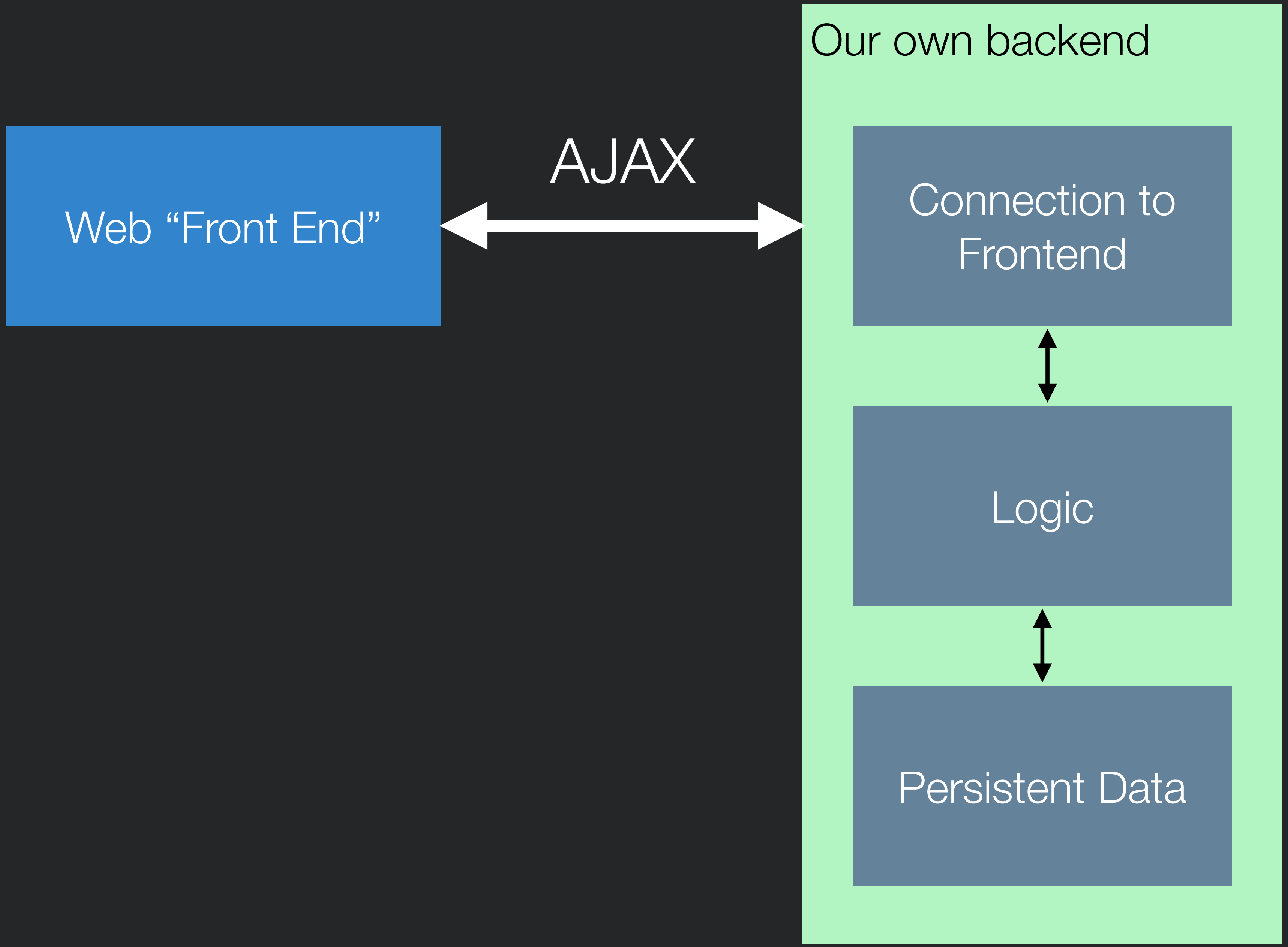
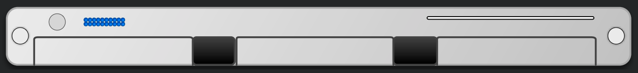


The "Good" Old Days of Backends

HTTP Request

```
GET /myApplicationEndpoint HTTP/1.1
Host: cs.gmu.edu
Accept: text/html
```

web server



Runs a program

Web Server Application

My Application Backend

HTTP Response

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=UTF-8

<html><head>...
```

The “Good” Old Days of Backends

HTTP Request

```
GET /myApplicationEndpoint HTTP/1.1
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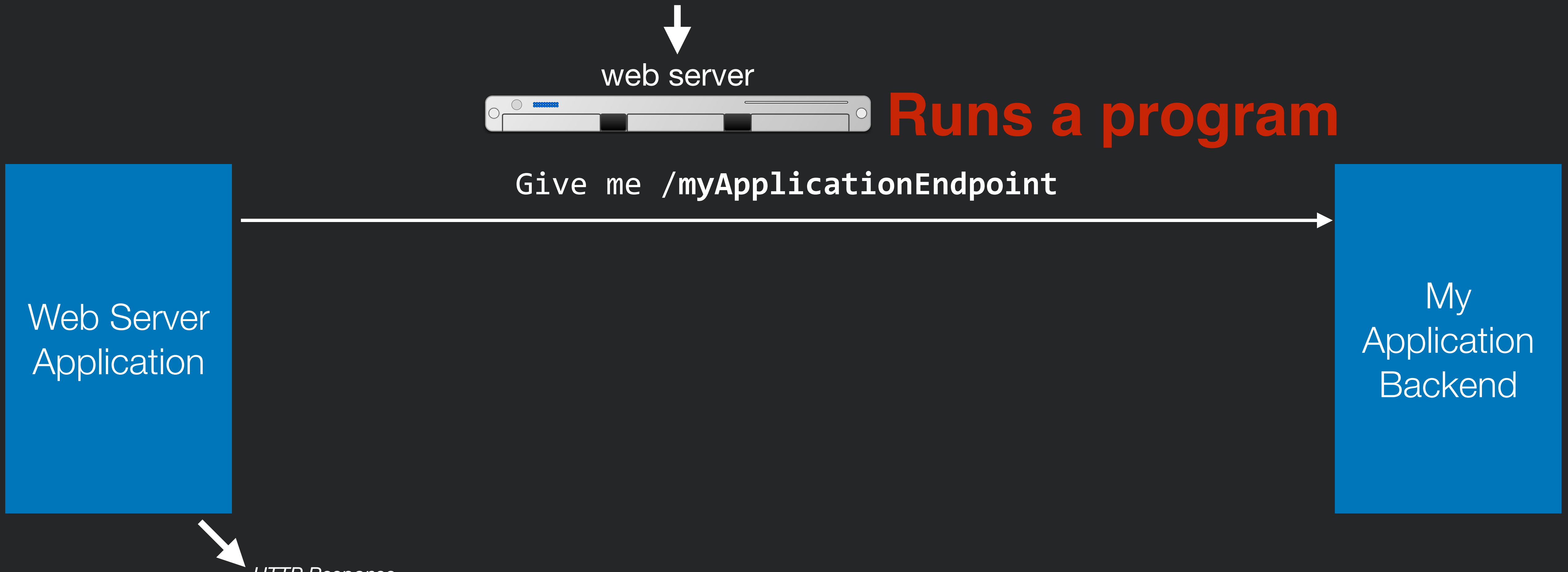

web server

Runs a program

```
Give me /myApplicationEndpoint
```

HTTP Response

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<html><head>...
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The "Good" Old Days of Backends

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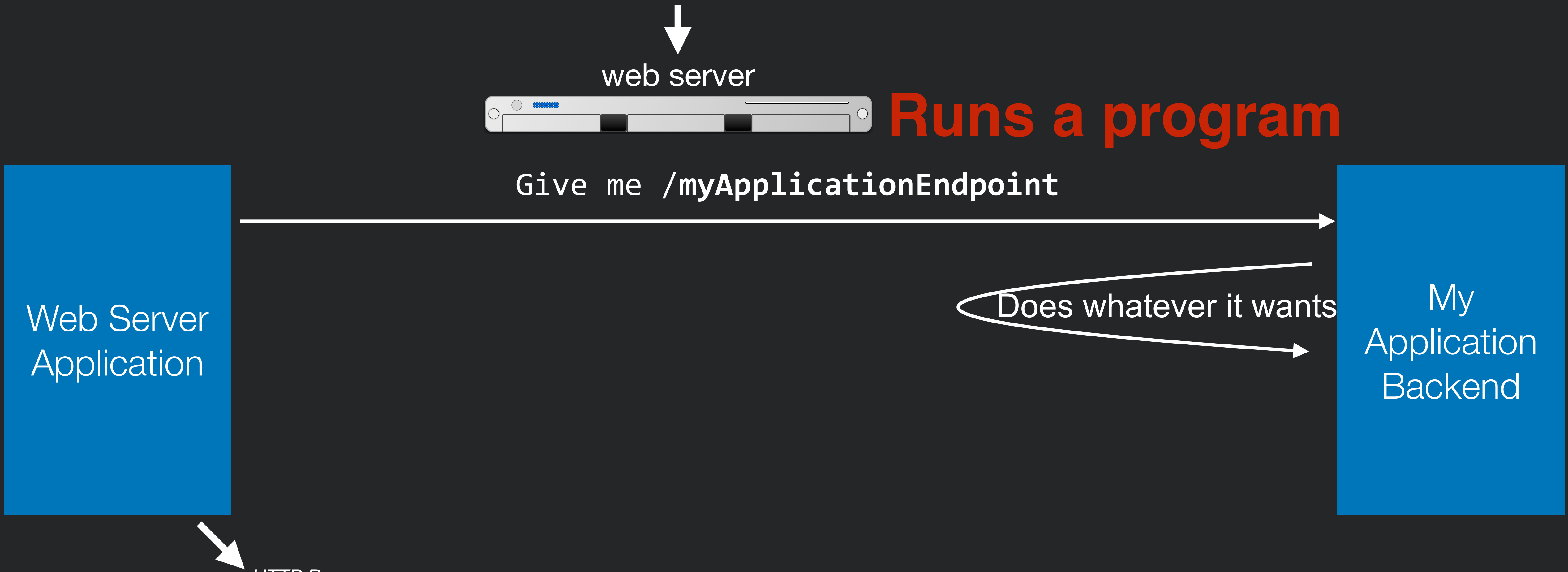

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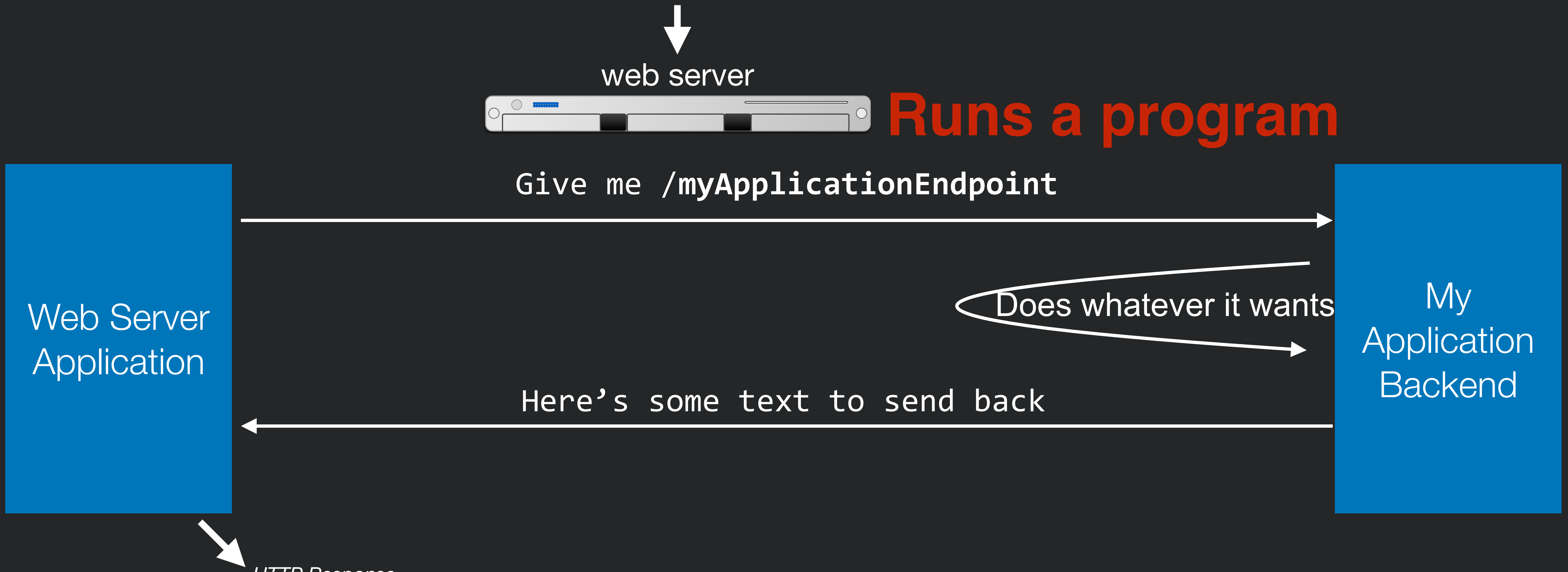


web server

Runs a program

Web Server Application

`Give me /myApplicationEndpoint`

Does whatever it wants

My Application Backend

`Here's some text to send back`

HTTP Response

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=UTF-8

<html><head>...
```

What's wrong with this picture?

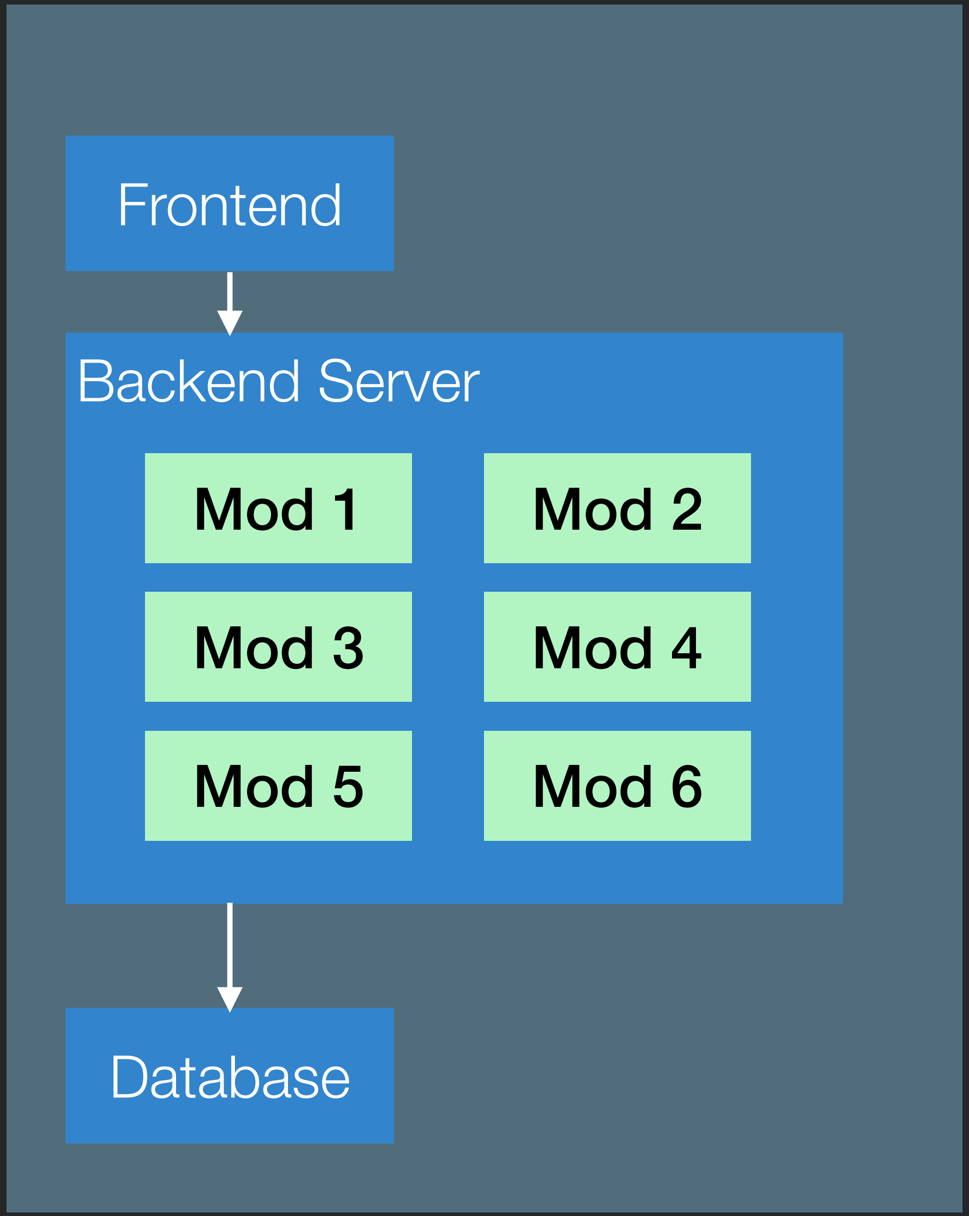
History of Backend Development

- In the beginning, you wrote whatever you wanted using whatever language you wanted and whatever framework you wanted
- Then… PHP and ASP
  - Languages “designed” for writing backends
  - Encouraged spaghetti code
  - A lot of the web was built on this
- A whole lot of other languages were also springing up in the 90’s…
  - Ruby, Python, JSP

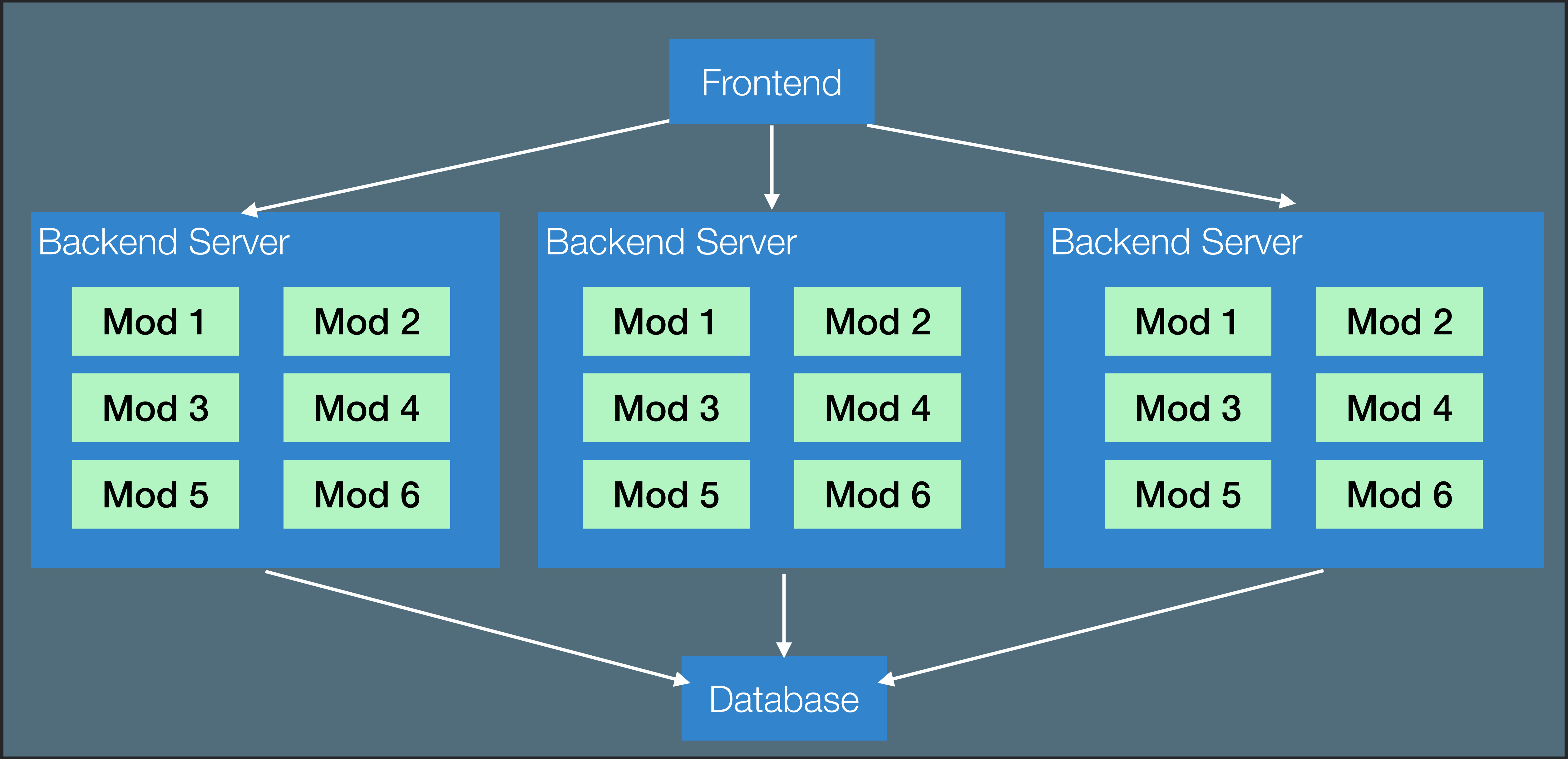
Microservices vs. Monoliths

- Advantages of microservices over monoliths include
  - Support for scaling
    - Scale vertically rather than horizontally
  - Support for change
    - Support hot deployment of updates
  - Support for reuse
    - Use same web service in multiple apps
    - Swap out internally developed web service for externally developed web service
  - Support for separate team development
    - Pick boundaries that match team responsibilities
  - Support for failure

Support for Scaling



Now How Do We Scale It?



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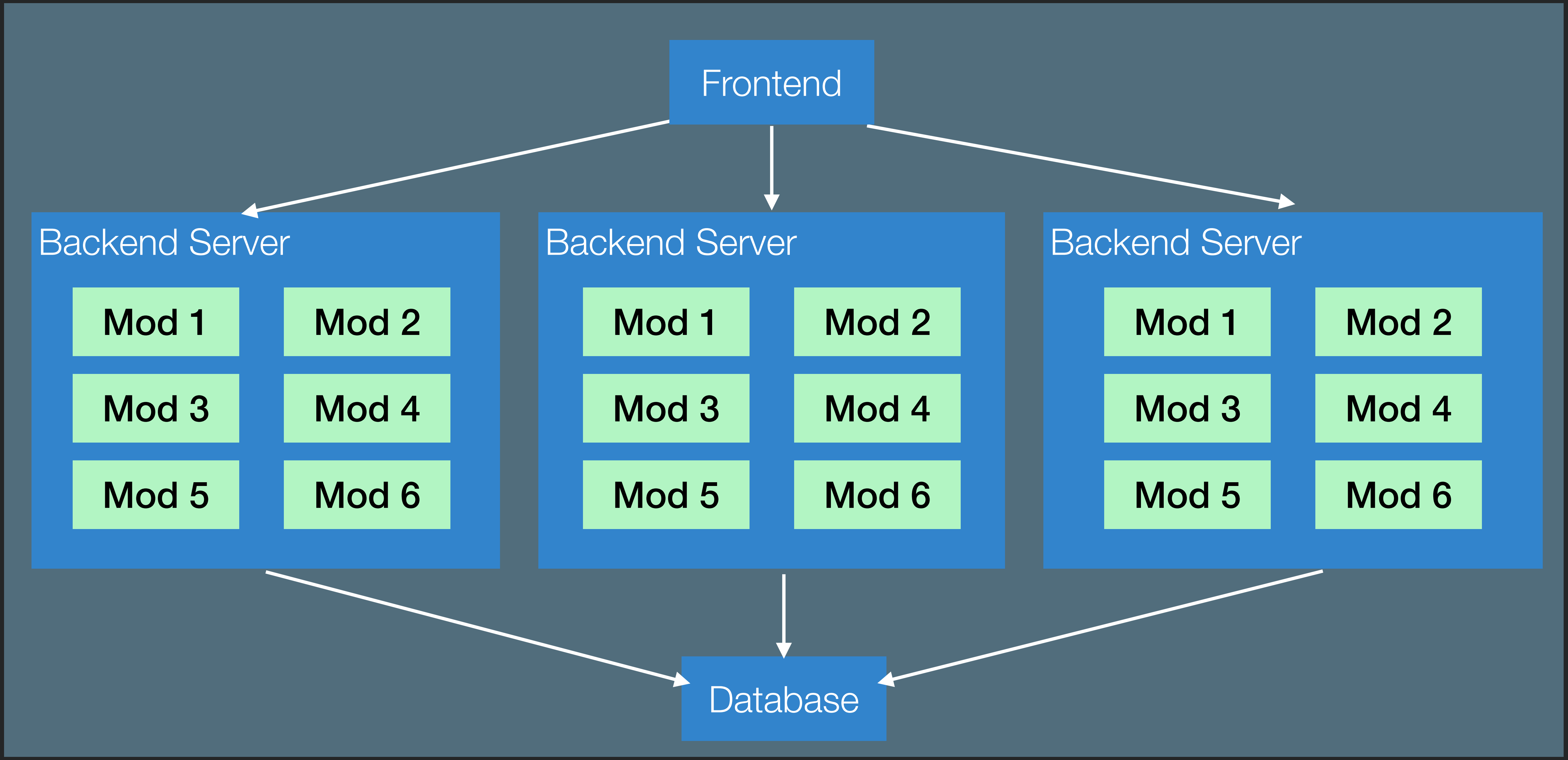
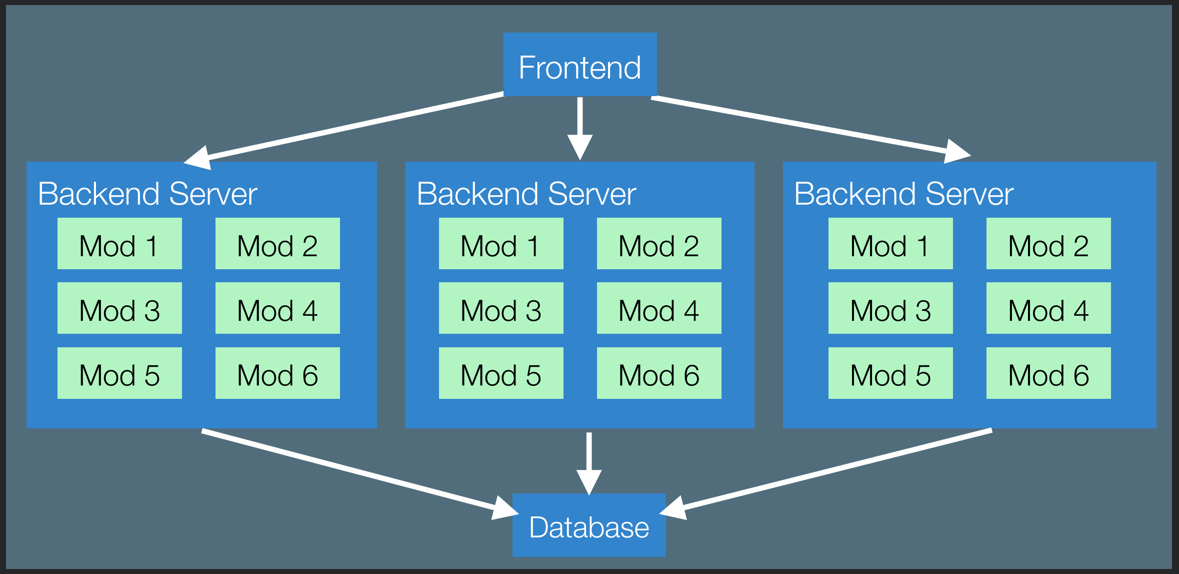


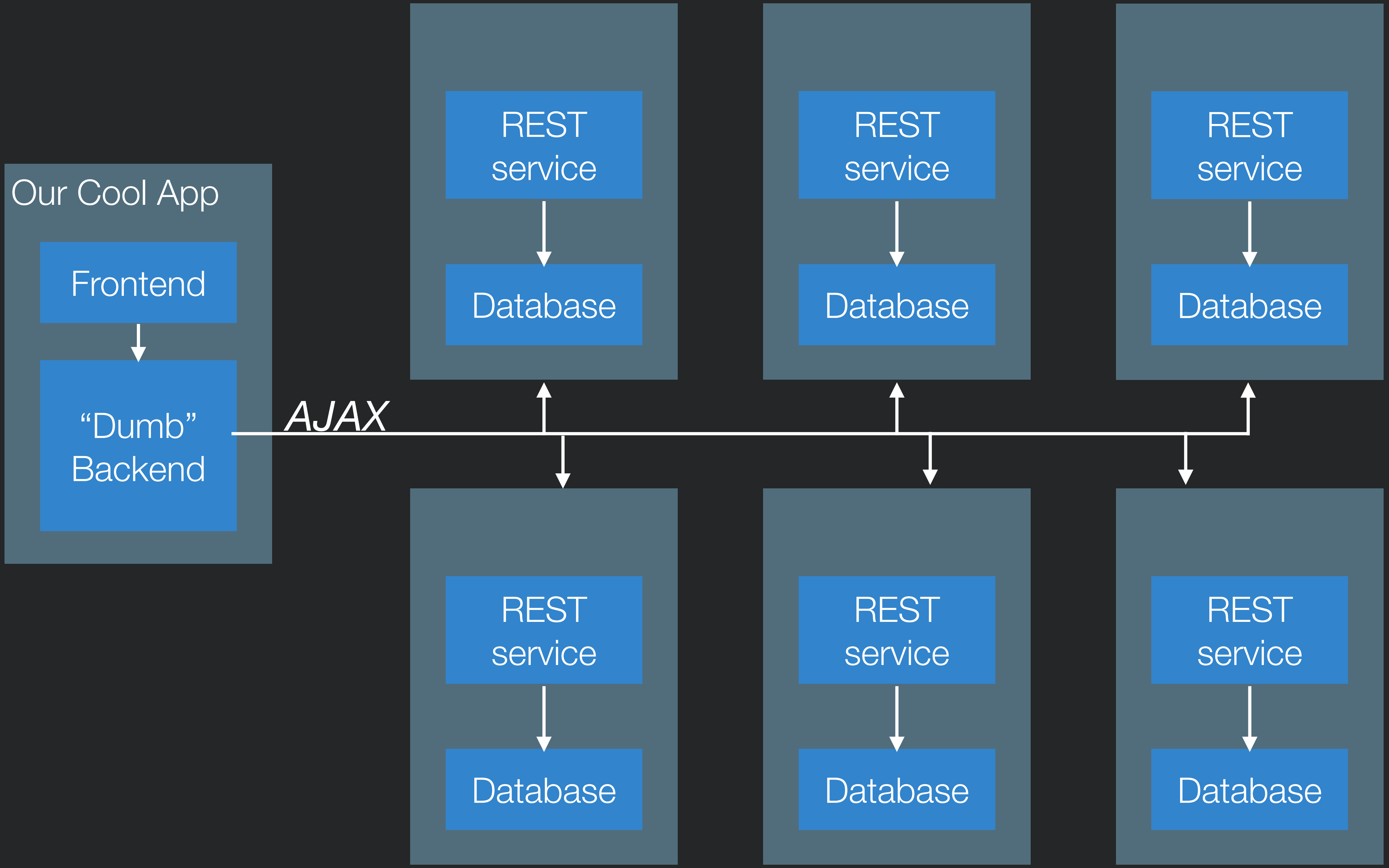
We run multiple copies of the backend, each with each of the modules

What's wrong with this picture?

- This is called the "monolithic" app
- If we need 100 servers…
- Each server will have to run EACH module
- What if we need more of some modules than others?



Microservices



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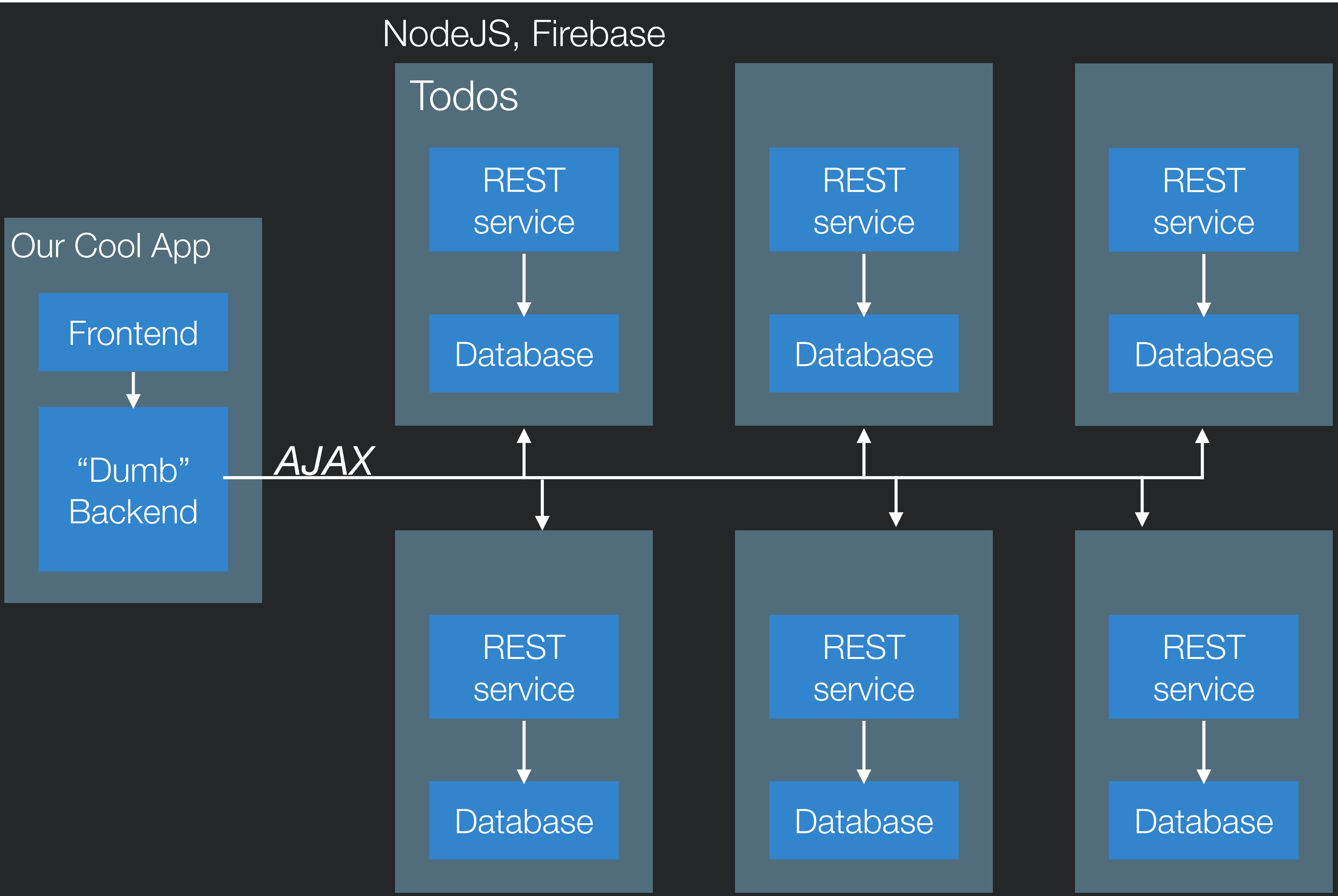

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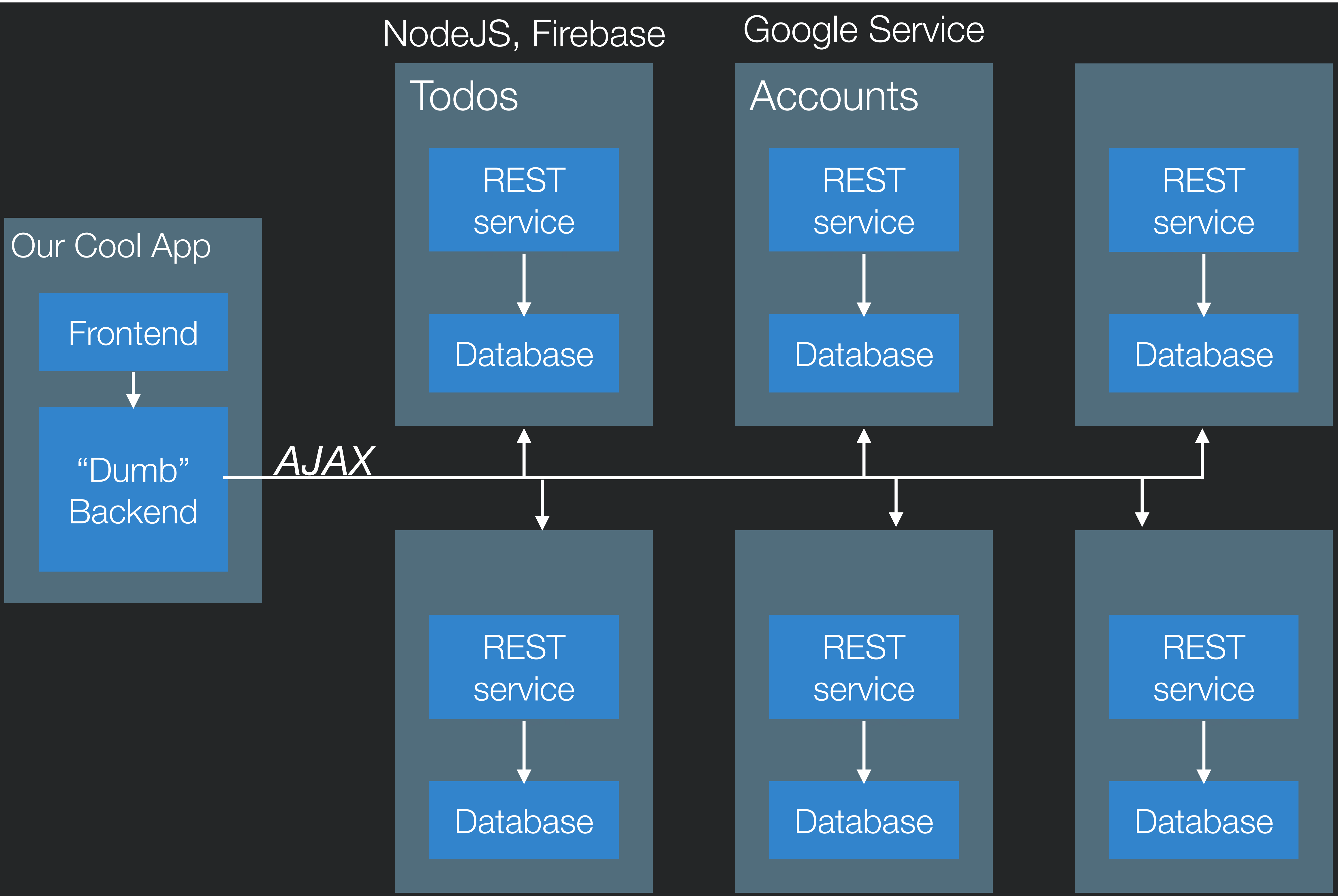

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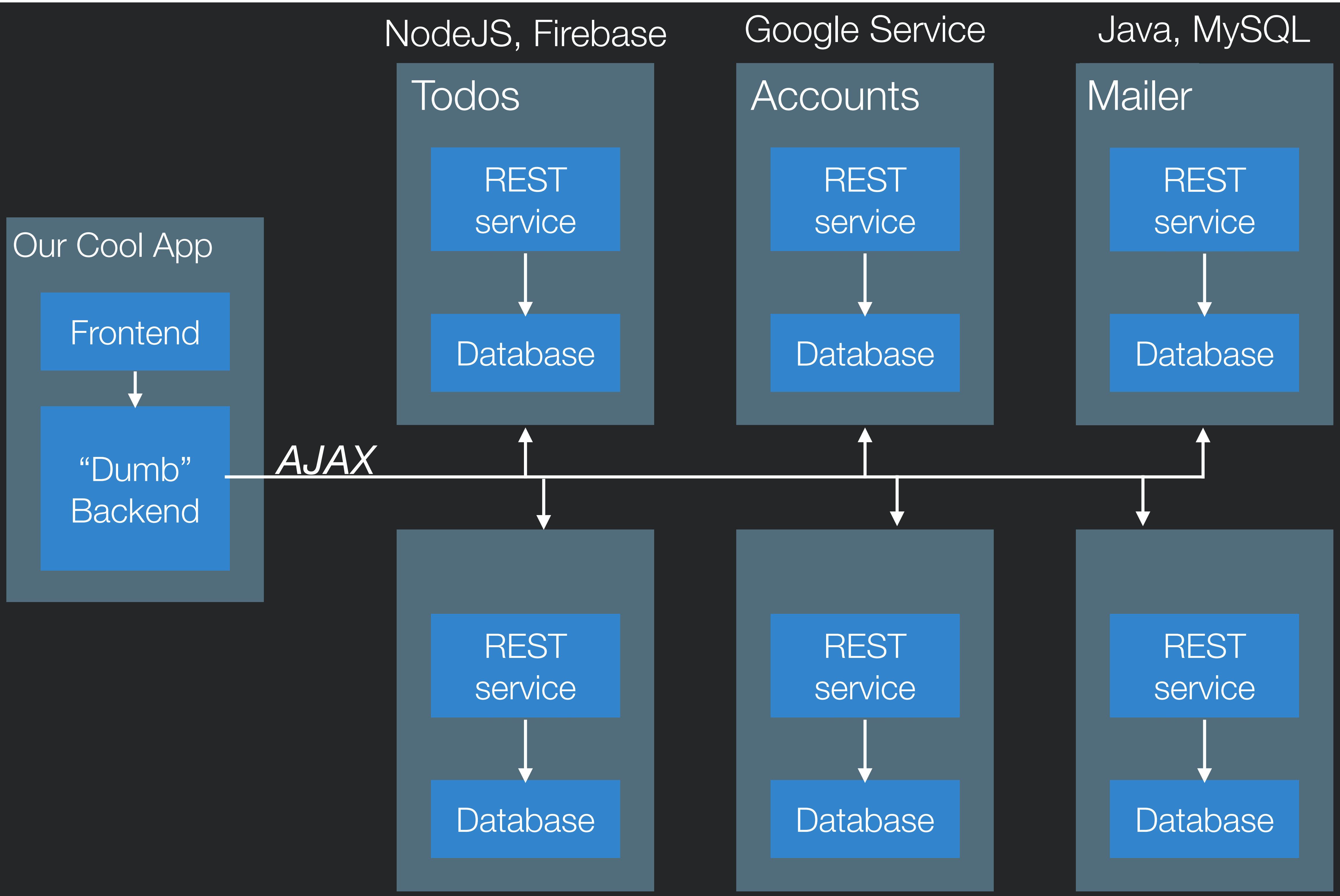

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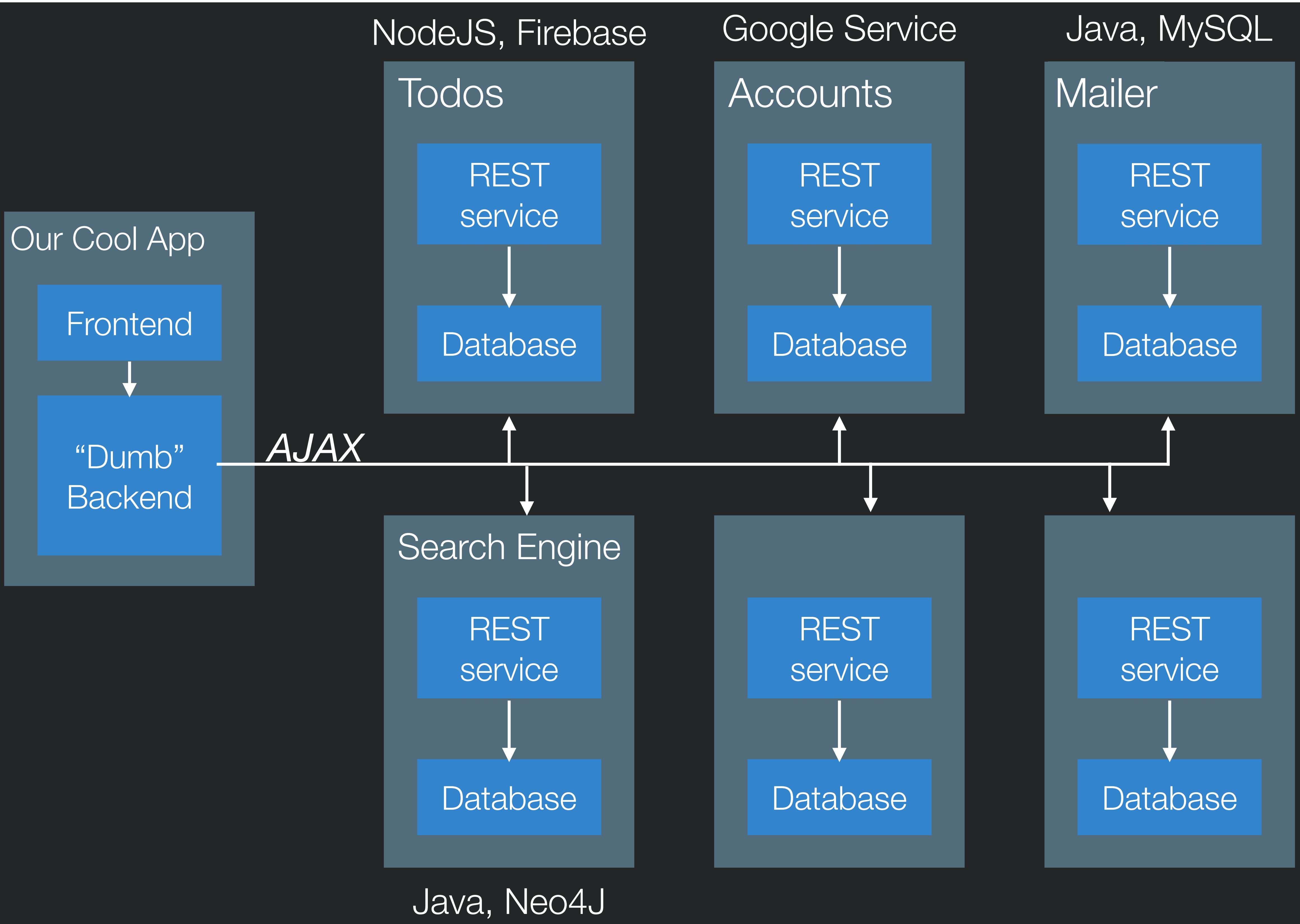

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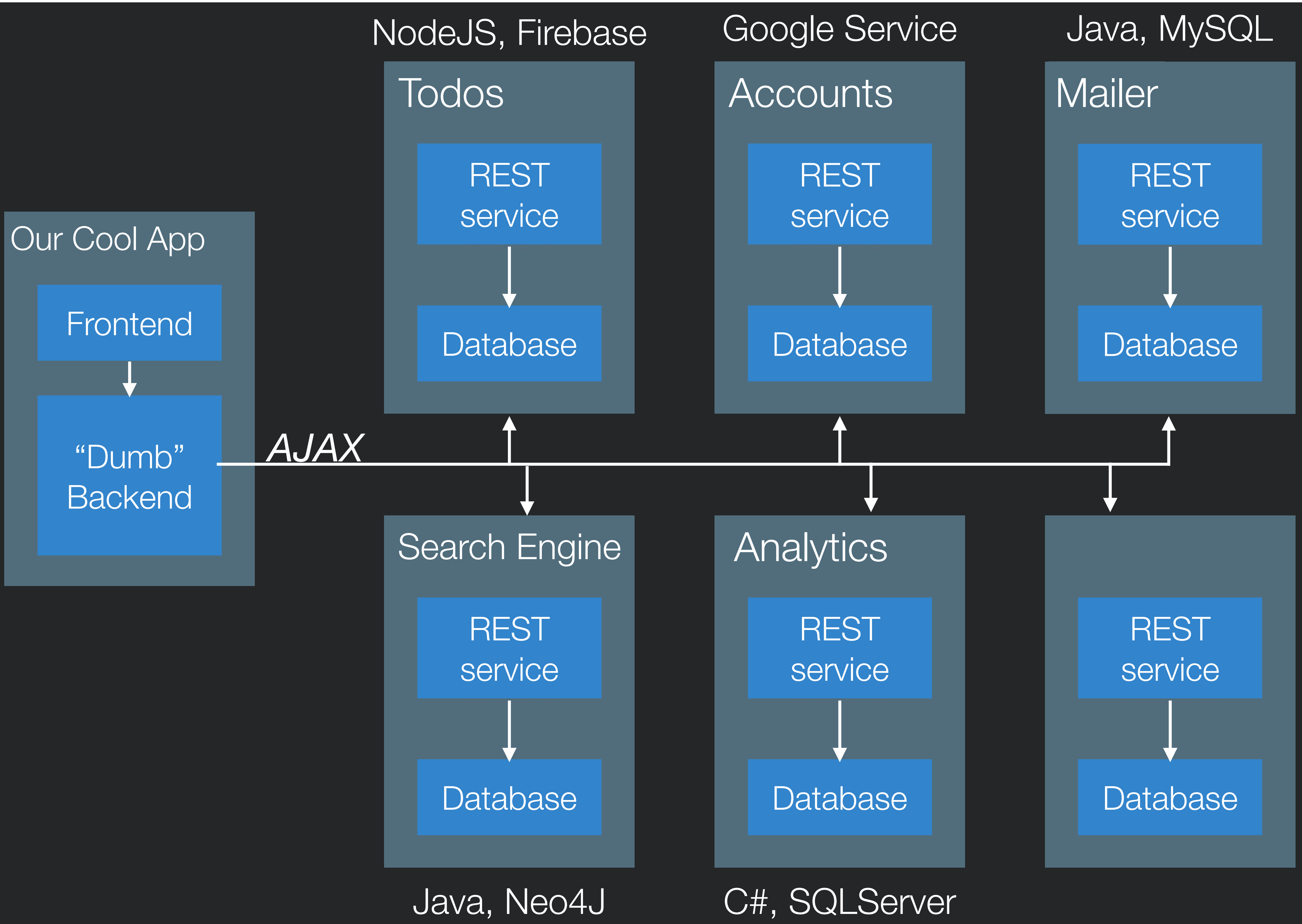

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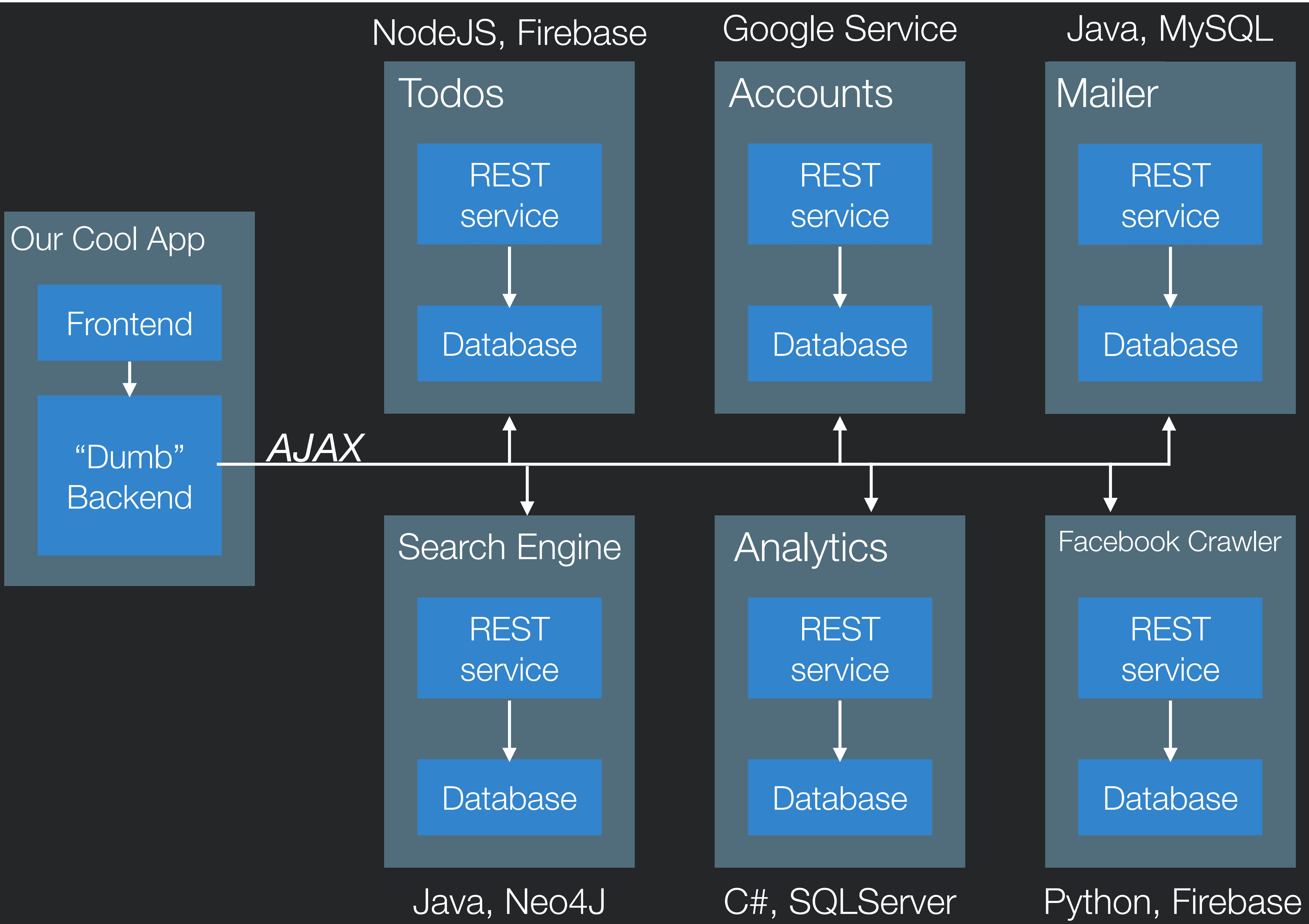

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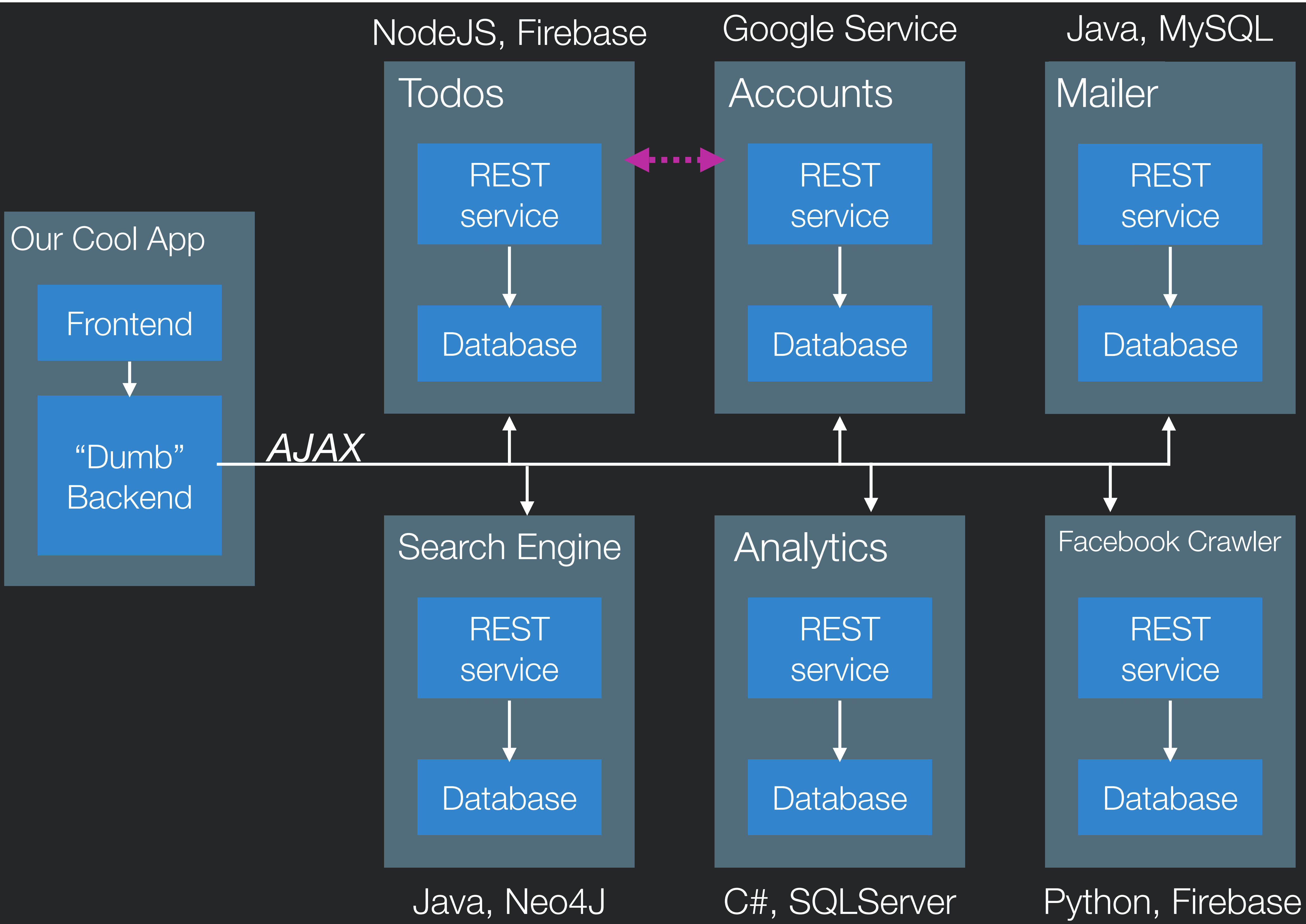
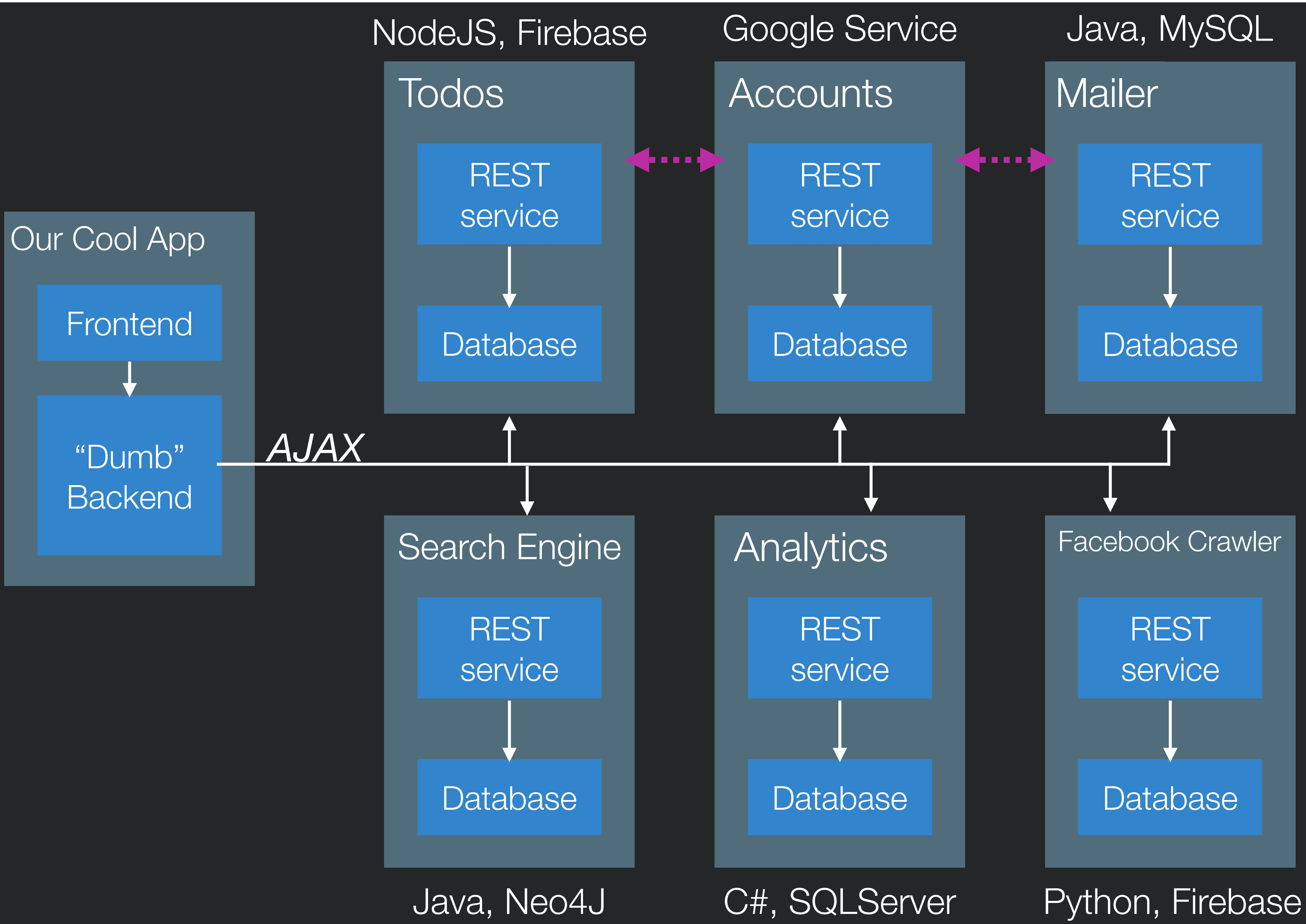
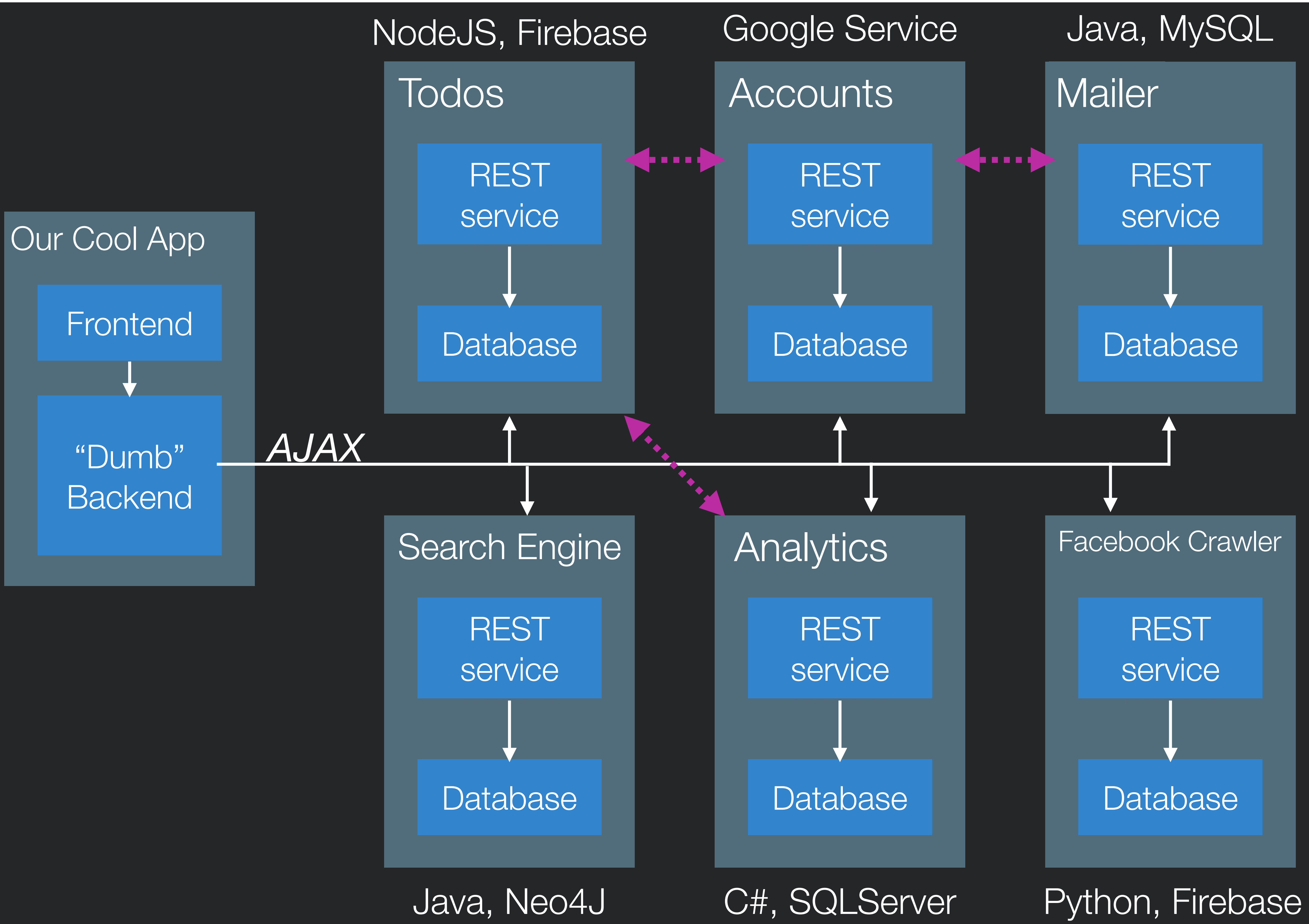


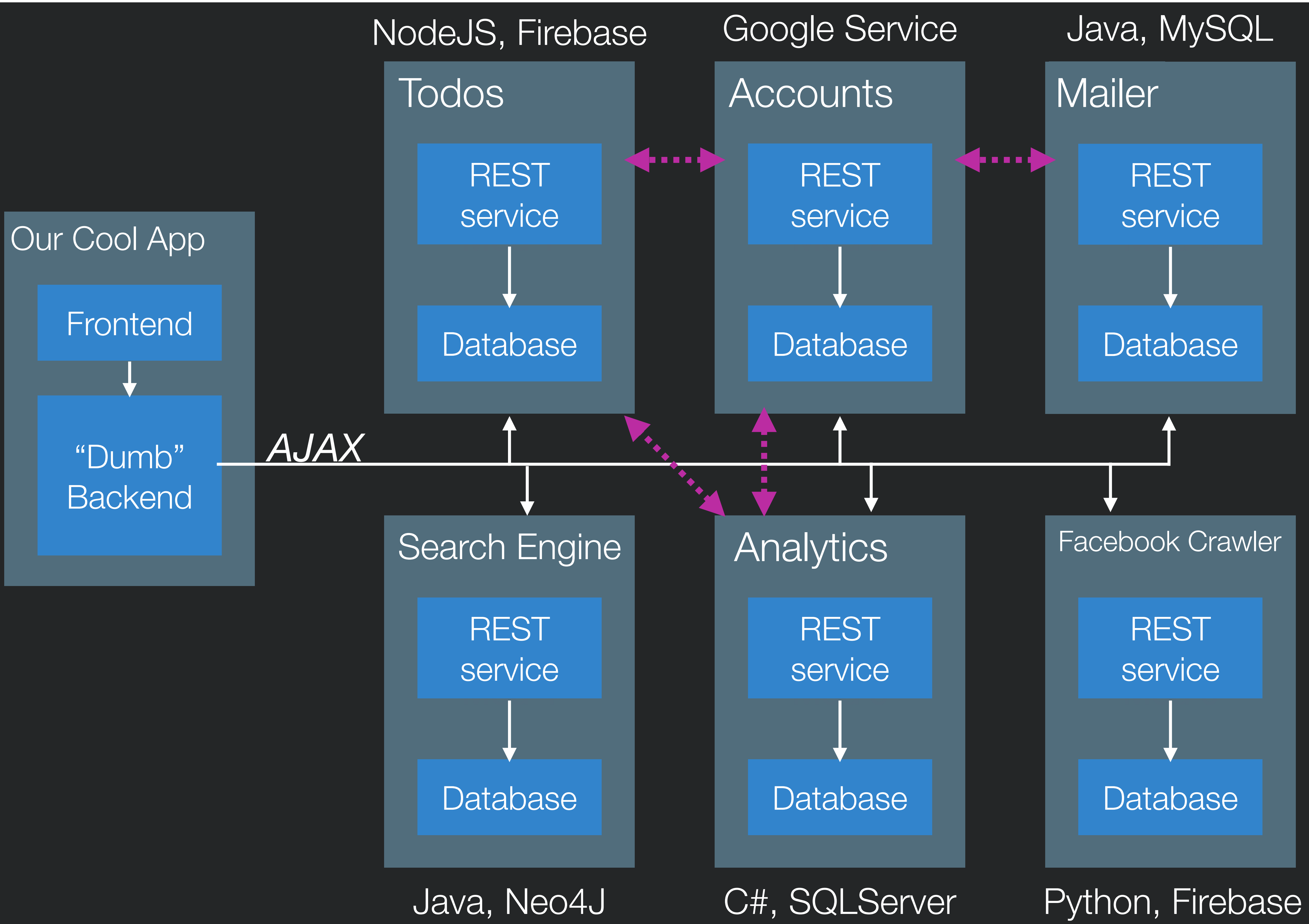
Microservices



Microservices



Microservices



Goals of Microservices

- Add them independently
- Upgrade the independently
- Reuse them independently
- Develop them independently

- ==> Have ZERO coupling between microservices, aside from their shared interface

Node.JS

- We’re going to write backends with Node.JS
- Why use Node?
  - Event based: really efficient for sending lots of quick updates to lots of clients
  - Very large ecosystem of packages, as we've seen
- Why not use Node?
  - Bad for CPU heavy stuff

Express

- Basic setup:
  - For get:

```
app.get("/somePath", function(req, res){
    //Read stuff from req, then call res.send(myResponse)
});
```

  - For post:

```
app.post("/somePath", function(req, res){
    //Read stuff from req, then call res.send(myResponse)
});
```

  - Serving static files:

```
app.use(express.static('myFileWithStaticFiles'));
```

    - Make sure to declare this *last*
- Additional helpful module - bodyParser (for reading POST data)

https://expressjs.com/

Demo: Hello World Server

1: Make a directory, `myapp`

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2: Enter that directory, type `npm init` (accept all defaults)

Creates a configuration file for your project

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Tells NPM that you want to use express, and to save that in your project config

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Creates a configuration file for your project

3: Type `npm install express --save`

Tells NPM that you want to use express, and to save that in your project config

4: Create text file `app.js`:

```
var express = require('express');
var app = express();
var port = process.env.PORT || 3000;
app.get('/', function (req, res) {
  res.send('Hello World!');
});

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

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

5: Type `node app.js`

Runs your app

6: Point your browser to http://localhost:3000

Demo: Hello World Server

```
var express = require(‘express');

var app = express();

var port = process.env.PORT || 3000;

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


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Demo: Hello World Server

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var port = process.env.PORT || 3000; // Decide what port we want express to listen on

app.get('/', function (req, res) {   // Create a callback for express to call
  res.send('Hello World!');          when we have a “get” request to “/“.
});                                  That callback has access to the request
                                     (req) and response (res).

app.listen(port, function () {
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```

Demo: Hello World Server

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var express = require(‘express');
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// Import the module express

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```

// Create a new instance of express

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var port = process.env.PORT || 3000;
```

// Decide what port we want express to listen on

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

// Create a callback for express to call when we have a “get” request to “/“.

That callback has access to the request (req) and response (res).

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

// Tell our new instance of express to listen on port, and print to the console once it starts successfully

Demo: Hello World Server

```
Legacy:Express-Example KevinMoran$ 
```

Demo: Hello World Server

```
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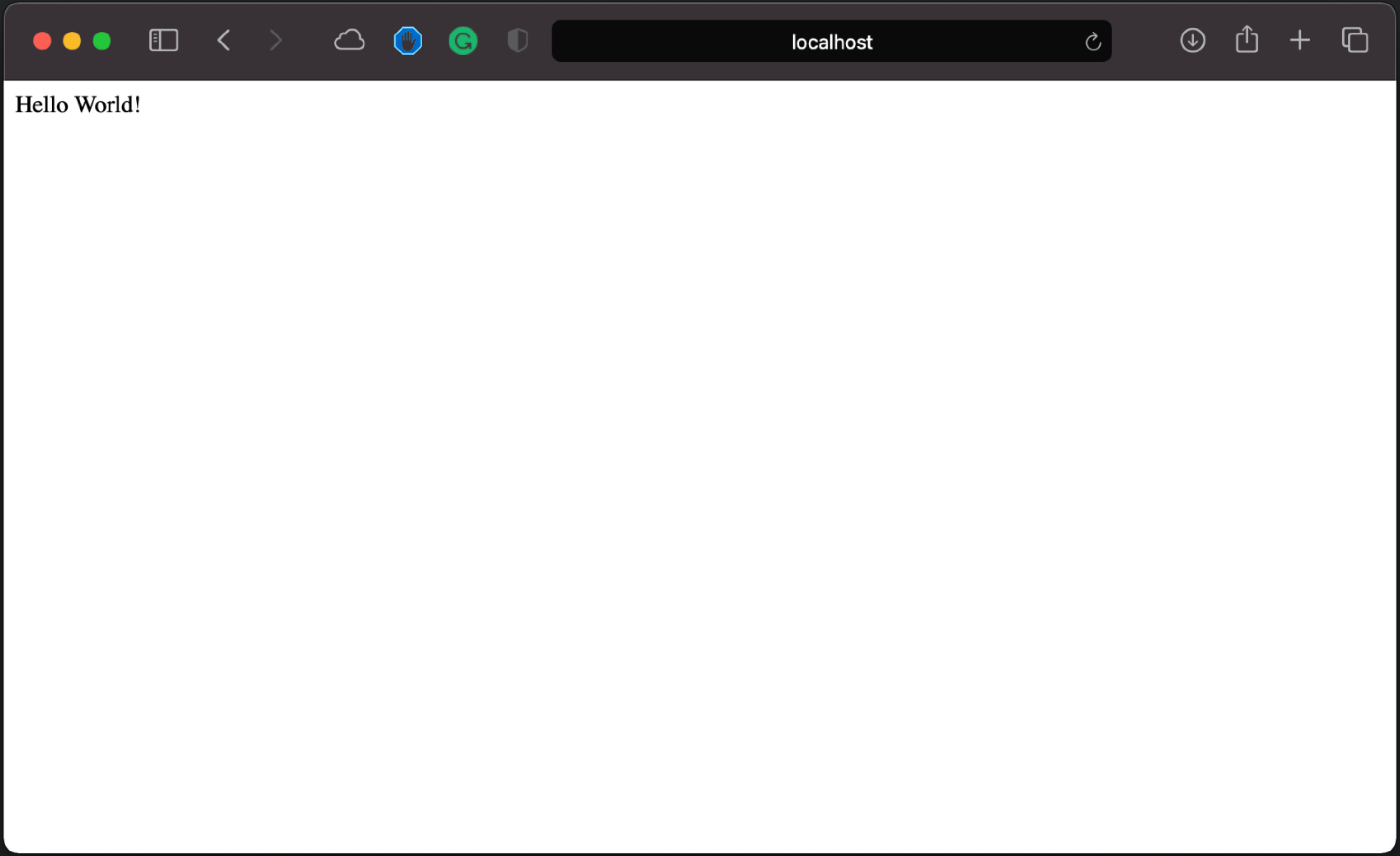
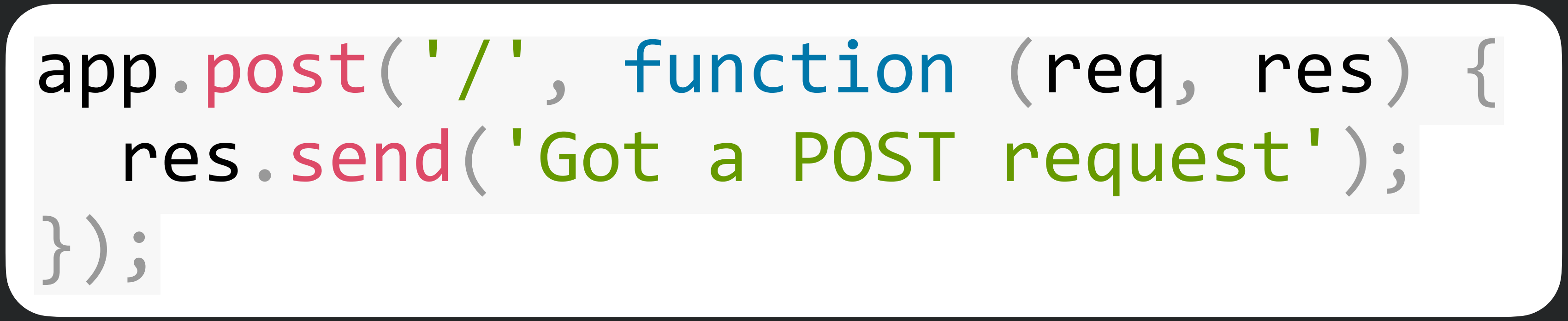
Demo: Hello World Server



Hello World!

Core Concept: Routing

- The definition of end points (URIs) and how they respond to client requests.
    - app.METHOD(PATH, HANDLER)
    - METHOD: all, get, post, put, delete, [and others]
    - PATH: string (e.g., the url)
    - HANDLER: call back



```
app.post('/', function (req, res) {
  res.send('Got a POST request');
});
```

Route Paths

- Can specify strings, string patterns, and regular expressions
  - Can use ?, +, *, and ()
- Matches request to root route

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

- Matches request to /about

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

- Matches request to /abe and /abcde

```
app.get('/ab(cd)?e', function(req, res) {
 res.send('ab(cd)?e');
});
```

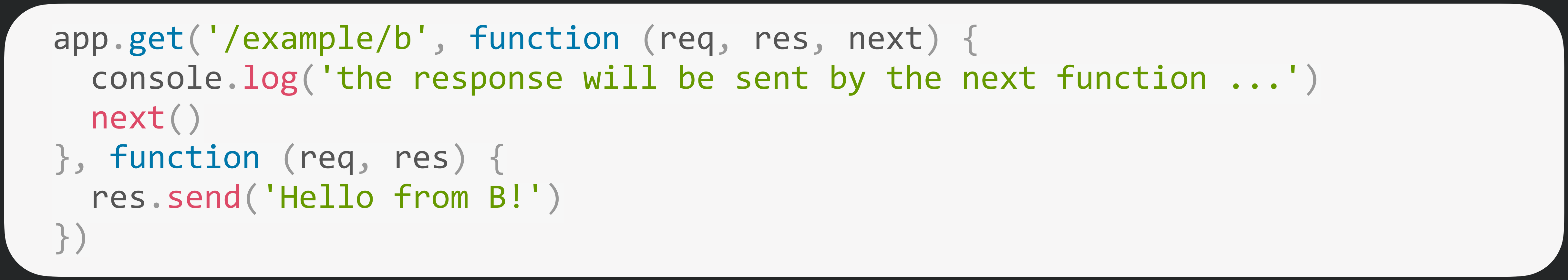
Route Parameters

- Named URL segments that capture values at specified location in URL
  - Stored into `req.params` object by name
- Example
  - Route path */users/**:userId**/books/**:bookId***
  - Request URL *http://localhost:3000/users/34/books/8989*
  - Resulting `req.params: { "userId": "34", "bookId": "8989" }`

```
app.get('/users/:userId/books/:bookId', function(req, res)
{
  res.send(req.params);
});
```

Route Handlers

- You can provide multiple callback functions that behave like middleware to handle a request
- The only exception is that these callbacks might invoke next('route') to bypass the remaining route callbacks.
- You can use this mechanism to impose pre-conditions on a route, then pass control to subsequent routes if there’s no reason to proceed with the current route.



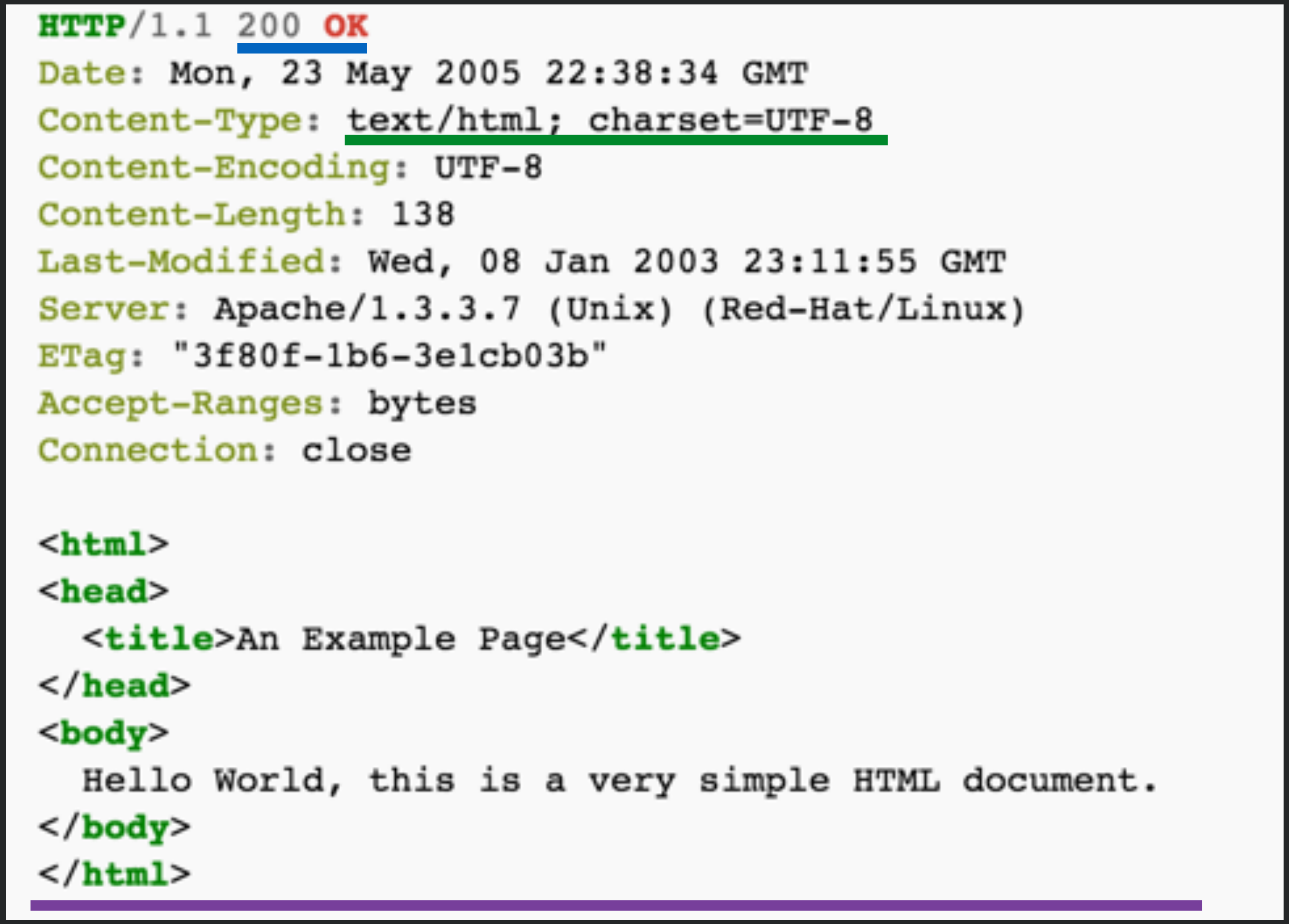
```
app.get('/example/b', function (req, res, next) {
  console.log('the response will be sent by the next function ...')
  next()
}, function (req, res) {
  res.send('Hello from B!')
})
```

Request Object

- Enables reading properties of HTTP request
  - `req.body`: JSON submitted in request body (*must* define body-parser to use)
  - `req.ip`: IP of the address
  - `req.query`: URL query parameters

HTTP Responses

- Larger number of response codes (200 OK, 404 NOT FOUND)
- Message body only allowed with certain response status codes



```
HTTP/1.1 200 OK
Date: Mon, 23 May 2005 22:38:34 GMT
Content-Type: text/html; charset=UTF-8
Content-Encoding: UTF-8
Content-Length: 138
Last-Modified: Wed, 08 Jan 2003 23:11:55 GMT
Server: Apache/1.3.3.7 (Unix) (Red-Hat/Linux)
ETag: "3f80f-1b6-3e1cb03b"
Accept-Ranges: bytes
Connection: close

<html>
<head>
  <title>An Example Page</title>
</head>
<body>
  Hello World, this is a very simple HTML document.
</body>
</html>
```

HTTP Responses

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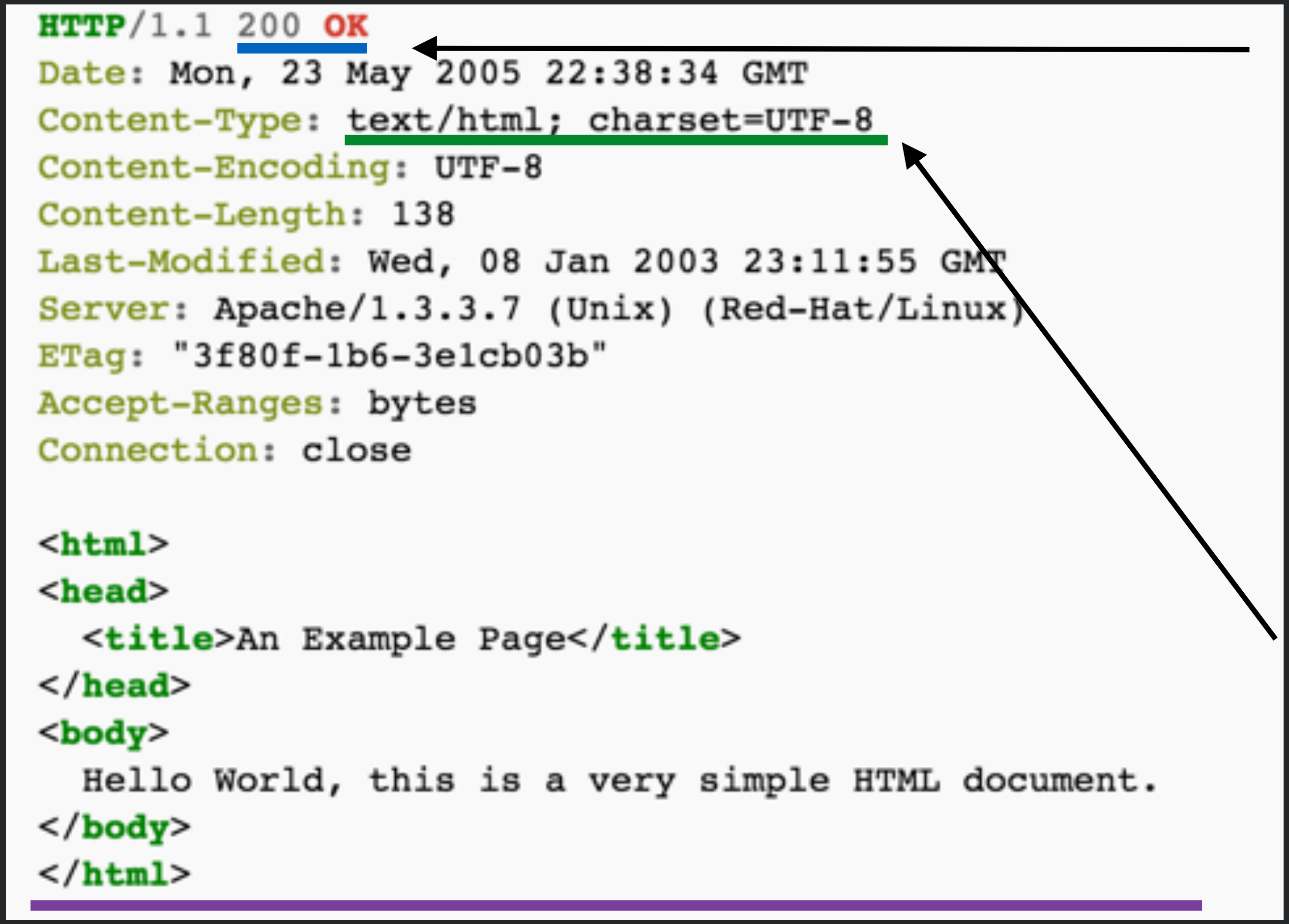

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```

“OK response”

“HTML returned content”

[HTML data]

HTTP Responses

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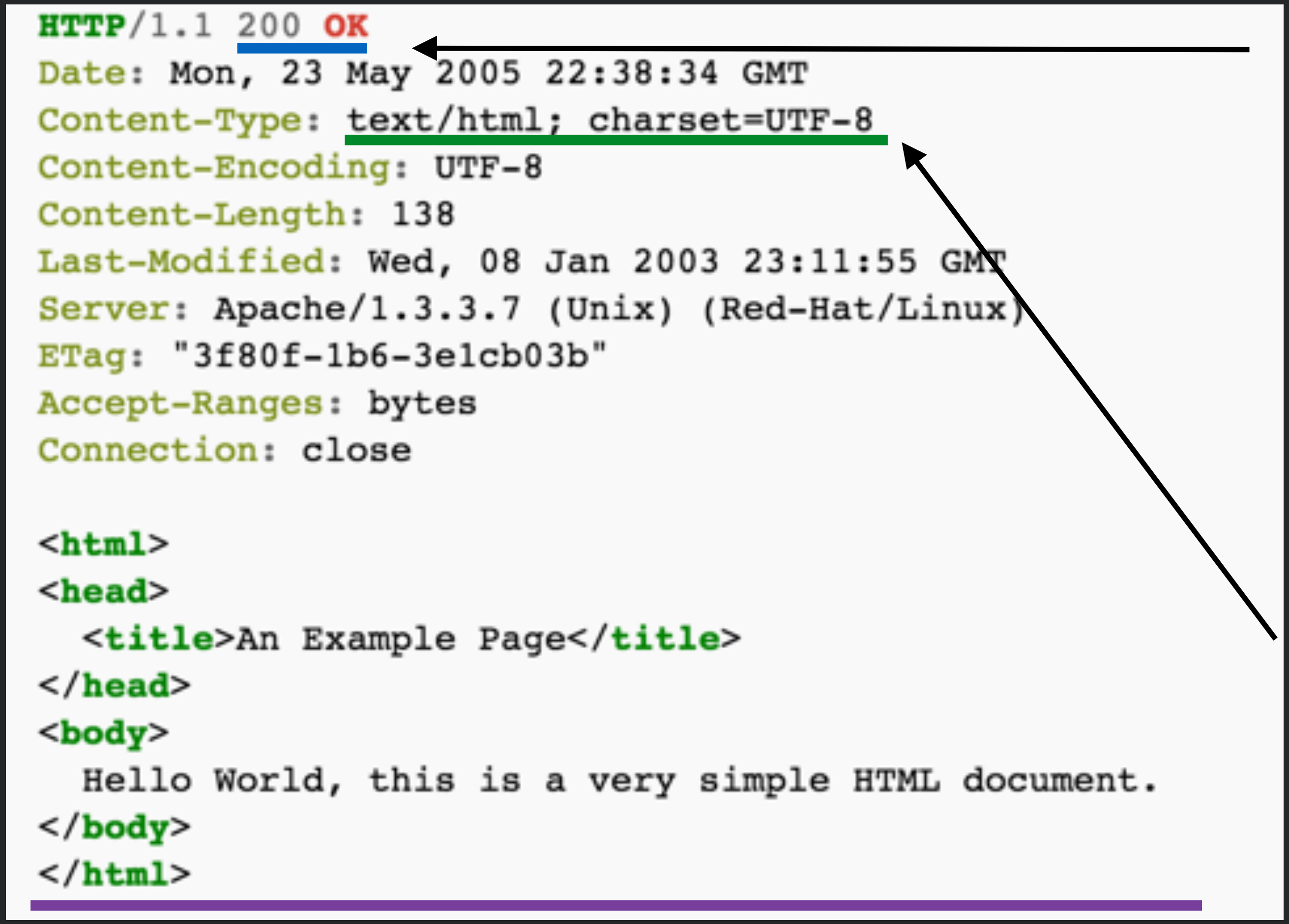

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```

"OK response"

Response status codes:
1xx Informational
2xx Success
3xx Redirection
4xx Client error
5xx Server error

"HTML returned content"

[HTML data]

HTTP Responses

- Larger number of response codes (200 OK, 404 NOT FOUND)
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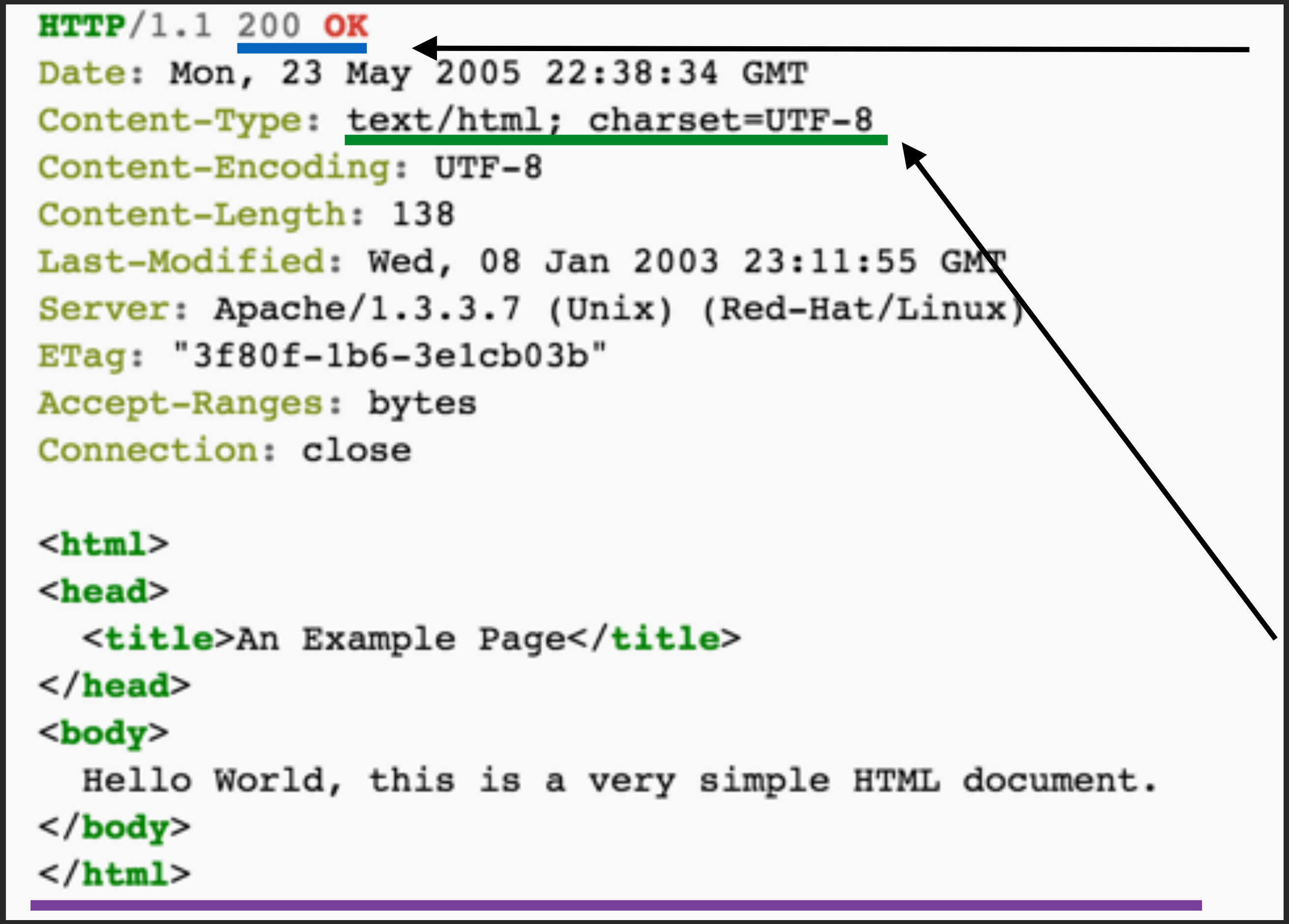

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</html>
```

[HTML data]

"OK response"

Response status codes:
1xx Informational
2xx Success
3xx Redirection
4xx Client error
5xx Server error

"HTML returned content"

Common MIME types:
application/json
application/pdf
image/png

Response Object

- Enables a response to client to be generated
  - `res.send()` - send string content
  - `res.download()` - prompts for a file download
  - `res.json()` - sends a response w/ application/json Content-Type header
  - `res.redirect()` - sends a redirect response
  - `res.sendStatus()` - sends only a status message
  - `res.sendFile()` - sends the file at the specified path

```
app.get('/users/:userId/books/:bookId', function(req, res) {
  res.json({ “id”: req.params.bookID });
});
```

Describing Responses

- What happens if something goes wrong while handling HTTP request?
  - How does client know what happened and what to try next?
- HTTP offers response status codes describing the nature of the response
  - 1xx Informational: Request received, continuing
  - 2xx Success: Request received, understood, accepted, processed
    - 200: OK
  - 3xx Redirection: Client must take additional action to complete request
    - 301: Moved Permanently
    - 307: Temporary Redirect

https://en.wikipedia.org/wiki/List_of_HTTP_status_codes

Describing Errors

- 4xx Client Error: client did not make a valid request to server. Examples:
  - 400 Bad request (e.g., malformed syntax)
  - 403 Forbidden: client lacks necessary permissions
  - 404 Not found
  - 405 Method Not Allowed: specified HTTP action not allowed for resource
  - 408 Request Timeout: server timed out waiting for a request
  - 410 Gone: Resource has been intentionally removed and will not return
  - 429 Too Many Requests

Describing Errors

- 5xx Server Error: The server failed to fulfill an apparently valid request.
  - 500 Internal Server Error: generic error message
  - 501 Not Implemented
  - 503 Service Unavailable: server is currently unavailable

Error Handling in Express

- Express offers a default error handler
- Can specific error explicitly with status
  - `res.status(500);`

Persisting Data in Memory

- Can declare a global variable in node
  - i.e., a variable that is not declared inside a class or function
- Global variables persist between requests
- Can use them to store state in memory
- Unfortunately, if server crashes or restarts, state will be lost
  - Will look later at other options for persistence

Making HTTP Requests

- May want to request data from other servers from backend
- Fetch
  - Makes an HTTP request, returns a Promise for a response
  - Part of standard library in browser, but need to install library to use in backend
- Installing:

```
npm install node-fetch --save
```

- Use:

```
const fetch = require('node-fetch');

fetch('https://github.com/')
    .then(res => res.text())
    .then(body => console.log(body));

var res = await fetch('https://github.com/');
```

https://www.npmjs.com/package/node-fetch

Responding Later

- What happens if you'd like to send data back to client in response, but not until something else happens (e.g., your request to a different server finishes)?
- Solution: wait for event, then send the response!

```
fetch('https://github.com/')
    .then(res => res.text())
    .then(body => res.send(body));
```

SWE 432 - Web Application Development

George Mason University

Instructor:
Dr. Kevin Moran

Teaching Assistant:
David Gonzalez Samudio

Class will start in:

10:01

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Handling HTTP Requests

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Class will start in:

07:01

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07:01

Review: Express

```
var express = require(‘express');


var app = express();


var port = process.env.port || 3000;


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



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

Review: Express

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That callback has access to the request (`req`) and response (`res`).

```
app.listen(port, function () {
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// Tell our new instance of express to listen on `port`, and print to the console once it starts successfully

Review: Route Parameters

- Named URL segments that capture values at specified location in URL
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- Example
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  - Request URL *http://localhost:3000/users/34/books/8989*
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```
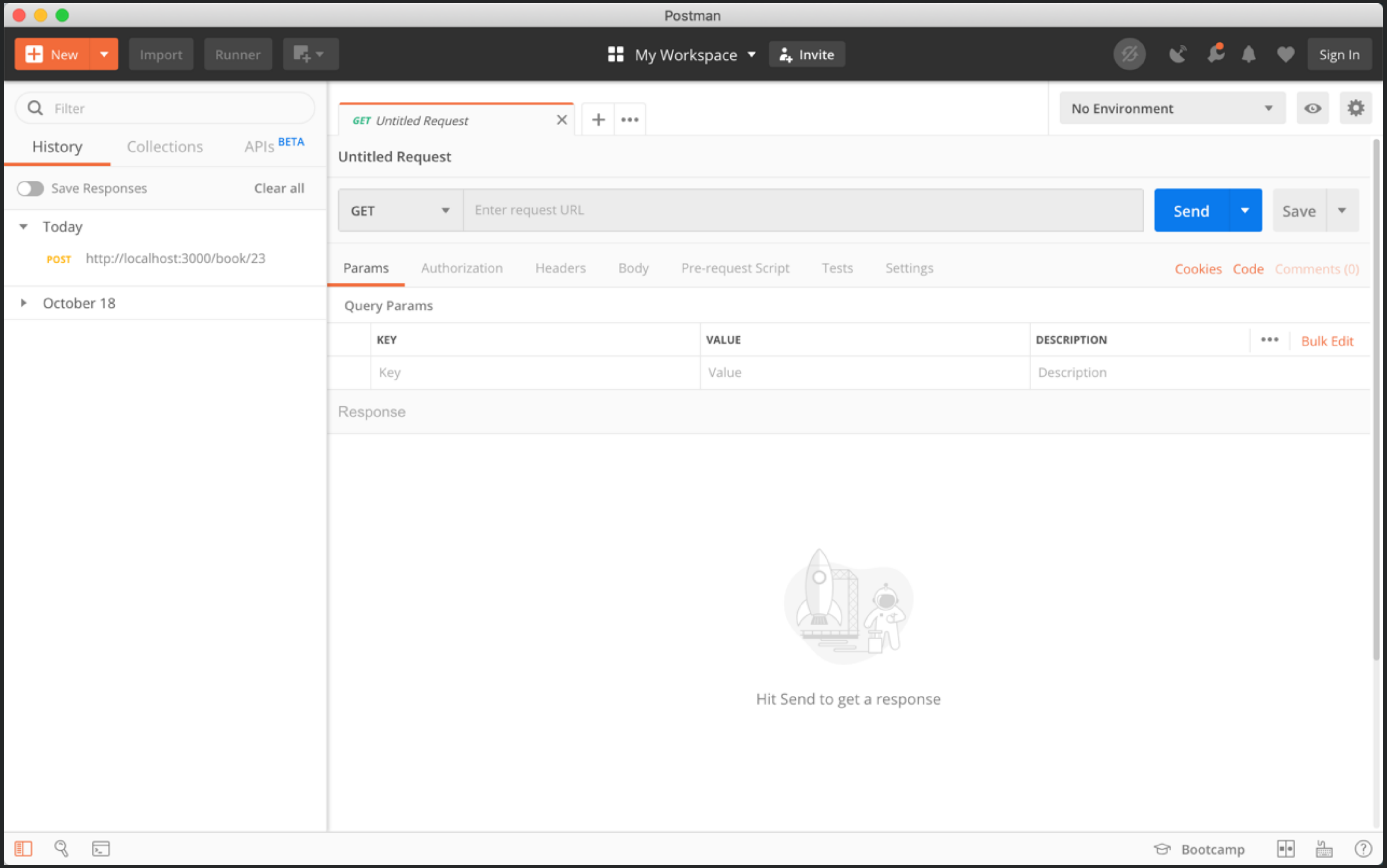

https://www.npmjs.com/package/node-fetch

Using Fetch to Post Data

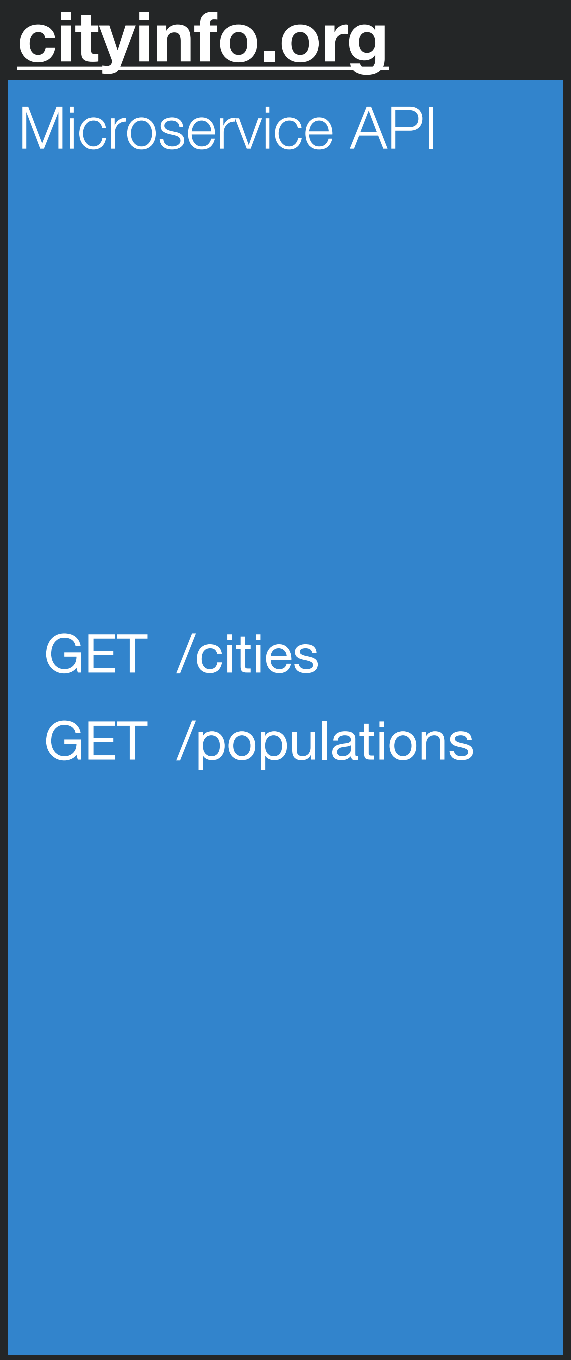
```
var express = require('express');
var app = express();
const fetch = require('node-fetch');

const body = { 'a': 1 };

fetch(‘http://localhost:3000/cities', {
    method: 'post',
    body:    JSON.stringify(body),
    headers: { 'Content-Type': 'application/json' },
})
    .then(res => res.json())
    .then(json => console.log(json));
```

Making HTTP Request with Postman



https://www.getpostman.com/

Demo: Building a Microservice w/ Express



cityinfo.org

Microservice API

GET /cities

GET /populations

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Legacy:hw2-starter-repo KevinMoran$ 
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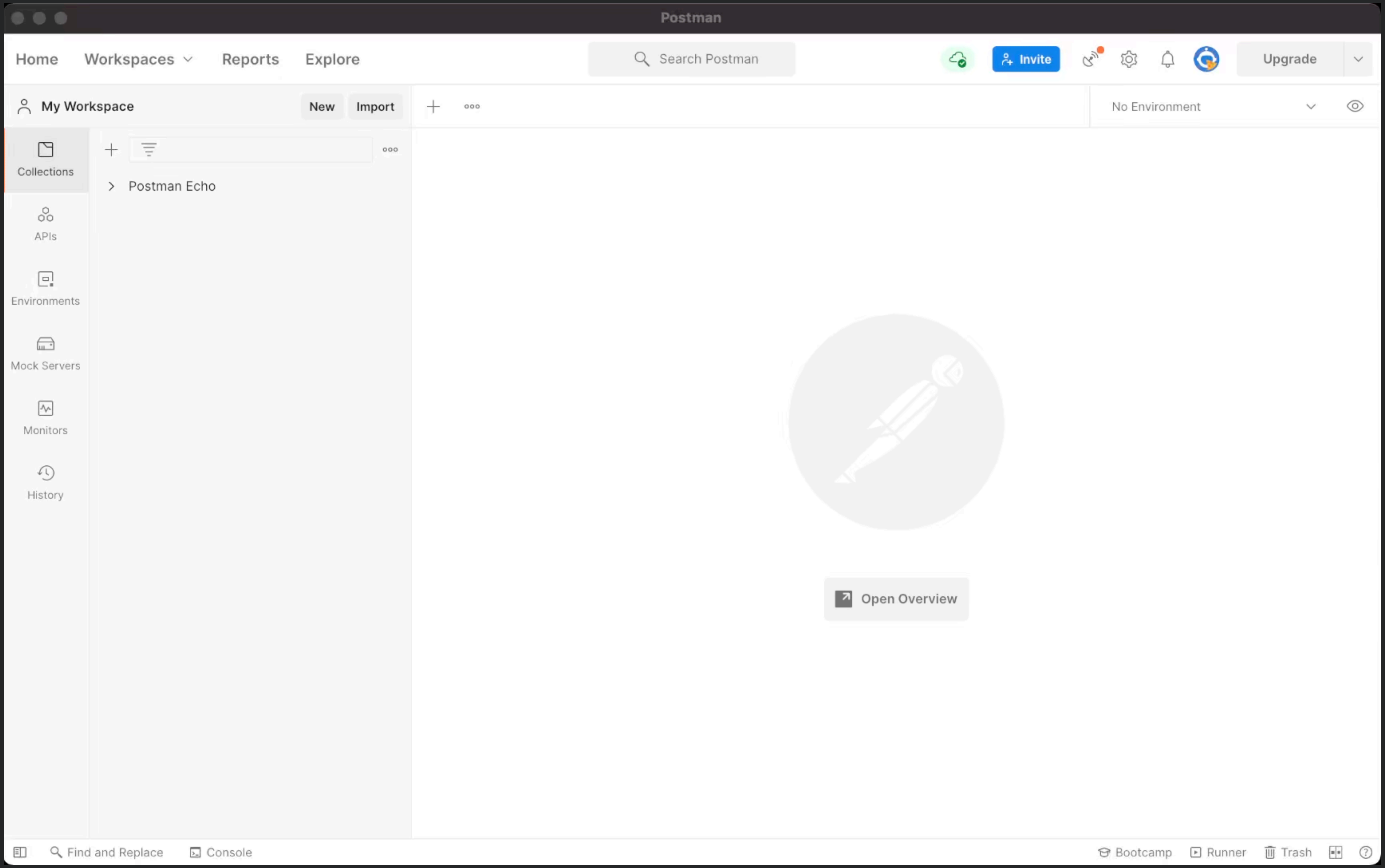

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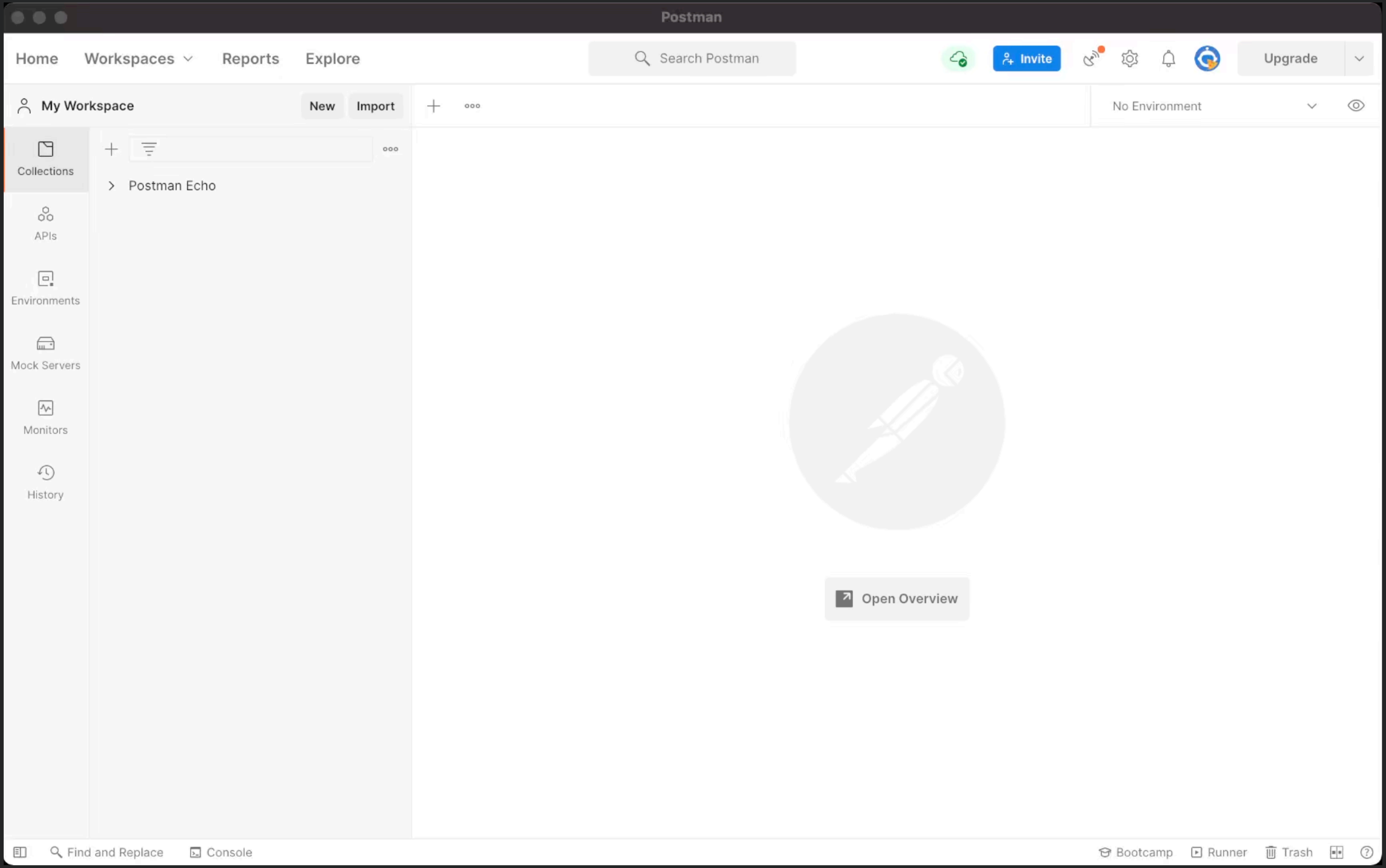

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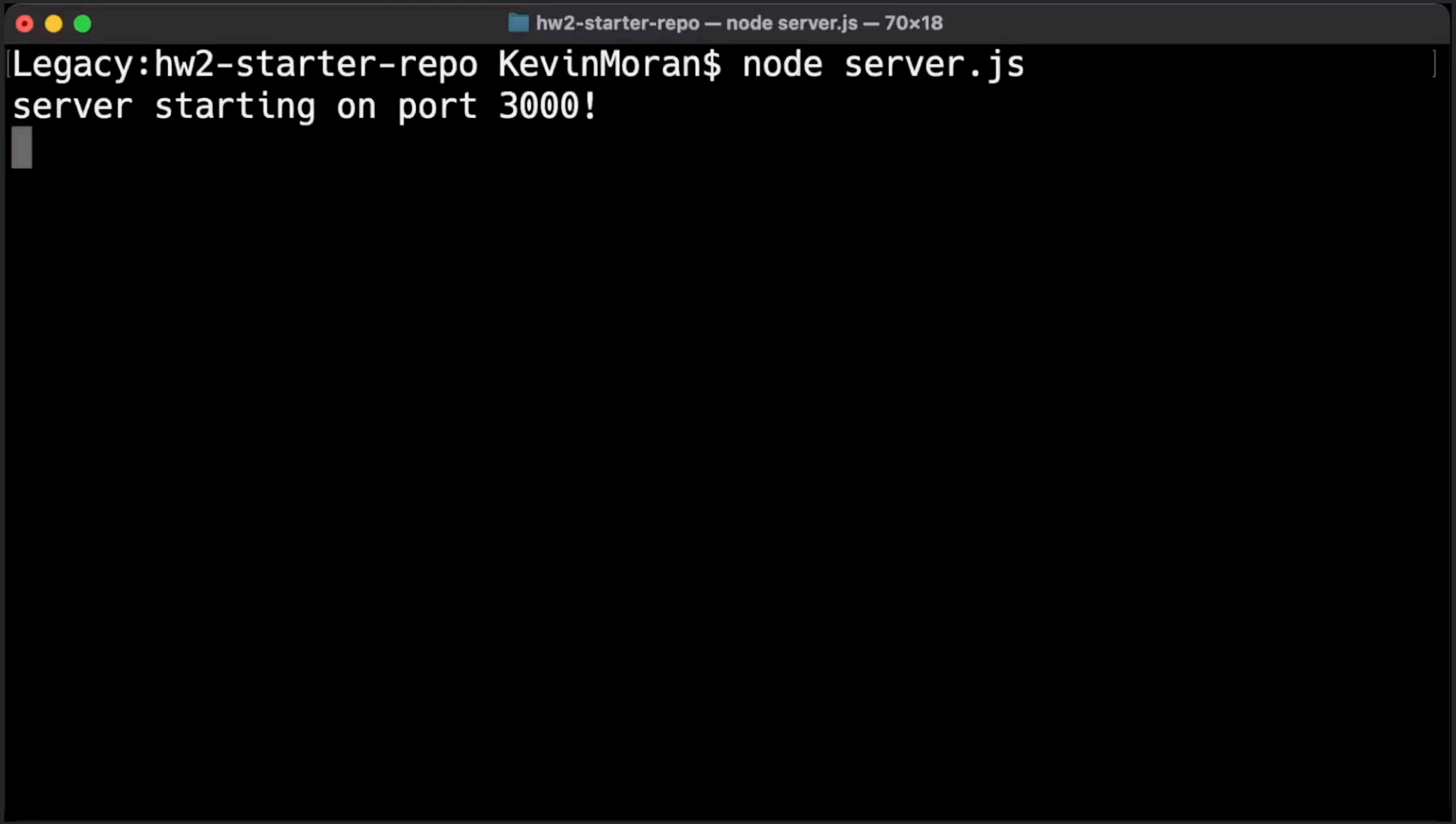

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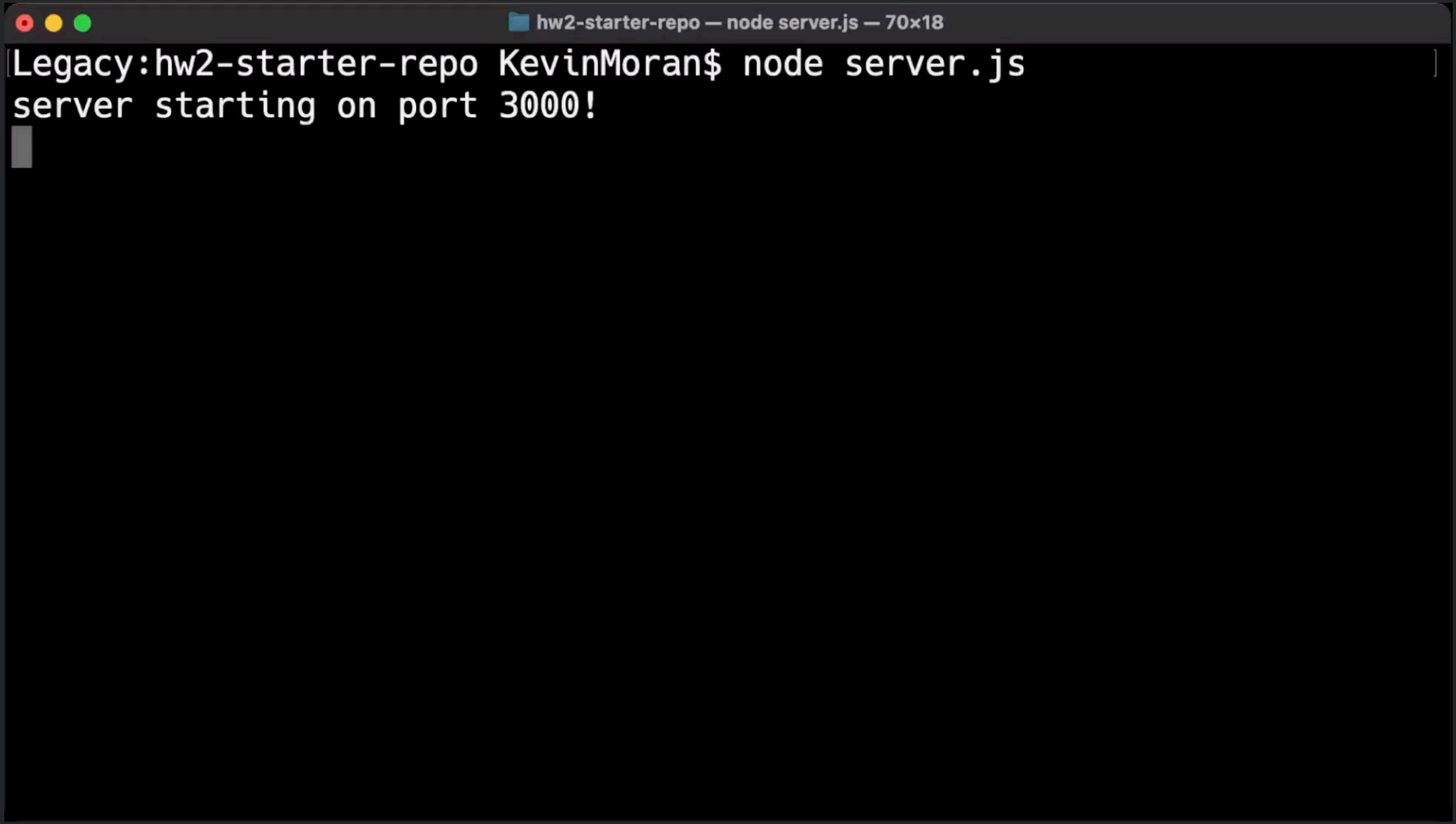

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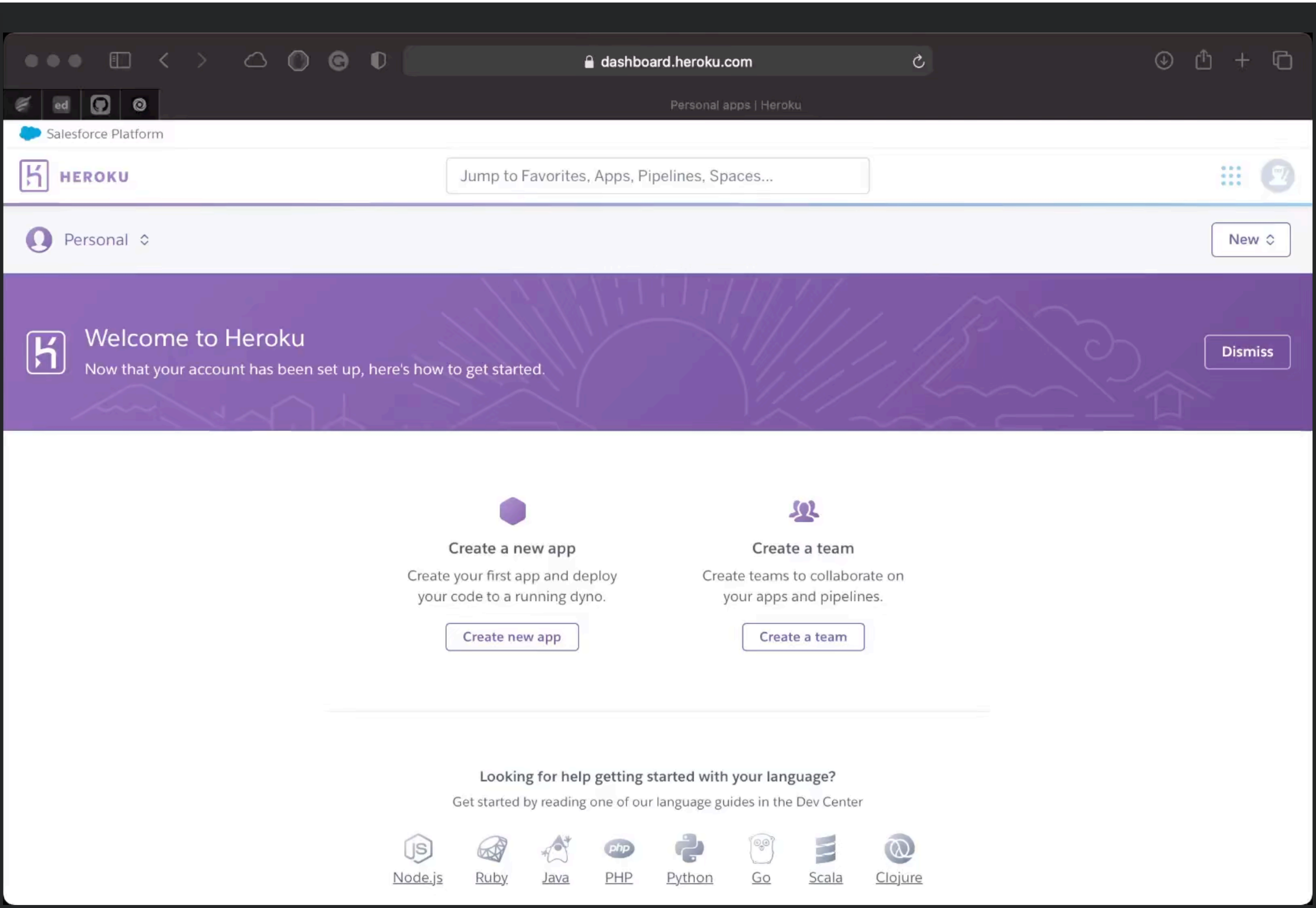

dashboard.heroku.com

Personal apps | Heroku

Salesforce Platform

HEROKU

Jump to Favorites, Apps, Pipelines, Spaces...

Personal

New

Welcome to Heroku

Now that your account has been set up, here's how to get started.

Dismiss

Create a new app

Create your first app and deploy your code to a running dyno.

Create new app

Create a team

Create teams to collaborate on your apps and pipelines.

Create a team

Looking for help getting started with your language?

Get started by reading one of our language guides in the Dev Center

Node.js Ruby Java PHP Python Go Scala Clojure

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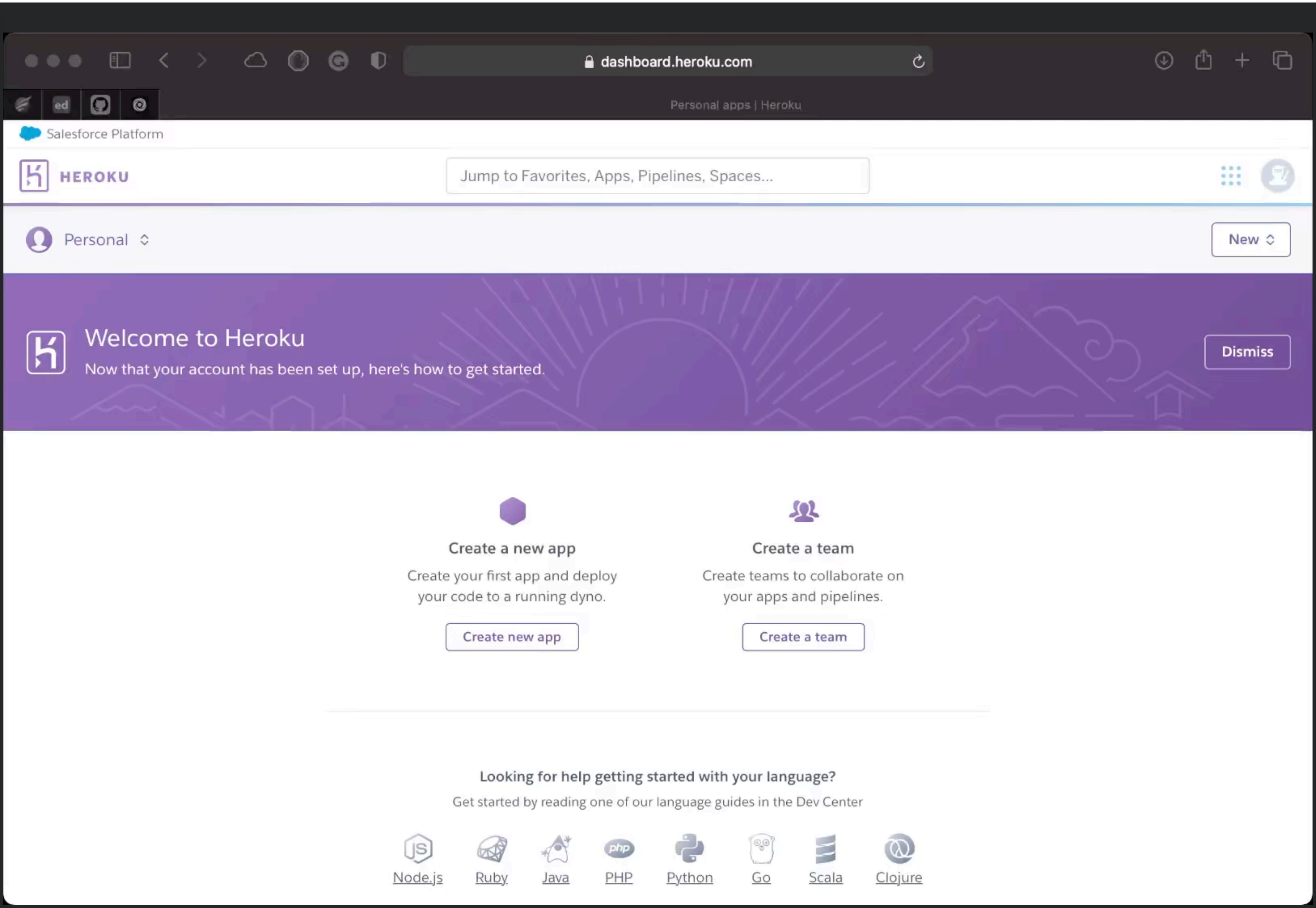

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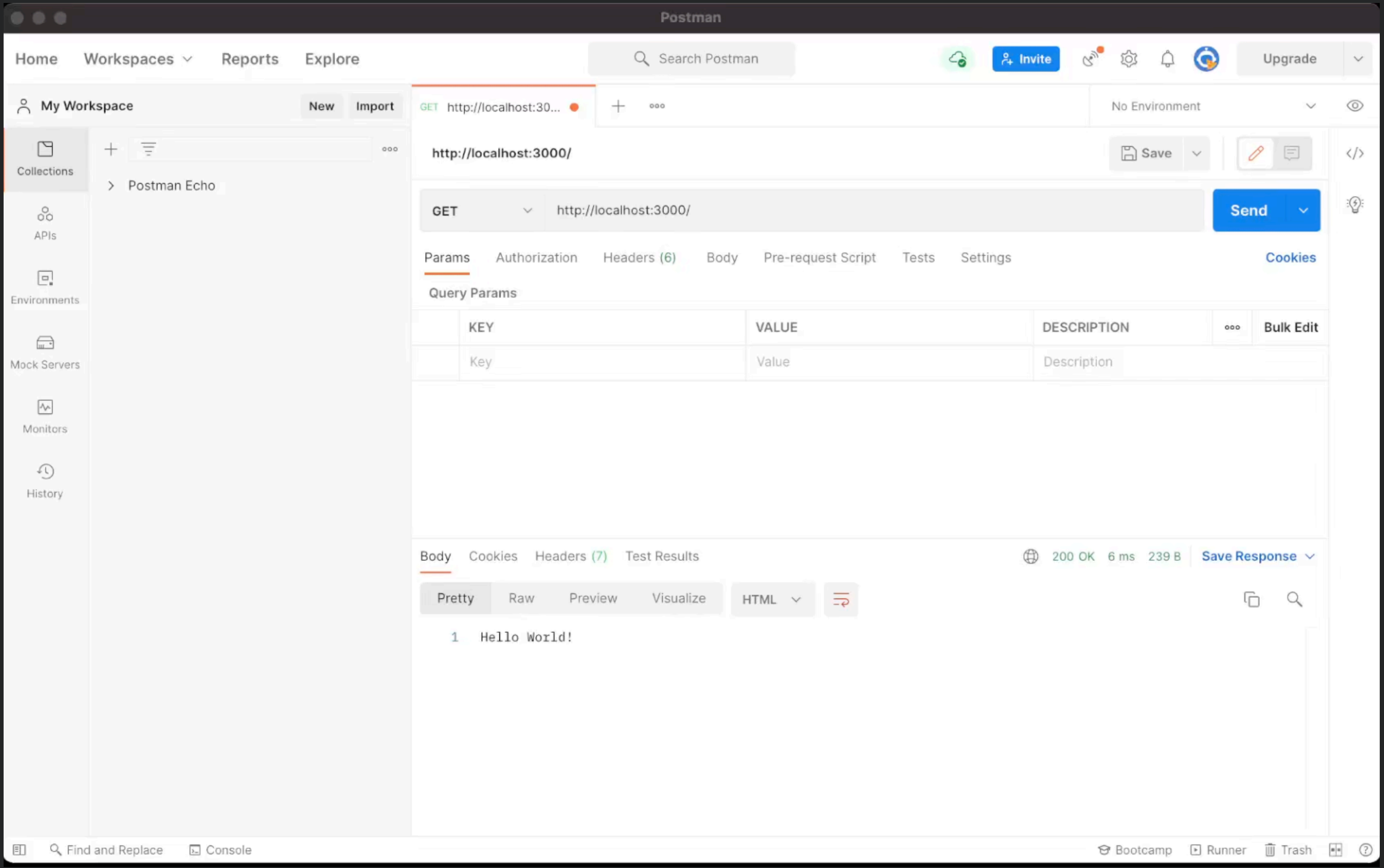


http://localhost:3000/

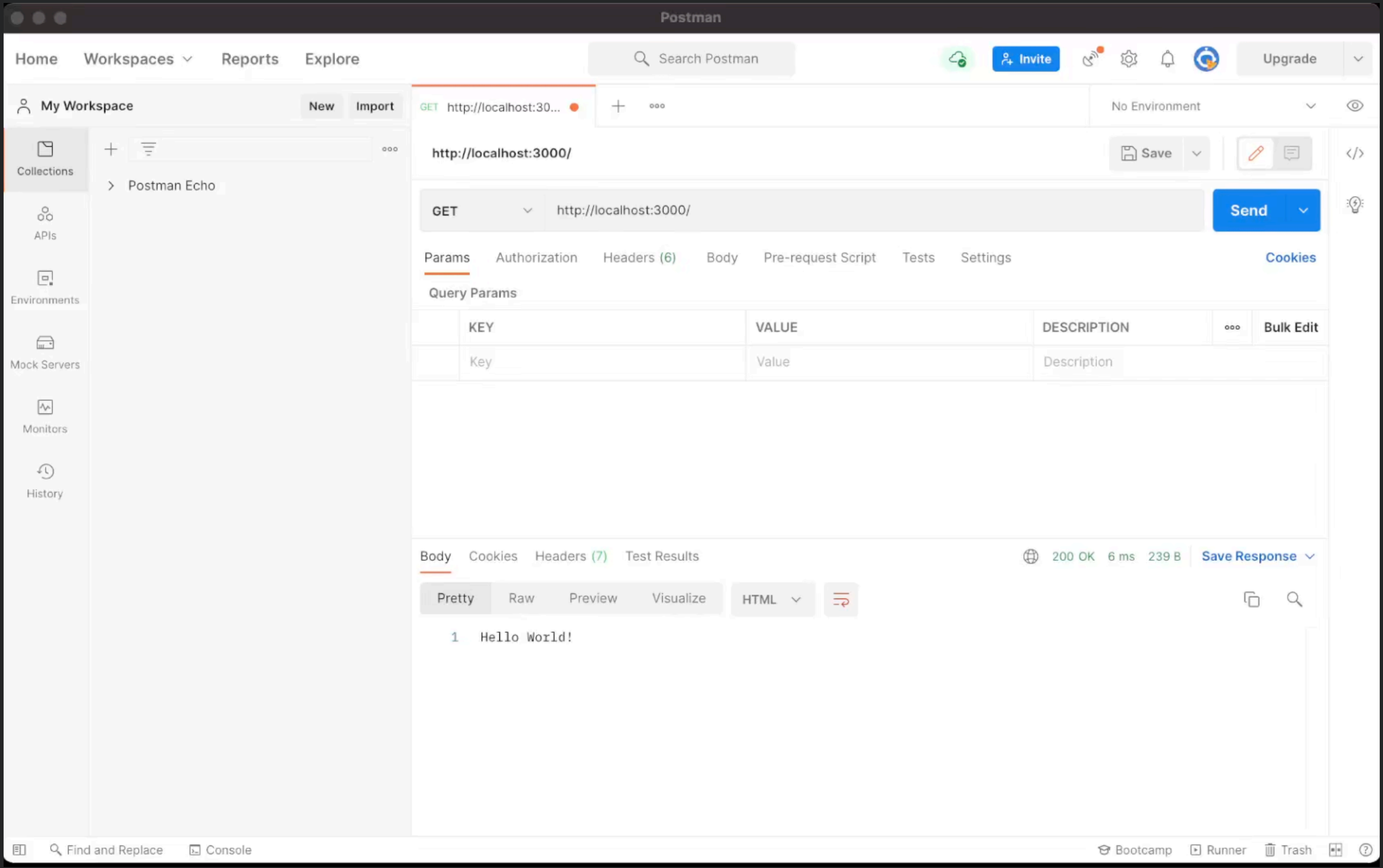
GET http://localhost:3000/

KEY	VALUE	DESCRIPTION
Key	Value	Description

Body — 200 OK 6 ms 239 B

```
Hello World!
```

Demo: Building a Microservice w/ Express



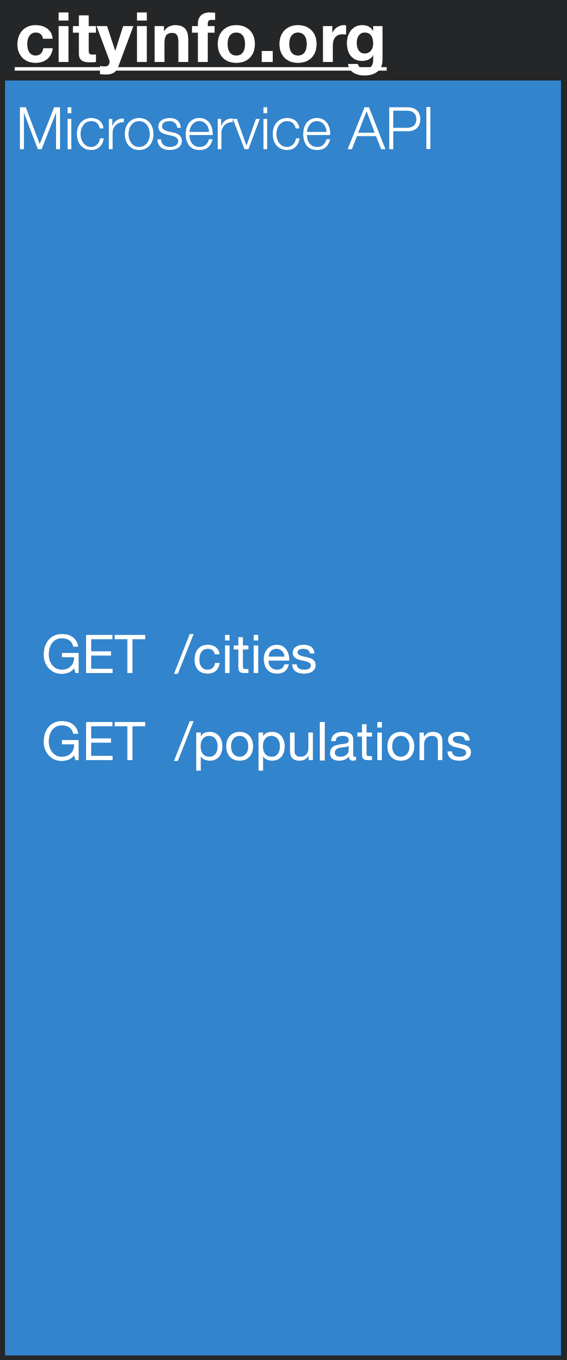
http://localhost:3000/

GET http://localhost:3000/

200 OK 6 ms 239 B

```
Hello World!
```

API: Application Programming Interface



cityinfo.org

Microservice API

GET /cities

GET /populations

- Microservice offers public **interface** for interacting with backend
  - Offers abstraction that hides implementation details
  - Set of endpoints exposed on micro service
- Users of API might include
  - Frontend of your app
  - Frontend of other apps using your backend
  - Other servers using your service

APIs for Functions and Classes

V1

```
function sort(elements)
{
    [sort algorithm A]
}
```

```
class Graph
{
    [rep of Graph A]
}
```

Implementation change ↓

Consistent interface

V2

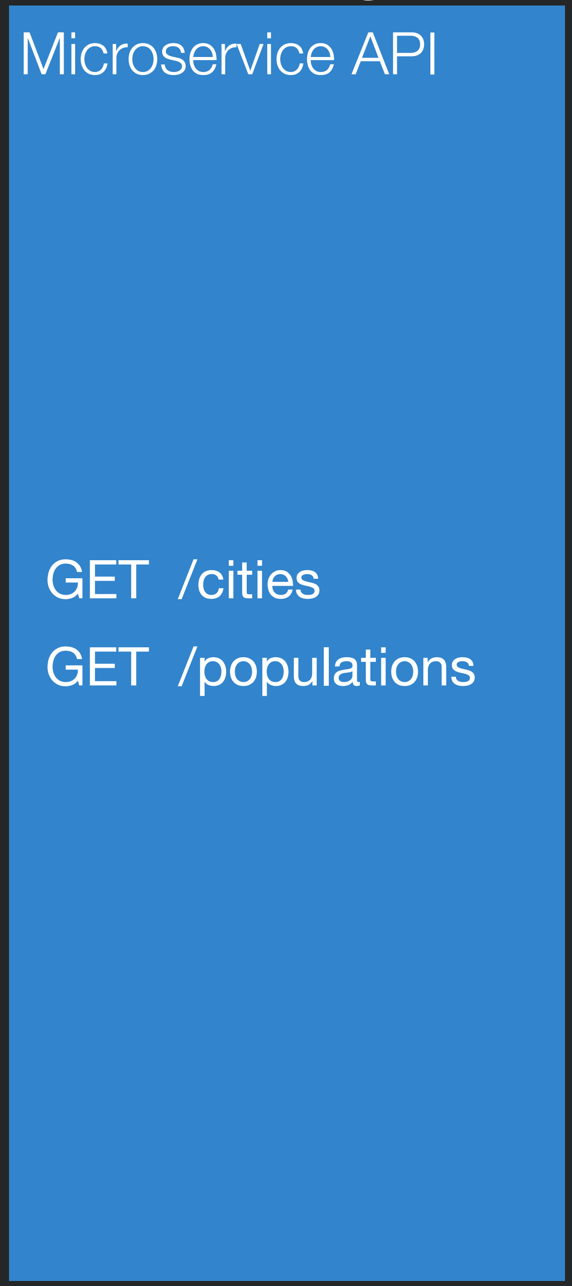
```
function sort(elements)
{
    [sort algorithm B]
}
```

```
class Graph
{
    [rep of Graph B]
}
```

Support Scaling

- Yesterday, cityinfo.org had 10 daily active users. Today, it was featured on several news sites and has 10,000 daily active users.
- Yesterday, you were running on a single server. Today, you need more than a single server.
- Can you just add more servers?
  - What should you have done yesterday to make sure you can scale quickly today?

cityinfo.org



Microservice API

GET /cities

GET /populations

Support Change

- Due to your popularity, your backend data provider just backed out of their contract and are now your competitor.
- The data you have is now in a different format.
- Also, you've decided to migrate your backend from PHP to node.js to enable better scaling.
- How do you update your backend without breaking all of your clients?

cityinfo.org

Microservice API

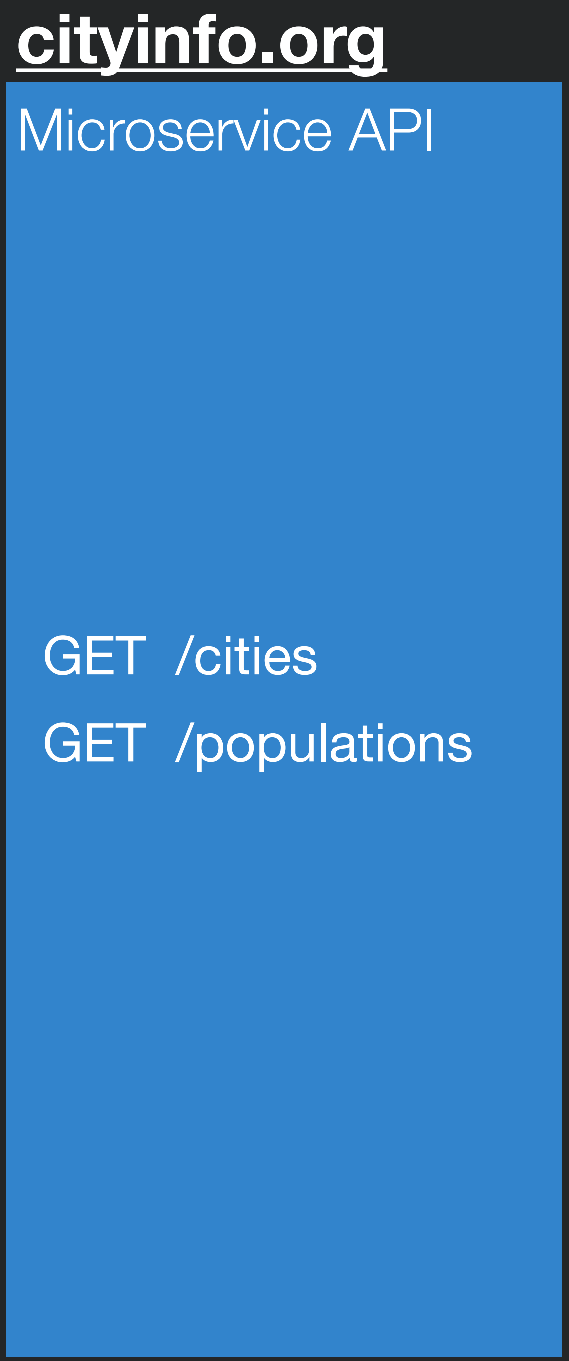
GET /cities

GET /populations

Support Reuse

- You have your own frontend for cityinfo.org. But everyone now wants to build their own sites on top of your city analytics.

- Can they do that?



cityinfo.org

Microservice API

GET /cities

GET /populations

Design Considerations for Microservice APIs

- API: What requests should be supported?
- Identifiers: How are requests described?
- Errors: What happens when a request fails?
- Heterogeneity: What happens when different clients make different requests?
- Caching: How can server requests be reduced by caching responses?
- Versioning: What happens when the supported requests change?

REST: REpresentational State Transfer

- Defined by Roy Fielding in his 2000 Ph.D. dissertation
  - Used by Fielding to design HTTP 1.1 that generalizes URLs to URIs
  - http://www.ics.uci.edu/~fielding/pubs/dissertation/fielding_dissertation.pdf
- *"Throughout the HTTP standardization process, I was called on to defend the design choices of the Web. That is an extremely difficult thing to do… I had comments from well over 500 developers, many of whom were distinguished engineers with decades of experience. That process honed my model down to a core set of principles, properties, and constraints that are now called REST."*
- Interfaces that follow REST principles are called RESTful

Properties of REST

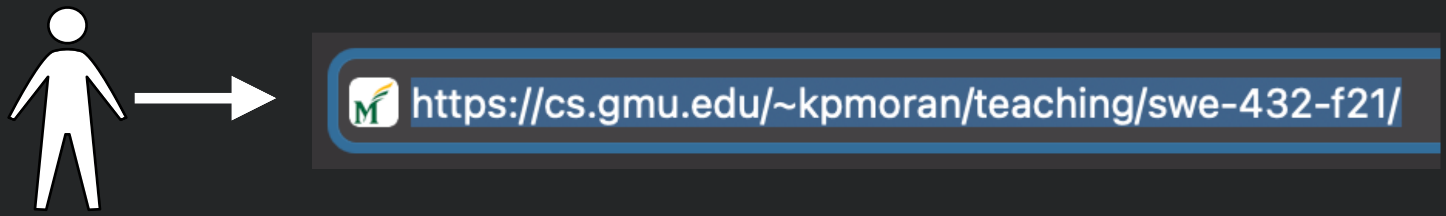
- Performance
- Scalability
- Simplicity of a Uniform Interface
- Modifiability of components (even at runtime)
- Visibility of communication between components by service agents
- Portability of components by moving program code with data
- Reliability

Principles of REST

- Client server: separation of concerns (reuse)
- Stateless: each client request contains all information necessary to service request (scaling)
- Cacheable: clients and intermediaries may cache responses. (scaling)
- Layered system: client cannot determine if it is connected to end server or intermediary along the way. (scaling)
- Uniform interface for resources: a single uniform interface (URIs) simplifies and decouples architecture (change & reuse)

HTTP: HyperText Transfer Protocol

High-level protocol built on TCP/IP that defines how data is transferred on the web



https://cs.gmu.edu/~kpmoran/teaching/swe-432-f21/

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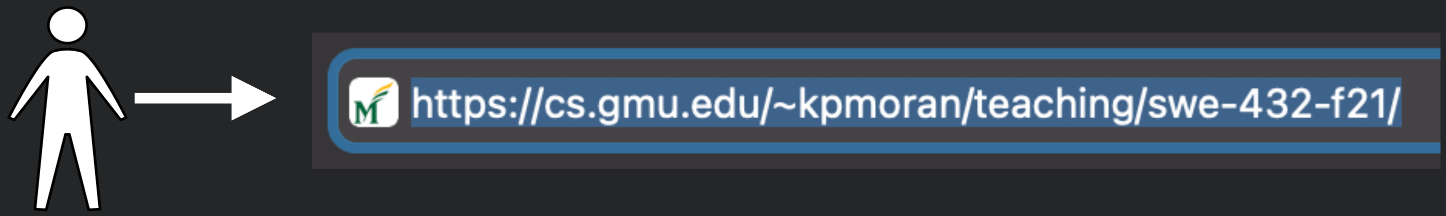

https://cs.gmu.edu/~kpmoran/teaching/swe-432-f21/

HTTP Request

```
GET /~kpmoran/swe-432-f21.html HTTP/1.1
Host: cs.gmu.edu
Accept: text/html
```

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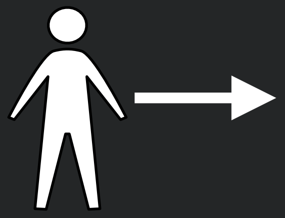

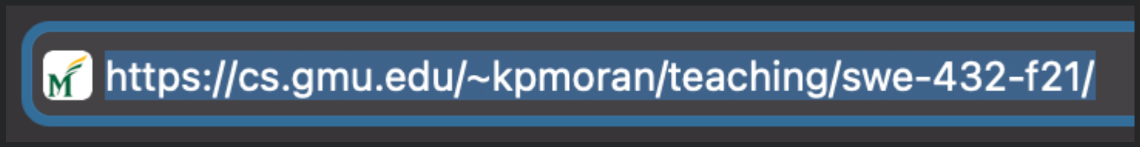

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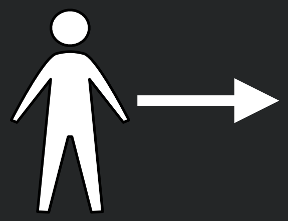

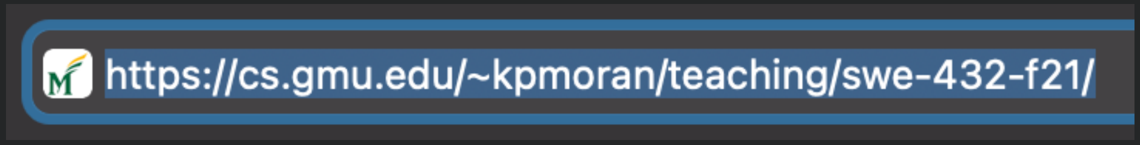

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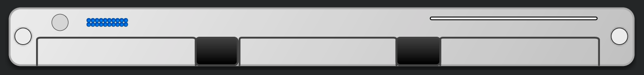
web server



HTTP Request

```
GET /~kpmoran/swe-432-f21.html HTTP/1.1
Host: cs.gmu.edu
Accept: text/html
```

Reads file from disk

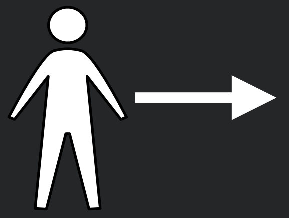
HTTP Response

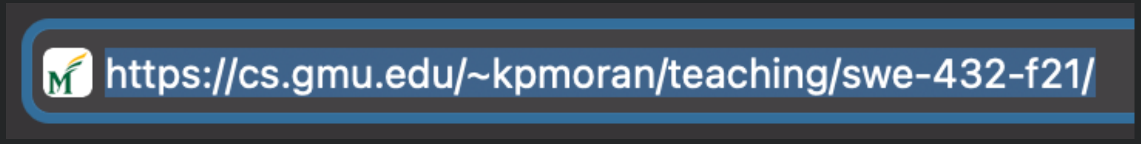
```
HTTP/1.1 200 OK
Content-Type: text/html; charset=UTF-8

<html><head>...
```

HTTP: HyperText Transfer Protocol

High-level protocol built on TCP/IP that defines how data is transferred on the web





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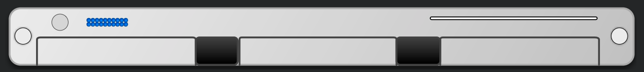

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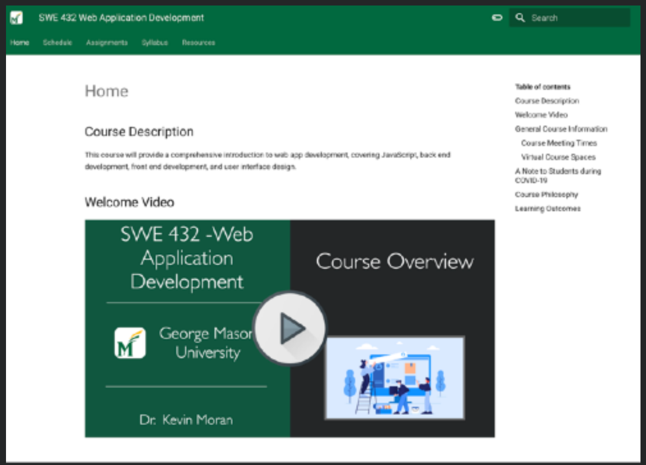


SWE 432 Web Application Development

Home

Course Description

This course will provide a comprehensive introduction to web app development, covering JavaScript, back end development, front end development, and user interface design.

Welcome Video

Table of contents
Course Description
Welcome Video
General Course Information
Course Meeting Times
Virtual Course Spaces
A Note to Students during COVID-19
Course Philosophy
Learning Outcomes

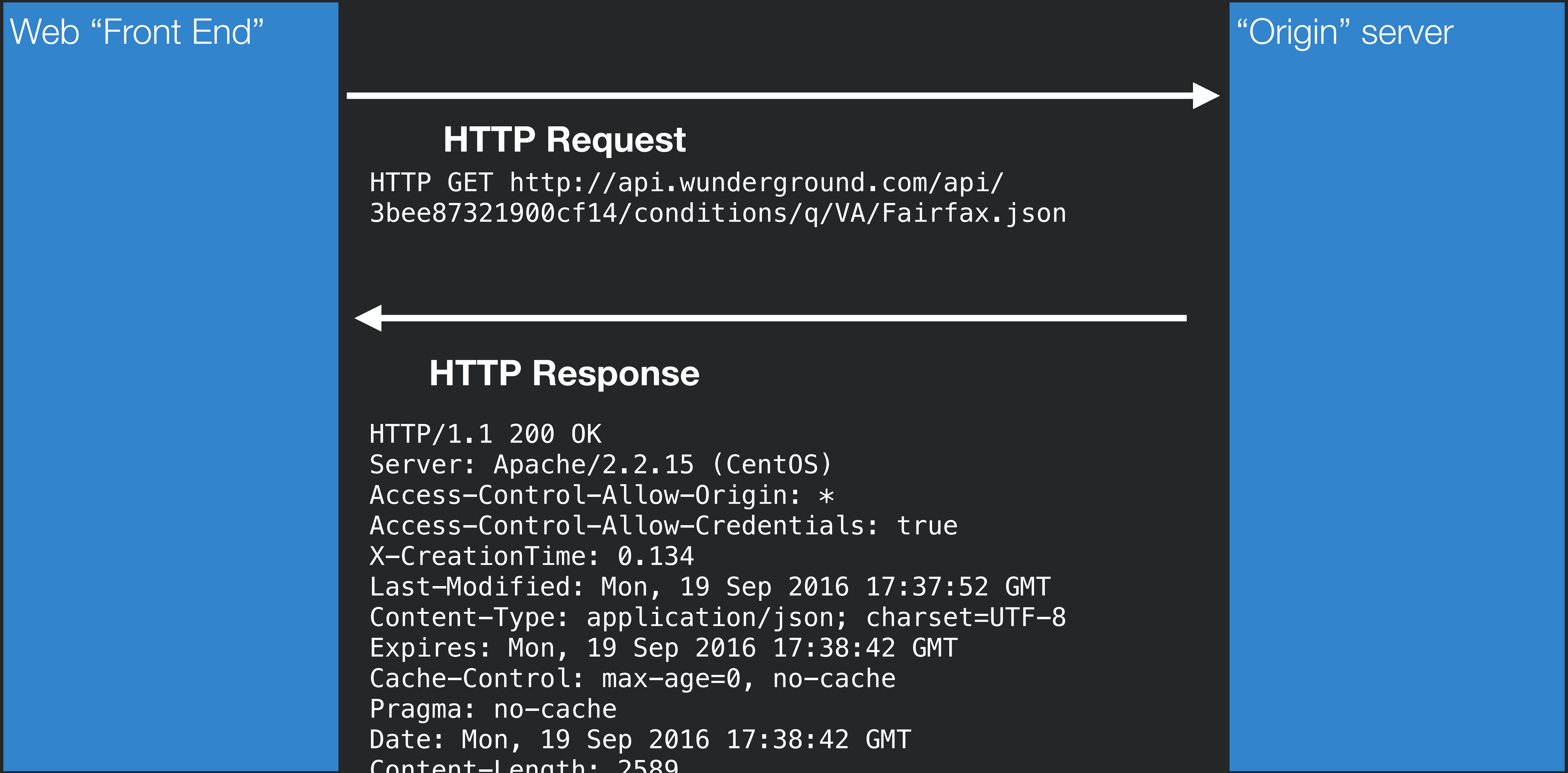
Uniform Interface for Resources

- Originally files on a web server
  - URL refers to directory path and file of a resource
- But… URIs might be used as an identity for any entity
  - A person, location, place, item, tweet, email, detail view, like
  - *Does not matter* if resource is a file, an entry in a database, retrieved from another server, or computed by the server on demand
  - Resources offer an *interface* to the server describing the resources with which clients can interact

URI: Universal Resource Identifier

- Uniquely describes a resource
  - https://mail.google.com/mail/u/0/#inbox/157d5fb795159ac0
  - https://www.amazon.com/gp/yourstore/home/ref=nav_cs_ys
  - http://gotocon.com/dl/goto-amsterdam-2014/slides/StefanTilkov_RESTIDontThinkItMeansWhatYouThinkItDoes.pdf
  - Which is a file, external web service request, or stored in a database?
    - It does not matter
- As client, only matters what actions we can *do* with resource, not how resource is represented on server

Intermediaries



Web “Front End”

“Origin” server

HTTP Request

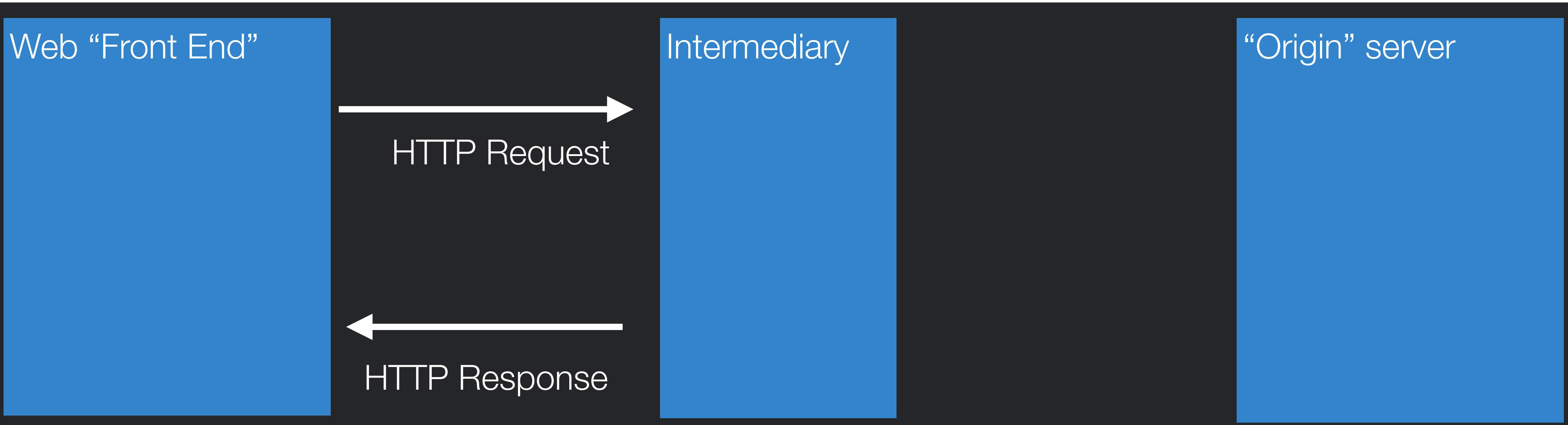
```
HTTP GET http://api.wunderground.com/api/
3bee87321900cf14/conditions/q/VA/Fairfax.json
```

HTTP Response

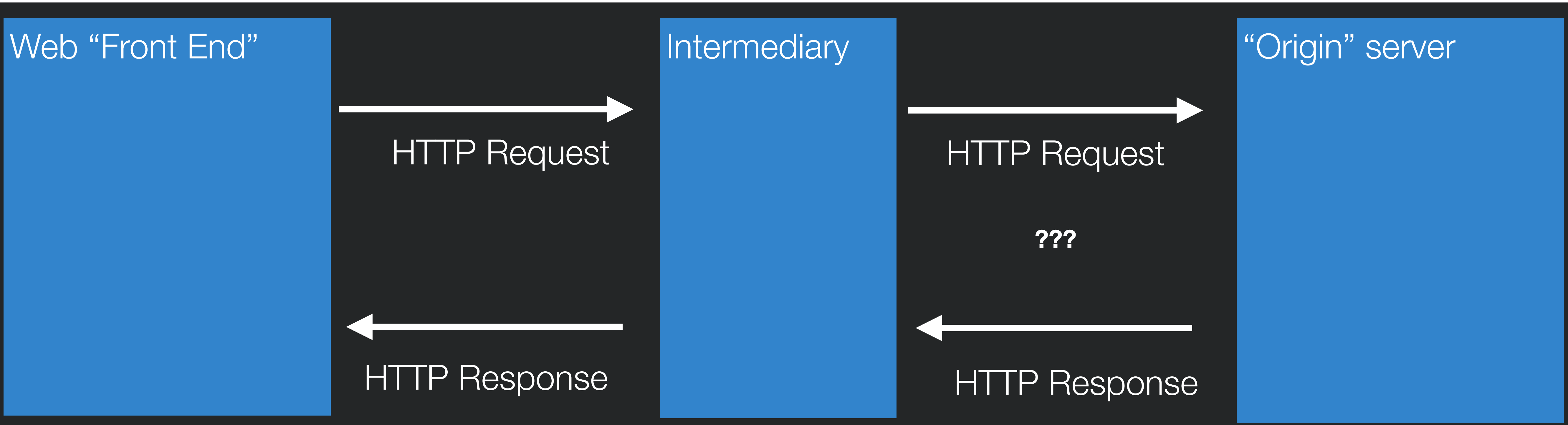
```
HTTP/1.1 200 OK
Server: Apache/2.2.15 (CentOS)
Access-Control-Allow-Origin: *
Access-Control-Allow-Credentials: true
X-CreationTime: 0.134
Last-Modified: Mon, 19 Sep 2016 17:37:52 GMT
Content-Type: application/json; charset=UTF-8
Expires: Mon, 19 Sep 2016 17:38:42 GMT
Cache-Control: max-age=0, no-cache
Pragma: no-cache
Date: Mon, 19 Sep 2016 17:38:42 GMT
Content-Length: 2589
Connection: keep-alive
```

```
{
  "response": {
  "version":"0.1"
```

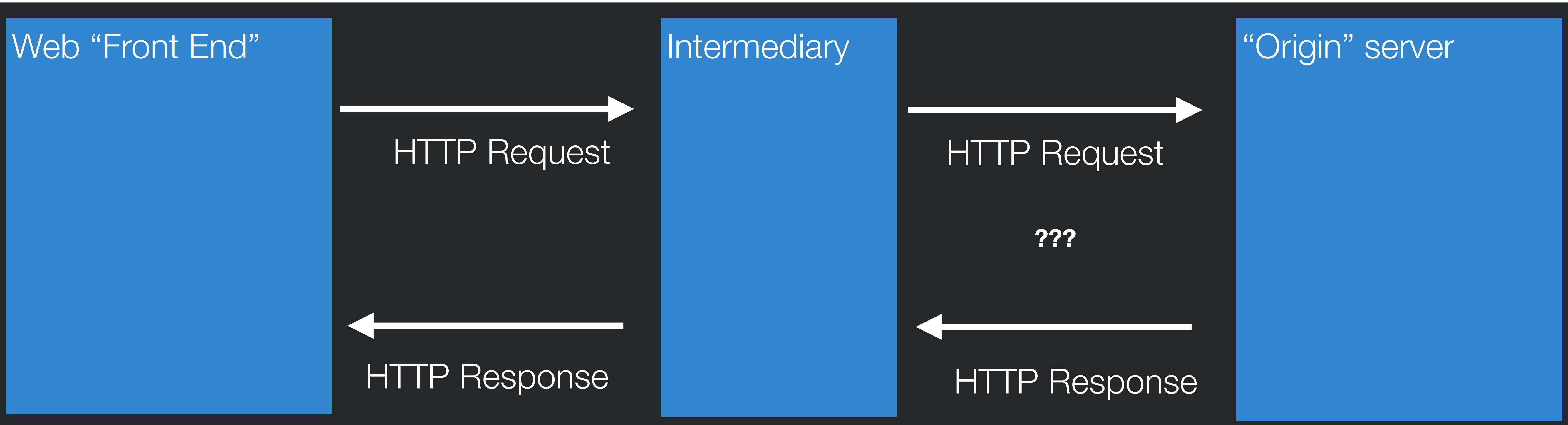
Intermediaries



Intermediaries



Intermediaries



- Client interacts with a resource identified by a URI
- But it never knows (or cares) whether it interacts with origin server or an unknown intermediary server
  - Might be randomly load balanced to one of many servers
  - Might be cache, so that large file can be stored locally
    - (e.g., GMU caching an OSX update)
  - Might be server checking security and rejecting requests

Challenges with intermediaries

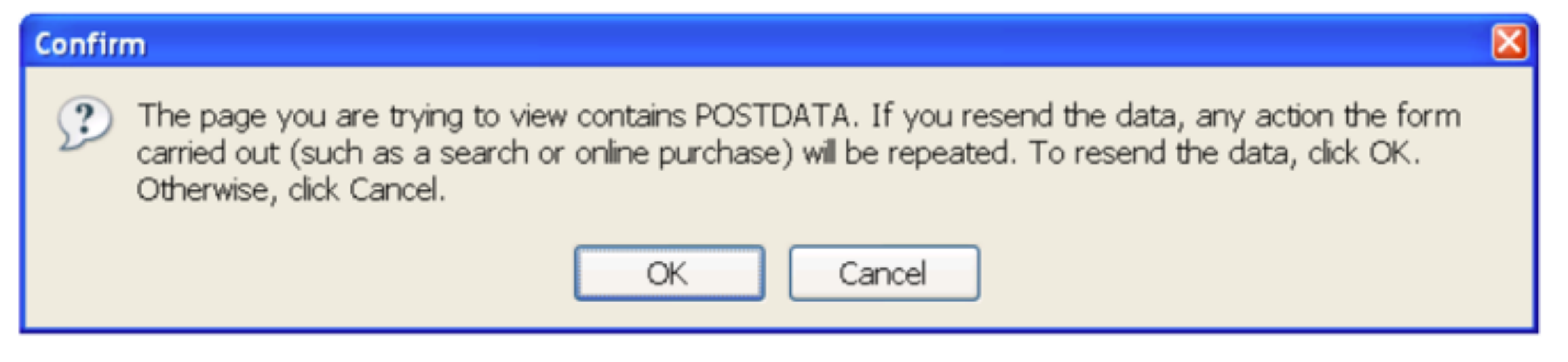
- But can all requests really be intercepted in the same way?
  - Some requests might produce a change to a resource
    - Can’t just cache a response… would not get updated!
  - Some requests might create a change every time they execute
    - Must be careful retrying failed requests or could create extra copies of resources

HTTP Actions

- How do intermediaries know what they can and cannot do with a request?
- Solution: HTTP Actions
  - Describes what will be done with resource
  - GET: retrieve the current state of the resource
  - PUT: modify the state of a resource
  - DELETE: clear a resource
  - POST: initialize the state of a new resource

HTTP Actions

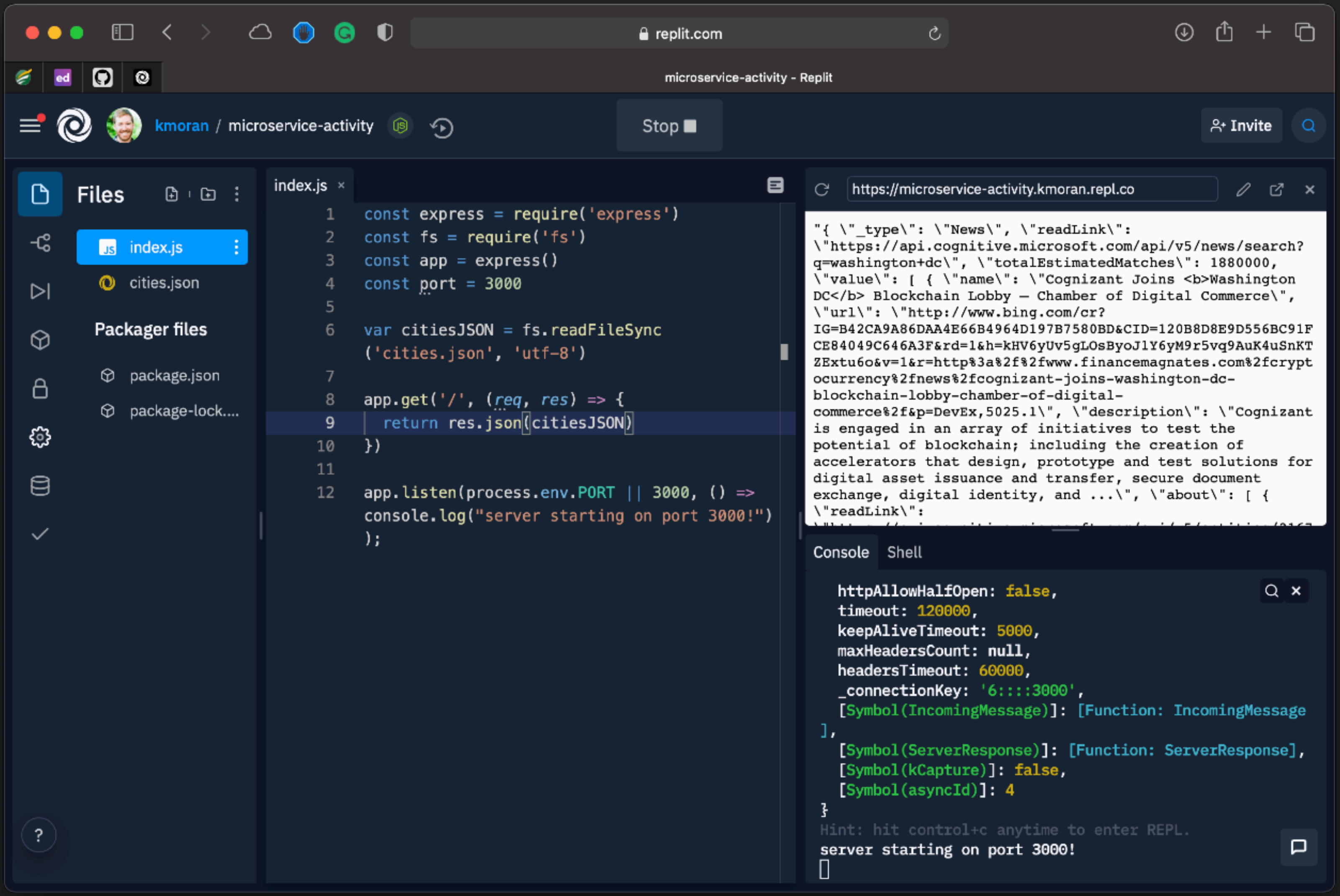
- GET: safe method with no side effects
  - Requests can be intercepted and replaced with cache response
- PUT, DELETE: idempotent method that can be repeated with same result
  - Requests that fail can be retried indefinitely till they succeed
- POST: creates new element
  - Retrying a failed request might create duplicate copies of new resource



The page you are trying to view contains POSTDATA. If you resend the data, any action the form carried out (such as a search or online purchase) will be repeated. To resend the data, click OK. Otherwise, click Cancel.

In-Class Activity: Exploring Express

Try creating a few different endpoints with different response types!


replit.com
microservice-activity - Replit
kmoran / microservice-activity
Stop
Invite
Files
index.js
cities.json
Packager files
package.json
package-lock....
https://microservice-activity.kmoran.repl.co
Console
Shell

```javascript
const express = require('express')
const fs = require('fs')
const app = express()
const port = 3000

var citiesJSON = fs.readFileSync('cities.json', 'utf-8')

app.get('/', (req, res) => {
  return res.json(citiesJSON)
})

app.listen(process.env.PORT || 3000, () => console.log("server starting on port 3000!"));
```

```
"{ \"_type\": \"News\", \"readLink\":
\"https://api.cognitive.microsoft.com/api/v5/news/search?
q=washington+dc\", \"totalEstimatedMatches\": 1880000,
\"value\": [ { \"name\": \"Cognizant Joins <b>Washington
DC</b> Blockchain Lobby – Chamber of Digital Commerce\",
\"url\": \"http://www.bing.com/cr?
IG=B42CA9A86DAA4E66B4964D197B7580BD&CID=120B8D8E9D556BC91F
CE84049C646A3F&rd=1&h=kHV6yUv5gLOsByoJ1Y6yM9r5vq9AuK4uSnKT
ZExtu6o&v=1&r=http%3a%2f%2fwww.financemagnates.com%2fcrypt
ocurrency%2fnews%2fcognizant-joins-washington-dc-
blockchain-lobby-chamber-of-digital-
commerce%2f&p=DevEx,5025.1\", \"description\": \"Cognizant
is engaged in an array of initiatives to test the
potential of blockchain; including the creation of
accelerators that design, prototype and test solutions for
digital asset issuance and transfer, secure document
exchange, digital identity, and ...\", \"about\": [ {
\"readLink\":
```

```
  httpAllowHalfOpen: false,
  timeout: 120000,
  keepAliveTimeout: 5000,
  maxHeadersCount: null,
  headersTimeout: 60000,
  _connectionKey: '6::::3000',
  [Symbol(IncomingMessage)]: [Function: IncomingMessage
],
  [Symbol(ServerResponse)]: [Function: ServerResponse],
  [Symbol(kCapture)]: false,
  [Symbol(asyncId)]: 4
}
Hint: hit control+c anytime to enter REPL.
server starting on port 3000!
```

https://replit.com/@kmoran/microservice-activity#index.js

This will also be posted to Ed

Acknowledgements

Slides adapted from Dr. Thomas LaToza's SWE 632 course