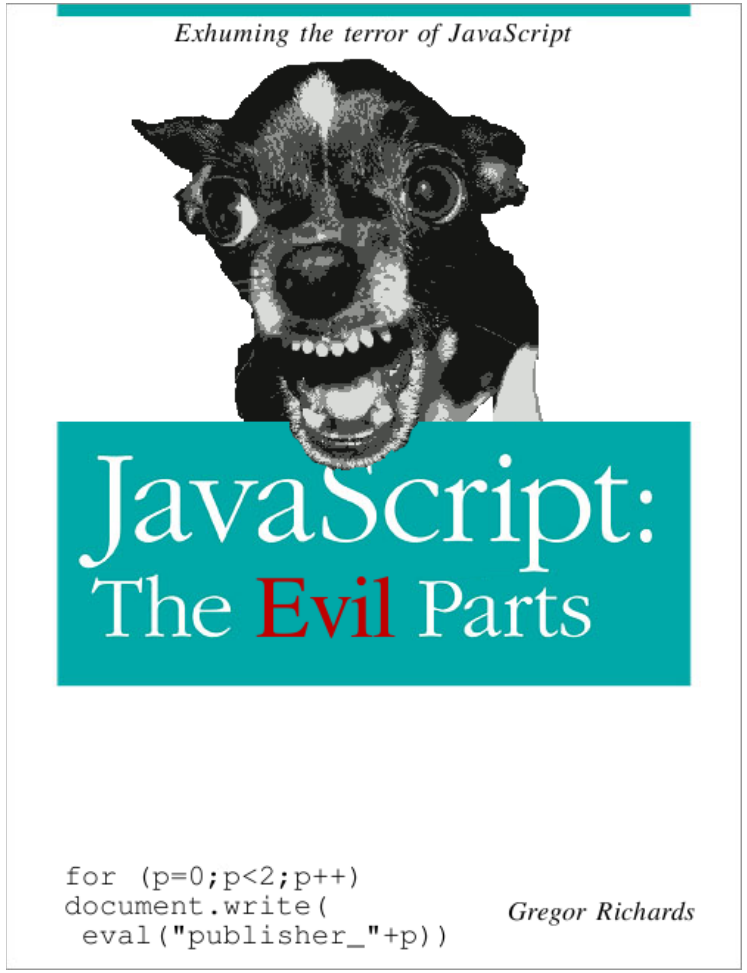
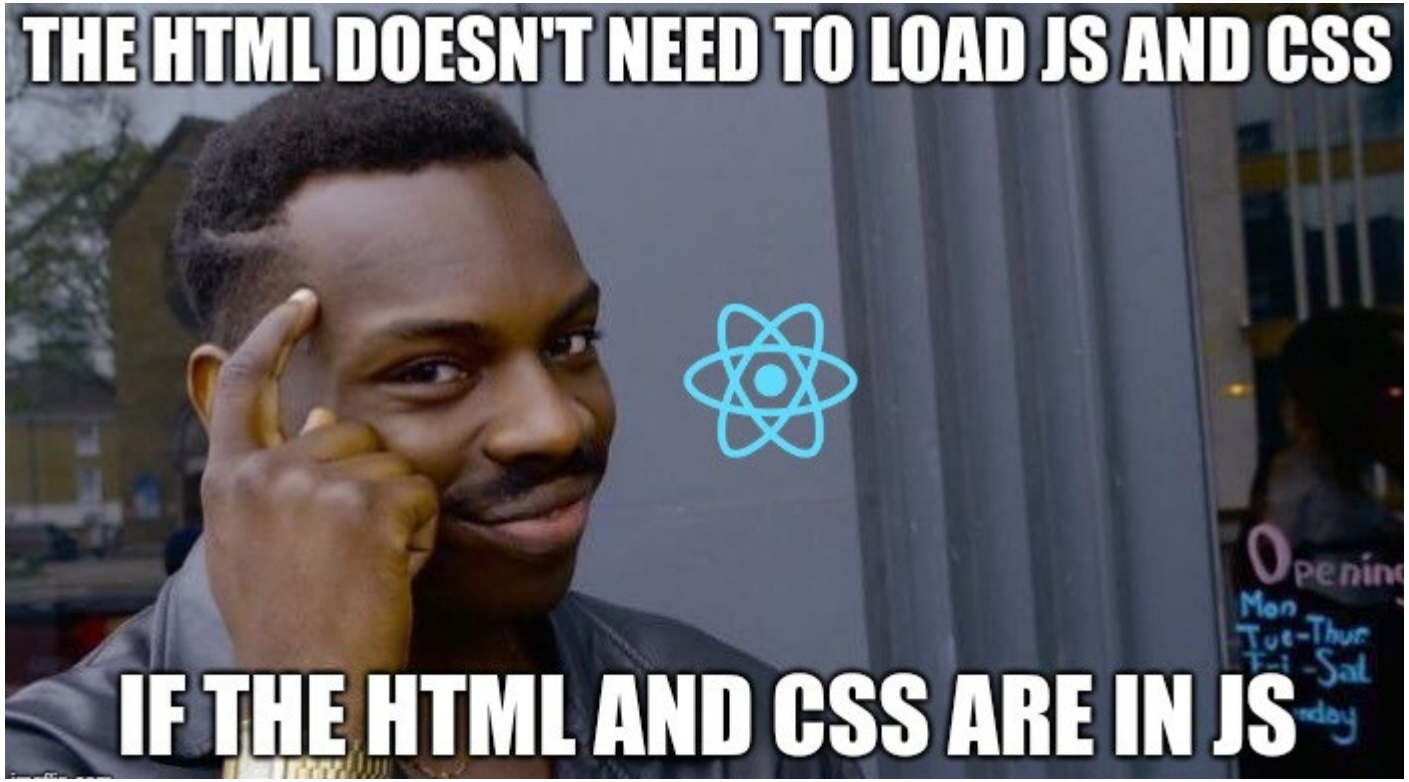
# JS II: client-side applications



# Review: JavaScript Part 1

- JavaScript is a *prototypical object-oriented language* with *functional* and *imperative* features
  - Everything is an object in JavaScript (including functions)
  - You can create objects using “new NameOfConstructorFunction(…);”
  - Objects “inherit from” a prototype object associated with that class’s constructor function

    function Book(x) { this.author = x; };  b1 = new Book();

    “Book” is itself an object (it inherits the Function prototype)

    B1 is a Book object (it inherits the Book prototype)
- JavaScript uses an **event queue** to manage asynchronous events
  - Like browser events, timeouts, and networking events

# Review: Exam-style Exercise

- What is the output of this code?

```
function f() {
  console.log(‘beginning');
  function callback1() {
    console.log('callback1');
  }
  setTimeout(callback1, 1000); //1s
  console.log('middle');
  function callback2() {
    console.log('callback2');
  }
  setTimeout(callback2, 2000); //2s
  console.log('end');
}
f();
```

# Review: Exam-style Exercise

- What is the output of this code?

```
function f() {
  console.log(‘beginning');
  function callback1() {
    console.log('callback1');
  }
  setTimeout(callback1, 1000); //1s
  console.log('middle');
  function callback2() {
    console.log('callback2');
  }
  setTimeout(callback2, 2000); //2s
  console.log('end');
}
f();
```

Beginning
Middle
End
Callback1
Callback2

**Critical:** setTimeout *queues an event in the event queue*. It returns immediately

If function **f()** is called at time **0**, then **callback1** is scheduled to run at time **1000**, and **callback2** at time **2000**
(jitter and precision notwithstanding)

# Review: JavaScript Event Queue

- Much like the runtime stack and heap, JavaScript's runtime environment includes an event queue for managing asynchronous events

- **Consider**: What would happen if we didn't have an event queue to manage UI events?
  - Click a button, send HTTP request, *wait for response*, then let the UI update

- The event queue is a hack that allows us to design UIs without hanging and without multithreading (JS is single-threaded)

# One-Slide Summary: JavaScript part 2

- We have already seen how we can **modify the DOM** by placing random strings of HTML into various elements
  - Document API: document.getElementById(“blah”).innerHTML = “ Hi ”
- We can construct **arbitrarily complicated DOM subtrees** by creating DOM tree nodes manually and modifying DOM node relationships
  - Create a node, assign it as a child of another node, etc.
- We can use the **fetch** API to generate HTTP requests within JavaScript to reach REST API endpoints
  - Then, we can use the JSON returned to inform our DOM modifications
- We use frameworks like **React** to simplify DOM modifications
  - They’re *slow* – Reach uses a **virtual DOM** to speed up batches of changes

# Outline

- **Review: event-driven programming**
- Building DOM in JavaScript from JSON
- Fetch API and Promises
- Closures
- Frameworks

# Review: Event-driven programming

```
let count = 0;
function callback() {
   count++;
   if (count < 2) {
      setTimeout(callback, 0);
   }
   console.log(count);
}

setTimeout(callback, 0);
// what will print?
```

# Common mistake: for-in loops

- `for-in` loops often yield unexpected results
  - They iterate "up the prototype chain"

```
> const chickens = ['Magda', 'Marilyn', 'Myrtle II'];
> for (let chicken in chickens) {
>   console.log(chicken);
> }
1
2
3
```

- ES6's for-of loops are nice, but are hard to analyze statically, so some style guides do not allow them

```
> for (let chicken of chickens) {
>   console.log(chicken);
> }
Magda
Marilyn
Myrtle II
```

# Iteration with `forEach` and `map`

- `forEach` loops "do the right thing"
  - Behave like other programming languages (C, C++, Perl, Python ...)
  - We'll learn about the => syntax soon (it's an anonymous function)

```
const chickens = ['Magda', 'Marilyn', 'Myrtle II'];

chickens.forEach((chicken) => {
  console.log(chicken);
});
```

- `map` is another nice option
  - Use it to transform an array into another array

```
const chickens_say = chickens.map(chicken => (
  `${chicken} says cluck`
));
console.log(chickens_say);
//[ 'Magda says cluck', 'Marilyn says cluck',
//  'Myrtle II says cluck' ]
```

# JavaScript: functional programming

- In **functional programming**, execution occurs **by composing functions** together *rather than* executing sequences of *statements*
- Example:

```
function myCalcImperative() {
  let x = [1, 2, 3, 4, 5];
  let result = 0;
  for (let i=0; i<x.length; i++) {
    if (x[i] % 2 === 0) {
      result += x[i] * 10;
    }
  }
  return result;
}
```

```
function myCalcFunctional1() {
  let x = [1, 2, 3, 4, 5];

  return x.filter( n => n % 2 === 0)
          .map(a => a * 10)
          .reduce( (a,b) => a + b );
}
```

# JavaScript: functional programming

- In **functional programming**, execution occurs **by composing functions** together *rather than* executing sequences of *statements*
- Example (alternate):

```
function myCalcFunctional2() {
  let x = [1, 2, 3, 4, 5];
  let result = 0;

  let filteredX = [];
  x.forEach( n => if (n % 2 === 0) filteredX.push( n ); );
  filteredX.forEach( n => n * 10; );
  filteredX.forEach( n => result += n; );
  return result;
}
```

# JavaScript: Functional programming??

- Consider this scenario:
  - User clicks a button
  - Browser sends a POST request
  - Browser waits for server response
  - Browser renders changes in DOM tree
- Looks something like this in JavaScript:

```
document.getElementById("myButton").onclick = function () {
  makePostRequest("api.lol.com/api/path",
                  {"subject": "hello", "text": "world"},
                  onSuccessFunction,
                  onFailFunction);
}
```

# JavaScript: Functional programming??

- Consider this scenario:
  - User clicks a button
  - Browser sends a POST request
  - Browser waits for server response
  - Browser renders changes in DOM tree
- Looks something like this in JavaScript:

```
document.getElementById("myButton").onclick = function () {
  makePostRequest("api.lol.com/api/path",
                  {"subject": "hello", "text": "world"},
                  function( data ) { /* do some changes to DOM based on data */},
                  function( data ) { /* do some failure handling */);
}
```

# JavaScript: Functional programming

- **Note**: the onclick function handler runs when the button gets clicked
  - *We don't want the browser to "freeze" when the user clicks the button*
  - **Instead**, we *schedule events* in the event queue to occur:
    - Immediately make a POST request
    - Schedule a onSuccessFunction to run when the request finishes
    - Schedule a onFailFunction to run if the request fails (e.g., server doesn't respond)
  - This way, we don't have to wait around for the server on every UI event

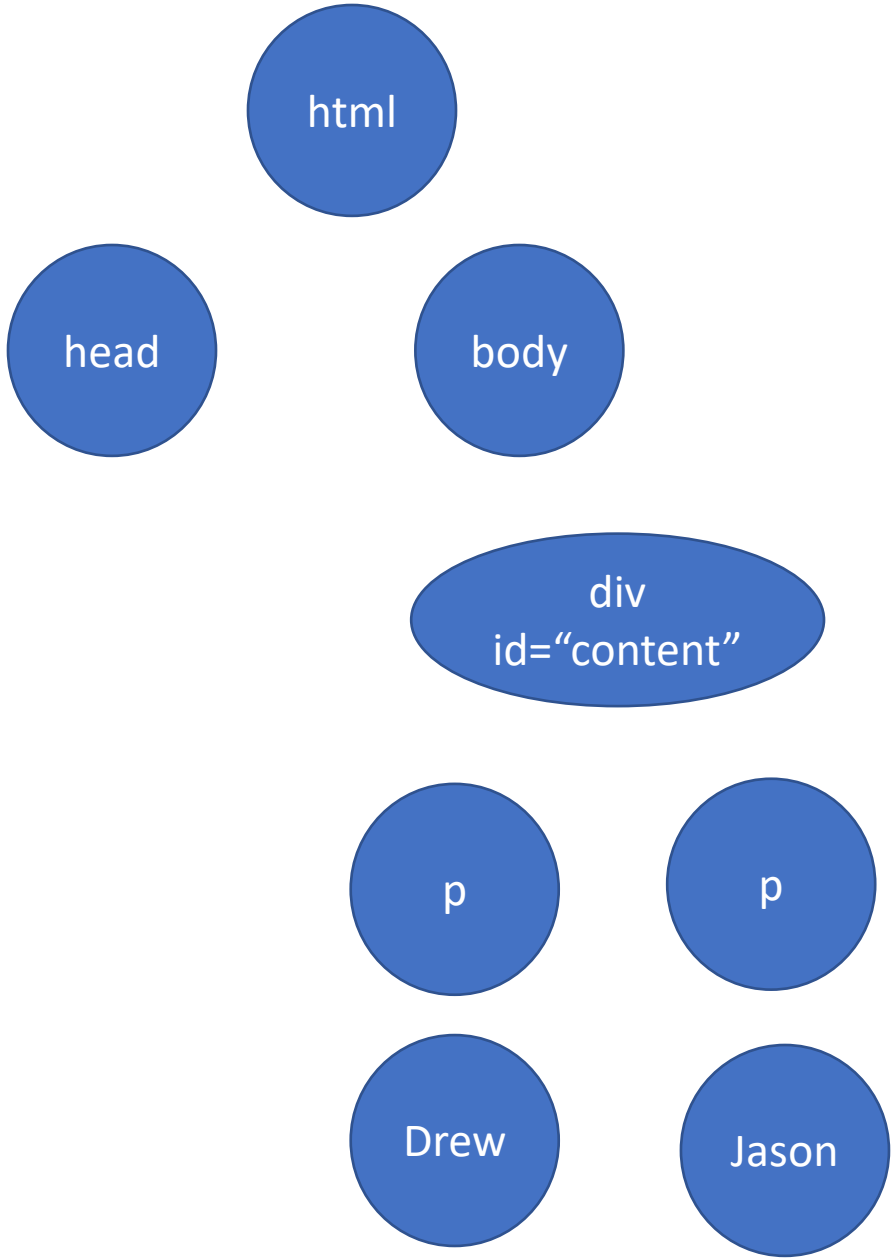
```
document.getElementById("myButton").onclick = function () {
  makePostRequest("api.lol.com/api/path",
                  {"subject": "hello", "text": "world"},
                  onSuccessFunction,
                  onFailFunction);
}
```

# Outline

- Review: event-driven programming
- **Building DOM in JavaScript from JSON**
- Fetch API and Promises
- Closures
- Frameworks

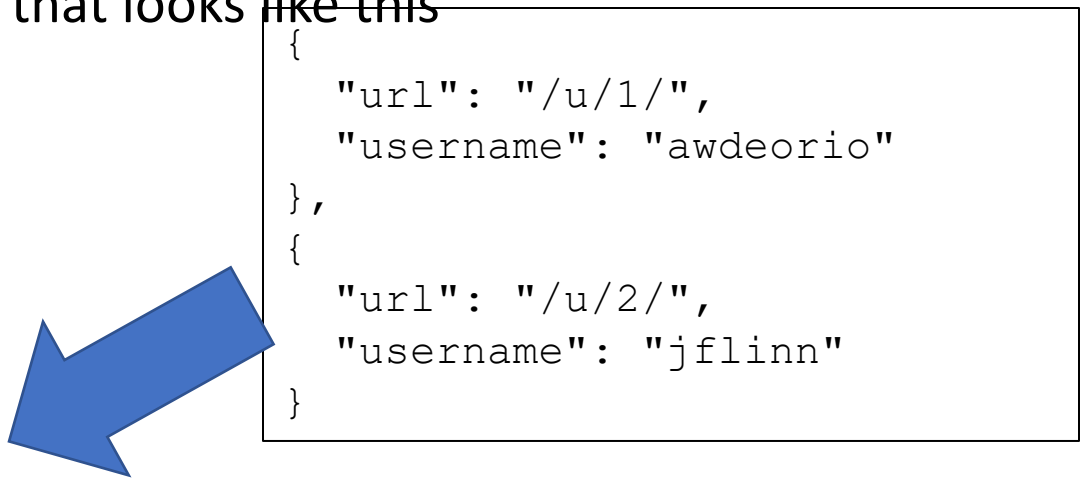
# DOM Review

```
<html>
  <head></head>
  <body>
    <div id="content">
      <p>Drew DeOrio</p>
      <p>Jason Flinn</p>
    </div>
  </body>
</html>
```



# Overview

- Turn JSON data into a webpage that looks like this



```
{
  "url": "/u/1/",
  "username": "awdeorio"
},
{
  "url": "/u/2/",
  "username": "jflinn"
}
```

```
<html>
  <head></head>
  <body>
    <div id="content">
      <p class="user">awdeorio's link <a href="/u/1/">here</a></p>
      <p class="user">jflinn's link <a href="/u/2/">here</a></p>
    </div>
  </body>
</html>
```

```
myObj.forEach( user => {
    // make <p>
    let myNewParagraph = document.createElement('p');
    // make it <p class="user">
    myNewParagraph.setAttribute('class', 'user');

    //Make the string to go inside
    let myString = document.createTextNode("User "+user.username+"'s link ");

    // Make the link
    let newLink = document.createElement('a');
    newLink.setAttribute('href', user.url);
    // make Link text ("here")
    let newLinkText = document.createTextNode("here");

    // put link text in link
    newLink.appendChild(newLinkText);

    // put myString and newLink inside the paragraph
    myNewParagraph.appendChild(myString);
    myNewParagraph.appendChild(newLink);

    // append this DOM subtree into the content Div
    myDivElement.appendChild(myNewParagraph);
});
```

# Outline

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- **Fetch API and Promises**
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# Fetch

- JavaScript provides a “fetch” API for making HTTP requests
- These do not require browser reloads

- Idea: use fetch to make requests of a REST API
  - API responds with JSON object
  - Use JSON to update DOM in some way

- Example: client request “fetch post ID 50”
  Server responds OK “{ ‘author’ : ‘kevin’, ‘content’: ‘hello’}

# Fetch API

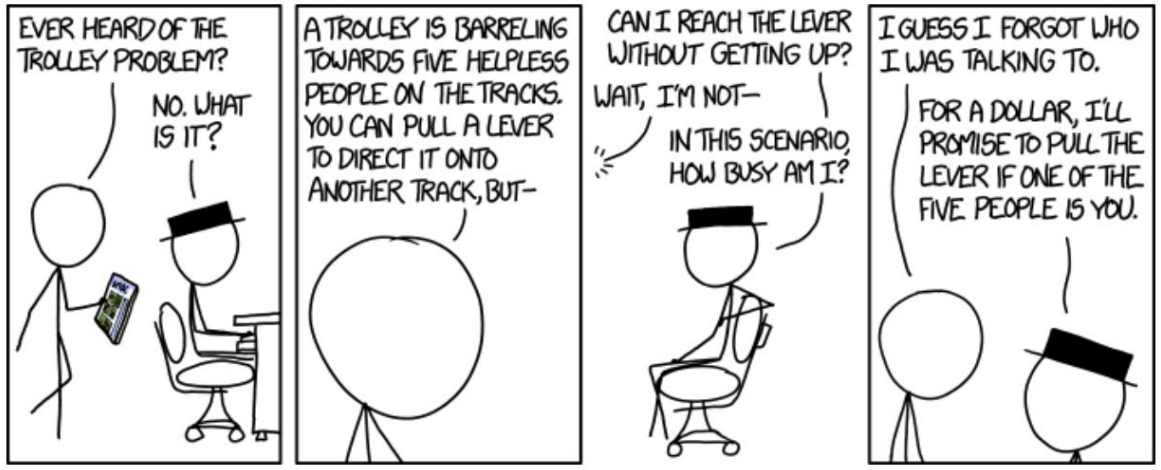
- How JavaScript requests data from a REST API
- JavaScript function that loads data from the server
- Returns a "promise"

```
fetch("https://dijkstra.eecs.umich.edu/kleach/eecs485/su20/s/users.json")
    .then(handleResponse)
    .then(handleData);
```

# Promises

- Promise: a function that returns some time in the future
  - Put a function call on the event queue
- Needed for fetch because request/response is not instant
  - Recall: JavaScript is single-threaded.  We don't want the UI to freeze up while the request is being serviced

```
fetch("https://dijkstra.eecs.umich.edu/kleach/eecs485/su20/s/users.json")
    .then(handleResponse)
    .then(handleData);
```



# Outline

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- Building DOM in JavaScript from JSON
- Fetch API and Promises
- **Closures**
- Frameworks

# Closures

```
function outer() {
   let x = 0;
   function inner() {
      x++;
      console.log(x);
   }
   return inner;
}

let f = outer();
f();
f();
```

Notice: *f* is a function pointer to “inner” (the thing returned by “outer”)

# Closures

- Notice that the inner function has access to outer function's variables
- Lexically scoped name binding
- This is called a closure

```
function showUsers() {
  const entry = document.getElementById('JSEntry');
  //...
  function handleData(data) {
    //...
    entry.appendChild(node);
  }
  fetch(/* ... */) // ...
}
```

# Closures

```
function showUsers() {
  const entry = document.getElementById('JSEntry');

  function handleResponse(response) { /*... */ }

  function handleData(data) {
    // ...
    entry.appendChild(node);
  }

  fetch(/*...*/)
    .then(handleResponse)
    .then(handleData)
    .catch(error => console.log(error));
}
```

- The inner function has a longer lifetime than the outer function
- `handleData()` has access to `entry` even though `showUsers()` has already returned!

# Closures in the interpreter

```
function showUsers() {
  const entry = /*...*/;

  function handleResponse(response)
  { /*...*/ }

  function handleData(data) {
    // ...
    entry.appendChild(node);
  }

  fetch(/*...*/)
    .then(handleResponse)
    .then(handleData)
}
```

1. Objects created for `entry`, `handleResponse`, `handleData`
2. `fetch` function executes
   1. Enqueue callbacks `handleResponse`, `handleData`
   2. `fetch` returns before response arrives
3. .... wait for response
4. Later, response arrives and `handleResponse` executes
5. Later, JSON data is ready and `handleData` executes

# Why closures important in web development

- Callback Functions are everywhere
  - Event handlers: click
  - Promise handlers: .then()

- These functions need to remember their context
  - Remember that execution keeps going past a fetch() call

# Anonymous functions

- These callback functions are used only once

```
function showUsers() {
  const entry = document.getElementById('JSEntry');

  function handleResponse(response) {/*... */}

  function handleData(data) {/*...*/}

  fetch('/api/v1/users/')
    .then(handleResponse)
    .then(handleData);
}
```

# Anonymous functions

- Refactor to use *anonymous functions*

```
function showUsers() {
  const entry = document.getElementById('JSEntry');

  function handleResponse(response) {/*... */}

  function handleData(data) {/*...*/}

  fetch('/api/v1/users/')
    .then(function(response) {
      //...
    })
    .then(function(data) {
      //...
    })
}
```

# Anonymous functions

- Works exactly the same way as when the functions had names
- Also called a lambda function or function literal

```
function showUsers() {
  const entry = document.getElementById('JSEntry');


  fetch('/api/v1/users/')
    .then(function(response) {
      //...
    })
    .then(function(data) {
      //...
    })
}
```

# Anonymous functions in ES6

- ES6 provides a convenient syntax for anonymous functions
- "Arrow functions"

```
function showUsers() {
  const entry = document.getElementById('JSEntry');


  fetch('/api/v1/users/')
    .then((response) => {
      //...
    })
    .then((data) => {
      //...
    })
}
```

# Anonymous functions in ES6

- Anatomy of an anonymous function
  - Inputs
  - Body
  - Arrow
- Creates a function object on the heap
  - Just like "regular" functions
- Long format

```
(INPUTS) => {
  // BODY
}
```

- Short cut for body with one function call

```
INPUT => my_function(INPUT)
```

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- **Frameworks**

# A problem with raw JavaScript

- Large JavaScript applications quickly become unwieldly
- All functions act on the DOM, DOM acts like a giant global variable
- Difficult to decompose program into abstractions

```
function showUser() {
  fetch()
  .then(function(data) {
      const users = data.results;
      users.forEach((user) => {
        const node = document.createElement('p');
        //...
        node.appendChild(textnode);
        entry.appendChild(node);
      });
    })
//...
```

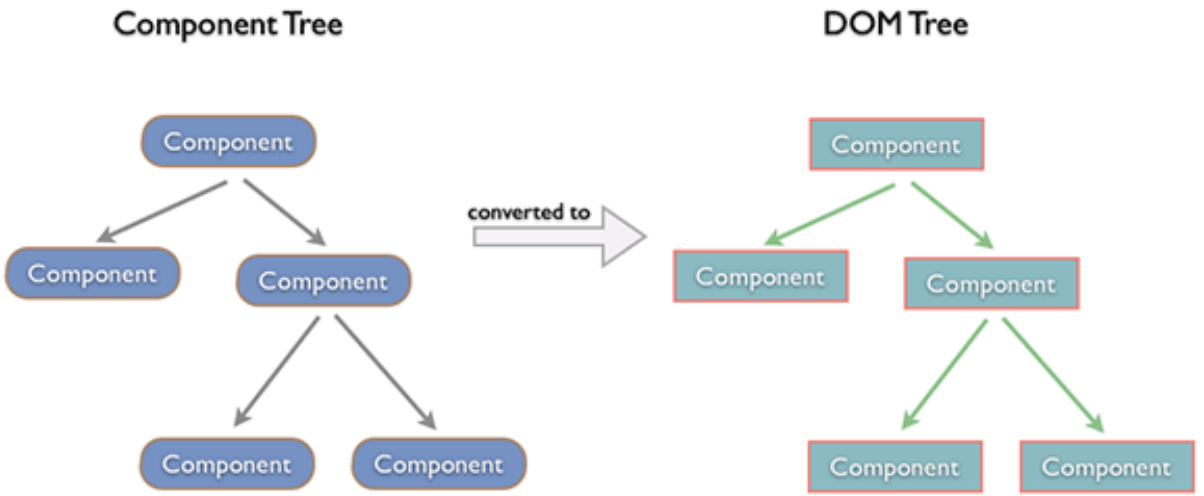
# React

- React is a framework built by Facebook
- Build encapsulated components that manage their own state
  - Compose them to make complex UIs
- Efficient updates to the DOM

- https://reactjs.org/

# React

- Components
  - Functional: usually stateless
  - Class-type: usually stateful
- Tree of composable components -> DOM



# Virtual DOM

- Components rendering cause other components to render
- This would cause lots of DOM updates, which are slow
  - Because the actual screen changes
- Solution: a Virtual DOM

- Periodically reconcile virtual DOM with real DOM
  - Avoids unnecessary changes

- For lots of details: https://reactjs.org/docs/reconciliation.html

# React documentation

- Required reading for project 3: https://reactjs.org/docs/hello-world.html

- Live example https://codepen.io/awdeorio/pen/yzXjzZ?editors=1010