CS 4530: Fundamentals of Software Engineering
Module 7: React

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Learning Objectives for this Lesson

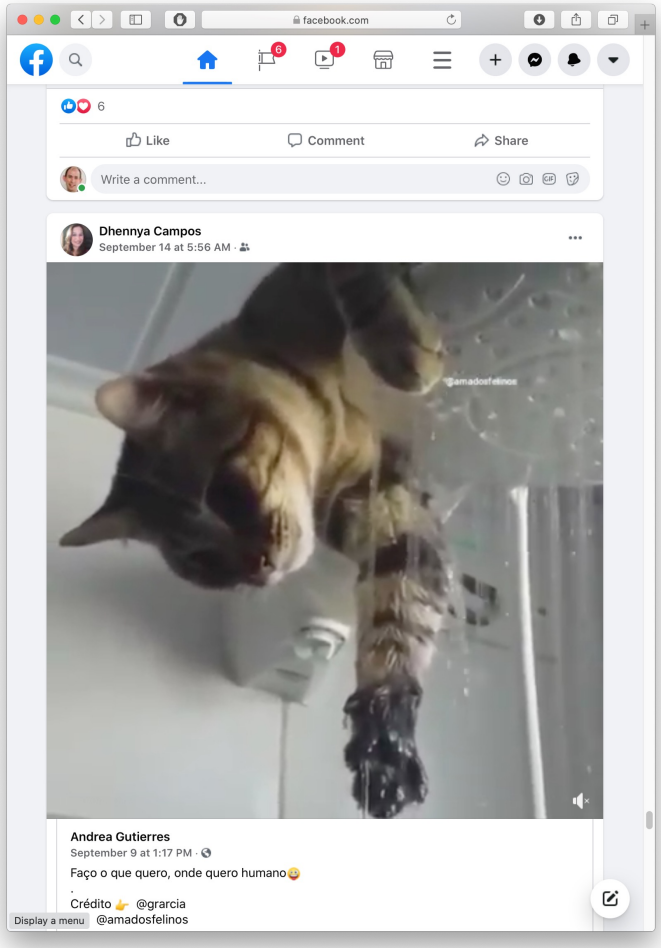
- By the end of this lesson, you should be able to:
  - Understand how the React framework binds data (and changes to it) to a UI
  - Create simple React components that use state and properties
  - Be able to map the three core steps of a test (construct, act, check) to UI component testing

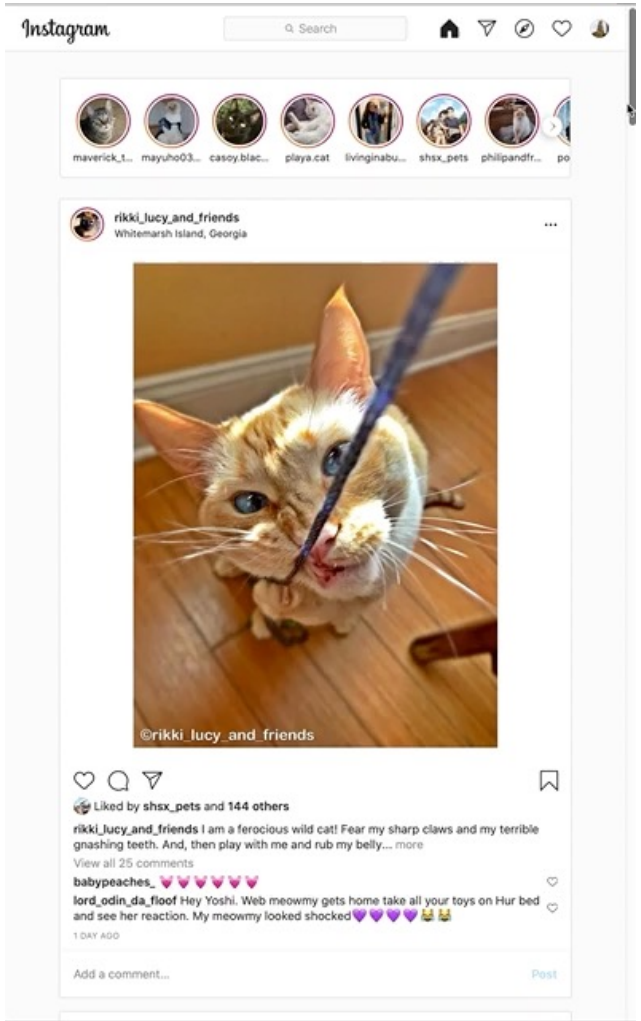
HTML: The Markup Language of the Web

- Language for describing structure of a document
- Denotes hierarchy of elements
- What might be elements in this document?

Rich, interactive web apps

- Infinite scrolling of cats



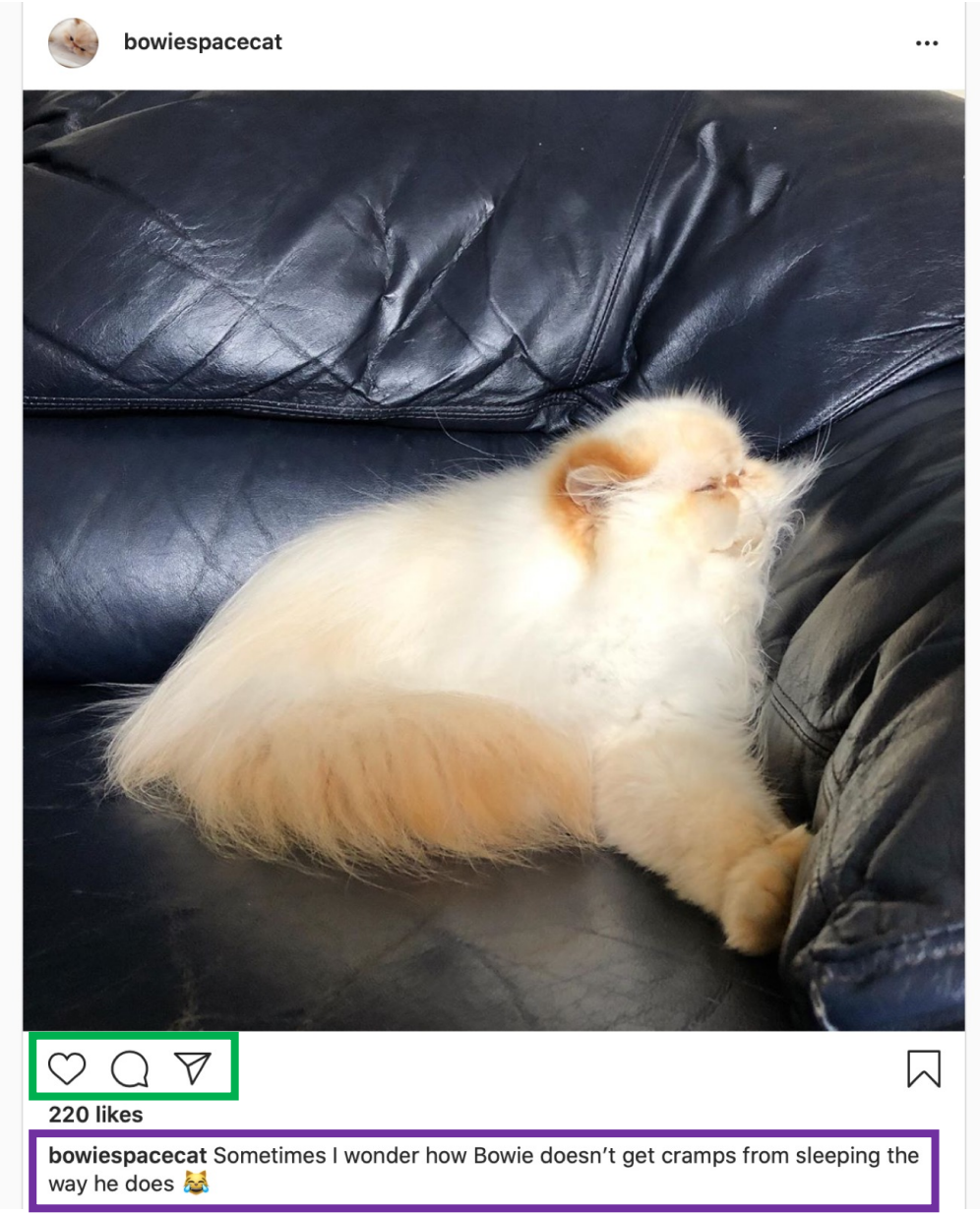


Typical properties of web app Uis
Building abstractions for web app development?

- Each widget has both visual presentation & logic
  - e.g., clicking on like button executes some logic related to the containing widget
  - Logic and presentation of individual widget strongly related, loosely related to other widgets
- Some widgets occur more than once
  - e.g., comment/like widgets
- Changes to data should cause changes to widget
  - e.g., new images, new comments should show up in real time

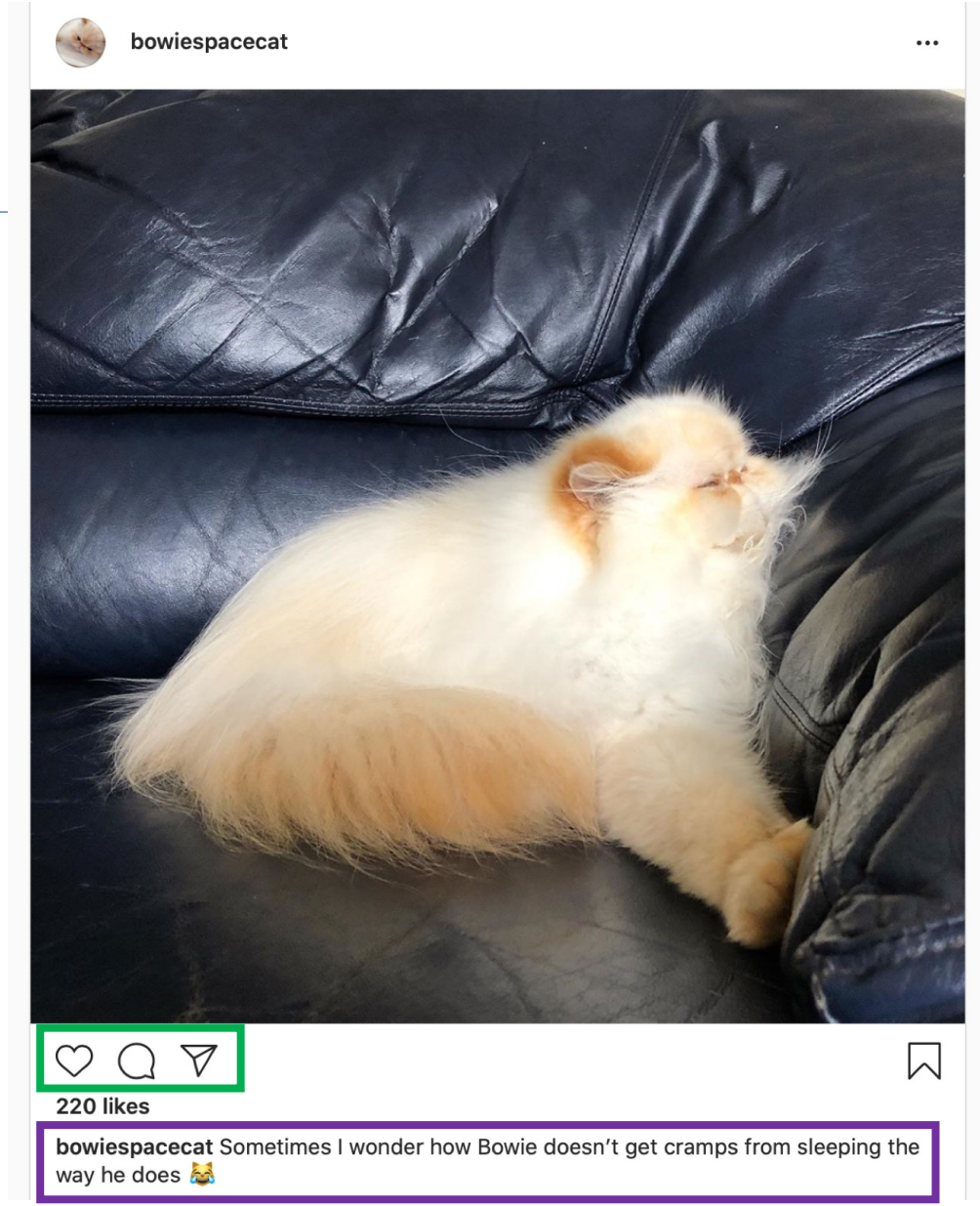
Key Idea: Components

- Web pages are complex, with lots of logic and presentation
- How can we organize web page to maximize modularity?
- Solution: Components - Easy to repeat, cohesive pieces of code (hopefully with low coupling)



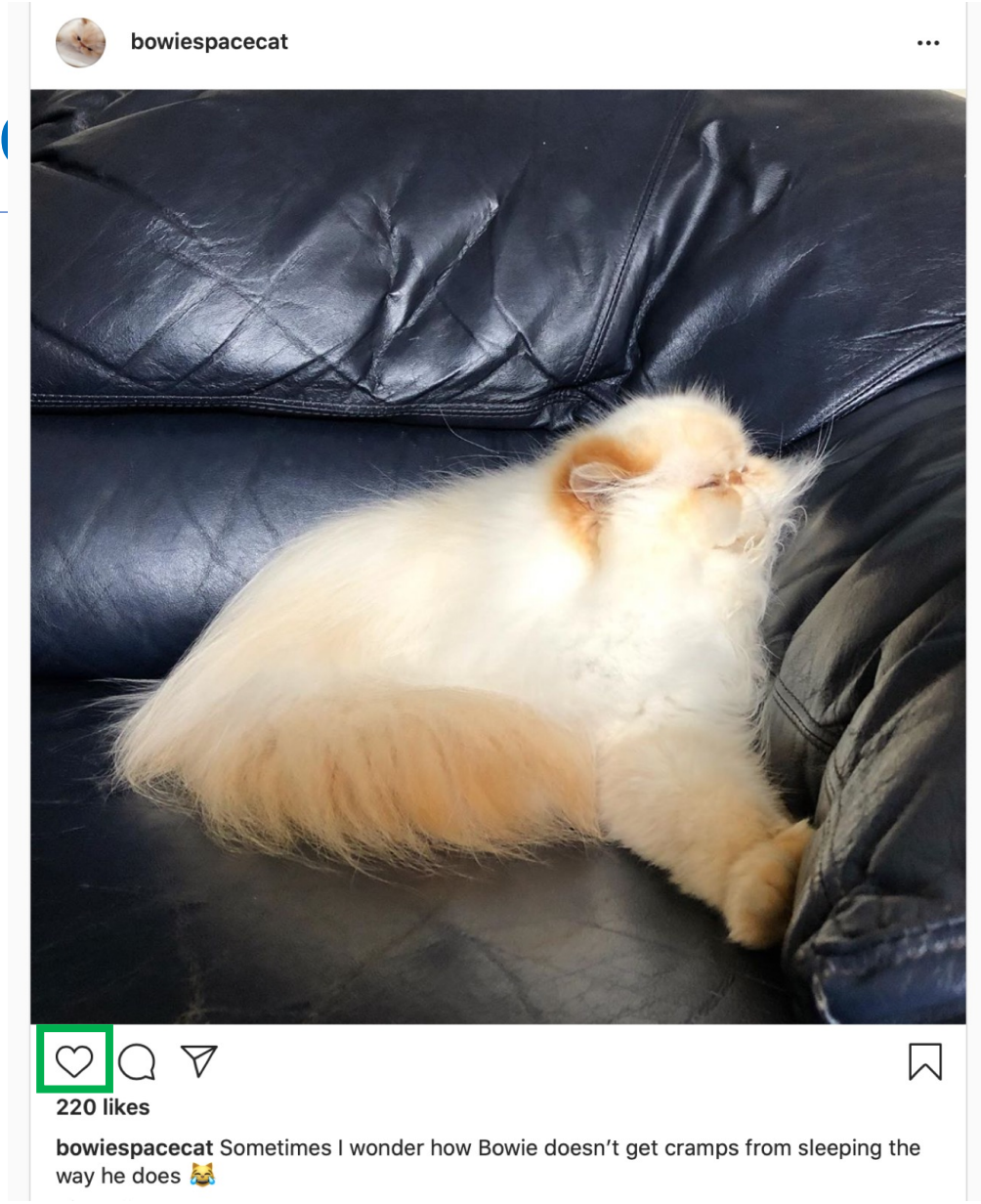
Components

- Organize related logic and presentation into a single unit
  - Includes necessary state and the logic for updating this state
  - Includes presentation for rendering this state into HTML
- Synchronizes state and visual presentation
  - Whenever state changes, HTML should be rendered again



Components
Example: Like button compo

- What does the button keep track of?
  - Is it liked or not
  - What post this is associated with
- What logic does the button have?
  - When changing like status, send update to server
- How does the button look?
  - Filled in if liked, hollow if not



Server side vs. client side

- Where should template/component be instantiated?

- Server-side frameworks: Template instantiated on server
  - Examples: JSP, ColdFusion, PHP, ASP.NET
  - Logic executes on server, generating HTML that is served to browser

- Front-end framework: Template runs in web browser
  - Examples: React, Angular, Meteor, Ember, Aurelia, …
  - Server passes template to browser; browser generates HTML on demand

Expressing Logic

- Templates/components require combining logic with HTML
  - Conditionals - only display presentation if some expression is true
  - Loops - repeat this template once for every item in collection

- How should this be expressed?
  - Embed code in HTML (ColdFusion, JSP, Angular)
  - Embed HTML in code (React)

Embedding Code in HTML

- Template takes the form of an HTML file, with extensions
  - Popular for server-side frameworks
  - Uses another language (e.g., Java, C) or custom language to express logic
  - Found in frameworks such as PHP, Angular, ColdFusion, ASP (NOT React)
  - Can’t type check anything

```
<html>
<head><title>First JSP</title></head>
<body>
  <%
    double num = Math.random();
    if (num > 0.95) {
  %>
      <h2>You'll have a luck day!</h2><p>(<%= num %>)</p>
  <%
    } else {
  %>
      <h2>Well, life goes on ... </h2><p>(<%= num %>)</p>
  <%
    }
  %>
```

Embedding HTML in TypeScript Aka JSX or TSX

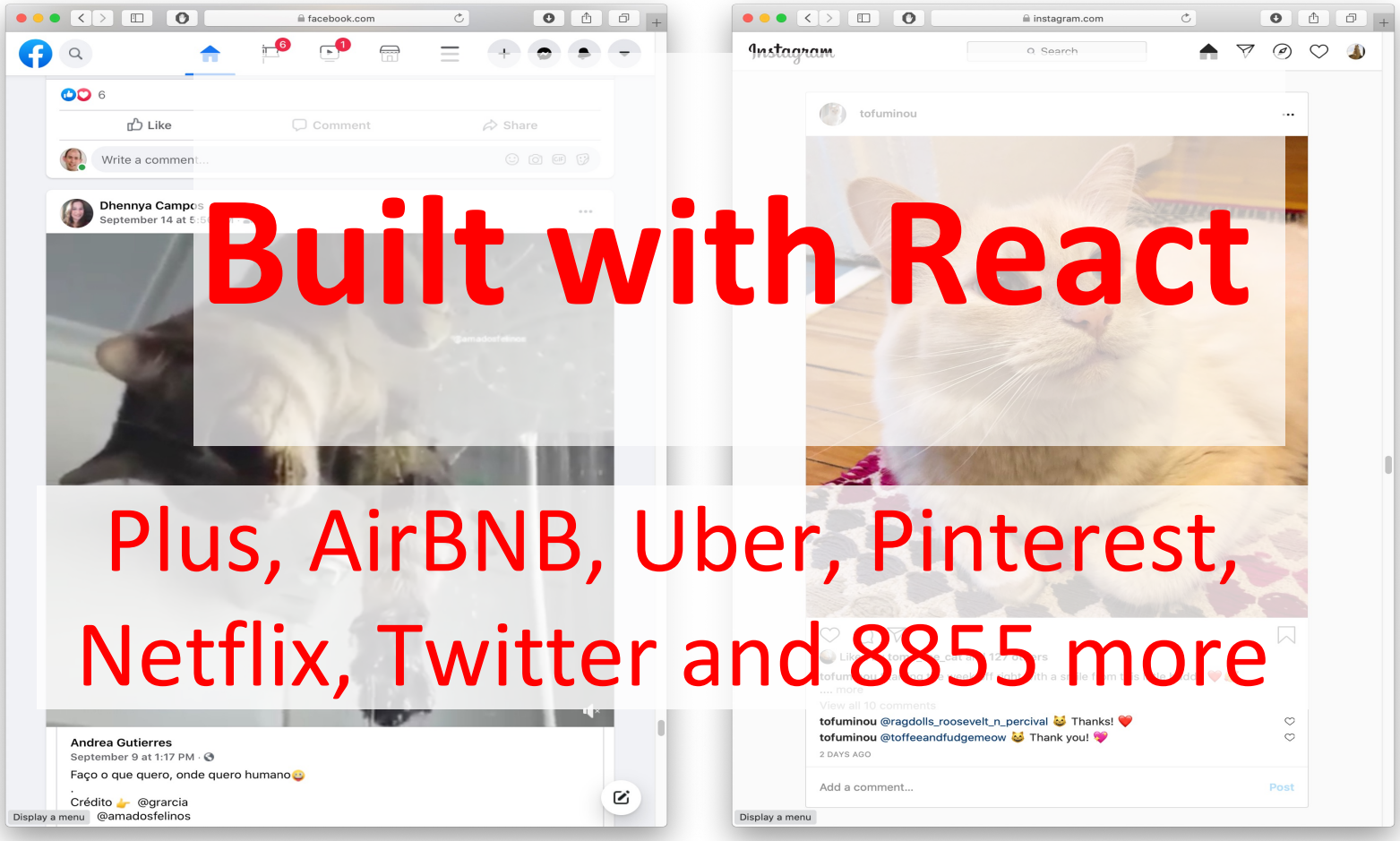
- How do you embed HTML in TypeScript and get syntax checking?
- Idea: extend the language: JSX, TSX
  - JavaScript (or TypeScript) language, with additional feature that expressions may be HTML
- It's a new language
  - Browsers do not natively run JSX (or TypeScript)
  - We use build tools that compile everything into JavaScript

```tsx
export function HelloMessage(props: IProps) {
  return (
    <div>
      Hello, {props.name}
    </div>
  )
}

ReactDOM.render(
  <React.StrictMode>
    <HelloMessage name='Satya' />
  </React.StrictMode>,
  document.getElementById('root')
);
```

React: Front End Framework for Components

- Created by Facebook
- Powerful abstractions for describing frontend UI components
- Official documentation & tutorials: https://reactjs.org/
- Key concepts:
  - Embed HTML in TypeScript
  - Track application “state”
  - Automatically and efficiently re-render page in browser based on changes to state

Rich, interactive web apps
Infinite scrolling of cats



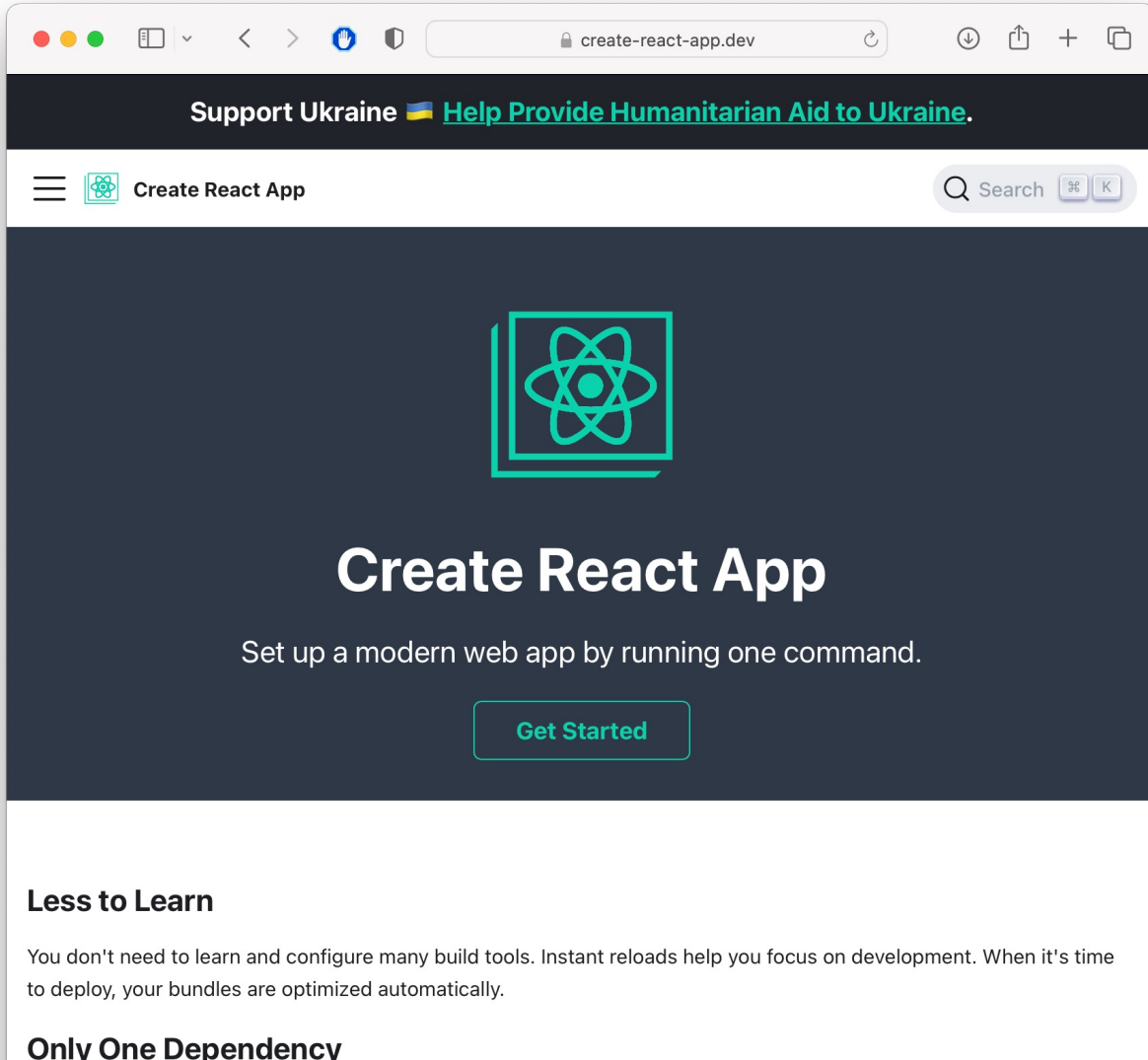
Embedding HTML in TypeScript

```
return <div>Hello {someVariable}</div>;
```

- HTML embedded in TypeScript
  - HTML can be used as an expression
  - HTML is checked for correct syntax
- Can use { expr } to evaluate an expression and return a value
  - e.g., { 5 + 2 }, { foo() }
- To wrap on multiple lines, wrap the TSX in (parentheses)
- Output of expression is HTML

Creating New React Applications

- React applications must be “transpiled” into a format that browsers can understand
- “Create React App” is a set of scripts to automate this all
- Get started: `npx create-react-app my-app --template typescript`
- Implement in App.tsx, run `npm start` to run in web browser



Hello World in React

```
export function HelloMessage(){
  return <div>Hello, World!</div>
}
```

"Declare a Hello component"

Declares a new component
that can be rendered by React

"Return the following HTML whenever the component is rendered"

The HTML is dynamically
generated by the library.

```
function App(){
  return <HelloWorld />;
}
```

"Render a Hello Component"

Components are rendered as if they were
HTML tags

You may see “Class” components, too – but we won’t write them

```
var HelloMessage = React.createClass({
  render: function() {
    return <div>Hello, World!</div>
  }
})
```

Hello World, Circa 2016
(Before the “Class” keyword!)

```
class HelloMessage extends React.Component {
  render(){
    return <div>Hello, World!</div>
  }
}
```

Hello World, Circa 2020
(Defined as a Class)

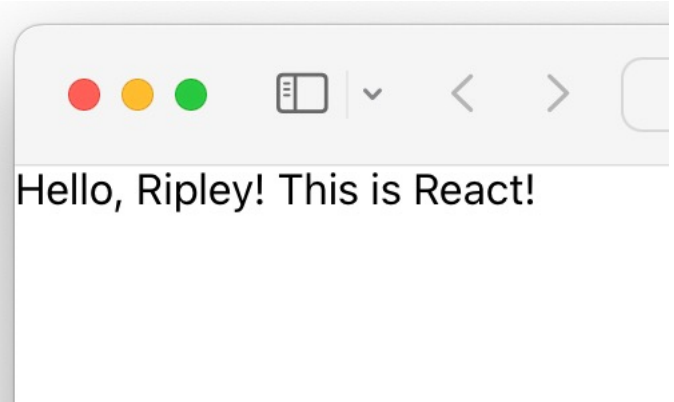
```
export function HelloMessage(){
  return <div>Hello, World!</div>
}
```

Hello World, Circa 2022
(Defined as a function)

React Components Can Receive Properties

- Properties are passed in an argument to the component
- Properties are specified as attributes when the component is instantiated
- Properties can *not* be changed by the component
- Reminder: inside of HTML code, execute TypeScript code using {mustaches}

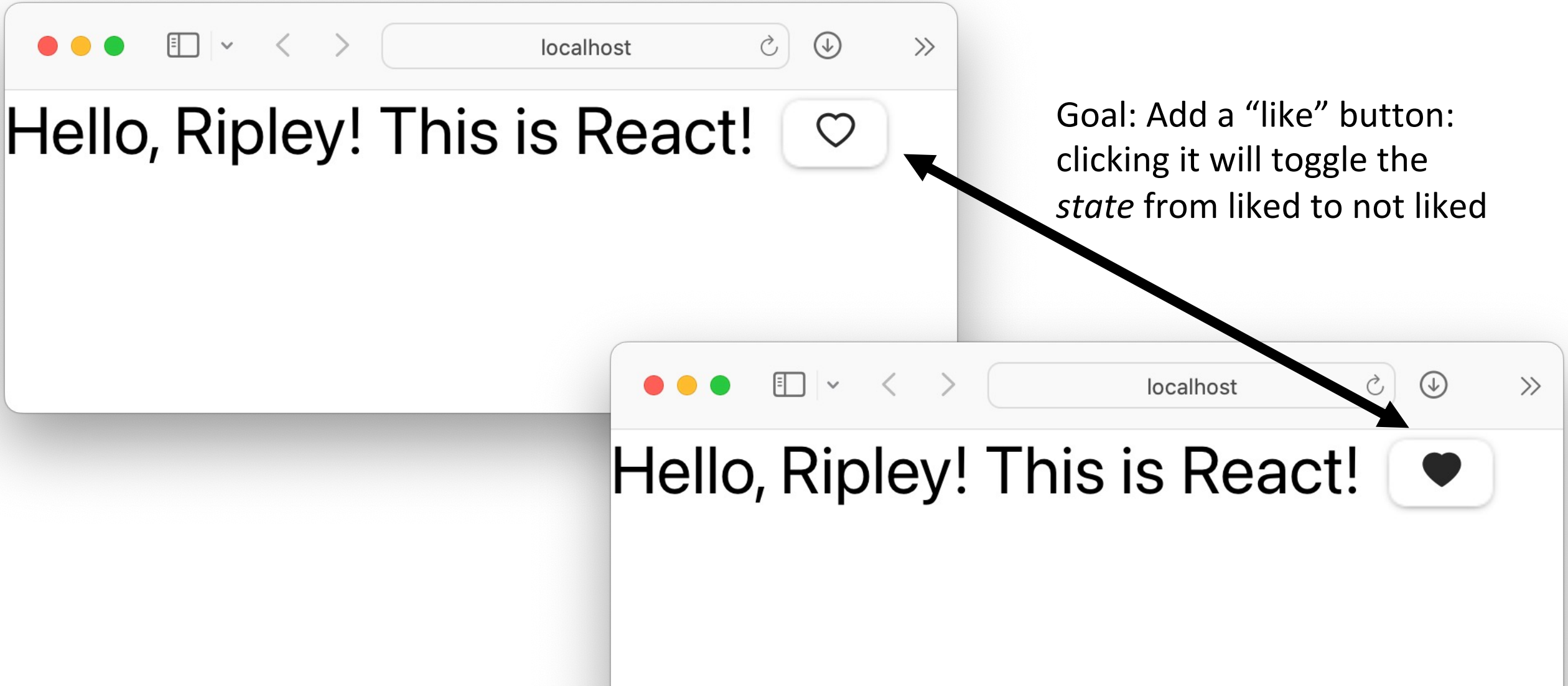
```
export function PersonalizedHello(props: {name: string}){
  return <div>Hello, {props.name}! This is React!</div>
}
<PersonalizedHello name="Ripley" />
```



Component State is Data That Changes

- All internal component data that, when changed, should trigger UI update
  - Stored as state variables in the component
    - Created using useState<stateType>(defaultValue)
    - E.g. const [isLiked, setIsLiked] = *useState*(false);
    - Import *useState* from React
  - The only way to change the value of a state variable is with the setter
  - You *could* choose any names for the variable and its setter; for this class, please follow the convention of const [goodVariableName, setGoodVariableName]

React State Example: “Like” Button



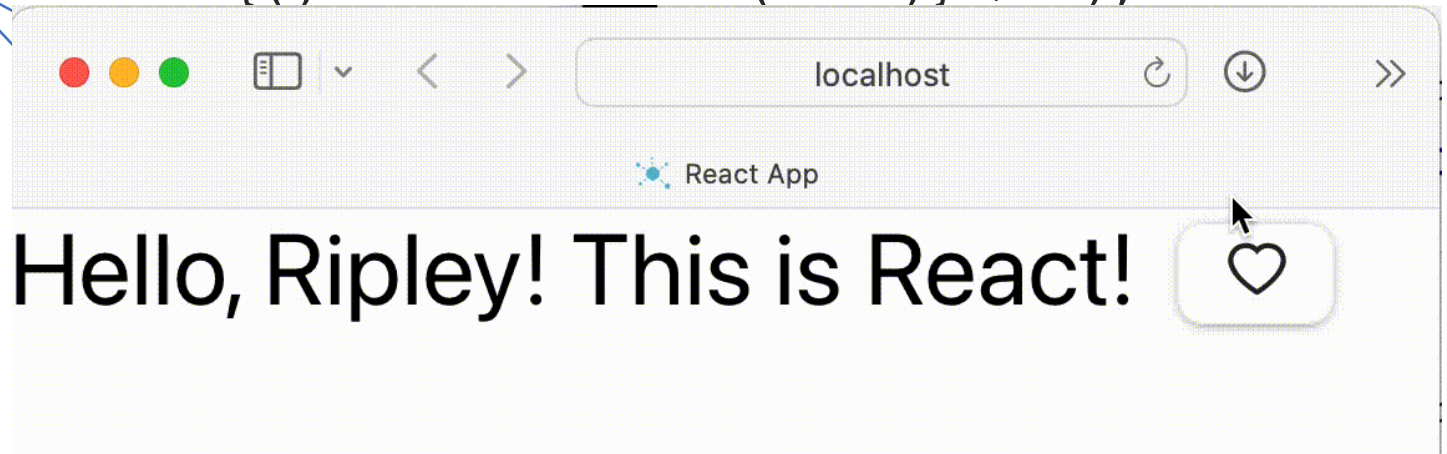
Goal: Add a “like” button: clicking it will toggle the *state* from liked to not liked

React State Example: "Like" Button

Create a state variable called isLiked, and a *state setter*, defaulting to *false*

```
function PersonalizedLikableHello(props: { name: string }) {
  const [isLiked, setIsLiked] = useState(false);
  let likeButton;
  if (isLiked) {
    likeButton = (<IconButton aria-label="unlike"
        icon={<AiFillHeart />} onClick={() => setIsLiked(false)} /> );
  } else {
    likeButton = (<IconButton aria-label="like"
        icon={<AiOutlineHeart />} onClick={() => setIsLiked(true)} /> );
  }
  return (
    <div>
      Hello, {props.name}! This is
    </div>
  );
}
```

Depending on the state, show a filled-in or outlined button



Sidebar: React Has a Rich Component Library

chakra

Search the docs ⌘ K

v2.2.9

- Getting Started
- Styled System
- Components
- Hooks
- Community
- Changelog
- Blog

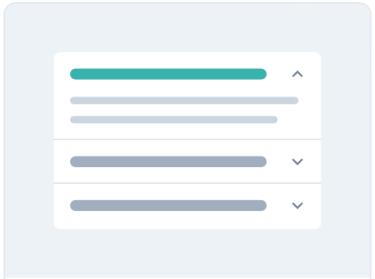
LAYOUT

- Aspect Ratio
- Box
- Center
- Container
- Flex
- Grid

Components

Chakra UI provides prebuild components to help you build your projects faster. Here is an overview of the component categories:

Disclosure



Accordion

Tabs

Visual

Feedback

Install UI libraries from NPM just like any other kind of module, e.g.

```
npm install --save @chakra-ui/react
```

Avatar with badge

In some products, you might need to show a badge on the right corner of the avatar. We call this a **badge**. Here's an example that shows if the user is online:

EDITABLE EXAMPLE

COPY

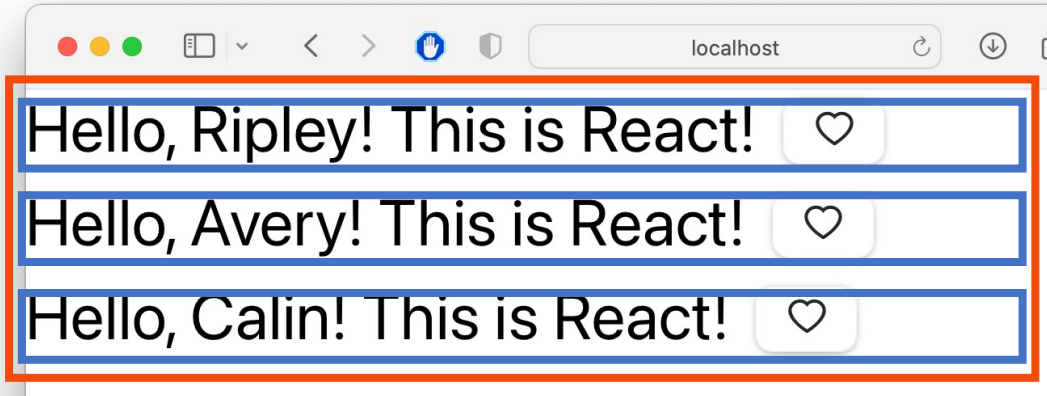
```
<Stack direction='row' spacing={4}>
  <Avatar>
    <AvatarBadge boxSize='1.25em' bg='green.500' />
  </Avatar>

  {/* You can also change the borderColor and bg of the badge */}
  <Avatar>
    <AvatarBadge borderColor='papayawhip' bg='tomato' boxSize='1.25em' />
  </Avatar>
</Stack>
```

Nest Components, Passing State as Properties

- A common pattern in React is to store state in one component, and nest others in it, passing properties
- Example: Creating multiple PersonalizedHello's:

```
export function MultiHellos() {
const [names, setNames] = useState(["Ripley", "Avery", "Calin"]);
  return (
    <div>
      {names.map((eachName) => (
         <PersonalizedLikableHello name={eachName} />
     ))}
    </div>
  );
}
```

- Problem: How to add "delete" buttons?

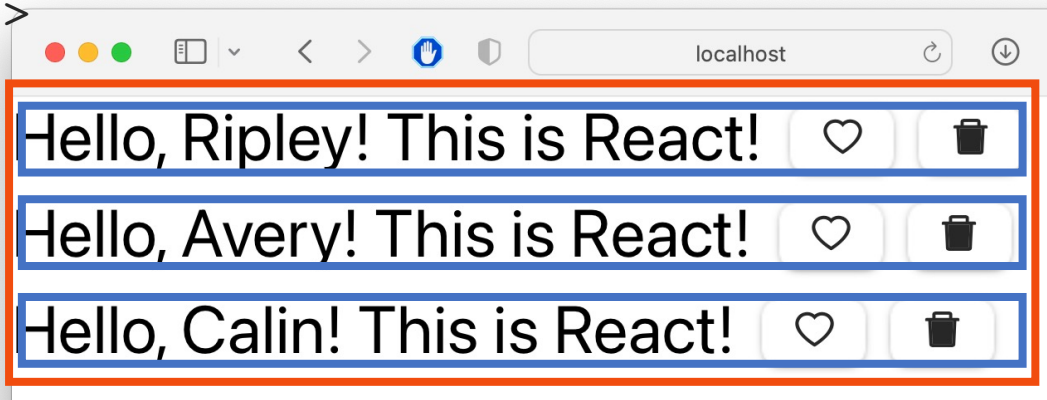


Do not reference this slide for study (spoiler alert!)

Nest Components, Passing State (and setter) as Properties

- Add a “delete” button inside of each Hello Message
- What should the delete button do? The state with the list of names is stored in the MultiHellos component
- Solution: Pass an “onDelete” handler to each

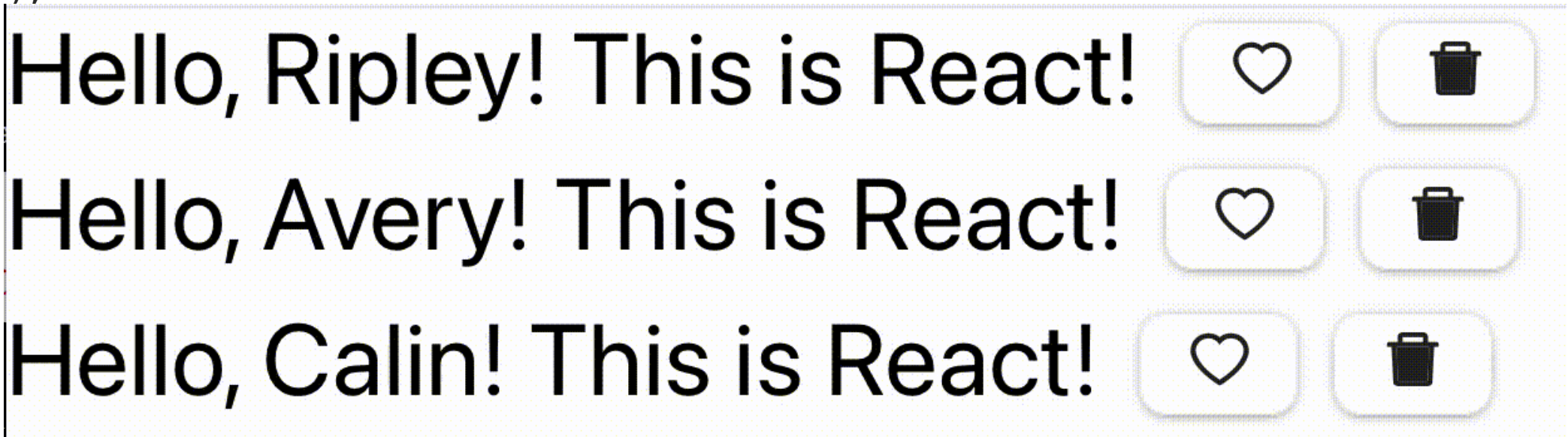
```
export function MultiHellos() {
  const [names, setNames] = useState(["Ripley", "Avery", "Calin"]);
  return (<div>
      {names.map((eachName) => (
          <PersonalizedLikableDeletableHello name={eachName}
          onDelete={()=> setNames(names.filter(
         filteredName => filteredName !== eachName))}/>
      ))}
      </div>
  );
}
```



Do not reference this slide for study (spoiler alert!)

Testing the “Delete” button

```
export function MultiHellos() {
  const [names, setNames] = useState(["Ripley", "Avery", "Calin"]);
  return (<div>
      {names.map((eachName) => (
          <PersonalizedLikableDeletableHello name={eachName}
          onDelete={()=> setNames(names.filter(
         filteredName => filteredName !== eachName))}/>
      ))}
      </div>
  );
}
```

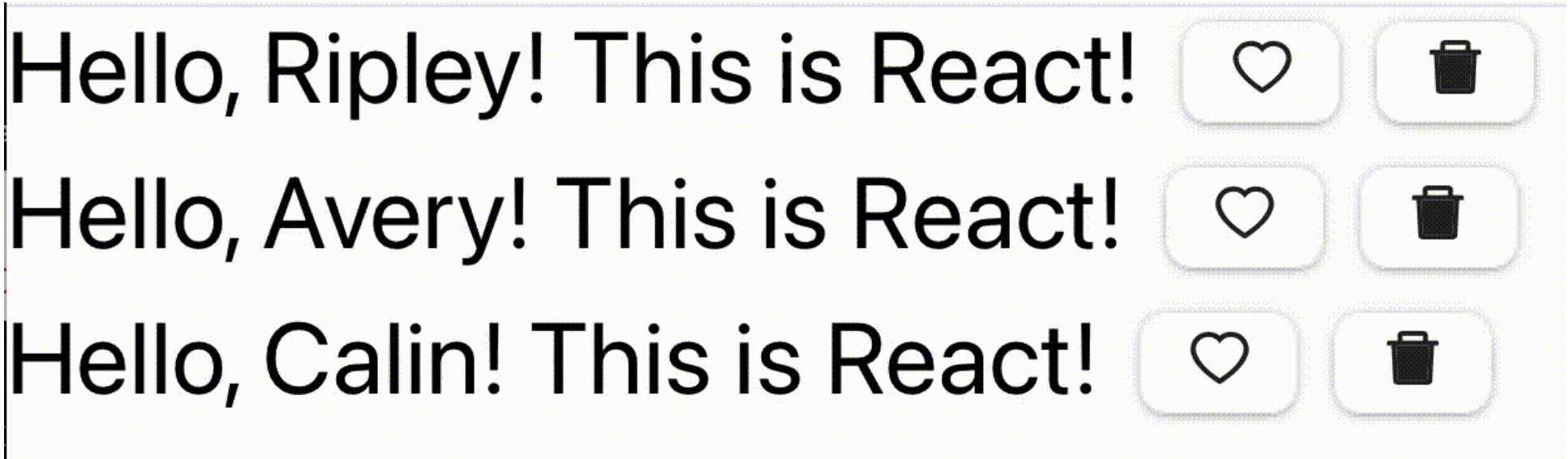


Testing the Delete AND Like Buttons

```
export function MultiHellos() {
  const [names, setNames] = useState(["Ripley", "Avery", "Calin"]);
  return (<div>
      {names.map((eachName
          <PersonalizedLik
          onDelete={()=> s
         filteredName => f
      ))}
      </div>
  );
}
```

Warning: Each child in a list should have a unique "key" prop. printWarning — react-jsx-dev-runtime.development.js:87

Check the render method of `MultiHellos`. See https://reactjs.org/link/warning-keys for more information.
PersonalizedLikableDeletableHello@http://localhost:3000/static/js/bundle.js:91:80
MultiHellos@http://localhost:3000/static/js/bundle.js:161:76
App



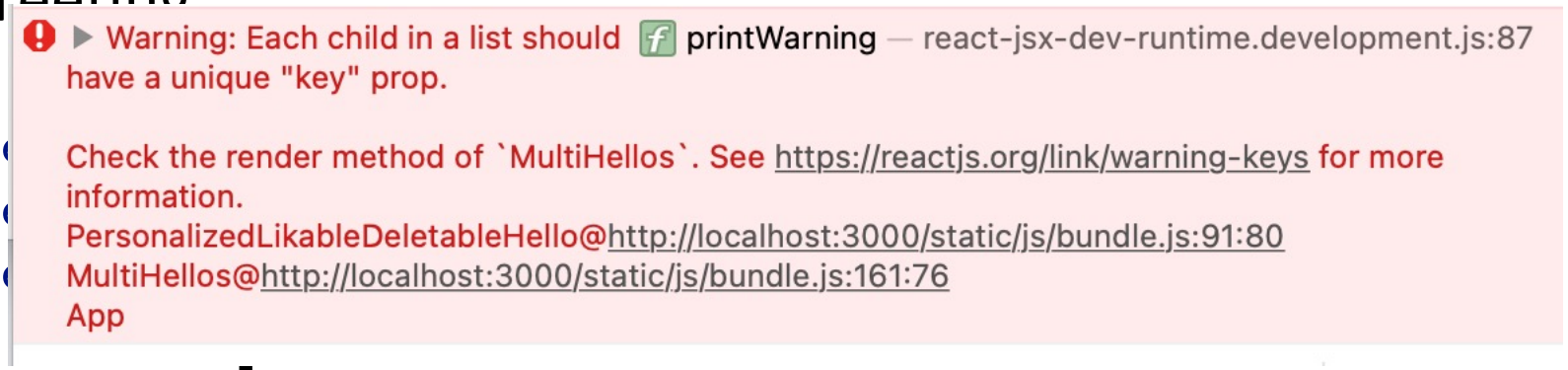
Reacting to change: How does the page update automatically?

- Re-rendering is *asynchronous*: do not happen immediately upon calling a state setter
- Reconciliation: Framework diffs the previously rendered DOM with the new DOM, updating only part of DOM that changed
- Updating the DOM in the browser is slow - it is *vital* that React does efficient diff'ing
  - Example: adding a new comment on a YouTube video shouldn't make the browser re-layout the whole page

Reconciliation Must Differentiate Updates from Deletions/Additions

Before deleting Ripley's Greeting:

```
<div>
  <PersonalizedLikableD
  <PersonalizedLikableD
  <PersonalizedLikableD
</div>
```



After deleting Ripley's Greeting:

```
<div>
  <PersonalizedLikableDeletableHello name="Avery" />
  <PersonalizedLikableDeletableHello name="Calin" /> /* isLiked=true */
</div>
```

React processed this change as:
Ripley's greeting becomes Avery's greeting
Avery's greeting becomes Calin's greeting
Calin's greeting is deleted

Reconciliation with Keys

- Add the “key” attribute to each component in a list
- Keys must be unique
- React will use the “key” to determine which elements are added, deleted, or re-ordered when re-rendered

```
export function MultiHellos() {
  const [names, setNames] = useState(["Ripley", "Avery", "Calin"]);
  return (<div>
      {names.map((eachName) => (
          <PersonalizedLikableDeletableHello name={eachName}
          key={eachName}
          onDelete={()=> setNames(names.filter(filteredName => filteredName !== eachName))}/>
      ))}
      </div>
  );
}
```

Write UI component tests just like any other test

Follow the generic testing model from Module 2:

- Assemble the situation:
  - Set up system under test (SUT) to get the state ready
  - [Optional: Prepare collaborators]
- Act - Apply the operation inputs.
- Assess - Check the outputs, verify the state change, handle the behavior

1: Render component into a testing DOM tree

2: Interact with the rendered component

3: Check the rendered result

UI Testing Libraries make Component Tests Lightweight

- Render components into a “virtual DOM”
  - Just like browser would, but no browser
- Interact with components by “firing events” like a user would
  - Click, enter text, etc. on DOM nodes, just like a user would in a browser
- Inspect components that are rendered
  - Tests specify how to “find” a component in that virtual DOM

“Testing Library”
https://testing-library.com
Compatible with many UI libraries and many testing frameworks

Rendering Components in Virtual DOM

```
let deleteCalled = false;
beforeEach(() => {
  deleteCalled = false;
  render(
    <PersonalizedLikableDeletableHello name="Ripley"
      onDelete={() => { deleteCalled = true; }} /> );
});
```

- The *render* function prepares our component for testing:
  - Creates a virtual DOM
  - Instantiates our component, mounts it in DOM
  - Mocks all behavior of the core of React
  - Allows us to inspect the rendered result in the *screen* import

https://testing-library.com/docs/react-testing-library/api#render

Inspecting Rendered Components: By Text

SUT

```
return (
    <div>
      Hello, {props.name}! This is React! {likeButton}
      <IconButton aria-label='delete' icon={<AiTwotoneDelete />}
           onClick={props.onDelete} />
    </div>
);
```

Test

```
test("It renders the greeting", ()=>{
  const greeting = screen.getByText(/Hello, Ripley!/);
  expect(greeting).toBeInTheDocument();
})
```

First approach to inspect rendered components: match by text

Inspecting Rendered Components: ARIA label

SUT

```
if (isLiked) {
  likeButton = (<IconButton aria-label="unlike"
      icon={<AiFillHeart />} onClick={() => setIsLiked(false)} /> );
} else {
  likeButton = (<IconButton aria-label="like"
      icon={<AiOutlineHeart />} onClick={() => setIsLiked(true)} /> );
}
```

Test

```
test("Like button defaults to not liked, clicking it likes, clicking again
unlikes", () => {
  const likeButton = screen.getByLabelText("like");
  fireEvent.click(likeButton);
  const unLikeButton = screen.getByLabelText("unlike");
  fireEvent.click(unLikeButton);
  expect(screen.getByLabelText("like")).toBeInTheDocument();
});
```

3 Tiers for Inspecting Rendered Components

- Queries that reflect how every users interacts with your app
  - byRole – Using accessibility tree
  - byLabelText – Using label on form fields
  - byPlaceHolderText – Using placeholder text on form field
  - byText – By exact text in an element
  - byDisplayValue – By current value in a form field
- Queries that reflect how some users interact with your app
  - byAltText – By alt text, usually not presented to sighted users
  - byTitle - By a “title” attribute, usually not presented to sighted users
- Queries that have nothing to do with how a user interacts with app
  - byTestId

More: https://testing-library.com/docs/queries/about

Testing Library Cheat Sheet

	No Match	1 Match	1+ Match	Await?
getBy	throw	return	throw	No
findBy	throw	return	throw	Yes
queryBy	null	return	throw	No
getAllBy	throw	array	array	No
findAllBy	throw	array	array	Yes
queryAllBy	[]	array	array	No

- Get and query have different behavior when there are different numbers of matches
- Find is *async* and will return a promise to wait for all rendering to complete

https://testing-library.com/docs/react-testing-library/cheatsheet

Review

- Now that you've studied this lesson, you should be able to:
  - Understand how the React framework binds data (and changes to it) to a UI
  - Create simple React components that use state and properties
  - Be able to map the three core steps of a test (construct, act, check) to UI component testing
- The next lesson will include a deep-dive on patterns of React, including useState and its friend, useEffect