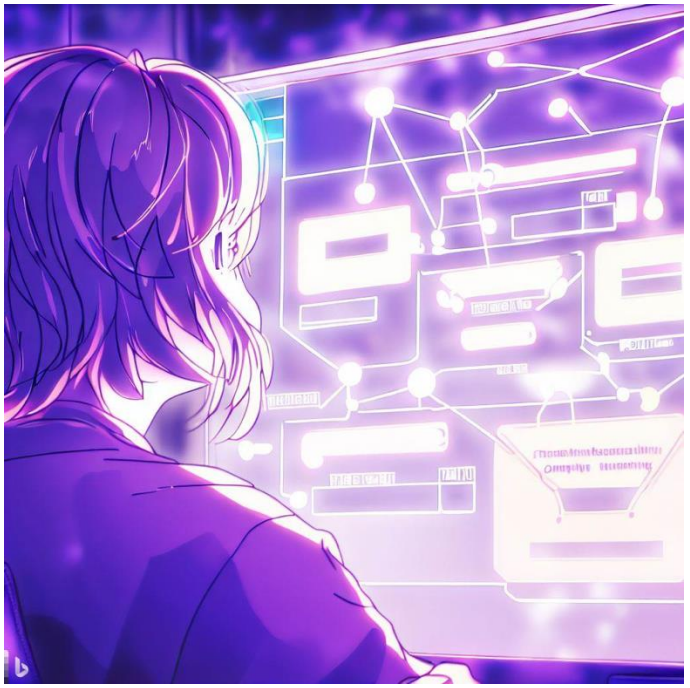


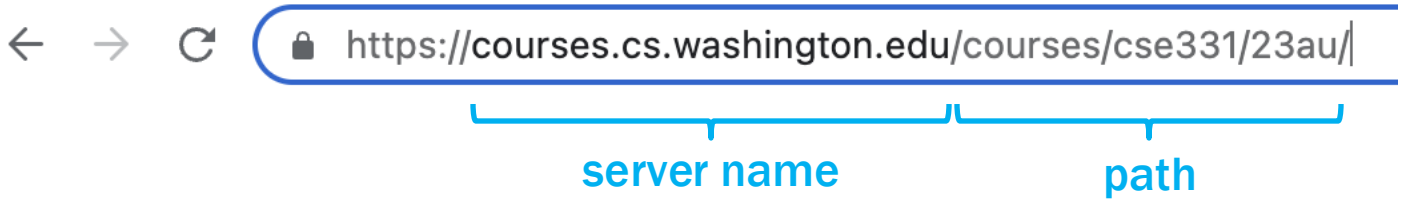
# CSE 331

## Intro to the Browser

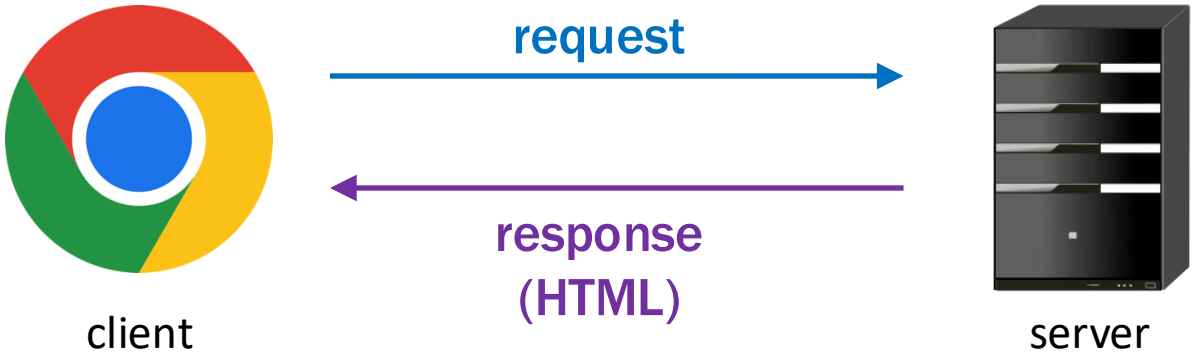
James Wilcox and Kevin Zatloukal

# Browser Operation

- Browser reads the URL to find what to load




- For URLs entered by users, the response is usually **HTML**



# Browser Operation

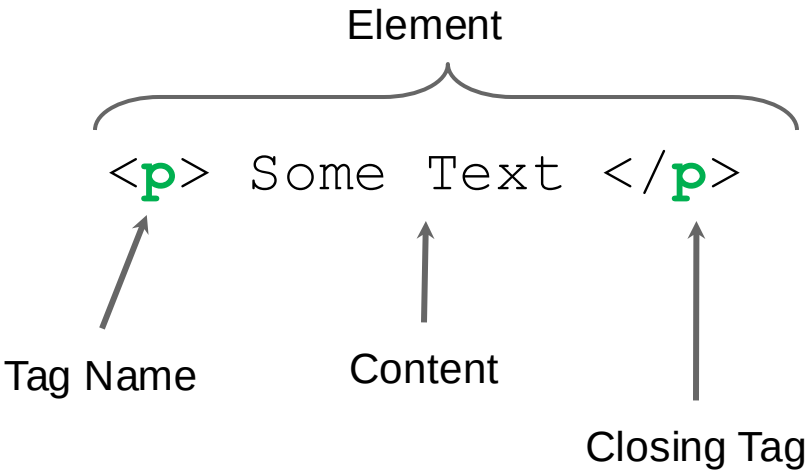

- Browser natively knows how to display HTML
- Page can also include JavaScript to execute
  - but it it is not required
  - if present, the JavaScript can *change* the HTML displayed

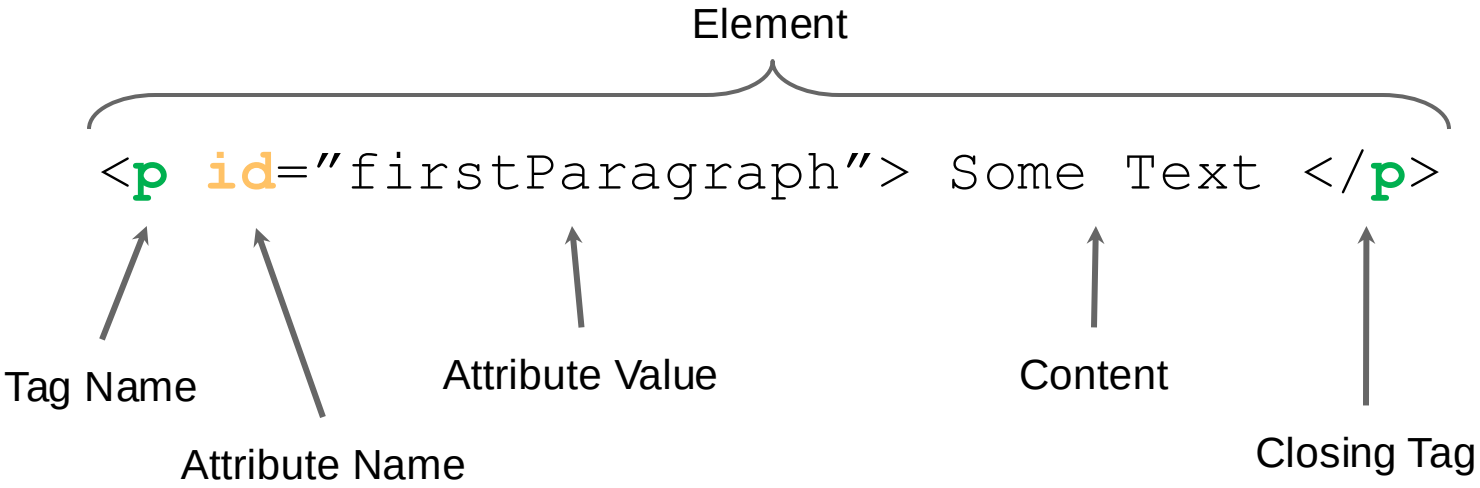
# HTML

- HTML = Hyper Text Markup Language
  - text format for describing a document / UI
  - text describes what you want *drawn* in the browser

- HTML text consists primarily of “tags” and text

# HTML Tags

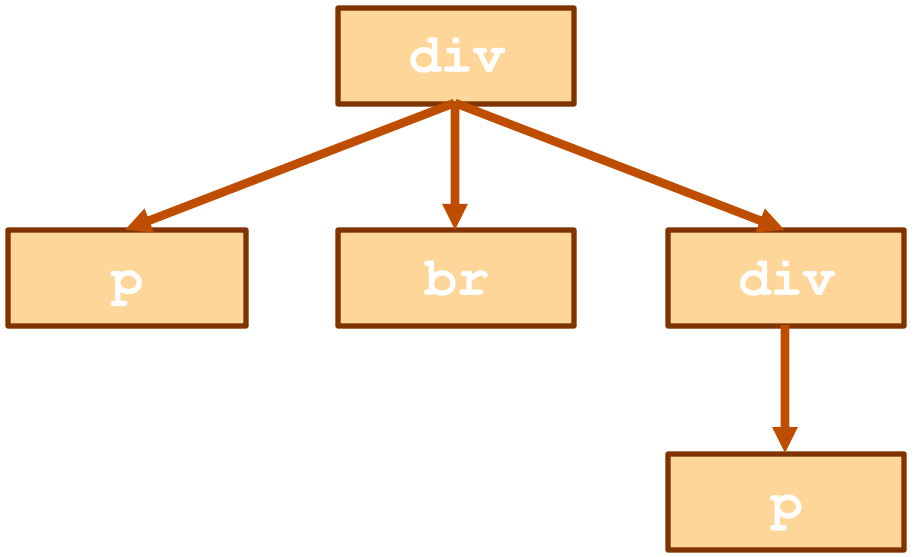

Element
 Some Text 
Tag Name
Content
Closing Tag


Element
 Some Text 
Tag Name
Attribute Name
Attribute Value
Content
Closing Tag

# Elements Form a Tree

- **Elements can have children (text or elements)**
  - **text is always a leaf in the tree**

```
<div>
    <p id="firstParagraph"> Some Text </p>
    <br>
    <div>
        <p>Hello</p>
    </div>
</div>
```

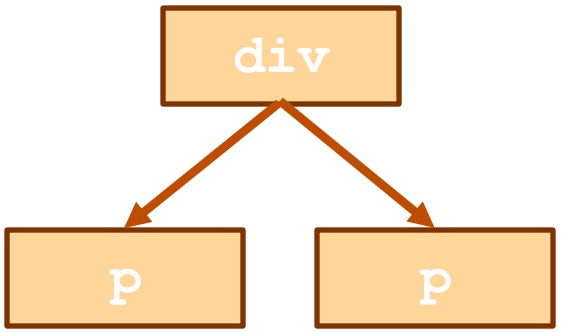


# More on HTML

- **HTML is a text format that describes a tree**
  - **nodes are elements or text**

```
<div>
  <p>Some text</p>
  <p>More text</p>
</div>
```

HTML text

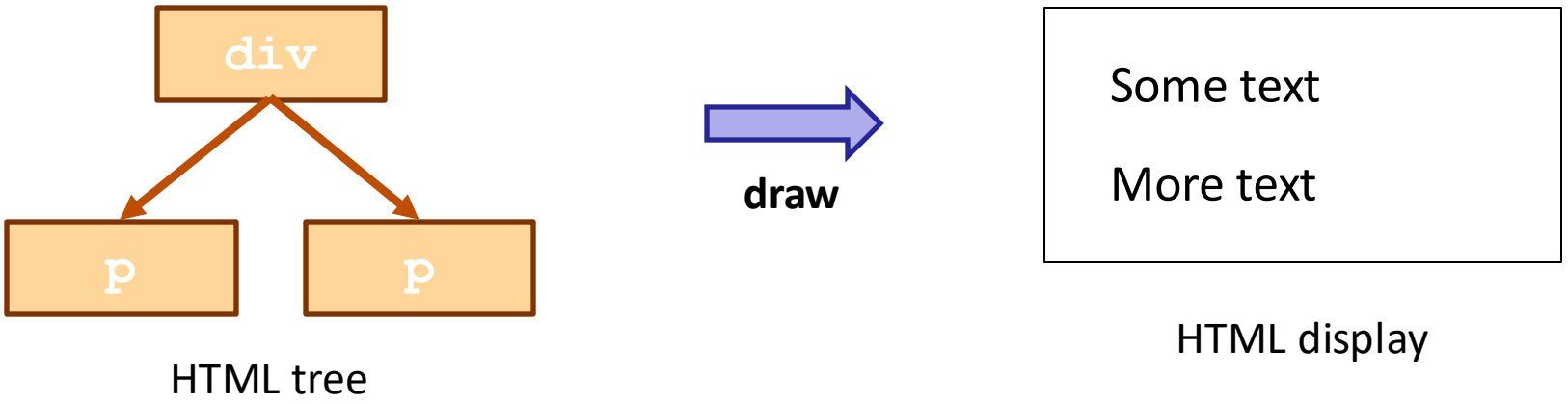

HTML tree

  - **HTML text is parsed into a tree ("DOM")**
  - **JS can access the tree in the variable "`document`"**

    our code lives in the world on the right side

# More on HTML

- **Browser window displays an HTML document**
  - **tree is turned into drawing in the page**




HTML tree

HTML display

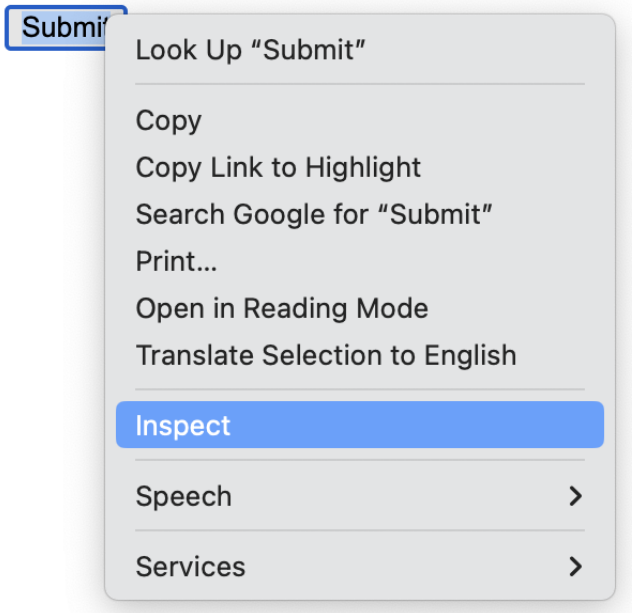
  - **browser displays the HTML in the window**

    browsers *parse* and d*raw* very quickly

  - **JS has *limited* access to display information**

# Developer Tools show the HTML

- Click on any HTML element and choose "Inspect"
  - can see exact size in pixels, colors, etc.




```
▼ <body>
  ▶ <p> ··· </p>
  ▼ <div id="submit">
      <button type="button" onclick="getAnswer(event);">Submit</button>
    </div>
```

# Styling

- The “style” attribute controls appearance details
  - margins, padding, width, fonts, etc.
  - see an HTML reference for details (when necessary)

- Attribute value can include many properties
  - each is “name: value”
  - separate multiple using “;”

```
<p>Hi,
  <span style="color: red; margin-left: 15px">Bob</span>!
</p>
```

Hi, Bob!

  - we will generally not worry much about looks in this class…

# Cascading Style Sheets (CSS)

- Commonly used styles can be named
  - association of names to styles goes in a `.css` file

```
// foo.css
span.fancy { color: red; margin-left: 15px }

// foo.html
… <p>Hi, <span class="fancy">Bob</span></p> …
```

- Useful to avoid repetition of styling
  - makes it easier to change

# Old School Web UI

# Including JavaScript in HTML

- Server usually sends back HTML to the browser
- Include code to execute inside of script tag:

```
<script>
  console.log("Hi, browser");
</script>
```

- Can also put the script into another file:

```
<script src="mycode.js"></script>
```

# Events in the Browser

- Client applications are event-driven
  - register "handlers" for various events

- Can do so like this in HTML (but don't!)

```
<button onClick="handleClick(event)">Click Me</button>

<script>
  const handleClick = (evt) => {
    console.log("ouch");
  };
</script>
```

# Changing the HTML

- Change the HTML displayed like this (but don't!)

```
<p>Add 2 to <input type="text" id="num"></input></p>

<p><button onClick="doAdd(event)">Submit</button></p>

<div id="answer"></div>

<script>
  const doAdd = (evt) => {
    const numElem = document.getElementById("num");
    const num = Number(numElem.value);

    const ansElem = document.getElementById("answer");
    ansElem.innerHTML = `The answer is ${num+2}`;
  };
</script>
```

# Many Kinds of Updates

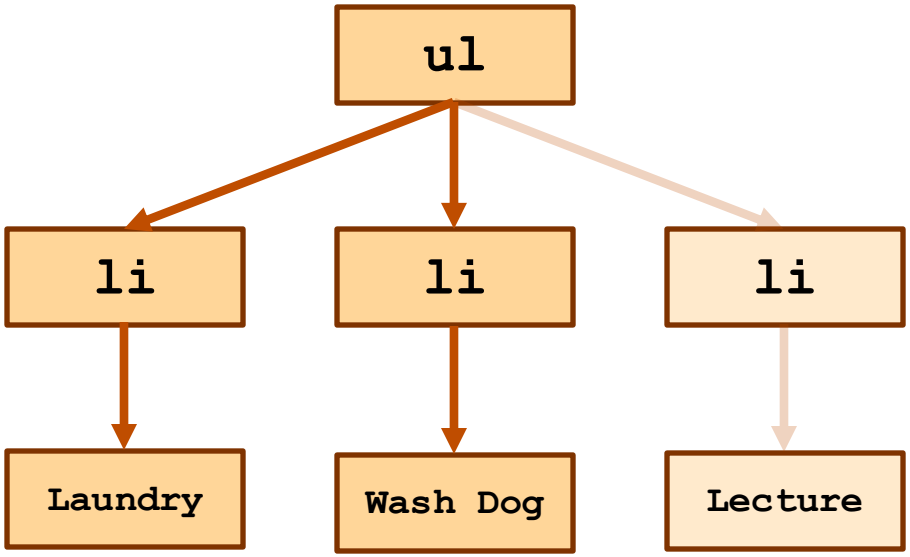
- **Adding a new item:**

```
<h3>To-Do List</h3>

<ul id="items">
  <li>Laundry</li>
  <li>Wash Dog</li>
</ul>
```

**To-Do List**

- Laundry
- Wash dog

New: Lecture Add



# Many Kinds of Updates

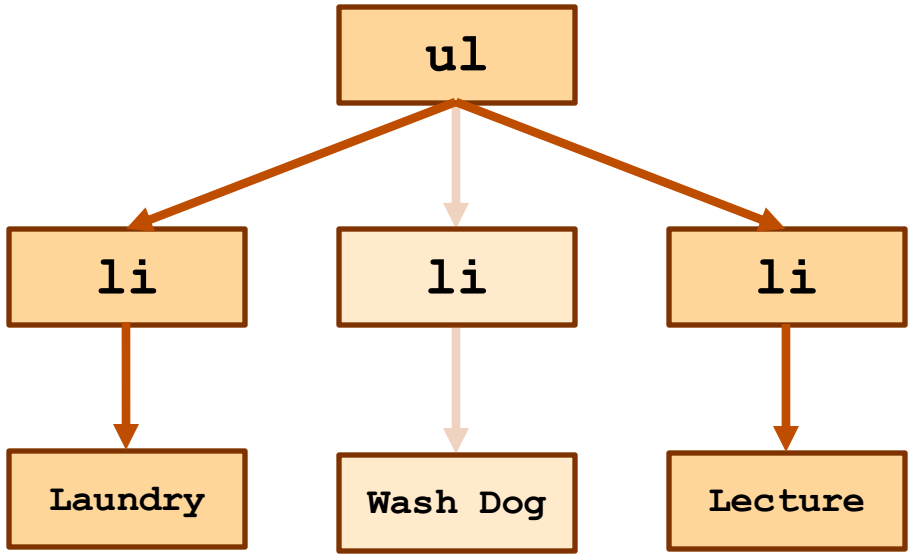
- **Removing item:**

```
<h3>To-Do List</h3>

<ul id="items">
  <li>Laundry</li>
  <li>Wash Dog</li>
  <li>Lecture</li>
</ul>
```

**To-Do List**

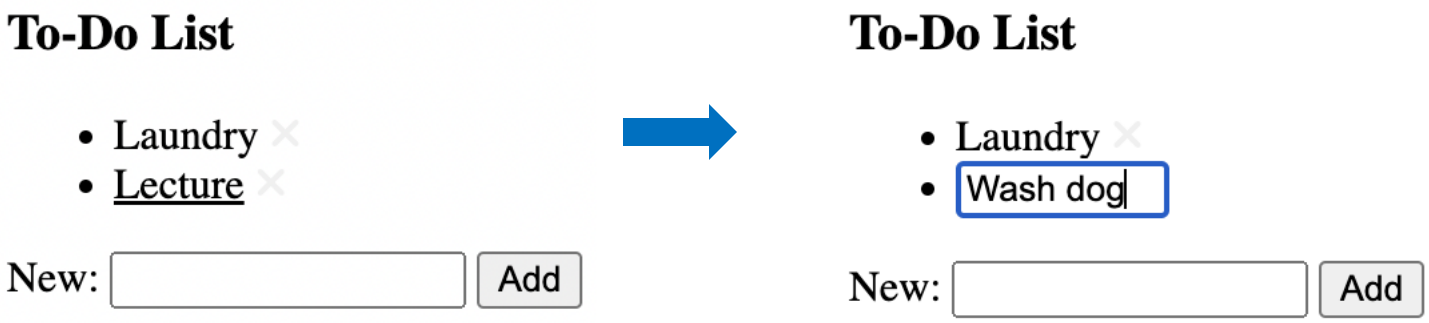
- Laundry ✕
- Wash dog ✕
- Lecture ✕

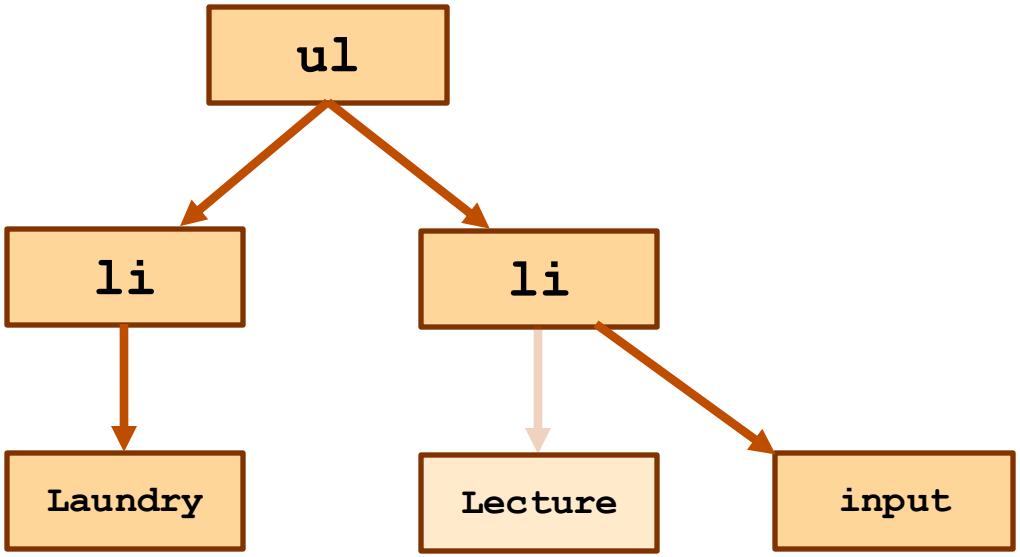
New: Add



# Many Kinds of Updates

- Editing an item:



# Problems with Old School UI

- Write code for every way the UI could change
  - many, many cases
- Not specific to HTML
  - same issue exists in Windows, iPhone, etc.
  - if you write code to put things on screen,
    then you write code to change where they are on screen

# New School UI

- New approach: what should it look like now?
  - write function that maps current state to desired HTML
  - compare desired HTML to what is on the screen now
  - make any changes needed to turn former into latter
- Huge improvement in productivity
  - introduced in Meta's "React" library
  - library performs the "compare" and "change" parts
- Faster to write HTML UI than anything else
  - similar libraries could be written for other platforms

# React Components

# HTML Literals

- Extension of JS allows HTML expressions
  - file extension must be `.jsx`

```
const x = <p>Hi there!</p>;
```

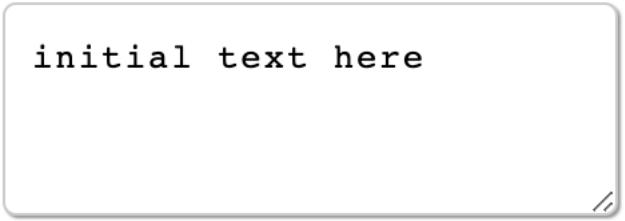
# HTML Literals

- Supports substitution like `` `. . .` `` string literals,
  - but uses `{ . . }` not `${ . . }`

```
const name = “Fred”;
return <p>Hi {name}</p>;
```

- Can also substitute the value of an attribute:

```
const rows = 3;
return <textarea rows={rows} cols="25">
         initial text here
       </textarea>;
```



# JSX Gotchas

- Must have a single root tag (i.e., must be a tree)
  - e.g., cannot do this

```
return <p>one</p><p>two</p>;
```

  - instead, wrap in a  or just <> . . </> (“fragment”)

- Replacements for attributes matching keywords
  - use “className=” instead of “class=”
  - use “htmlFor=” instead of “for=”

# Cascading Style Sheets (CSS)

- CSS styling can be used in JSX

```
// foo.css
span.fancy { color: red; margin-left: 15px }

// foo.jsx
import './foo.css';  // another weird import
…
return <p>Hi, <span className="fancy">Bob</span>!</p>;
```

- Nice to get this out of the source code
  - usually not the programmers who need to change it

# Simplest React Component

- **Component that prints a Hello message:**

```
class HiElem extends Component {
  constructor(props) {
    super(props);

    this.state = {lang: "en"};
  }

  render = () => {
    if (this.state.lang === "en") {
      return <p>Hi, Kevin!</p>;
    } else {
      return <p>Hola, Kevin!</p>;
    }
  };
}
```

**How do we change "`lang`"?**

# Simplest React Component

# Simplest React Component

```
render = () => {
  if (this.state.lang === "en") {
    return <p>Hi, Kevin!
        <button onClick={this.doEspClick}>Esp</button>
      </p>;
  } else {
    return <p>Hola, Kevin!
       <button onClick={this.doEngClick}>Eng</button>
      </p>;
  }
};

doEspClick = (evt) => {
  this.setState({lang: "es"};
};
```

# Simplest React Component

```
<button onClick={this.doEspClick}>Esp</button>

doEspClick = (evt) => {
  this.setState({lang: "es"};
};
```

- **Must call `setState` to change the state**
  - **directly modifying `this.state` is a (painful) bug**
- **React will automatically re-render when state changes**
  - **but this does not happen *instantly***

# React Responds to `setState` calls

HTML on screen = render(this.state)

| | Component | React |
|---|---|---|
| t = 10 | this.state = $s_1$ | doc = $HTML_1$ = render($s_1$) |
| t = 20 | this.setState($s_2$) | |
| t = 30 | this.state = $s_2$ | doc $HTML_2$ = render($s_2$) |

**React updates** this.state **to** $s_2$ **and** doc **to** $HTML_2$ ***simultaneously***

# React Component with an Event Handler

- Pass method to be called as argument (a "callback"):

```
<button onClick={this.doEspClick}>Esp</button>
```

- Be careful not to do this:

```
<button onClick={this.doEspClick()}>Esp</button>
```

- Including parentheses here is a bug!
  - that would call the method inside render
    passing its return value as the value of the `onClick` attribute
  - we want to pass the method to the button, and have it called when the click occurs

# Putting the UI in the Page

- **Initial page has a placeholder in the HTML:**

```
<div id="main"></div>
```

(empty DIV in `index.html`)

- **Put HTML into it from code like this:**

```
const elem = document.getElementById("main");
const root = createRoot(elem);
root.render(<HiElem name={"Kevin"}/>);
```

  - `createRoot` **is a function provided by the React library**

    tells React that it should keep the HTML in the page matching what render returns

# Putting the UI in the Page

- **Initial page has a placeholder in the HTML:**

```
<div id="main"></div>
```

(empty DIV in `index.html`)

- **Put HTML into it from code like this:**

```
const elem = document.getElementById("main");
const root = createRoot(elem);
root.render(<HiElem name={"Kevin"} size={3}/>);
```

  - in `HiElem`, `this.props` will be `{name: "Kevin", size: 3}`
  - each component is a custom tag with its own attributes ("properties")

# React Components

```
render = () => {
  if (this.state.lang === "en") {
    return <p>Hi, {this.props.name}!
        <button onClick={this.doEspClick}>Esp</button>
      </p>;
  …
  }
};
```

- `render` **can use both** `this.props` **and** `this.state`
  - **difference 1: caller give us props, but we set our state**
  - **difference 2: we can *change* our state**

# Summary of Last Time

- **Writing User Interface with React:**
  - **write a class that extends** `Component`
  - **implement the** `render` **method**

- **Each component becomes a new HTML tag:**

```
root.render(<HiElem name={"Kevin"}/>);
```

  - **in** `HiElem`, `this.props` **will be** `{name: "Kevin"}`

- **Can use** `props` **and** `state` **(and only those!) in** `render`**:**

```
render = () => {
  if (this.state.lang === "en") {
    return <p>Hi, {this.props.name}!
        <button onClick={this.doEspClick}>Esp</button>
      </p>;
  …
```

# Second React Component

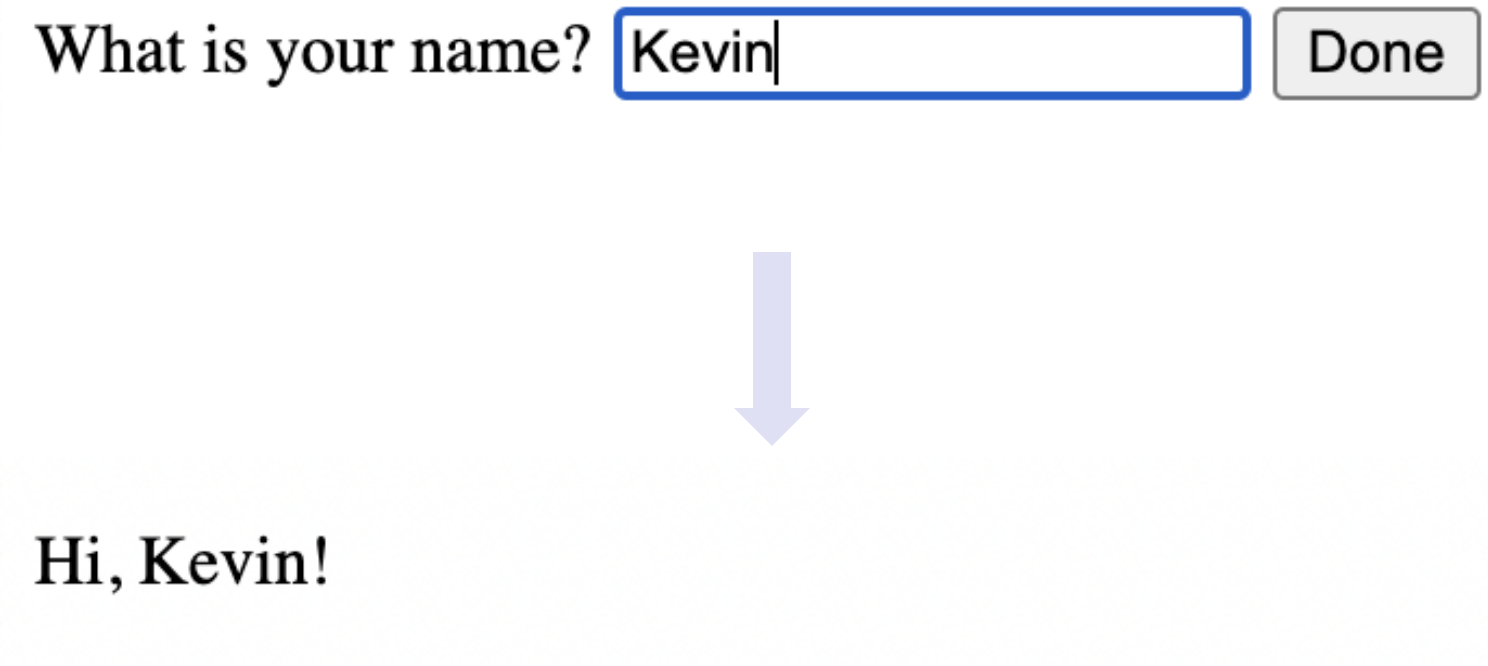
- **Put name in state and let the user change it:**

```
class HiElem extends Component {
  constructor(props) {
    super(props);

    this.state = {name: "Kevin"};
  }
  render = () => {
    return <p>Hi, {this.state.name}</p>;
  };
}
```

How do we change the name?

Ask the user for their name.

# Second React Component



# Second React Component

```
constructor(props) {
  super(props);
  this.state = {showGreeting: false};
}
render = () => {
  if (this.state.showGreeting) {
    return <p>Hi, {this.state.name}!</p>;
  } else {
    return <p>What is your name?
        <input type="text"></input>
        <button …>Done</button>
      </p>
  }
};
```

# Second React Component

```
      <input type="text"></input>
      <button onClick={this.doDoneClick}>Done</button>

doDoneClick = (evt) => {
  this.setState({showGreeting: true});
  // what about "name"?
};
```

How do we get the name text?

Do not reach into document!
(Always a bug. Often a *heisenbug*.)

# Text Value of Input Elememts

- **These two are different:**

```
<input type="text"></input>
```

```
<input type="text" value="abc"></input>
```


  - **missing `value` means `value=""`**

- **The `render` method says what HTML should be <u>now</u>**
  - **bug if calling render would inadvertently change things**
    particularly if it would delete user data!
  - **if we want the second picture, we need to set `value` in `render`**

# Second React Component

```
        <input type="text" value={this.state.name}
             onChange={this.doNameChange}></input>
        <button onClick={this.doDoneClick}>Done</button>

    doNameChange = (evt) => {
      this.setState({name: evt.target.value});
    };
```

- `evt.target` **is the** `input` **element**
- `evt.target.value` **is the current text in the** `input` **element**

# Second React Component

```
        <input type="text" value={this.state.name}
             onChange={this.doNameChange}></input>
        <button onClick={this.doDoneClick}>Done</button>

    doNameChange = (evt) => {
      this.setState({name: evt.target.value});
    };

    doDoneClick = (evt) => {
      this.setState({showGreeting: true});
    };
```

- Never reach into the document to get state!
  - React can re-render at any time
  - will be a heisenbug when you forget (usually, it still works!)

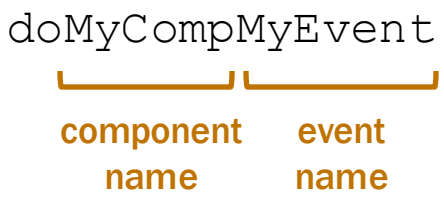
# Second React Component

```
        <input type="text" value={this.state.name}
             onChange={this.doNameChange}></input>
        <button onClick={this.doDoneClick}>Done</button>

    doNameChange = (evt) => {
      this.setState({name: evt.target.value});
    };

    doDoneClick = (evt) => {
      this.setState({showGreeting: true});
    };
```

- **Any state you need should be mirrored in your state**
  - **set** `value` **and handle** `onChange`

# Event Handler Conventions

- We will use this convention for event handlers




  - e.g., `doDoneClick`, `doNewNameChange`

- Reduces the need to explain these methods
  - method name is enough to understand what it is for
  - method name is the only thing you know they read

- Components should be just rendering & event handlers

# Example: To-Do List

# React Payoff

- No need to write code to
  - add a new item to the HTML
  - remove an item from the HTML
  - update an item in the HTML

    all of this is code is tricky (especially if state is not mirrored properly)

- We just write a `render` method
  - tell React what it should look like *right now*

- React figures out what to add, remove, and update

# React Requirements for Lists

- To do this, React needs more from
  - needs to distinguish change from add/remove

```
<li>wash dog</li>
<li>laundry</li>
```

```
<li>wash dog</li>
<li>write lecture</li>
<li>laundry</li>
```

  - did I insert a new item *or* change one and add another?

    impossible to really know without more information

- React requires each list item to have a `key=". ."` property that uniquely identifies it

# React Requirements for Lists

- To do this, React needs more from
  - needs to distinguish change from add/remove

```
<li key="1">wash dog</li>
<li key="2">laundry</li>
```

```
<li key="1">wash dog</li>
<li key="3">write lecture</li>
<li key="2">laundry</li>
```

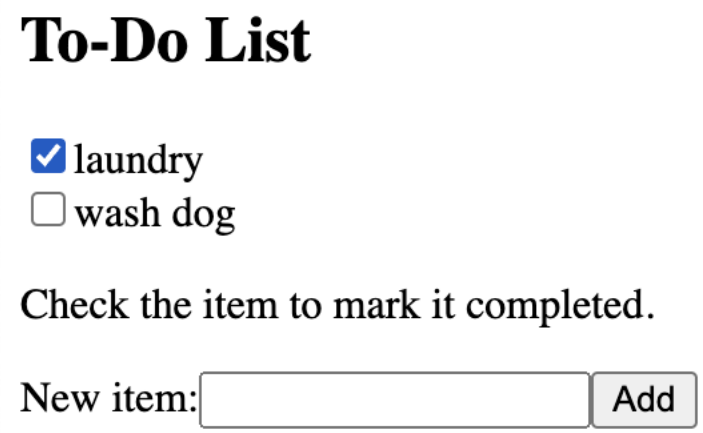
  - can now see that "2" was not changed
  - only difference is that "3" was inserted

- React will give you a warning (console) if you forget
  - will try its best to figure out what happened
  - always fix these to be safe

# Component Modularity

# More Complex UI

- To-Do List UI is basic
  - all of it easily fits in a single component (`TodoApp.tsx`)




- More complex UI can be too much code for one file
  - necessary to split it into multiple components

# Recall: Other Properties of High-Quality Code

- Professionals are expected to write high-quality code
- Correctness is the most important part of quality
  - users **hate** products that do not work properly
- Also includes the following:
  - easy to understand
  - easy to change
  - modular

} via abstraction

# Component Modularity

- Poor design to put all the app in one Component
  - it works, but is lacks properties of high-quality code
  - better to break it into smaller pieces (modular)

- Two ways to the UI into separate components:

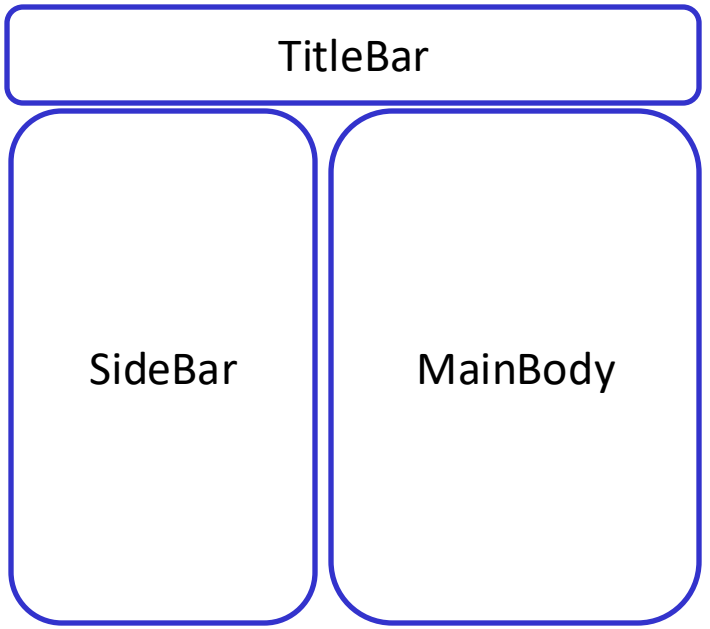
  1. Separate parts that are next to each other on screen

  2. Separate parts on the screen at different times

# Component Modularity

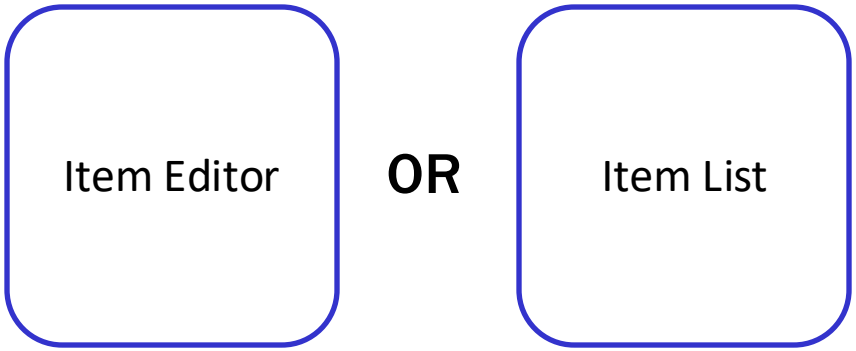
- **Separate parts that are next to each other**

```
class App extends Component<..> {
  render = (): JSX.Element {
    return (<div>
        <TitleBar title={“My App”}/>
        <SideBar/>
        <MainBody/>
      </div>);
  };
}
```



# Component Modularity

- Separate parts on the screen at different times
- App is always on the screen
  - App chooses which child component to display

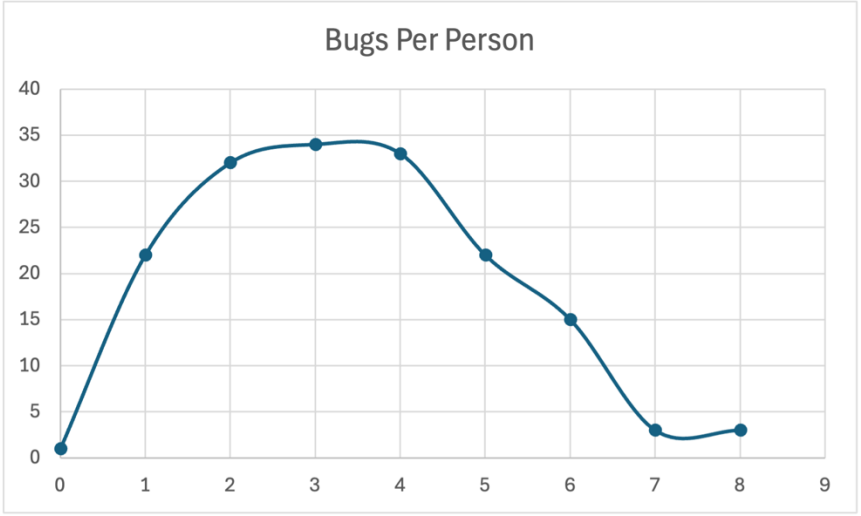



  - sometimes it has an Editor child and sometimes not

# Example: Hello (v3)

# Summary of HW1

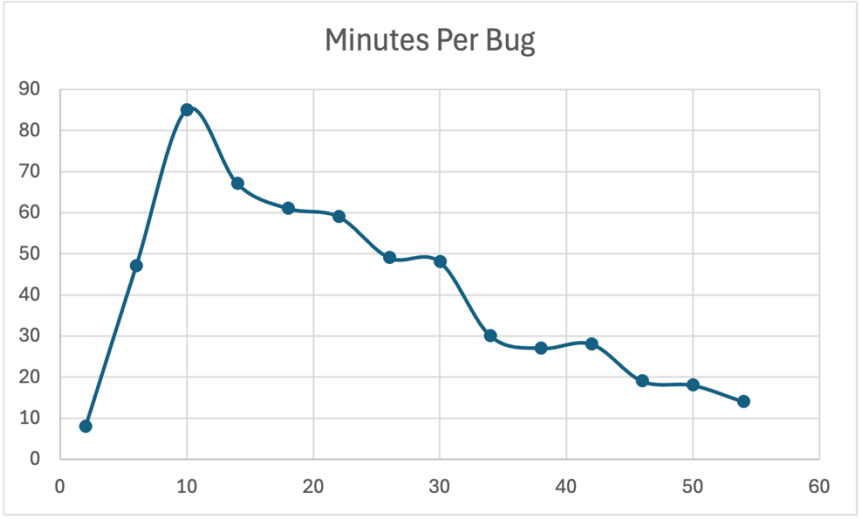
- Number of bugs logged:
  - average of 3.82 (median of 3)




- Average solution was 41 lines of code
  - 1 bug every 10.7 lines of code
  - 1 bug every 20–70 lines in industry (wide range of estimates)

# Summary of HW1

- Time spent per bug:
  - average of 37 minutes per bug
  - 90% more than 15 min… 10% more than 1 hour




- Every 10–15 lines you lose this much time
  - worthwhile to see what we can do to reduce debugging

# Summary of HW1

- Would a **type checker** help?
  - students reported 'yes' for 41% of bugs
  - industry studies found even higher numbers (over 60%)

- Moves from every 11 lines to every 18 lines
  - likely >50% productivity improvement

    assumes 5 minutes to type 10 lines of code

    most of the time spent is the debugging

- Large-scale application use type-checked languages
  - problems get even worse with multiple programmers
  - basically, unheard of to not use one

# TypeScript

# TypeScript Adds Declared Types to JavaScript

- TypeScript includes declared types for variables
  - file names end with `.ts` or `.tsx` (not `.js` or `.jsx`)
  - one extra config file `tsconfig.json`
- Compiler checks that the types are valid
  - produces JS just by *removing* the types
- Critical to **understand** how the type system works
  - know which bugs it catches and which it misses
  - you can then focus your attention on the second group

# TypeScript Adds Declared Types

- Type is declared after the variable name:

```
const u: bigint = 3n;
const v: bigint = 4n;

const add = (x: bigint, y: bigint): bigint => {
  return x + y;
};

console.log(add(u, v));  // prints 7n
```

  - return type is declared after the argument list (…) and before =>

- "Where types go" is the main syntax difference vs Java
  - other key differences are functions (=>) and equality (===)

# Basic Data Types of TypeScript

- **JavaScript includes the following types**

| | |
|---|---|
| `number` | |
| `bigint` | |
| `string` | |
| `boolean` | |
| `null` | |
| `undefined` | |
| `Object` | (record types) |
| `Array` | (e.g., `string[]` as in Java) |

- **TypeScript has these and also…**

| | |
|---|---|
| `unknown` | (could be anything) |
| **`any`** | (turns off type checking — do not use!) |

# Literal Types

- Any literal value is also a type:

```
let x: "foo" = "foo";
let y: 16n = 16n;
```

- Variable can only hold that specific value!
  - can assign it again, but only with the same value

- Seems silly, but turns out to be useful...

# Ways to Create New Types in TypeScript

- **Union Types** `string | bigint`
  - can be either one of these

- Not possible in Java!
  - TS can describe types of code that Java cannot

- Unknown type is (essentially) a union

```
type unknown = number | bigint | string | boolean | ...
```

# Enumerations

- Use unions of literals are “enums”

```
const dist = (dir: "left"|"right", amt: bigint): bigint => {
  if (dir === "right") {
    return amt;
  } else {
    return -amt;
  }
};
```

- TypeScript ensures that callers will only pass one of those two strings (“left” or “right”)
  - impossible to do this in Java

    (must fake it with the enumeration **design pattern**)

# Java Enums

- **Another design pattern built into Java:**

```
enum Dir {
  LEFT, RIGHT
}
```

- `Dir.LEFT` **etc. are the only 2 instances of** `Dir`

- **Cannot pass a** `Dir` **where** `String` **is expected**
  - **must add methods to convert between them**

# Ways to Create New Types in TypeScript

- Can create compound types in multiple ways
  - put multiple types together into one larger type

- **Record Types** `{x: bigint, s: string}`
  - anything with *at least* fields "x" and "s"

```
const p: {x: bigint, s: string} = {x: 1n, s: "hi"};
console.log(p.x);  // prints 1n
```

# Ways to Create New Types In TypeScript

- Can create compound types in multiple ways
  - put multiple types together into one larger type

- Tuple Types `[bigint, string]`
  - create them like this

```
const p: [bigint, string] = [1n, "hi"];  // an array
```

  - give names to the parts ("destructuring") to use them

```
const [x, y] = p;
console.log(x);  // prints 1n
```

  - 331 convention: destructure tuples but not records

    access values of compound types **by name**, not order

# Records vs Tuples

- **Records and tuples provide the same functionality**
  - **both allow you to put parts together into one object**
  - **conceptually interchangeable**

- **They differ in *who* names the parts and *when***
  - **record: creator picks the names**

    everyone must use the same name
  - **tuple: user of the tuple picks the names**

    each user can pick their own names

# Optional Fields in TypeScript

- Records can have optional fields

```
type T = {x: bigint, y?: bigint};

const t: T = {x: 1n};
```

  - type of "`t.y`" is "`bigint | undefined`"

- Functions can have optional arguments

```
const f = (a: bigint, b?: bigint): bigint => {
  console.log(b);
};
```

  - type of "`b`" is "`bigint | undefined`"

# Type Aliases

- TypeScript lets you give shorthand names for types

```
type Point = {x: bigint, y: bigint};

const p: Point = {x: 1n, y: 2n};
console.log(p.x);  // prints 1n
```

- Usually nicer but not necessary
  - e.g., this does the same thing

```
const p: {x: bigint, y: bigint} = {x: 1n, y: 2n};
console.log(x);  // prints 1n
```

# Structural vs Nominal Typing

- **Deep difference between TypeScript and Java types**

- **TypeScript uses "structural typing"**
  - **sometimes called "duck typing"**

    "if it walks like a duck and quacks like a duck, it's a duck"

```
type T1 = {a: bigint, b: string};
type T2 = {a: bigint, b: string};

const x: T1 = {a: 1n, b: "two"};
```

  - **can pass " `x` " to a function expecting a " `T2` "!**

# Structural vs Nominal Typing

- Java uses "**nominal typing**"

```
class T1 { int a; int b; }
class T2 { int a; int b; }

T1 x = new T1();
```

  - **cannot** pass "`x`" to a function expecting a "`T2`"

- Libraries do not interoperate unless it was pre-planned
  - create "adapters" to work around this

    example of a design pattern used to work around language limitations

# React Components

```
type HiProps = {name: string};
type HiState = {greeting: string};

class HiElem extends Component<HiProps, HiState> {

  constructor(props: HiProps) {
    super(props);

    this.state = {greeting: "Hi"};
  }
```

- Component is a generic type
  - first component is type of `this.props` (readonly)
  - second component is type of `this.state`

# Type Inference

- If you leave off the type, TS will try to guess it
  - often, but not always, it guesses correctly

- This will work fine

```
const p = {x: 1n, y: 2n};
console.log(p.x);  // prints 1n
```

  - compiler should correctly guess `{x: bigint, y: bigint}`
  - can see in VS Code by hovering over "`p`"

# Type Inference

- If you leave off the type, TS will try to guess it
  - often, but not always, it guesses correctly

- 331 convention: type declarations are required on…
  - function arguments and return values
  - variables declared outside of any function ("top-level")

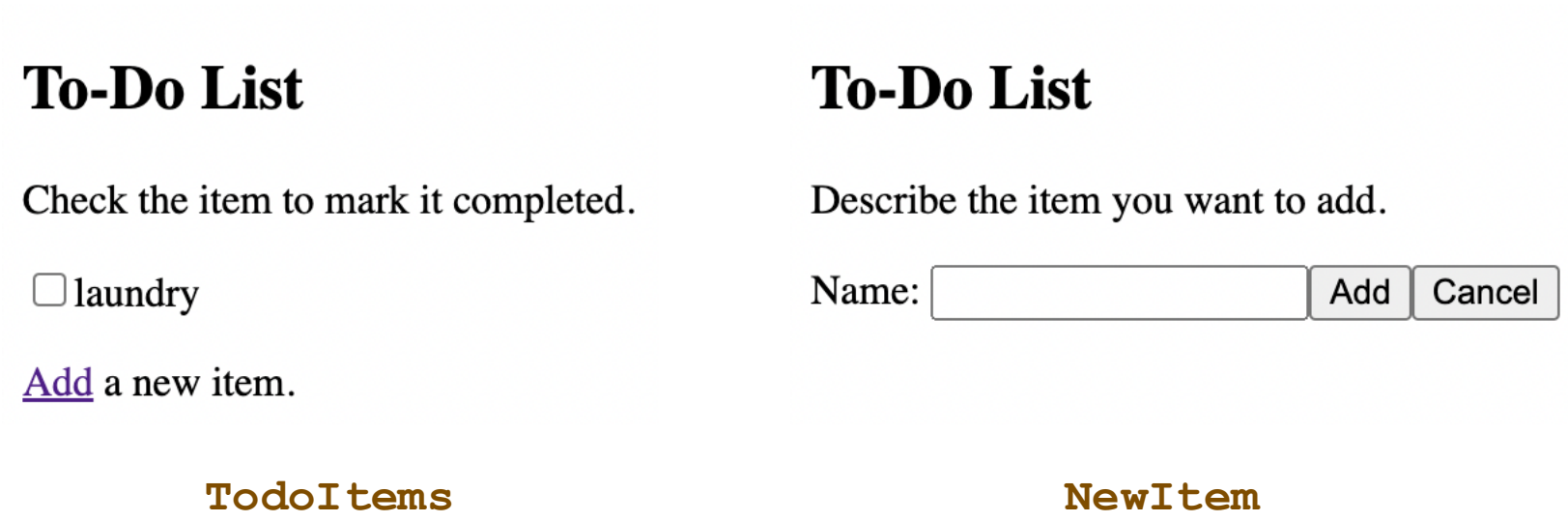
    these could be exported, so types should be explicit

- We do not require declarations on local variables
  - but it is fine to include them
  - if TS guesses wrong, you will need to include it

# Example: To-Do List (v2)

# Modular To-Do List

- App will have two different "pages":




  - clicking the "Add" link shows the "New Item" page
  - clicking the "Add" or "Cancel" button shows the list again

# Modular To-Do List

- State of the app keeps track of which page to show

```
this.state = {creating: false, items: []};
```

  - show "New Item" page if `creating` is true
  - show "Todo Items" page if `creating` is false

- List of items must be stored in `TodoApp`
  - needs to continue to exist even if `TodoItems` does not exist

# Modular To-Do List

- List of items must be stored in `TodoApp`
  - needs to continue to exist even if `TodoItems` does not exist

- How does `TodoItems` change the list?
  - it cannot do so directly
  - instead, it tells `TodoApp` to make the change

    invoke a callback passed by `TodoApp` to do so

- General Rule: state lives at the *closest* ancestor of all the components that need it
  - most state is not needed outside that one component

# Example: To-Do List (v3)

# Lifecycle Events

- **Warning: React doesn't unmount when props change**
  - **instead, it re-renders and calls `componentDidUpdate`**

    just as state can change, props can change
  - **you can detect a props change there**

```
componentDidUpdate = (prevProps) => {
  if (this.props.field !== prevProps.field) {
    …  // our props were changed!
  }
};
```

  - **better to avoid this if possible**

    good setup for **painful** debugging