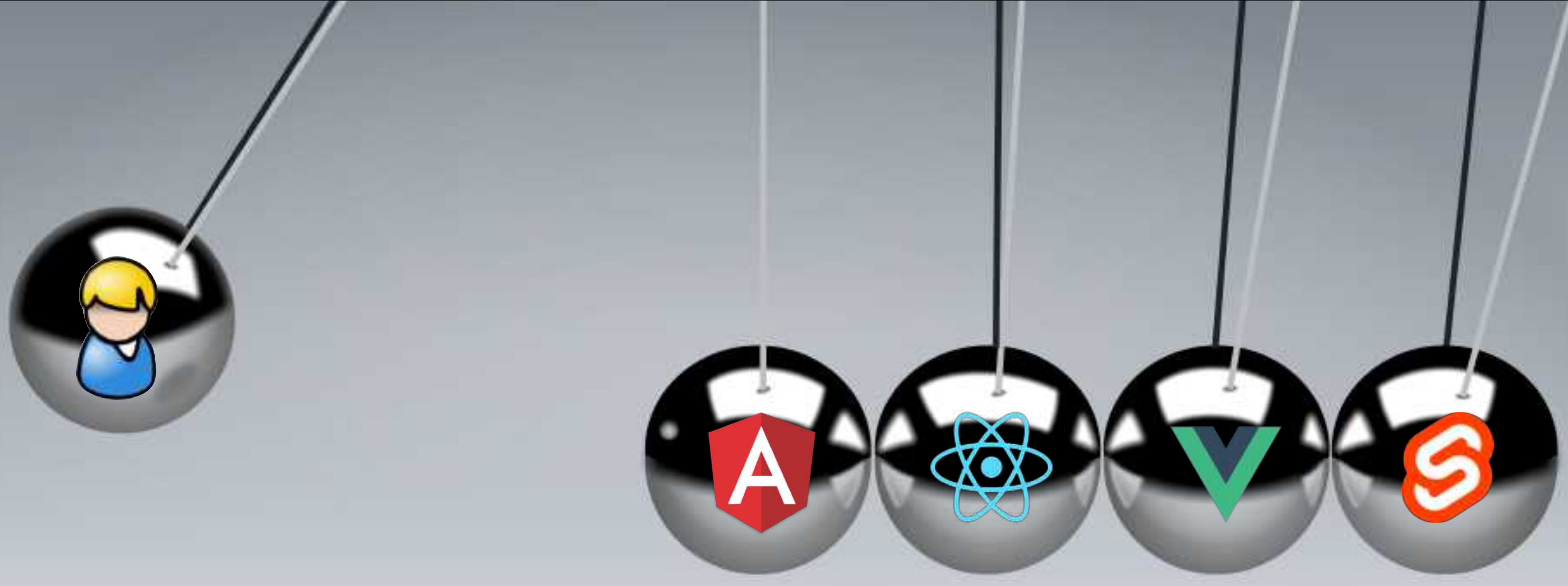
From User Action to Framework Reaction

Reactivity in modern Frontend Frameworks



Jonas Bandi

@jbandi

- Freelancer, in den letzten 8 Jahren vor allem in Projekten im Spannungsfeld zwischen modernen Webentwicklung und traditionellen Geschäftsanwendungen.
- Dozent an der Berner Fachhochschule seit 2007
- In-House Kurse & Beratungen zu Web-Technologien im Enterprise: UBS, Postfinance, Mobiliar, AXA, BIT, SBB, Elca, Adnovum, BSI ...

JavaScript / Angular / React / Vue.js
Schulung / Beratung / Coaching / Reviews

jonas.bandi@ivorycode.com

Reactivity ?

"There are as many definitions of reactive programming as there are reactive programmers."

Reactive Programming?

In computing, reactive programming is a declarative programming paradigm concerned with data streams and the propagation of change.

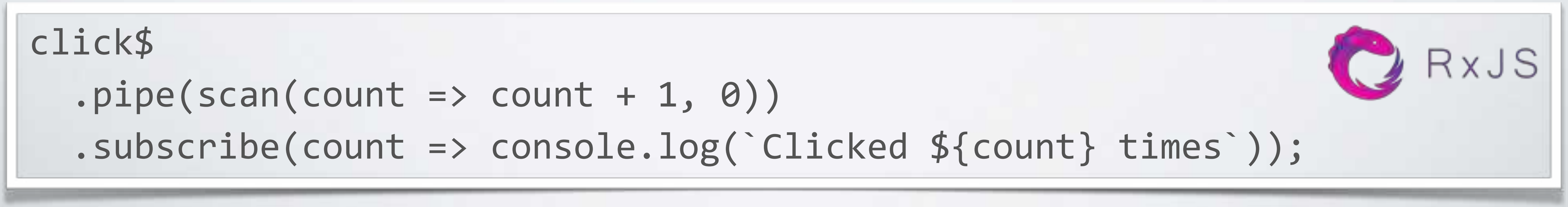
- Wikipedia

reactive programming is a paradigm in which declarative code is issued to construct asynchronous processing pipelines.

- Defining the "reactive"
https://developer.ibm.com/articles/defining-the-term-reactive/

Reactive programming is programming with asynchronous data streams.

- The introduction to Reactive Programming you've been missing
https://gist.github.com/staltz/868e7e9bc2a7b8c1f754

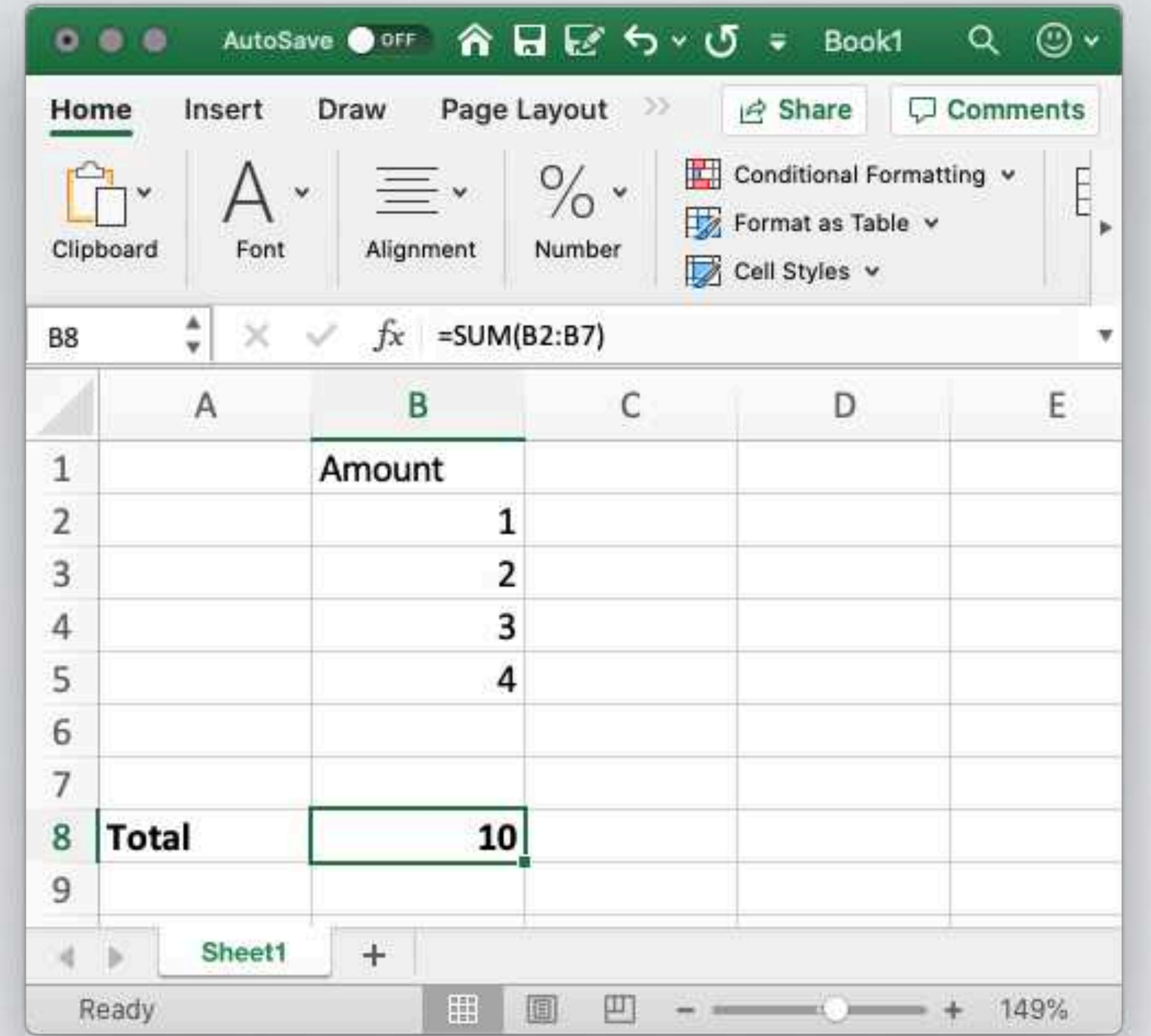


```
click$
  .pipe(scan(count => count + 1, 0))
  .subscribe(count => console.log(`Clicked ${count} times`));
```

"The essence of functional reactive programming is to specify the *dynamic behavior* of a value completely at the *time of declaration*"

- Heinrich Apfelmus, via Michel Westrate

https://www.youtube.com/watch?v=AdNJ3fydeao



B8 =SUM(B2:B7)

	A	B	C	D	E
1		Amount			
2		1			
3		2			
4		3			
5		4			
6					
7					
8	**Total**	**10**			
9					

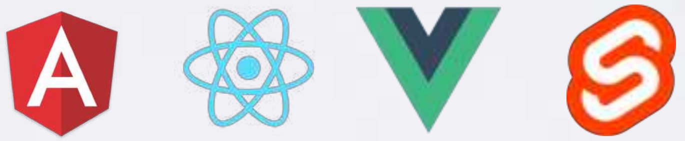
Agenda

Intro

Reactivity - What are we talking about here?

Exploration

"Out of the Box"-Reactivity of

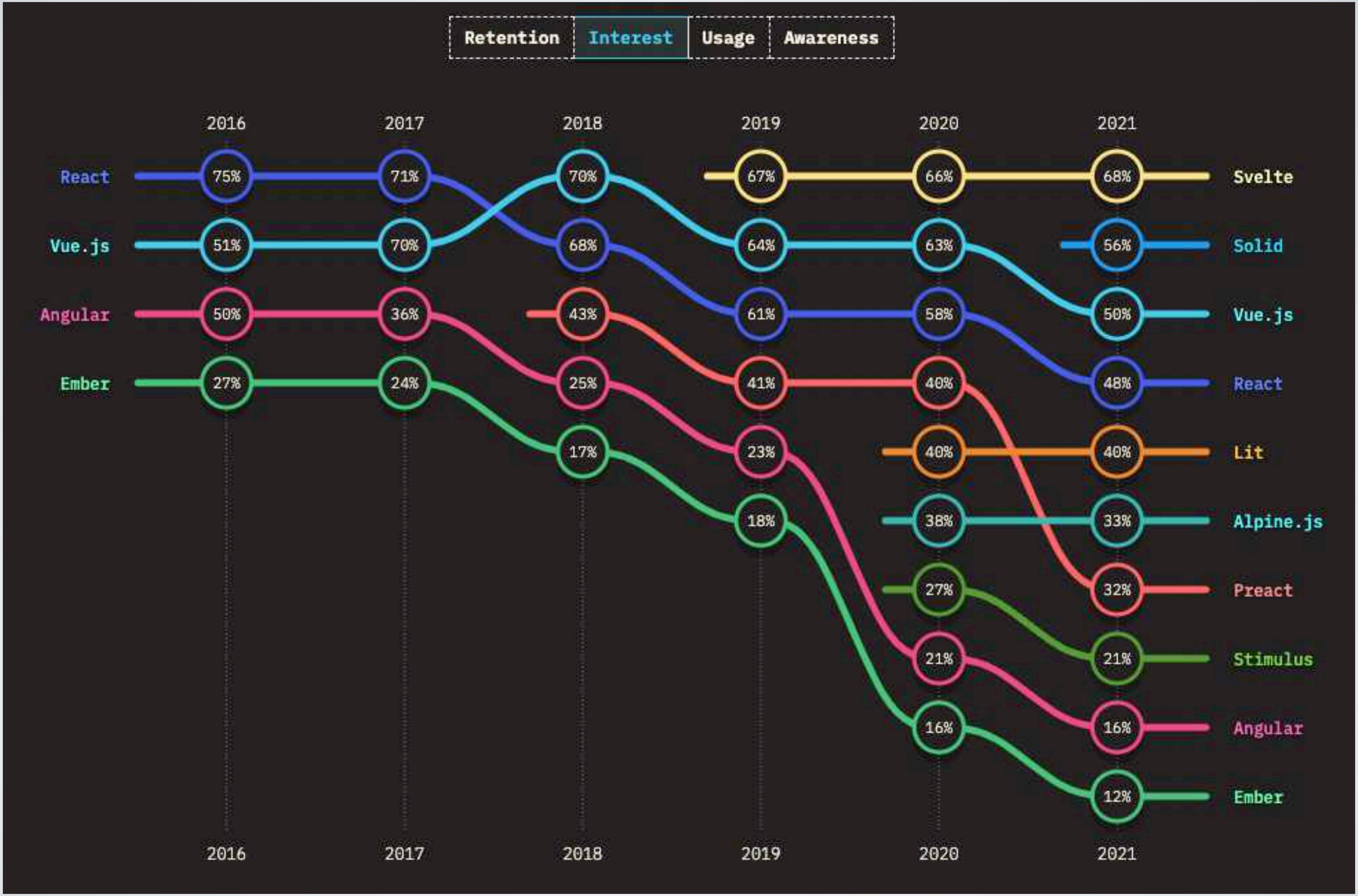


- Code Example
- How does it work?
- Implications
- One Advantage
- One Problem

Takeaway

A glimpse into each framework.
A "feeling" how the framework works.

State of JavaScript Survey 2021:

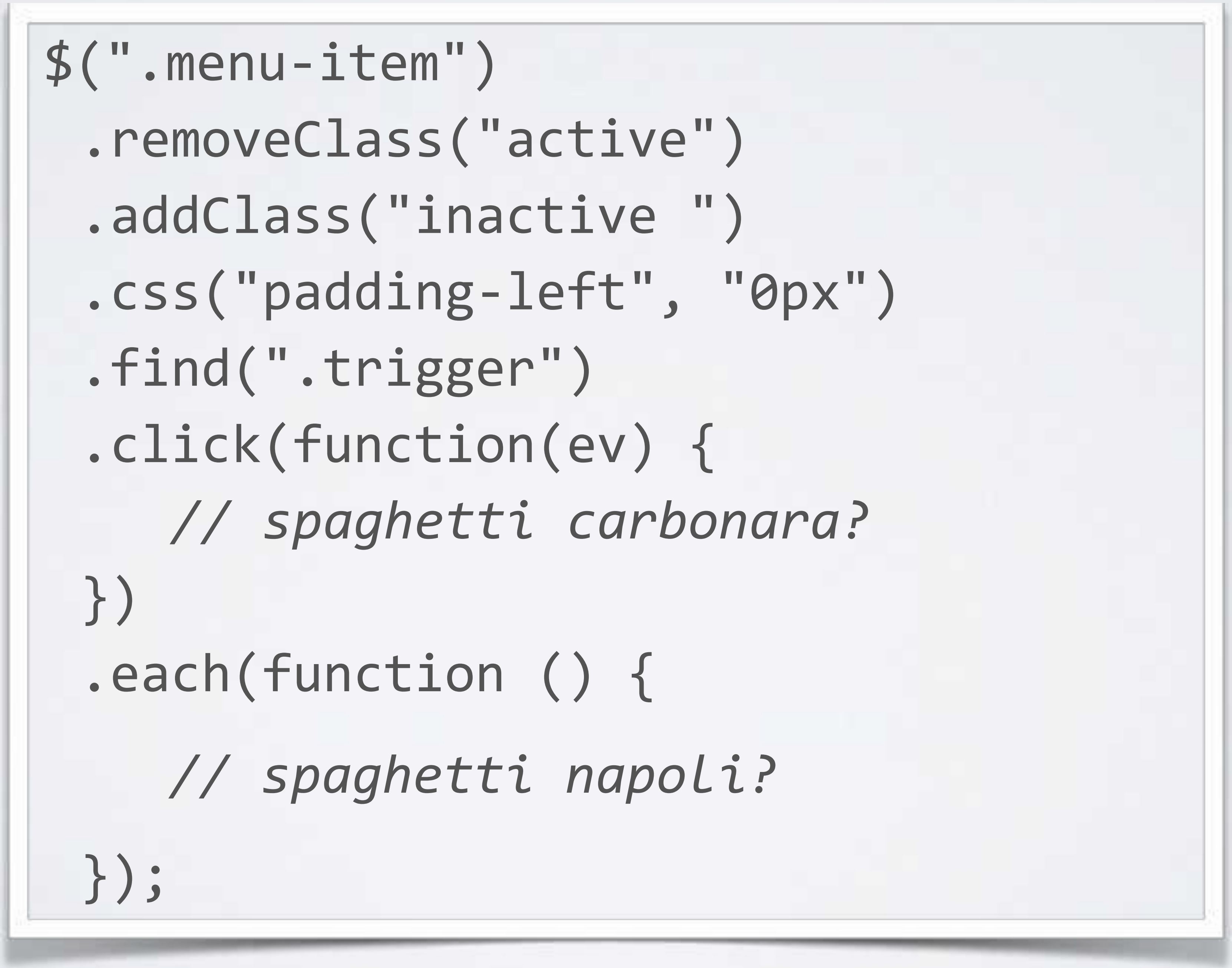


https://2021.stateofjs.com/en-US/libraries/front-end-frameworks

In the Beginning there was Darkness …

… then the DOM was created.

… and we manipulated the DOM …



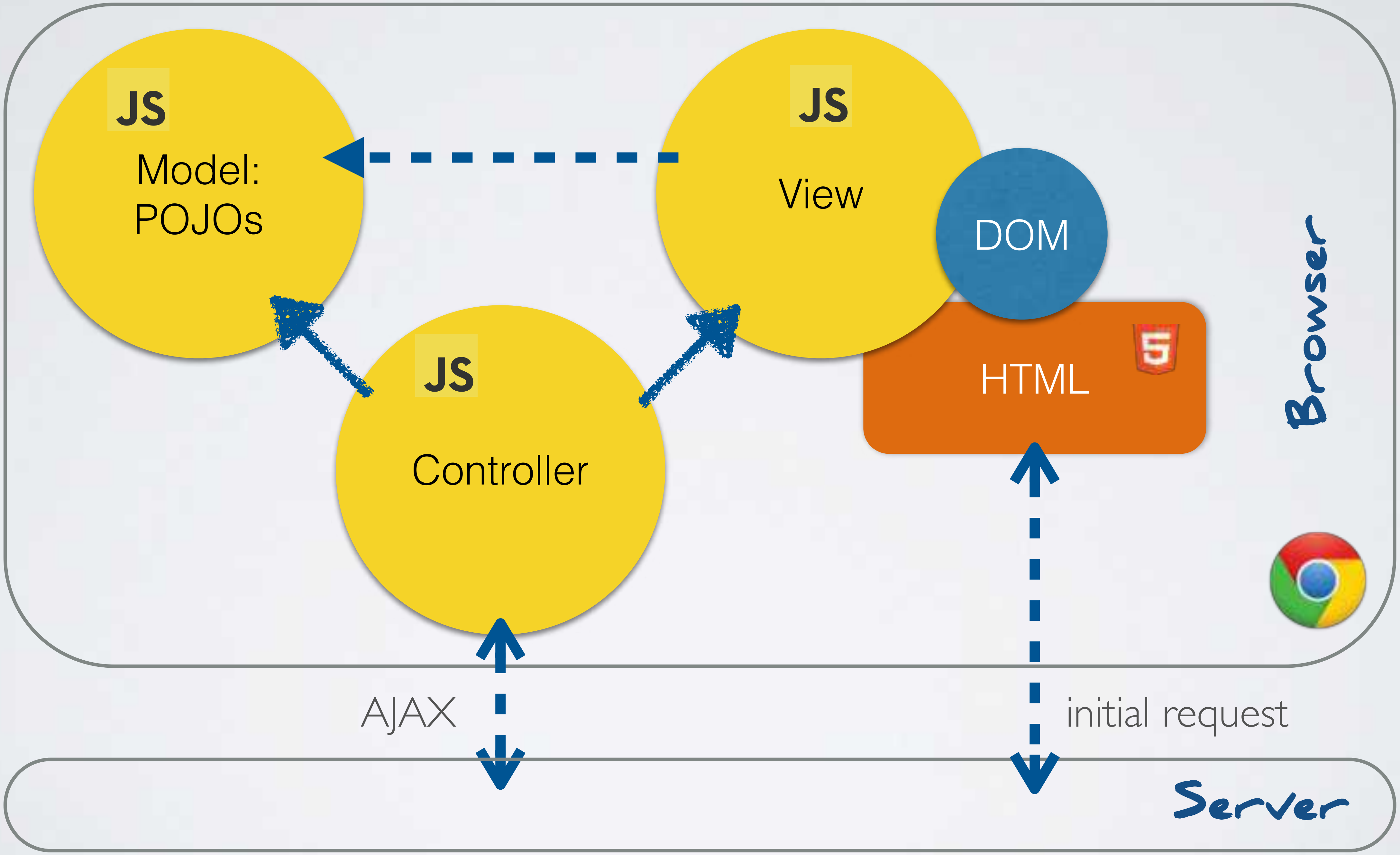
```
$(".menu-item")
 .removeClass("active")
 .addClass("inactive ")
 .css("padding-left", "0px")
 .find(".trigger")
 .click(function(ev) {
    // spaghetti carbonara?
 })
 .each(function () {
    // spaghetti napoli?
 });
```

… the Dark Ages of DOM …

… a new hope …

Model View Controller

Client Side MVC

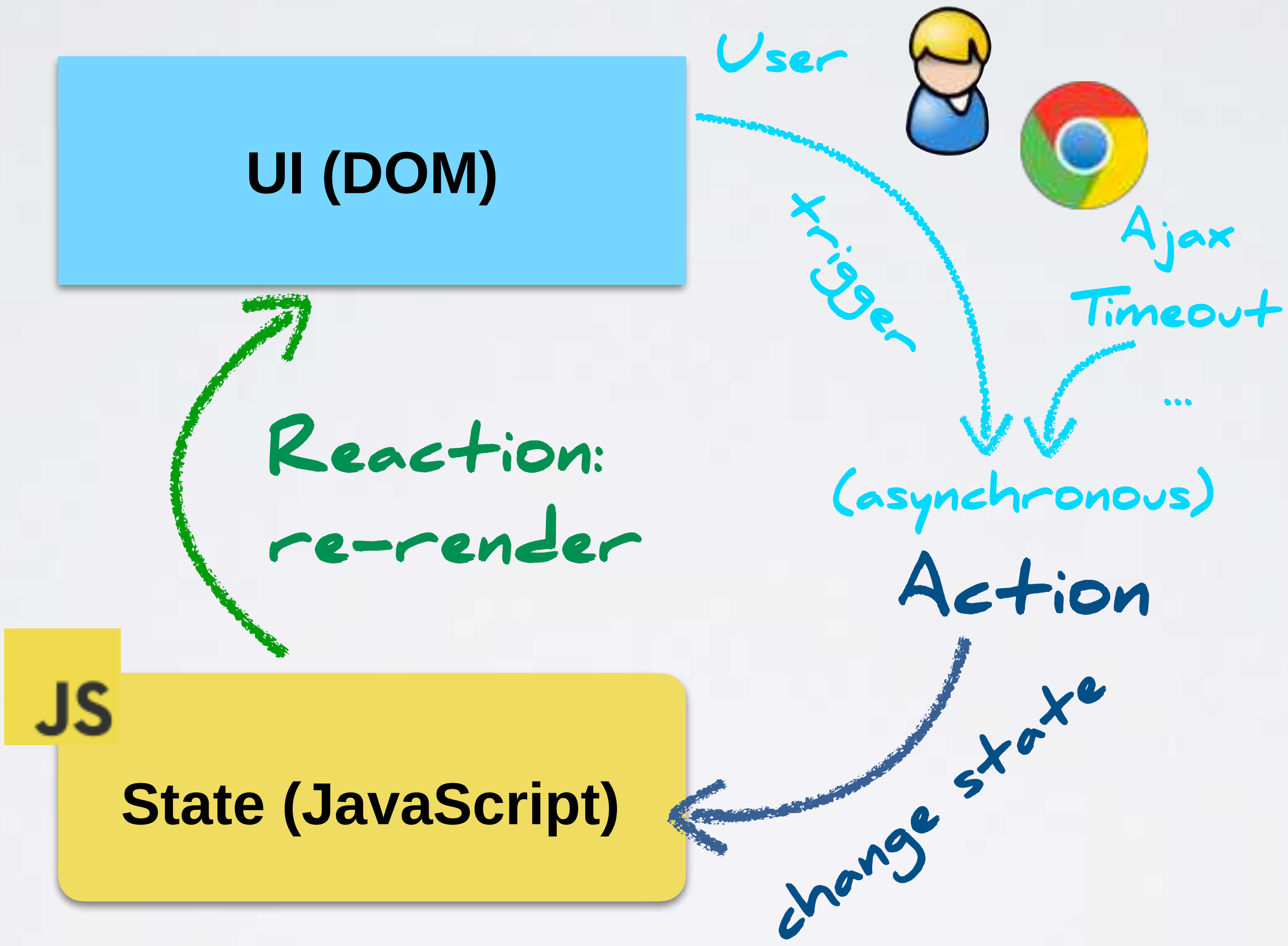


Thou shalt not manipulate the DOM!

the DOM *is* updated

State is Managed in JavaScript

The UI renders the state and "signals" events.


UI (DOM)

JS

State (JavaScript)

Reactivity in a SPA: The application reacts on state changes and updates the UI.

Evan You - Reactivity in Frontend JavaScript Frameworks: https://www.youtube.com/watch?v=r4pNEdIt_l4
http://teropa.info/blog/2015/03/02/change-and-its-detection-in-javascript-frameworks.html

Reactivity: What and Why?

Traditional "DOM-centric" applications →

UI = state

Browsers have "built-in" reactivity: If the DOM is changed, the UI is re-rendered.

Problem: the same state might be displayed at several places in the DOM.

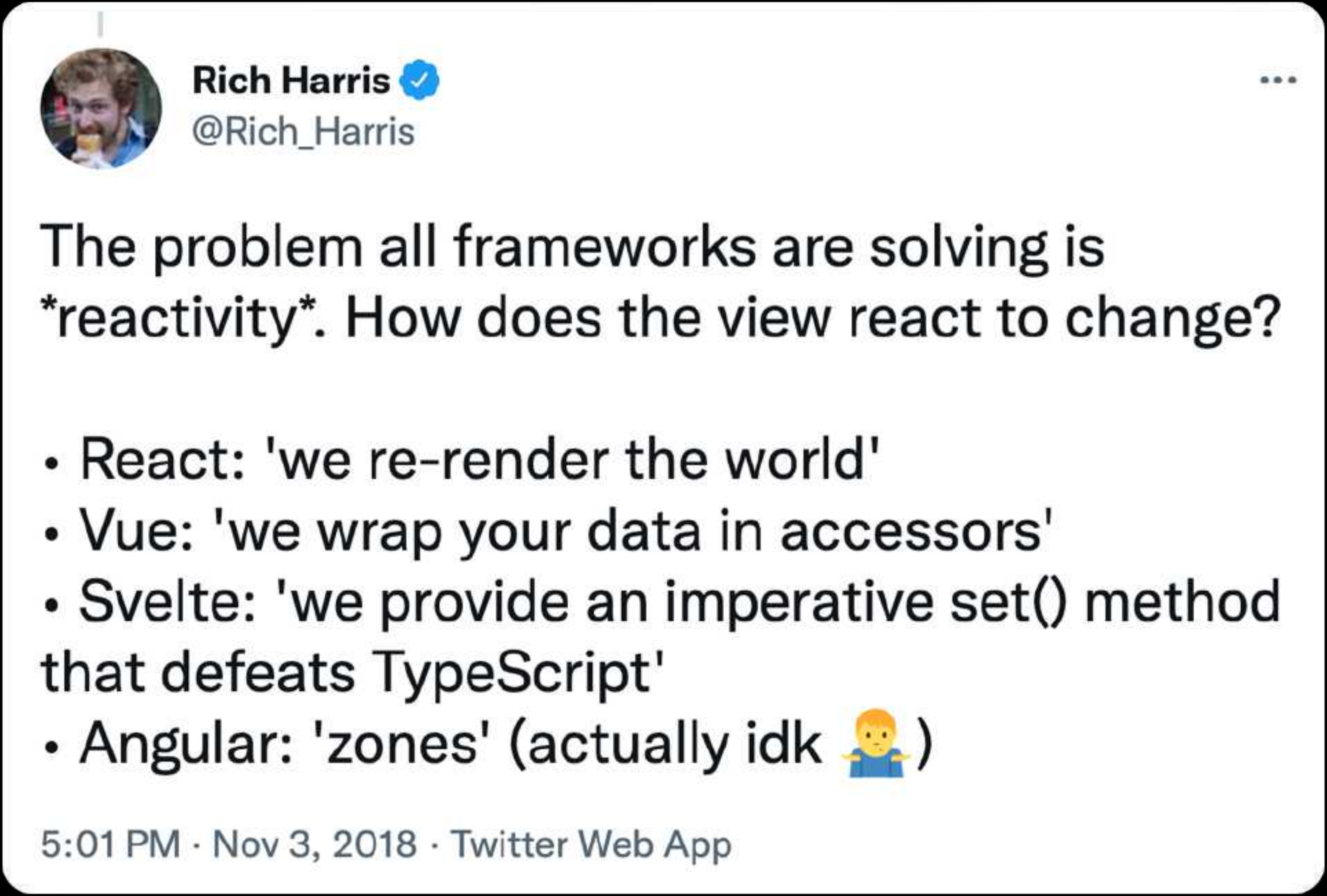
With client-side Single-Page-Applications, the state is represented as JavaScript objects. →

UI = f(state)

When to call?

The UI that you can see and manipulate on screen is the result of painting a visual representation of data.

This is the *Reactivity* we are investigating:
How do frameworks deal with state changes over time?
The UI should (automatically) update when the state changes.



Rich Harris

@Rich_Harris

The problem all frameworks are solving is *reactivity*. How does the view react to change?

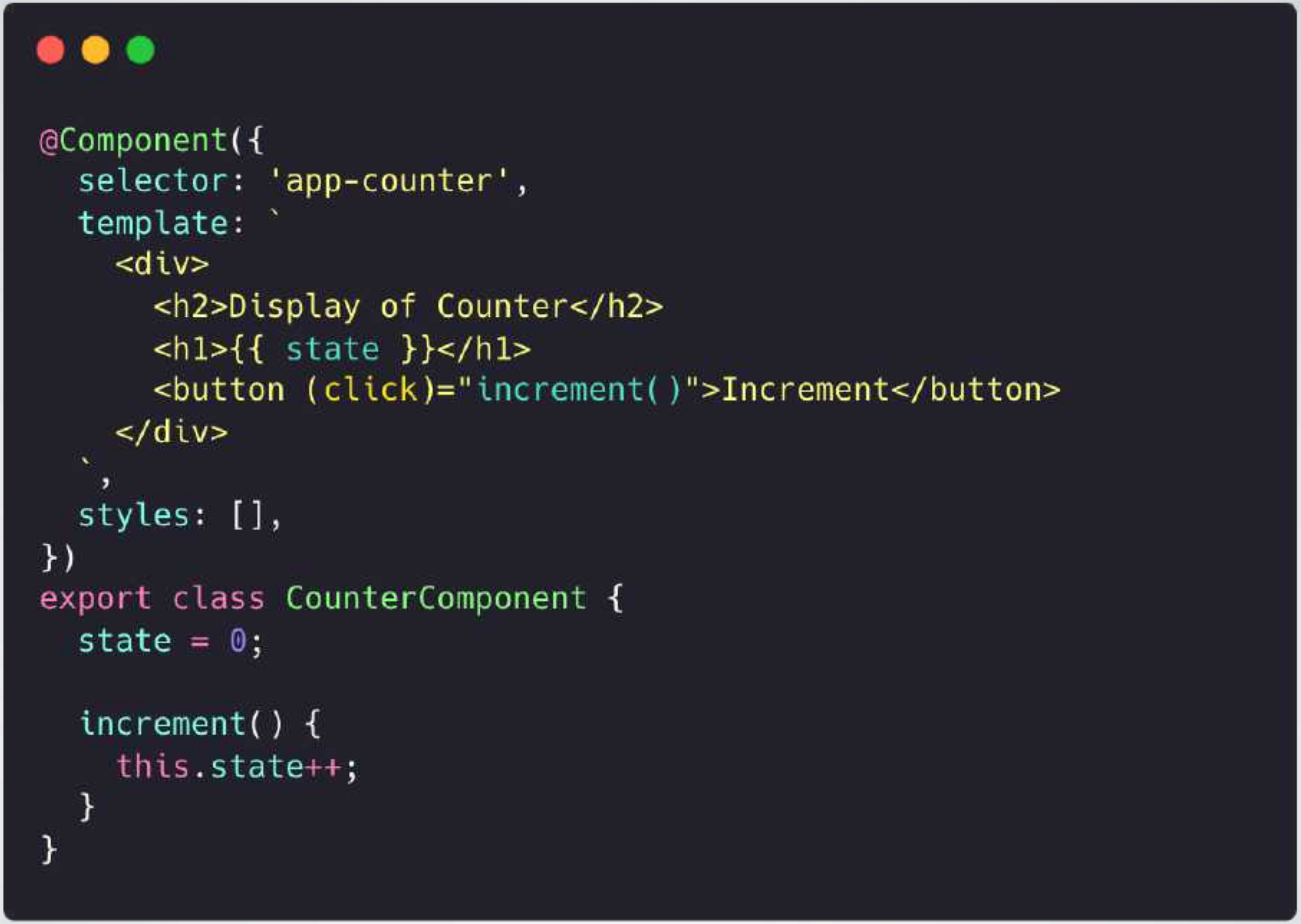
- React: 'we re-render the world'
- Vue: 'we wrap your data in accessors'
- Svelte: 'we provide an imperative set() method that defeats TypeScript'
- Angular: 'zones' (actually idk 🤷‍♂️)

5:01 PM · Nov 3, 2018 · Twitter Web App

https://twitter.com/Rich_Harris/status/1058751085706383362

Framework Reactivity

Angular Reactivity



```
@Component({
  selector: 'app-counter',
  template: `
    <div>
      <h2>Display of Counter</h2>
      <h1>{{ state }}</h1>
      <button (click)="increment()">Increment</button>
    </div>
  `,
  styles: [],
})
export class CounterComponent {
  state = 0;

  increment() {
    this.state++;
  }
}
```

🪄 `setInterval` 🪄

It's not what you think it is ...

Zone.js:

The "Magic" in Angular Change Detection

Zone.js is a JavaScript library provided by the Angular project that patches many asynchronous browser APIs. Listeners can then be triggered when these APIs are executed.

Patched APIs (examples): `setTimeout`, `Promise`, `XMLHttpRequest`, `prompt` and DOM events.

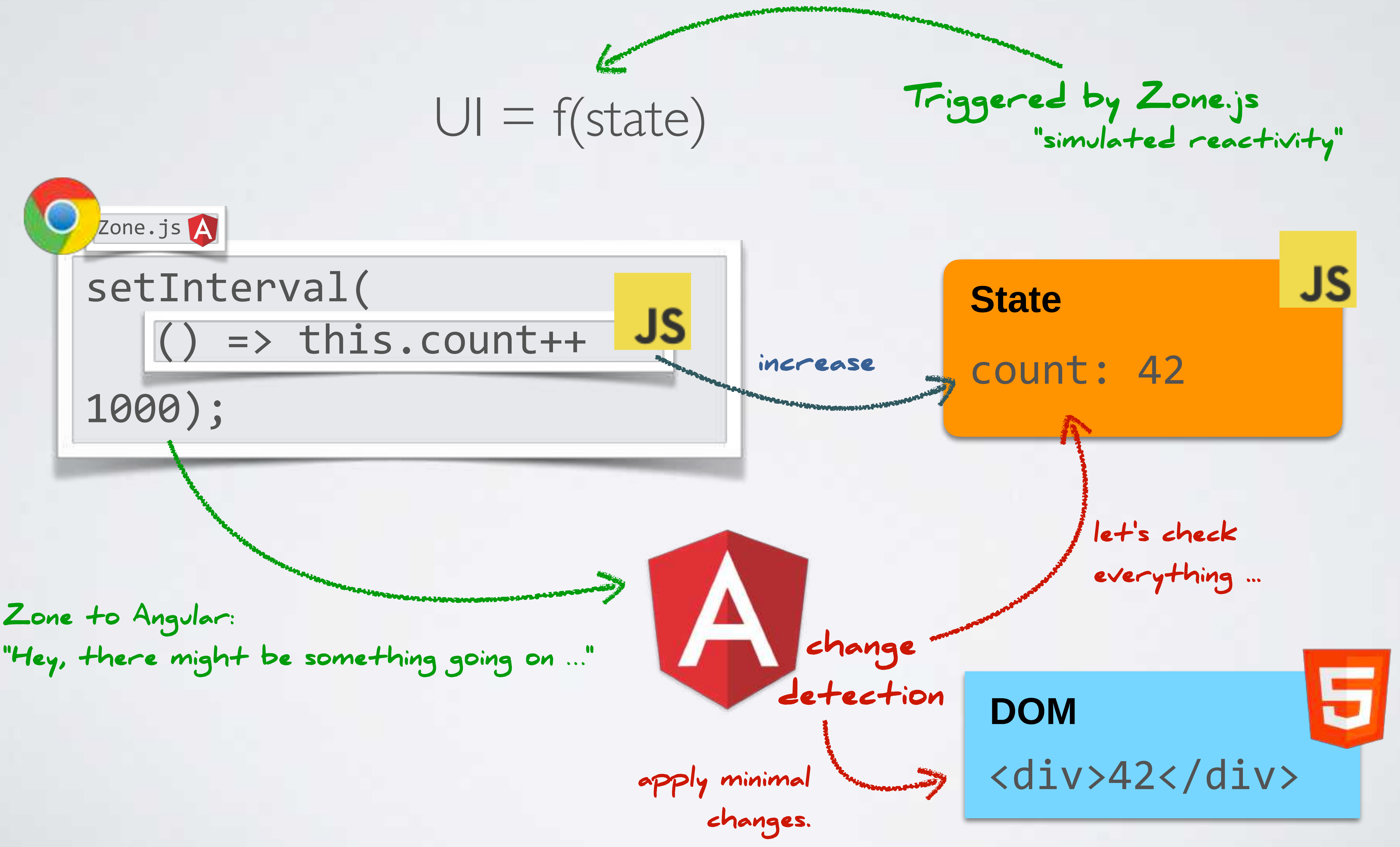
More details: https://github.com/angular/angular/blob/master/packages/zone.js/STANDARD-APIS.md

Angular relies on Zone.js to trigger automatic change detection. Angular is running inside the NgZone (a zone created via Zone.js). When async APIs are executed Angular gets notified when the execution has finished and triggers change detection.

https://github.com/angular/zone.js/
https://medium.com/better-programming/zone-js-for-angular-devs-573d89bbb890

Default Reactivity in Angular

"simulated reactivity"



UI = f(state)

Triggered by Zone.js
"simulated reactivity"

```
setInterval(
    () => this.count++
1000);
```

increase

State

count: 42

Zone to Angular:
"Hey, there might be something going on ..."

change detection

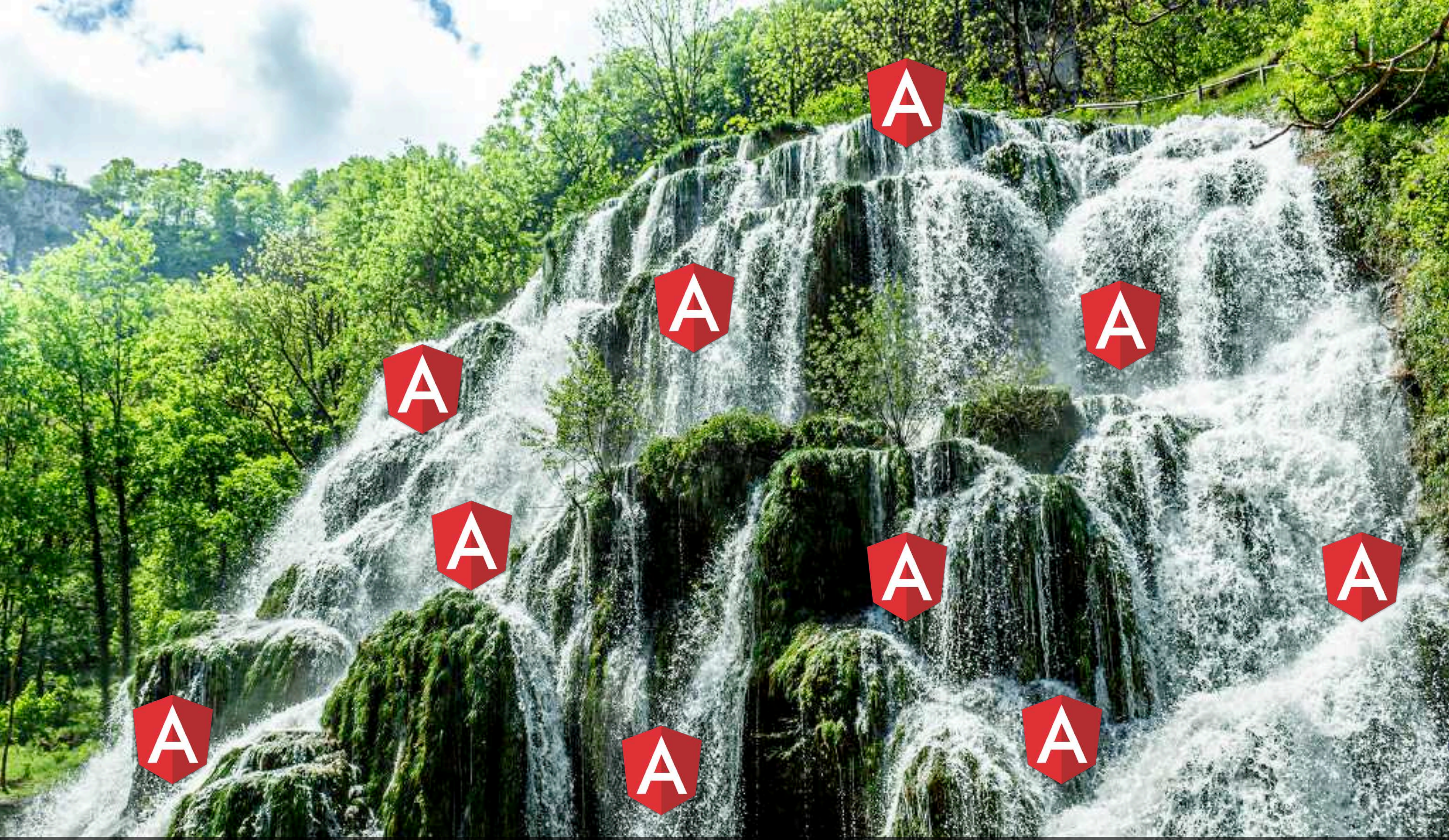
let's check everything ...

apply minimal changes.

DOM

```
<div>42</div>
```

Mutability



Change Detection Cascade

Default Reactivity in Angular

Zone.js with Default Change Detection:

- is a form of *simulated reactivity:* the framework does not react to changes but to events that might potentially have caused changes
- is a form of *transparent reactivity:* It makes reactivity an *implicit characteristic* of your program.

A common alternative in Angular is to model Reactivity explicitly with RxJS, this is a form of *explicit reactivity*.

The Taxonomy of Reactive Programming: https://vsavkin.com/the-taxonomy-of-reactive-programming-d40e2e23dee4
https://github.com/meteor/docs/blob/version-NEXT/long-form/tracker-manual.md

Default Angular Reactivity

"Simulated Reactivity"

Strength

Transparent Reactivity:
The programmer should be able to use ideomatic JavaScript, the Framework does the rest.

Programming model based on mutations.

Weakness

Zone.js: Patching the browser is problematic on many levels.

Brute-force approach of default change detection is not optimal in regard to performance.

Change Detection imposes constraints / rules ...

- unidirectional data-flow
- avoid setter/getters?
- no native async/await

Angular Reactivity Variations

`ChangeDetectionStrategy.OnPush`

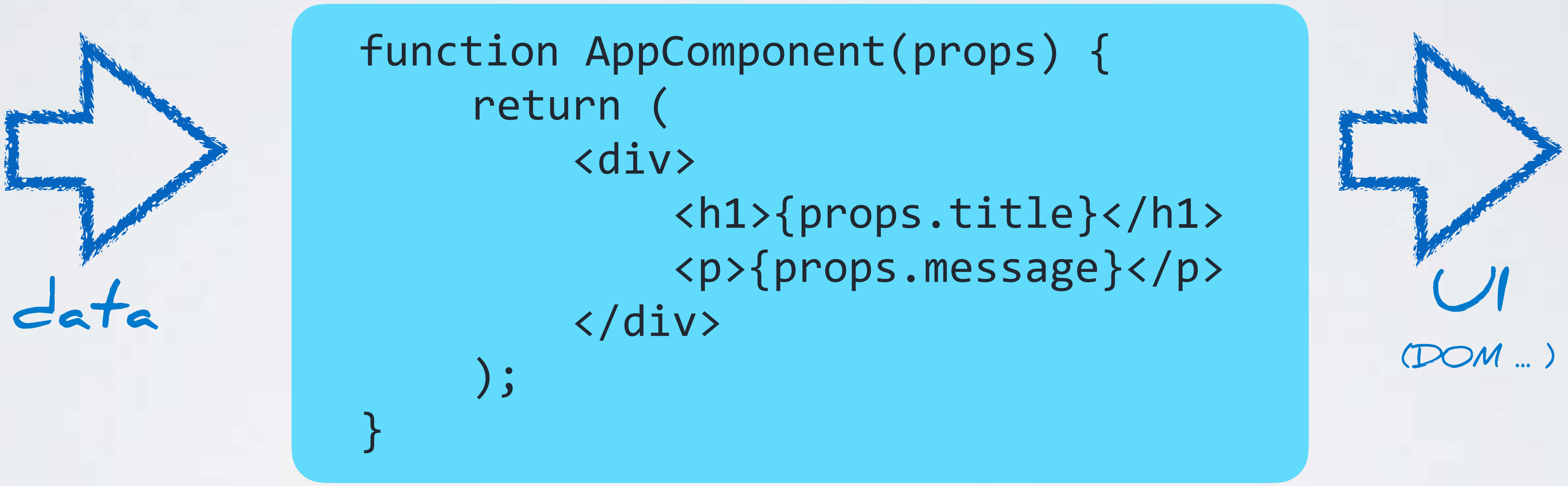
RxJS Observables

Zone-Less

(Missing?) Reactivity in React

Function Components

Components are written as plain JavaScript functions.

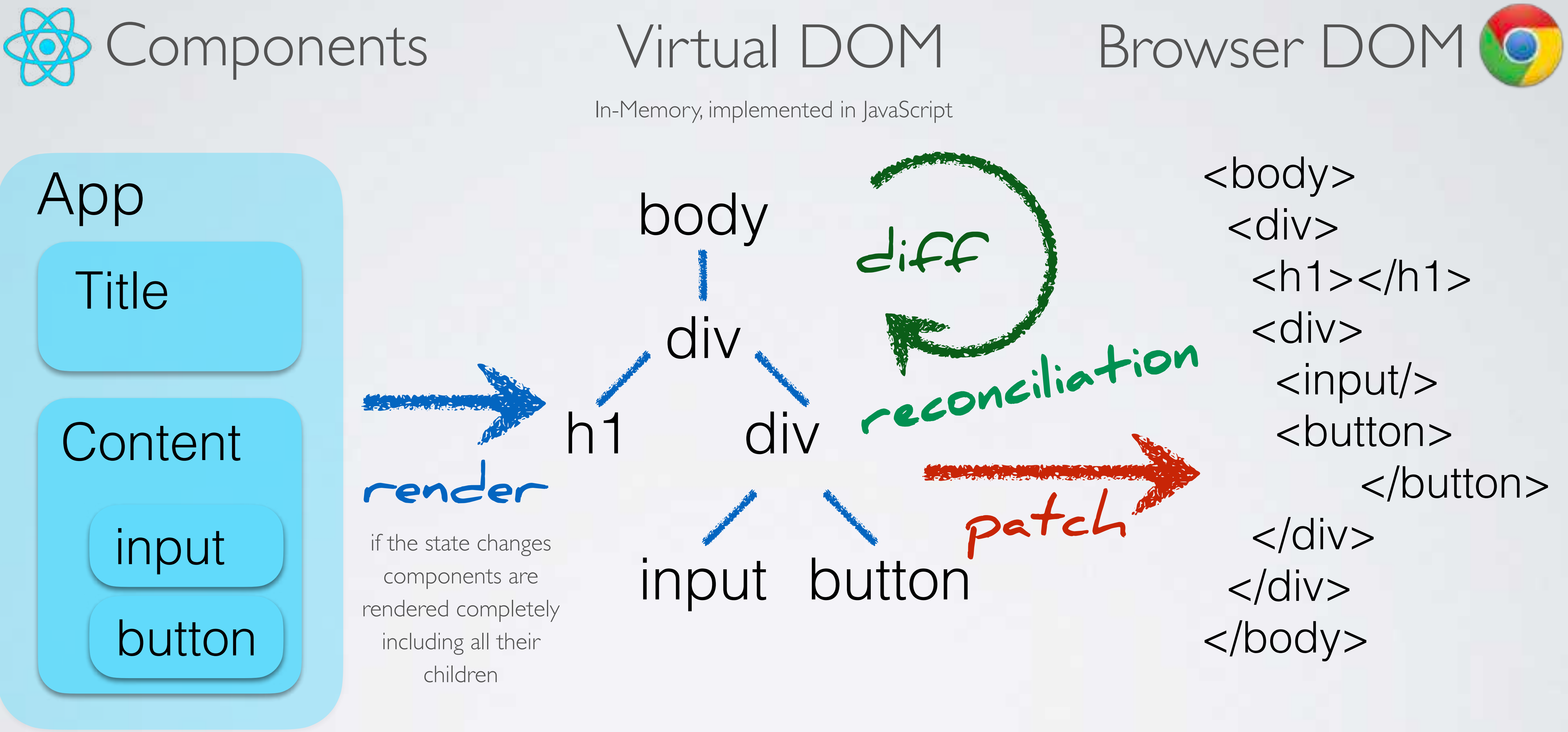


```
function AppComponent(props) {
    return (
        <div>
            <h1>{props.title}</h1>
            <p>{props.message}</p>
        </div>
    );
}
```

The function is called each time the UI is rendered (i.e. with *every* data-change)

A Visual Guide To React Mental Models:
https://obedparla.com/code/a-visual-guide-to-react-mental-models/

The Virtual DOM



Components

Virtual DOM

In-Memory, implemented in JavaScript

Browser DOM

App

Title

Content

input

button

if the state changes components are rendered completely including all their children

body

div

h1

div

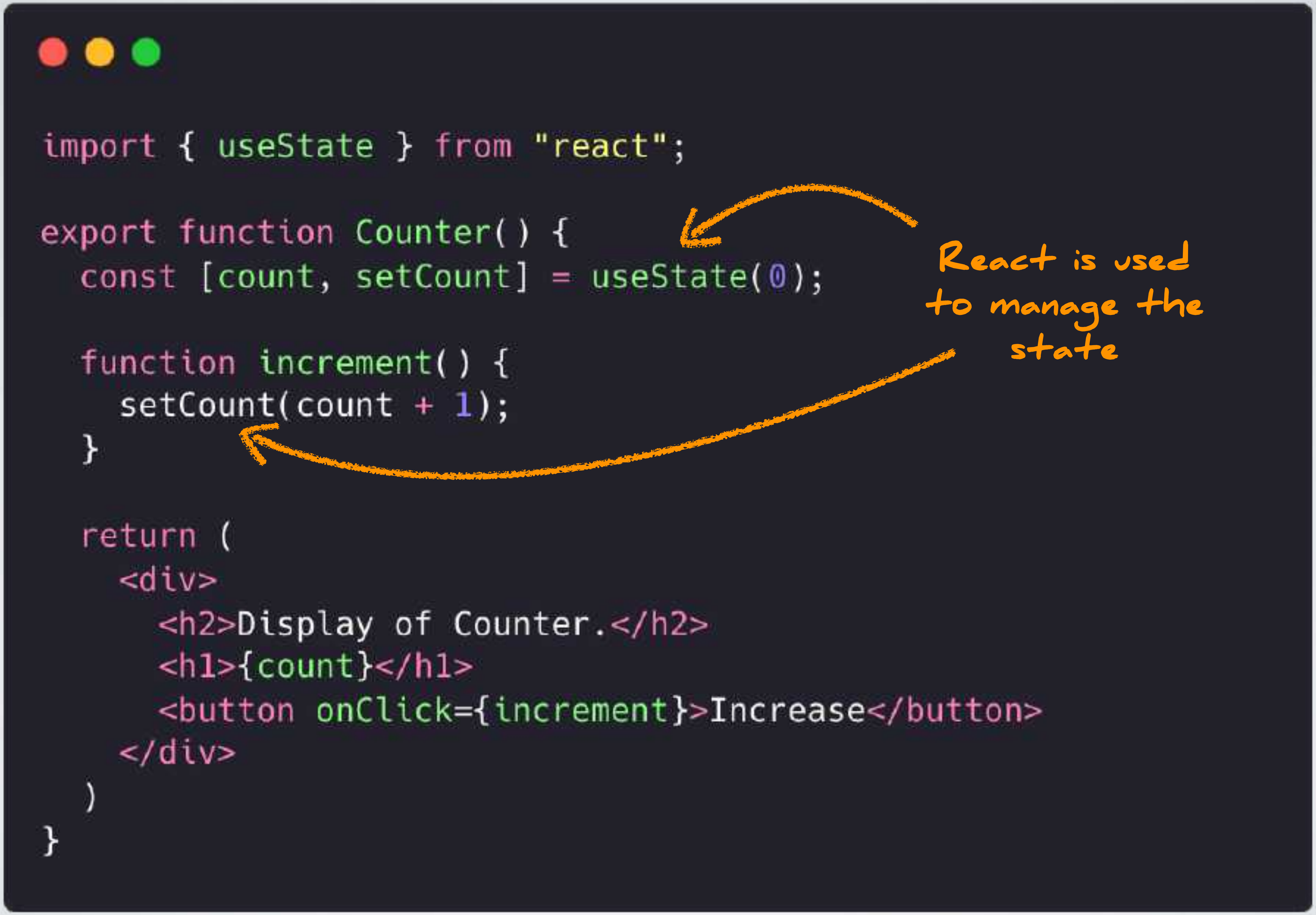
input

button

```
<body>
 <div>
  <h1></h1>
  <div>
   <input/>
   <button>
      </button>
  </div>
 </div>
</body>
```

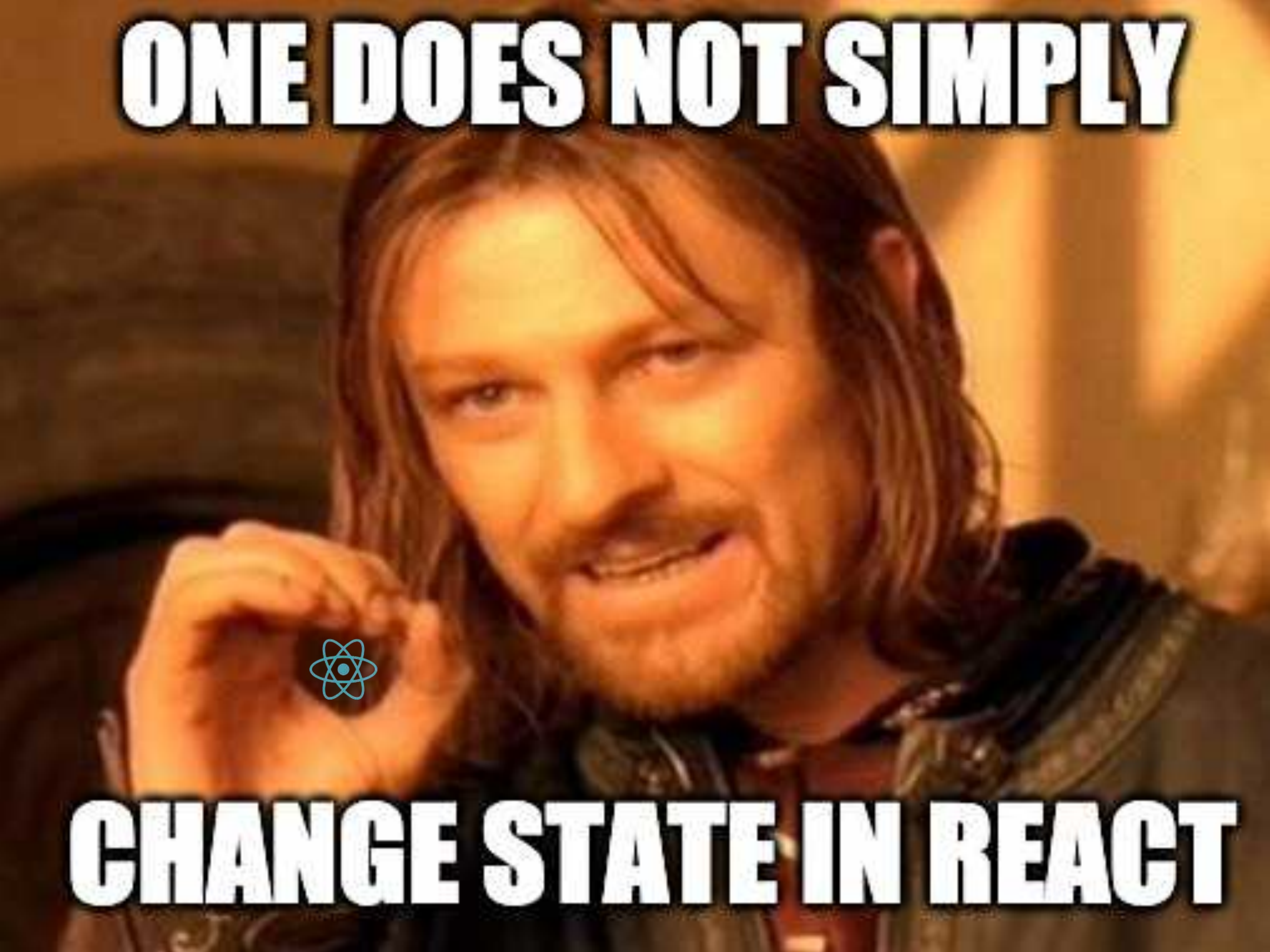
The Virtual DOM also enables server-side rendering and rendering to iOS/Android UIs.

https://reactjs.org/docs/reconciliation.html

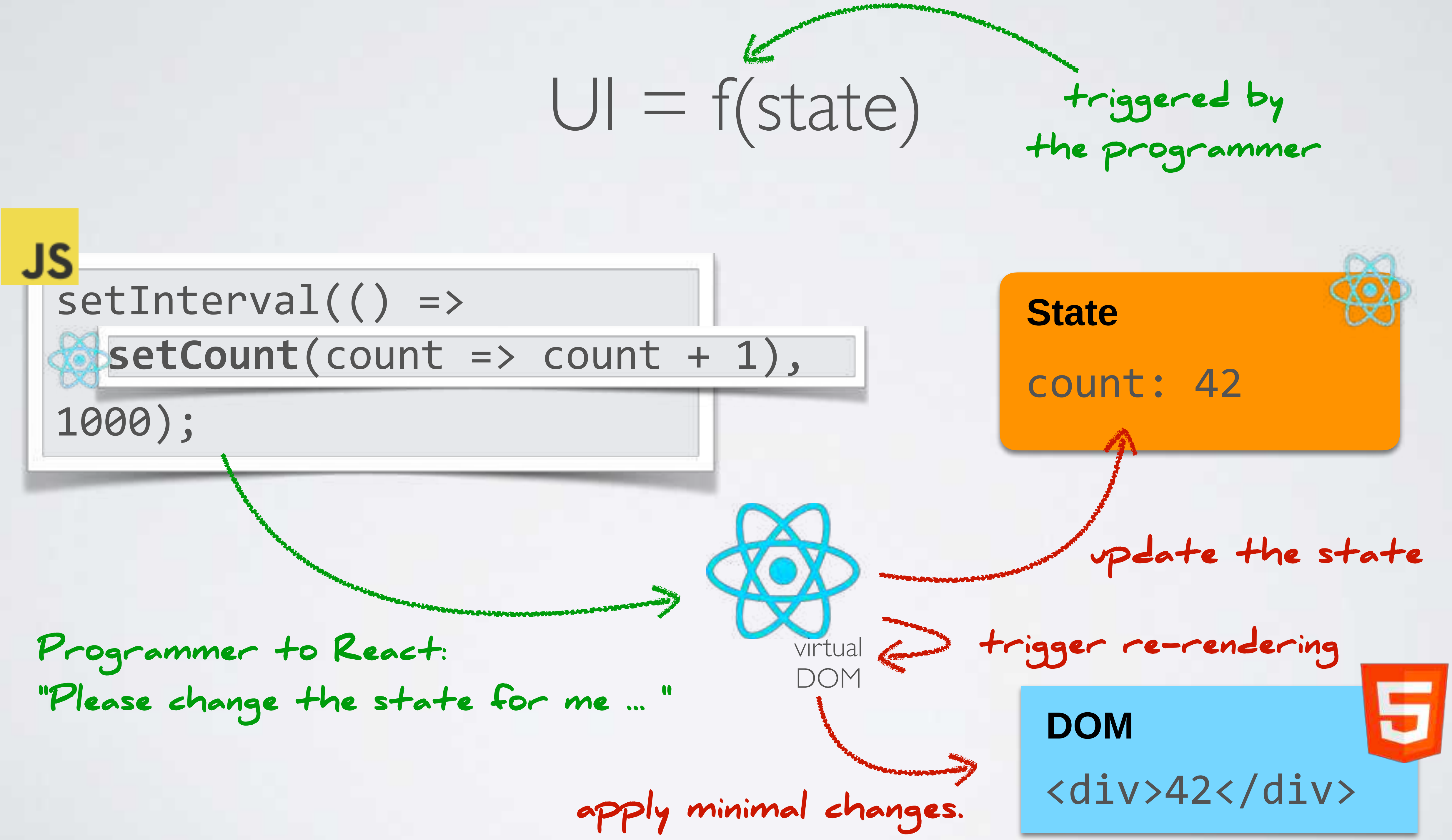


```
import { useState } from "react";

export function Counter() {
  const [count, setCount] = useState(0);

  function increment() {
    setCount(count + 1);
  }

  return (
    <div>
      <h2>Display of Counter.</h2>
      <h1>{count}</h1>
      <button onClick={increment}>Increase</button>
    </div>
  )
}
```

React is used
to manage the
state


ONE DOES NOT SIMPLY
CHANGE STATE IN REACT

Reactivity in React



UI = f(state)

triggered by the programmer

JS

```
setInterval(() =>
  setCount(count => count + 1),
1000);
```

Programmer to React:
"Please change the state for me … "

update the state

State

```
count: 42
```

trigger re-rendering

DOM

```
<div>42</div>
```

apply minimal changes.

Immutability

Render Cascade

React Reactivity

"Everything is rendered on every state change"

Strength

Functional Mindset:

- Rendering is a side-effect of state changes.
- Components transform state to ui.

Weakness

"Render everything" approach is wasteful.

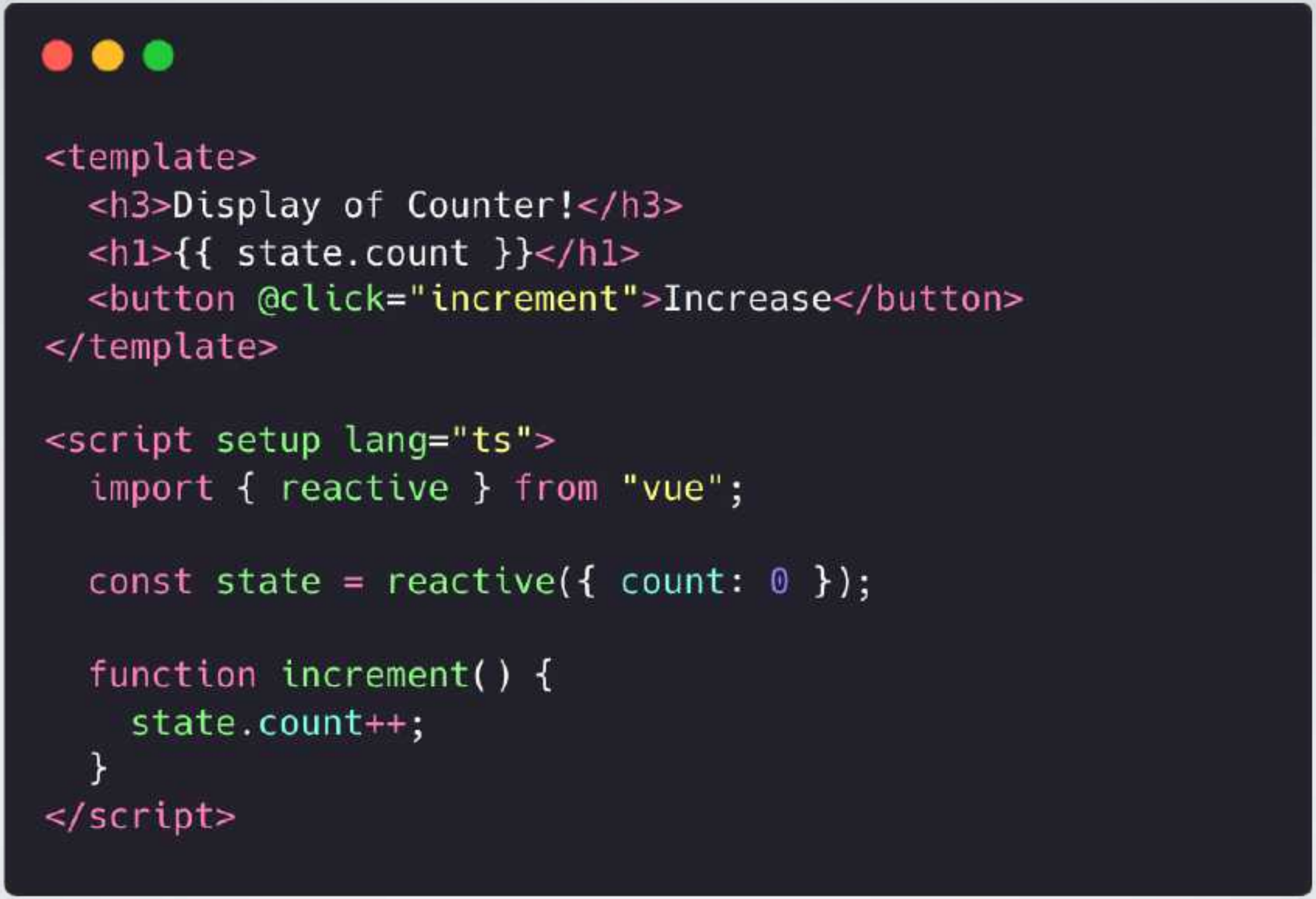
State is managed by React: we have to use the APIs and concepts of React.

Programming model enforces "immutable state management".

https://www.joshwcomeau.com/react/why-react-re-renders/

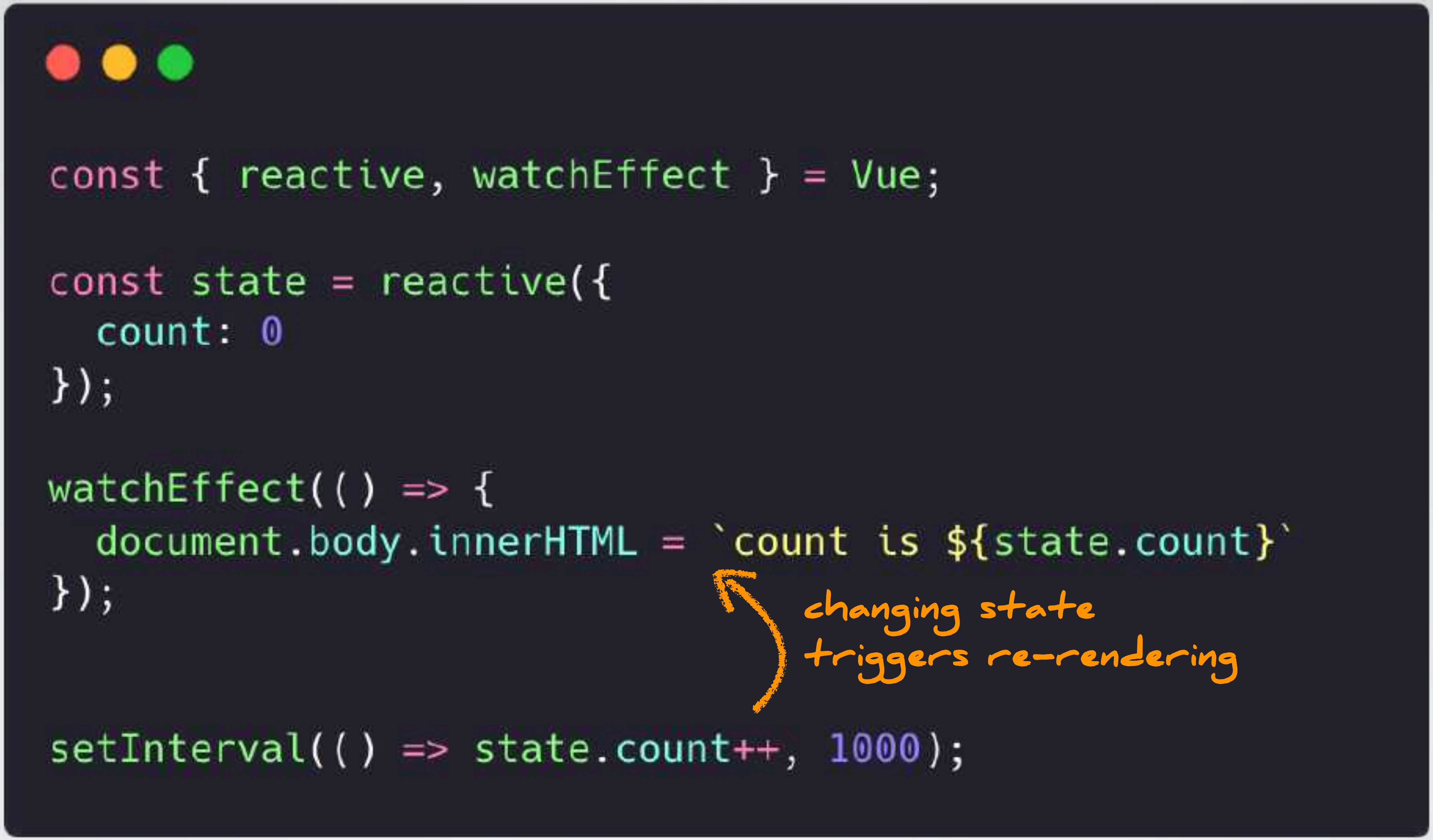
https://blog.isquaredsoftware.com/2020/05/blogged-answers-a-mostly-complete-guide-to-react-rendering-behavior/

Reactive State in Vue



```
<template>
  <h3>Display of Counter!</h3>
  <h1>{{ state.count }}</h1>
  <button @click="increment">Increase</button>
</template>

<script setup lang="ts">
  import { reactive } from "vue";

  const state = reactive({ count: 0 });

  function increment() {
    state.count++;
  }
</script>
```

"Naked" Reactive State in Vue:

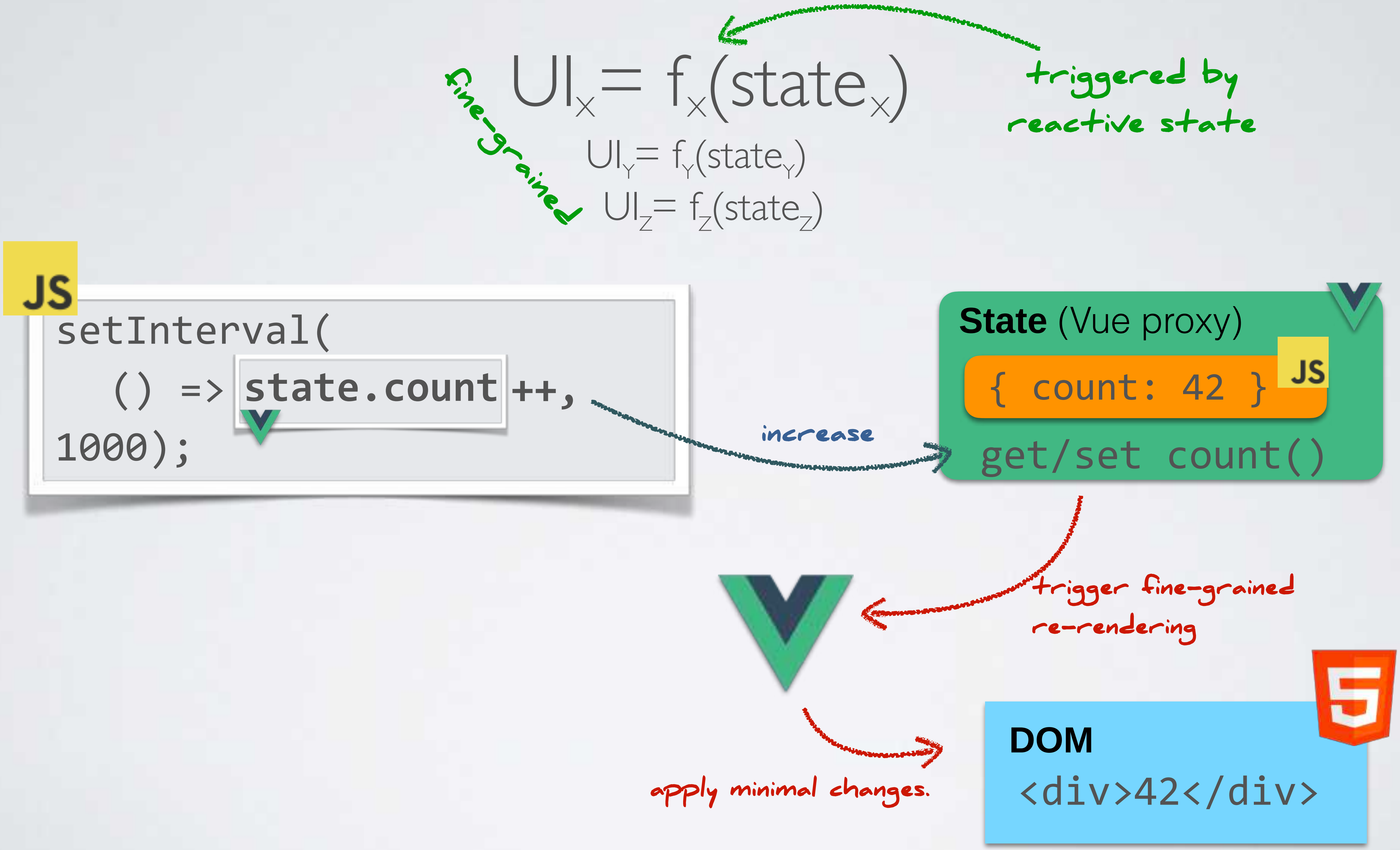


```
const { reactive, watchEffect } = Vue;

const state = reactive({
  count: 0
});

watchEffect(() => {
  document.body.innerHTML = `count is ${state.count}`
});


setInterval(() => state.count++, 1000);
```

changing state
triggers re-rendering

The example is using the Composition API of Vue 3:
https://vuejs.org/api/reactivity-core.html

Reactivity in Vue



$$UI_X = f_X(state_X)$$

$$UI_Y = f_Y(state_Y)$$

$$UI_Z = f_Z(state_Z)$$

```
setInterval(
   () => state.count ++,
1000);
```

State (Vue proxy)

```
{ count: 42 }
get/set count()
```

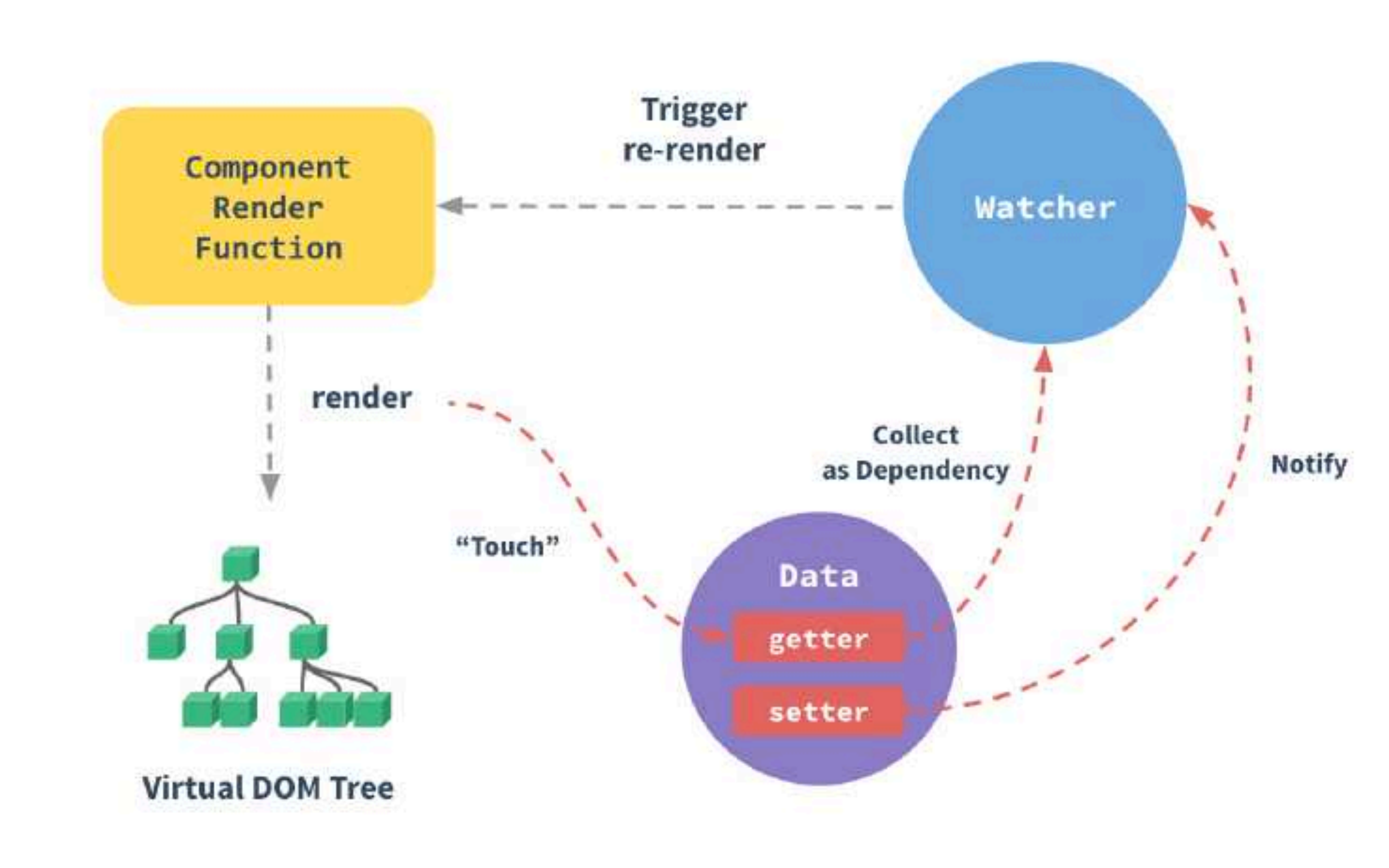
DOM

```
<div>42</div>
```

Note: Some statemanagment libraries implement the same concept for other frameworks (MobX, Jotai, Signals ...)

A Hands-on Introduction to Fine-Grained Reactivity: https://dev.to/ryansolid/a-hands-on-introduction-to-fine-grained-reactivity-3ndf

Change Tracking & Reactive State



https://vuejs.org/v2/guide/reactivity.html

Vue Reactivity

"Reactive State"

Strength

"True Reactivity": The state can be observed.

Fine-Grained Reactivity: only runs the code that need to be run.

Programming model embraces mutability.

Weakness

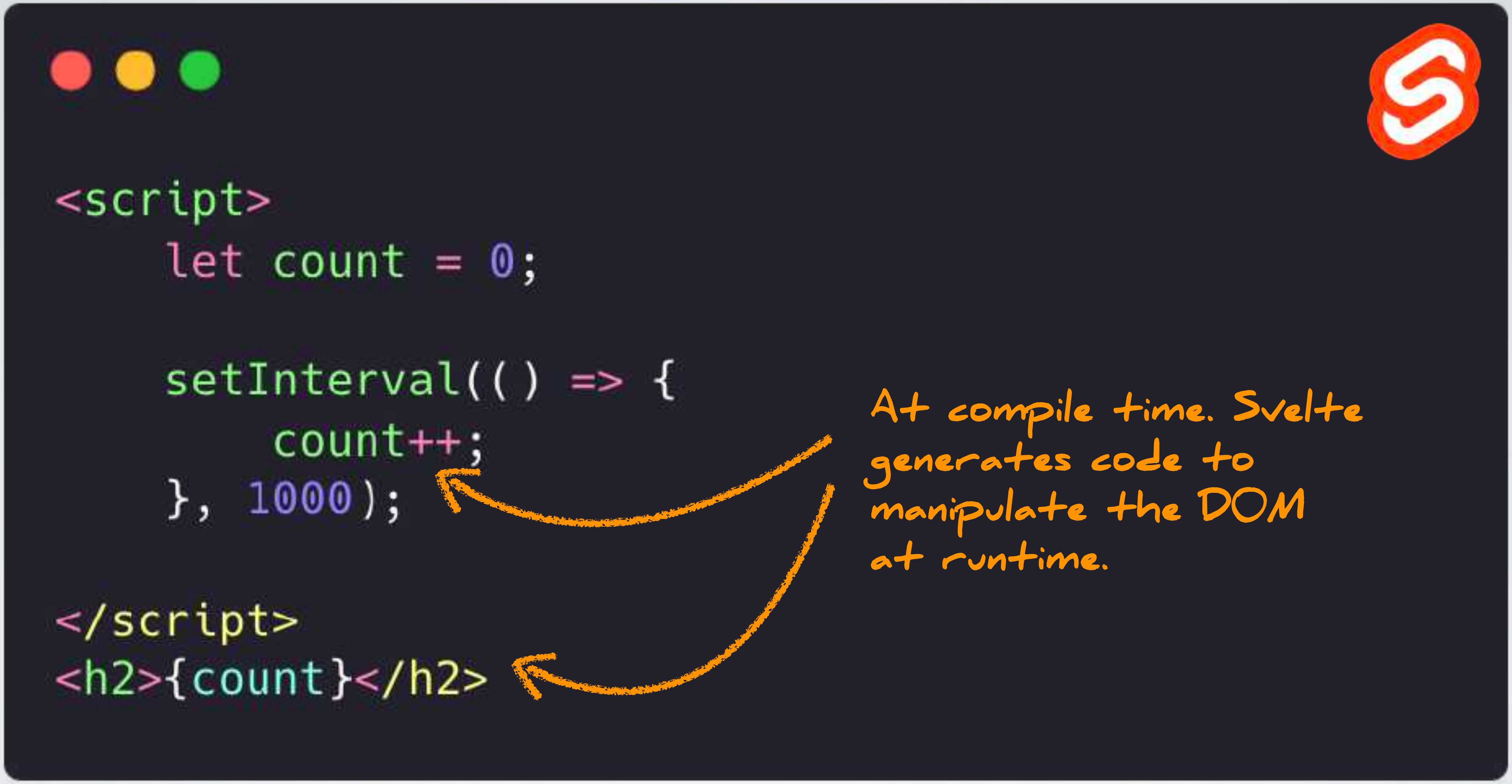
State is not "plain" JavaScript, which comes with its own limitations.

https://dev.to/ryansolid/a-hands-on-introduction-to-fine-grained-reactivity-3ndf

Svelte

"Embrace the Compiler!"

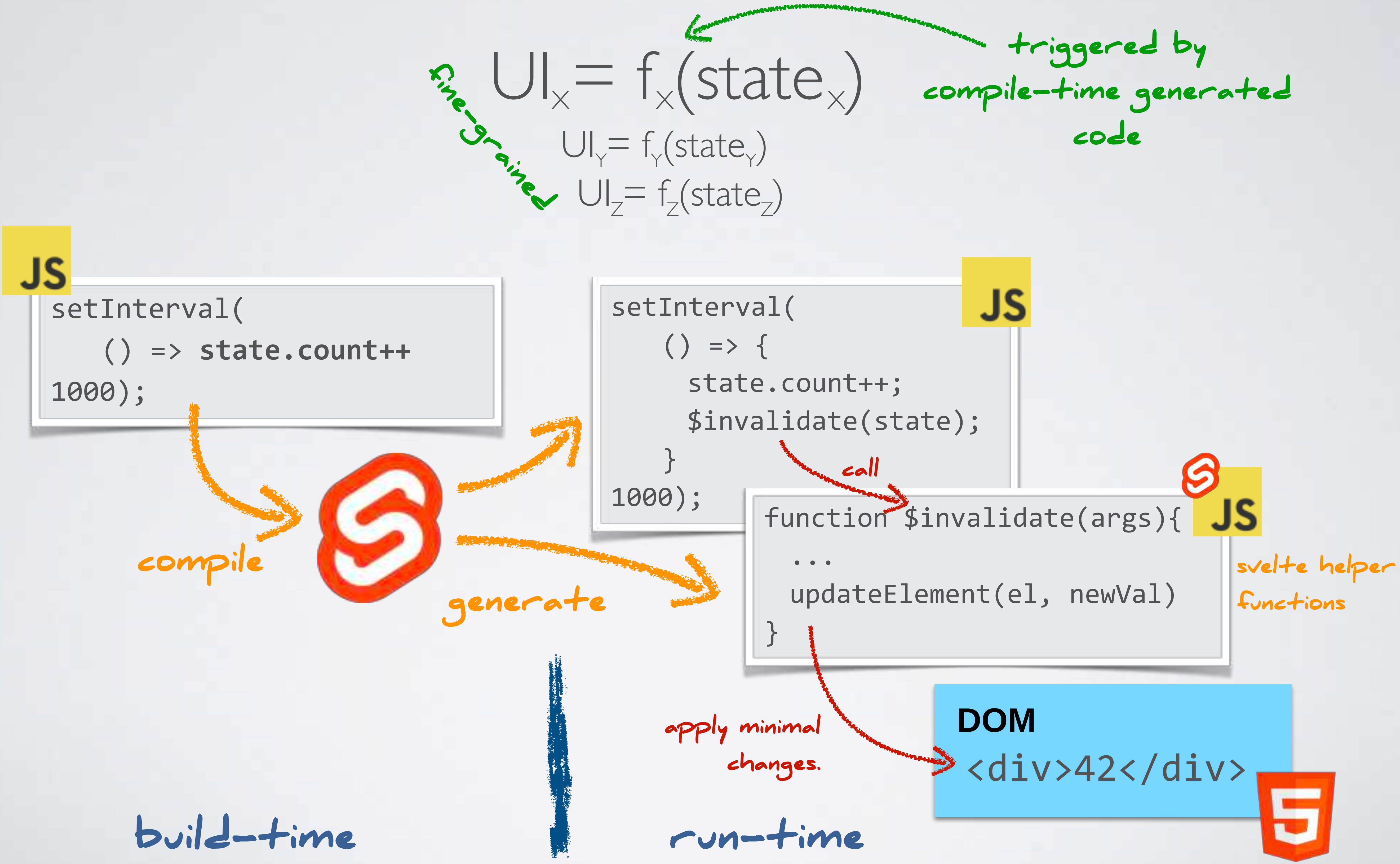
aka: Abandon JavaScript?



```
<script>
    let count = 0;

    setInterval(() => {
        count++;
    }, 1000);

</script>
<h2>{count}</h2>
```

At compile time. Svelte
generates code to
manipulate the DOM
at runtime.

Reactivity in Svelte



$$UI_X = f_X(state_X)$$

$$UI_Y = f_Y(state_Y)$$

$$UI_Z = f_Z(state_Z)$$

```
setInterval(
    () => state.count++
1000);
```

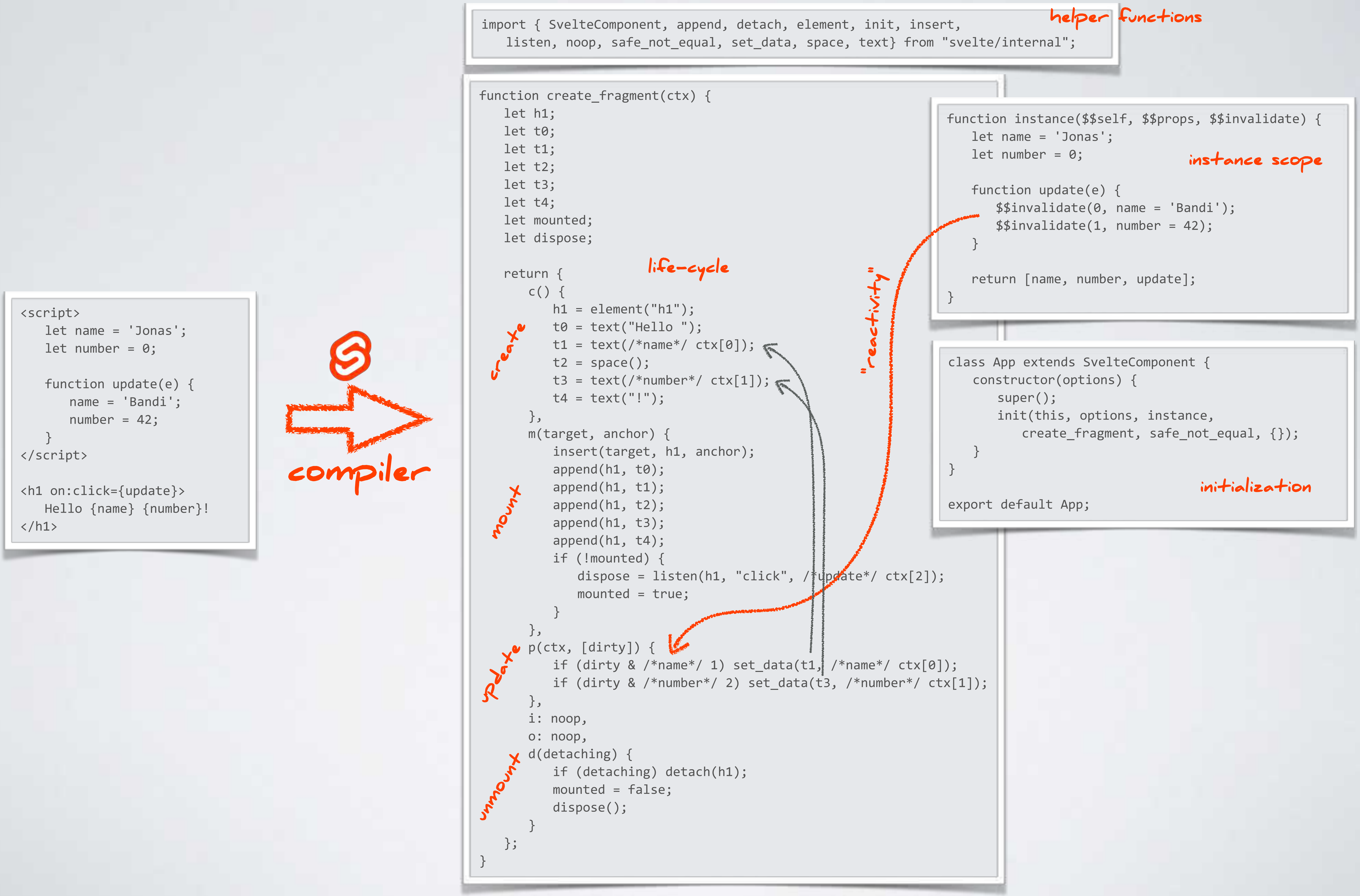
```
setInterval(
    () => {
      state.count++;
      $invalidate(state);
    }
1000);
```

```
function $invalidate(args){
  ...
  updateElement(el, newVal)
}
```

DOM

```
<div>42</div>
```

Compile-Time-Generated Reactivity



```
<script>
   let name = 'Jonas';
   let number = 0;

   function update(e) {
      name = 'Bandi';
      number = 42;
   }
</script>

<h1 on:click={update}>
   Hello {name} {number}!
</h1>
```

```
import { SvelteComponent, append, detach, element, init, insert,
   listen, noop, safe_not_equal, set_data, space, text} from "svelte/internal";
```

```
function create_fragment(ctx) {
   let h1;
   let t0;
   let t1;
   let t2;
   let t3;
   let t4;
   let mounted;
   let dispose;

   return {
      c() {
         h1 = element("h1");
         t0 = text("Hello ");
         t1 = text(/*name*/ ctx[0]);
         t2 = space();
         t3 = text(/*number*/ ctx[1]);
         t4 = text("!");
      },
      m(target, anchor) {
         insert(target, h1, anchor);
         append(h1, t0);
         append(h1, t1);
         append(h1, t2);
         append(h1, t3);
         append(h1, t4);
         if (!mounted) {
            dispose = listen(h1, "click", /*update*/ ctx[2]);
            mounted = true;
         }
      },
      p(ctx, [dirty]) {
         if (dirty & /*name*/ 1) set_data(t1, /*name*/ ctx[0]);
         if (dirty & /*number*/ 2) set_data(t3, /*number*/ ctx[1]);
      },
      i: noop,
      o: noop,
      d(detaching) {
         if (detaching) detach(h1);
         mounted = false;
         dispose();
      }
   };
}
```

```
function instance($$self, $$props, $$invalidate) {
   let name = 'Jonas';
   let number = 0;

   function update(e) {
      $$invalidate(0, name = 'Bandi');
      $$invalidate(1, number = 42);
   }

   return [name, number, update];
}
```

```
class App extends SvelteComponent {
   constructor(options) {
      super();
      init(this, options, instance,
         create_fragment, safe_not_equal, {});
   }
}

export default App;
```

Svelte Reactivity

"Compile-Time-Generated Reactivity"

Strength

Very compact and intuitive code.

Fine-Grained Reactivity: only runs the code that need to be run.

Significantly faster than the other mainstream frameworks.

Weakness

"extending" the semantics of JavaScript

Circling Back:
All Modern Frontend Frameworks are Compilers!

Angular	• TypeScript • Template • (workarounds)
React	• JSX • TypeScript
Vue	• SFC • Template • TypeScript

... but Svelte goes one step further.

Fun Fact:

React an Vue have plans for future compiler features
that are changing the samantics of JavaScript ...
(reducing biolerplate for convenience)

"React Forget" - A Memoizing Compiler

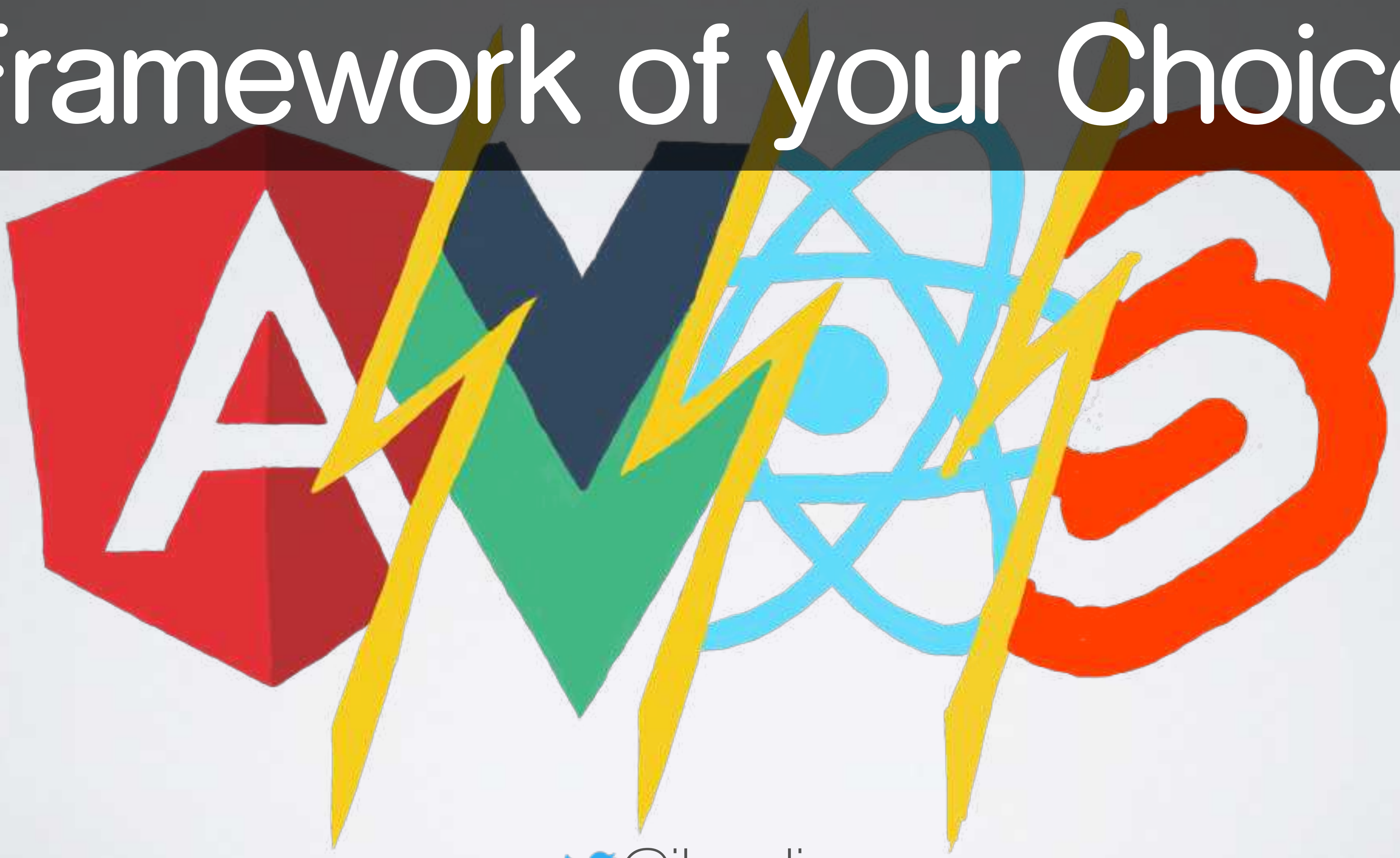
https://www.youtube.com/watch?v=lGEMwh32soc
https://reactjs.org/blog/2022/06/15/react-labs-what-we-have-been-working-on-june-2022.html

Vue Reactivity Transforms

https://vuejs.org/guide/extras/reactivity-transform.html

https://github.com/vuejs/rfcs/discussions/369

Have Fun with the Framework of your Choice!



@jbandi

Code: https://github.com/jbandi/framework-reactivity-2022

QUESTIONS?

JavaScript / Angular / React / Vue.js
Schulung / Beratung / Coaching / Reviews
jonas.bandi@ivorycode.com