

# < Frontend System Design /> Fundamentals



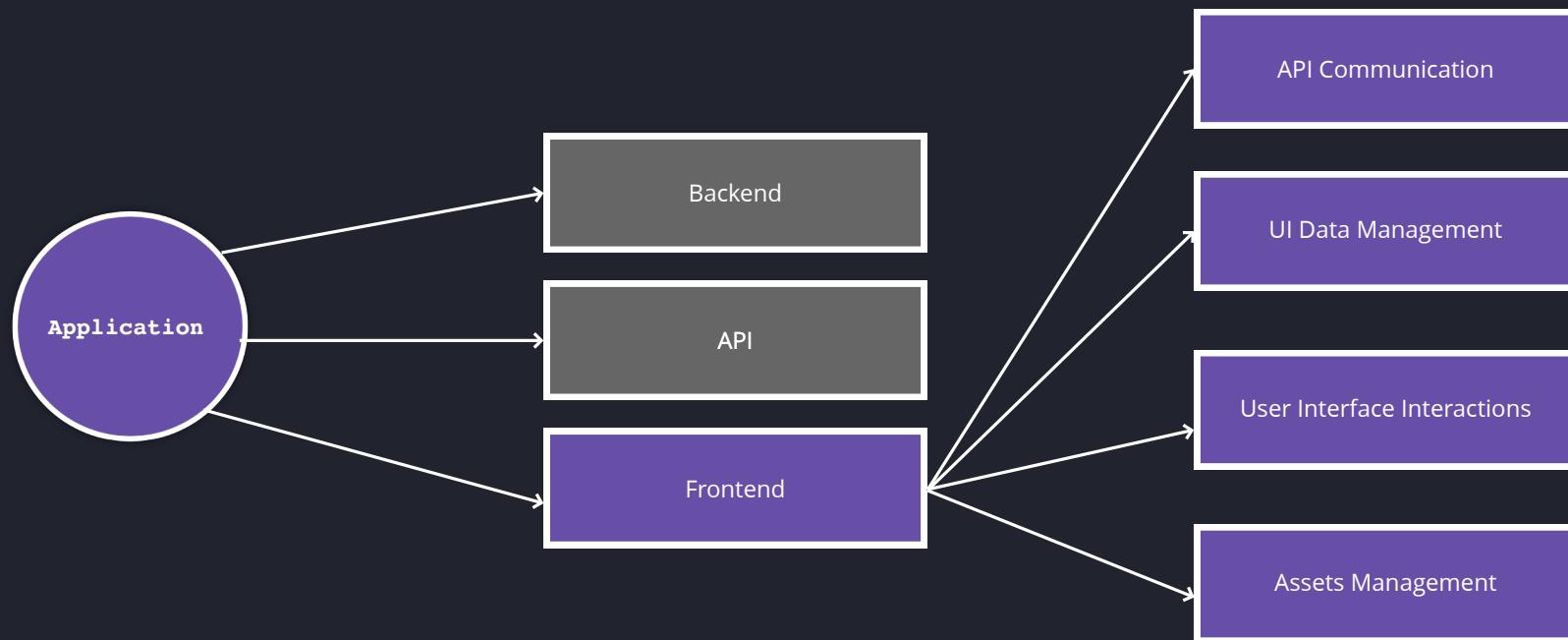
Evgenii Ray

# Introduction



- Who am I
- Goal of this course

# What's Frontend System Design



# Course Plan

## 1. Core Fundamentals

- Box Model
- Positioning System
- Formatting Context
- Stacking Context
- Browser Rendering Cycle and Reflow
- Composition Layers
- GPU Acceleration

## 2. DOM API

- API Refresher
- Querying methods comparison
- Optimizing query performance
- Coding Assignment #1

## 3. Web APIs for Complex UI Patterns

- Observer API Overview
- Intersection Observer
- Coding assignment #2
- Mutation Observer
- Coding assignment #3
- Resize Observer
- Coding Assignment #4

## 4. Virtualisation

- Pattern overview
- Live-coding

## 5. Application State design

- Search / Access Optimization
- Browser Storage API Overview
- Memory Offloading

## 6. Network

- Introduction to Browser Networking
- Protocols Overview
- Talking to server
  - Long-polling
  - Web-sockets
  - SSE
- REST / GraphQL

## 7. Web Application Performance

- Javascript
- CSS
- Images
- Other Assets

## 8. Bonus Section

# Part 1

< Core Fundamentals />

# Box Model

```
const allElements = document.querySelectorAll('*');
allElements.forEach(el => el.style.border = "2px solid green");
```

The screenshot shows a dark-themed web browser window displaying the FrontendMasters website. A purple rectangular overlay covers the top portion of the page, containing the title 'Box Model' and the explanatory code block above. Below this, the browser's developer tools are visible, specifically the Elements tab, which is currently selected. The main content area of the browser shows several course cards for 'Frontend & Fullstack Engineering Courses'. The courses listed are:

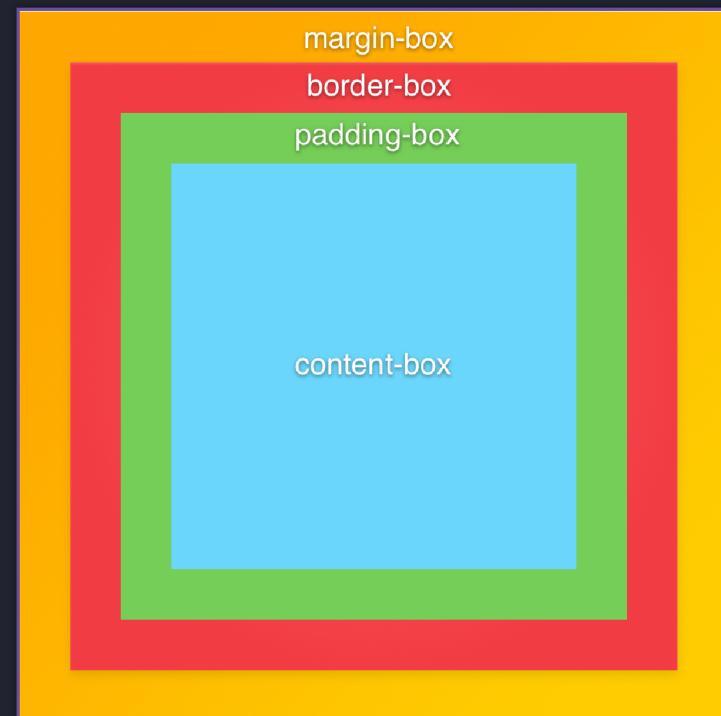
- Build Go Apps That Scale on AWS** by Melkey (Twitch) - 5 hours, 21 minutes
- Web App Testing & Tools** by Miško Hevery (Qwik Creator (Previously Angular)) - 3 hours, 54 minutes
- Enterprise Web App Accessibility (feat. React)** by Marcy Sutton Todd (Principle Studios) - Enhanced team understanding of testing for accessibility.
- Web App Accessibility (feat. React)** by Marcy Sutton Todd (Principle Studios) - Elevate React projects by integrating accessibility standards and practices. Gain expertise in WCAG, ARIA, screen readers.

The developer tools sidebar on the right includes sections for Console, Network, Performance, and Memory, along with a note about scroll-driven animations support and a new Autofill panel.

# Box Anatomy

The **box model** comprises several layers, each serving a distinct purpose in the layout of an element:

- **Content Box:** This is the area that contains the content of the block.
- **Padding Box:** This layer surrounds the content box, providing space around the content.
- **Border Box:** This includes the space of the border that encircles both the padding box and the content box.
- **Margin Box:** This represents the external space outside the element's border.





# Box Properties

Box Size

Intrinsic

Restricted

Box Type

Inline

Block

Anonymous

# Box Size

## The size can be:

1. **Intrinsic:** This means the box uses its content to determine the space it occupies.
2. **Restricted:** This indicates that the box's size is governed by a set of rules applied to it. It can be:
  1. Explicit **width** and **height** set via CSS.
  2. Constrained by parent elements or other boxes through mechanisms like:
    1. **flex** or **grid** layout systems.
    2. **Percentage (%)** of parent size.
    3. The **aspect-ratio** property of images, etc.
    4. The presence of other children in the DOM tree

<https://codepen.io/RayEuji/embed/NWjZLzO>

# Box type

**There are several types of boxes**

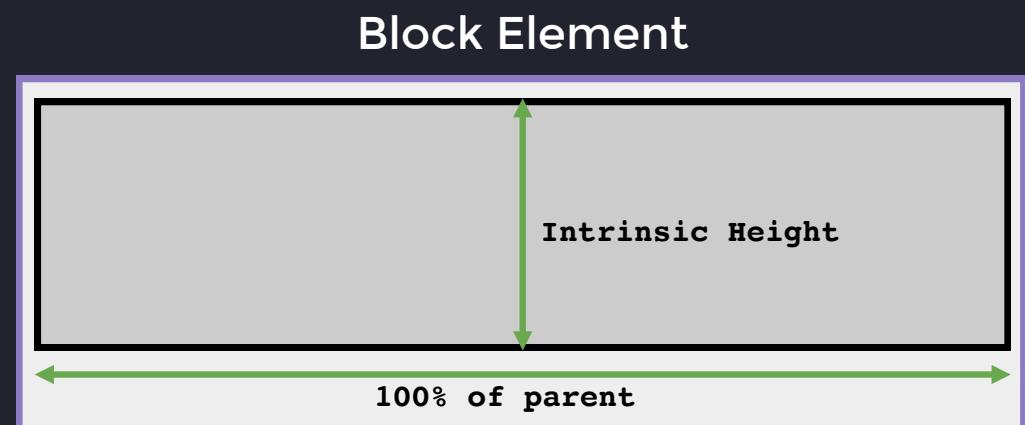
- **block** level ( including, but not restricted by **display: block** )
- **inline** level
- **Anonymous** box

<https://codepen.io/RayEiji/embed/yLwdQRj>

# Box type: Block

1. The element is rendered like a **block**.
1. Block level element takes **100%** of the **parent** container width
2. The **height** of the content is equal to the **intrinsic size**.
2. The element is rendered from **top to bottom**.
3. Participate in **Block Context Formatting (BCF)**

<address>	<article>	<aside>	<blockquote>	<canvas>
<dd>	<div>	<dl>	<dt>	<fieldset>
<figcaption>	<figure>	<footer>	<form>	<h1>-<h6>
<header>	<hr>	<li>	<main>	<nav>
<noscript>	<ol>	<p>	<pre>	<section>
<table>	<tfoot>	<ul>	<video>	

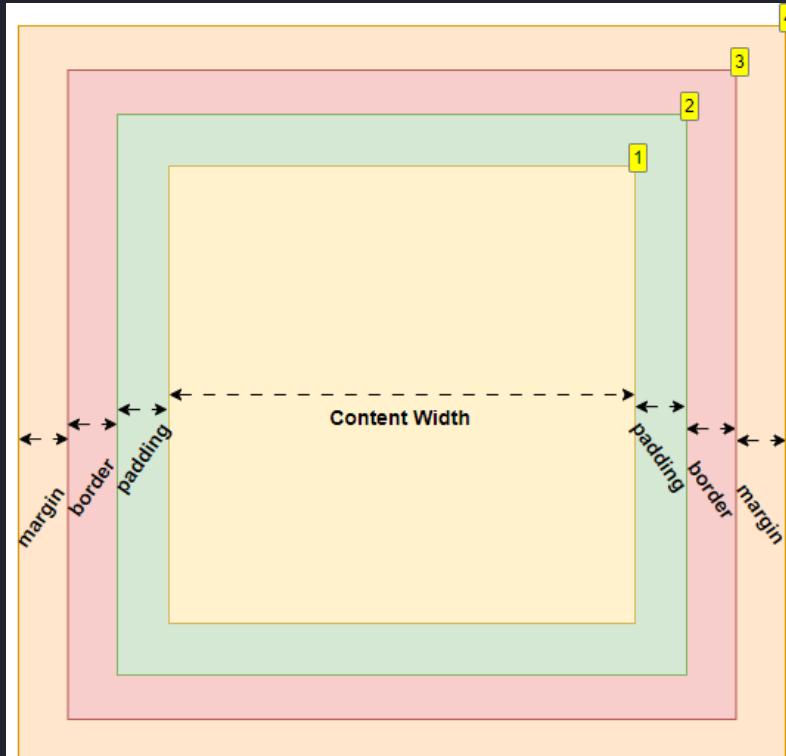


# Anonymous box

```
1 <div>
2   <p>
3     This will be wrapped into TextNode
4   </p>
5 </div>
6 ->> This will be an anonymous box -<<
```

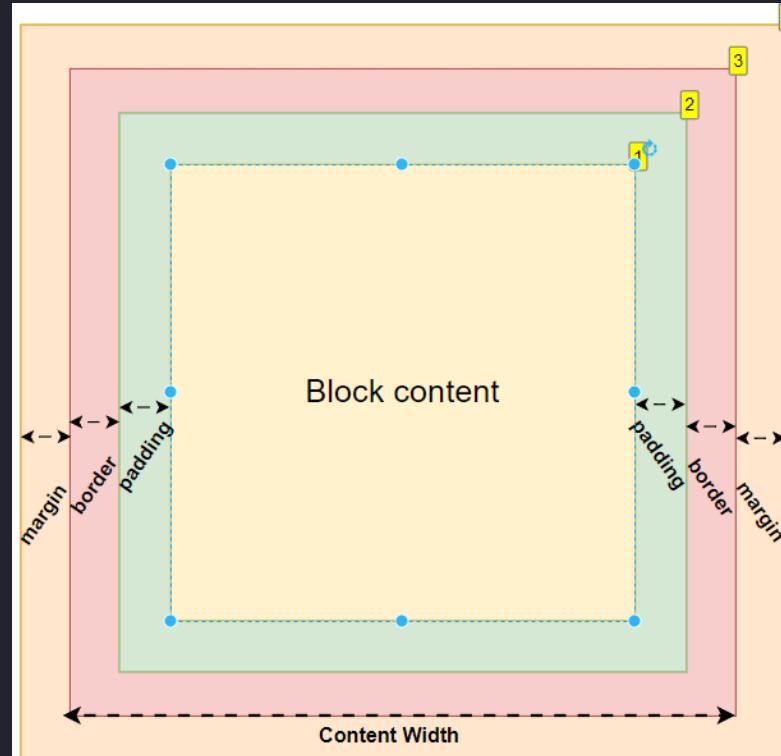
# Mathematics of Block Elements

**box-sizing: content-box**



```
width = margin-left + border-left + padding-left  
      + content-width  
      + padding-right + border-right + margin-right
```

**box-sizing: border-box**



```
width = margin-left + content-width + margin-right
```

# Inline Elements

The key characteristics of inline elements are:

1. They render as a **string**, flowing from **left to right** and from **top to bottom**.
2. They participate in an **Inline Formatting Context (IFC)**
3. They generate **inline-level** boxes.

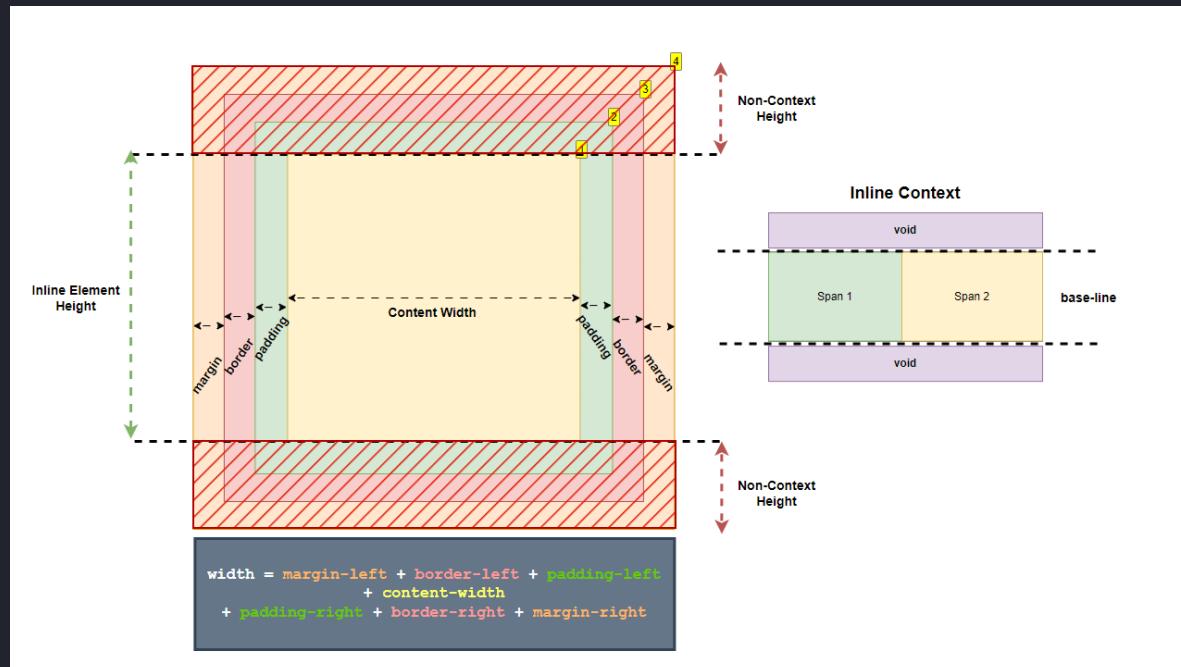
```
1 <div>
2   Some text inside the block element
3   <span>
4     This is inside inline context
5   </span>
6 </div>
```

<a>	<abbr>	<acronym>
 	<button>	<cite>
<i>	<img>	<input>
<object>	<output>	<q>
<small>	<span>	<strong>
<time>	<tt>	<var>

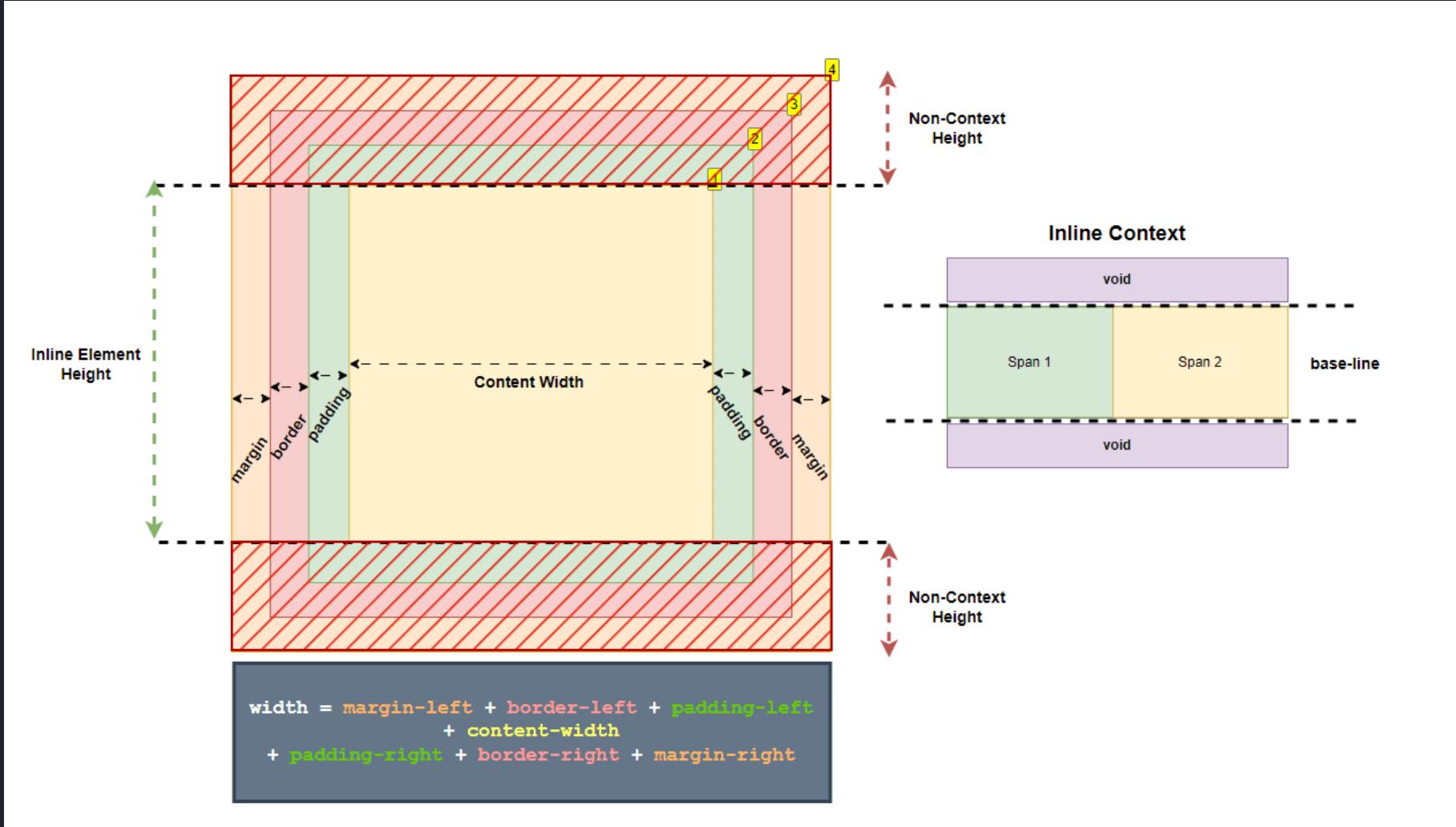
<b>	<bdo>	<big>
<code>	<dfn>	<em>
<kbd>	<label>	<map>
<samp>	<script>	<select>
<sub>	<sup>	<textarea>

# Mathematics of Inline Elements

1. Does not respond to **width** and **height** properties.
  1. Completely ignores them.
2. Does not react to **vertical margins**.
  1. Ignores them.
3. Inline **padding** does not alter the **height** of the inline element.



# Mathematics of Inline Elements



# Browser Formatting Context

# Browser Formatting Context - 1

Element

Formatting  
Context

Element is not affected by  
formatting context

# Browser Formatting Context - 1

Element

Formatting Context

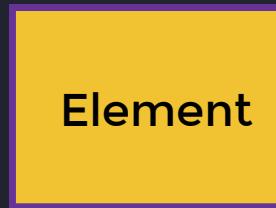
Formatting  
Context

Element

Element is not affected by  
formatting context

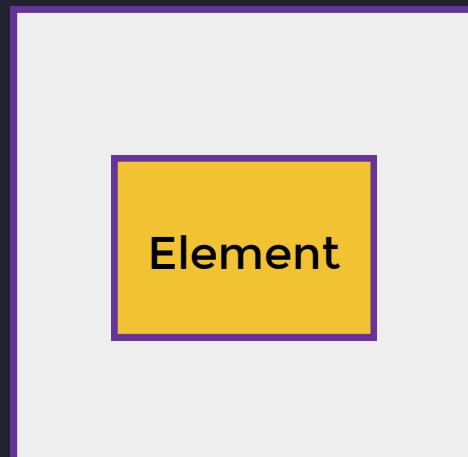
Element enters the formatting  
context

# Browser Formatting Context - 1



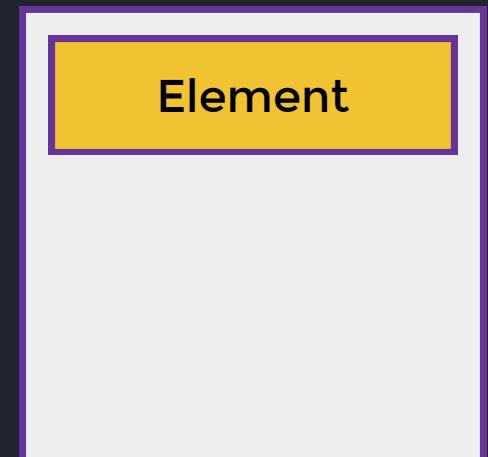
Element is not affected by  
formatting context

Formatting Context



Element enters the formatting  
context

Formatting Context



Now, element has to span  
across the whole container  
since it's a rule of formatting  
context

# Browser Formatting Context - 2

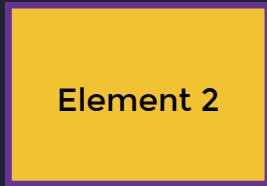
Element 2

Formatting Context

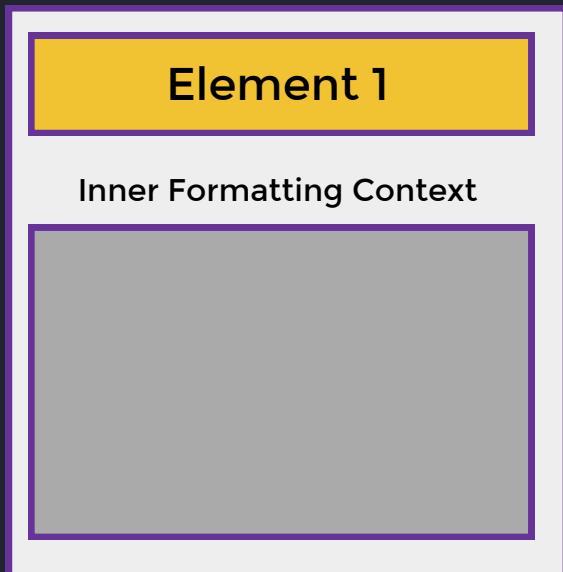
Element 1

Inner Formatting Context

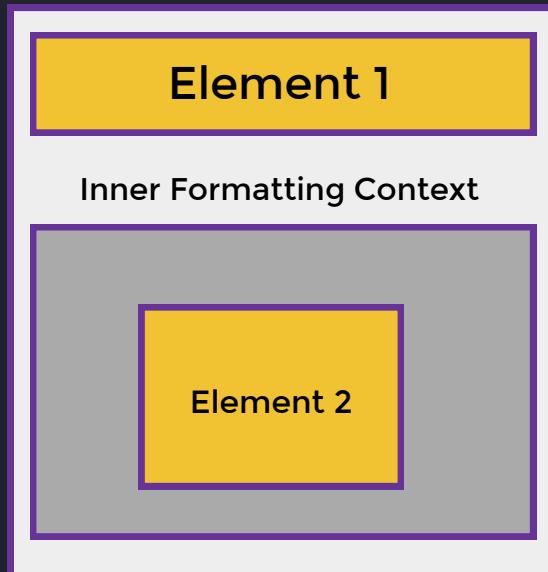
# Browser Formatting Context - 2



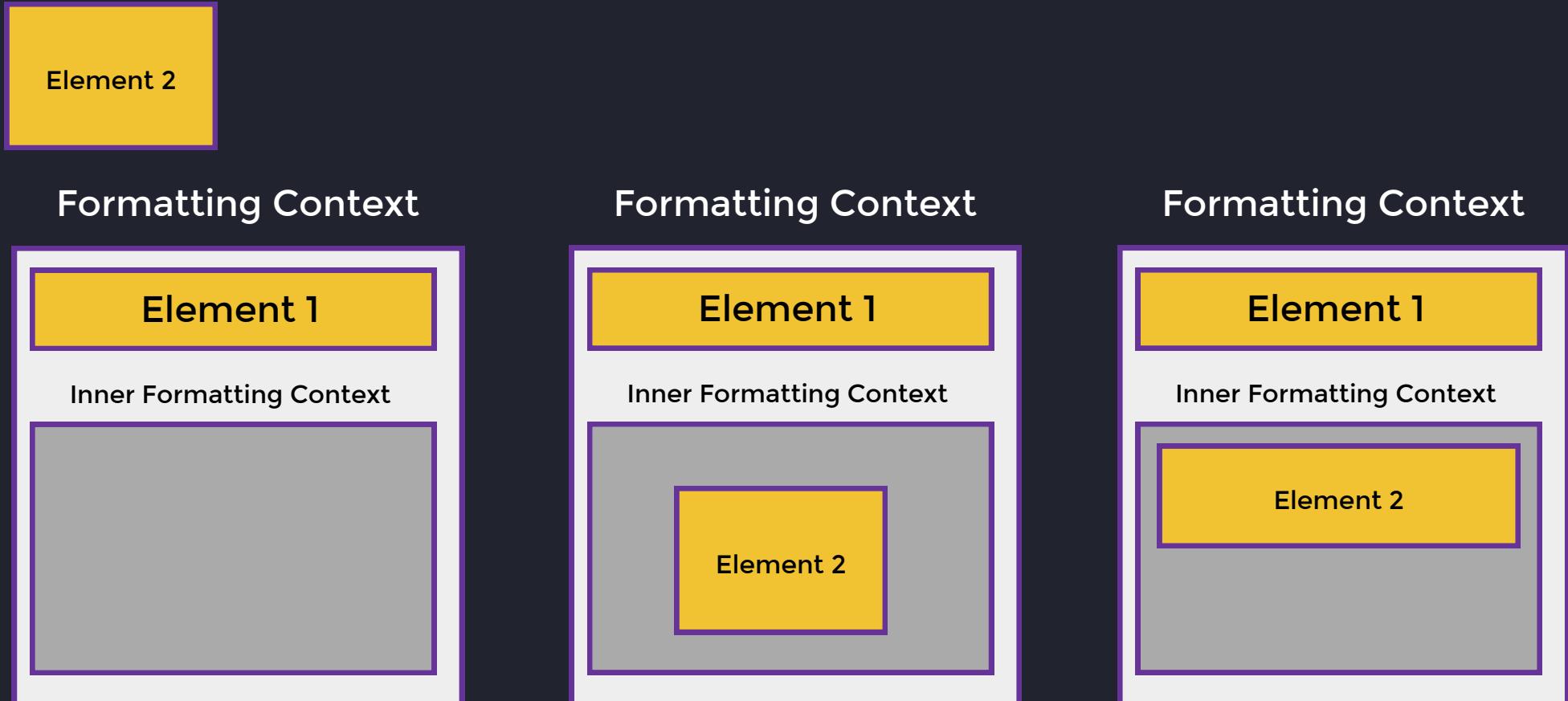
Formatting Context



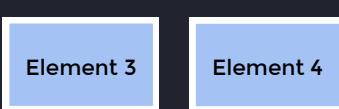
Formatting Context



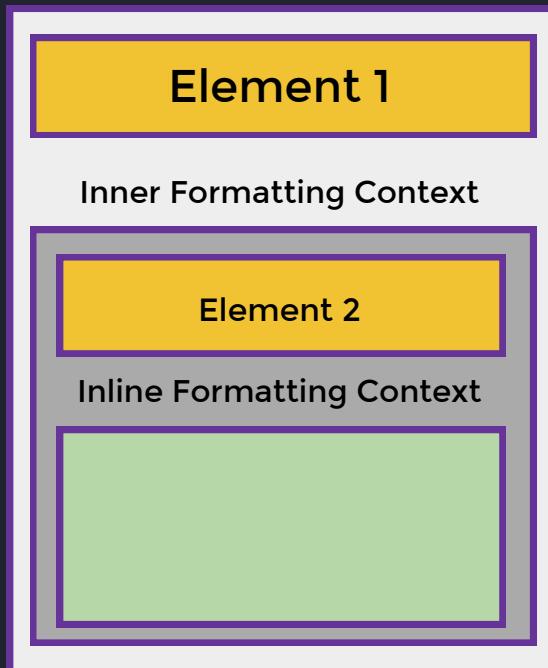
# Browser Formatting Context - 2



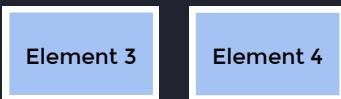
# Browser Formatting Context - 3



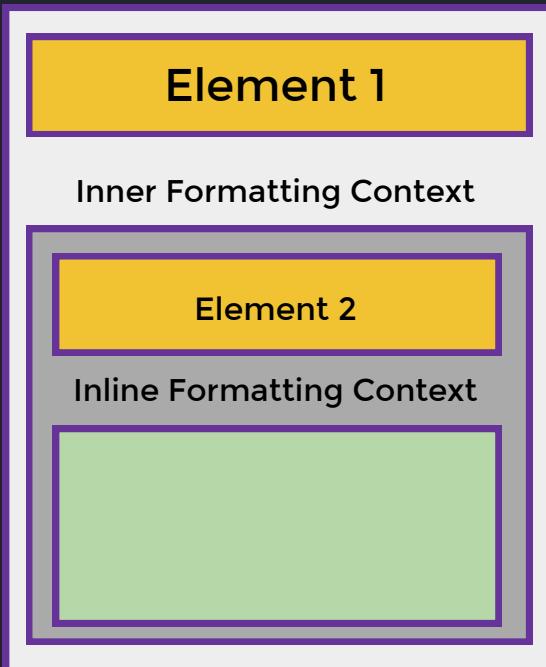
## Formatting Context



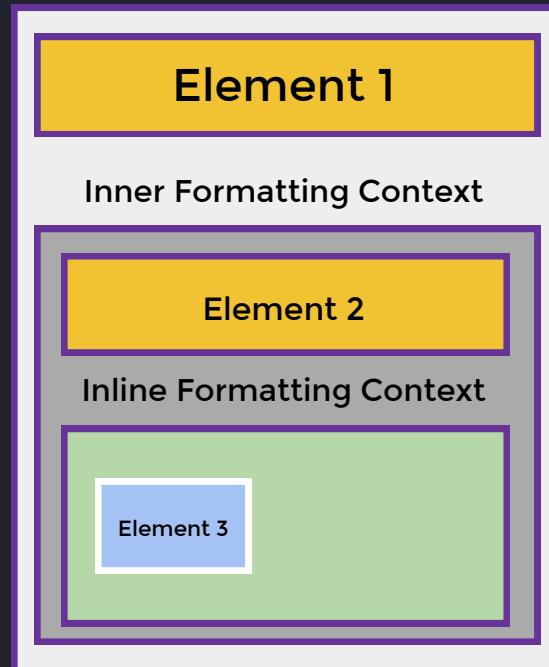
# Browser Formatting Context - 3



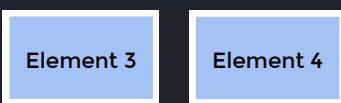
Formatting Context



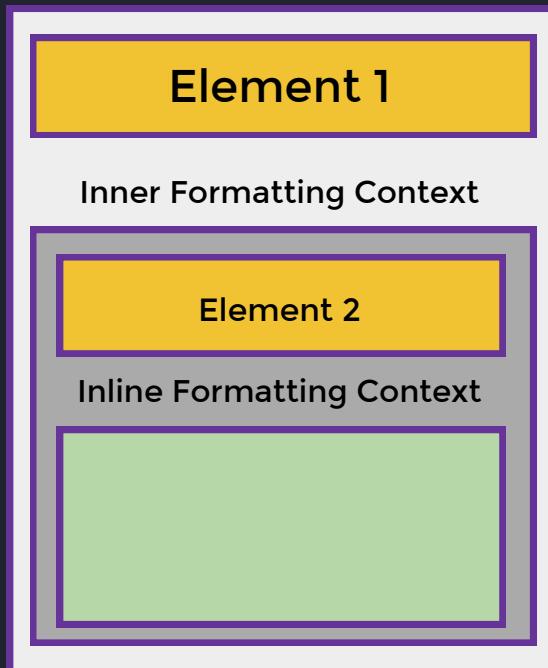
Formatting Context



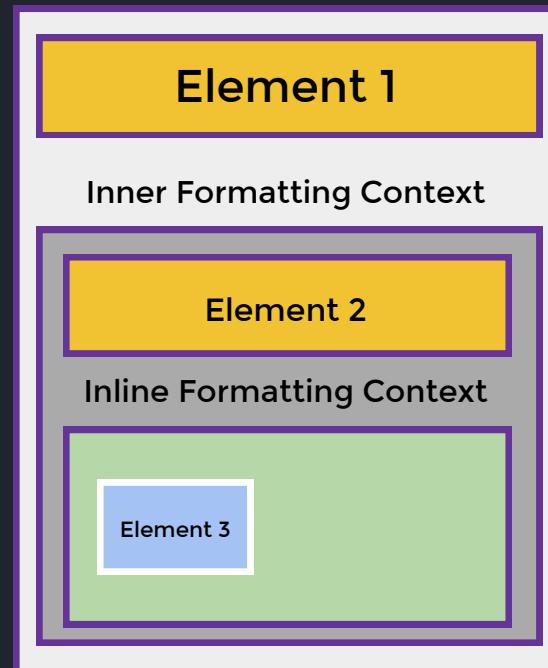
# Browser Formatting Context - 3



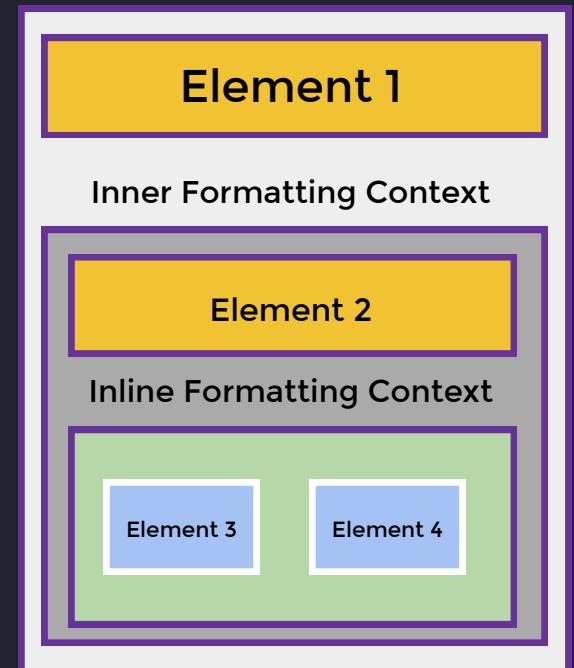
Formatting Context



Formatting Context



Formatting Context



# Formatting Context - Key Ideas

## The Key Ideas of Formatting Contexts:

- **Isolation:** Elements within a context are shielded from the rules of external contexts.
- **Scalability:** Introducing a new ruleset for elements is as simple as creating a new **Context** (examples: flex-box, grid).
- **Predictability:** With a strict set of rules, the placement of elements is predictable.

## Formatting Context Family

Flex

Grid

Inline

Block

# Time to become a browser

```
1 <html>
2 <body>
3 <h1>This is a Heading</h1>
4 <ul>
5   <li style="display:inline-block">
6     <p>Paragraph 1</p>
7     <p>Paragraph 2</p>
8   </li>
9   <li style="display:inline-block">
10    <p>Paragraph 3</p>
11    <p>Paragraph 4</p>
12  </li>
13  <section style="display: flex; flex-direction: row">
14    <p>Paragraph 5</p>
15    <p>
16      <span>Paragraph 6</span>
17    </p>
18  </section>
19 </ul>
20 </body>
21 </html>
```

## Block Formatting Context

```
1 <html>
2 <body>
3 <h1>This is a Heading</h1>
4 <ul>
5   <li style="display:inline-block">
6     <p>Paragraph 1</p>
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16     <span>Paragraph 6</span>
17   </p>
18 </section>
19 </ul>
20 </body>
21 </html>
```

## Block Formatting Context

```
<body>
```

```
1 <html>
2 <body>
3 <h1>This is a Heading</h1>
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5   <li style="display:inline-block">
6     <p>Paragraph 1</p>
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18 </section>
19 </ul>
20 </body>
21 </html>
```

## Block Formatting Context

```
<body>
```

```
    <h1>
```

```
1 <html>
2 <body>
3 <h1>This is a Heading</h1>
4 <ul>
5   <li style="display:inline-block">
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15   <p>
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17   </p>
18 </section>
19 </ul>
20 </body>
21 </html>
```

## Block Formatting Context

```
<body>
```

```
    <h1>
```

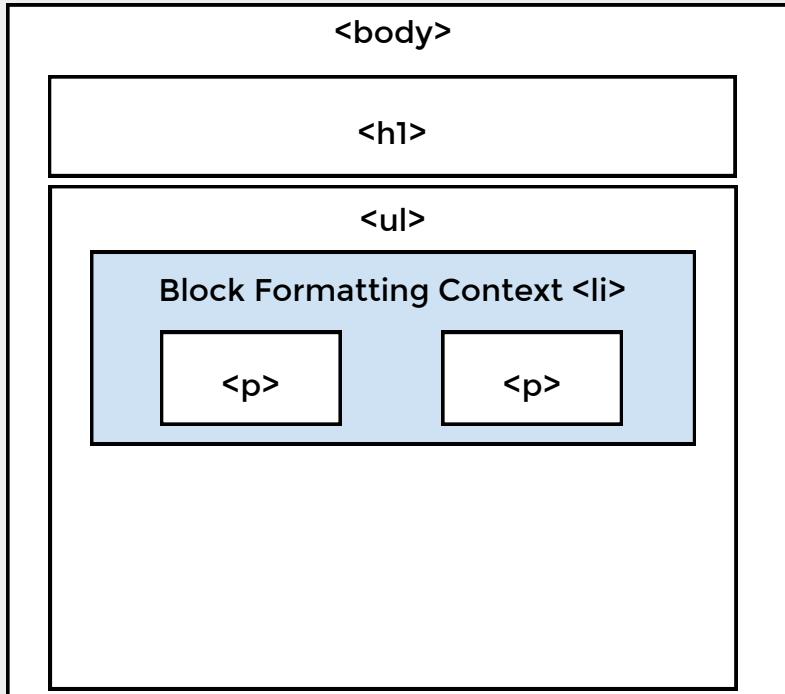
```
    <ul>
```

```
        Block Formatting Context
```

```
        <li>
```

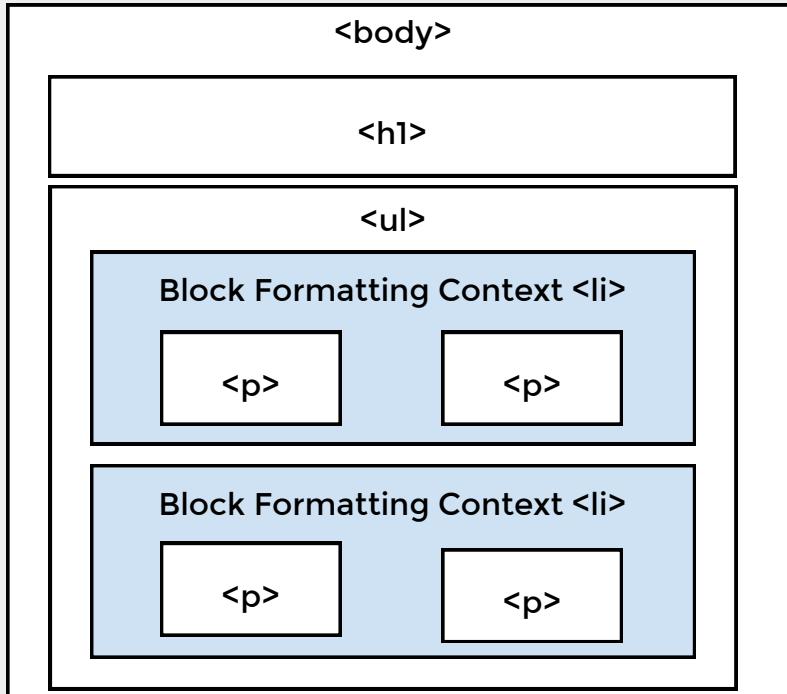
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1  <html>
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```

## Block Formatting Context



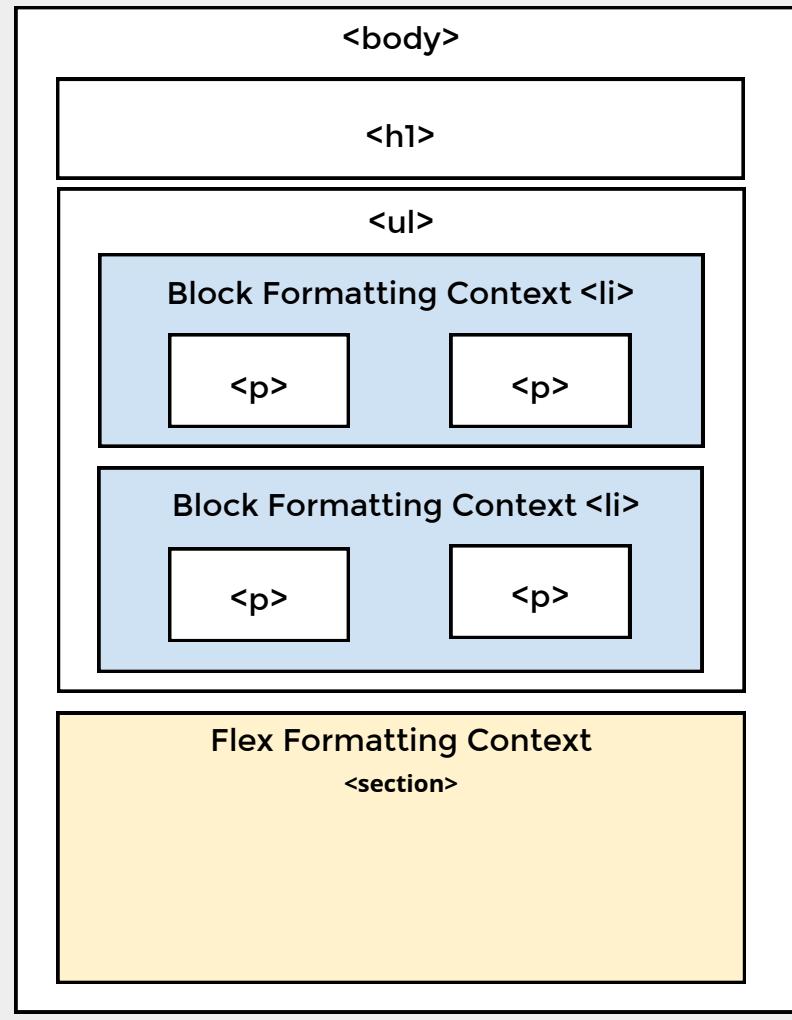
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15   <p>
16     <span>Paragraph 6</span>
17   </p>
18 </section>
19 </ul>
20 </body>
21 </html>
```

## Block Formatting Context

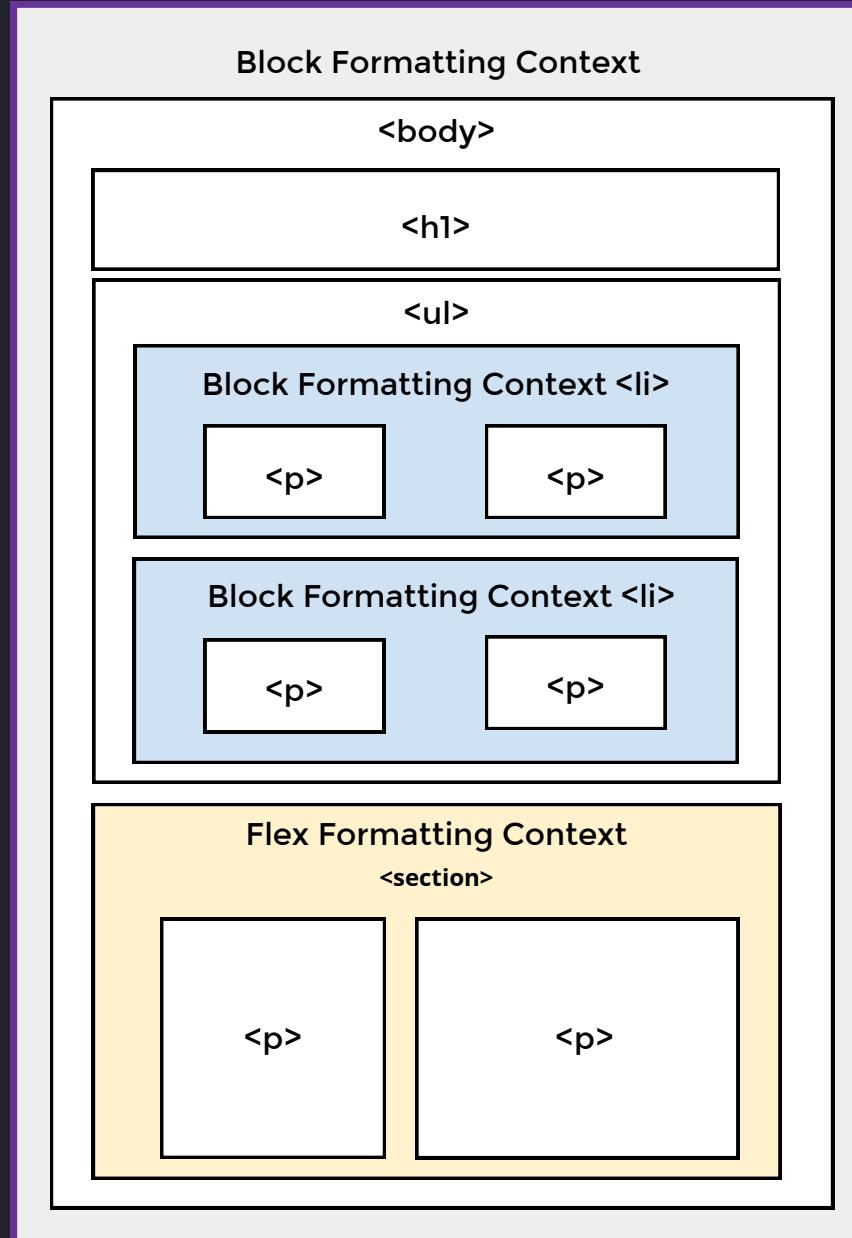


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1 <html>
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17   </p>
18 </section>
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20 </body>
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```

## Block Formatting Context



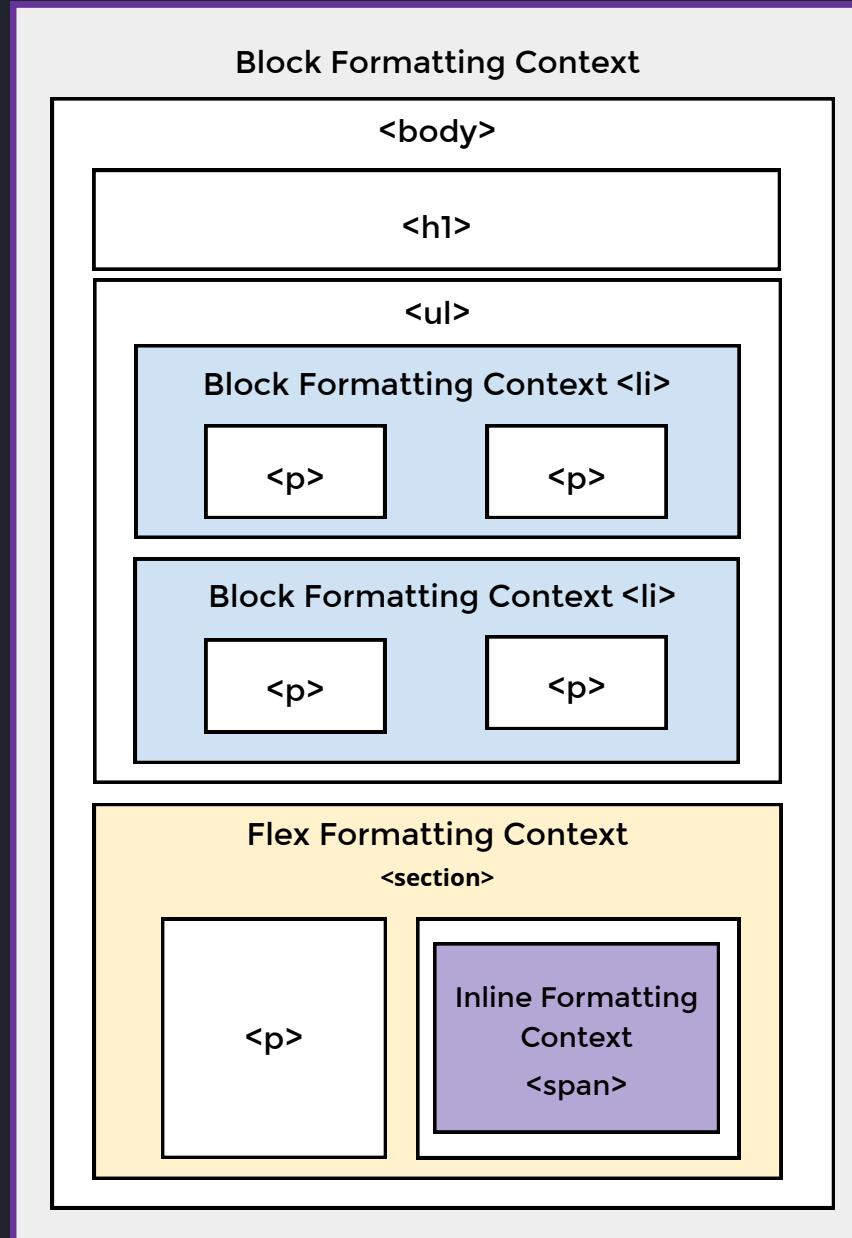
```
1 <html>
2 <body>
3 <h1>This is a Heading</h1>
4 <ul>
5   <li style="display:inline-block">
6     <p>Paragraph 1</p>
7     <p>Paragraph 2</p>
8   </li>
9   <li style="display:inline-block">
10    <p>Paragraph 3</p>
11    <p>Paragraph 4</p>
12  </li>
13 <section style="display: flex; flex-direction: row">
14   <p>Paragraph 5</p>
15   <p>
16     <span>Paragraph 6</span>
17   </p>
18 </section>
19 </ul>
20 </body>
21 </html>
```



```

1 <html>
2 <body>
3 <h1>This is a Heading</h1>
4 <ul>
5   <li style="display:inline-block">
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14   <p>Paragraph 5</p>
15   <p>
16     <span>Paragraph 6</span>
17   </p>
18 </section>
19 </ul>
20 </body>
21 </html>

```



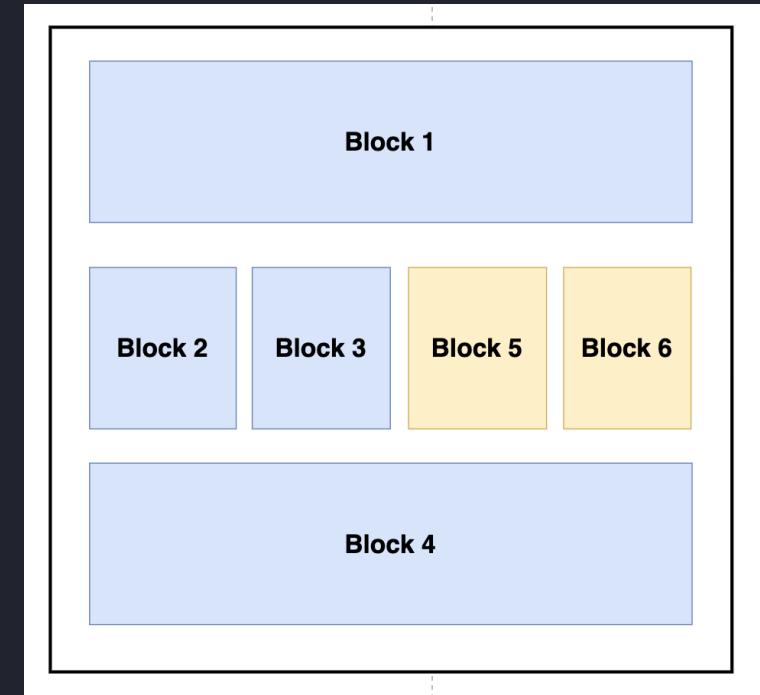
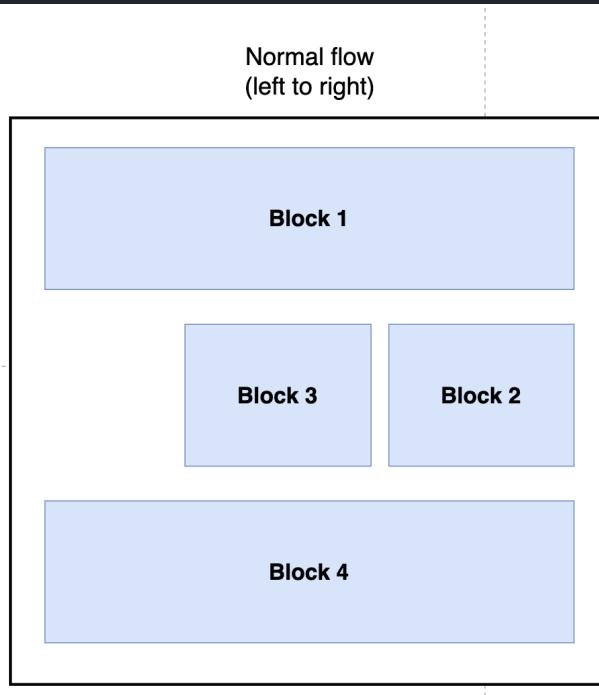
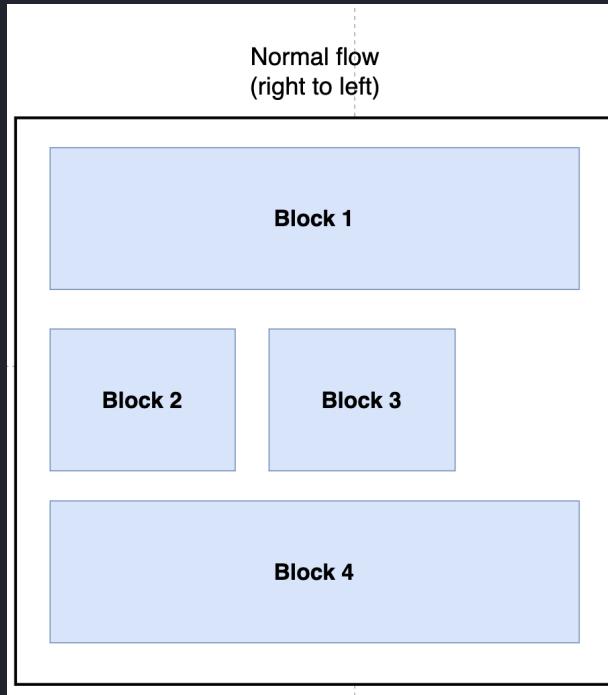
```

1 <html>
2 <body>
3   <h1>This is a Heading</h1>
4   <ul>
5     <li style="display:inline-block">
6       <p>Paragraph 1</p>
7       <p>Paragraph 2</p>
8     </li>
9     <li style="display:inline-block">
10       <p>Paragraph 3</p>
11       <p>Paragraph 4</p>
12     </li>
13   <section style="display: flex; flex-direction: row">
14     <p>Paragraph 5</p>
15     <p>
16       <span>Paragraph 6</span>
17     </p>
18   </section>
19 </ul>
20 </body>
21 </html>

```

# Browser Positioning System

# Normal Flow



# Changing Normal Flow

```
position: static | relative | absolute | sticky | fixed
```

The property **position** determines the variant of element positioning on the page, relative to the browser window or other elements on the page.

**Most commonly used:** **static, relative, absolute**

# Position: static

```
1 <main>
2   <div class="box">
3     Box Block
4   </div>
5   <div class="box inline">
6     Box Inline
7   </div>
8   <div class="box inline">
9     Box Inline
10  </div>
11  <div class="box">
12    Box Block
13  </div>
14  </main>
```

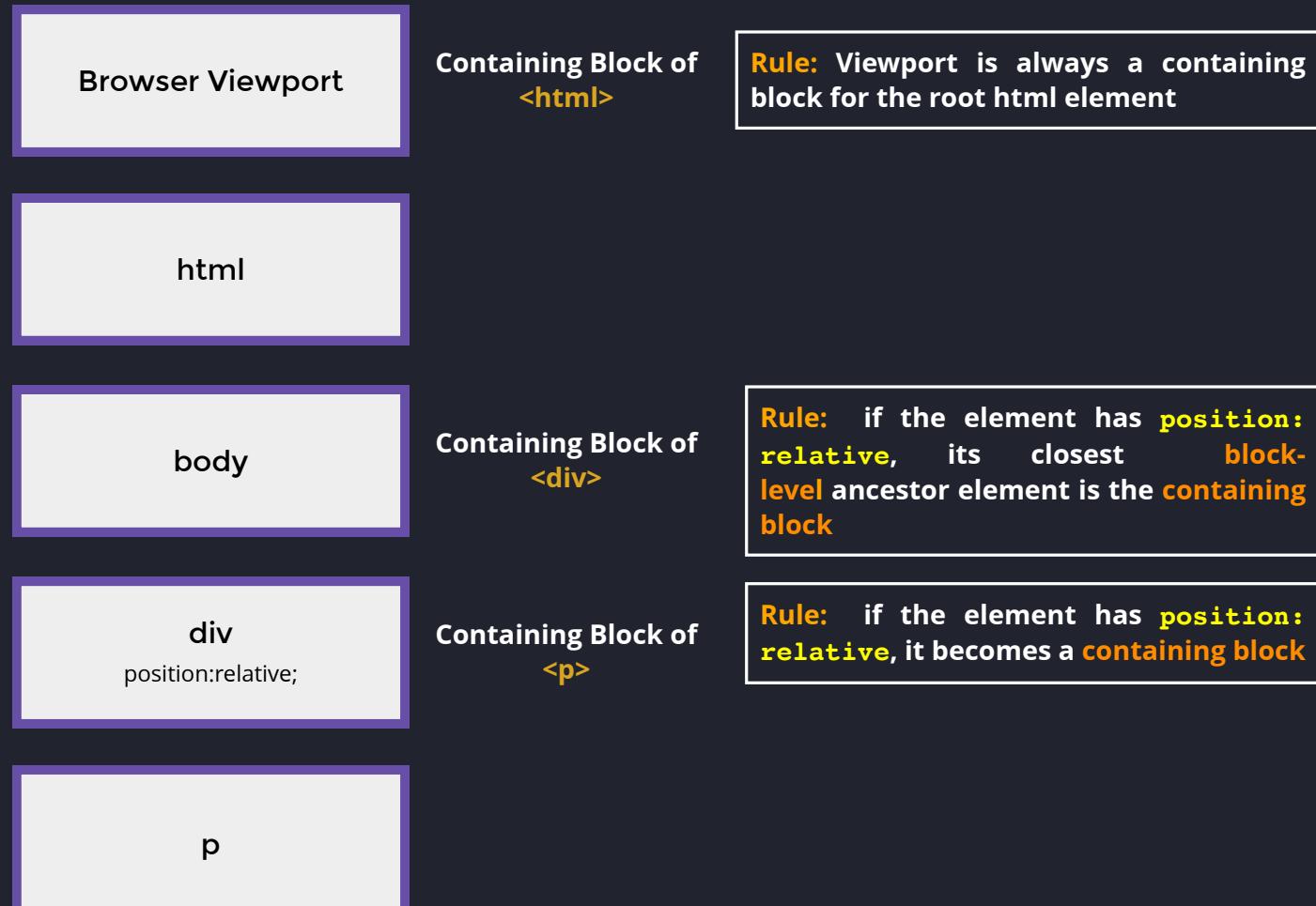
<https://codepen.io/RayEuji/embed/WNWrWzV>

# Position: relative

1. The element is positioned according to the **normal flow** of the document
  - **offset** applied relative to itself based on the values of **top**, **right**, **bottom**, and **left**.
2. The **offset** does not affect the position of any other elements; thus, the space allocated for the element in the page layout remains the same as if the position were **static**.
3. This value creates a new **stacking context** when the value of **z-index** is not **auto**.

<https://codepen.io/RayEuji/embed/gOyPyQq>

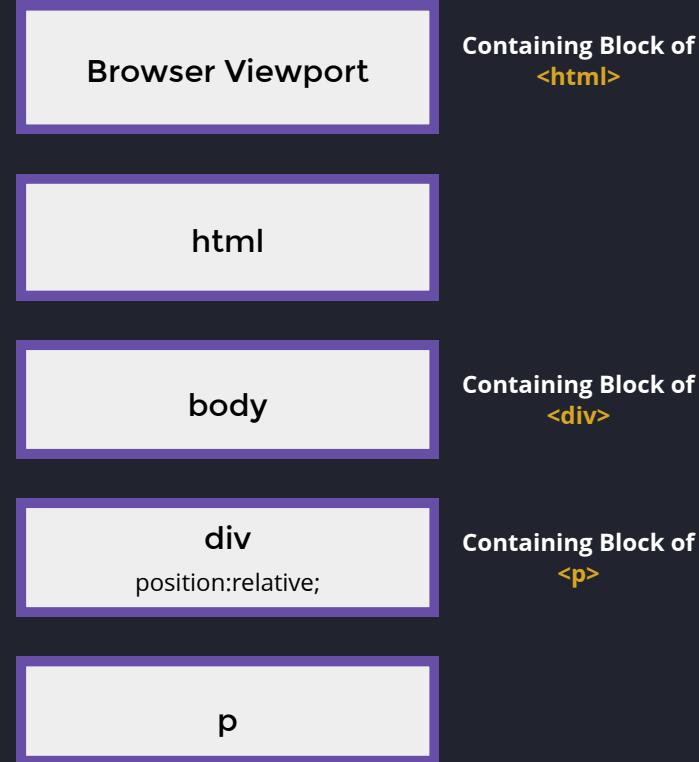
# Containing block



# Position: absolute

- The **element** is removed from the **normal document flow**
- no space is reserved for the element in the page layout.
- It is **positioned relative** to its closest **positioned ancestor** if one exists; otherwise, it is placed relative to the **initial containing block**.
- Final position is determined by the values of **top, right, bottom, and left**.
- This positioning creates a new **stacking context** when the **z-index** value is not **auto**.

## Default Stacking Context



# Position: absolute

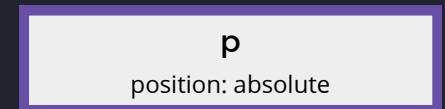
- The **element** is removed from the **normal document flow**
- no space is reserved for the element in the page layout.
- It is **positioned relative** to its closest **positioned ancestor** if one exists; otherwise, it is placed relative to the **initial containing block**.
- Final position is determined by the values of **top, right, bottom, and left**.
- This positioning creates a new **stacking context** when the **z-index** value is not **auto**.

## Default Stacking Context



Containing Block of  
<html>

## Stacking Context 1



Containing Block of  
<div>

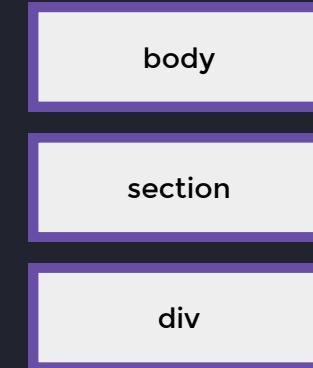
Reference point

Containing Block of  
<p>

# Position: absolute

```
1 <body>
2   <section class="container">
3     <div style="position: relative; height: 150px;">
4       <div class="box red absolute">Box 1</div>
5       <div class="box blue absolute">Box 2</div>
6     </div>
7   </section>
8 </body>
```

## Stacking Context 0

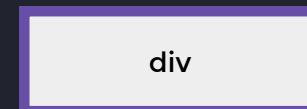
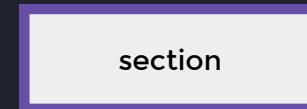
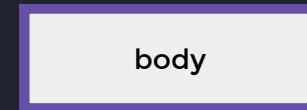


# Position: absolute

```
1 <section class="container">
2   <div style="position: relative; height: 150px;">
3     <div class="box red absolute">Box 1</div>
4     <div class="box blue absolute">Box 2</div>
5   </div>
6 </section>
```

- Box 1 was removed from the normal flow and placed in a separate stacking context.

Stacking Context 0      Stacking Context 1

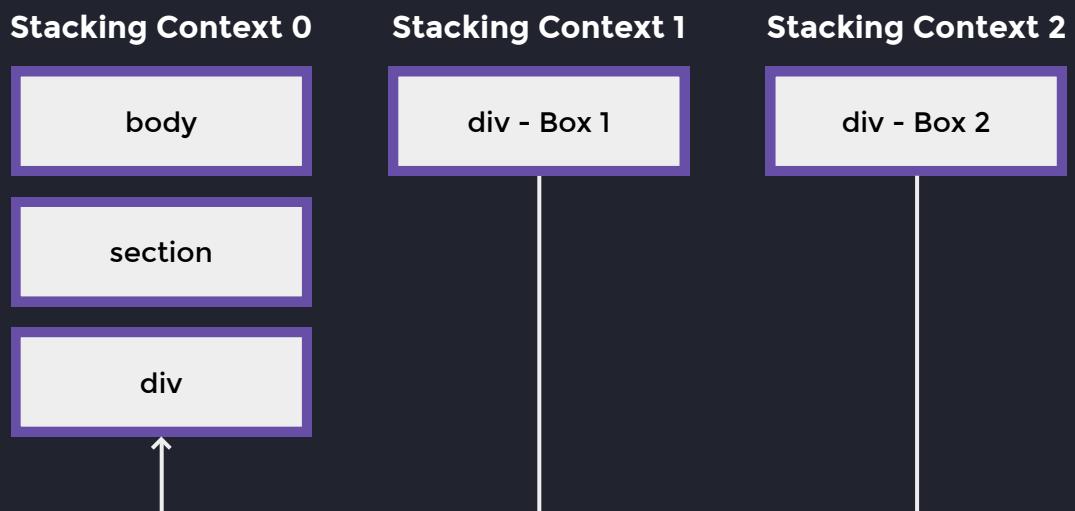


# Position: absolute

```
1 <section class="container">
2   <div style="position: relative; height: 150px;">
3     <div class="box red absolute">Box 1</div>
4     <div class="box blue absolute">Box 2</div>
5   </div>
6 </section>
```

<https://codepen.io/RayEiji/embed/qBwbGpQ>

- **Box 1** was removed from the **normal flow** and placed in a separate stacking context.
- **Box 2** was also removed from the normal flow and placed in the same stacking context as **Box 1**.  
Since a later element is always stacked above the previous one, **Box 1** is positioned behind **Box 2**.



# Key summary

The importance of these two types of positions — **relative** & **absolute** — lies in their ability to remove items from the **normal flow**

If we use positioning wise, we can achieve:

- **Isolation** - modifications made to elements positioned in this way will not affect other elements within the normal flow
- **Performance optimization** - key prerequisite for optimizing and minimizing updates to the **DOM tree**

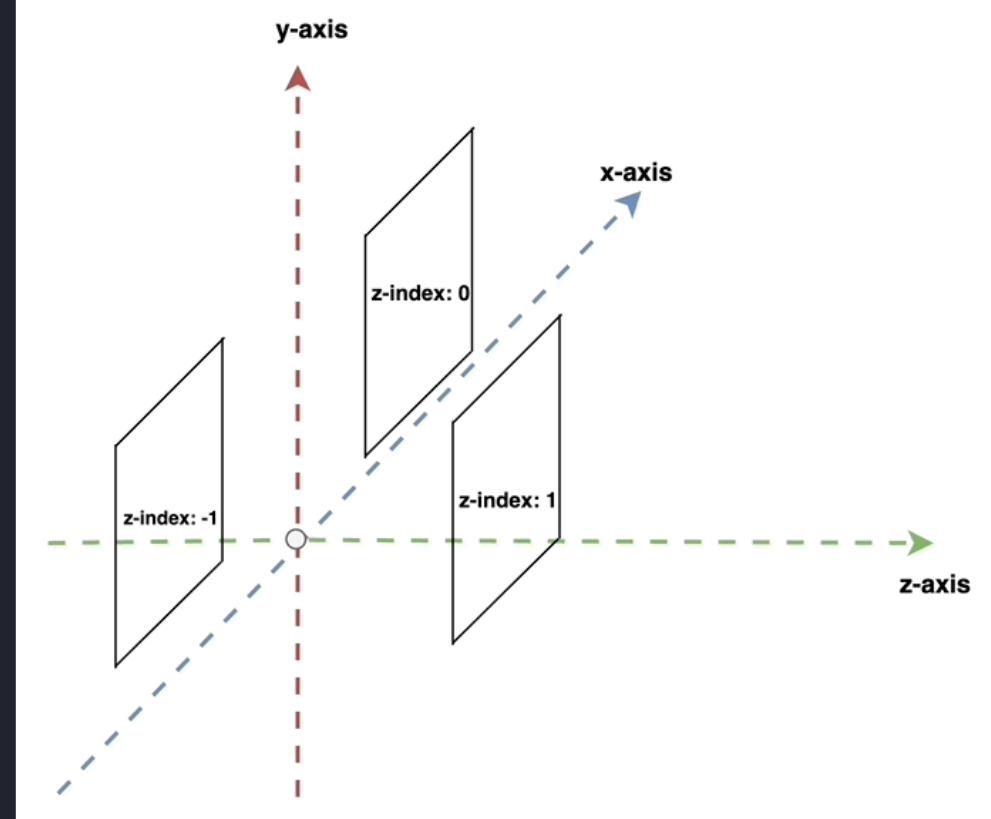
# Stacking Context

When we build layouts, we work only with the **X** and **Y axis**, meaning everything is placed on a **single layer**.

However, when we engage in any **3D transformation**, **absolute positioning**, or any action that moves an element from **the normal flow**, we activate an additional axis known as the **Stacking Context** or **Z-axis**.

## So, why does the browser need a stacking context?

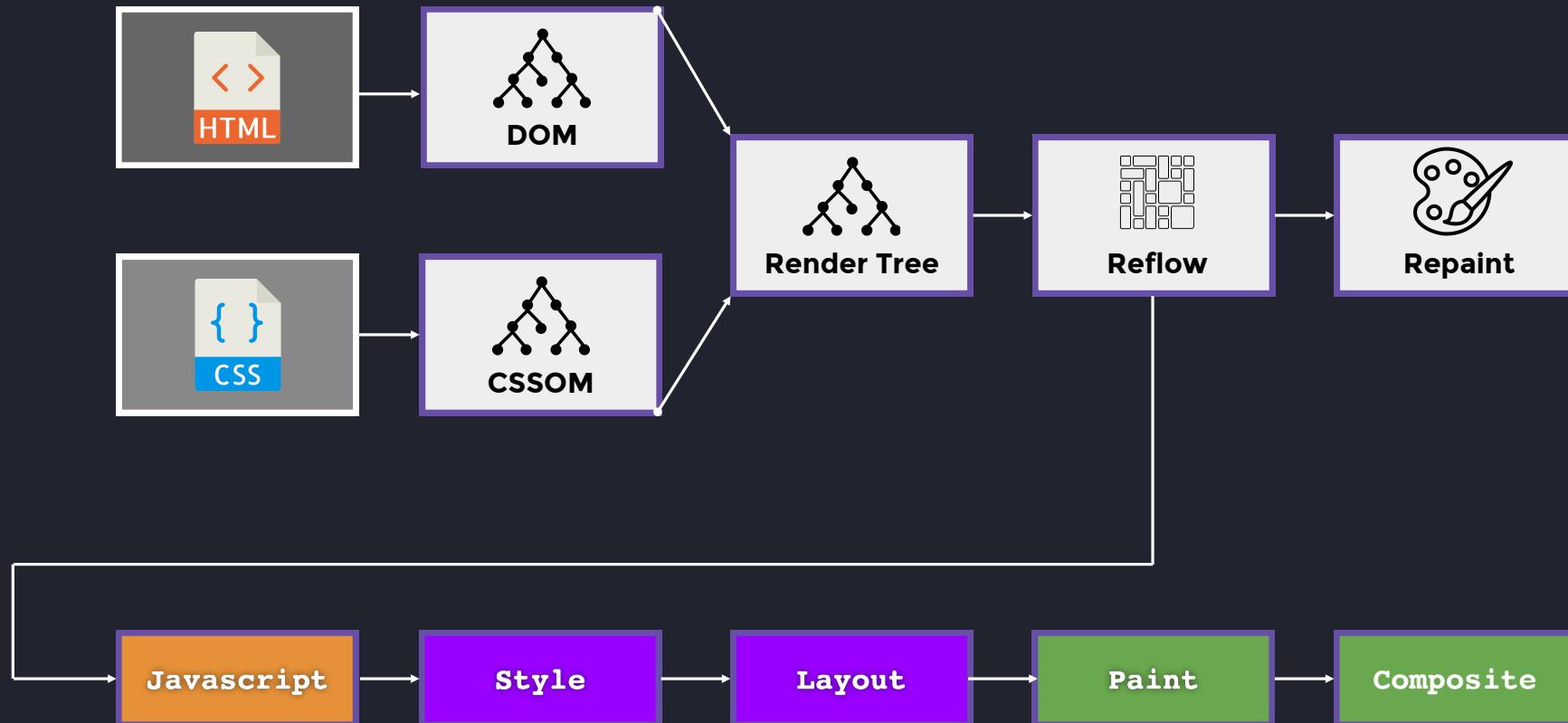
1. **Layering:** We need a way to represent layers in our layouts.
2. **Performance Optimization:**
  1. Elements removed from the **normal flow** are placed into a new stacking context.
  2. Modifications to every element within a separate **stacking context** do not impact any other elements within the **normal flow**.
  3. All CSS Transformations are GPU accelerated, meaning the browser doesn't need to recalculate the DOM Tree when such operations are performed. This minimizes the **reflow cycle**.



## Stacking Context - 3D Example

<https://codepen.io/RayEuji/embed/QWMXreZ>

# Reflow

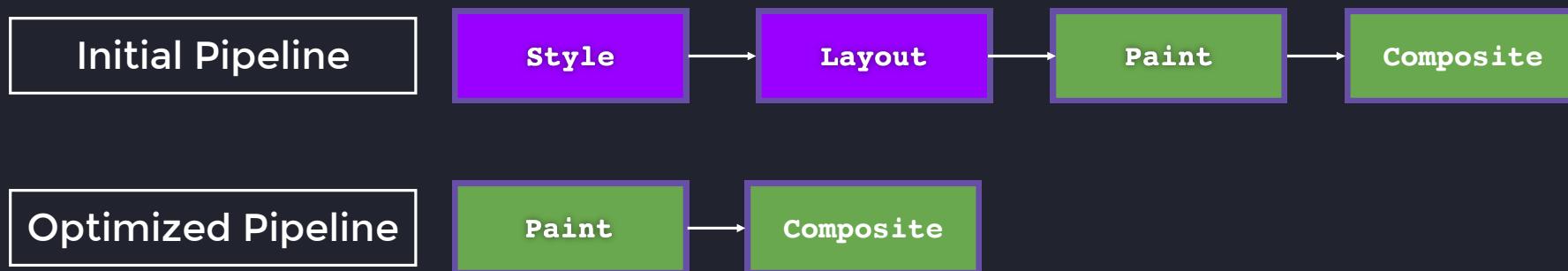






<https://codepen.io/RayEuji/embed/jjyqQvw>

# 4 lines of code: massive difference

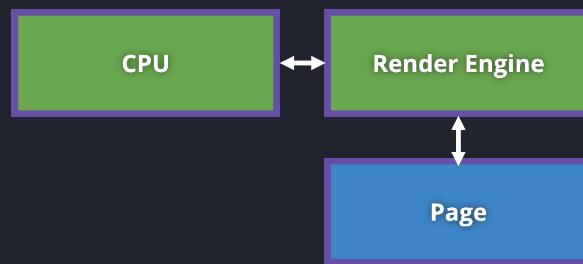


```
@keyframes moving-down-slow {  
  from { margin-top: 0; }  
  to { margin-top: 500px; }  
}
```

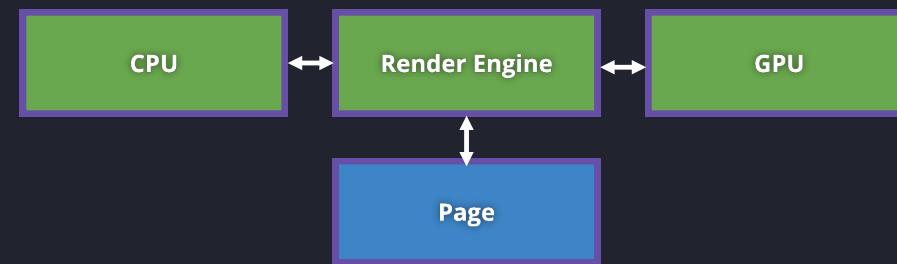
```
@keyframes moving-down-fast {  
  from { transform: translateY(0px); }  
  to { transform: translateY(500px); }  
}
```

# Composition Layers

Old Browsers



New Browsers



# Composition Layers

```
1 <html>
2 <body>
3 <main>
4   <div class="box red"></div>
5   <div class="box yellow"></div>
6   <div class="box green"></div>
7   <div class="box blue"></div>
8 </main>
9 </body>
10 </html>
```

html

body

main

div

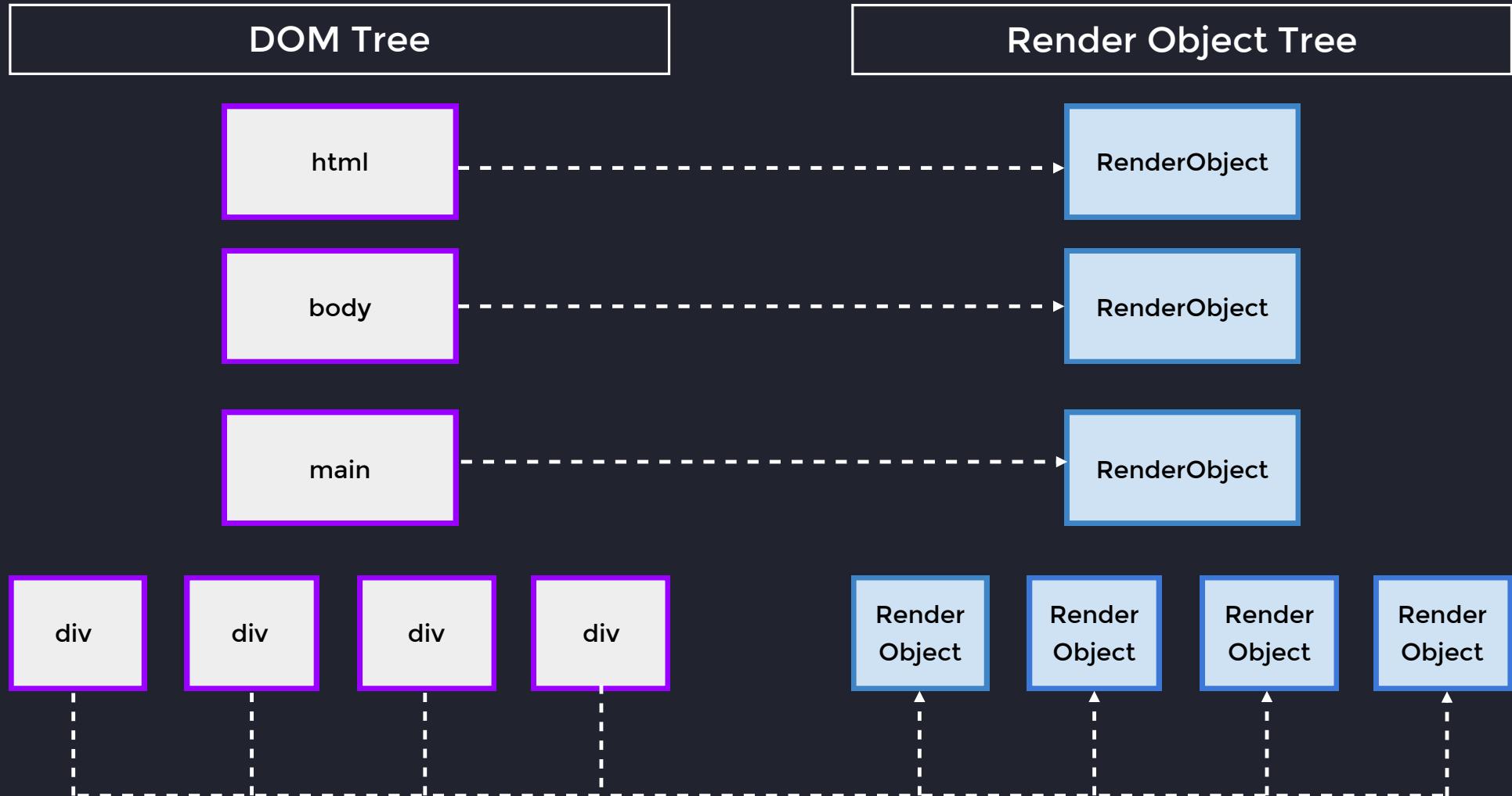
div

div

div

<https://codepen.io/RayEuji/embed/qBwNbLm?editors=1100>

# Browser Graphics API: Render Object

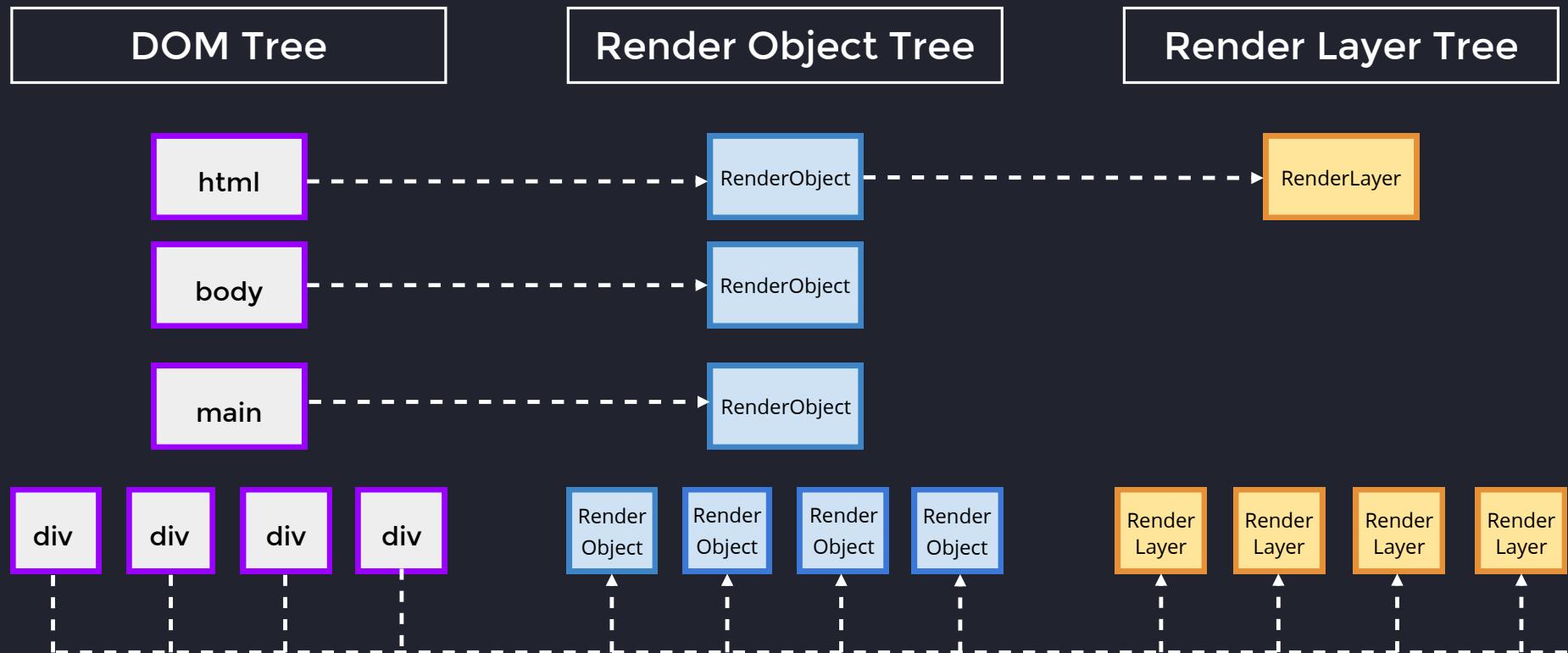


# Browser Graphics API: Render Layer

**Render Layer** for element is constructed when element:

- It has explicit CSS properties:
  - **position: relative | absolute**
  - **transform**
- It's the root object for the page - **<html/>**
- It is **transparent**
- Has a **CSS filter**
- Corresponds to **<canvas>** element that has a 3D (WebGL) context or an accelerated 2D context
- Corresponds to a **<video>** element

# Browser Graphics API: Render Layer

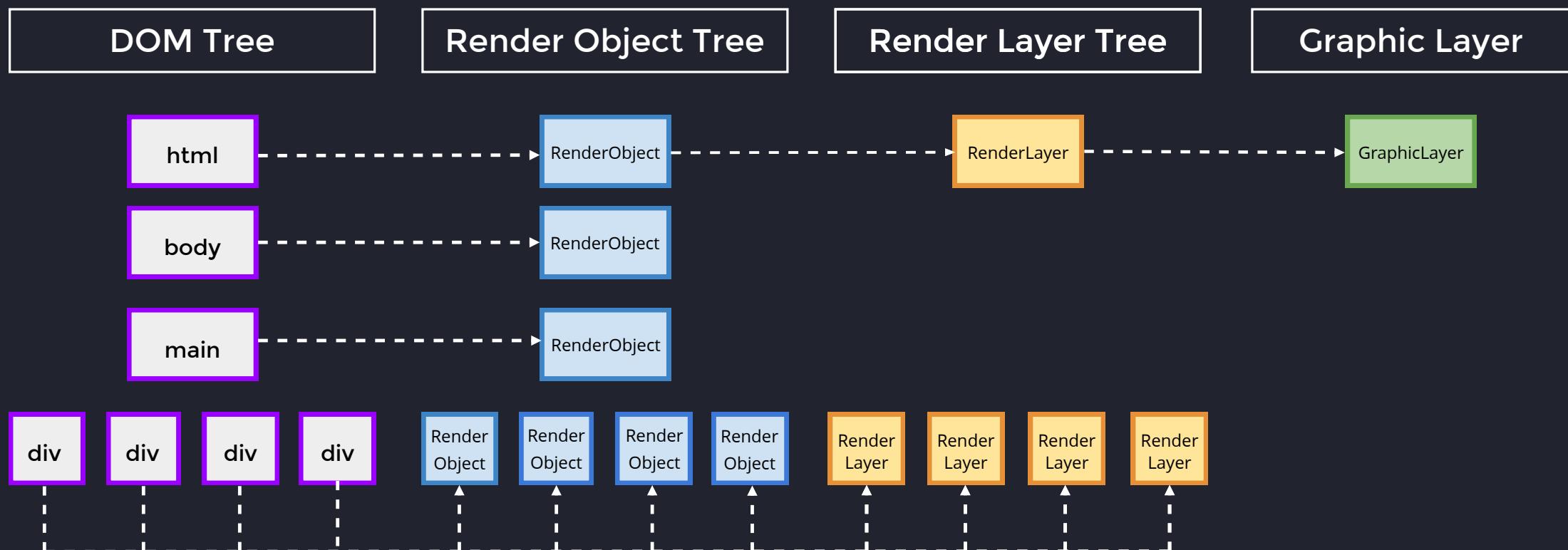


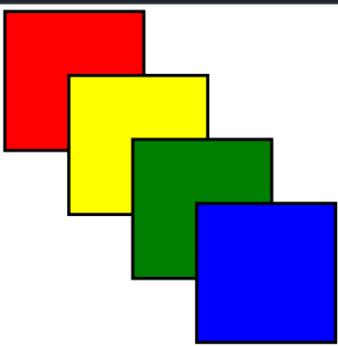
# Browser Graphics API: Graphic Layer

**Graphic Layer** is constructed when:

- Render Layer has **3D** or **perspective transform** CSS properties
- Layer is used by:
  - **<video>** element using accelerated video decoding
  - **<canvas>** with **3D/2D context**
- Layer uses:
  - CSS animation for its **opacity**
  - animated **web-kit transform**
- Layer uses accelerated **css filters**
- Layer has a descendant that is a **compositing layer**
- Layer has a sibling with a lower **z-index** which has a compositing layer (in other words the layer overlaps a composited layer and should be rendered on top of it)

# Browser Graphics API: Graphic Layer





Layers panel might be deprecated soon. Share your thoughts and concerns before we decide. [Send feedback](#)

Paints Slow scroll rects

The screenshot shows the Chrome DevTools Layers panel. At the top, there's a warning about the deprecation of the Layers panel. Below that, there are two checkboxes: 'Paints' and 'Slow scroll rects'. The main area displays a white canvas with the four colored squares from the left image. In the bottom-left corner of the canvas, there's some small text. To the right of the canvas, there's a 'Details' section with the following information:

Size	1022 x 1304 (at 0, 0)
Compositing Reasons	Is the document.rootScroller. Is a scrollable overflow element using accelerated scrolling.
Memory estimate	5.3 MB
Paint count	1
Slow scroll regions	
Sticky position constraint	

At the bottom of the DevTools window, there are tabs for 'Console' and 'What's new' (which is currently selected). Below the tabs, it says 'Highlights from the Chrome 124 update'. There are two sections: 'Scroll-driven animations support' and 'New Autocomplete panel'. The 'New Autocomplete panel' section includes a link to 'Debug the forms that Chrome automatically fills with saved info with the new Autocomplete panel.' To the right of these sections is a blue thumbnail with a play button icon and the word 'new'.

# Caveats

*"With great power comes great responsibility"*

**Graphic Layer** is expensive object to initialize, overusing  
it can blow-up your device as it uses **VRAM** and **CPU**

Let's check the **DEMO**

# Let's become a browser: Part 2

## Our task is to:

- Build all **Formatting Contexts**
- Detect elements outside of **normal flow**
- Build a **Stacking context**
- Build **DOM**, **RenderObject**, **RenderLayer** and  
**GraphicLayer** Trees

```
1 <html>
2   <body>
3     <section style="display:flex">
4       <div>Flex Item 1</div>
5       <div>Flex Item 2</div>
6     </section>
7     <div style="position:absolute">
8       <span>Modal</span>
9     </div>
10    <div style="display: inline-block">
11      <div>List item</div>
12    </div>
13    <div style="position: absolute; transform: translateZ(0);>
14      Transformed
15    </div>
16  </body>
17 </html>
```

# Step 1

DOM Tree

```
<html>
```

Graphic Layer Tree

```
GraphicLayer
```

Stacking Context (Root)

Block Formatting Context (Root)

Render Object Tree

```
RenderObject
```

Render Layer Tree

```
RenderLayer
```

```
1 <html>
2   <body>
3     <section style="display:flex">
4       <div>Flex Item 1</div>
5       <div>Flex Item 2</div>
6     </section>
7     <div style="position:absolute">
8       <span>Modal</span>
9     </div>
10    <div style="display: inline-block">
11      <div>List item</div>
12    </div>
13    <div style="position: absolute; transform: translateZ(0);>
14      Transformed
15    </div>
16  </body>
17 </html>
```

## Step 2

DOM Tree

```
<html>  
<body>
```

Graphic Layer Tree

```
GraphicLayer
```

Stacking Context (Root)

Block Formatting Context (Root)

Render Object Tree

```
RenderObject  
RenderObject
```

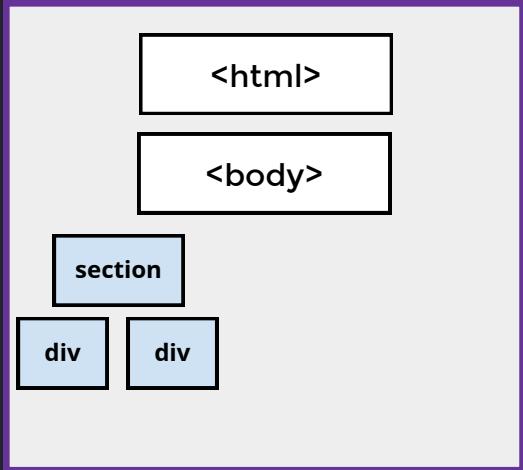
Render Layer Tree

```
RenderLayer
```

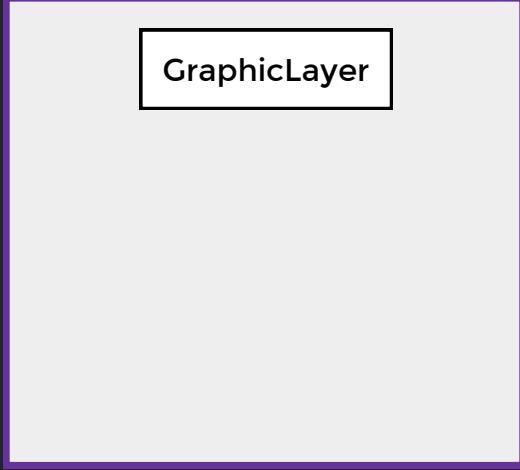
```
1 <html>  
2   <body>  
3     <section style="display:flex">  
4       <div>Flex Item 1</div>  
5       <div>Flex Item 2</div>  
6     </section>  
7     <div style="position:absolute">  
8       <span>Modal</span>  
9     </div>  
10    <div style="display: inline-block">  
11      <div>List item</div>  
12    </div>  
13    <div style="position: absolute; transform: translateZ(0);  
14      Transformed  
15    </div>  
16  </body>  
17 </html>
```

## Step 3: render <section>

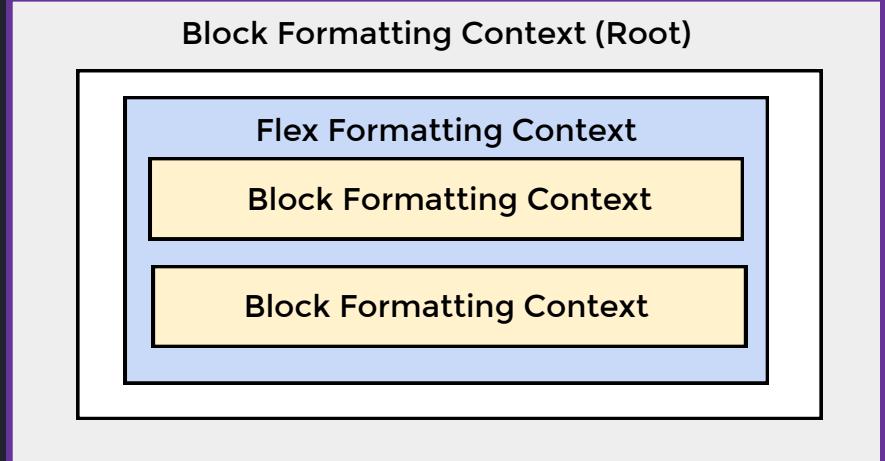
DOM Tree



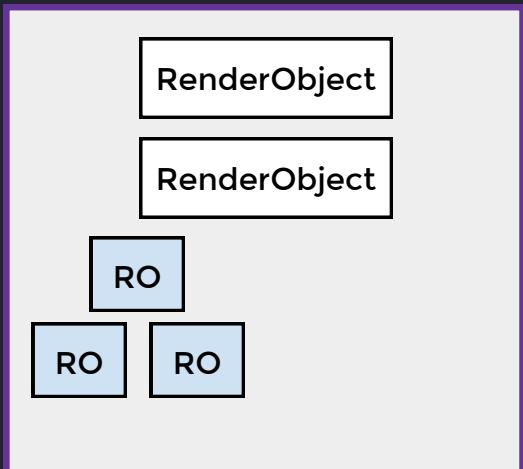
Graphic Layer Tree



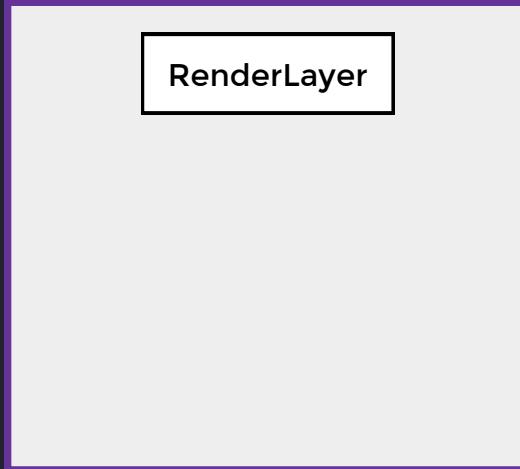
Stacking Context (Root)



Render Object Tree



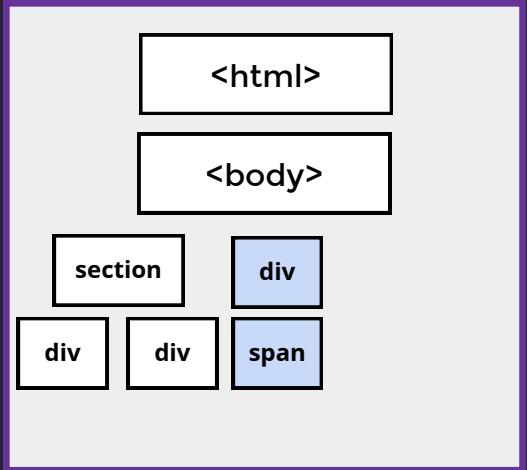
Render Layer Tree



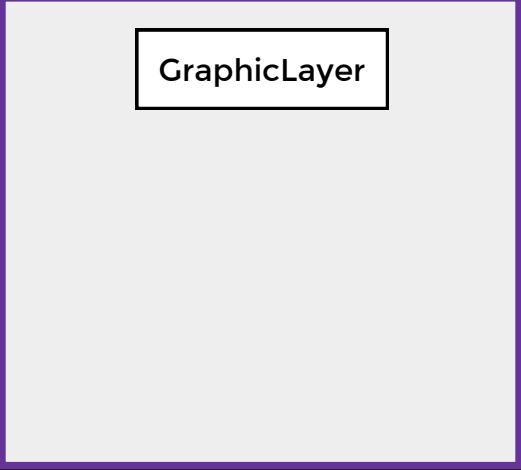
```
1 <html>
2   <body>
3     <section style="display:flex">
4       <div>Flex Item 1</div>
5       <div>Flex Item 2</div>
6     </section>
7     <div style="position:absolute">
8       <span>Modal</span>
9     </div>
10    <div style="display: inline-block">
11      <div>List item</div>
12    </div>
13    <div style="position: absolute; transform: translateZ(0);>
14      Transformed
15    </div>
16   </body>
17 </html>
```

## Step 4: render <div> with absolute position

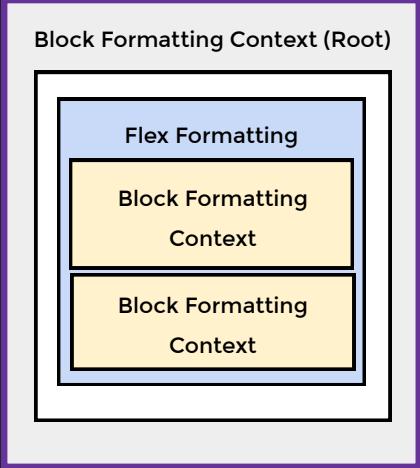
DOM Tree



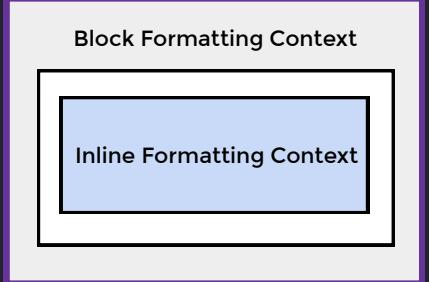
Graphic Layer Tree



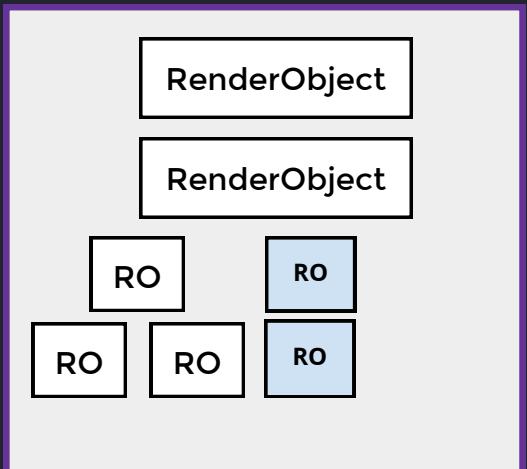
Stacking Context (Root)



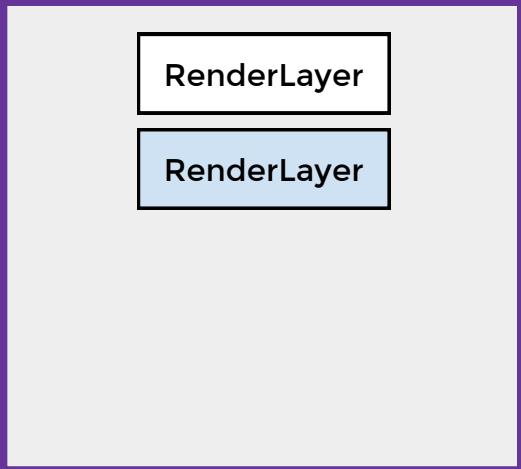
Stacking Context 1



Render Object Tree



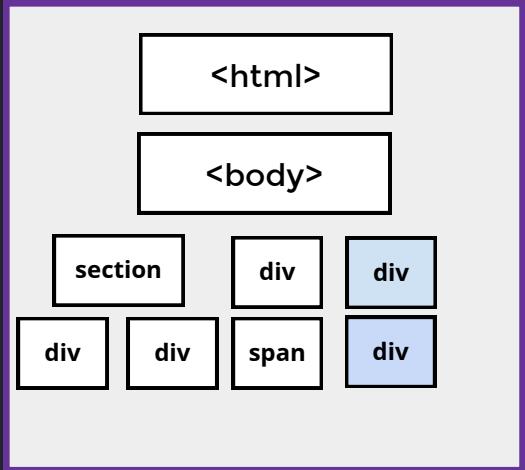
Render Layer Tree



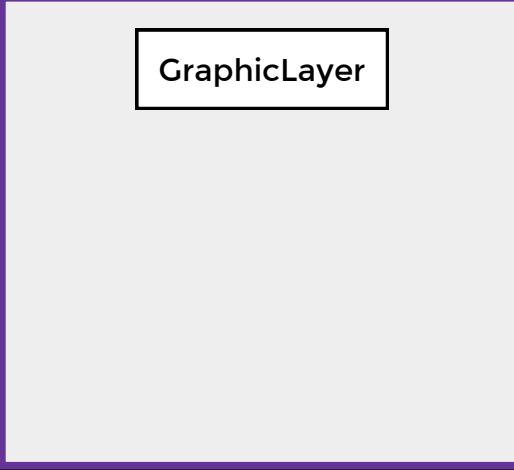
```
1 <html>
2   <body>
3     <section style="display:flex">
4       <div>Flex Item 1</div>
5       <div>Flex Item 2</div>
6     </section>
7     <div style="position:absolute">
8       <span>Modal</span>
9     </div>
10    <div style="display: inline-block">
11      <div>List item</div>
12    </div>
13    <div style="position: absolute; transform: translateZ(0);>
14      Transformed
15    </div>
16  </body>
17 </html>
```

## Step 5: render <div> with display: inline-block

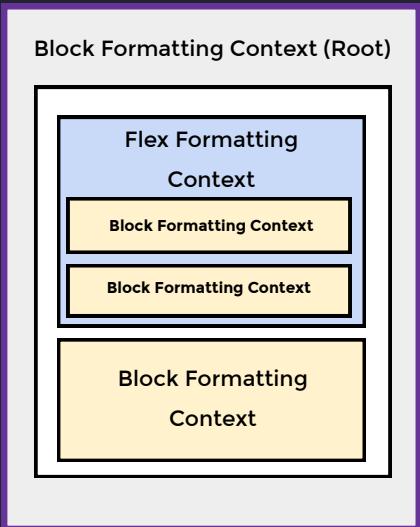
DOM Tree



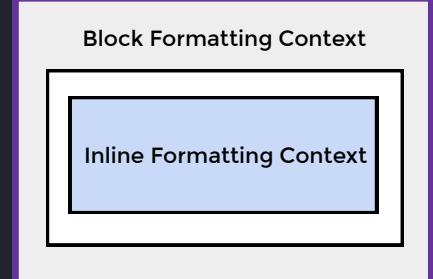
Graphic Layer Tree



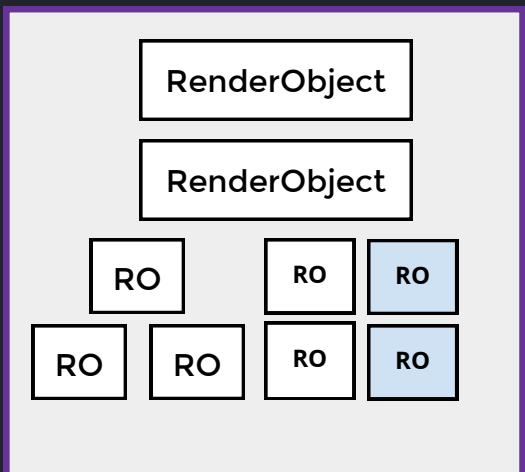
Stacking Context (Root)



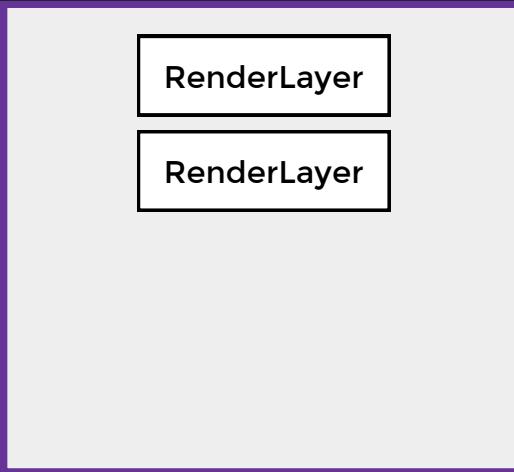
Stacking Context 1



Render Object Tree



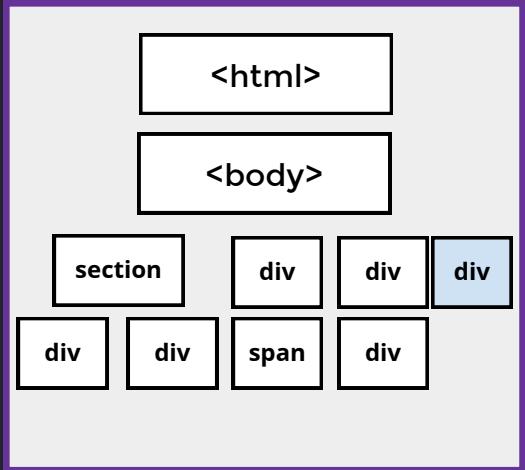
Render Layer Tree



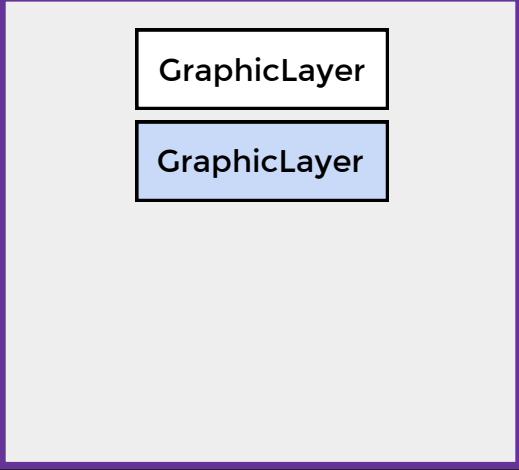
```
1 <html>
2   <body>
3     <section style="display:flex">
4       <div>Flex Item 1</div>
5       <div>Flex Item 2</div>
6     </section>
7     <div style="position:absolute">
8       <span>Modal</span>
9     </div>
10    <div style="display: inline-block">
11      <div>List item</div>
12    </div>
13    <div style="position: absolute; transform: translateZ(0);>
14      Transformed
15    </div>
16   </body>
17 </html>
```

## Step 6: render <div> with transform attribute

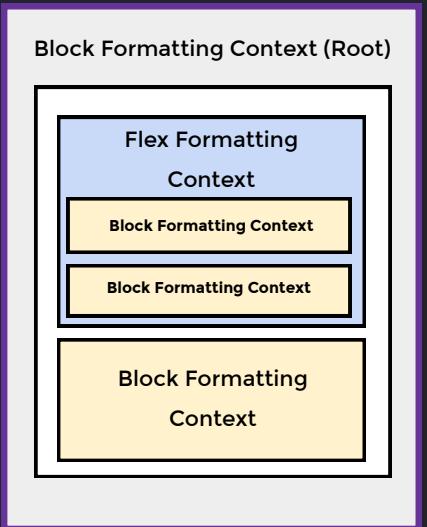
DOM Tree



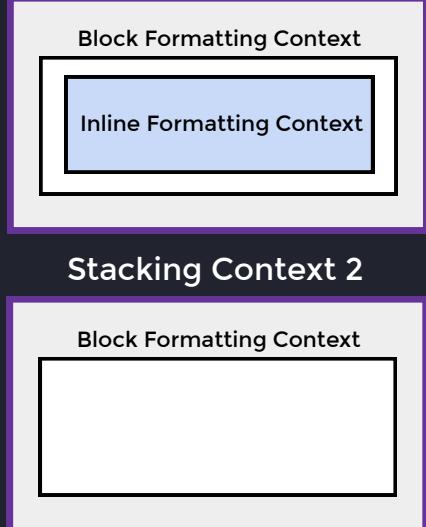
Graphic Layer Tree



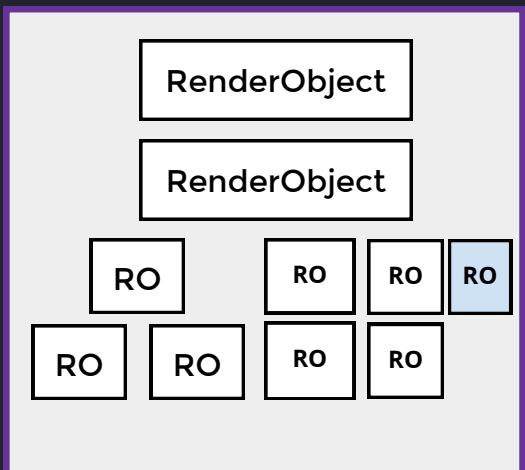
Stacking Context (Root)



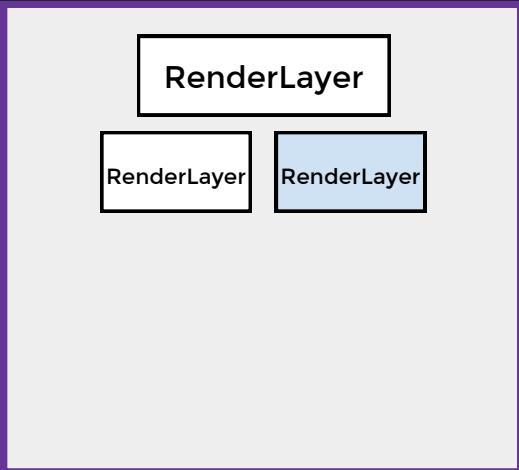
Stacking Context 1



Render Object Tree

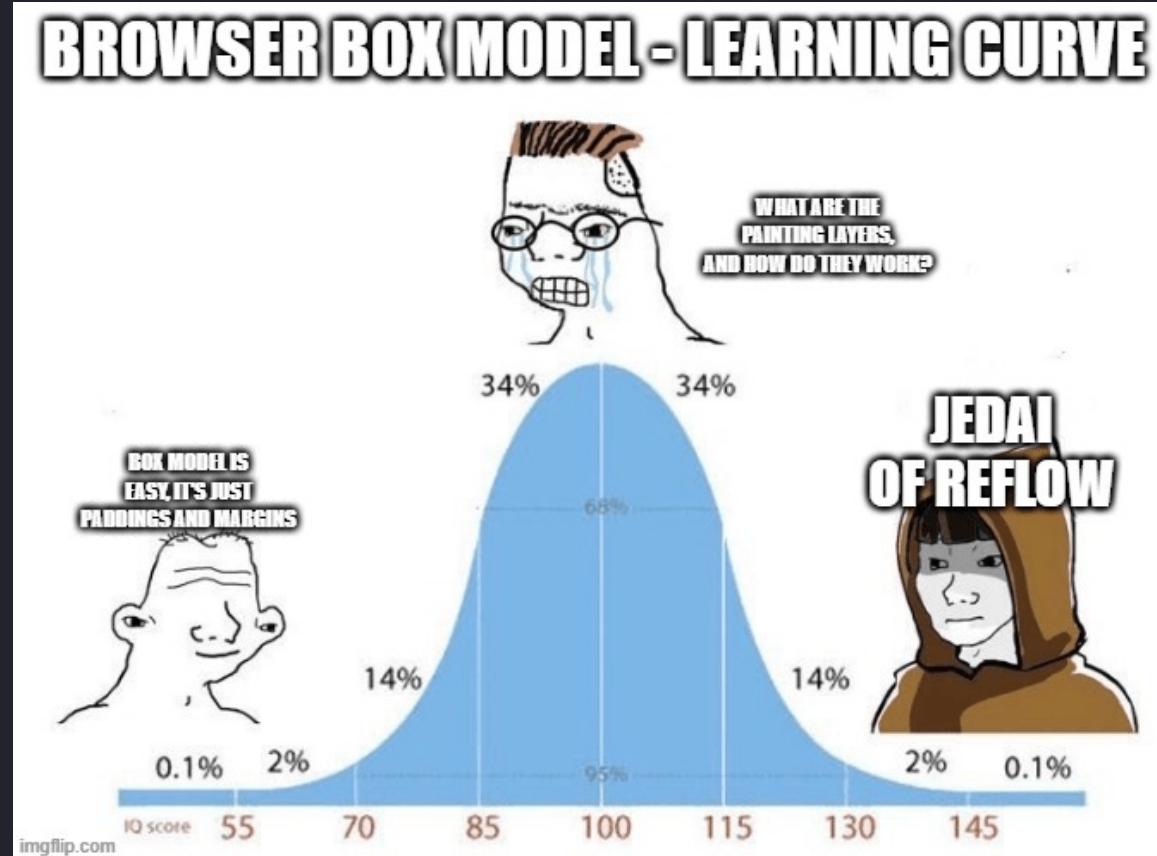


Render Layer Tree



```
1 <html>
2 <body>
3   <section style="display:flex">
4     <div>Flex Item 1</div>
5     <div>Flex Item 2</div>
6   </section>
7   <div style="position:absolute">
8     <span>Modal</span>
9   </div>
10  <div style="display: inline-block">
11    <div>List item</div>
12  </div>
13  <div style="position: absolute; transform: translateZ(0);>
14    Transformed
15  </div>
16 </body>
17 </html>
```

DONE!



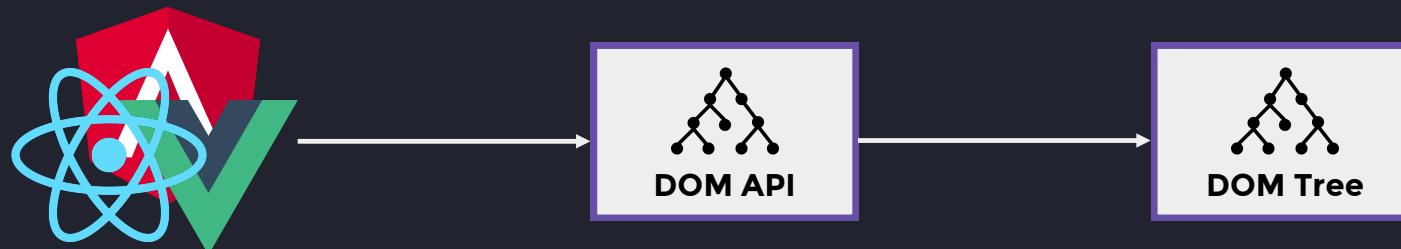
# DOM API

# DOM API

The **DOM API** is a set of methods we can utilise in JavaScript to manipulate the DOM.

## When to use it?

1. Building a low-level library (e.g., virtualisation, DOM management, etc.).
2. Creating generic components (such as a Video Player or Chart Engine).
3. Developing minimal-blueprint apps.



# DOM API: Global Objects

## Browser Window

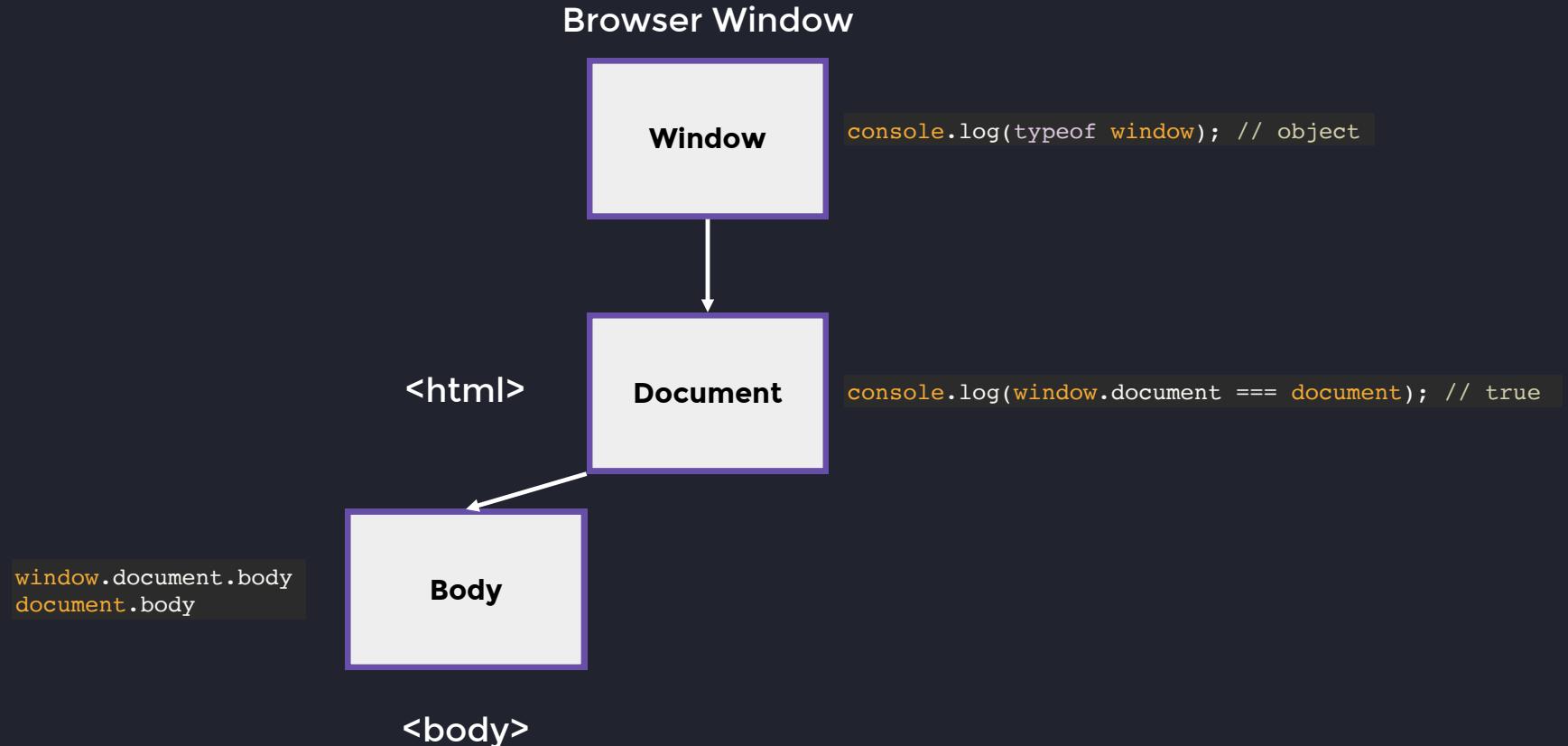
**Window**

```
console.log(typeof window); // object
```

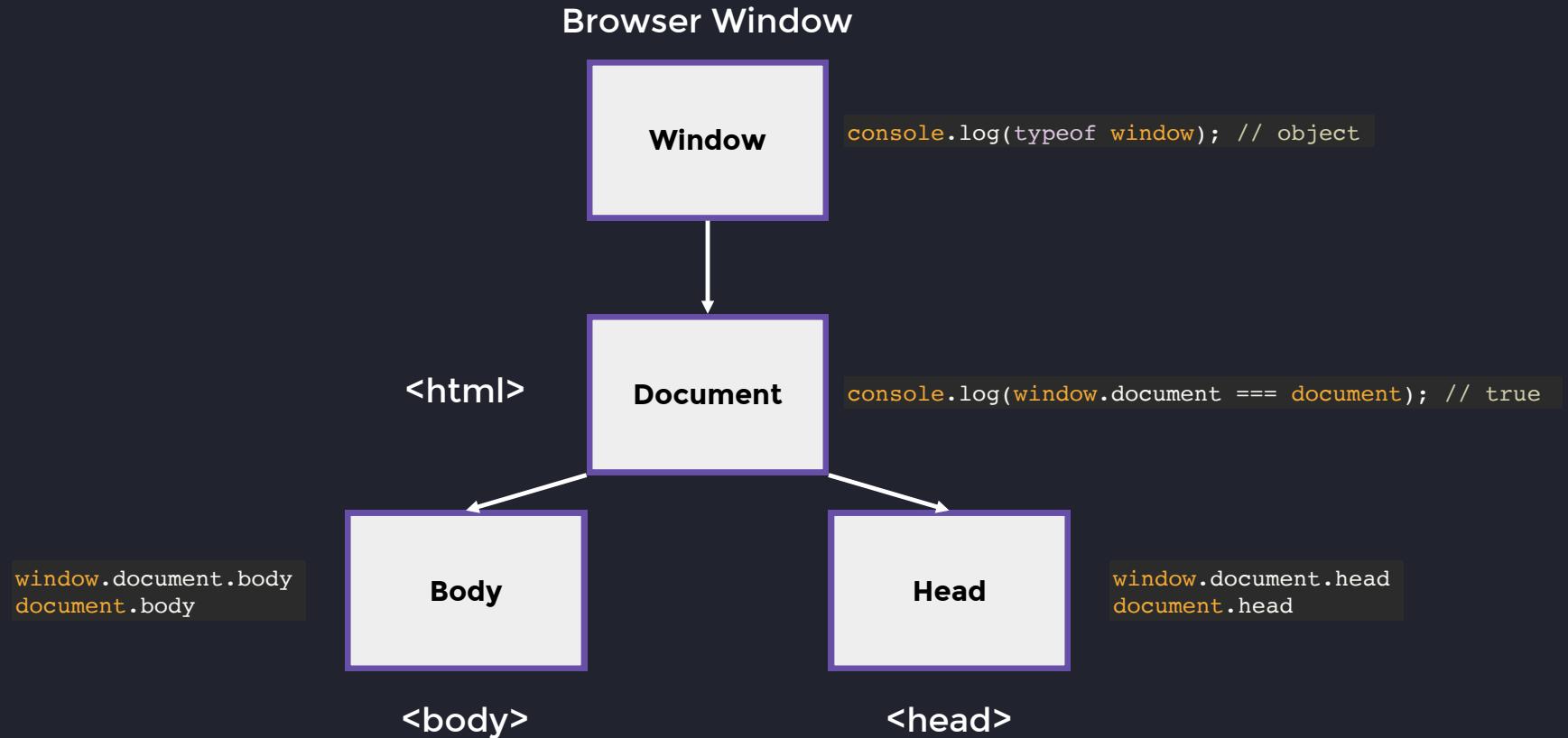
# DOM API: Global Objects



# DOM API: Global Objects



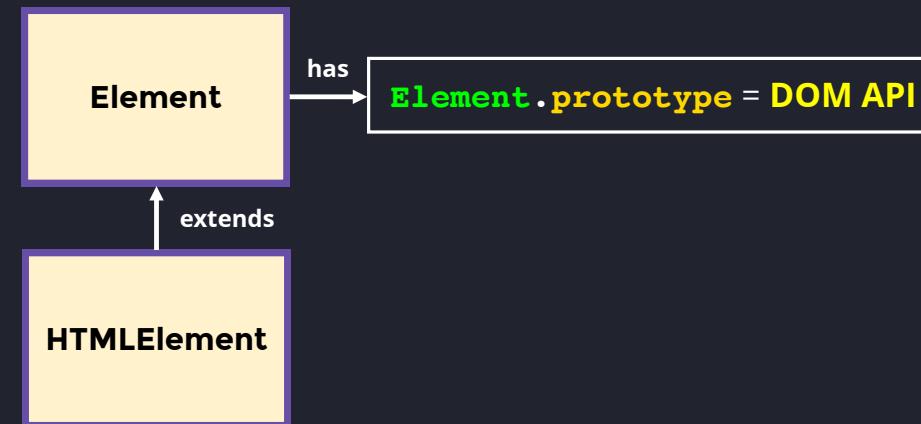
# DOM API: Global Objects



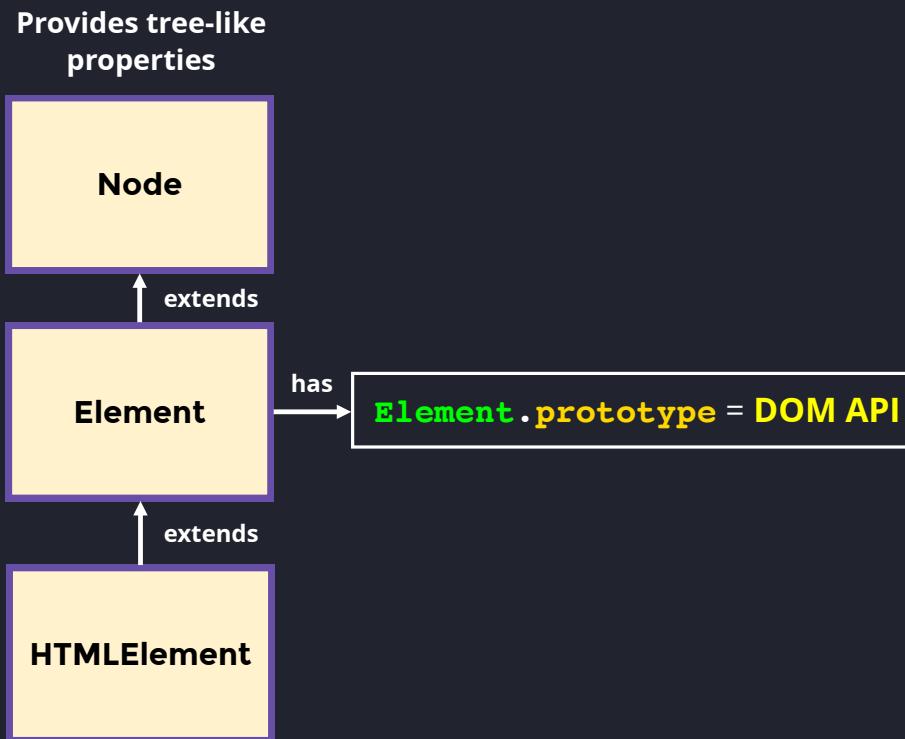
# DOM API: Class Hierarchy

**HTMLElement**

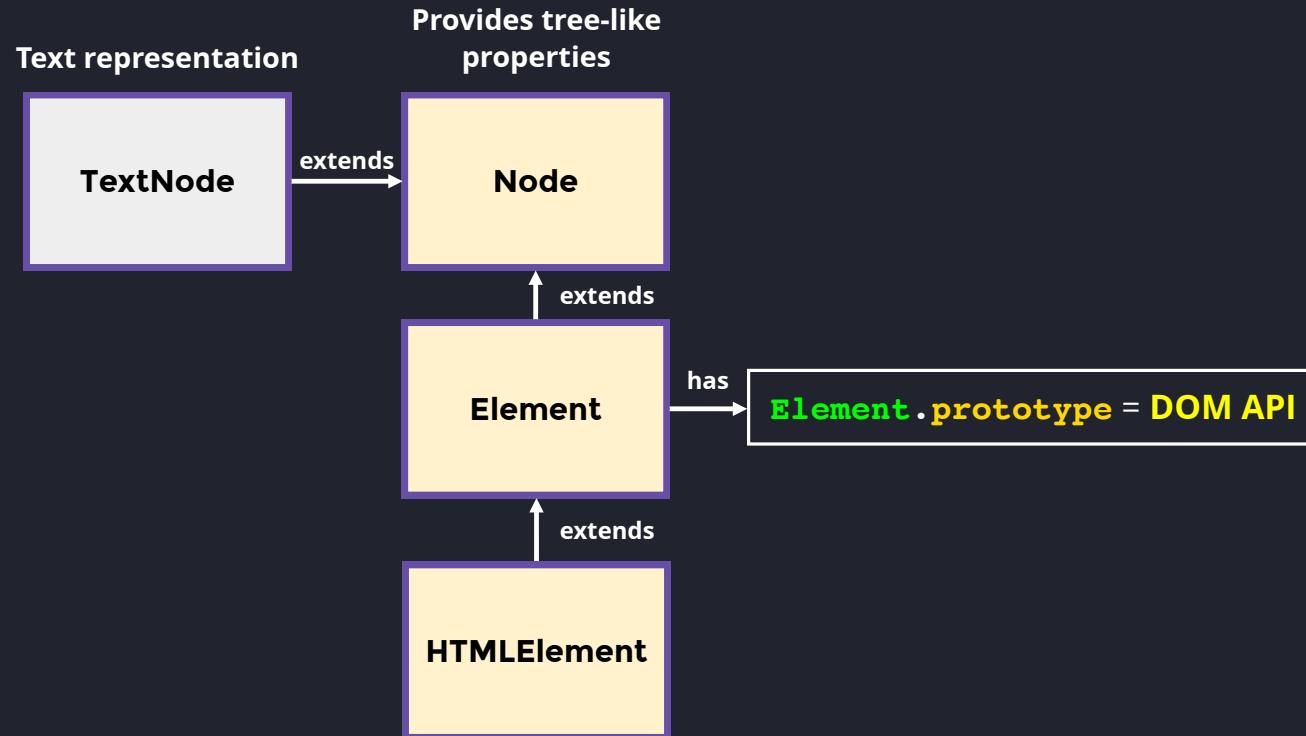
# DOM API: Class Hierarchy



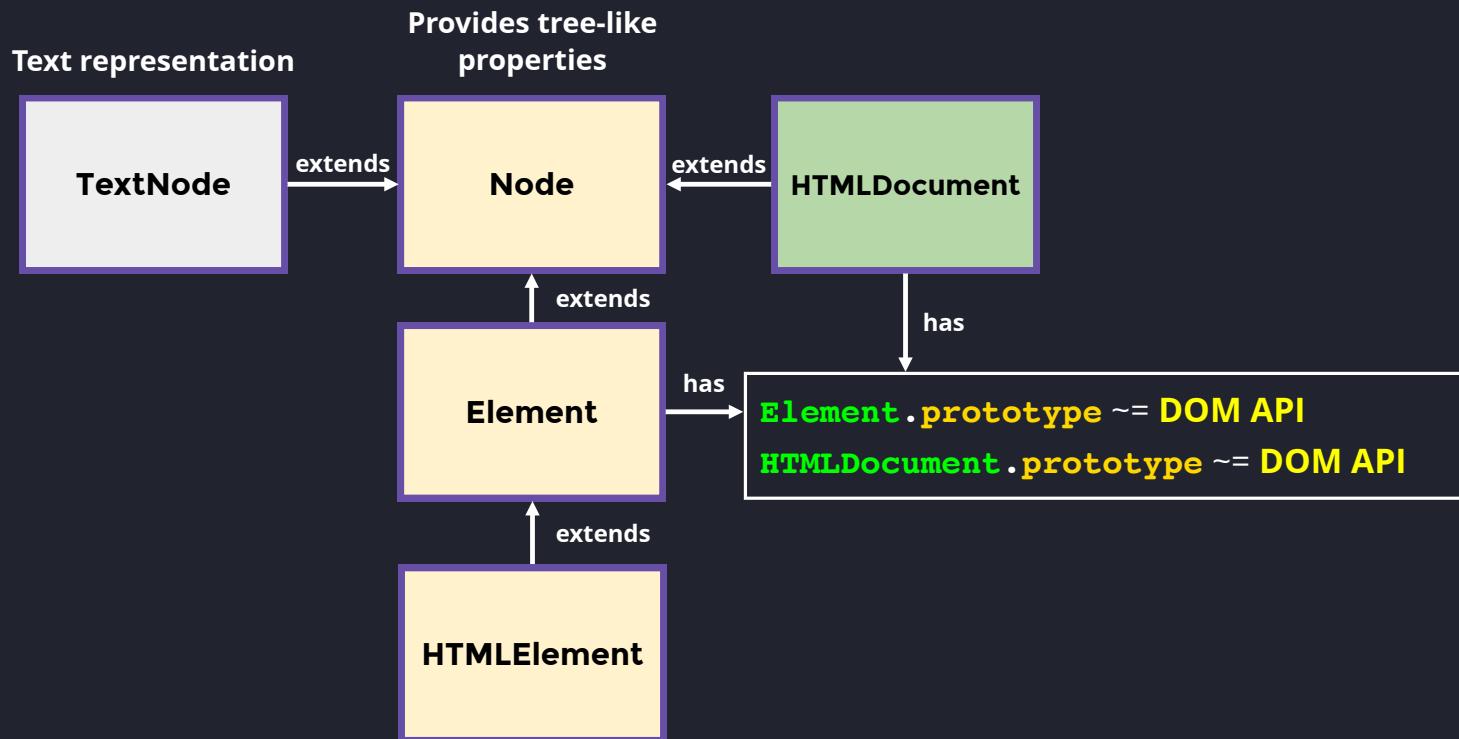
# DOM API: Class Hierarchy



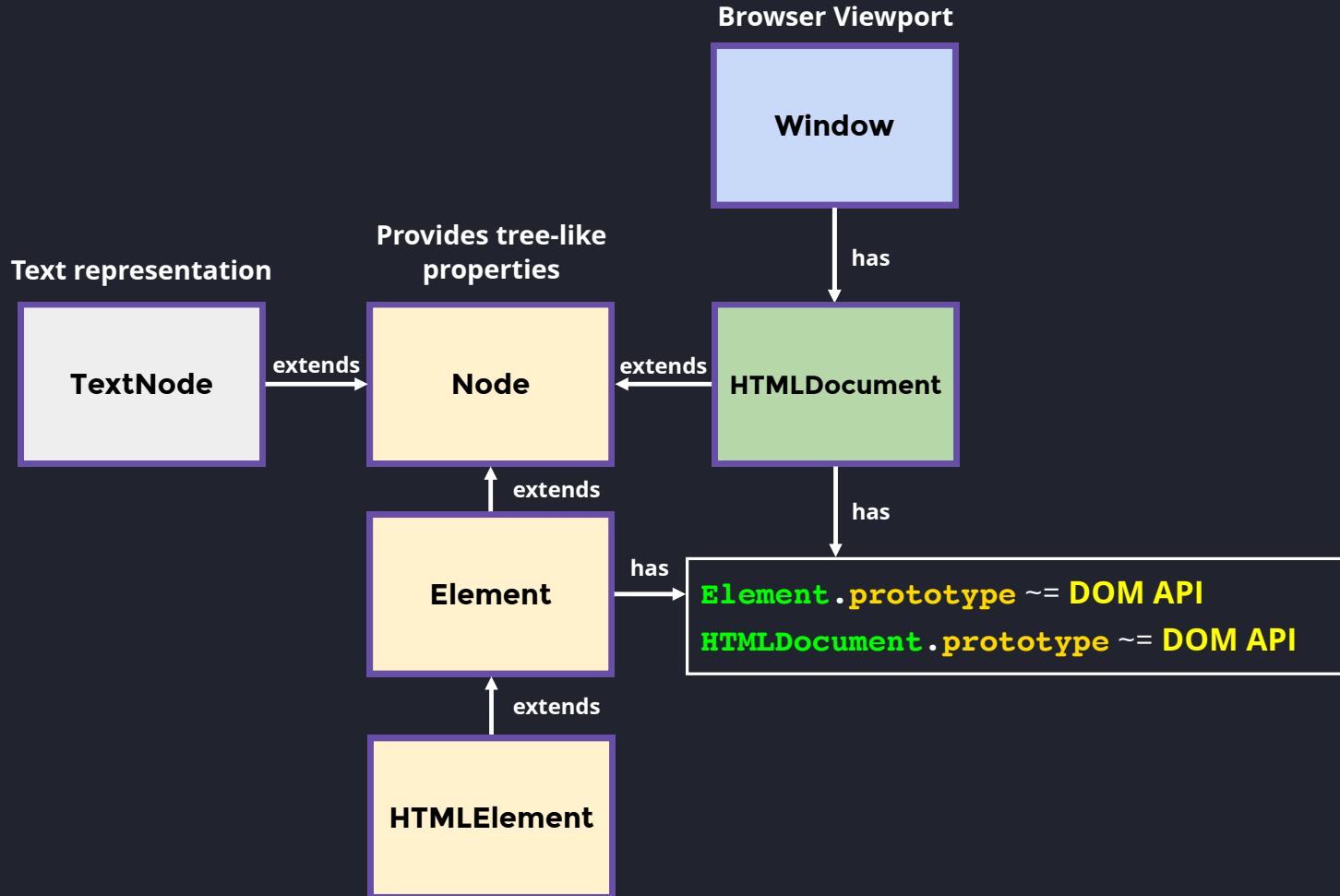
# DOM API: Class Hierarchy



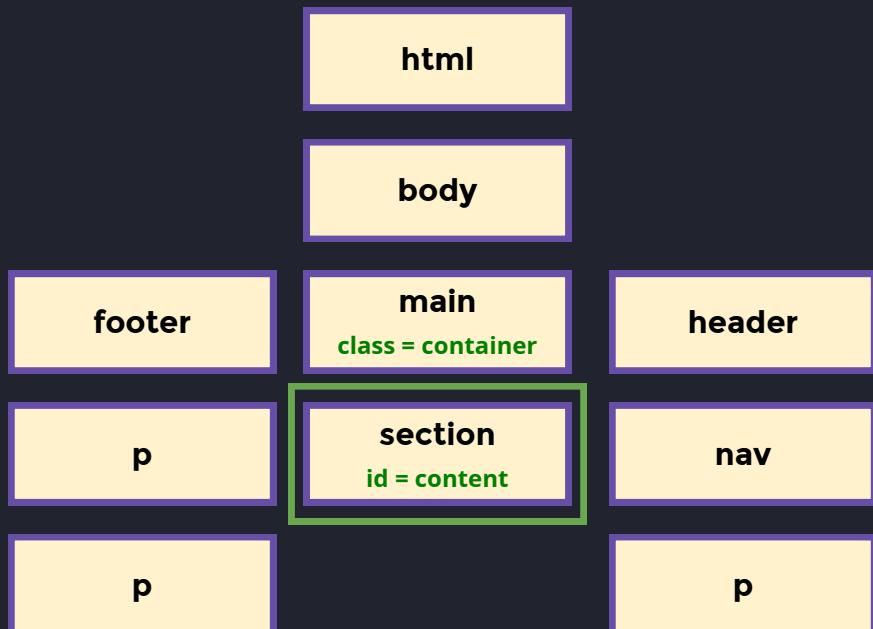
# DOM API: Class Hierarchy



# DOM API: Class Hierarchy



# DOM Querying: getElementById



```
document.getElementById("content") .
```

ID	Ref
"content"	HTMLElement

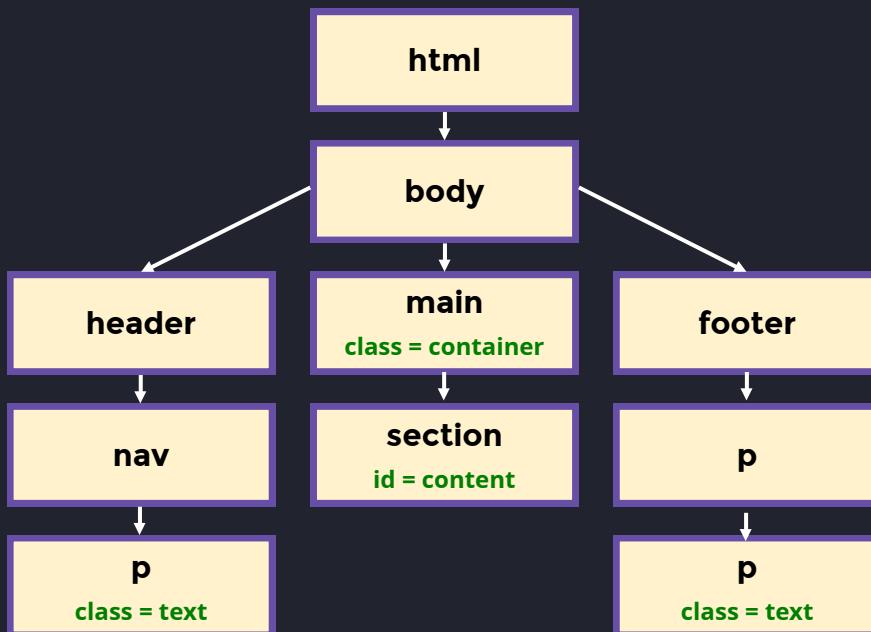
**Return type:** Element

**Time Complexity:** O(1)

**Read Cost:** O(1)

**Memory Cost:** O(1)

# DOM Querying: `getElementsByClassName`



`document.getElementsByClassName( "text" )`

**Return type:** `HTMLCollection`

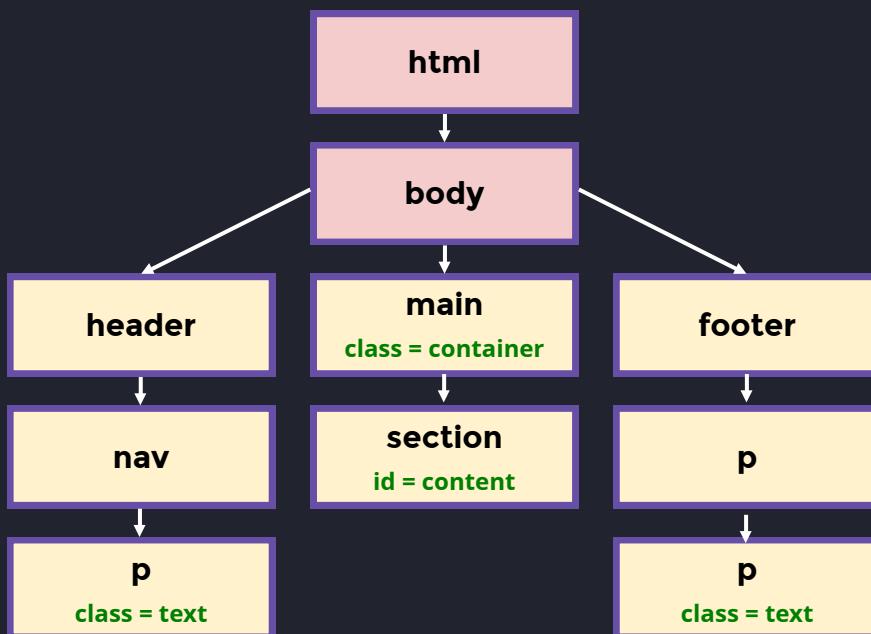
**Time Complexity:**  $O(N)$  \*

**Read Cost:**  $O(N)$  \*

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `getElementsByClassName`



`document.getElementsByClassName("text")`

**Return type:** `HTMLCollection`

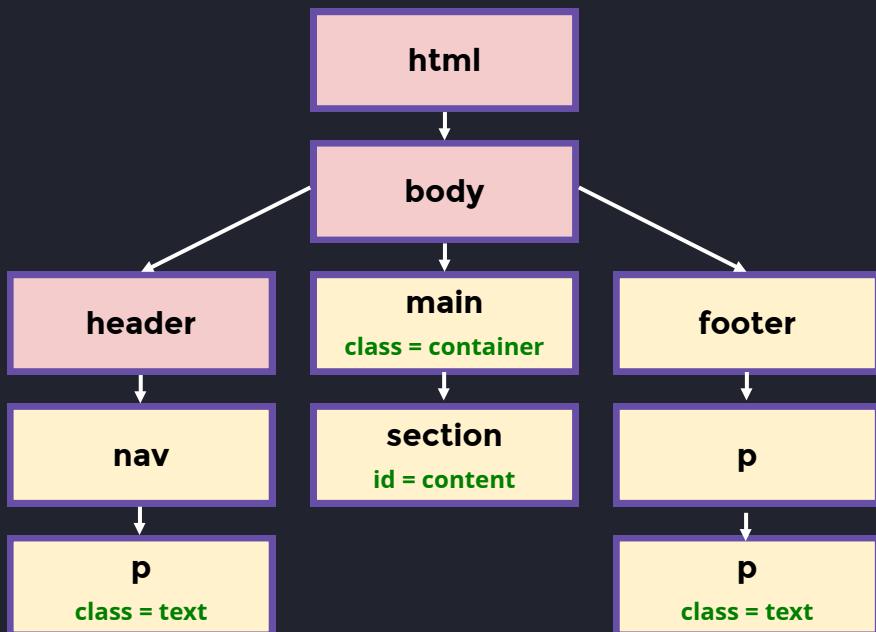
**Time Complexity:**  $O(N)$ \*

**Read Cost:**  $O(N)$ \*

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `getElementsByClassName`



`document.getElementsByClassName("text")`

**Return type:** `HTMLCollection`

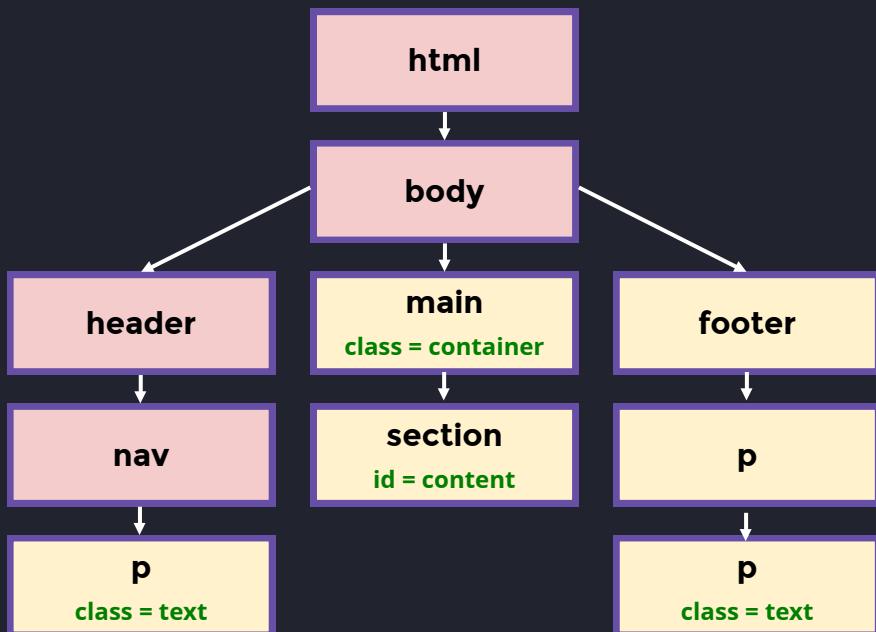
**Time Complexity:**  $O(N)$ \*

**Read Cost:**  $O(N)$ \*

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `getElementsByClassName`



`document.getElementsByClassName("text")`

**Return type:** `HTMLCollection`

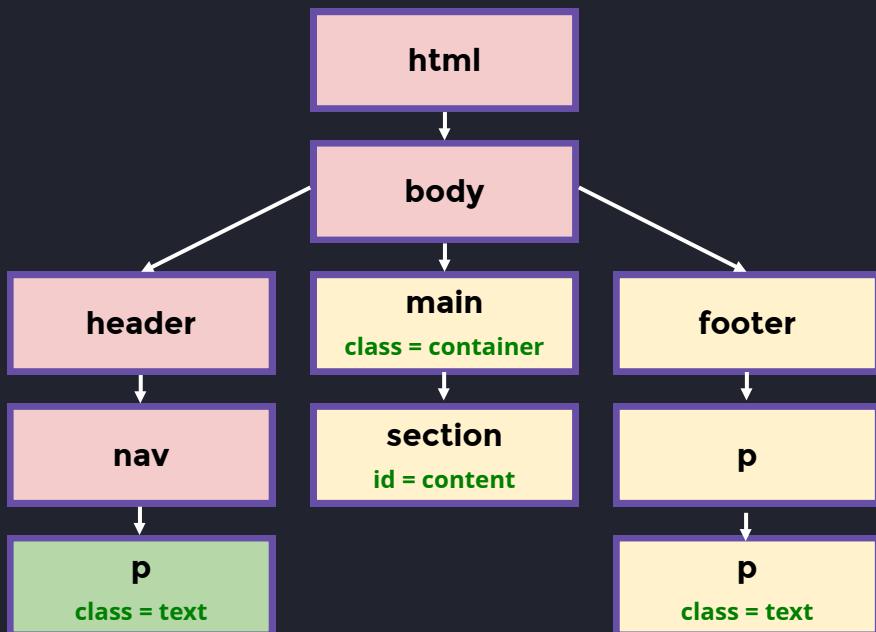
**Time Complexity:**  $O(N)$ \*

**Read Cost:**  $O(N)$ \*

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `getElementsByClassName`



`document.getElementsByClassName("text")`

**Return type:** `HTMLCollection`

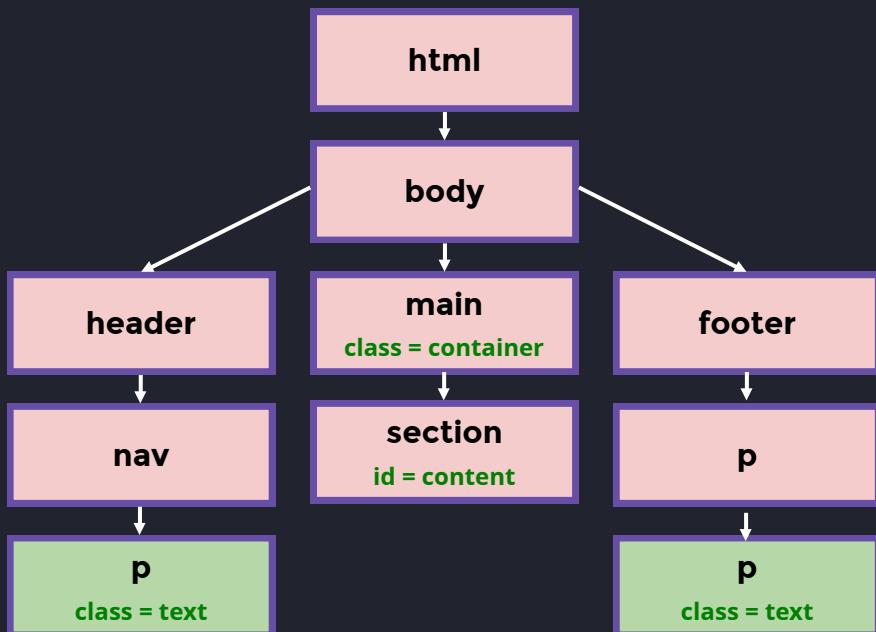
**Time Complexity:**  $O(N)$ \*

**Read Cost:**  $O(N)$ \*

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `getElementsByClassName`



`document.getElementsByClassName("text")`

**Return type:** `HTMLCollection`

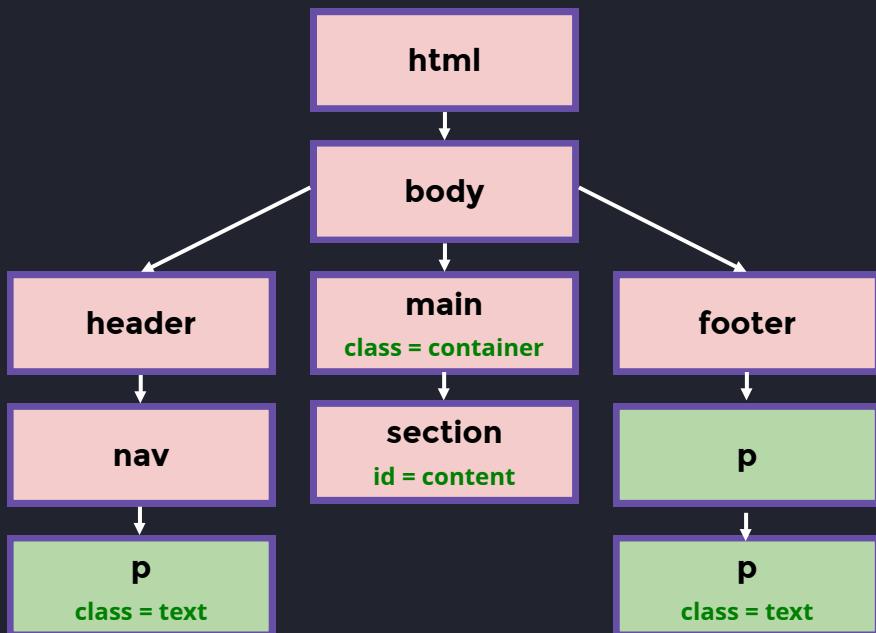
**Time Complexity:**  $O(N) *$

**Read Cost:**  $O(N) *$

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `getElementsByName`



`document.getElementsByClassName("p"):`

**Return type:** `HTMLCollection`

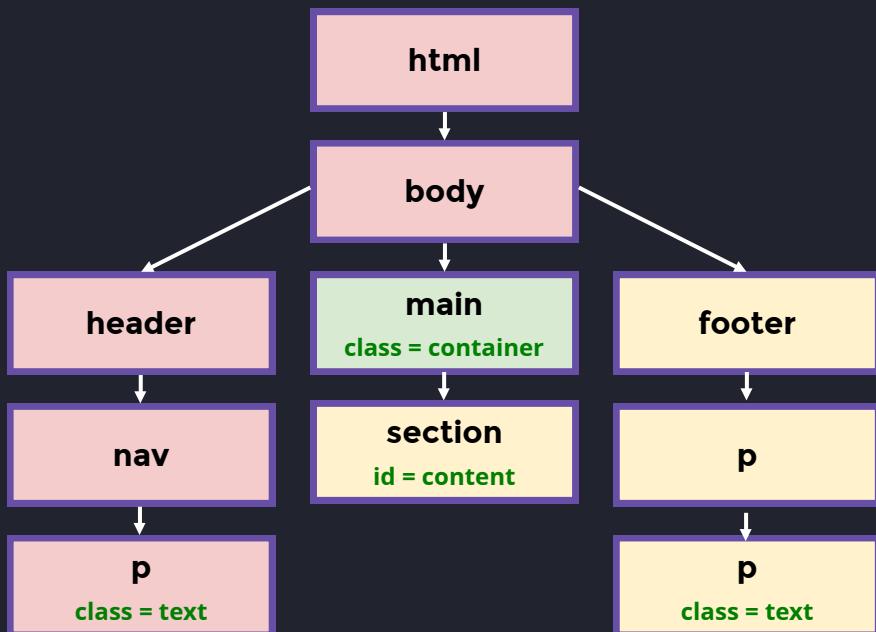
**Time Complexity:**  $O(N)$ \*

**Read Cost:**  $O(N)$ \*

**Memory Cost:** `Low`

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `querySelector`



`document.querySelector("main.container")`

**Return type:** `Element`

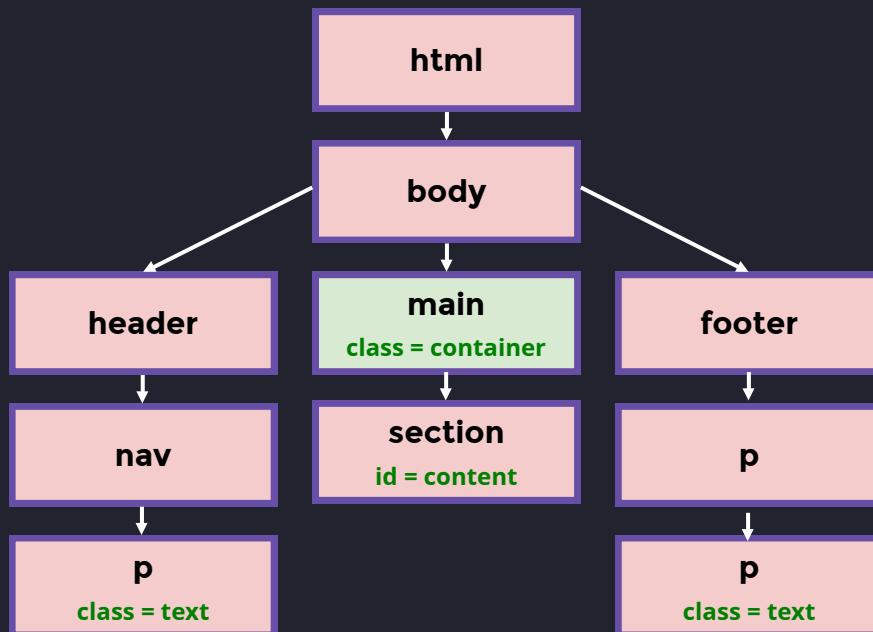
**Time Complexity:**  $O(1)/O(N)$  (depends on selector)

**Read Cost:**  $O(1)$

**Memory Cost:**  $O(1)$

**Query Algorithm:** `DFS + Hashmap`

# DOM Querying: `querySelectorAll`



`document.querySelectorAll("main.container")`

**Return type:** `NodeList`

**Time Complexity:**  $O(N)$  (depends on selector)

**Read Cost:**  $O(1)$

**Memory Cost:**  $O(N)$

**Query Algorithm:** `DFS + Hashmap`

# Performance overview

**getElementsByID** - provides the best performance in terms of time and space complexity. The browser builds an index table, allowing instant access to the element.

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**getELEMENTBYID** - **provides the best performance** in terms of time and space complexity. The browser builds an index table, allowing instant access to the element.

**getELEMENTSBYCLASSNAME, getELEMENTSBYTAGNAME** - provide low-memory overhead since the browser doesn't need to clone objects. Read access is high, although it's compensated by maintaining a live collection of elements.

# Performance overview

**getELEMENTBYID** - **provides the best performance** in terms of time and space complexity. The browser builds an index table, allowing instant access to the element.

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**querySELECTOR** - Offers slightly worse performance compared to **getELEMENTBYID**. However, due to caching and browser optimizations, it is comparable on repetitive runs.

# Performance overview

**getELEMENTBYID** - **provides the best performance** in terms of time and space complexity. The browser builds an index table, allowing instant access to the element.

**getELEMENTSBYCLASSNAME, getELEMENTSBYTAGNAME** - provide low-memory overhead since the browser doesn't need to clone objects. Read access is high, although it's compensated by maintaining a live collection of elements.

**querySELECTOR** - Offers slightly worse performance compared to **getELEMENTBYID**. However, due to caching and browser optimizations, it is comparable on repetitive runs.

**querySELECTORALL** - Potentially high-memory overhead. However, since it returns a non-live collection, read access is cheap.

# Performance best-practices

**Simplify Selector:** Complex selectors take time to compute, especially when querying a large set of elements. Simplify your selectors whenever possible.

```
div > div > section > .flex > .target  
#container.flex > .target.
```

# Performance best-practices

**Simplify Selector:** Complex selectors take time to compute, especially when querying a large set of elements. Simplify your selectors whenever possible.

```
div > div > section > .flex > .target  
#container.flex > .target.
```

**Use IDs of Core Containers:** Utilize IDs for core containers whenever feasible. IDs provide direct and efficient access to specific elements.

# Performance best-practices

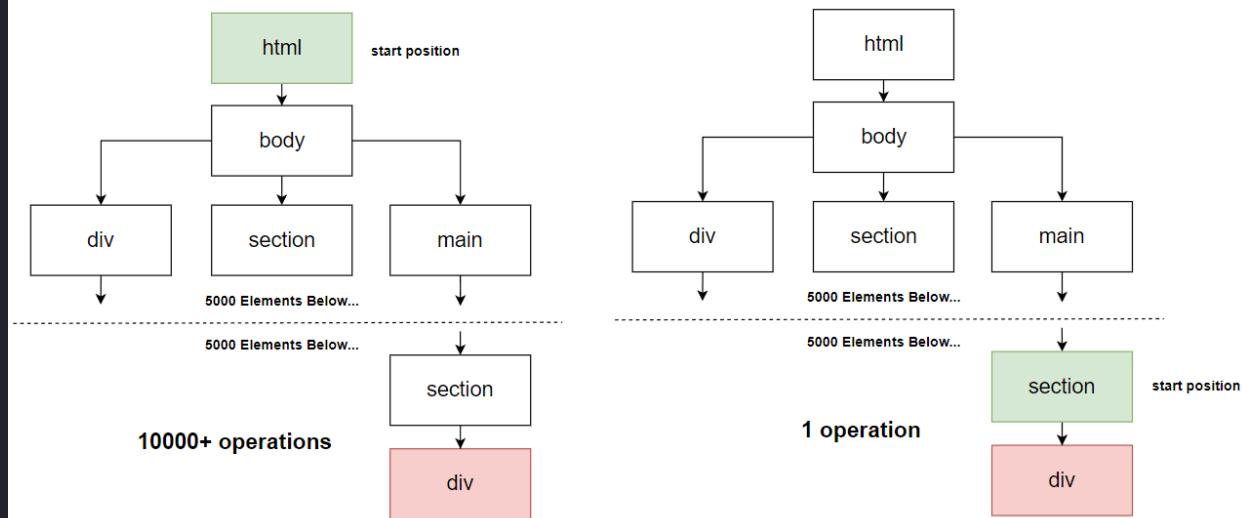
**Simplify Selector:** Complex selectors take time to compute, especially when querying a large set of elements. Simplify your selectors whenever possible.

`div > div > section > .flex > .target`  
`#container.flex > .target.`

**Use IDs of Core Containers:** Utilize IDs for core containers whenever feasible. IDs provide direct and efficient access to specific elements.

**Pick the Right Start Point:** Choose the most appropriate starting point for your queries. Starting from a closer ancestor to the desired elements can significantly improve query performance.

## Query Performance: Picking a right start position



# Adding / Removing elements

# Adding new elements

Method name	Perf Impact
<code>Element.prototype.innerHTML</code>	Extreme
<code>Element.prototype.insertAdjacentHTML(pos, html)</code>	Extreme
<code>Element.prototype.insertAdjacentElement(pos, html)</code>	High
<code>Element.prototype.appendChild(element)</code>	High

<https://codepen.io/RayEiji/embed/GRLjrQJ>

# Removing elements

```
const el = document.getElementById('node');
el.remove();
```

```
const el = document.getElementById('node');
el.innerHTML = "";
```

**Exercise time**

# Exercise time

```
1 const container = document.getElementById('container');
2
3
4 const html = `<article class="card">
5   <h3></h3>
6   <div class="card__body">
7     <div class='card__body__image'></div>
8     <section class='card__body__content'>
9       </section>
10    </div>
11  </article>`;
12
13
14 /**
15  * @param {string} title
16  * @param {string} body
17  *
18  * @return {HTMLElement}
19  */
20 function createCardComponent(title, body) {
21   // @todo - Implement function
22 }
23
24 const component = createCardComponent(
25   "Frontend System Design: Fundamentals",
26   "This is a random body text"
27 );
28
29 container.appendChild(component);
30
31
```

## Instruction

1. Checkout [repository](#)
2. Select branch - 1-dom-begin
3. Open folder - begin
4. Open file - **index.html**

# Exercise: Solution 1 (not-recommended)

```
1 const container = document.getElementById("container");
2 let card = ` 
3   <article class="card">
4     <h3>_title_</h3>
5     <div class="card__body">
6       <div class='card__body__image'></div>
7       <section class='card__body__content'>
8         _content_
9         </section>
10      </div>
11    </article>
12 ` .trim();
13
14 card = card
15   .replace("_title_", "Frontend System Design Fundamentals")
16   .replace("_content_", "This is a random text");
17
18 container.innerHTML = card;
```

# DocumentFragment

```
<template id="card_template">
  <article class="card">
    <h3></h3>
    <div class="card__body">
      <div class='card__body__image'></div>
      <section class='card__body__content'>
        </section>
    </div>
  </article>
</template>
```

1. **DocumentFragment** is a lightweight in-memory **HTMLElement** representation
2. Modifying it's content doesn't cause a **reflow**
3. It can be reused **many times**
4. It's **isolated** from the main **DOM Tree**
5. You can utilize HTML to create markup of component

# Exercise: Solution 2

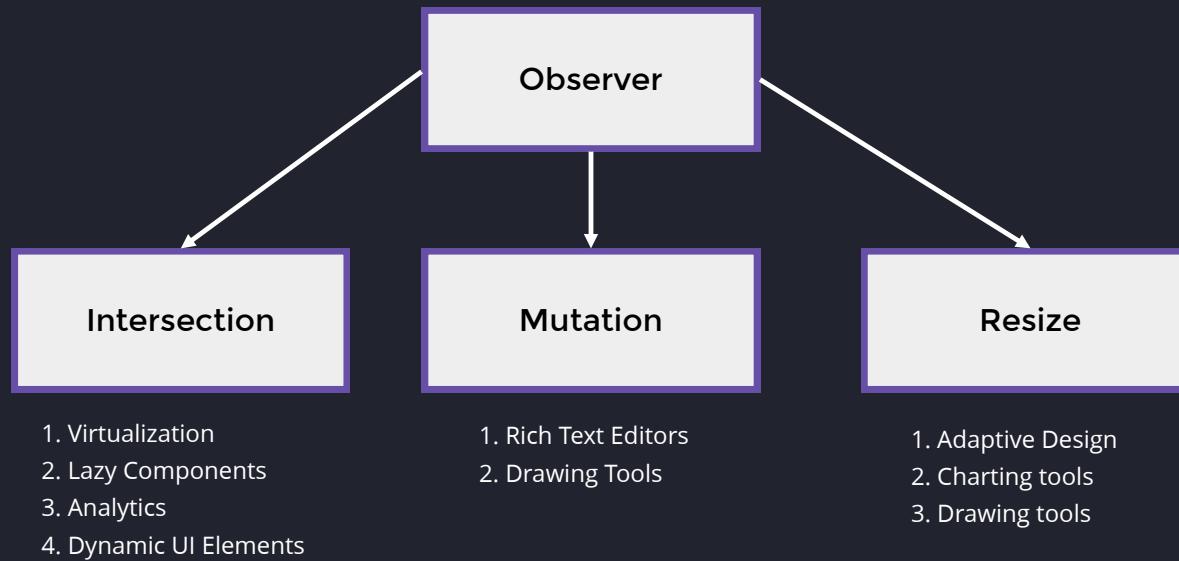
```
<template id="card_template">
<article class="card">
  <h3></h3>
  <div class="card_body">
    <div class='card_body_image'></div>
    <section class='card_body_content'>
    </section>
  </div>
</article>
</template>
```

```
1 const container = document.getElementById('container');
2
3 function createCardElement(title, body) {
4   const template = document.getElementById('card_template');
5   const element = template.content.cloneNode(true).firstElementChild;
6   const cardTitle = element.querySelector("h3");
7   const cardBody = element.querySelector("section");
8   [cardTitle.textContent, cardBody.textContent] = [title, body];
9   return element;
10 }
11
12 container.appendChild(
13   createCardElement(
14     "Frontend System Design: Fundamentals",
15     "This is a random content"
16   ));
17
```

# Summary: DOM API

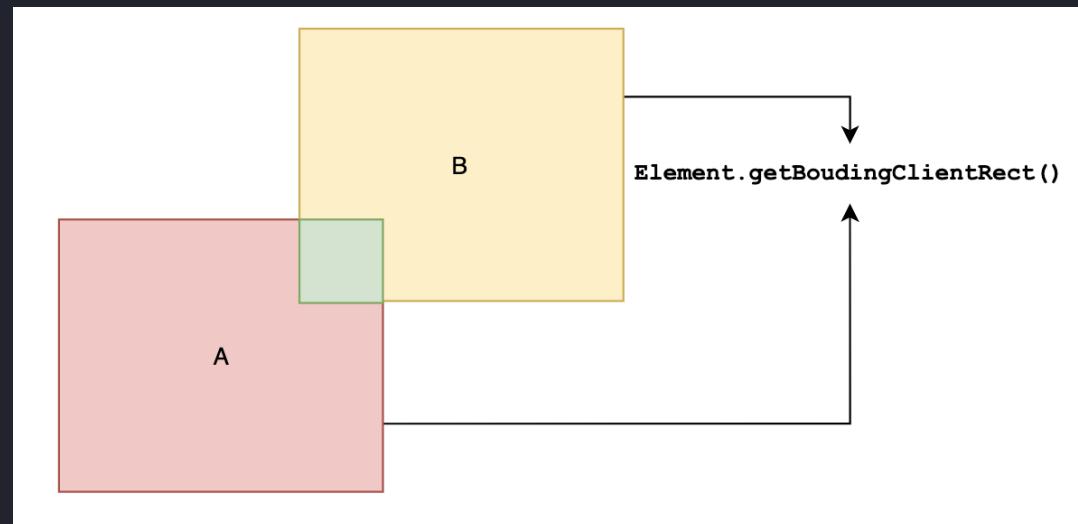
# Observer API

# Observer API



# Intersection Observer: vanilla approach

```
1 const A = document.getElementById('A');
2 const B = document.getElementById('B');
3
4 setInterval(() => {
5   const rectA = A.getBoundingClientRect();
6   const rectB = B.getBoundingClientRect();
7   const isIntersection = rectA.bottom > rectB.top
8             && rectA.right > rectB.left
9             && rectA.top < rectB.bottom
10            && rectA.left < rectB.right;
11   if(isIntersection) {
12     // do stuff
13   }
14 }, 50);
```



# Intersection Observer

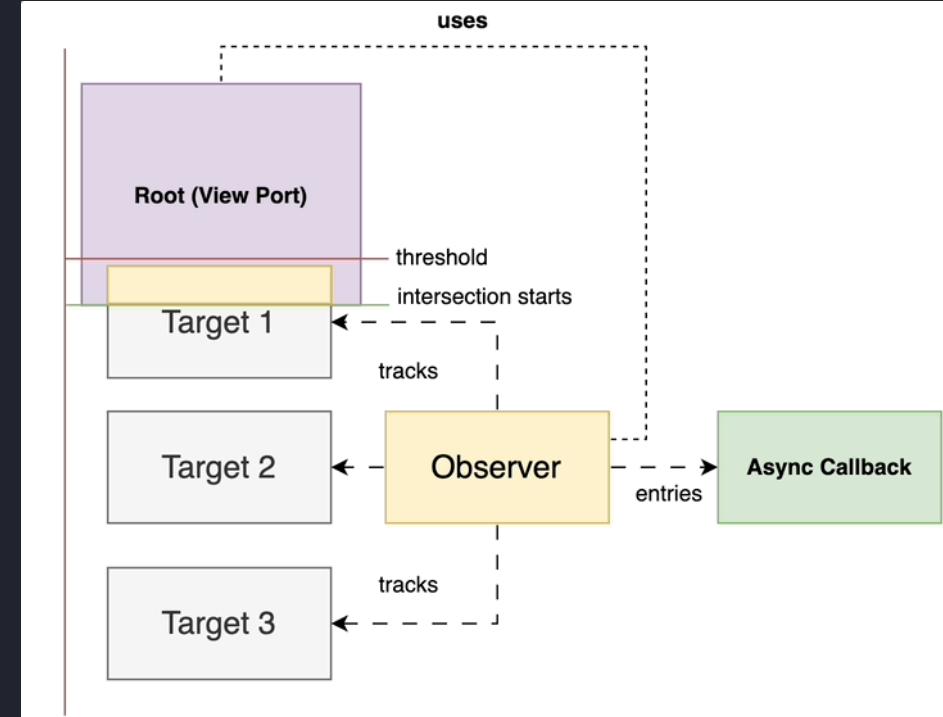
**target:** element we're tracking

**config:**

    -> **root**       the “**window**” that we check the intersection against

    -> **threshold**   the minimal intersection ratio that is required to trigger the callback

    -> **callback**     function to execute on intersection



# Intersection Observer: Creation

```
1 const callback = () => {};
2 const observer = new IntersectionObserver(
3   callback,
4   {
5     root: document.getElementById("container"),
6     threshold: 0.1
7   }
8 );
```

## config:

- root** the “**window**” that we check the intersection against
- threshold** the minimal intersection ratio that is required to trigger the callback
- callback** function to execute on intersection

# Intersection Observer: Creation

```
1 const callback = () => {};
2 const observer = new IntersectionObserver(
3   callback,
4   {
5     root: document.getElementById("container"),
6     threshold: 0.1
7   }
8 ).
```

```
1 const callback = (entries, observer) => {
2   entries.forEach(entry => {
3     if(entry.isIntersecting) {
4       // logic is here
5     }
6   });
7 }.
```

## config:

- root** the “**window**” that we check the intersection against
- threshold** the minimal intersection ratio that is required to trigger the callback
- callback** function to execute on intersection

## callback:

- IntersectionObserverEntry[]** - array of entries that were triggered. Entry may intersect or may stop intersecting with object, so it's important to check **isIntersecting** property
- observer** - instance of Observer

# Intersection Observer: Creation

```
1 const callback = () => {};
2 const observer = new IntersectionObserver(
3   callback,
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8 ).
```

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- root** the "window" that we check the intersection against
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```
1 const callback = (entries, observer) => {
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5     }
6   });
7 }.
```

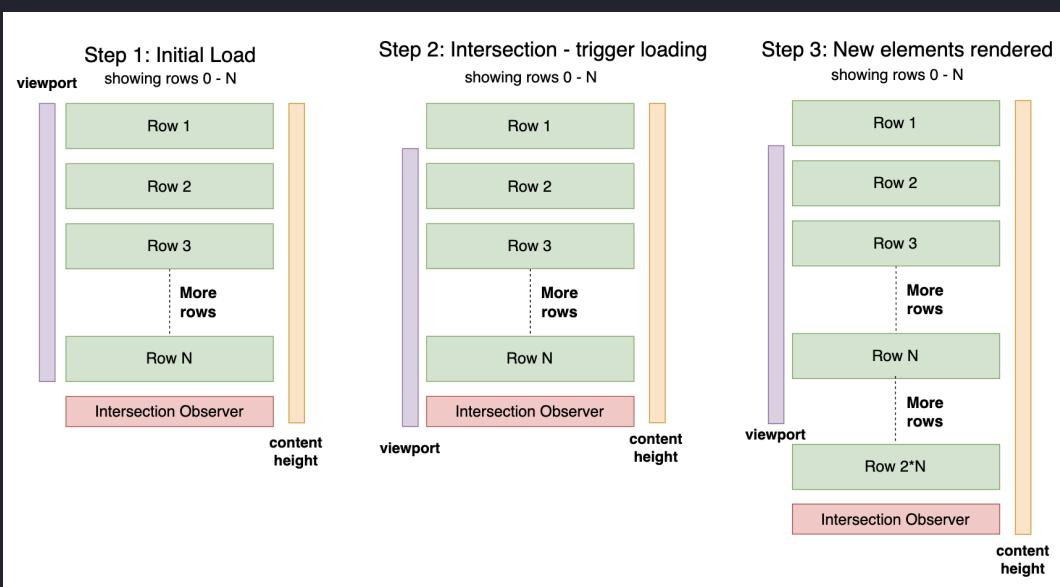
## callback:

- IntersectionObserverEntry[]** - array of entries that were triggered. Entry may intersect or may stop intersecting with object, so it's important to check **isIntersecting** property

**observer** - instance of Observer

```
1 observer.observe(
2   document.getElementById('target');
3 )
```

# Exercise Time: Intersection Observer



<https://codepen.io/RayEuji/embed/wvZJvKN>

Branch name: 2-intersection-observer-begin

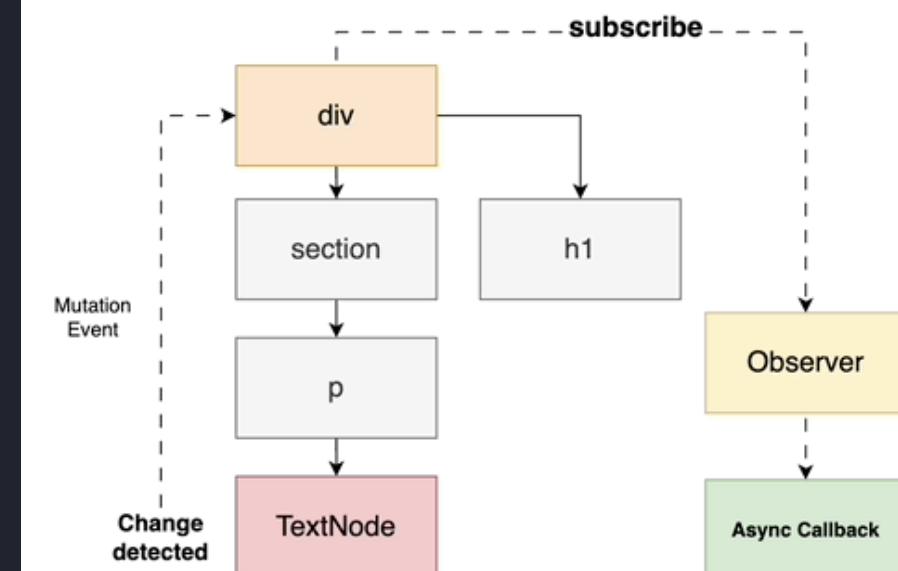
# Solution: Intersection Observer

```
1 let page = 0;
2 const observer = new IntersectionObserver(async ([entry]) => {
3   if(entry.isIntersecting) {
4     const data = await db.getPage(page++);
5     const fragment = new DocumentFragment();
6     for (const datum of data) {
7       const card = createCardElement(datum.title, datum.body)
8       fragment.appendChild(card);
9     }
10    list.appendChild(fragment);
11  }
12 }, { threshold: 0.2 })
13
14 observer.observe(observerElement);
```

<https://codepen.io/RayEiji/embed/wvZjvKN>

# Mutation Observer

```
function callback (mutations) {}  
  
let observer = new MutationObserver(callback);  
  
observer.observe(targetNode, observerOptions);
```



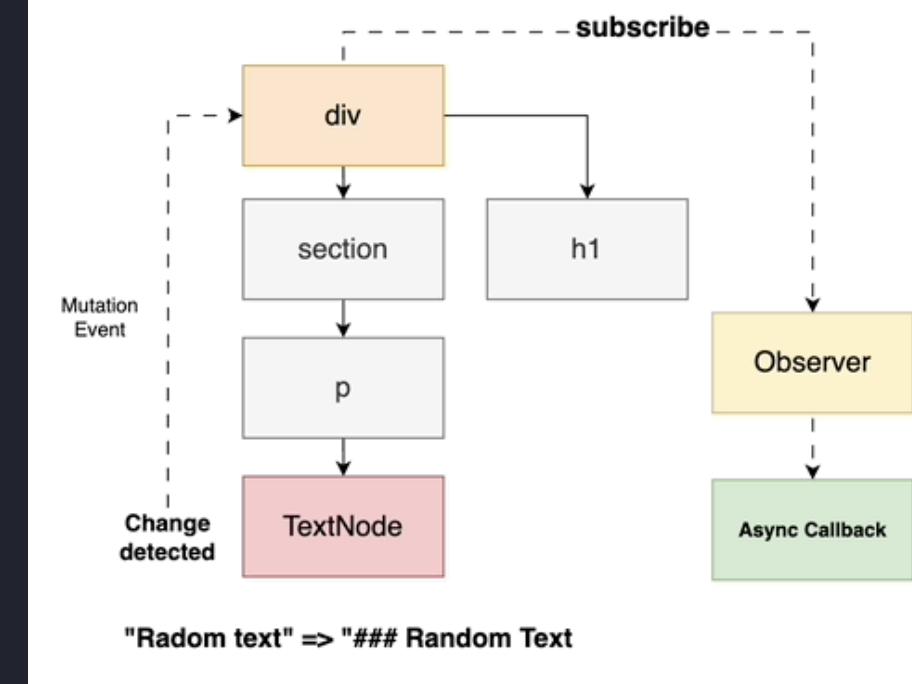
# Mutation Observer

```
function callback (mutations) {}

let observer = new MutationObserver(callback);

observer.observe(targetNode, observerOptions);
```

```
const observerOptions = {
  childList: false,          // changes in the direct children of node
  attributes: false,         // changes in element attributes
  characterData: true,       // changes in textContent of the Element
  subtree: false,             // changes in any descendants
  attributeFilter: ['one', 'two'], // attributes array to observe
```



# Mutation Observer

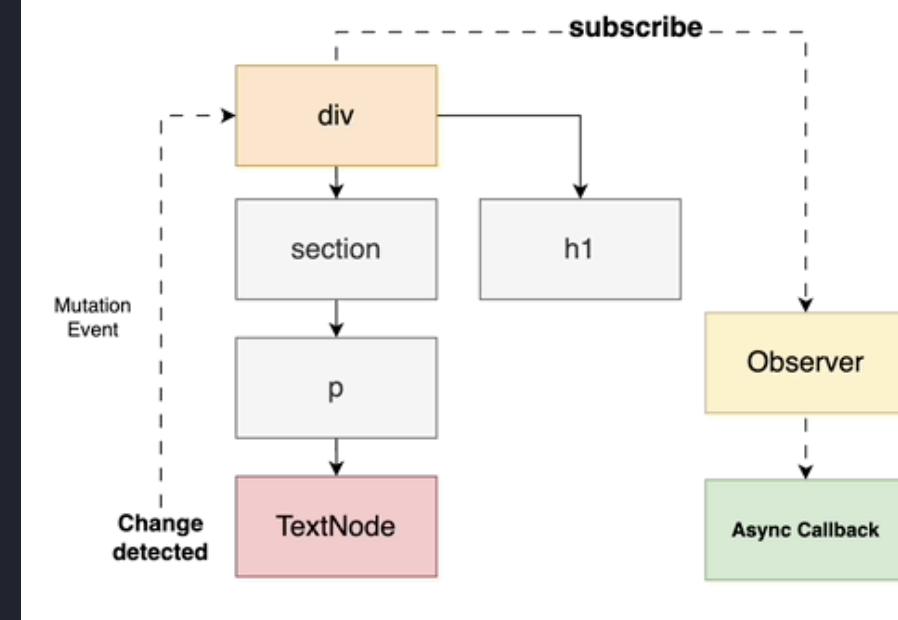
```
function callback (mutations) {}

let observer = new MutationObserver(callback);

observer.observe(targetNode, observerOptions);
```

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const observerOptions = {
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  characterData: true,       // changes in.textContent of the Element
  subtree: false,            // changes in any descendants
  attributeFilter: ['one', 'two'], // attributes array to observe
```

```
type MutationRecord ={
  type: "attributes"
  | "characterData"
  | "childList";           // What to track
  target: Node;            // Which object to track
  addedNodes: NodeList;    // Nodes that were added with mutation
  removedNodes: NodeList; // Nodes that were added with mutation
  oldValue: ?string;        // Previous value
  ,
```



# Mutation Observer

```
function callback (mutations) {}

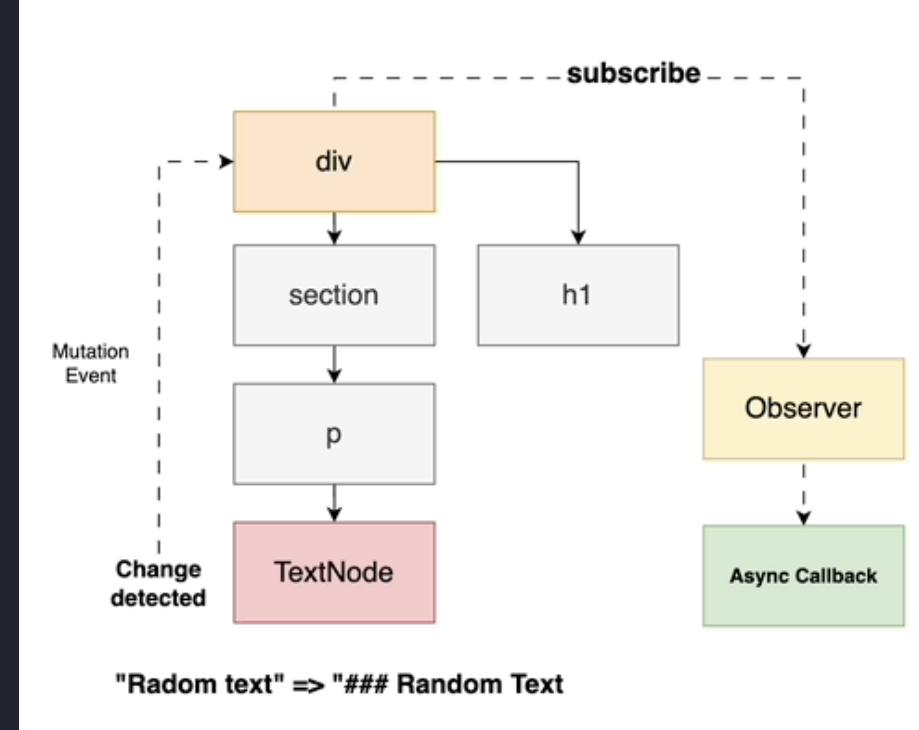
let observer = new MutationObserver(callback);

observer.observe(targetNode, observerOptions);
```

```
const observerOptions = {
  childList: false,          // changes in the direct children of node
  attributes: false,         // changes in element attributes
  characterData: true,       // changes in.textContent of the Element
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  attributeFilter: ['one', 'two'], // attributes array to observe
```

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type MutationRecord ={
  type: "attributes"
  | "characterData"
  | "childList";           // What to track
  target: Node;            // Which object to track
  addedNodes: NodeList;    // Nodes that were added with mutation
  removedNodes: NodeList; // Nodes that were added with mutation
  oldValue: ?string;        // Previous value
  ,
```

```
function callback (mutations) {
  for(let mutation of mutations) {
    if(mutation.type === 'characterData') {
      // Your logic
    }
  }
}
```



# Exercise time: Mutation Observer

1. Add `contenteditable` attribute to `section` with class `card__body__content`
2. Create `MutationObserver` with the following parameters that would allow us to track text changes in `TextNodes`:
  1. `characterData: true`
  2. `subtree: true`
3. Implement callback for `MutationObserver`
4. Observer text section for each card
5. Use single observer for all rendered cards

<https://codepen.io/RayEiji/embed/ExJWaEO>

Branch name: 3-mutation-observer-start

# Solution: Mutation Observer

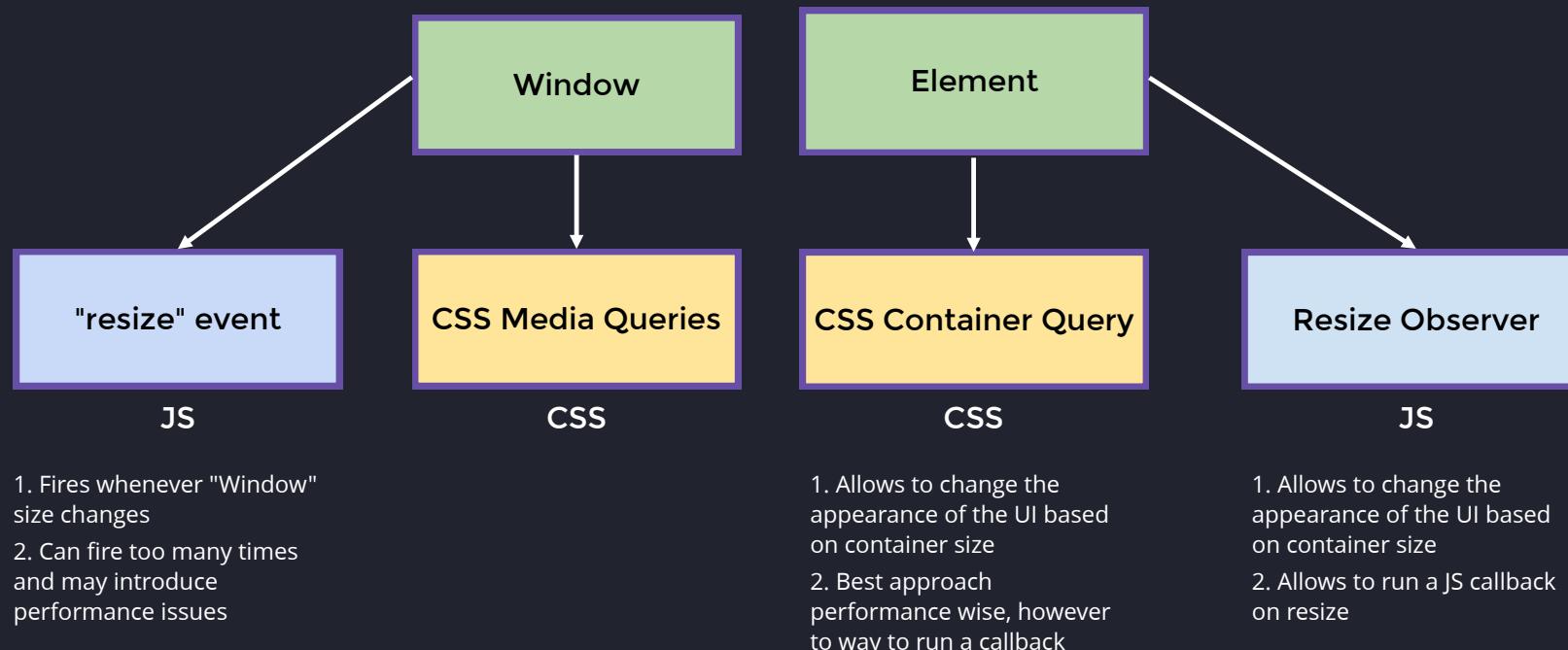
```
1 const mutationObserver = new MutationObserver((mutations) => {
2     for (const {target, type} of mutations) {
3         if (
4             type === 'characterData' &&
5             SUPPORTED_ELEMENTS.has(target?.textContent)
6         ) {
7             const element = getHeading(target);
8             target.replaceWith(element);
9             element.focus();
10        }
11    }
12 })
```

<https://codepen.io/RayEiji/embed/ExJWaEO>

**Branch name: 3-mutation-observer-end**

# Resize Observer

# How to track resize of elements



# When to use each

	Performance	Callback	Element tracking	When to use
CSS Media Queries	Super Fast ✓	✗	✗	General adaptive layout cases when there is no need to run any JS Code due to main <a href="#">Window resize</a>
CSS Container Query	Super Fast ✓	✗	✓	Combine with CSS Media Queries for general adaptive layout cases when running JavaScript code is unnecessary.
"resize" event	Potentially Slow ✗	✓	✗ (window only)	<b>Use with caution:</b> If <a href="#">ResizeObserver</a> is not supported and you need to run logic when the main window size changes, be wary.
Resize Observer	Fast ✓ (10x faster than resize)	✓	✓	Combine with <a href="#">CSS Media Queries</a> for general adaptive layout cases when running JavaScript code is unnecessary.

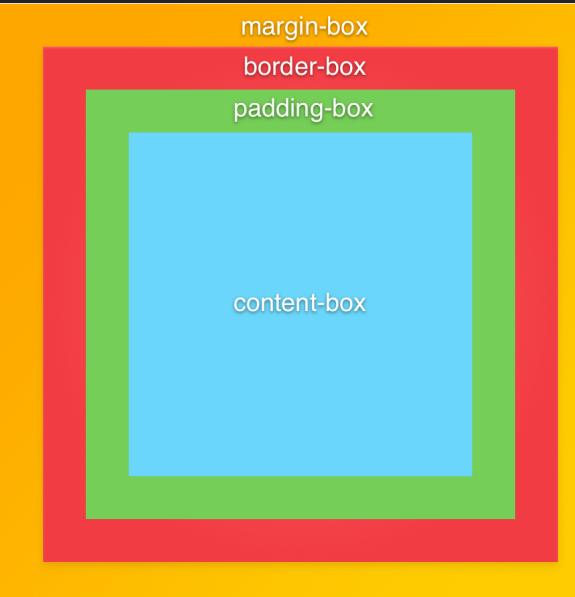
# ResizeObserver API

```
const callback = () => {};
const observer = new ResizeObserver(callback);
```

# ResizeObserver API

```
const callback = () => {};
const observer = new ResizeObserver(callback);
```

```
const observerOptions = {
  box: 'content-box' | // Size of the content area as defined in CSS
    'border-box' // Size of the border area as defined in CSS
};
observer.observe(
  document.body,
  { box: 'border-box' }
```

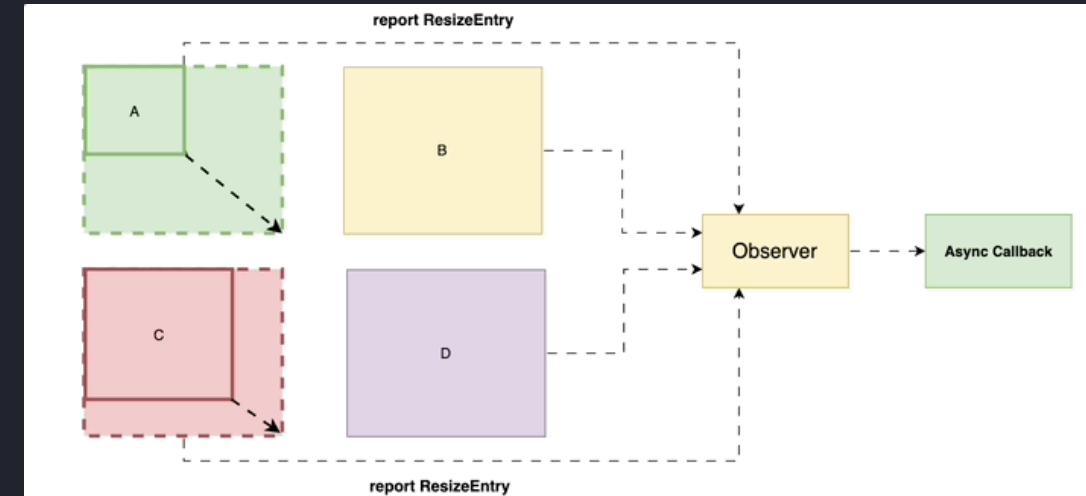
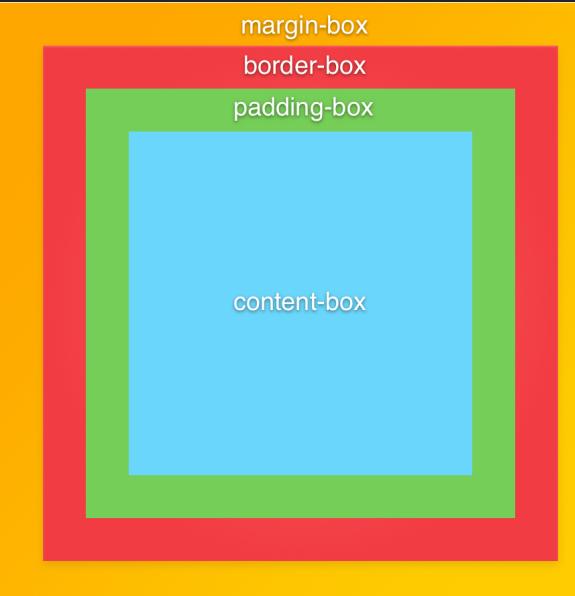


# ResizeObserver API

```
const callback = () => {};
const observer = new ResizeObserver(callback);
```

```
const observerOptions = {
  box: 'content-box' // Size of the content area as defined in CSS
  'border-box' // Size of the border area as defined in CSS
};
observer.observe(
  document.body,
  { box: 'border-box' }  
`
```

```
type ResizeObserverEntry = {
  borderBoxSize: Array<Box>;
  contentBoxSize: Array<Box>;
  contentRect: DOMRectReadOnly;
  target: Element;
```



# ResizeObserver API

```
const callback = () => {};
const observer = new ResizeObserver(callback);
```

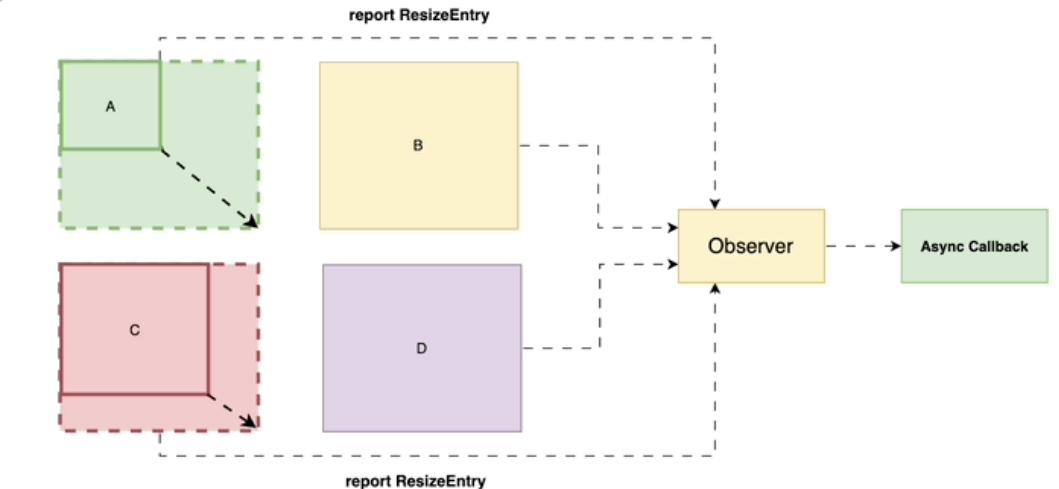
```
const observerOptions = {
  box: 'content-box' // Size of the content area as defined in CSS
  'border-box' // Size of the border area as defined in CSS
};
observer.observe(
  document.body,
  { box: 'border-box' }  
`
```

```
type ResizeObserverEntry = {
  borderBoxSize: Array<Box>;
  contentBoxSize: Array<Box>;
  contentRect: DOMRectReadOnly;
  target: Element;
```

```
const callback = (entries) => {
  for (const entry of entries) {
    const [width, height] = [
      entry.borderBoxSize[0].inlineSize,
      entry.borderBoxSize[0].blockSize
    ];
    // do stuff
  }
};
```

margin-box  
border-box  
padding-box

content-box



# Exercise time: ResizeObserver

1. You're given 4 resizable boxes - A, B, C, D
2. Create `ResizeObserver` so each box becomes a circle when `width` and height of the box is less than `150px`

```
1 <main id="container">
2   <div class="box">
3     A
4   </div>
5   <div class="box">
6     B
7   </div>
8   <div class="box">
9     C
10  </div>
11  <div class="box">
12    D
13  </div>
14 </main>
```

<https://codepen.io/RayEiji/embed/QWPprNE>

Branch-name: **4-resize-observer-start**

# Solution: ResizeObserver

```
1 const observer = new ResizeObserver((entries) => {
2     for(let entry of entries) {
3         const {
4             borderBoxSize: [
5                 {
6                     inlineSize, blockSize
7                 }
8             ],
9             target
10        } = entry;
11        if(inlineSize < 150 && blockSize < 150) {
12            target.style.borderRadius = "100%";
13            target.style.borderWidth = "4px"
14        } else {
15            target.style.borderRadius = "unset";
16            target.style.borderWidth = "unset"
17        }
18    }
19 })
20 const elements = document.querySelectorAll('.box');
21 elements.forEach(el => observer.observe(el));
```

<https://codepen.io/RayEuji/embed/QWPprNE>

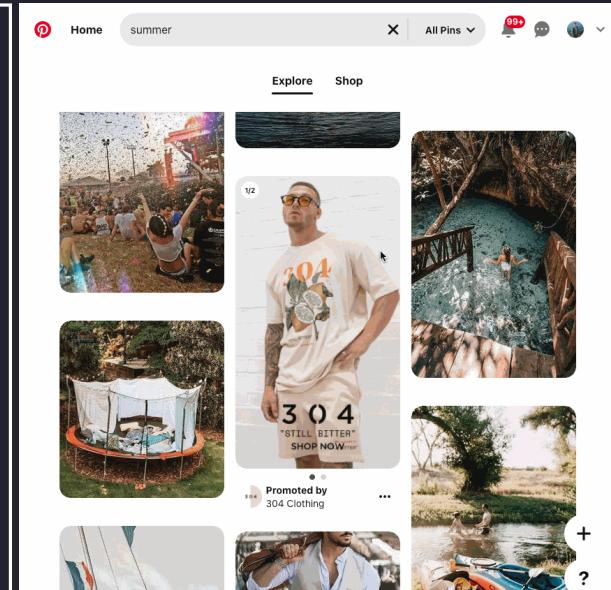
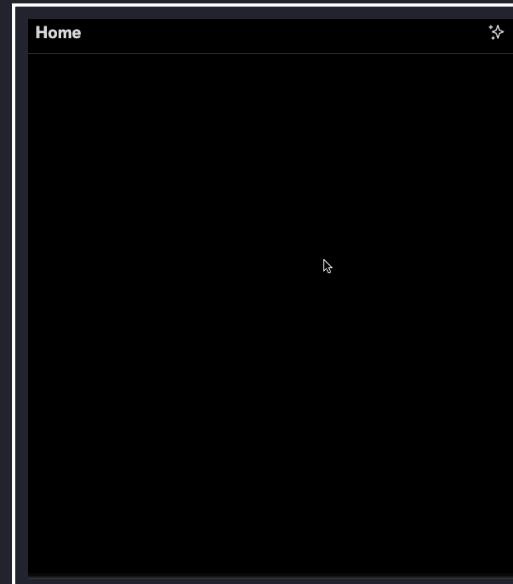
## Summary: Observer API

# Virtualisation

**Virtualization** is a **UI optimization technique** that involves maintaining a data in memory while rendering only a limited subset, often referred to as a '**sliding window**'

## Goals of the pattern:

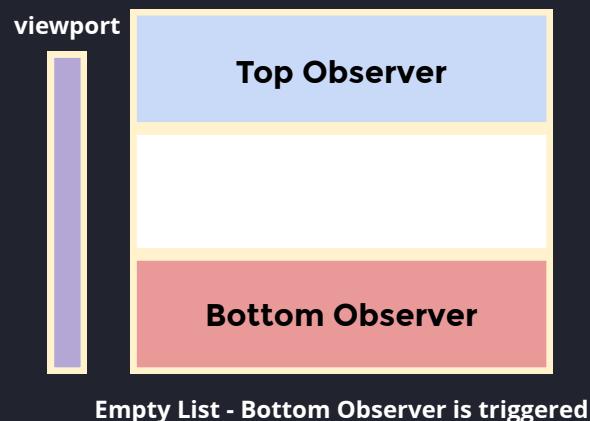
1. Minimize number of elements rendered in the DOM Tree
2. Minimize number of DOM Mutations
3. Minimize CPU & Memory usage that is required to maintain a DOM Tree



# Virtualisation: High-level overview

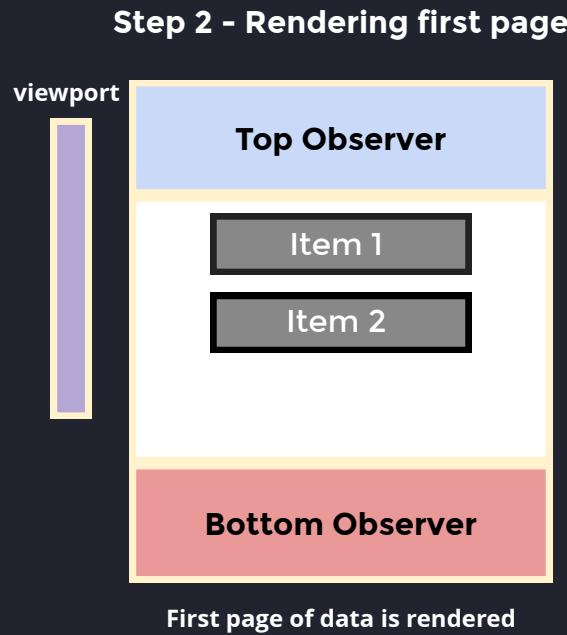
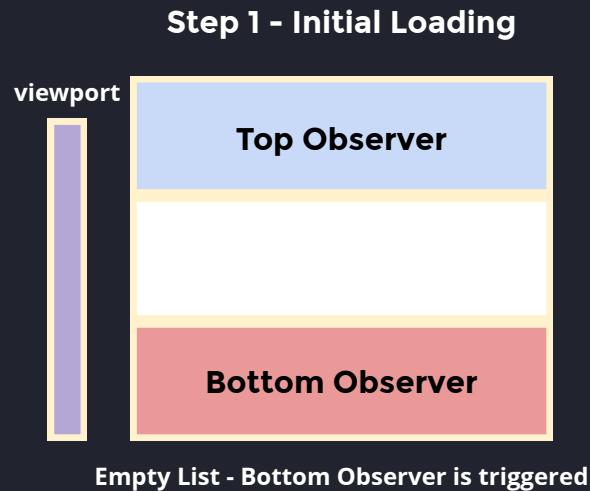
## Pool Initiation Phase

### Step 1 - Initial Loading



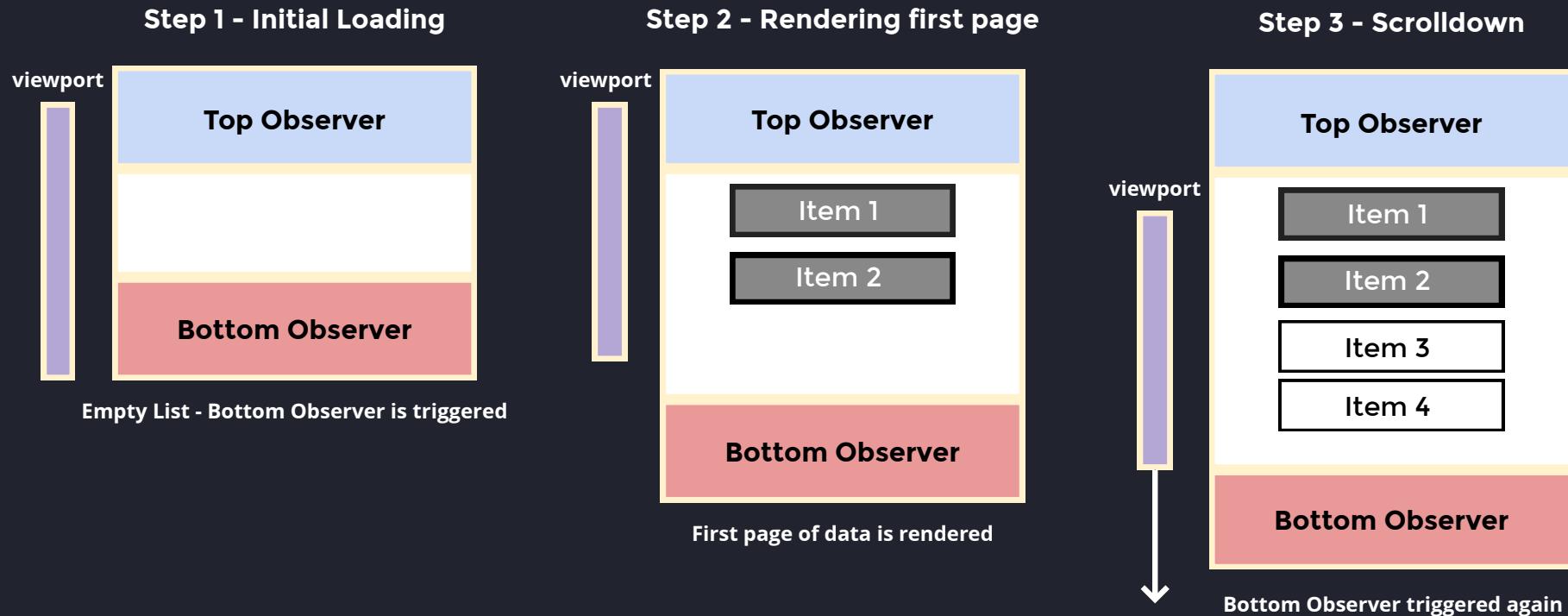
# Virtualisation: High-level overview

## Pool Initiation Phase



# Virtualisation: High-level overview

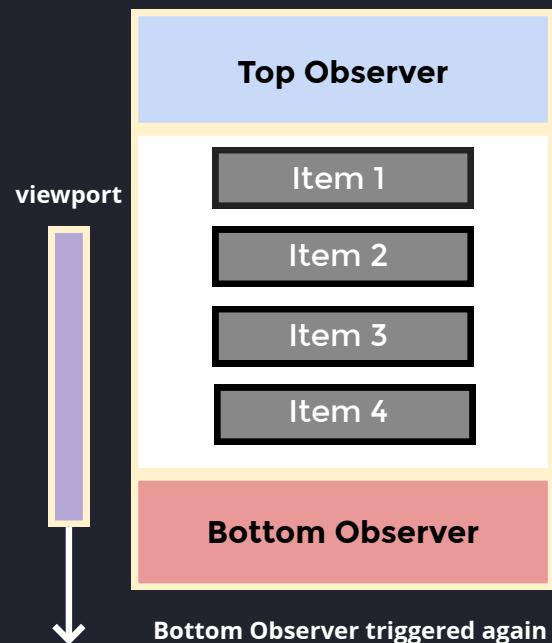
## Pool Initiation Phase



# Virtualisation: High-level overview

Recycling Phase

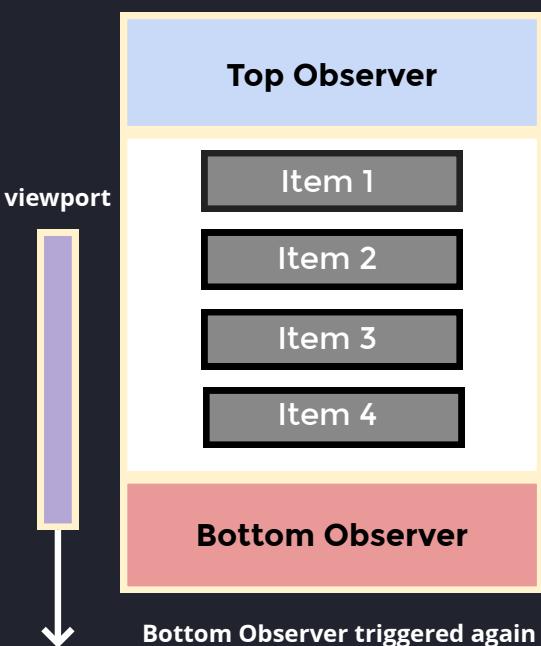
## Step 4 - Scrolldown



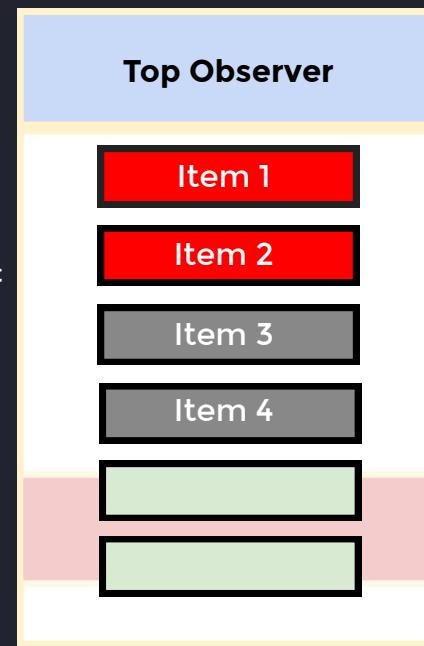
# Virtualisation: High-level overview

## Recycling Phase

Step 4 - Scrolldown



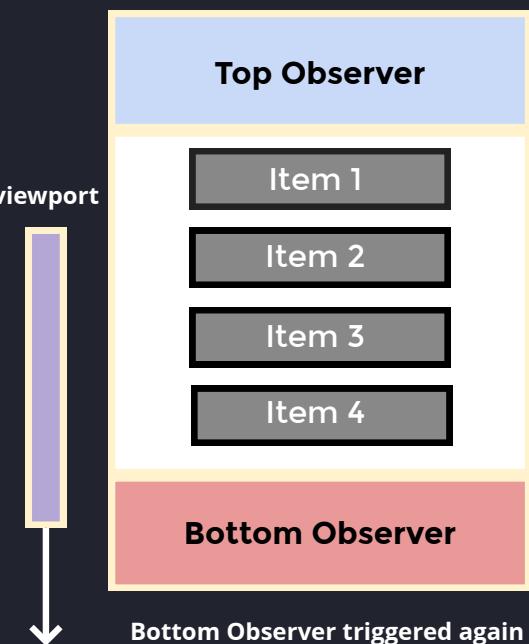
Step 5 - Selecting Elements to recycle



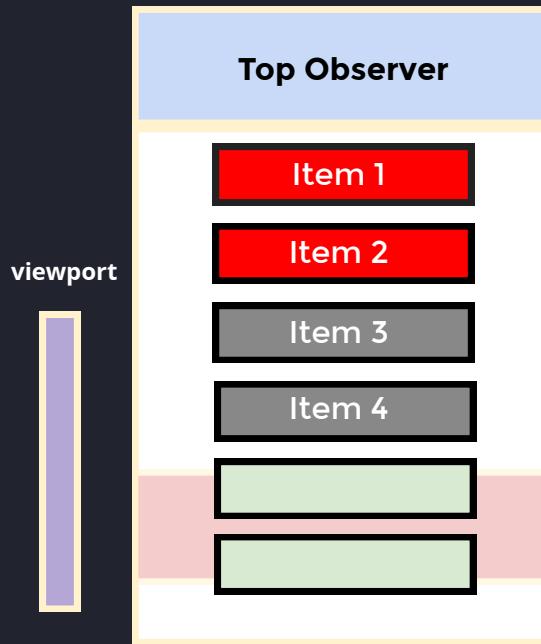
# Virtualisation: High-level overview

## Recycling Phase

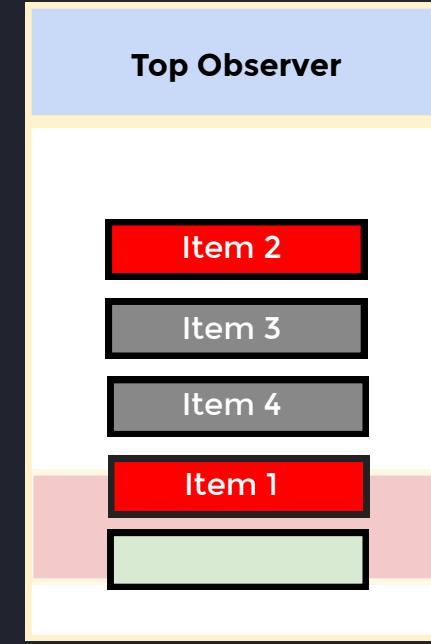
Step 4 - Scrolldown



Step 5 - Selecting Elements to recycle



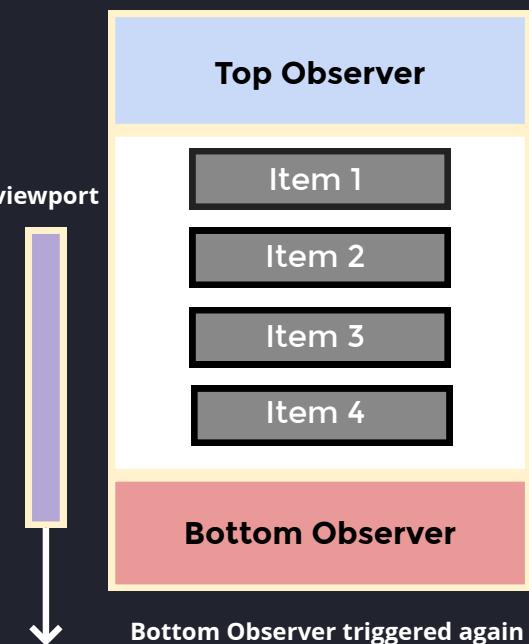
Step 6 - Recycling Item 1



# Virtualisation: High-level overview

## Recycling Phase

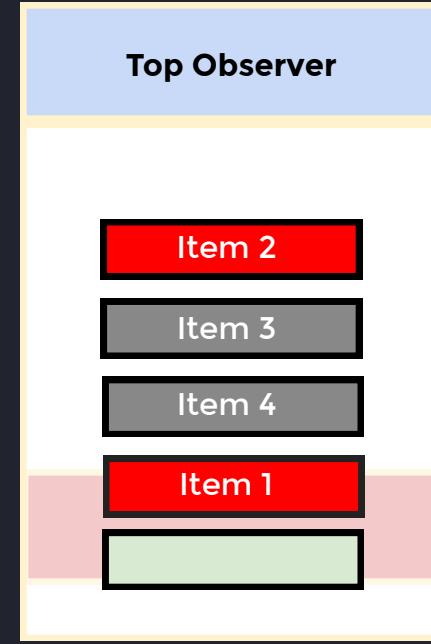
Step 4 - Scrolldown



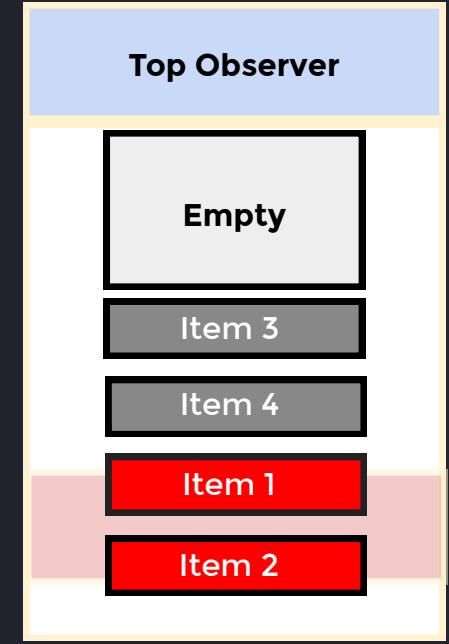
Step 5 - Selecting Elements to recycle



Step 6 - Recycling Item 1



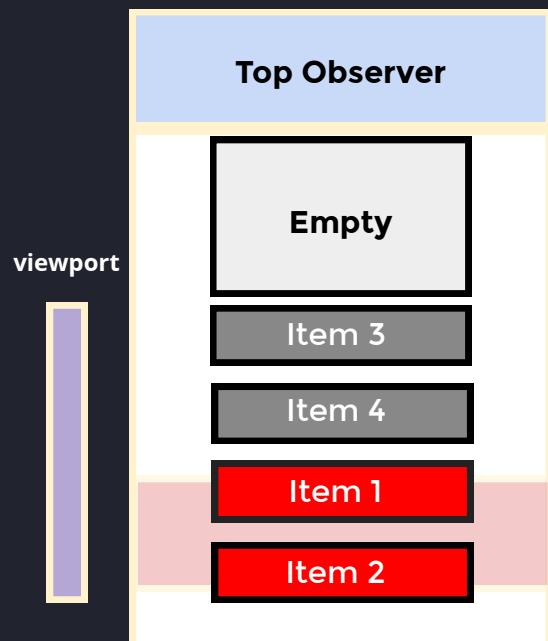
Step 6 - Recycling Item 2



# Virtualisation: High-level overview

Update Phase

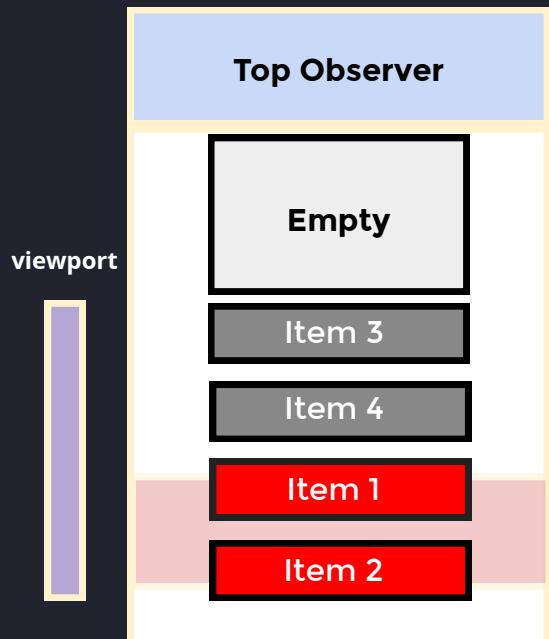
Step 6 - Recycling finished



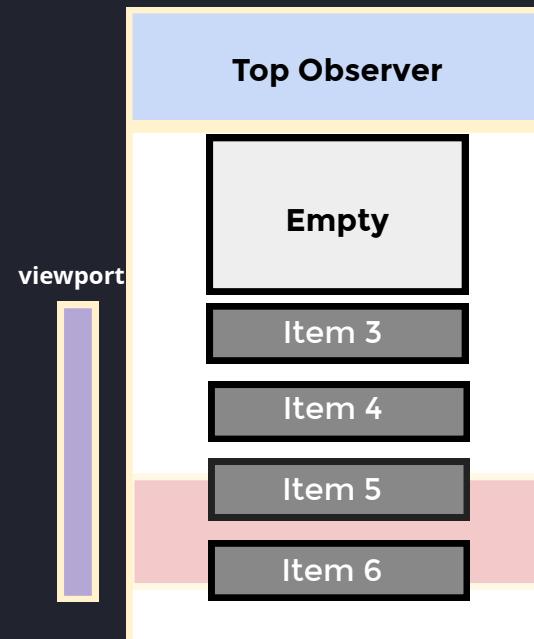
# Virtualisation: High-level overview

## Update Phase

Step 6 - Recycling finished



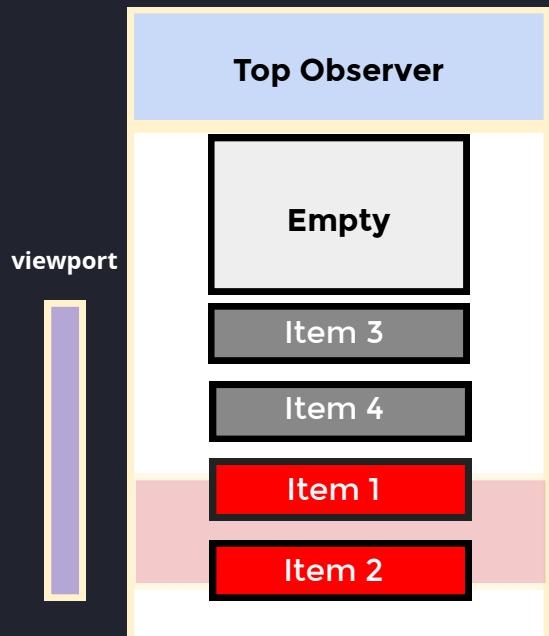
Step 7 - Update the data



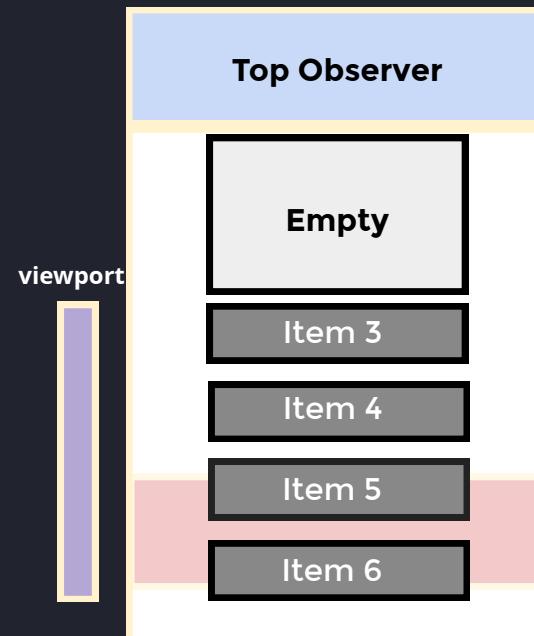
# Virtualisation: High-level overview

## Update Phase

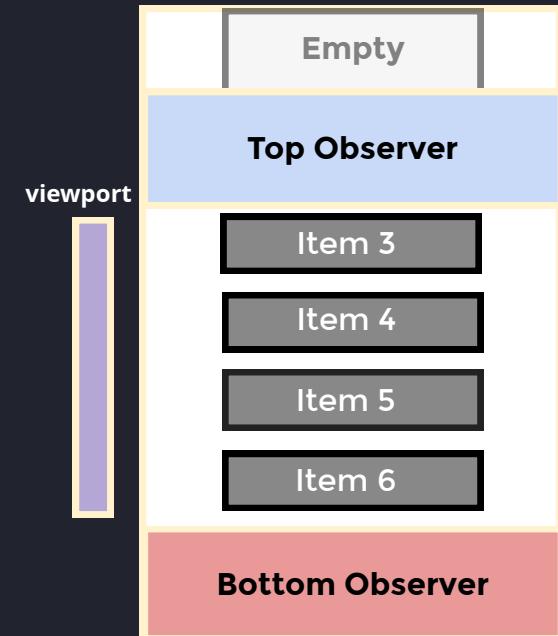
Step 6 - Recycling finished



Step 7 - Update the data



Step 8 - Update Observers position



# Virtualisation: Live Coding



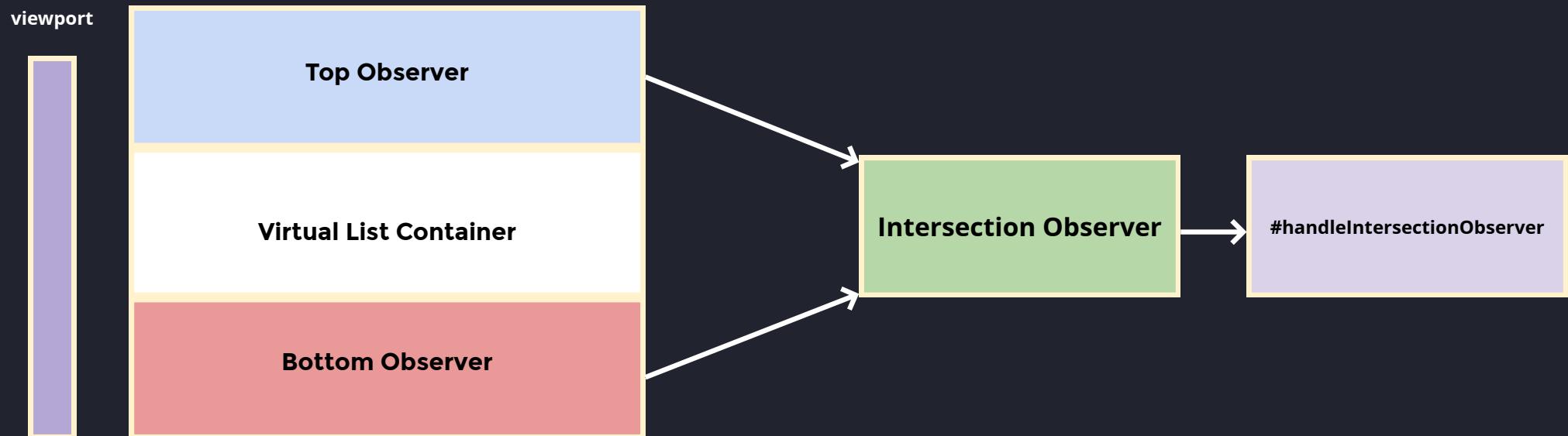
1. Check-out the branch - **5.1-virtualization-skeleton-start**
2. Open a filename - **5-virtualisation/5-1-skeleton/begin/virtual-list.js**
3. Repo url: **<https://shorturl.at/Hc6p0>**

```
Branch
5-1-virtualisation-skeleton-end
5-1-virtualisation-skeleton-start
5-6-scroll-preservation-end
5-6-scroll-preservation-begin
5-5-top-observer-end
5-5-top-observer-begin
5-4-2-elements-pool-and-recycling-rendering-end
5-4-2-elements-pool-and-recycling-rendering-start
5-4-1-elements-pool-and-recycling-preparation-end
5-4-1-elements-pool-and-recycling-preparation-begin
5-3-property-model-and-loading-end
5-3-property-model-and-loading-begin
5-2-observer-handling-end
5-2-observer-handling-start
```

# Virtualisation: Live Coding

Part 1 and 2: Skeleton

## Step 1 - Skeleton



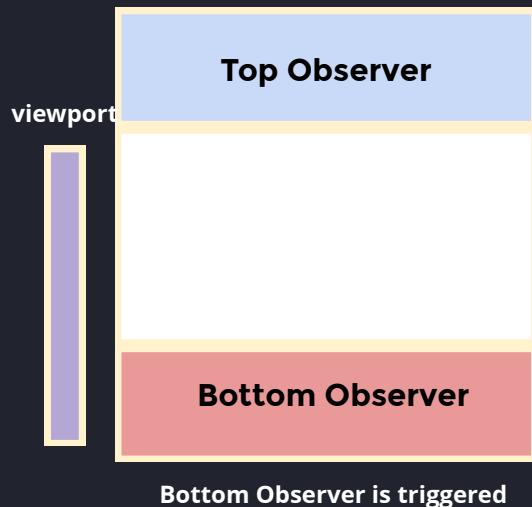
Solution: 5.1-virtualization-skeleton-end

Solution: 5.2-observer-handling-end

# Virtualisation: Live Coding

Part 3: Loading data and filling up the pool

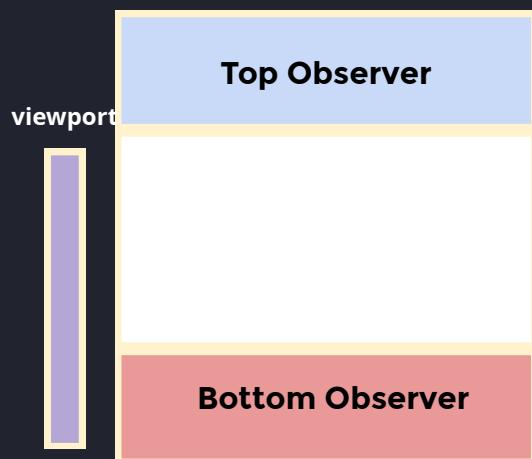
Step 3 - Scrolldown - Load new data



# Virtualisation: Live Coding

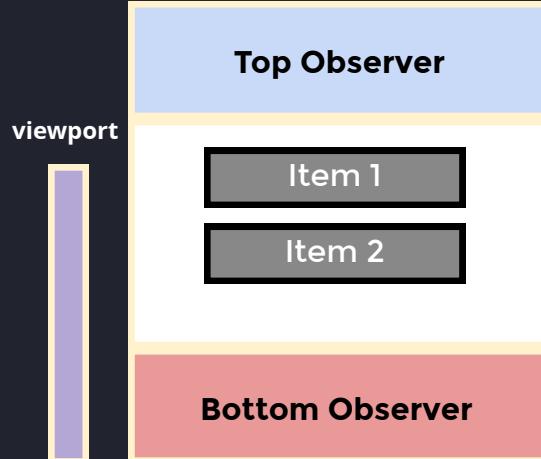
Part 3: Loading data and filling up the pool

Step 3 - Scrolldown - Load new data



Bottom Observer is triggered

Step 4 - Load more data



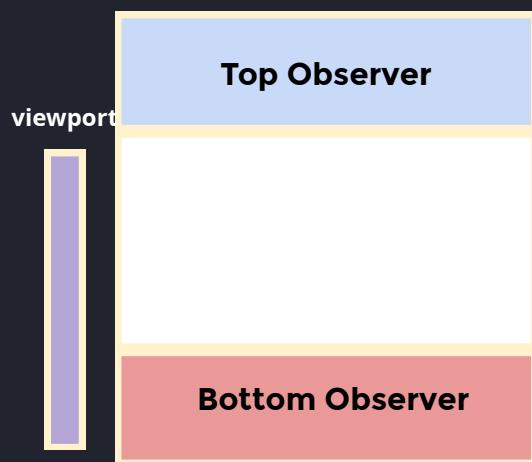
Bottom Observer triggered again



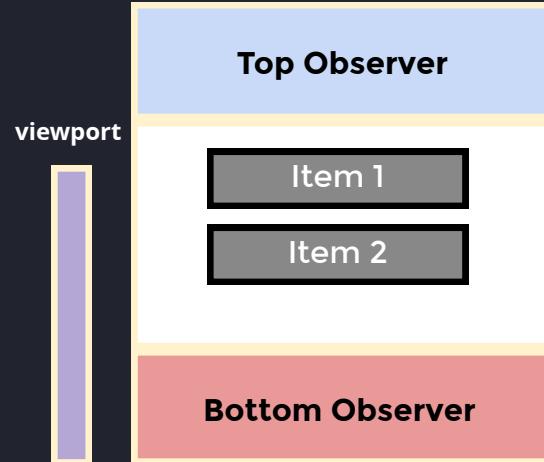
# Virtualisation: Live Coding

Part 3: Loading data and filling up the pool

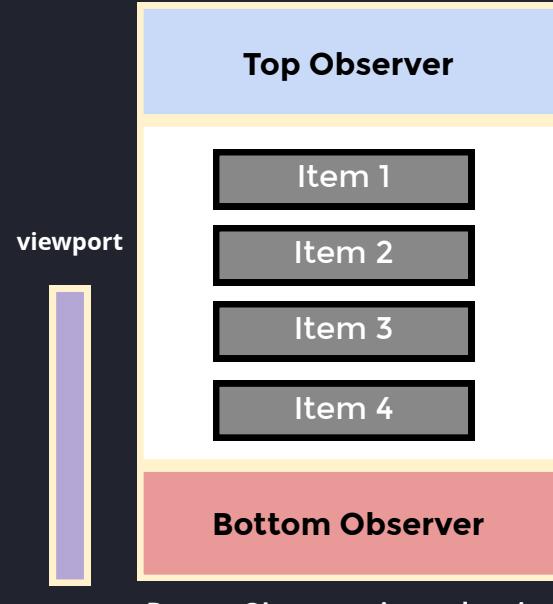
Step 3 - Scrolldown - Load new data



Step 4 - Load more data



Step 5 - Load more data



start

Page 1

end

start

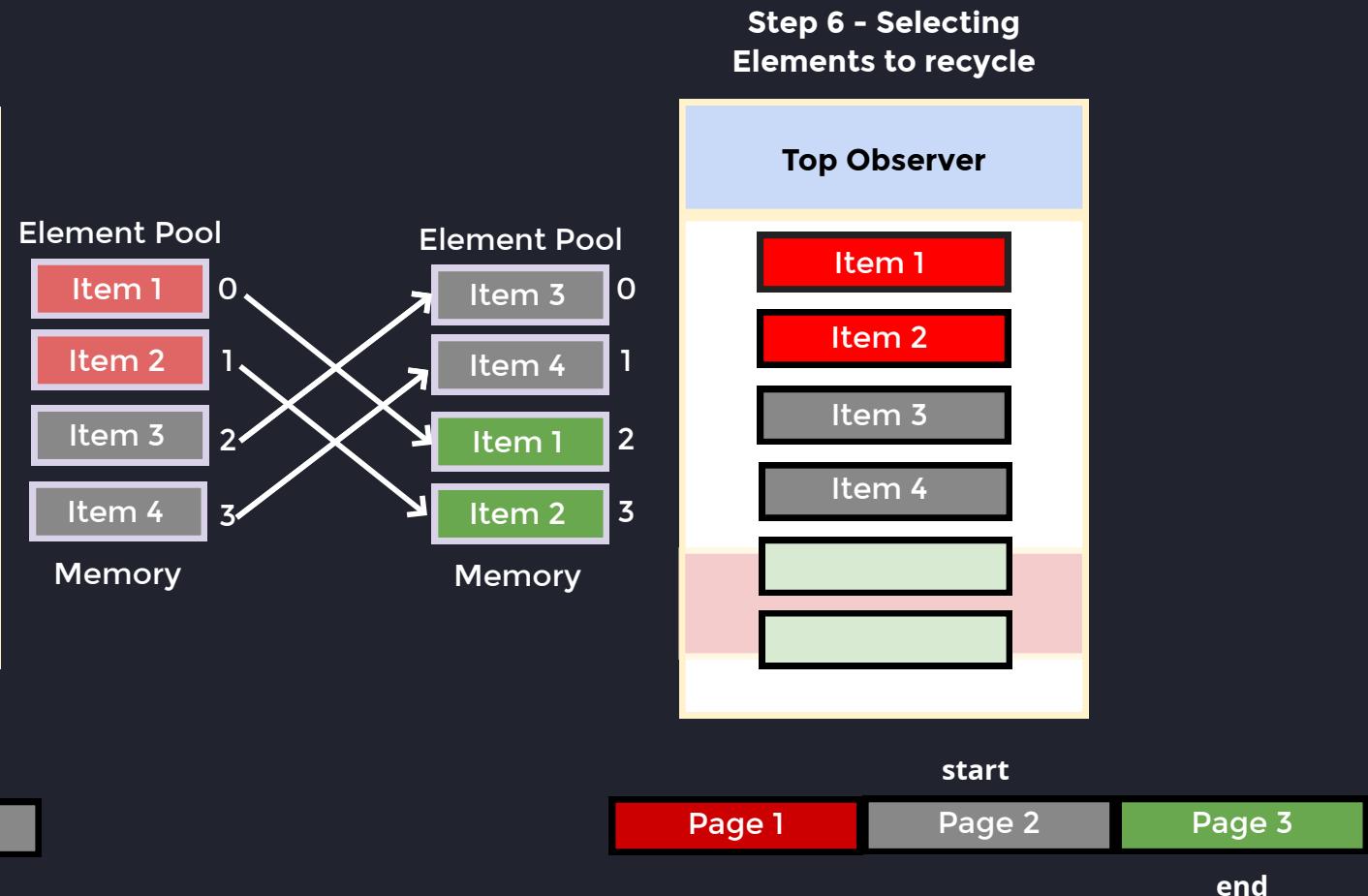
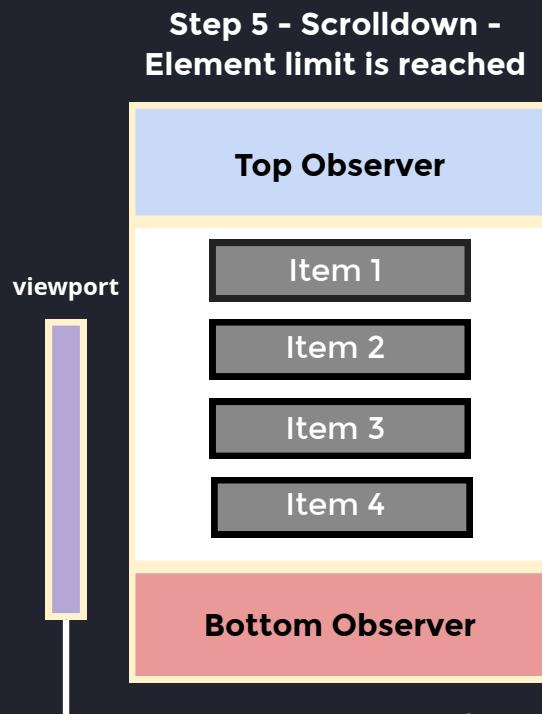
Page 1

Page 2

end

# Virtualisation: Live Coding

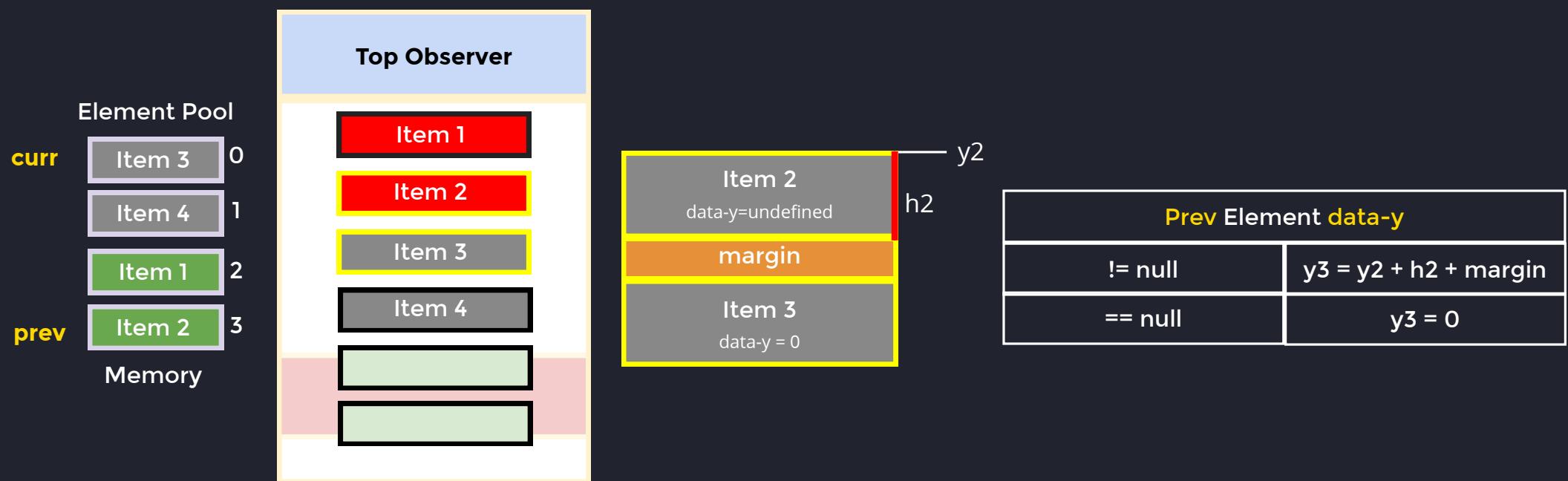
## Part 4: Selecting and Preparing elements for recycling



# Virtualisation: Live Coding

## Part 5: Handle bottom virtualization

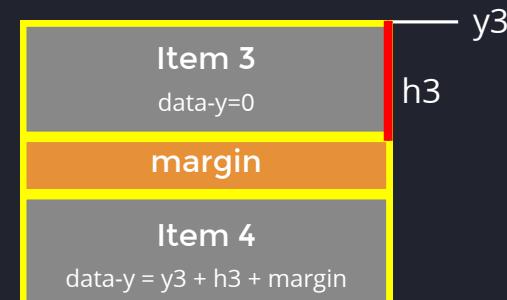
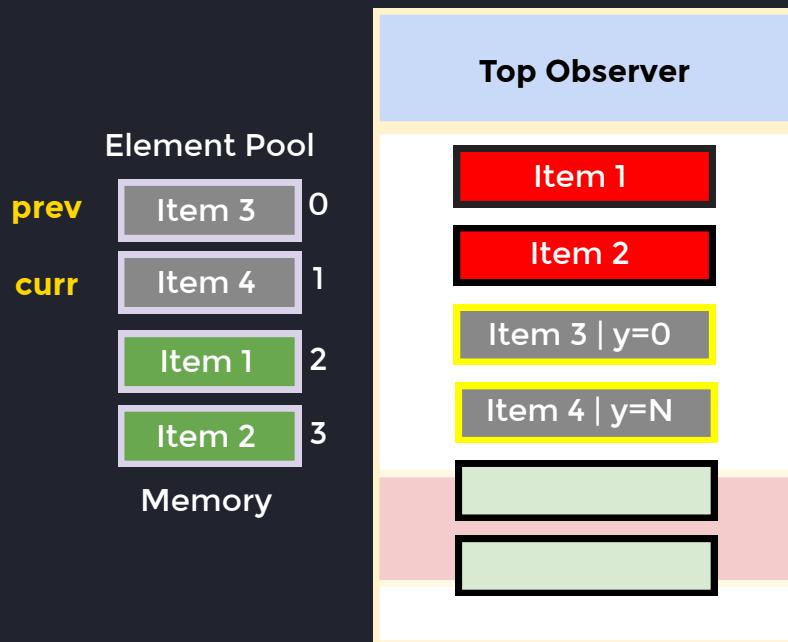
Step 6 - Selecting Elements to recycle



# Virtualisation: Live Coding

## Part 5: Handle bottom virtualization

Step 7 - Looping through the pool



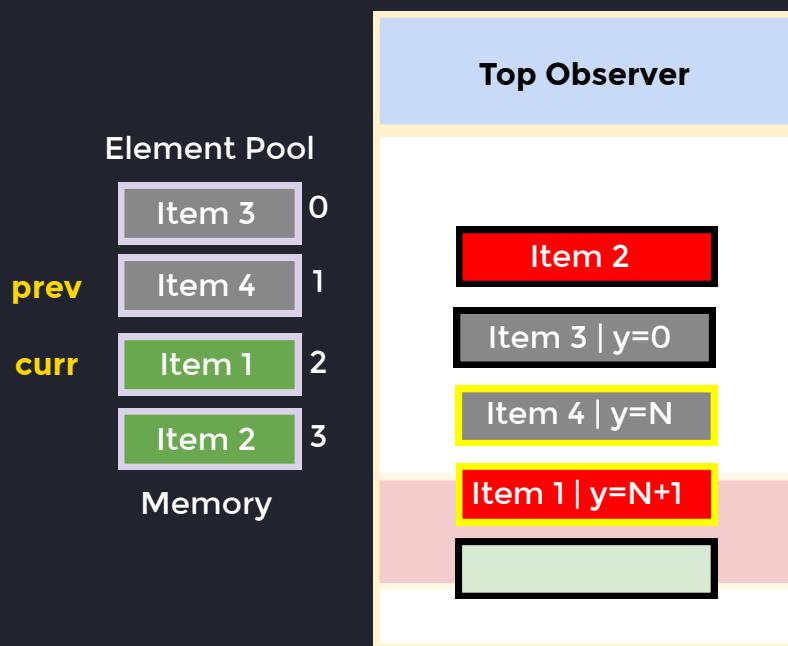
Prev Element <b>data-y</b>	
<code>!= null</code>	<code>y4 = y3 + h3 + margin</code>
<code>== null</code>	<code>y3 = 0</code>

```
current.style.transform = 'translateY(${N}px)'
```

# Virtualisation: Live Coding

## Part 5: Handle bottom virtualization

Step 8 - Looping through the pool



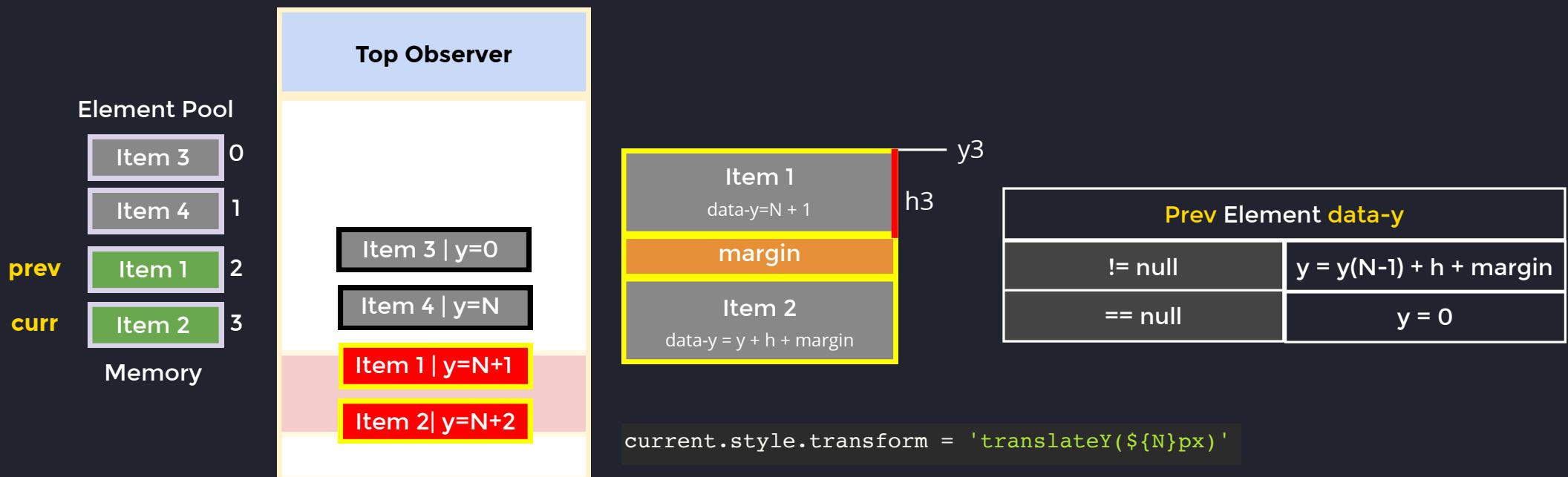
Prev Element data-y	
!= null	$y = y_4 + h_4 + \text{margin}$
== null	$y_4 = 0$

```
current.style.transform = 'translateY(${N}px)'
```

# Virtualisation: Live Coding

## Part 5: Handle bottom virtualization

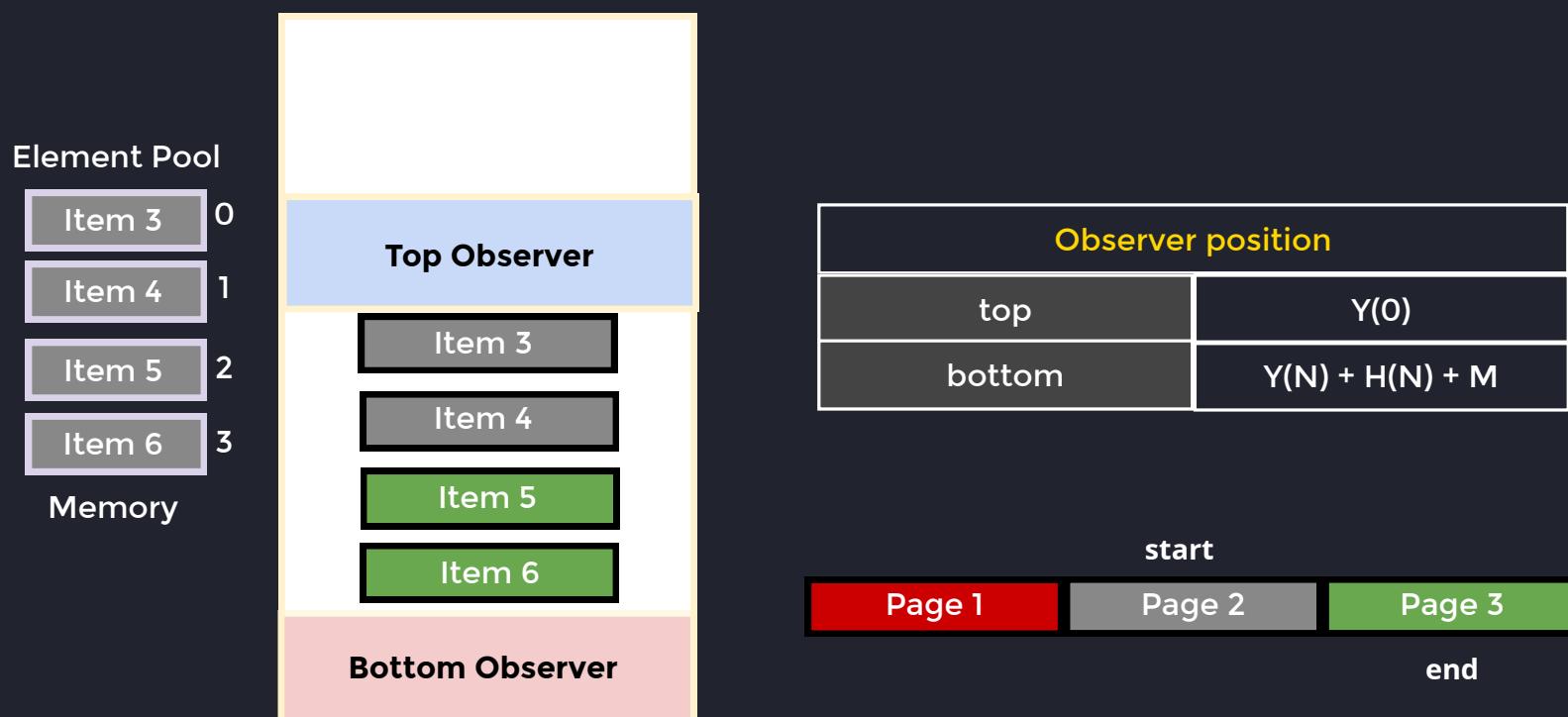
Step 9 - Looping through the pool



# Virtualisation: Live Coding

## Part 5: Handle bottom virtualization

### Step 10 - Update observers and data



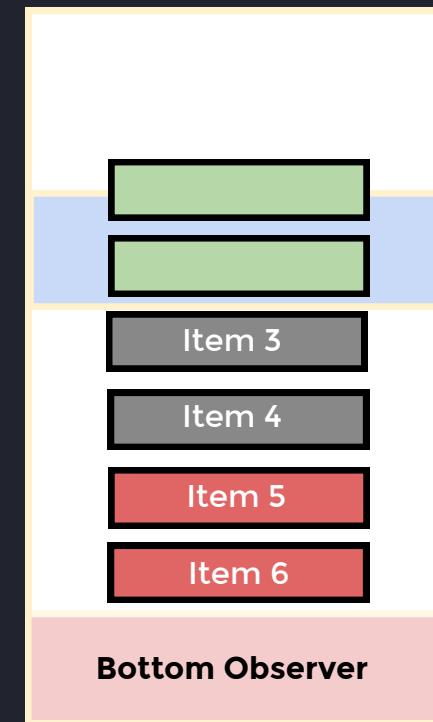
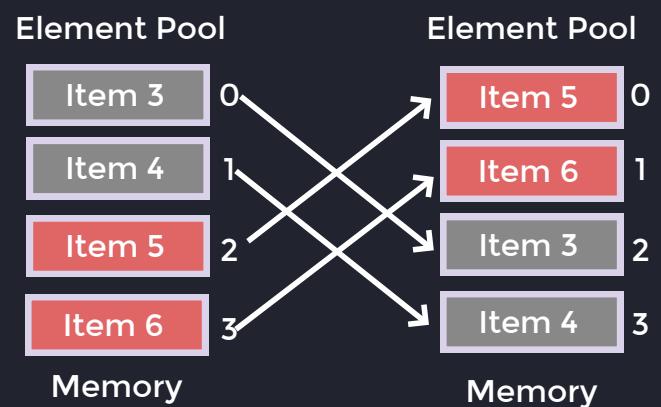
# Virtualisation: Live Coding

## Part 6: Handle top virtualization

Step 10 - Top observer is triggered

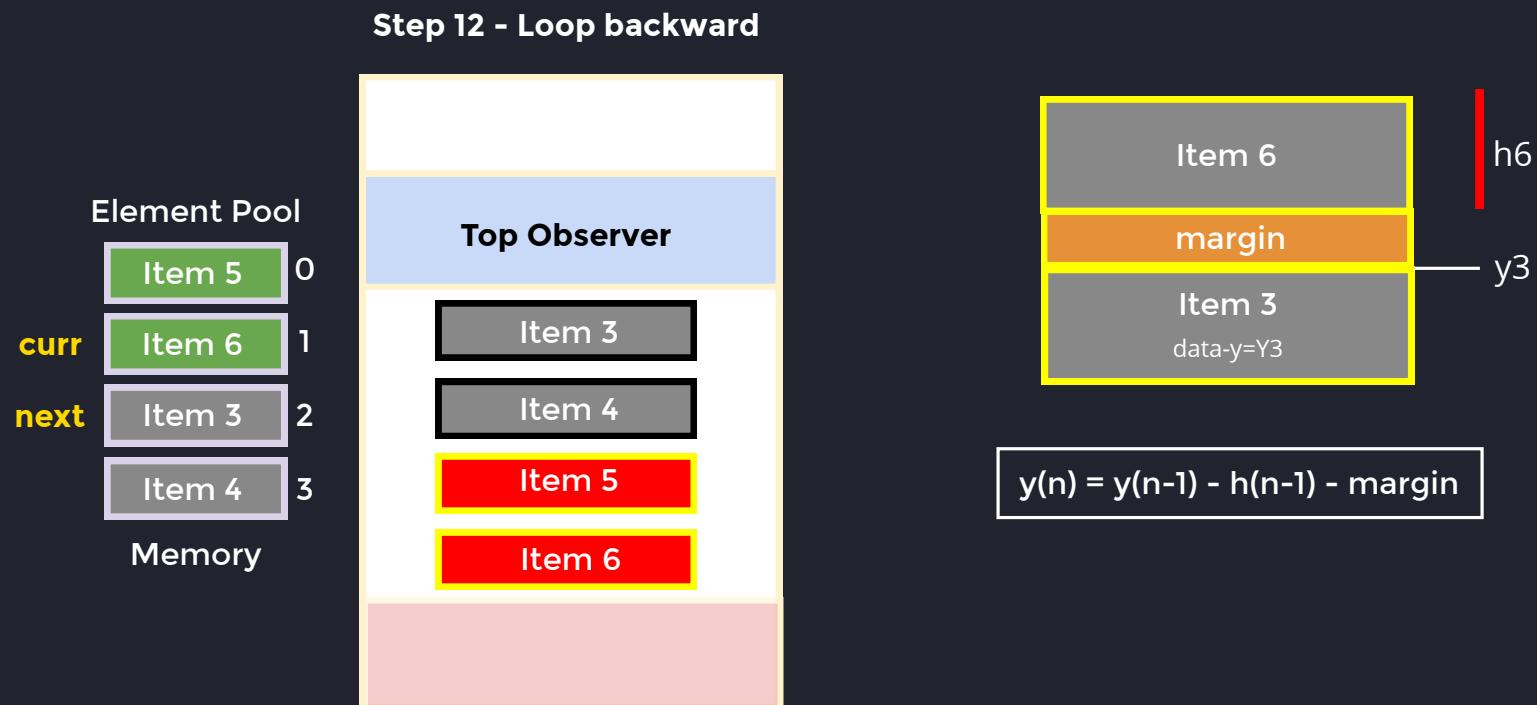


Step 11 - Prepare elements for recycling



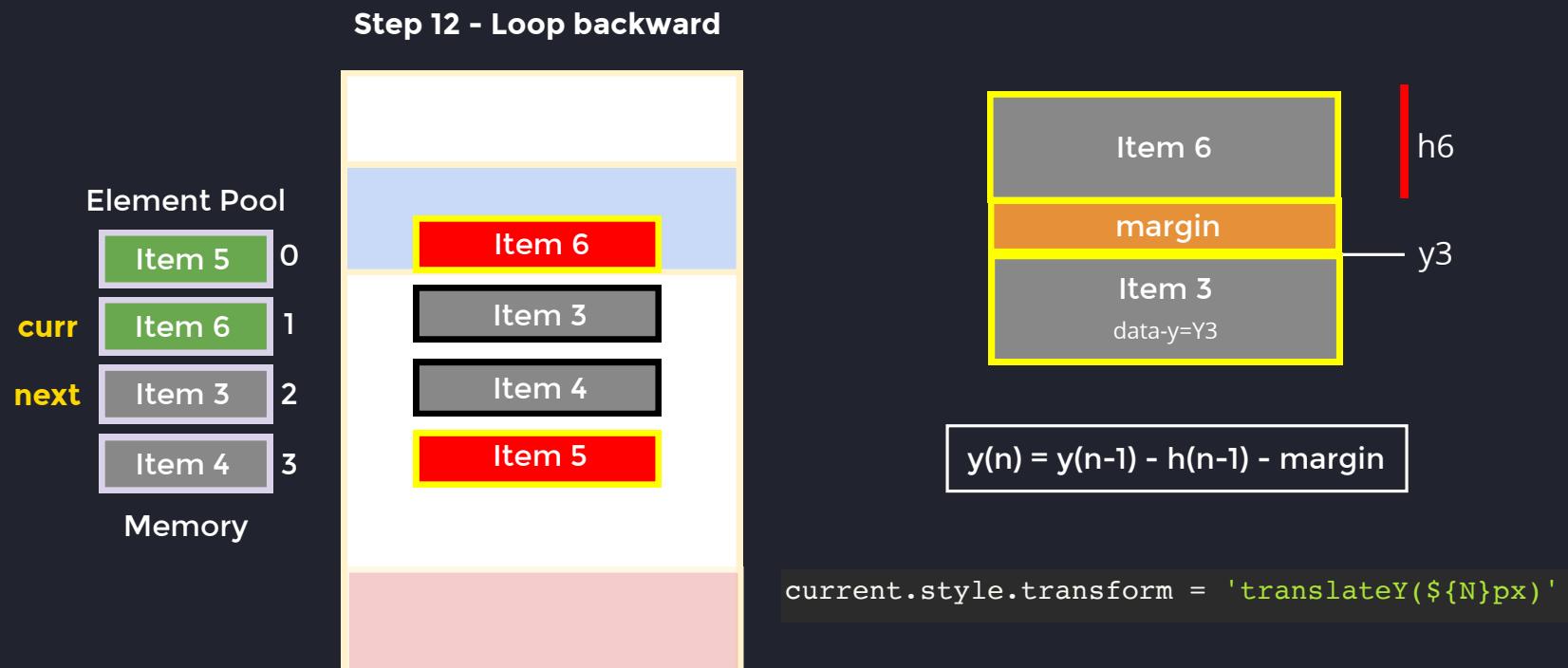
# Virtualisation: Live Coding

## Part 6: Handle top virtualization



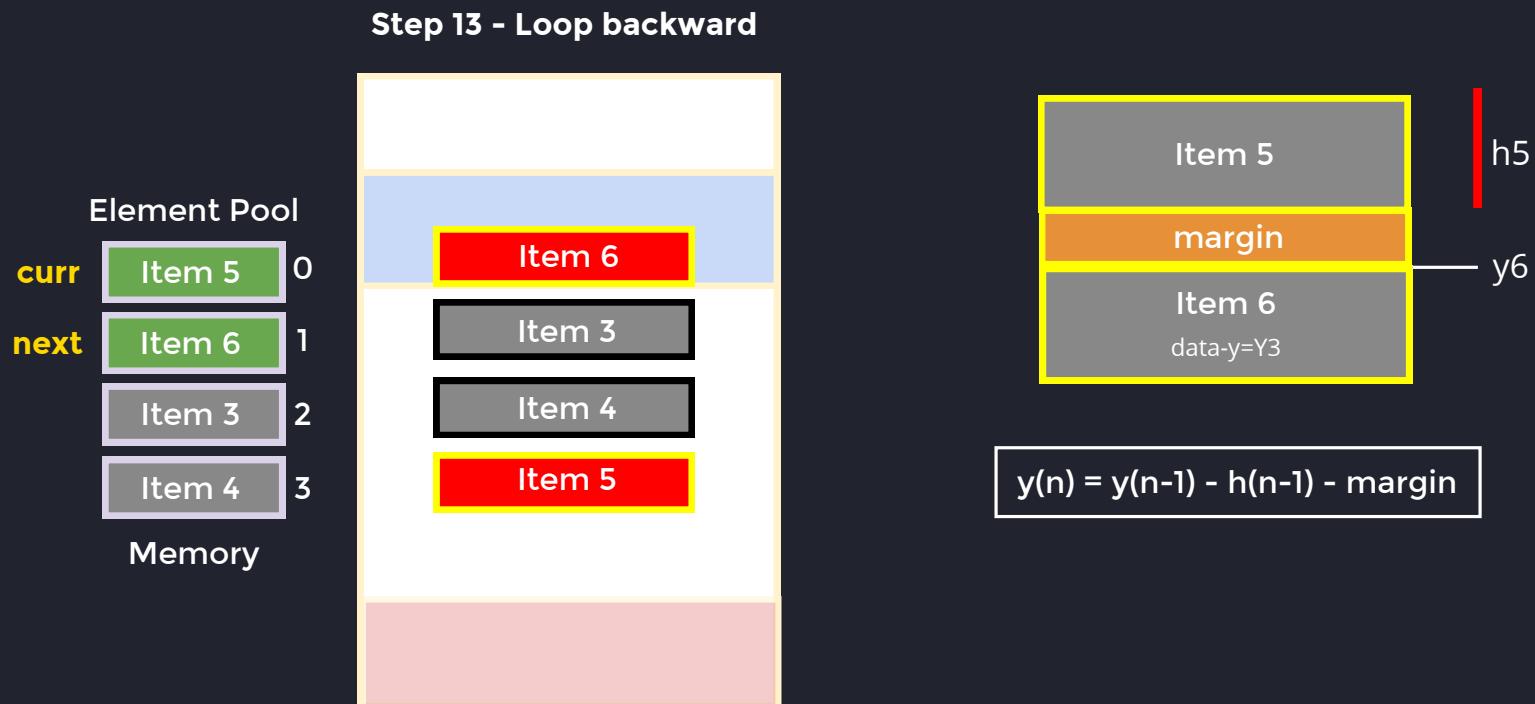
# Virtualisation: Live Coding

## Part 6: Handle top virtualization



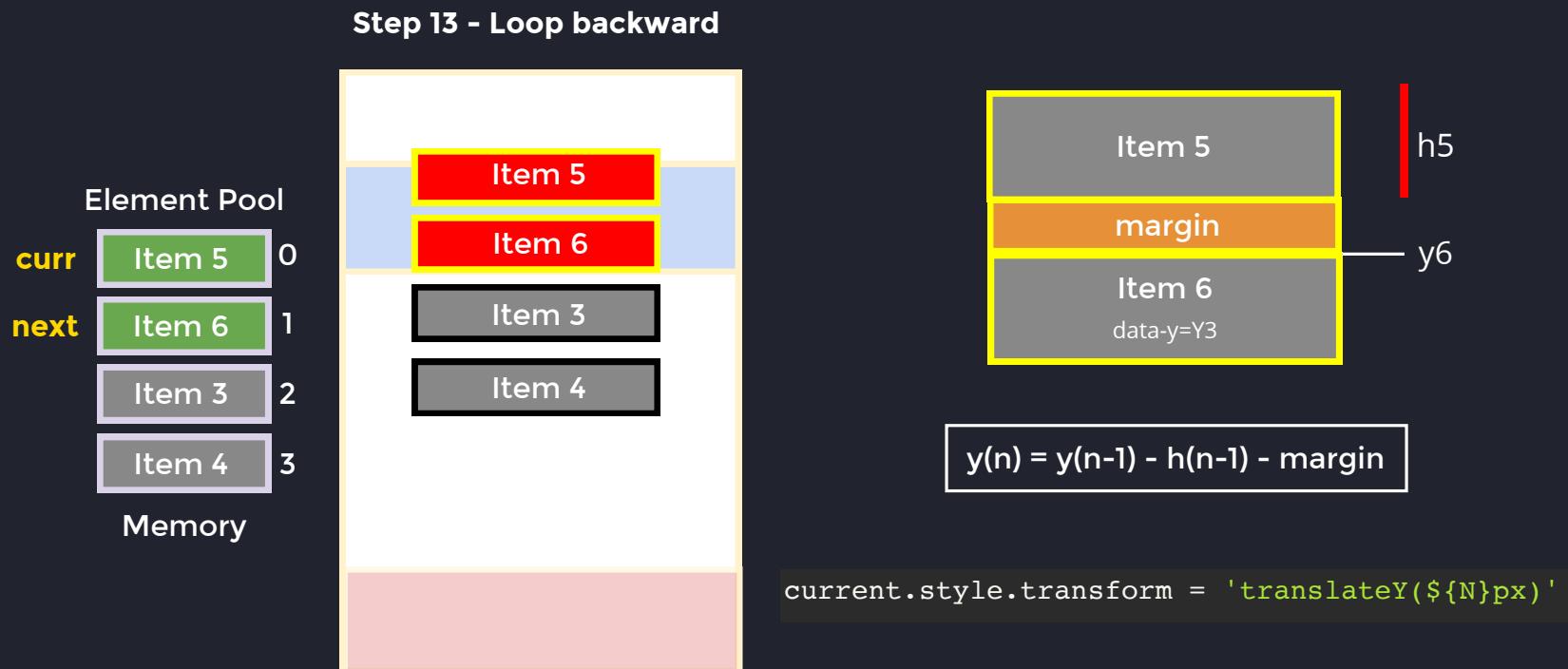
# Virtualisation: Live Coding

## Part 6: Handle top virtualization



# Virtualisation: Live Coding

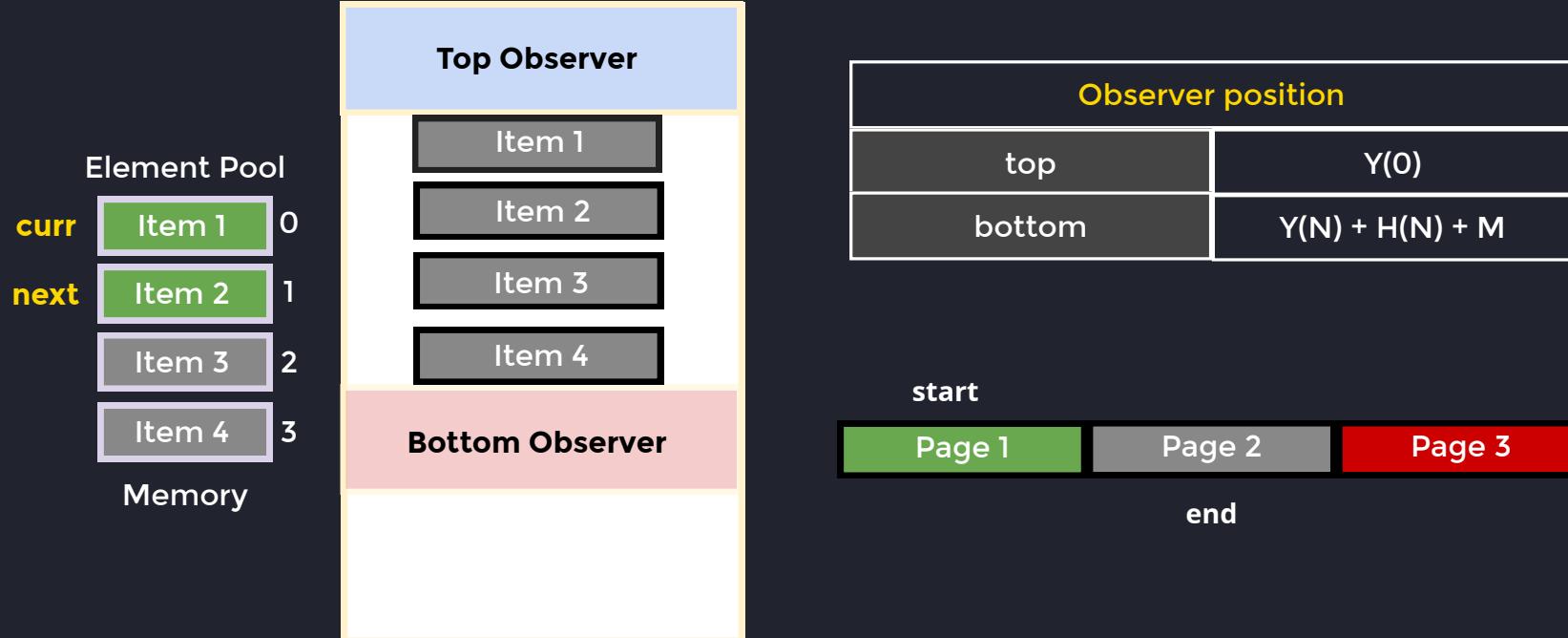
## Part 6: Handle top virtualization



# Virtualisation: Live Coding

## Part 6: Handle top virtualization

### Step 14 - Update Data and Observers



# Virtualisation: DONE!!!



# Application State Design



# Application State: Data classes and properties

Data Classes

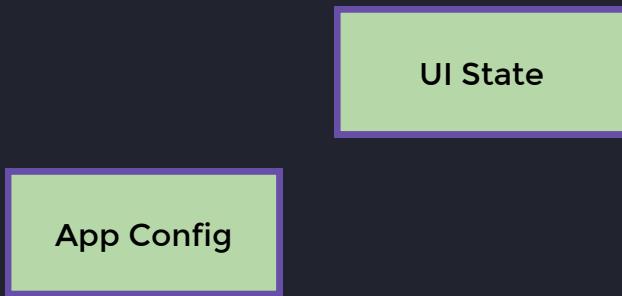


Data Properties



# Application State: Data classes and properties

## Data Classes



1. User theme
2. Locale
3. font-size
4. accessibility settings

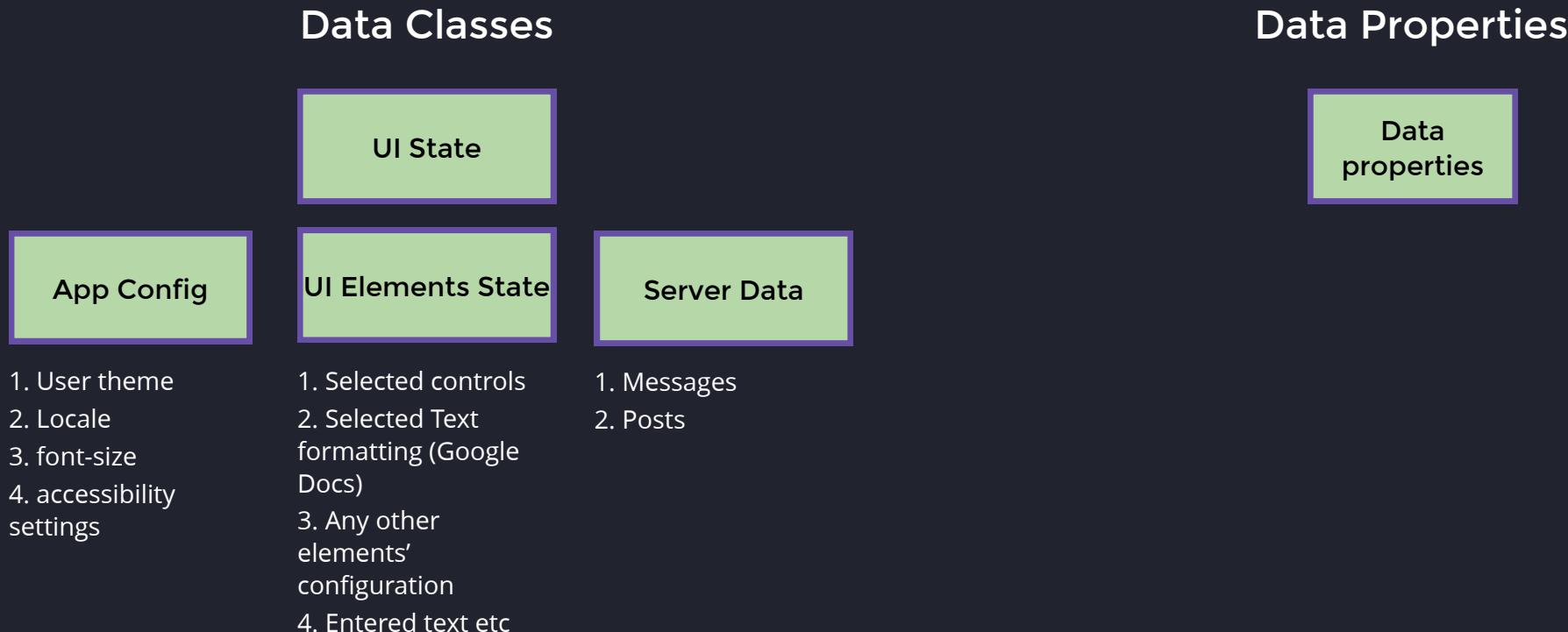
## Data Properties



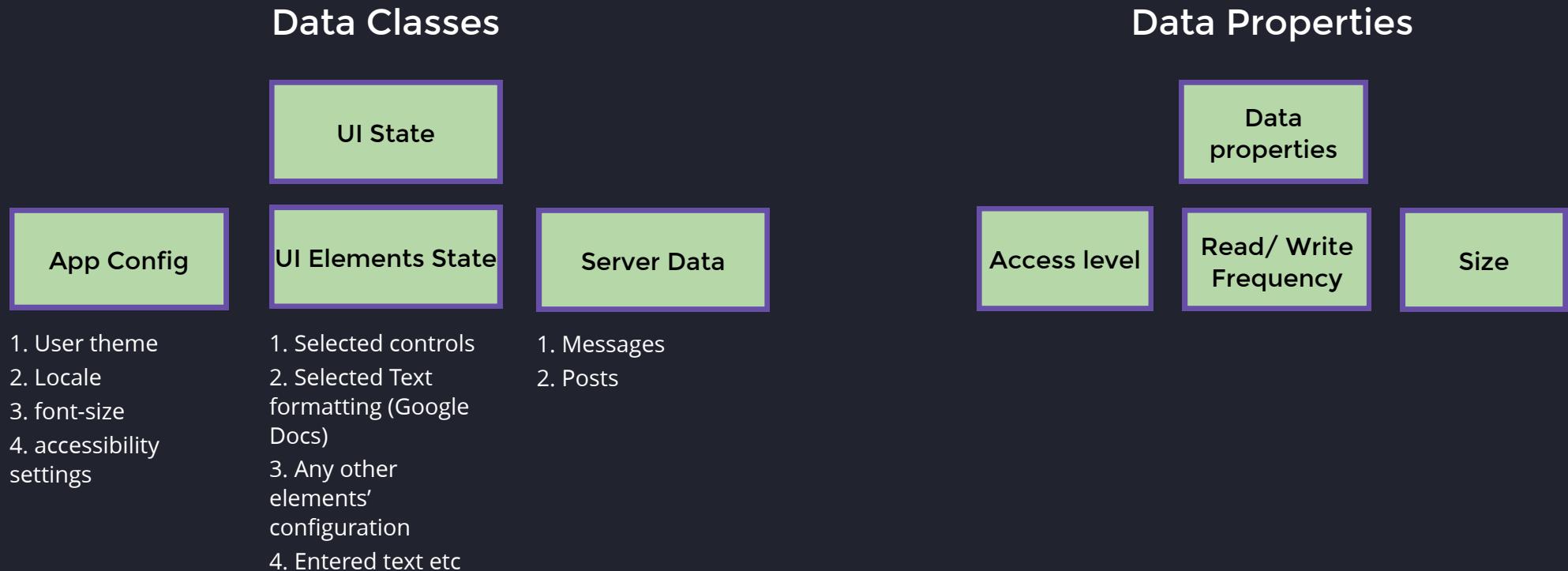
# Application State: Data classes and properties



# Application State: Data classes and properties



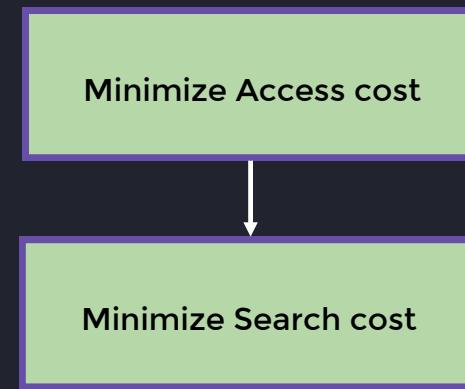
# Application State: Data classes and properties



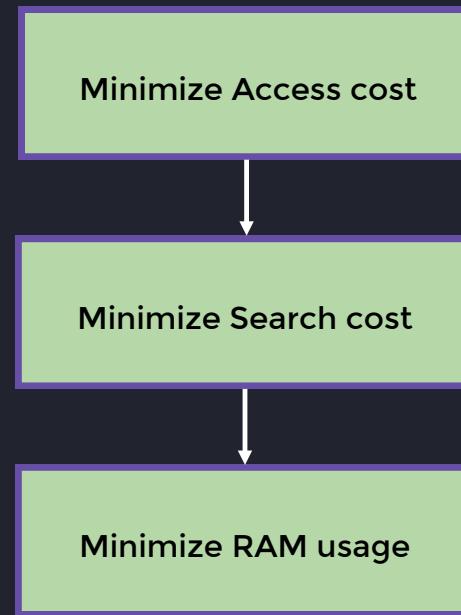
# Application State: General Principles

Minimize Access cost

# Application State: General Principles

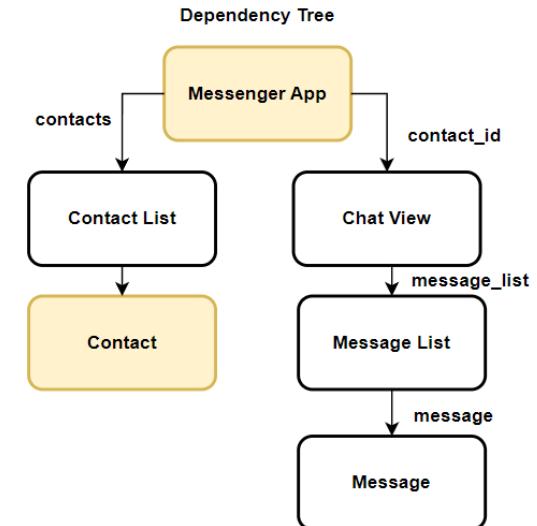
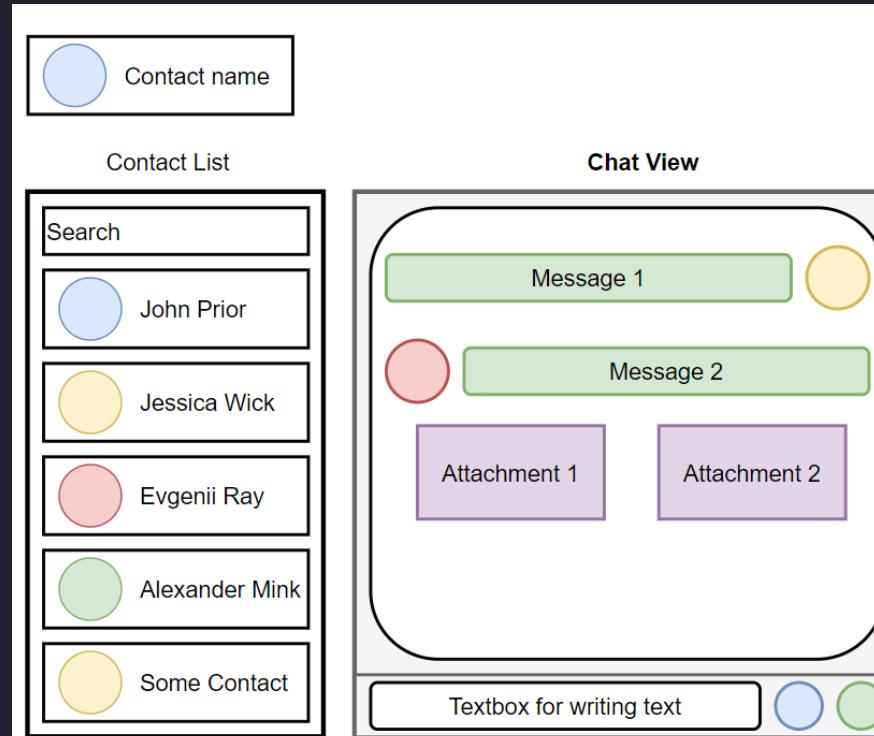


# Application State: General Principles



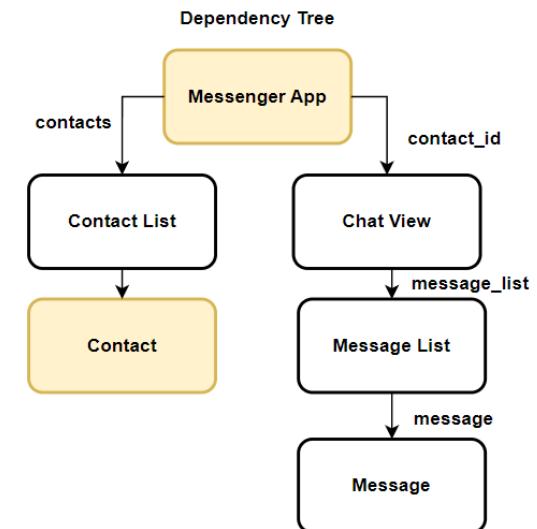
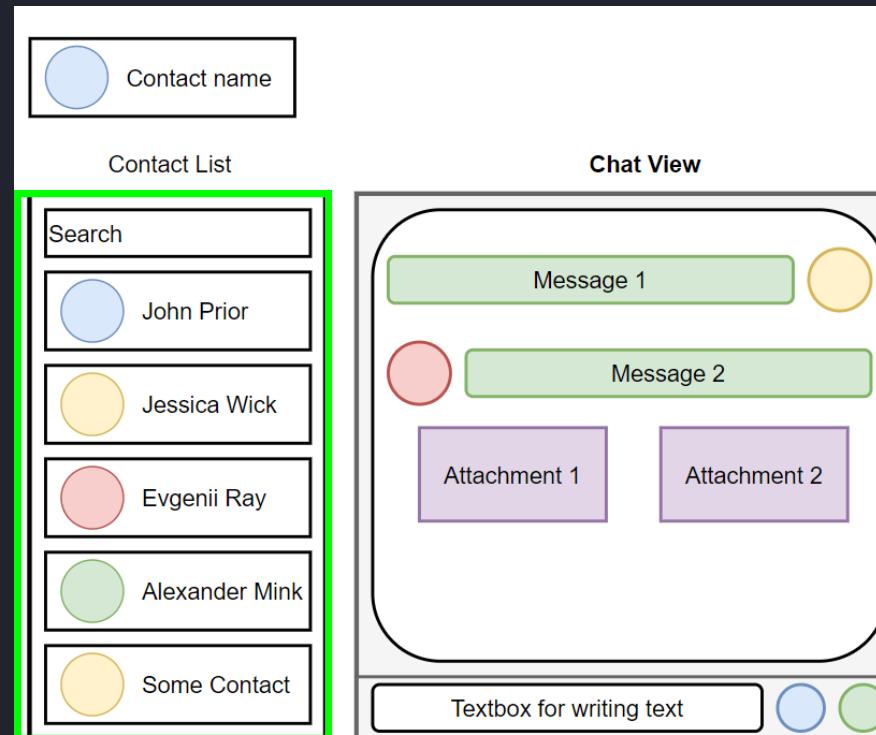
# Application State: Minimize data access cost

```
type TUser = {  
    contacts: TContact[];  
}  
  
type TContact = {  
    id: string;  
    name: string;  
    conversation: TConversation;  
}  
  
type TConversation = {  
    messages: TMessage[];  
}  
  
type TMessage = {  
    receiver_id: string;  
    sender_id: string;  
    message_id: string;  
    timestamp: number;  
    img: URL;  
    title: string;  
    content: string;  
}  
  
type TAppState = {  
    contacts: TContact[];  
}
```



# Application State: Minimize data access cost

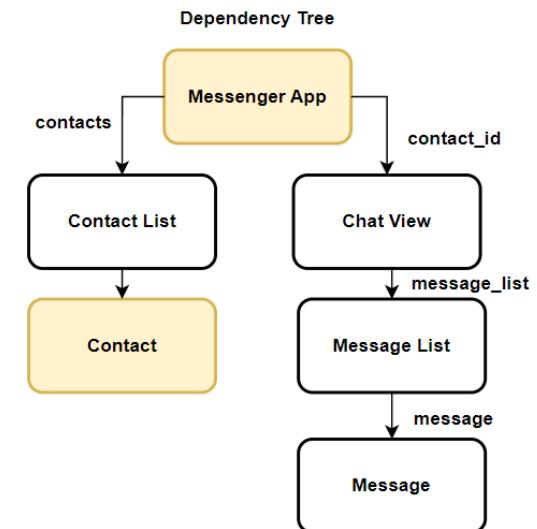
```
type TUser = {  
    contacts: TContact[];  
}  
  
type TContact = {  
    id: string;  
    name: string;  
    conversation: TConversation;  
}  
  
type TConversation = {  
    messages: TMessage[];  
}  
  
type TMessage = {  
    receiver_id: string;  
    sender_id: string;  
    message_id: string;  
    timestamp: number;  
    img: URL;  
    title: string;  
    content: string;  
}  
  
type TAppGlobalState = {  
    contacts: TContact[];  
}
```



# Application State: Minimize data access cost

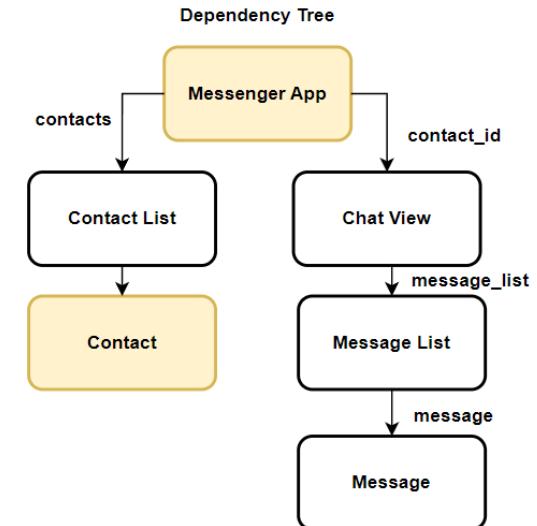
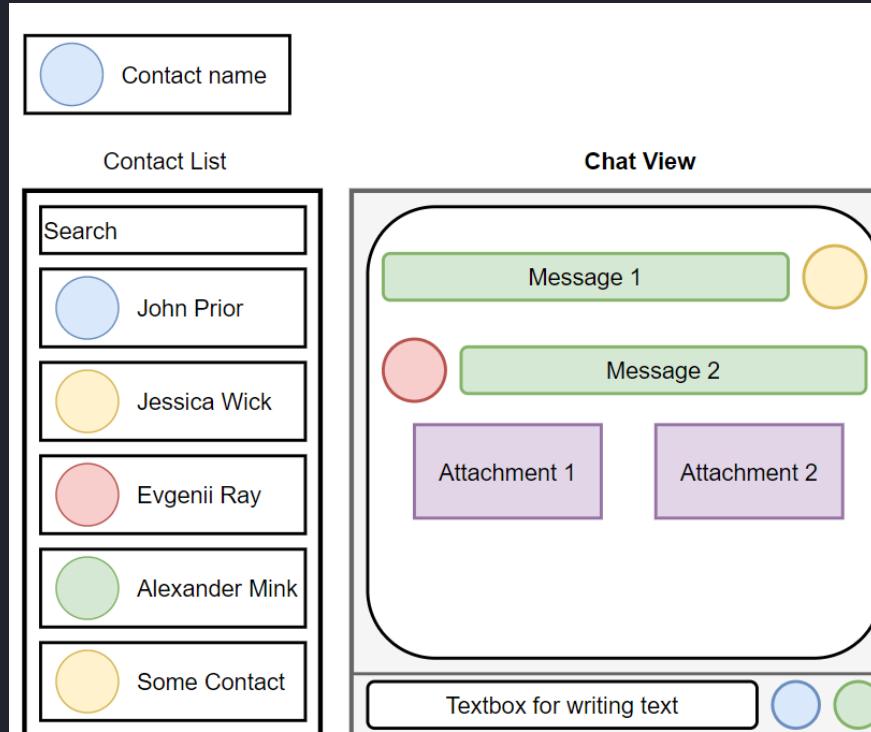
```
type TUser = {  
    contacts: TContact[];  
}  
  
type TContact = {  
    id: string;  
    name: string;  
    conversation: TConversation;  
}  
  
type TConversation = {  
    messages: TMessage[];  
}  
  
type TMessage = {  
    receiver_id: string;  
    sender_id: string;  
    message_id: string;  
    timestamp: number;  
    img: URL;  
    title: string;  
    content: string;  
}  
  
type TAppGlobalState = {  
    contacts: TContact[];  
}
```

The image shows two UI components. On the left is a 'Contact List' component with a header 'Contact name' and a list of contacts: Search, John Prior, Jessica Wick, Evgenii Ray, Alexander Mink, and Some Contact. On the right is a 'Chat View' component with a header 'Chat View' and a list of messages: Message 1, Message 2, Attachment 1, and Attachment 2. Below the Chat View is a 'Textbox for writing text' field.



# Application State: Minimize data access cost

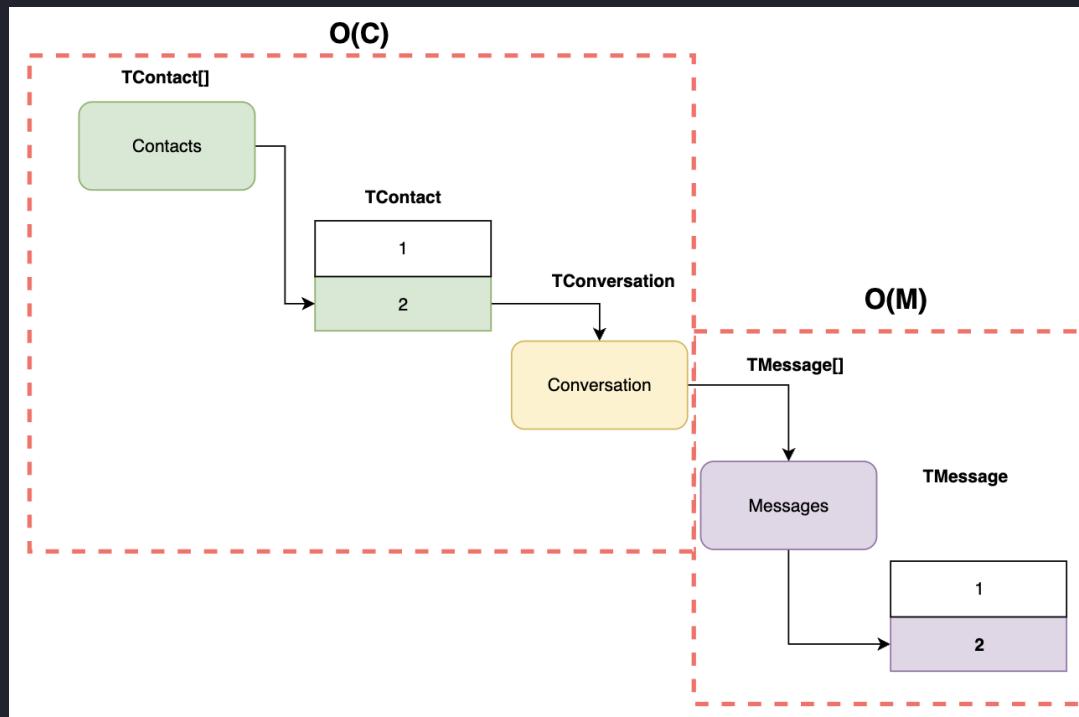
```
type TUser = {  
    contacts: TContact[];  
}  
  
type TContact = {  
    id: string;  
    name: string;  
    conversation: TConversation;  
}  
  
type TConversation = {  
    messages: TMessage[];  
}  
  
type TMessage = {  
    receiver_id: string;  
    sender_id: string;  
    message_id: string;  
    timestamp: number;  
    img: URL;  
    title: string;  
    content: string;  
}  
  
type TAppGlobalState = {  
    contacts: TContact[];  
}
```



# Application State: Minimize data access cost

```
// Get contact entity
const contact = state.contacts.find(c => c.id === 'jane_smith');

// Get Message entity
const message = contact.conversation.messages.find(m => m.id === 5);
```



1. Accessing contact - **O(C)**
2. Accessing message - **O(M)**

**Access cost:  $O(C) + O(M)$**

# Application State: **Minimize data access cost**

## Data Normalization

### Goals of Data Normalization

1. Optimized Access Performance
2. Optimized Storage Structure
3. High Developer Readability and Maintenance

# Application State: Minimize data access cost

## Data Normalization

Non NF

```
1 {
2   id: "1",
3   name: "Evgenii",
4   job: {
5     id: "UIE",
6     title: "UI Engineer",
7     department: "Engineering"
8   },
9   location: { code: "UK", name: "United Kingdom" }
10 }
```

1NF

1. Data is atomic
2. It has primary key

```
1 {
2   id: "1",
3   name: "Evgenii",
4   job_id: "UIE",
5   job_title: "UI Engineer",
6   department: "Engineering",
7   country_code: "UK",
8   country_name: "United Kingdom"
9 }
```

# Application State: Minimize data access cost

## Data Normalization

Non NF

1NF

1. Data is atomic
2. It has primary key

```
1 {
2   id: "1",
3   name: "Evgenii",
4   job: {
5     id: "UIE",
6     title: "UI Engineer",
7     department: "Engineering"
8   },
9   location: { code: "UK", name: "United Kingdom" }
10 }
```

```
1 {
2   id: "1",
3   name: "Evgenii",
4   job_id: "UIE",
5   job_title: "UI Engineer",
6   department: "Engineering",
7   country_code: "UK",
8   country_name: "United Kingdom"
9 }
```

# Application State: Minimize data access cost

## Data Normalization

1NF

1. Data is atomic
2. It has primary key

2NF

1NF + non-primary keys depend  
on entity primary key

```
1 {
2   id: "1",
3   name: "Evgenii",
4   job_id: "UIE",
5   job_title: "UI Engineer",
6   department: "Engineering",
7   country_code: "UK",
8   country_name: "United Kingdom"
9 }
```

# Application State: Minimize data access cost

## Data Normalization

1NF

1. Data is atomic
2. It has primary key

2NF

1NF + non-primary keys depend  
on entity primary key

```
1 {  
2   id: "1",  
3   name: "Evgenii",  
4   job_id: "UIE",  
5   job_title: "UI Engineer",  
6   department: "Engineering",  
7   country_code: "UK",  
8   country_name: "United Kingdom"  
9 }
```

```
1 const users = {  
2   "1": {  
3     name: "Evgenii",  
4     job_id: 'UIE',  
5     country_code: "UK",  
6     country_name: "United Kingdom"  
7   }  
8 }  
9 const jobs = {  
10   UIE: {  
11     title: "UI Enginer",  
12     department: 'Engineering'  
13 };  
14 const user_jobs = { "1": "UIE" };
```

# Application State: Minimize data access cost

## Data Normalization

1NF

1. Data is atomic
2. It has primary key

2NF

1NF + non-primary keys depend  
on entity primary key

```
1 {
2   id: "1",
3   name: "Evgenii",
4   job_id: "UIE",
5   job_title: "UI Engineer",
6   department: "Engineering",
7   country_code: "UK",
8   country_name: "United Kingdom"
9 }
```

```
1 const users = {
2   "1": {
3     name: "Evgenii",
4     job_id: 'UIE',
5     country_id: "UK",
6   }
7 }
8
9 const jobs = {
10   UIE: {
11     title: "UI Enginer",
12     department: 'Engineering'
13   };
14
15 const user_jobs = { "1": "UIE" };
16
17 const countries = { UK: "United Kingdom" };
```

# Application State: Minimize data access cost

## Data Normalization

2NF

1. 1NF
2. non-primary keys depend on entity primary key

3NF

1. 2NF
2. non-primary keys **ONLY** depend on entity primary key

```
1 const users = {  
2   "1": {  
3     name: "Evgenii",  
4     job_id: 'UIE',  
5     country_id: "UK",  
6   }  
7 }  
8 const jobs = {  
9   UIE: {  
10    title: "UI Enginer",  
11    department: 'Engineering'  
12  };  
13 const user_jobs = { "1": "UIE" };  
14  
15 const countries = { UK: "United Kingdom" };
```

```
1 const users = {  
2   "1": {  
3     name: "Evgenii",  
4     job_id: 'UIE',  
5     country_id: "UK",  
6   }  
7 }  
8 const jobs = { UIE: "UI Enginer" }  
9  
10 const department = { UIE: "Engineering" }  
11  
12 const user_jobs = { "1": "UIE" };  
13  
14 const countries = { UK: "United Kingdom" };
```

# Application State: 1NF and 2NF

## Non NF

```
1 type TContact = {  
2   id: string;  
3   name: string;  
4   conversation: TConversation;  
5 }
```

```
1 type TMessage = {  
2   receiver_id: string;  
3   sender_id: string;  
4   message_id: string;  
5   timestamp: number;  
6   img: URL;  
7   title: string;  
8   content: string;  
9 }
```

```
1 type TConversation = {  
2   id: string;  
3   title: string;  
4   messages: TMessage[];  
5 }
```

# Application State: 1NF and 2NF

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9 }
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4   messages: TMessage[];  
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```

# Application State: 1NF and 2NF

## Non NF

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1 type TContact = {  
2   id: string;  
3   name: string;  
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5 }
```

## Atomic Fields

```
1 type TContact = {  
2   id: string;  
3   name: string;  
4   conversation_id: string  
5 }
```

```
1 type TMessage = {  
2   receiver_id: string;  
3   sender_id: string;  
4   message_id: string;  
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## Atomic Fields

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1 type TContact = {  
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5 }
```

## Primary Keys

```
1 type TContact = {  
2   id: string;  
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4   conversation_id: string  
5 }
```

```
1 type TMessage = {  
2   receiver_id: string;  
3   sender_id: string;  
4   message_id: string;  
5   timestamp: number;  
6   img: URL;  
7   title: string;  
8   content: string;  
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8   content: string;  
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```

```
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```

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4   message_id: string;  
5   timestamp: number;  
6   img: URL;  
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8   content: string;  
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```
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4   message_id: string;  
5   conversation_id: string  
6   timestamp: number;  
7   img: URL;  
8   content: string;  
9 }
```

```
1 type TConversation = {  
2   id: string;  
3   title: string;  
4 }
```

## App State

```
1 type TAppState = {  
2   messages: {  
3     [message_id: string]: TMessage;  
4   }  
5   conversations: {  
6     [convo_id: string]: TConversation;  
7   },  
8   contacts: {  
9     [user_id: string]: TContact;  
10  }  
11 }
```

# Application State: Minimize search cost

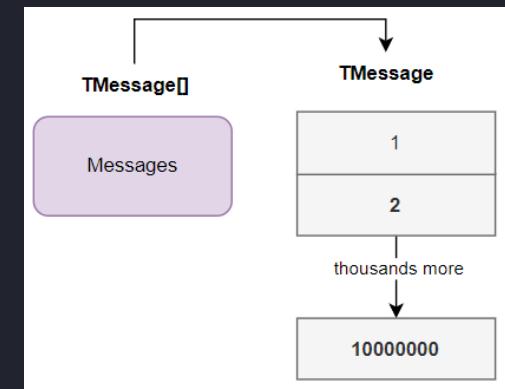
## App State

```
type TAppState = {
  messages: {
    [message_id: string]: TMessage;
  }
  conversations: {
    [convo_id: string]: TConversation;
  },
  contacts: {
    [user_id: string]: TContact;
  }
}
```

## Message Entity

```
1 type TMessage = {
2   receiver_id: string;
3   sender_id: string;
4   message_id: string;
5   conversation_id: string;
6   timestamp: number;
7   img: URL;
8   content: string;
}
```

## Search



# Application State: Minimize search cost

## Indexing - Inverted Index Table

Messages

ID	Content	Timestamp
1	Hello, Jane	1000
2	Hey, How are u?	2000

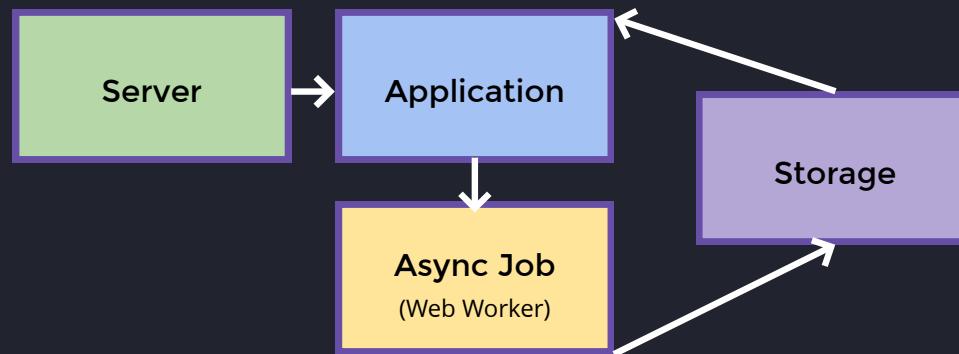
Inverted Index Table

Key	Messages
Jane	[ [1, 1000] ]
Hey	[ [2, 2000] ]

```
1 type TMessageInvertedIndex = {  
2   [key: string]: Array<  
3     [  
4       message_id: string,  
5       timestamp: number  
6     ]  
7   >  
8 }
```

# Application State: Minimize search cost

## Indexing - Inverted Index Table



Messages

ID	Content	Timestamp
1	Hello, Jane	1000
2	Hey, How are u?	2000

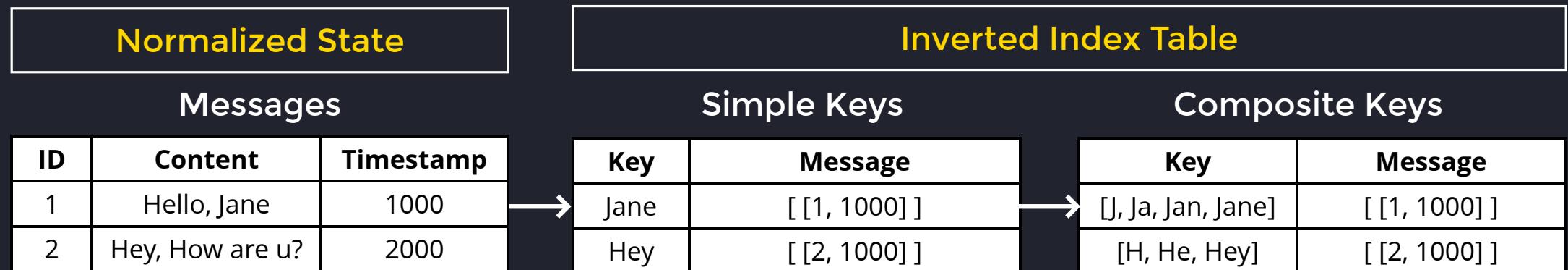
Inverted Index Table

Key	Message Tuple
Jane	[ [1, 1000] ]
Hey	[ [2, 2000] ]

```
1 type TMessageInvertedIndex = {
2   [key: string]: Array<
3     [
4       message_id: string,
5       timestamp: number
6     ]
7   >
8 }
```

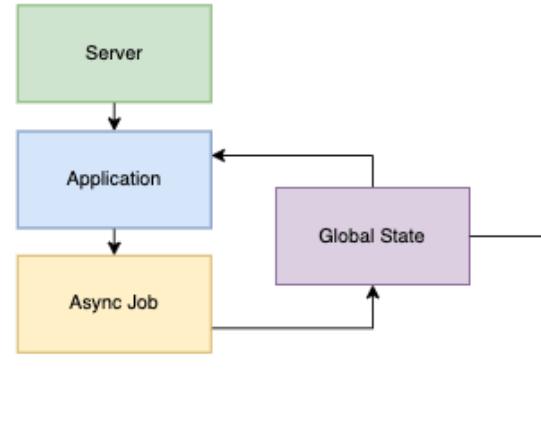
# Application State: Minimize search cost

## Indexing - Composite Inverted Index Table



```
type TAppState = {
  messages: {
    [message_id: string]: TMessage;
  }
  conversations: {
    [convo_id: string]: TConversation;
  },
  contacts: {
    [user_id: string]: TContact;
  }
  message_index: TMessageInvertedIndex;
}
```

# Application State: Memory Offloading



**Contact List**

Search
John
Jessica Wick
Evgenii Ray

**Chat View**

Message 1

Message 2

Textbox for writing text

A green box highlights the "John" contact entry in the Contact List.

The screenshot shows a mobile application interface. On the left is a **Contact List** screen with a search bar at the top. Below it is a list of contacts with profile icons and names: John, Jessica Wick, and Evgenii Ray. The "John" entry is highlighted with a green box. On the right is a **Chat View** screen showing two messages: "Message 1" and "Message 2". At the bottom is a text input field labeled "Textbox for writing text".

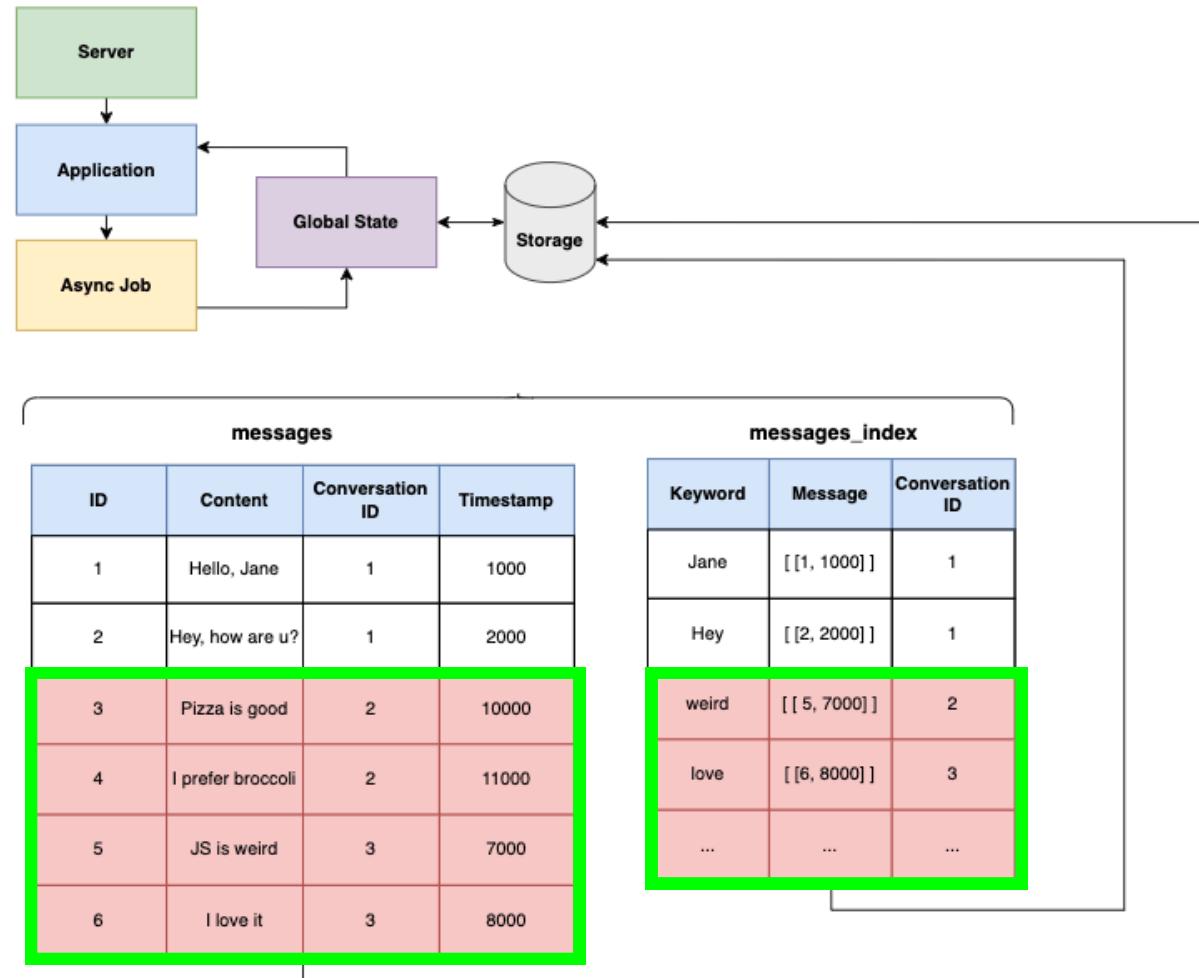
messages			
ID	Content	Conversation ID	Timestamp
1	Hello, Jane	1	1000
2	Hey, how are u?	1	2000
3	Pizza is good	2	10000
4	I prefer broccoli	2	11000
5	JS is weird	3	7000
6	I love it	3	8000

messages_index		
Keyword	Message	Conversation ID
Jane	[[1, 1000]]	1
Hey	[[2, 2000]]	1
weird	[[5, 7000]]	2
love	[[6, 8000]]	3
...	...	...

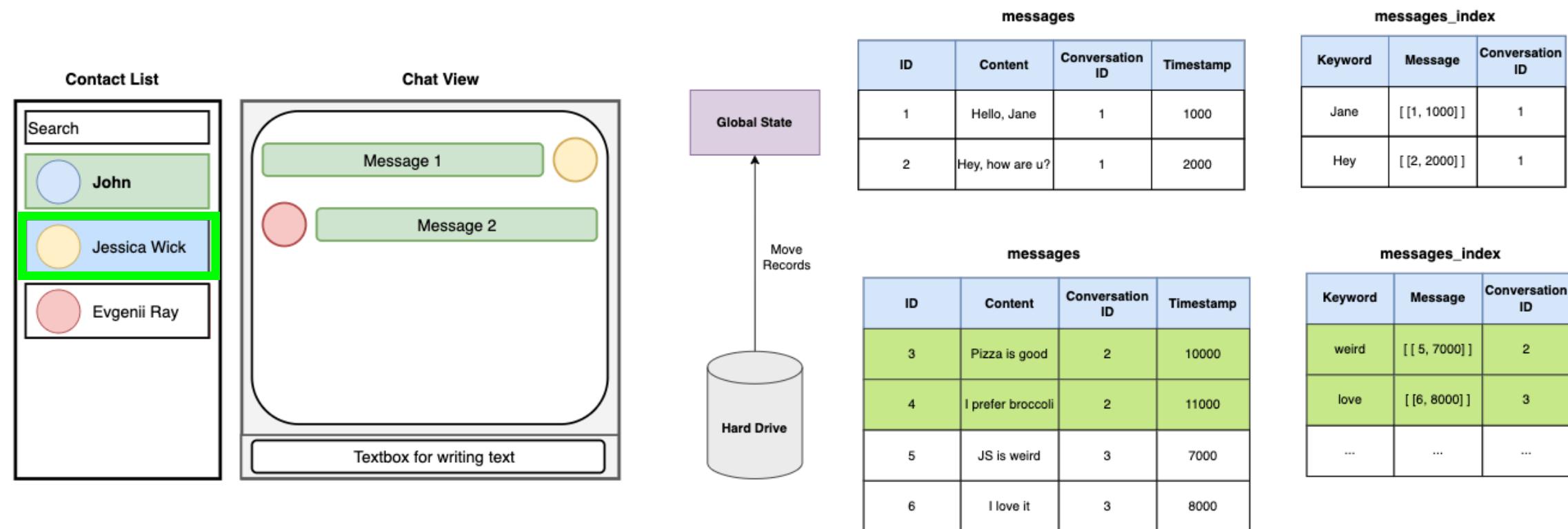
# Application State: Memory Offloading

Identifying un-used data



# Application State: Memory Offloading

Fetching data from hard-drive



# Memory offloading: Choosing a storage

**Storage Properties**

Type	Indexed DB	Local Storage	Session Storage
<b>Storage Cap</b>	Unlimited	5 Mb	5 mb
<b>Indexing</b>	Yes	No	No
<b>Advanced search</b>	Yes	No	No
<b>Data Types</b>	number, date, string, binary, or array	string	string
<b>Blocking thread</b>	No	Yes	Yes

**Use-cases**

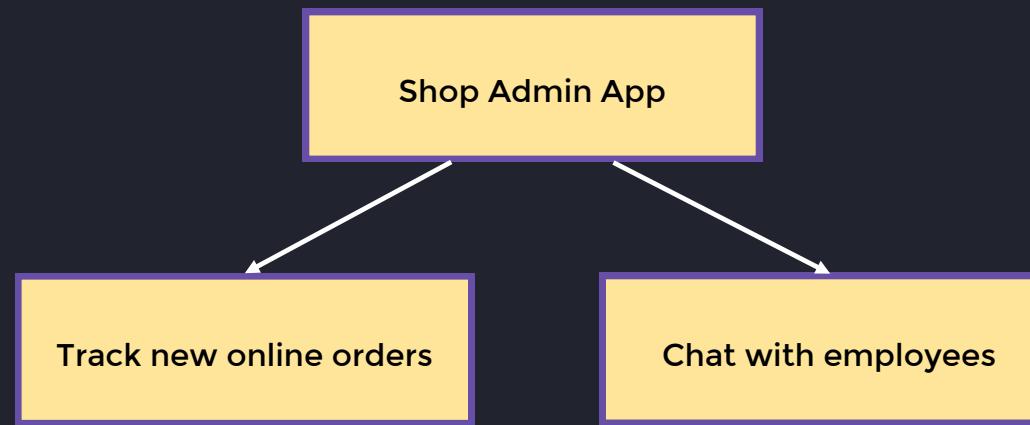
Usecase	IndexedDB	Local Storage	Session Storage
<b>User preferences, small configs</b>			
<b>Non-persistent data</b>			
<b>Large data with query support</b>			
<b>Offline Mode</b>			
<b>High Read / Writes</b>			
<b>Multi-storage support</b>			

## Summary: Application state design

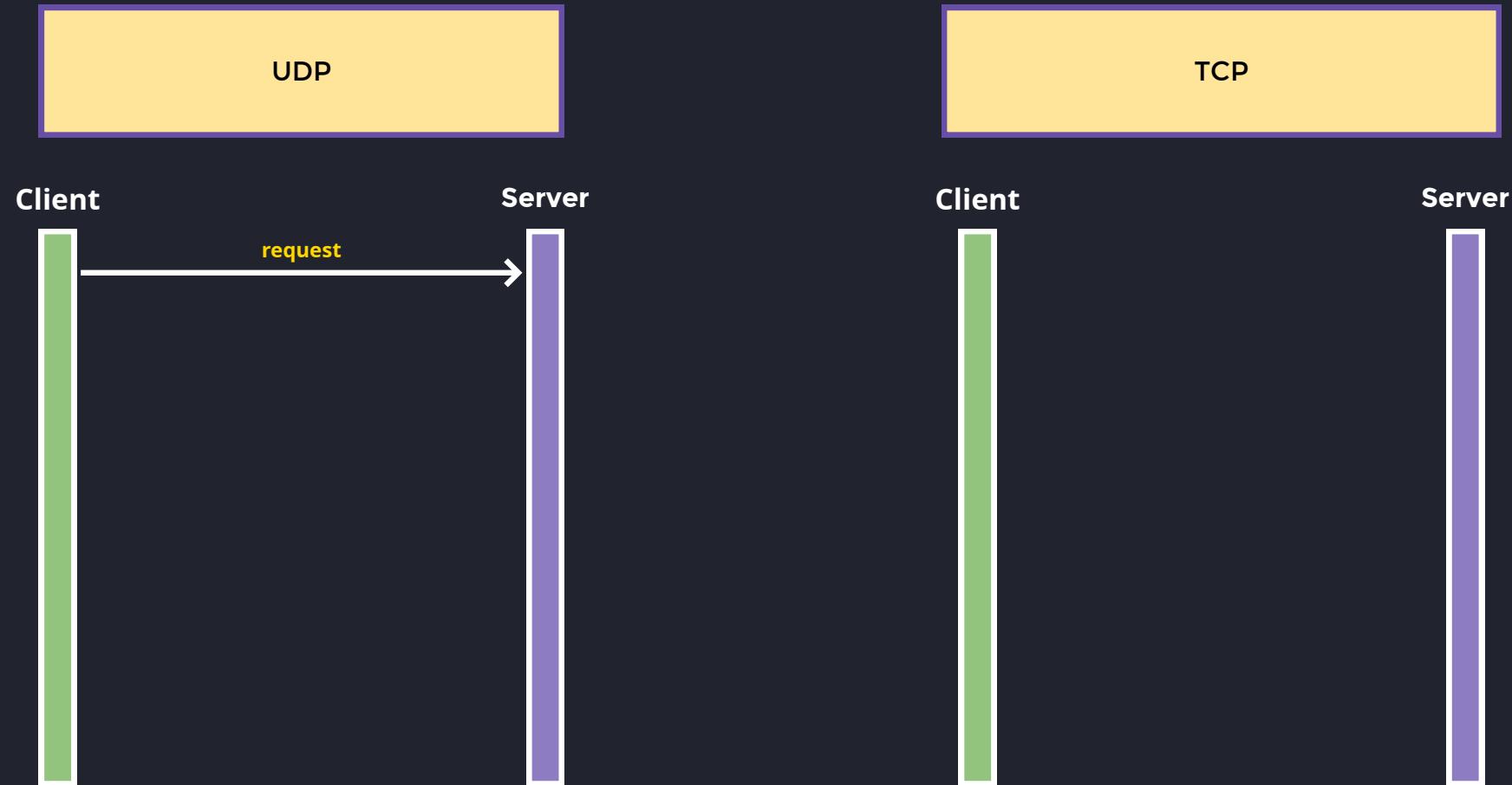
1. **Know your scale** - optimize accordingly
2. Always start with how you **structure your data**
3. Use **Normal forms** to optimize access cost
4. Use **Indexes** if in-app search is required
5. **Offload data** to hard-drive when it's needed
6. Pick a **suitable storage**

# **Network Connectivity**

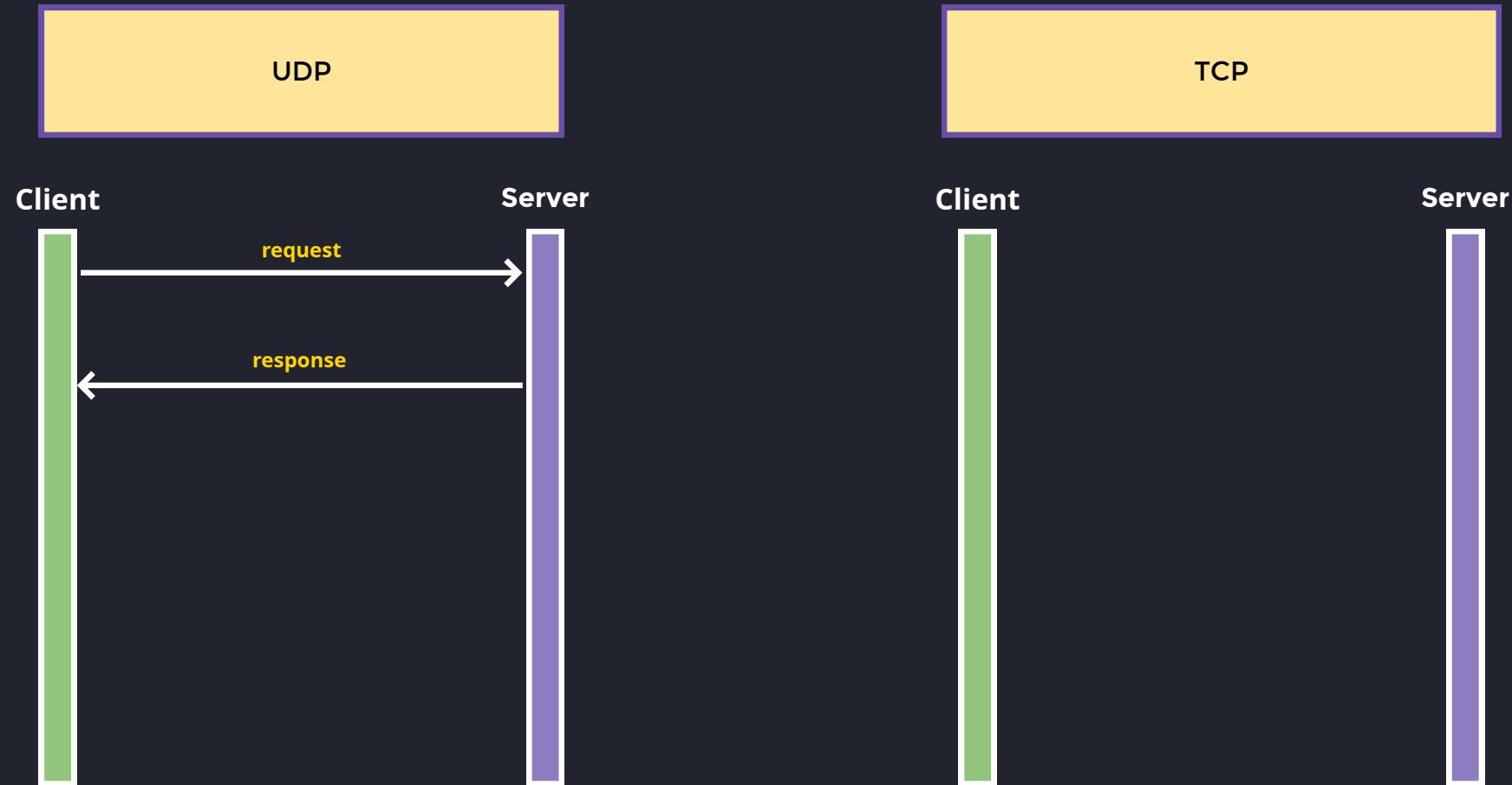
# Network Connectivity



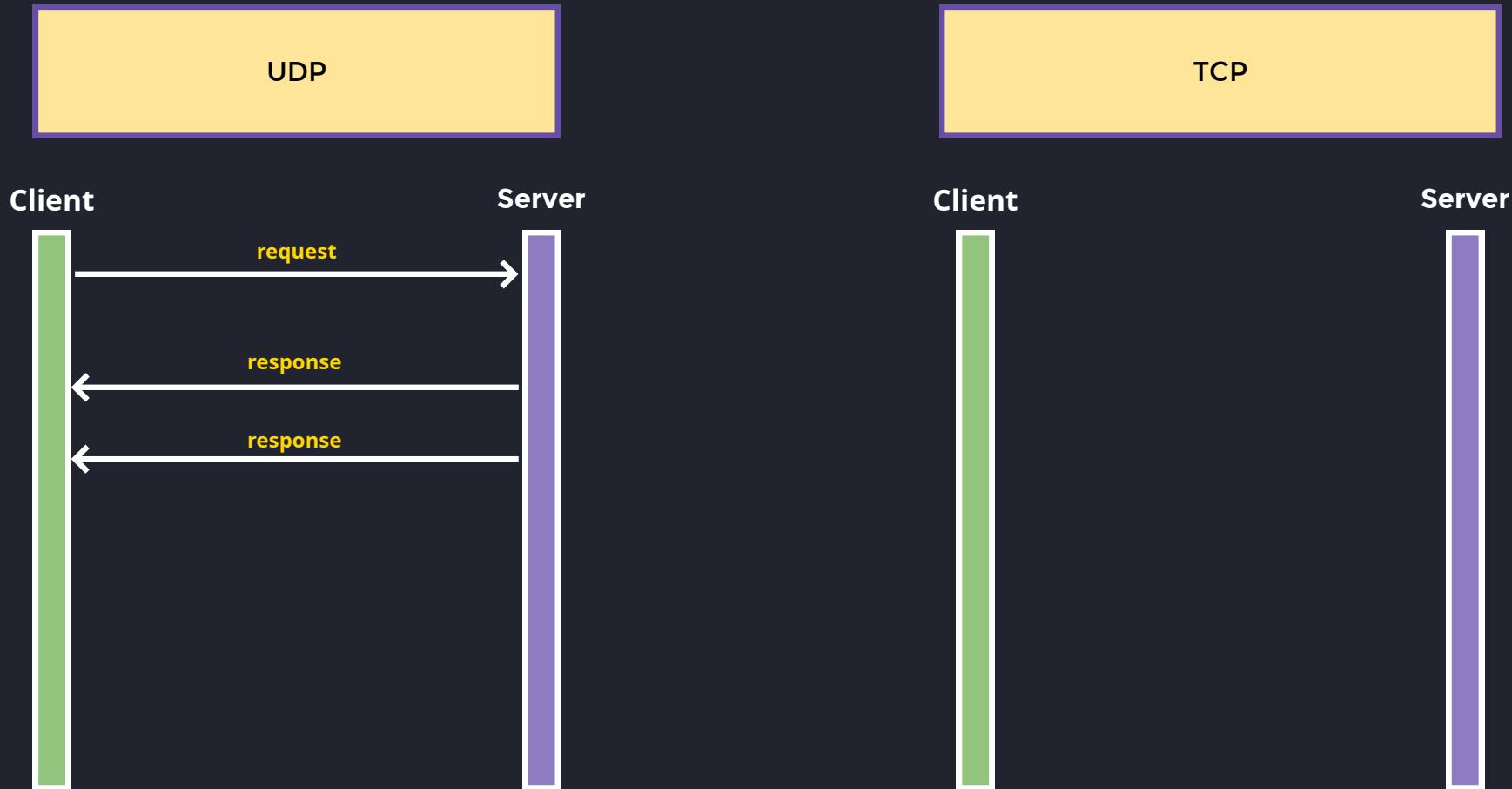
# Network Connectivity: Protocols overview



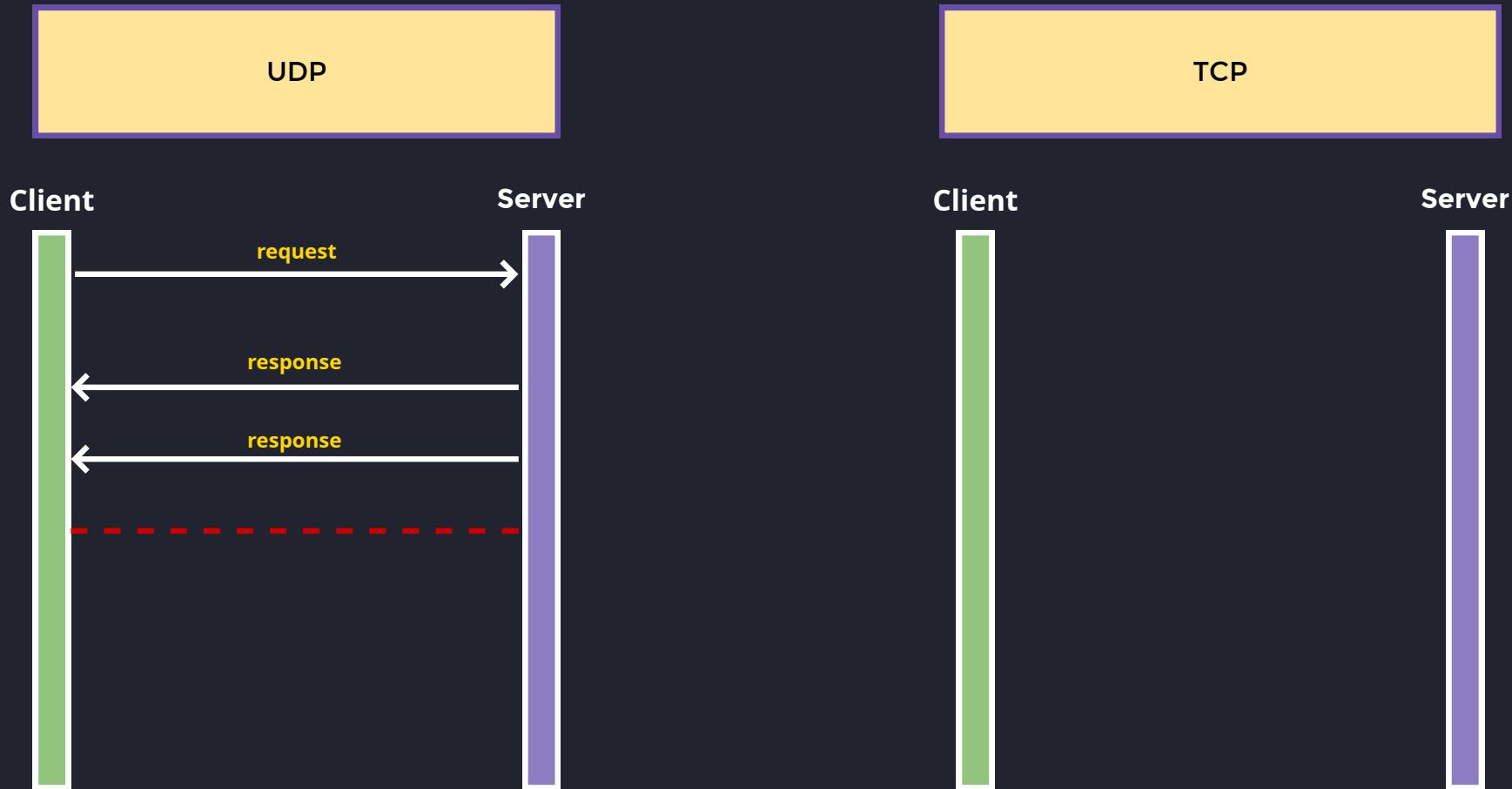
# Network Connectivity: Protocols overview



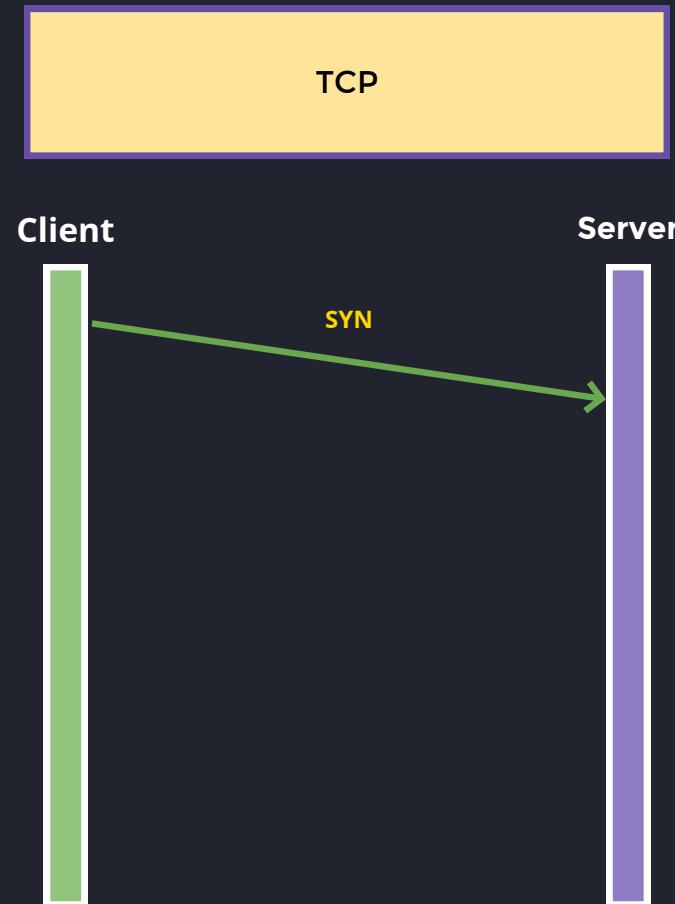
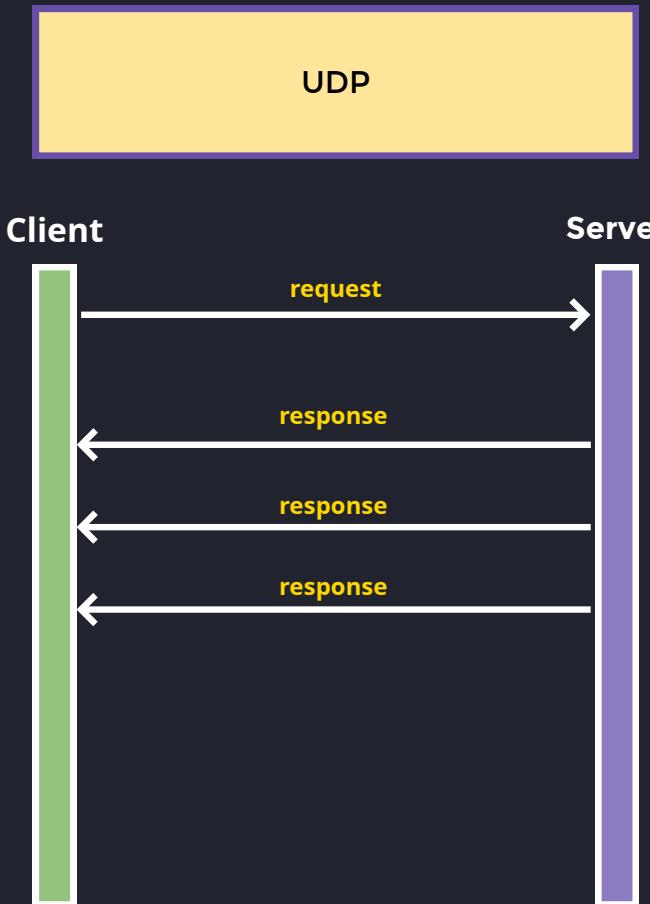
# Network Connectivity: Protocols overview



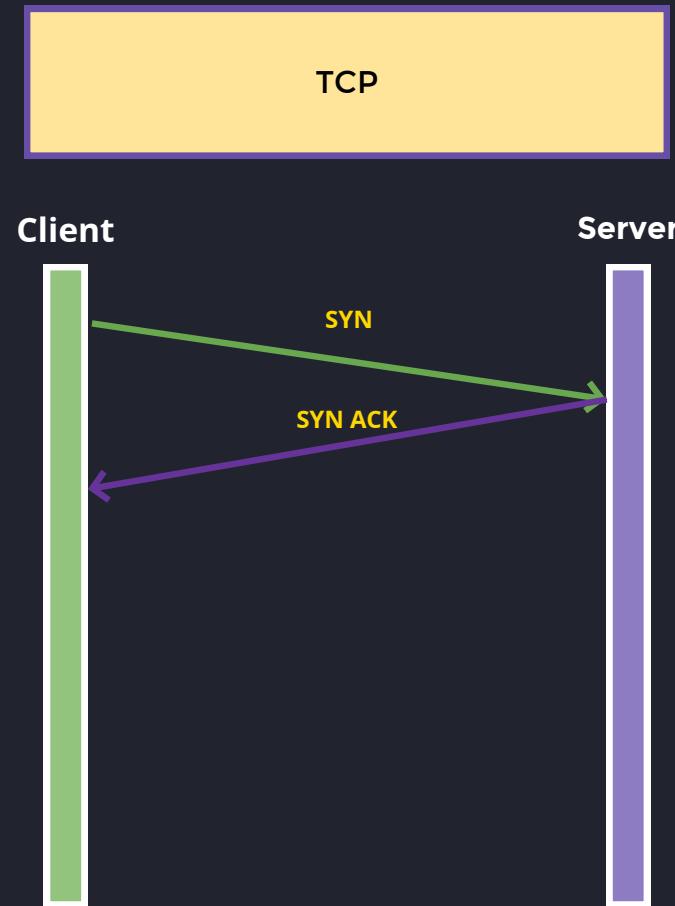
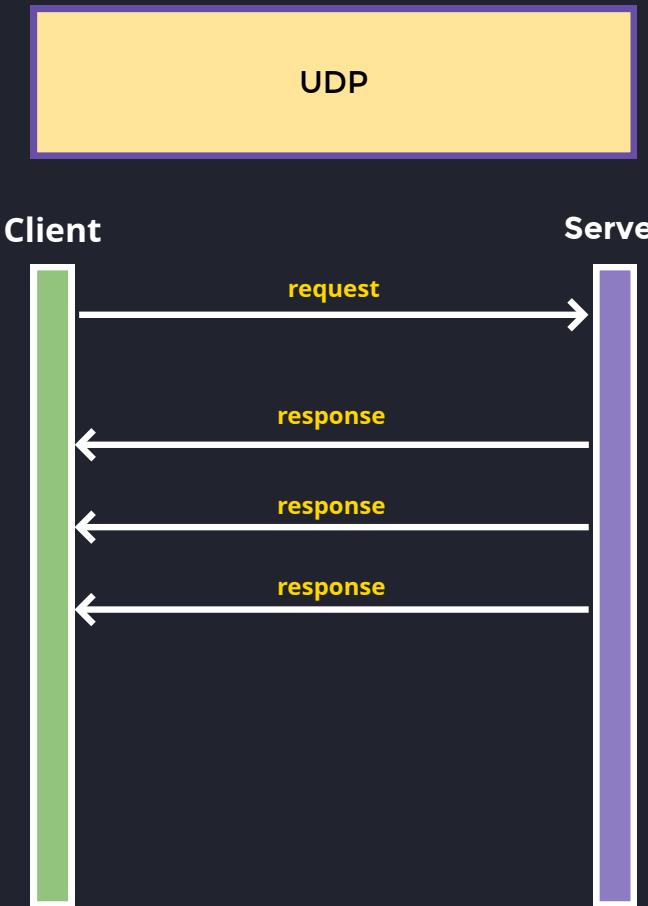
# Network Connectivity: Protocols overview



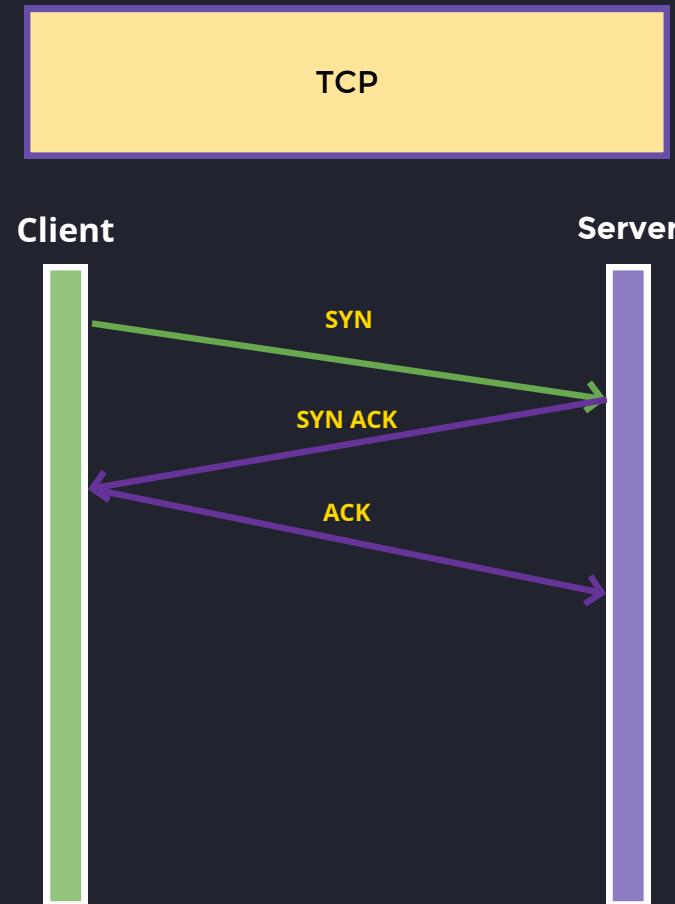
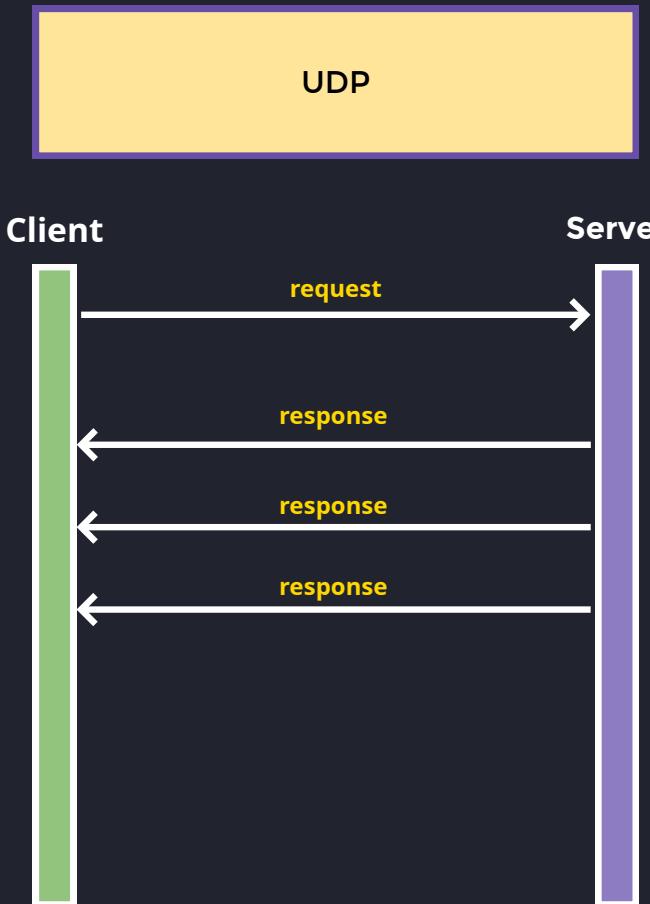
# Network Connectivity: Protocols overview



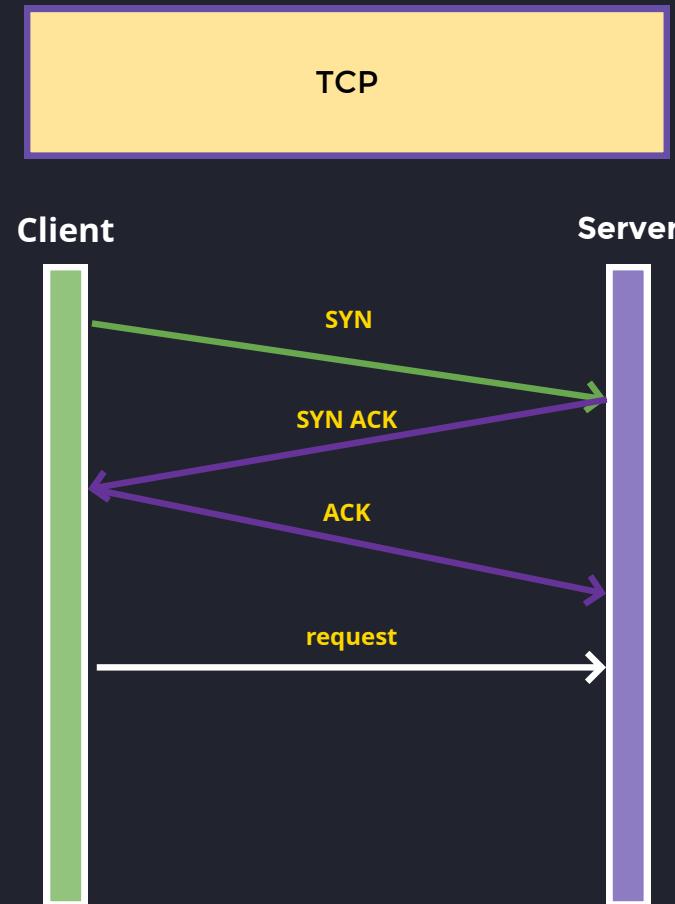
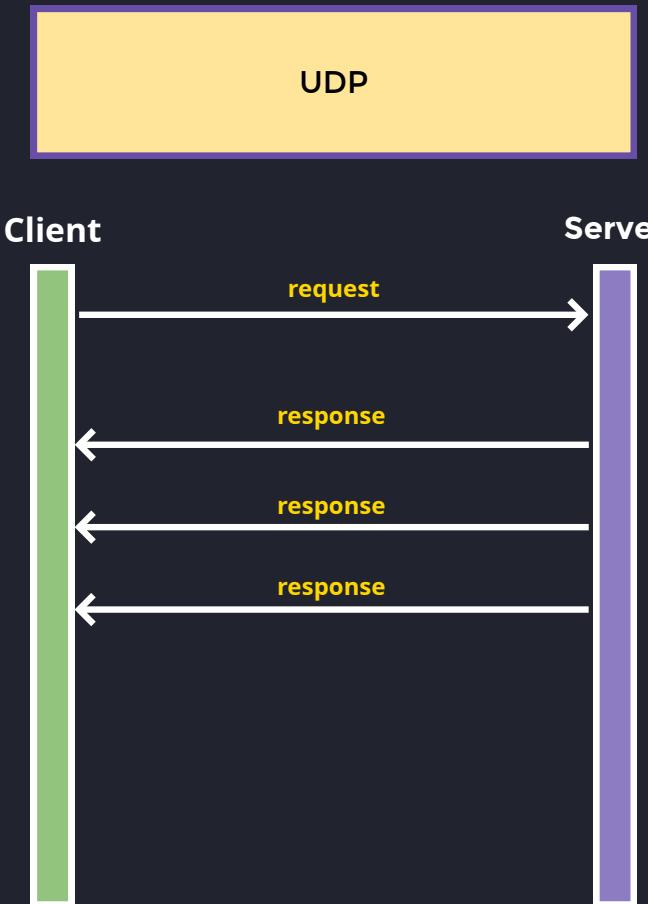
# Network Connectivity: Protocols overview



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# Network Connectivity: Protocols overview

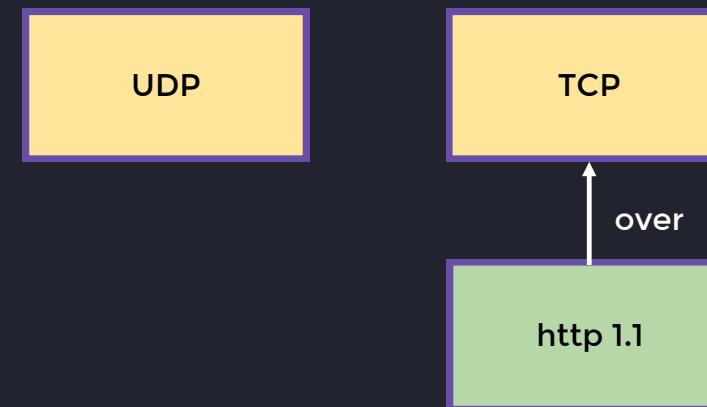


# Network Connectivity: Protocols overview

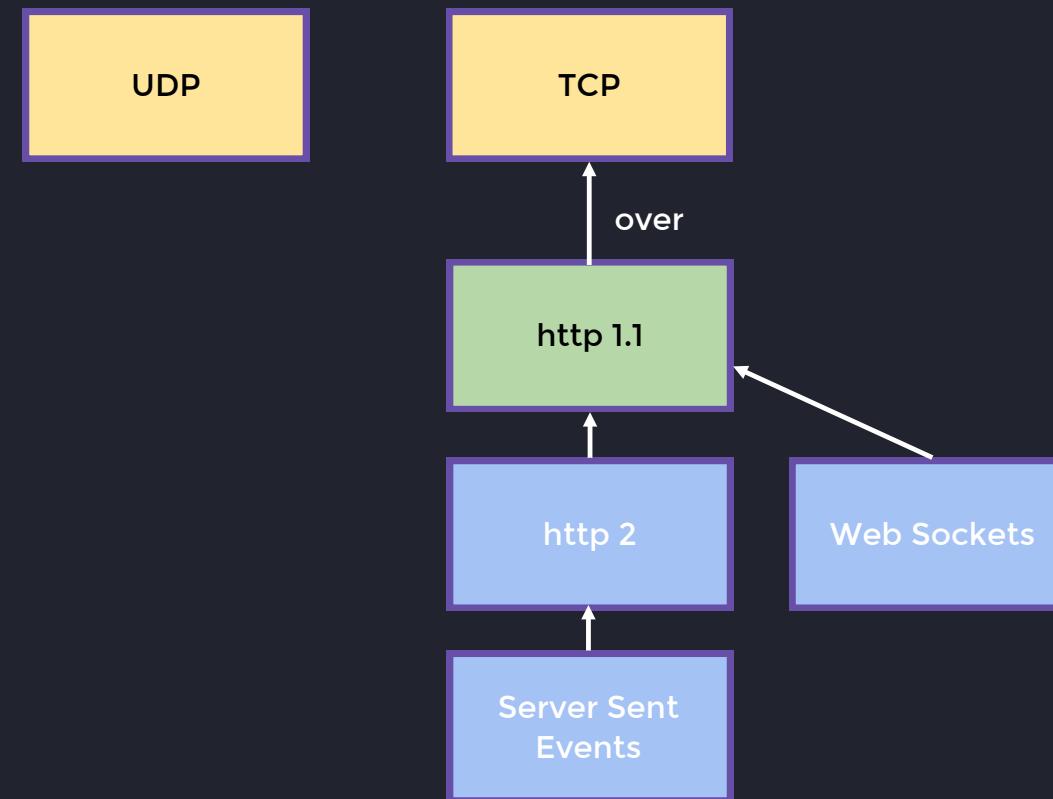
UDP

TCP

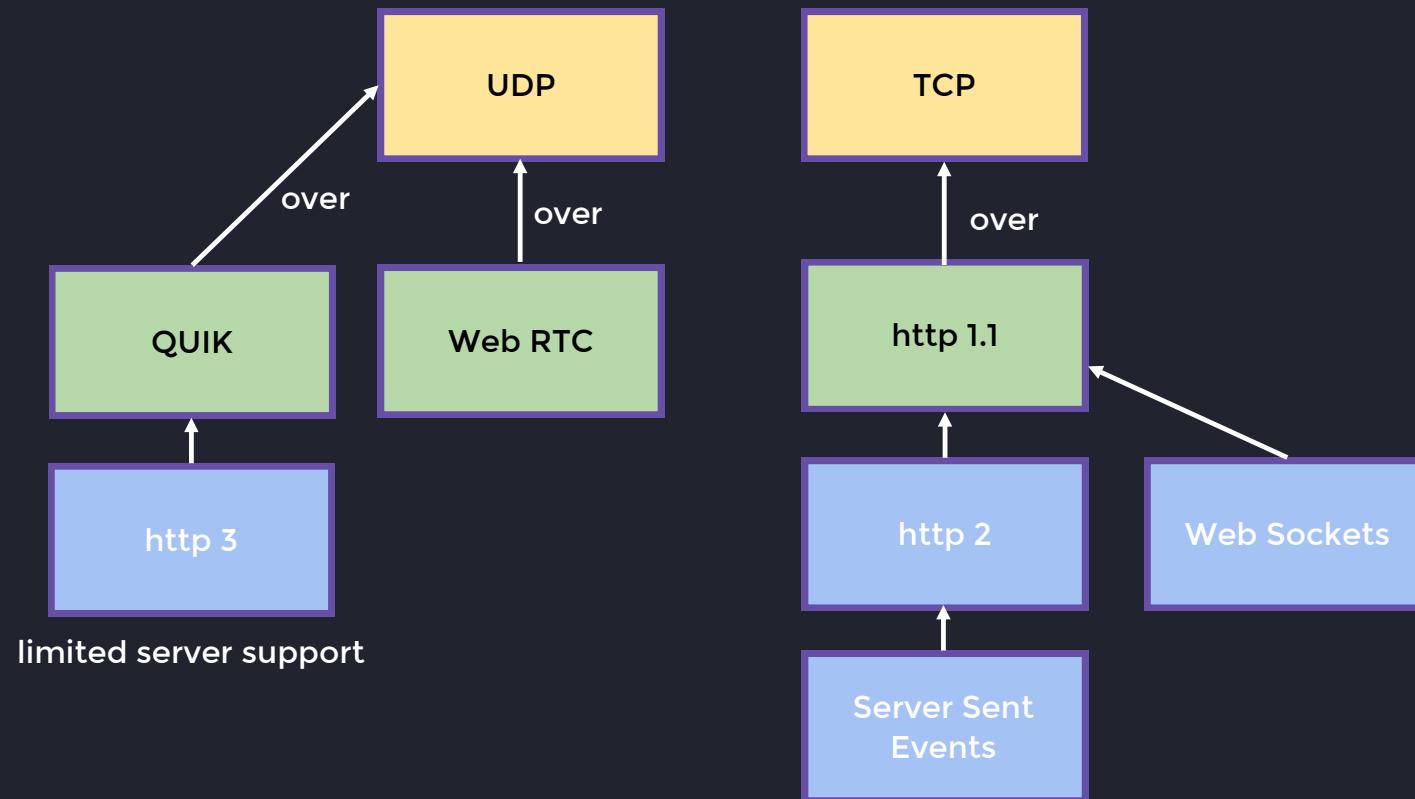
# Network Connectivity: Protocols overview



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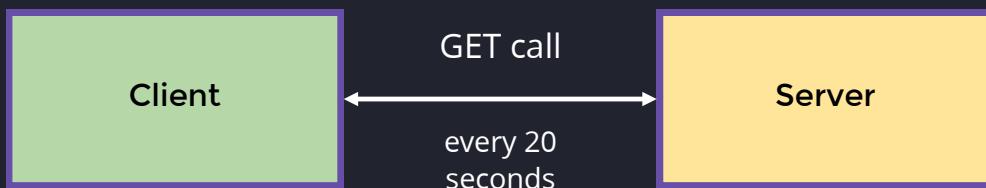


# Network Connectivity: Protocols overview



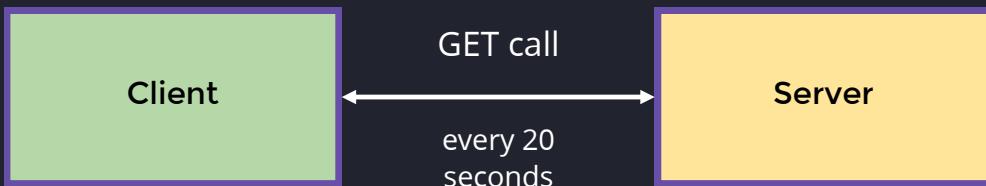
# Network Connectivity: Long polling

Getting new order



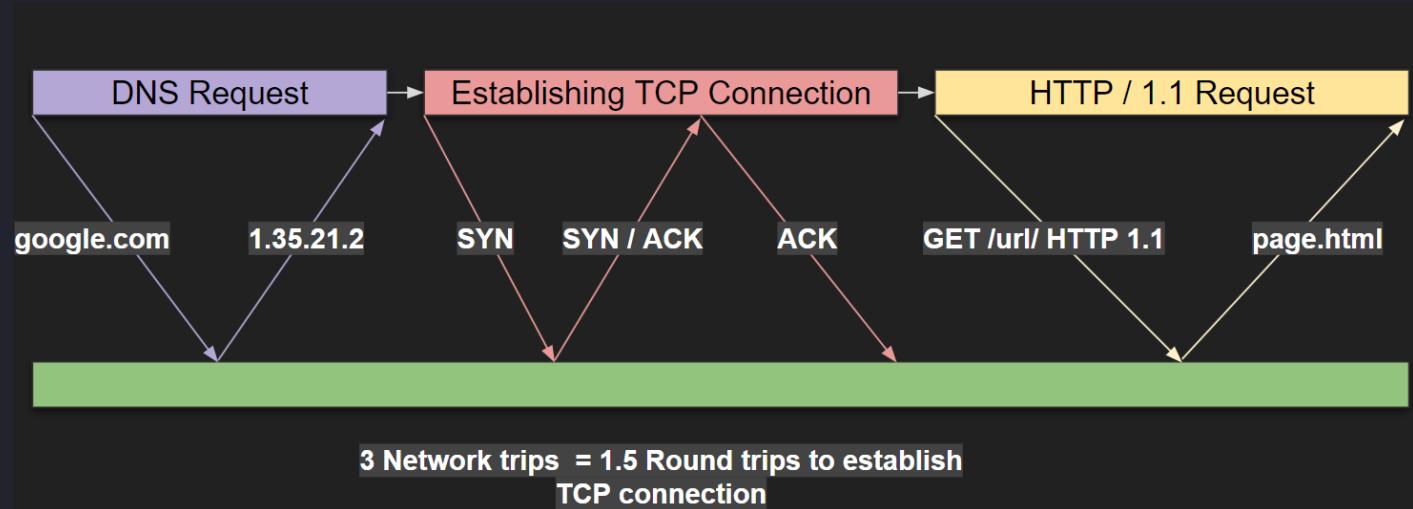
# Network Connectivity: Long polling

Getting new order

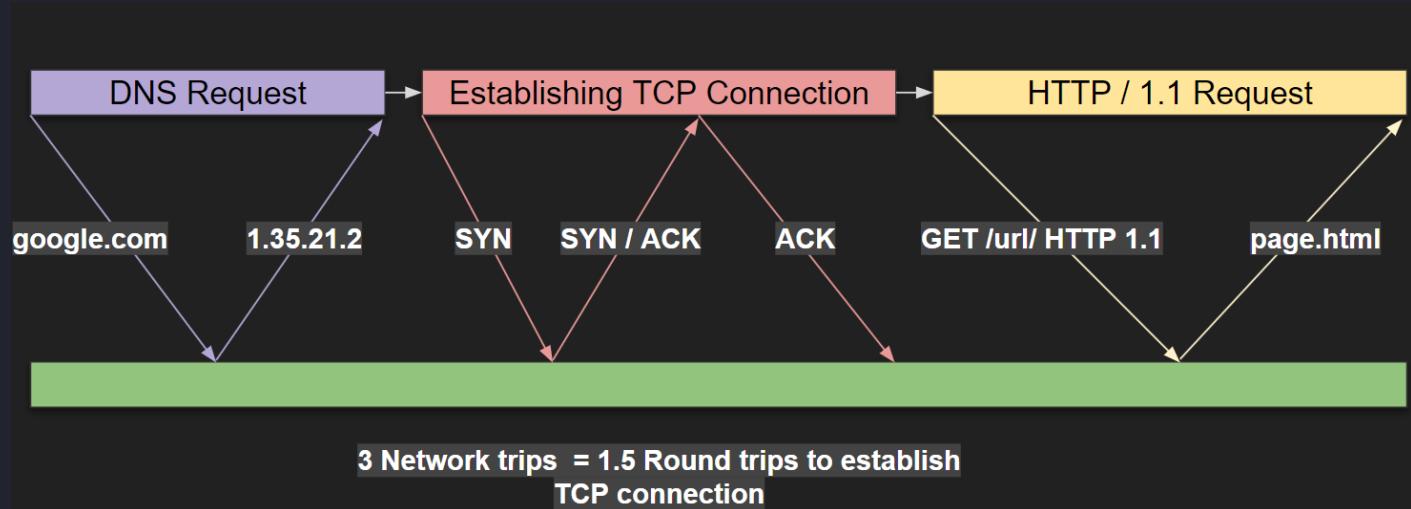


```
1 setInterval(() => {  
2   fetch(api, params).then(updateOrders);  
3 }, timeout);
```

# Problem 1: Energy Consumption



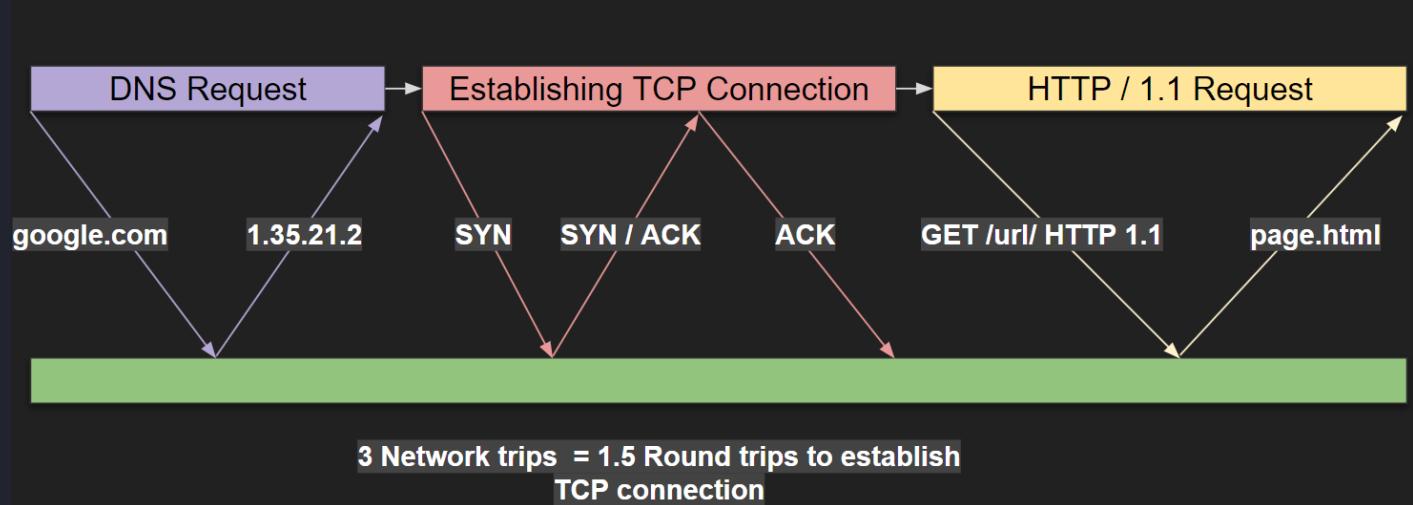
# Problem 1: Energy Consumption



## Establishing the connection:

- It costs **a lot of CPU time**.
- **Drains energy** as a result
- **Inefficient network usage** since you need to send the header data in each request

# Problem 1: Energy Consumption



## Establishing the connection:

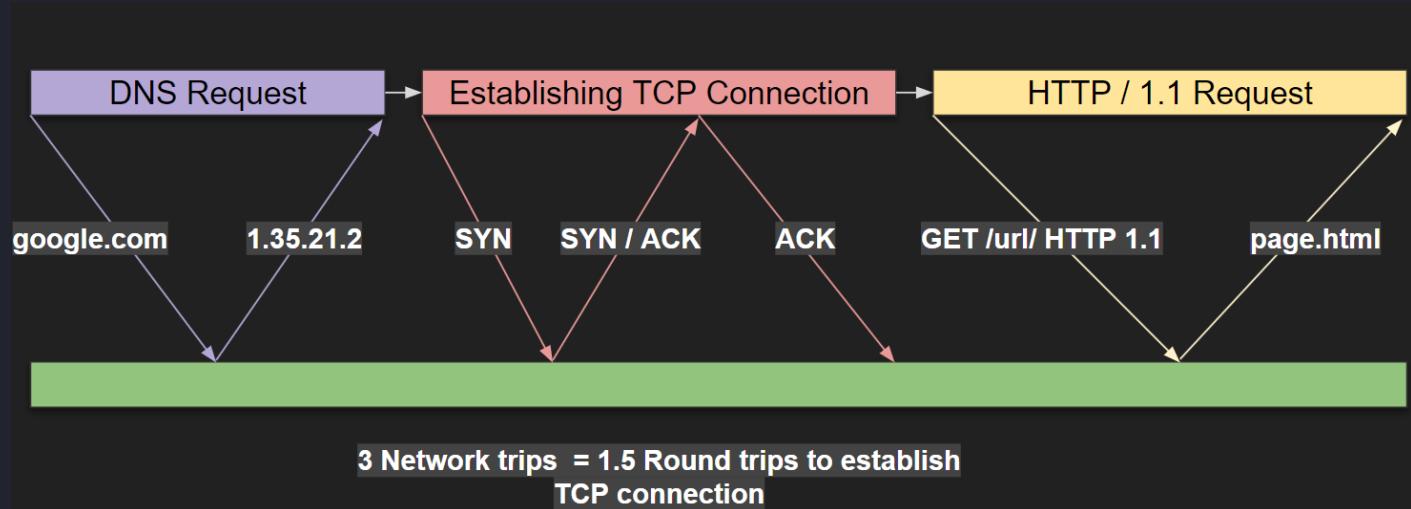
- It costs **a lot of CPU processing**.
- **Drains energy** as a result
- **Inefficient network usage** since you need to send the header data in each request

## Energy drain estimate ([link](#)):

**Timeout:** 30 seconds  
**Timeframe:** 5 minutes  
**Battery:** 2000 mAh / 3.7V  
**Energy use:** 600 joules / 5-minute

----  
**Battery life:** 3.7 hours

# Problem 1: Energy Consumption



## Establishing the connection:

- It costs **a lot of CPU processing**.
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Mobile Network Module

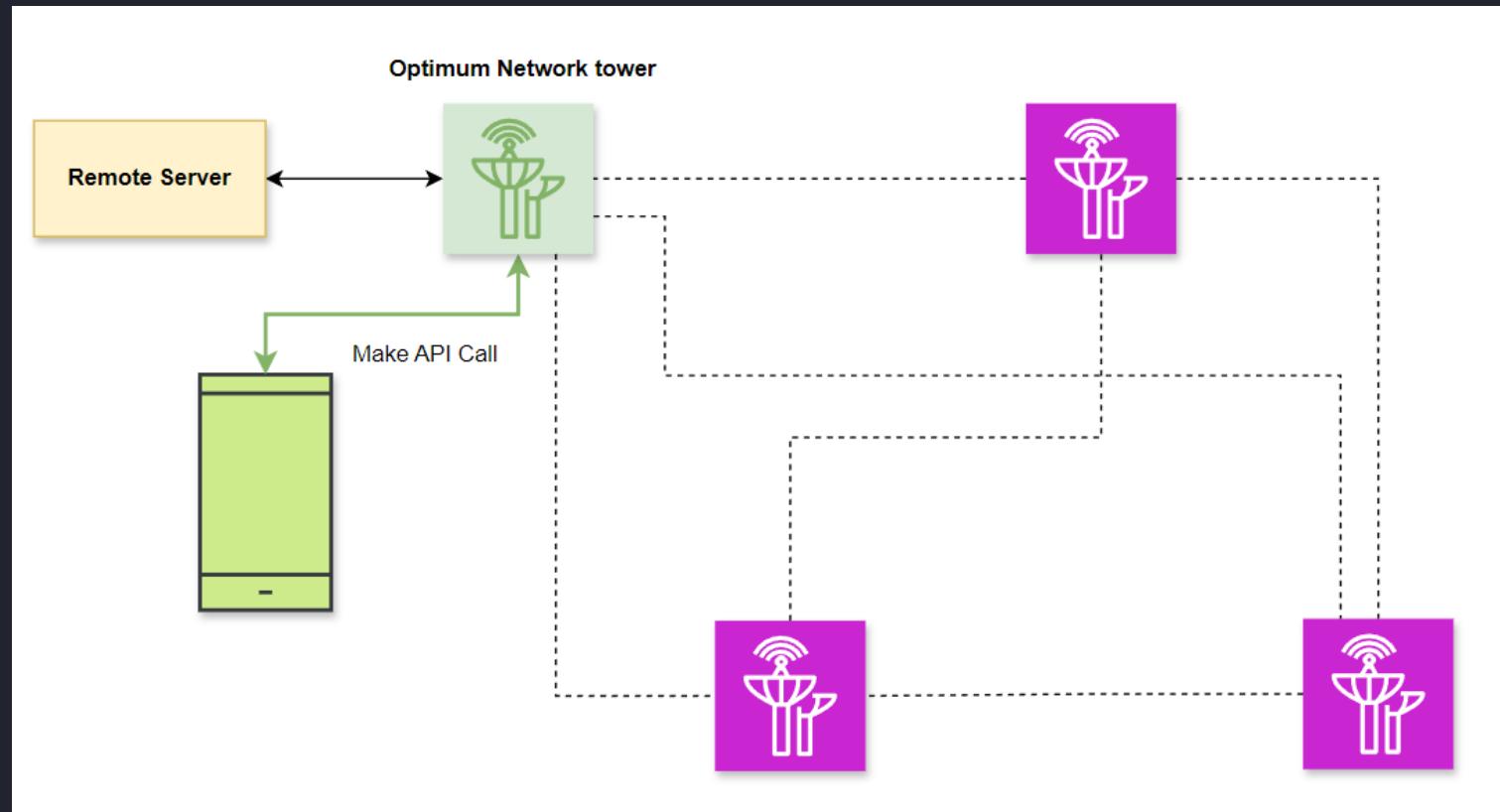
Mono (receive-only)

Duplex (bi-directional)

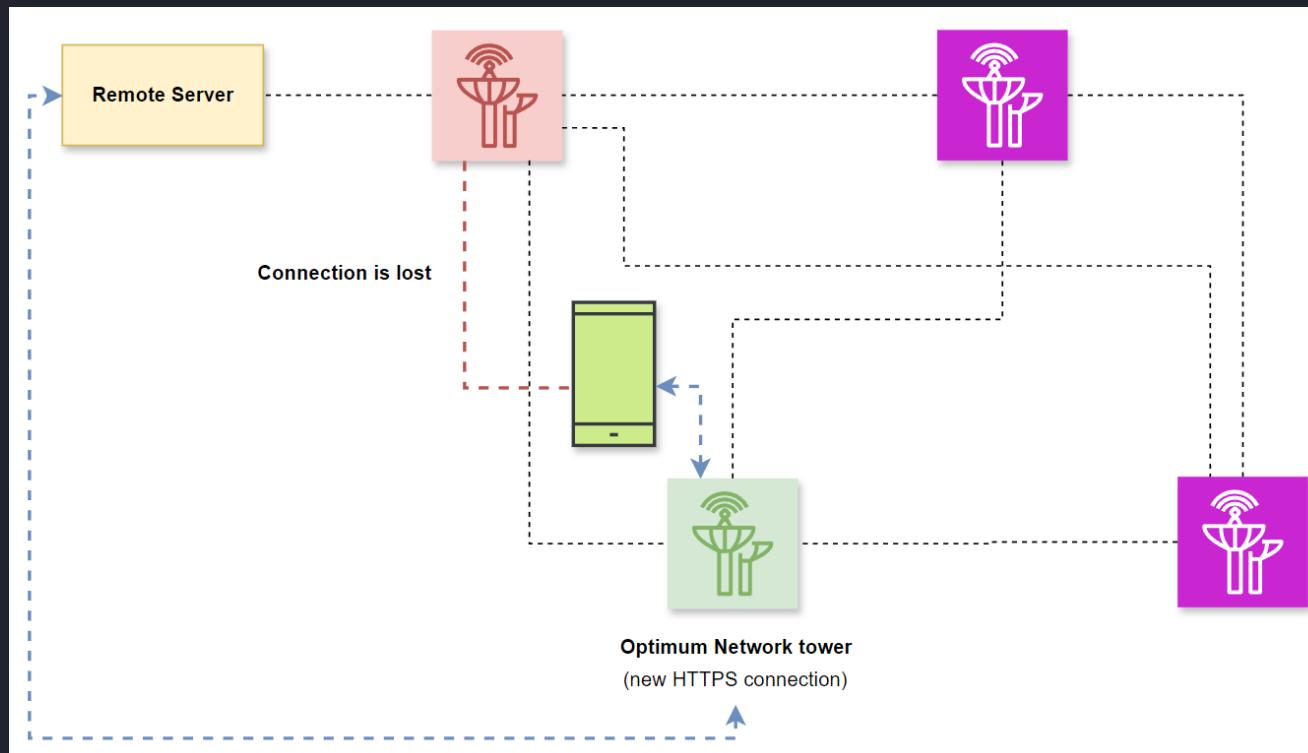
Energy efficient, but can only receive data

Can receive and sent the data, but use a lot of energy

## Problem 2: Latency



## Problem 2: Latency



### Reconnection complexities:

1. Server needs to keep a state
2. Reconnection needs to be implemented on the client
3. New TCP connection (3 way hand-shake)

# Long Polling: Summary

## Pros:

1. Easy & cheap to implement
2. No additional infrastructure is needed.
3. 99.9% of servers will support that

## When to use it

A desktop web application where some delays are acceptable. For instance, loading new group posts is totally fine with long polling on a desktop.

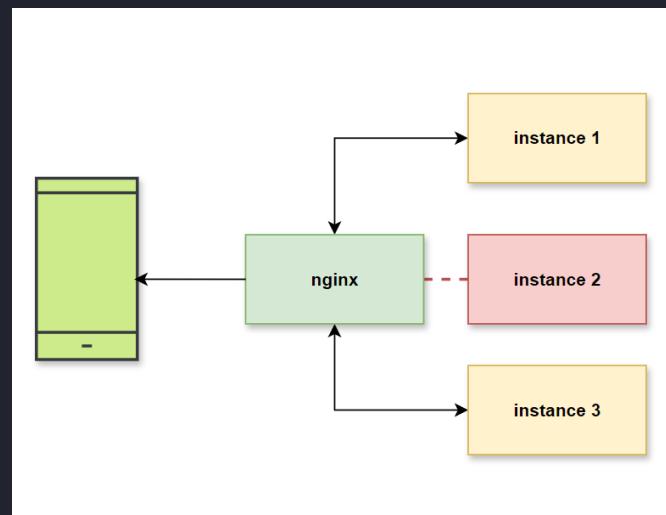
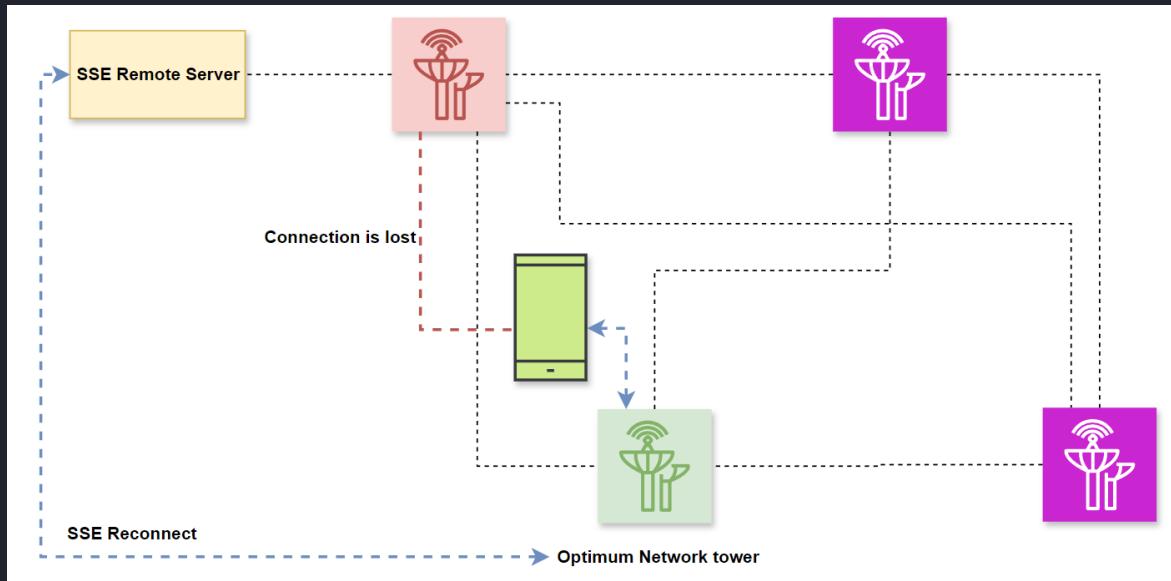
## Cons:

1. Battery inefficient (High CPU usage due to open TCP connection and transmitter usage)
2. Network & Data inefficient
3. HTTP 1.1 requires request headers to be sent with every request
4. Latency can degrade very quickly on mobile networks.

## When to avoid

Mobile web application

# Network Connectivity: Server Sent Events



## Benefits of SSE

1. Duplex communication is only used when establishing initial connection
2. It doesn't send junk data (unnecessary headers)
3. Reconnection is **handled automatically**
4. Easy to scale since servers don't need to know the state
5. Since SSE is HTTP2 based, it can re-use existing TCP connection with a server

# Summary: Server Sent Events

## Pros:

1. Automatic reconnection handling
2. Battery efficient (uses only receiver antenna)
3. Relatively easy to scale in terms of infrastructure
4. Minimal network overhead (you only receive the actual data without header overhead)
5. Fast

## Cons:

1. You can't push the data to the server.
2. Only string data is supported - you'll have to parse the payload

## When to use it

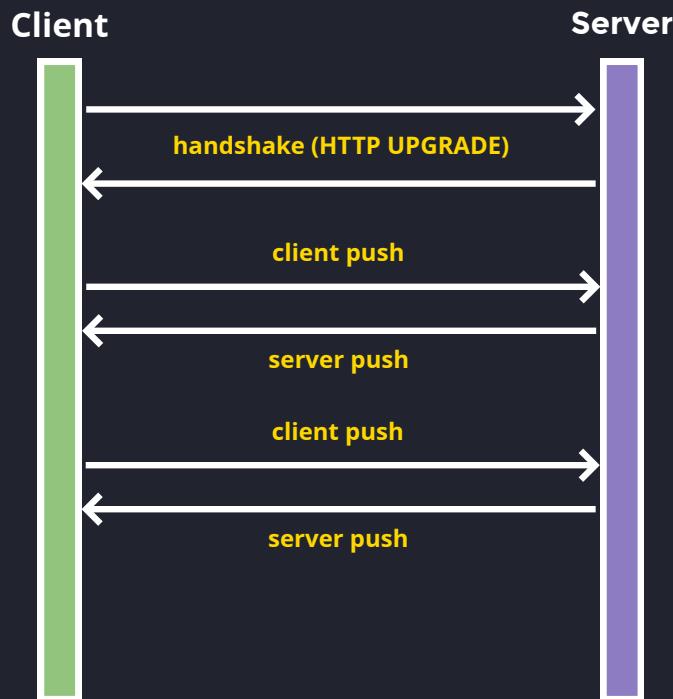
1. A desktop / mobile web application where you must receive data with minimum latency.
2. It can also be an alternative to `WebSockets` when some minor latency is acceptable.
3. Large text-data streaming

## When to avoid

Simple desktop apps, you'll be fine with long-polling

# Network Connectivity: Web-Sockets

## Anatomy



1. The client sends a handshake request with **UPGRADE** headers.
2. The server responds with a successful request.
3. Browser upgrades the protocol to **Web-Sockets**
4. Client and Server has a **bi-directional** communication meaning that it will use TCP connection to send binary packages

# Network Connectivity: Web-Sockets

## HTTP vs Web-Sockets

How web-sockets are different from HTTP requests?

1. HTTP is used make only initial **handshake**
2. Pure TCP connection is used afterwards
3. TCP-protocol allows to establish ~65K connections within one socket

### Pros:

1. web-sockets provide almost **real-time** communication mechanism
2. Unlimited number of connections

### Cons:

1. **Infrastructure cost.**
2. **Engineering cost.**
3. **Reconnection is not implemented.**
4. **Web-Sockets** are stateful.
5. **Computing resource inefficiency.**
  1. needs to maintain a constant TCP connection,
  2. uses duplex antenna
  3. drains energy and utilizes CPU

# Summary: Web-Sockets

## When to use it

**Real-time** communication environments. This is a huge advantage of the protocol.

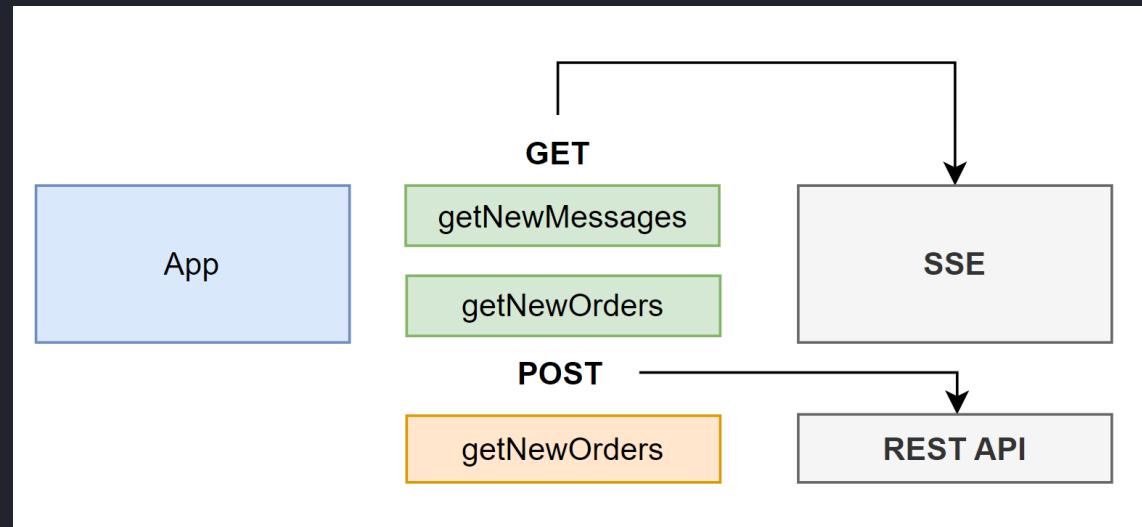
**Environments such as:**

1. Work with machine sensors / controls
2. Online gaming
3. Trading
4. Precise location tracking

# Summary: API Design example

Mobile      Desktop

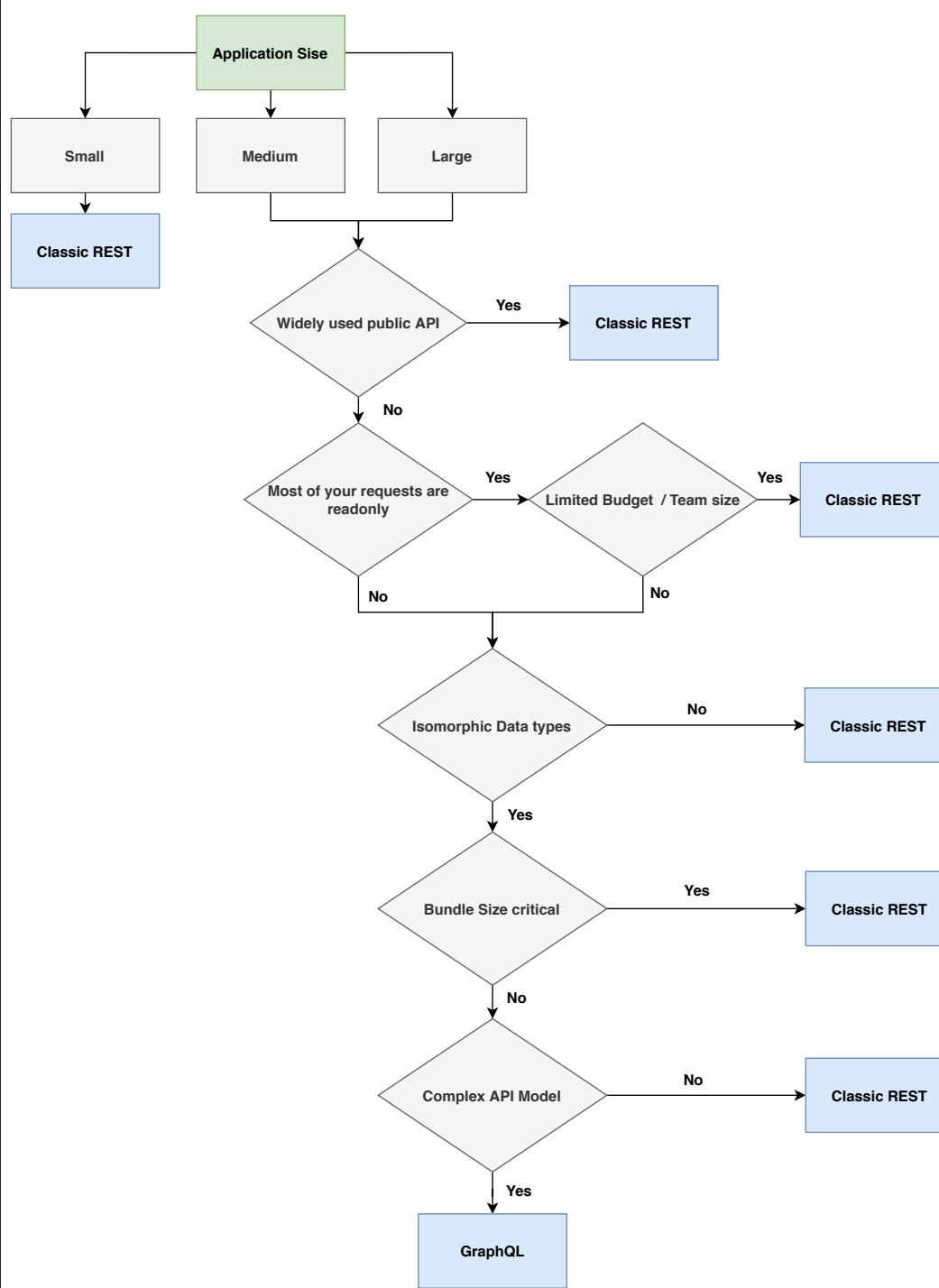
Mobile	Desktop		
getShoppingOrders	SSE	Long-polling, SSE	<code>getShoppingOrders(timestamp: number, count: number, token): Order</code>
getNewMessages	SSE	Short-polling, SSE	<code>getNewMessages(timestamp: number, count: number, token): Message</code>
sendMessage	HTTP POST	HTTP POST	<code>sendMessage(message, token): Message</code>



# Classic REST / GraphQL

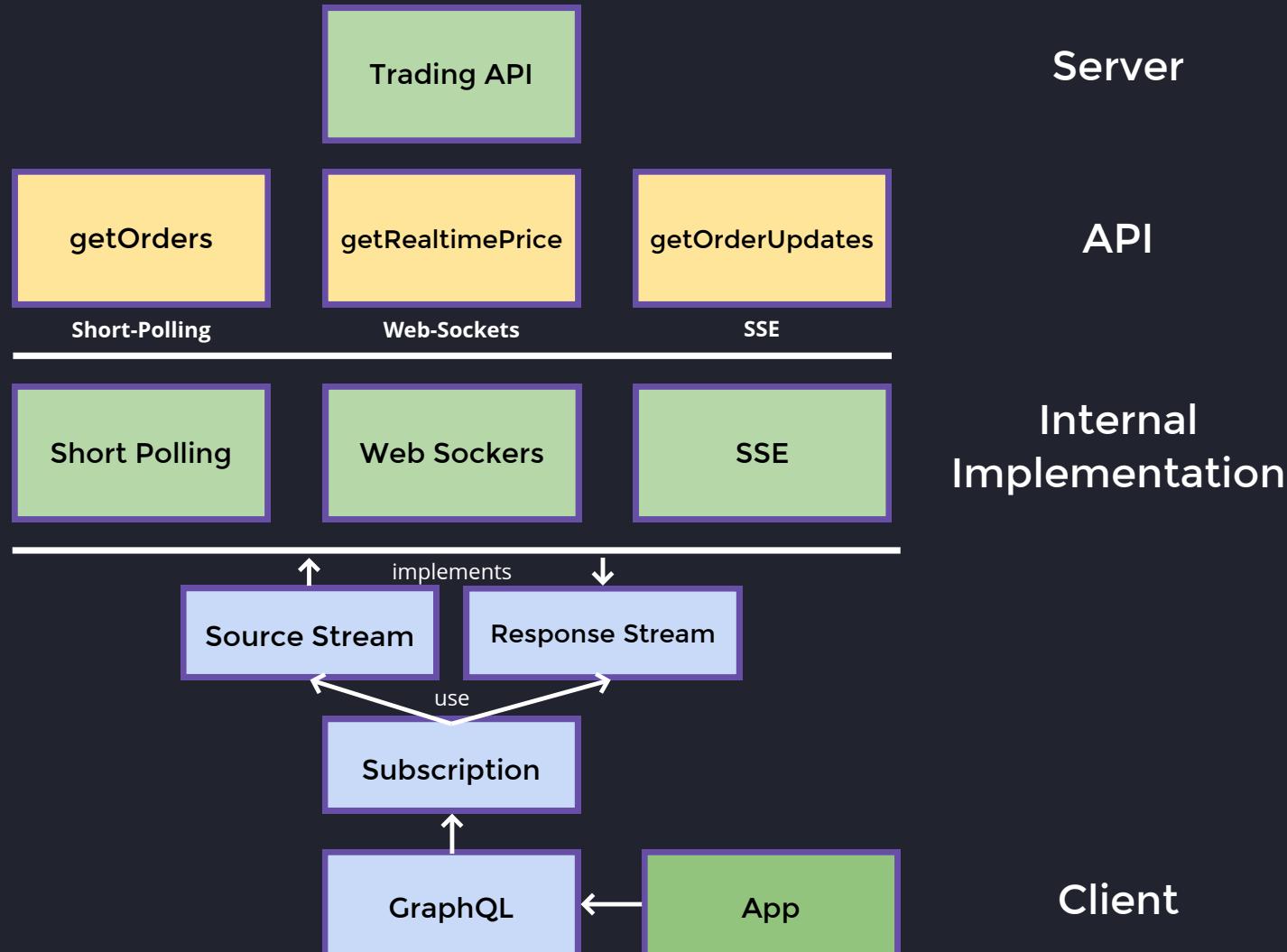
**GraphQL introduces additional complexity:**

1. Additional **client library** to work with server **GraphQL API**
2. Additional **client caching** layer
3. Additional **state manager - GraphQL Client** is responsible for syncing state between client and the server
4. Potential impact on your web-bundle size



**GraphQL provides the most value in Complex Apps.**

# GraphQL can reduce the complexity



## Summary: Network Connectivity

# Performance Optimization

# Performance Optimization: Web Vitals

## 1. Largest Contentful Paint (LCP):

- **What it measures:** Loading performance.
- **Goal:** LCP <= 2.5 seconds of page load start for a good user experience.

## 2. Interaction to Next Paint (INP):

- **What it measures:** Interactivity.
- **Goal:** INP <= 200 milliseconds or less for optimal user experience.

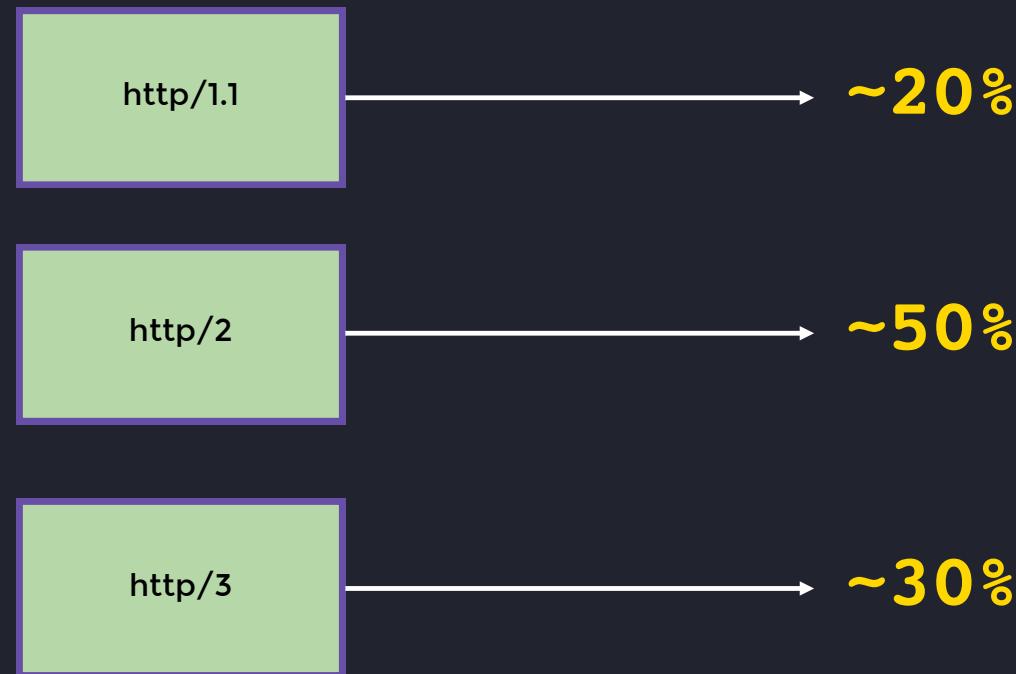
## 3. Cumulative Layout Shift (CLS):

- **What it measures:** Visual stability.
- **Goal:** Maintain a CLS of 0.1 or less to ensure a visually stable experience.



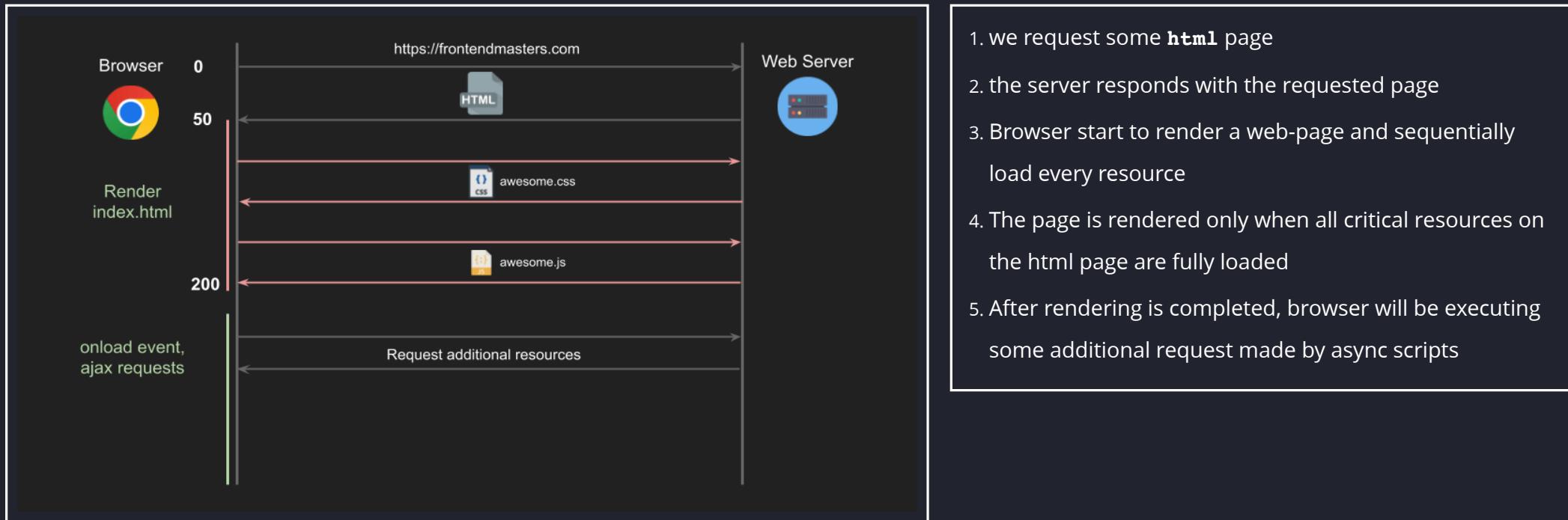
# Performance Optimization: Network Performance

## Communication Protocol



# Performance Optimization: Network Performance

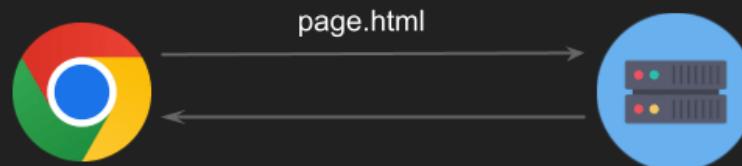
**http/1.1 - Loading efficiency limitation**



# Performance Optimization: Network Performance

**http/1.1 - data overhead**

```
GET /page.html HTTP/1.1
Accept: text/html,application/xhtml+xml,image/jxr/*/*
Accept-Encoding: gzip, deflate, br
Accept-Language: en-GB,en-US;q=0.8,en;q=0.6
Host: www.frontend-engineer.com
User-Agent: Chrome 1.1
```



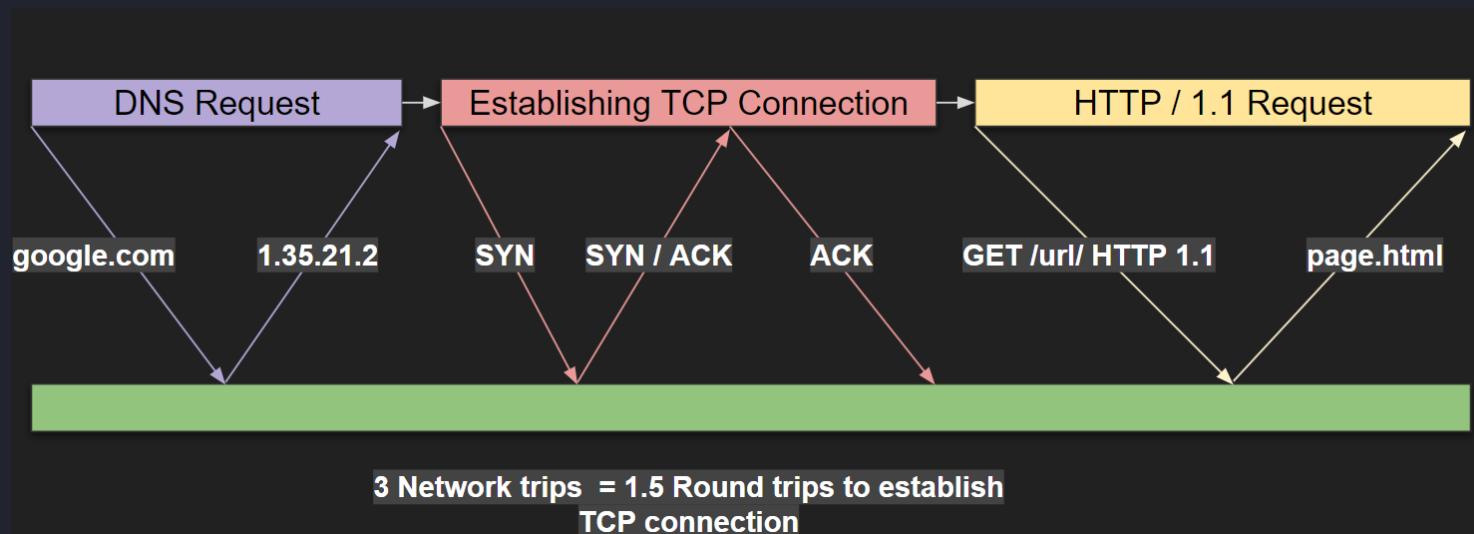
# Performance Optimization: Network Performance

**http/1.1 - maintenance cost**

**HTTP/1.1 server costs more for business in the long run**

# Performance Optimization: Network Performance

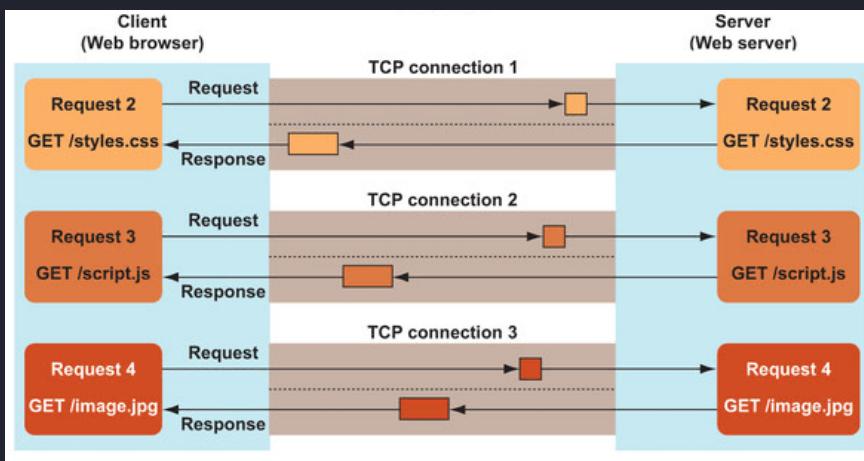
## Benefits of http/2 and http/3



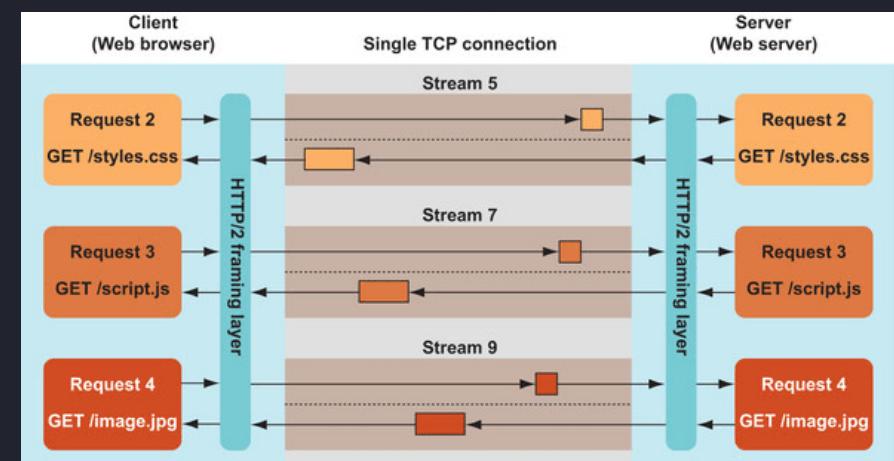
# Performance Optimization: Network Performance

## Benefits of http/2 and http/3 - Multiplexing

HTTP/1



HTTP/2



# Performance Optimization: Network Performance

## Benefits of http/2 and http/3 - Header Compression

HTTP/2+ provides 98% header compression

HTTP / 1.1 Header overhead

5KB

HTTP / 2 Header overhead

12.5 bytes

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

Guess the bundle size?

```
"FrontendMasters".matchAll(/Frontend/);
```

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

Guess the bundle size?

```
"FrontendMasters" .matchAll( /Frontend/ );
```

Function	ES5 Bundle Size	ES2020 Bundle size
String.prototype.matchAll	16.9 KB	69 B

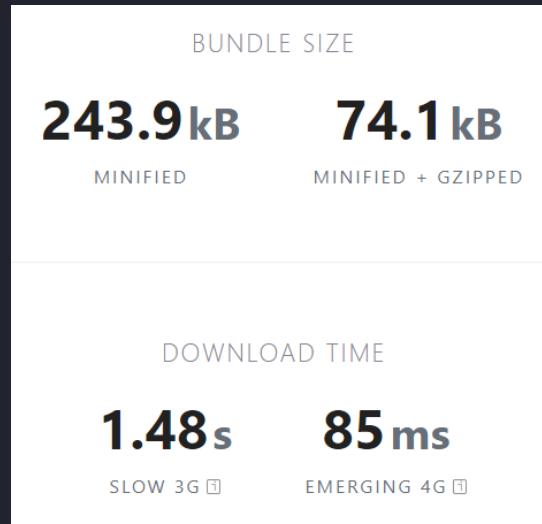
# Performance Optimization: Network Performance

## Javascript Bundle Optimization

Guess the bundle size?

```
"FrontendMasters" .matchAll( /Frontend/ );
```

Function	ES5 Bundle Size	ES2020 Bundle size
String.prototype.matchAll	16.9 KB	69 B



Core JS

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

Do we actually need polyfills?

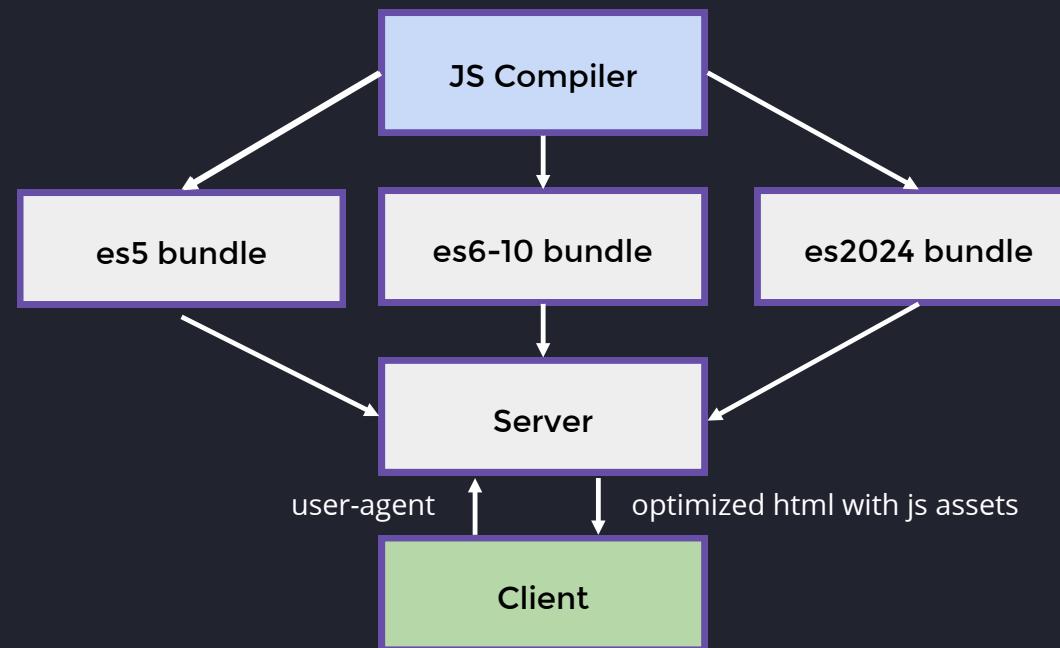
Here are a few facts:

1. **ES6** has a support of 98.2%
2. **ES7-10** has a support of 96%
3. **ES11** - 90%
4. **ES12** - 89%

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Multi-bundle approach

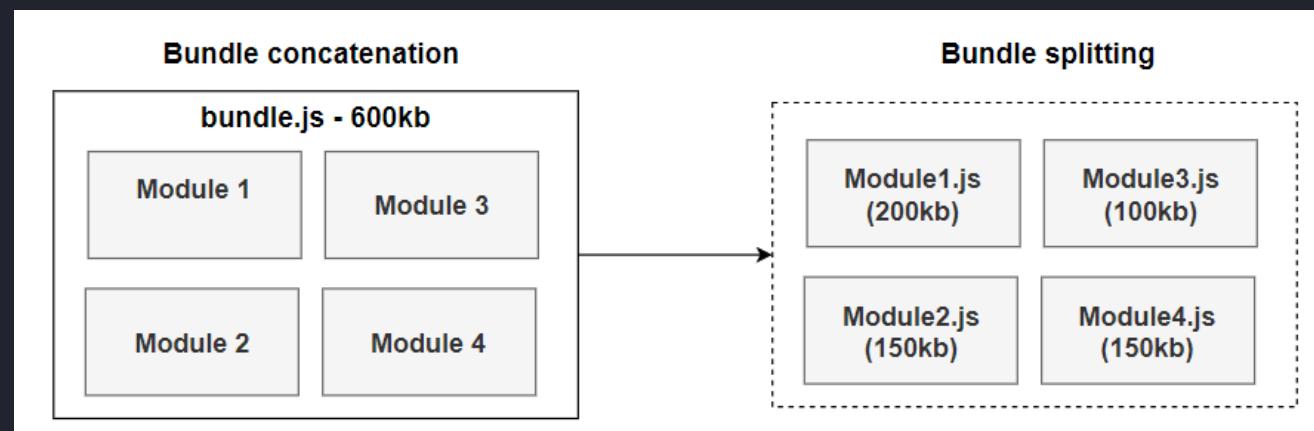


# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Code Split

```
const cta = document.getElementById("next-button");
cta.addEventListener('click', async () => {
  const {render} = await import('./module2.js');
  render(root);
}
);
```



# Performance Optimization: Network Performance

## Javascript Bundle Optimization

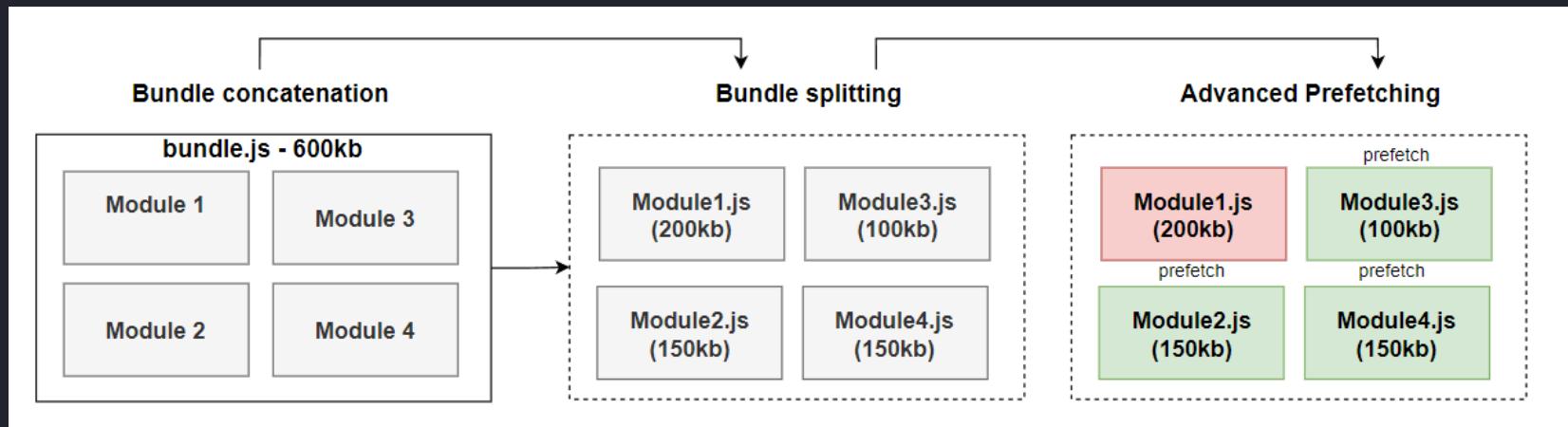
### Code Pre-fetch

Two values that are particular useful in these case are:

`<link rel="preload">` - preloads a resource in background with a high priority.

`<link rel="prefetch">` - preloads and caches a resource in background with a low priority.

```
<link rel="prefetch" href="./module2.js">
<link rel="prefetch" href="./module3.js">
<link rel="prefetch" href="./module4.js">
```



# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Code Minification & Compression

```
function helloworld() {  
  const longVariableName = 5 + 5;    —————> function h(){return 5+5}  
  return longVariableName;  
}
```

Average size reduction ~ 20%  
1MB -> 800KB

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Code Minification & Compression

```
function helloworld() {  
  const longVariableName = 5 + 5;    —————> function h(){return 5+5}  
  return longVariableName;  
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# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Code Minification & Compression

#### There are two main options

**brotli** is 20-30% more efficient, but less supported by older browsers

**gzip** is much faster and is supported in most of the browser

Library	Algorithm	Initial Size	Compressed	Ratio
jquery-3.7.1.js	Brotli	302 KiB	69 KiB	77%
jquery-3.7.1.js	gzip	302 KiB	83 KiB	73%
jquery-3.7.1.min.js	Brotli	85 KiB	27 KiB	68%
jquery-3.7.1.min.js	gzip	85 KiB	30 KiB	65%
lodash-4.17.21.js	Brotli	531 KiB	73 KiB	86%
lodash-4.17.21.js	gzip	531 KiB	94 KiB	82%
lodash-4.17.21.min.js	Brotli	71 KiB	23 KiB	68%
lodash-4.17.21.min.js	gzip	71 KiB	25 KiB	65%

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Code Minification & Compression

#### There are two main options

**brotli** is 20-30% more efficient, but less supported by older browsers

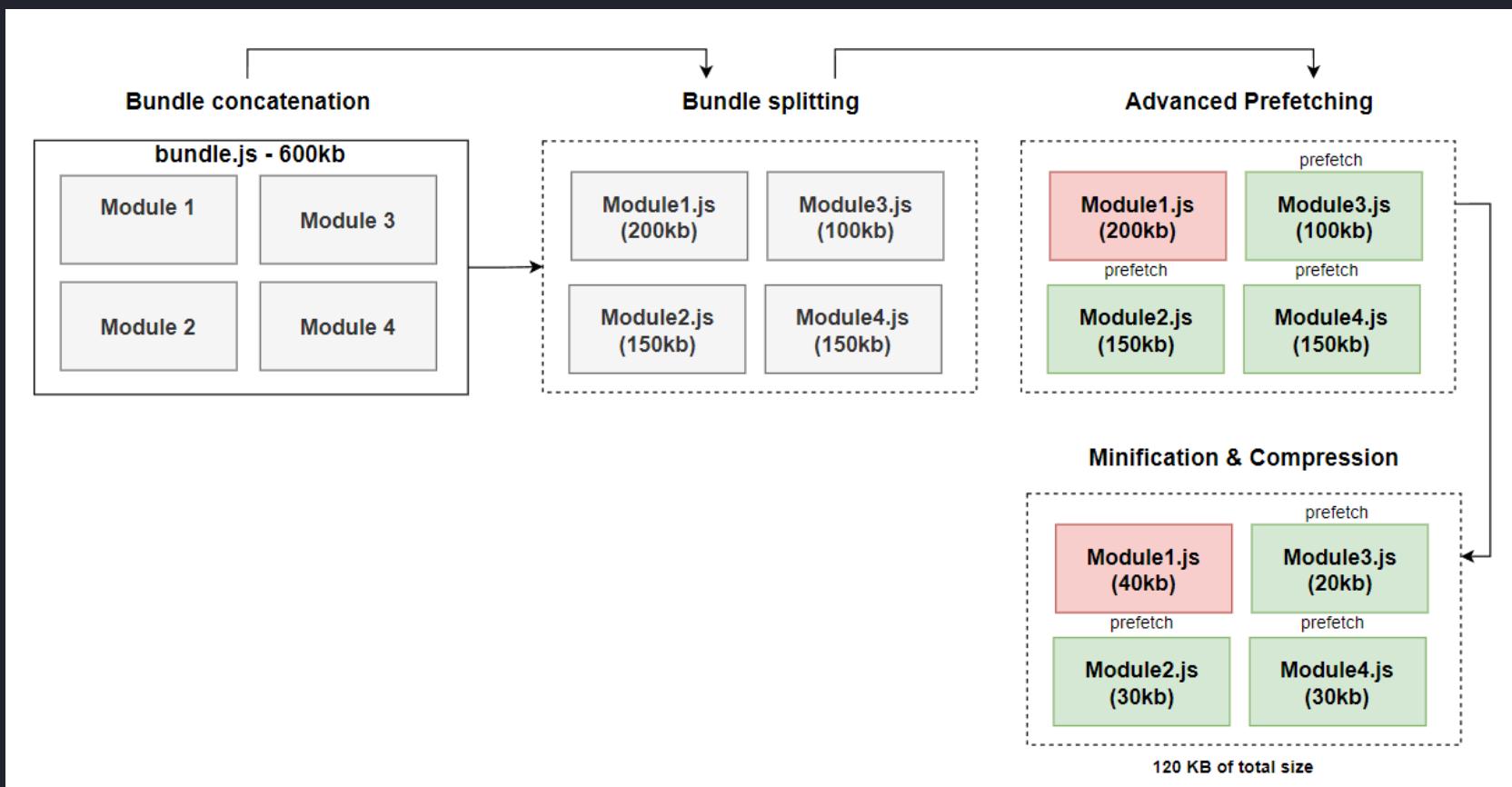
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lodash-4.17.21.min.js	gzip	71 KiB	25 KiB	65%

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Code Minification & Compression



# Performance Optimization: Network Performance

## Javascript Bundle Optimization

### Deferred Load

```
<script src="module1.js"></script> → 1  
<script src="analytics.js"></script> → 2  
<script src="telemetry.js"></script> → 3  
<script src="module2.js"></script> → 4
```

Normal loading order

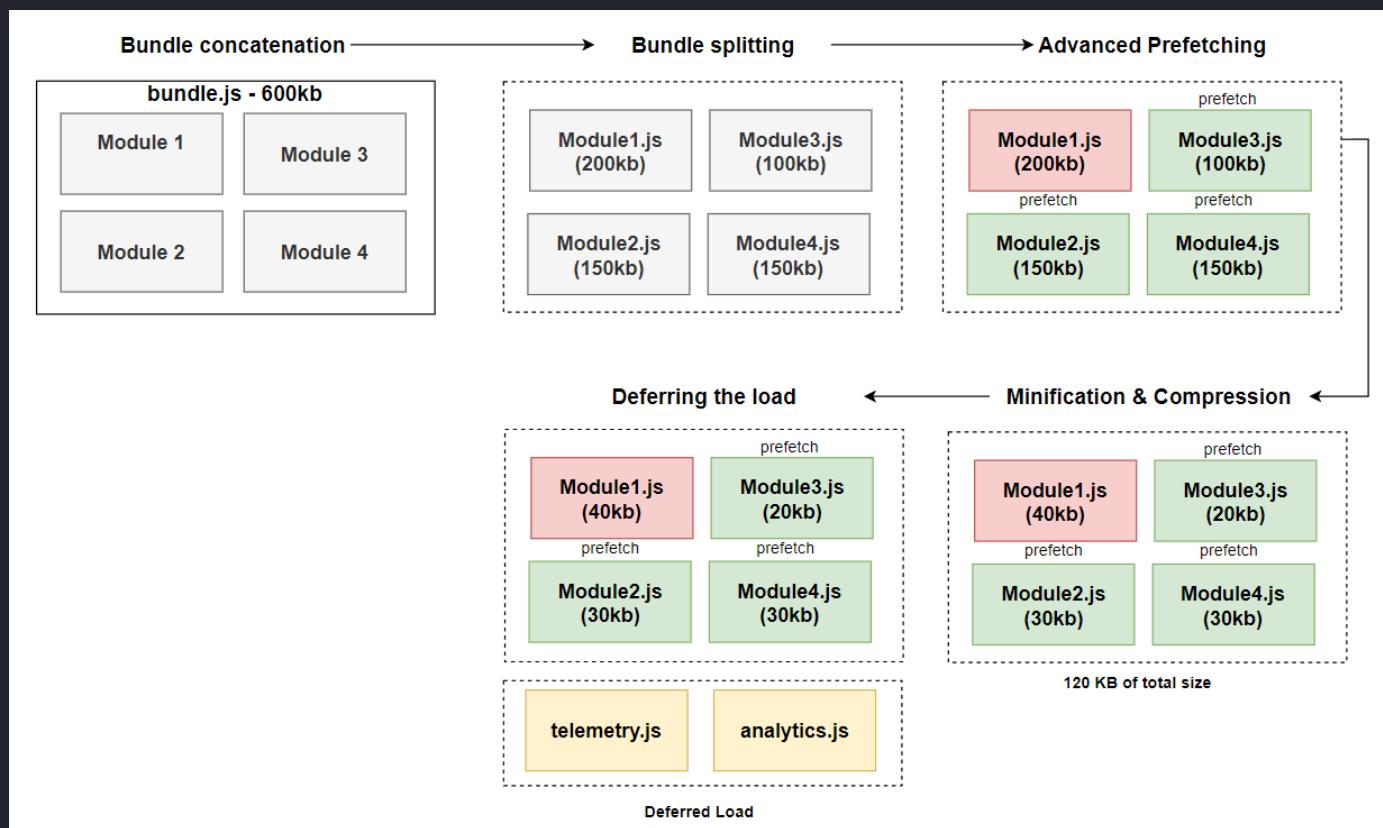
```
<script src="module1.js"></script> → 1  
<script src="analytics.js" defer></script> → 3  
<script src="telemetry.js" defer></script> → 4  
<script src="module2.js"></script> → 2
```

Load when every other asset is ready

# Performance Optimization: Network Performance

## Javascript Bundle Optimization

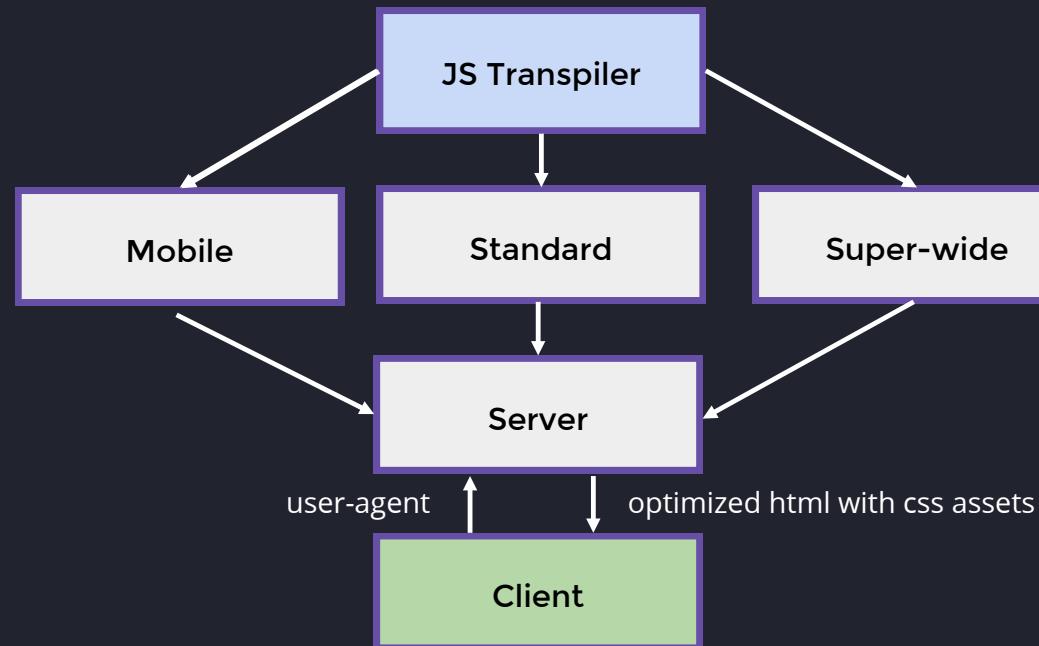
### Deferred Load



# Performance Optimization: Network Performance

## CSS Bundle Optimization

### Bundle Split



# Performance Optimization: Network Performance

## CSS Bundle Optimization

Minification and compression

### Tailwind

Uncompressed	Minified	Gzip	Brotli
2413.4kB	1967.4kB	190.2kB	46.2kB

# Performance Optimization: Network Performance

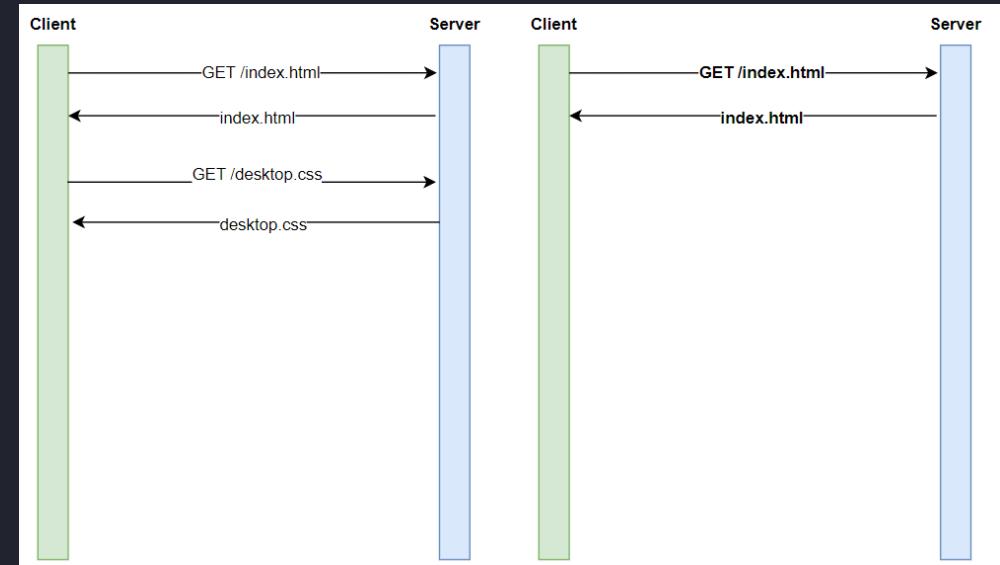
## CSS Bundle Optimization

### Critical style extraction

**There are two types of styles within the app:**

**critical** - application won't be rendered properly and can't be used

**non-critical** - pop-ups, advanced graphic features, inactive pages. Application will be able to work properly without it



# Performance Optimization: Network Performance

## CSS Bundle Optimization

### Critical style extraction

Non-optimized

```
<html>
  <head>
    <link rel="stylesheet"
          href="https://cdn.com/desktop.css"/>
  </head>
  <body></body>
</html>
```

Optimized

```
<html>
  <head>
    <style>
      #root { // Styles }
    </style>
  </head>
  <body></body>
</html>
```

# Performance Optimization: Network Performance

## CSS Bundle Optimization

### Fetching non-critical styles

#### Using media=print

```
<html>
<head>
<style>
  #root { // Critical Styles }
</style>
<link rel="stylesheet"
      href="https://cdn.com/non-critical.css"
      media="print"
      onload="this.media='all'"/>
</head>
<body></body>
</html>
```

#### Using "preload" marker

```
<html>
<head>
<style>
  #root { // Critical Styles }
</style>
<link rel="preload"
      as="style"
      href="https://cdn.com/non-critical.css"/>
</head>
<body></body>
</html>
```

# Performance Optimization: Network Performance

## CSS Bundle Optimization

### Summary

**Split** the bundle when necessary

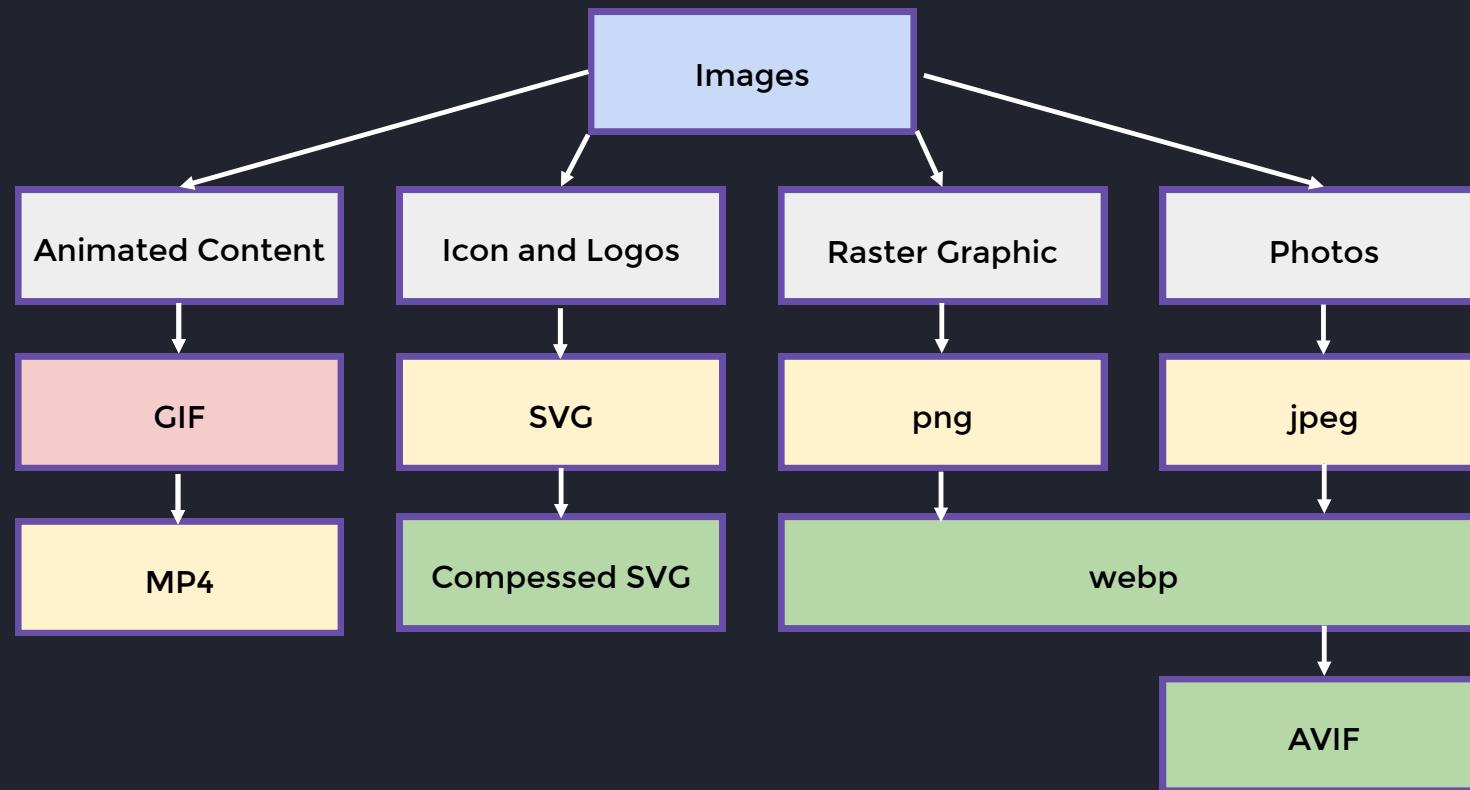
**Minify** and Compress

**Inline** critical resource

Non-critical resource can be downloaded on background

# Performance Optimization: Network Performance

## Image Assets Optimization: Choosing right format



# Performance Optimization: Network Performance

Image Assets Optimization: **Choosing right format**

16KB GIF



5KB webp



# Performance Optimization: Network Performance

## Image Assets Optimization: Choosing right format

webp

designed to replace **png**, **jpg** and **gif** for usage on the web pages

AVIF

New image encoding format has the same benefits of **web** with even better compression and picture quality

AVIF (Uncompressed) 6.2MB



WEBP (Uncompressed) 7.5MB



Quality	Size	Format	Result
Original	10 MB	jpeg	0
Original	7.5 MB	webp	-25%
Original	6.2 MB	avif	-38%
50%	1.2 MB	jpeg	-88%
50%	1.1 MB	webp	-89%
50%	1.1 MB	avif	-89%

# Performance Optimization: Network Performance

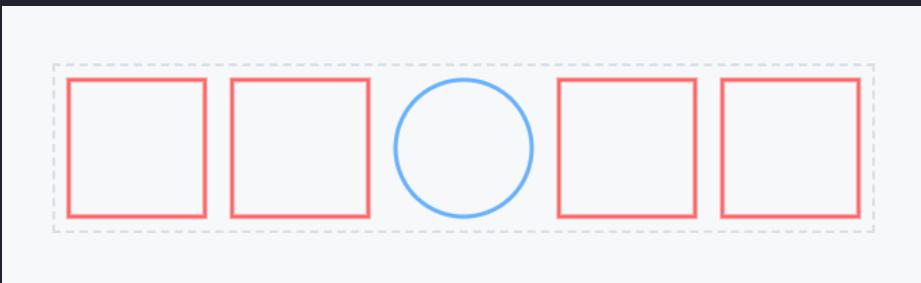
## Image Assets Optimization: Choosing right format



# Performance Optimization: Network Performance

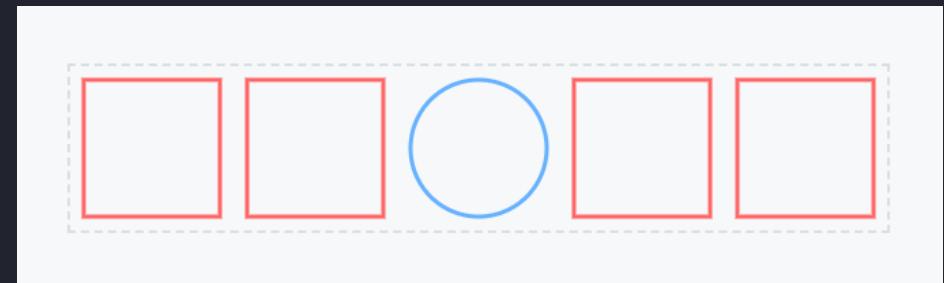
## Image Assets Optimization: SVG Path compression

Uncompressed - 0.7KB



```
1 <!-- 480 characters -->
2 <svg width="600" height="120" fill="none">
3   <rect x="10" y="10" width="100"
4     height="100" stroke-width="3"
5     stroke="#ff6666">
6   </rect>
7   <rect x="130" y="10"
8     width="100" height="100"
9     stroke-width="3" stroke="#ff6666">
10  </rect>
11  <ellipse cx="300" cy="60"
12    rx="50" ry="50"
13    stroke-width="3" stroke="#66b2ff">
14  </ellipse>
15  <rect x="370" y="10"
16    width="100" height="100"
17    stroke-width="3" stroke="#ff6666">
18  </rect>
19  <rect x="490" y="10"
20    width="100" height="100"
21    stroke-width="3" stroke="#ff6666">
22  </rect>
23 </svg>
```

Compressed- 0.2KB



```
1 <!-- 263 characters -->
2 <svg width="600" height="120" fill="none" stroke-width="3">
3   <path d="M10 10h100v100H10zm120 0h100v100H130z"
4     stroke="#f66">
5   </path>
6   <circle cx="300" cy="60"
7     r="50" stroke="#66b2ff"></circle>
8   <path d="M370 10h100v100H370zm120 0h100v100H490z"
9     stroke="#f66">
10  </path>
11 </svg>
```

# Performance Optimization: Network Performance

## Image Assets Optimization

### Summary

1. Compress images for web
2. Use optimized formats
3. Use SVG Path compression

# Performance Optimization: Network Performance

## Font Loading Optimization

Allow browser to display content when custom font is downloading

```
1 @font-face {  
2   src: "https://my-custom-font.com/font/";  
3   font-display: 'auto';  
4 }
```

Browser waits for 3 seconds to load

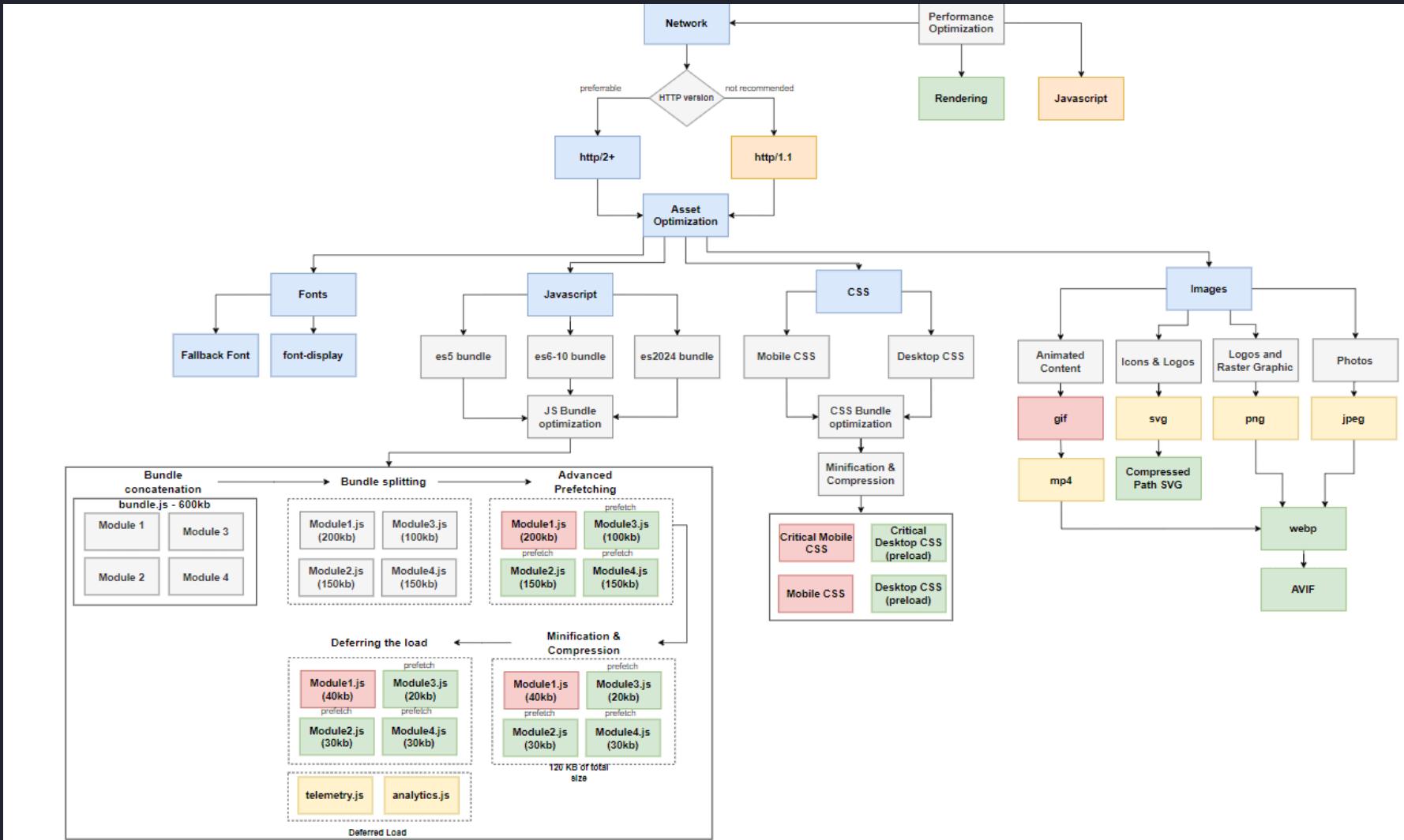
```
1 @font-face {  
2   src: "https://my-custom-font.com/font/";  
3   font-display: 'fallback';  
4 }
```

Render unstyled text immediately,  
switch if font is loaded within 3  
seconds

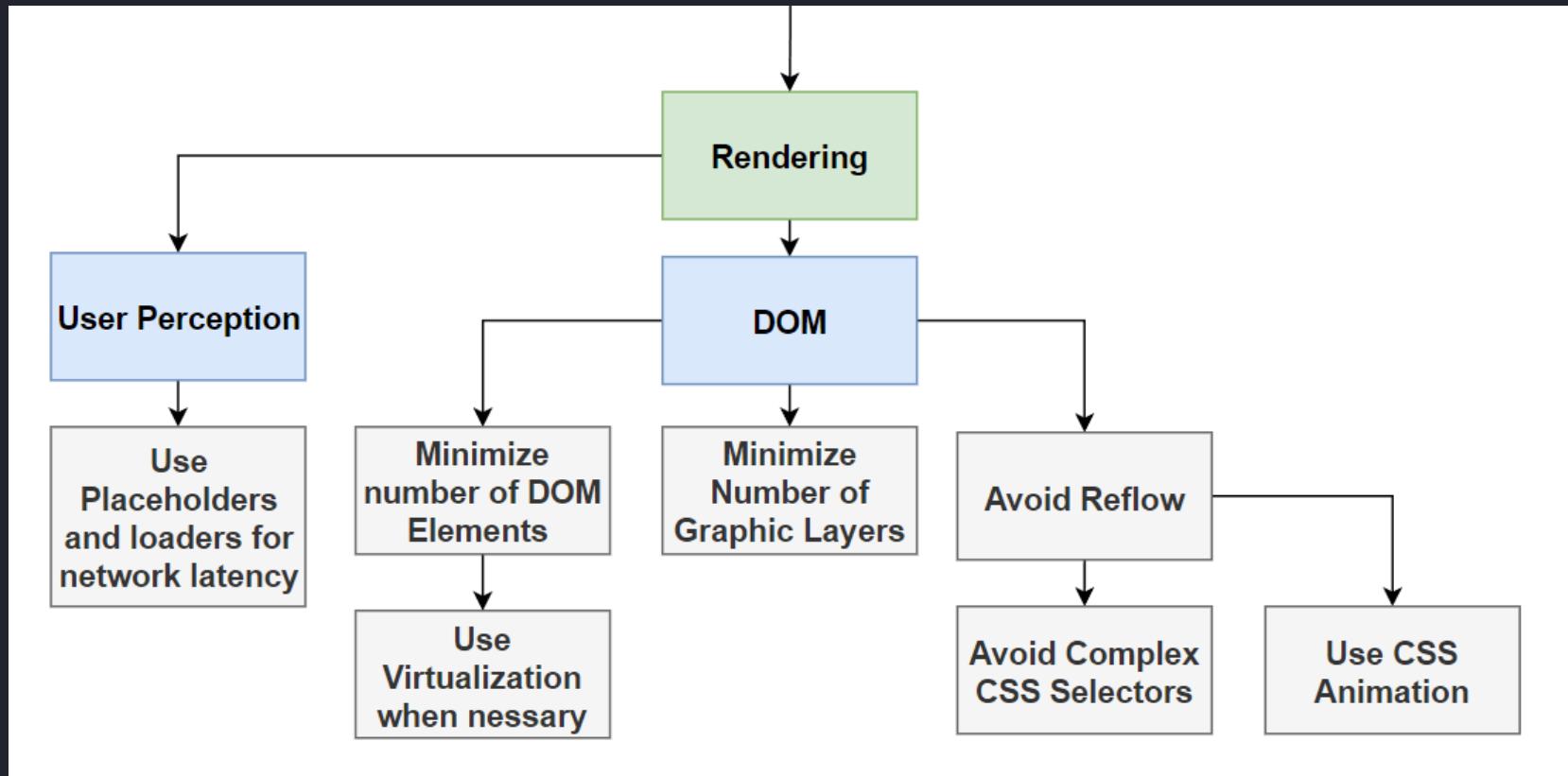
```
1 @font-face {  
2   src: "https://my-custom-font.com/font/";  
3   font-display: 'optional';  
4 }
```

Render unstyled text immediately,  
switch only on refresh if it's  
downloaded

# Network Performance - Summary

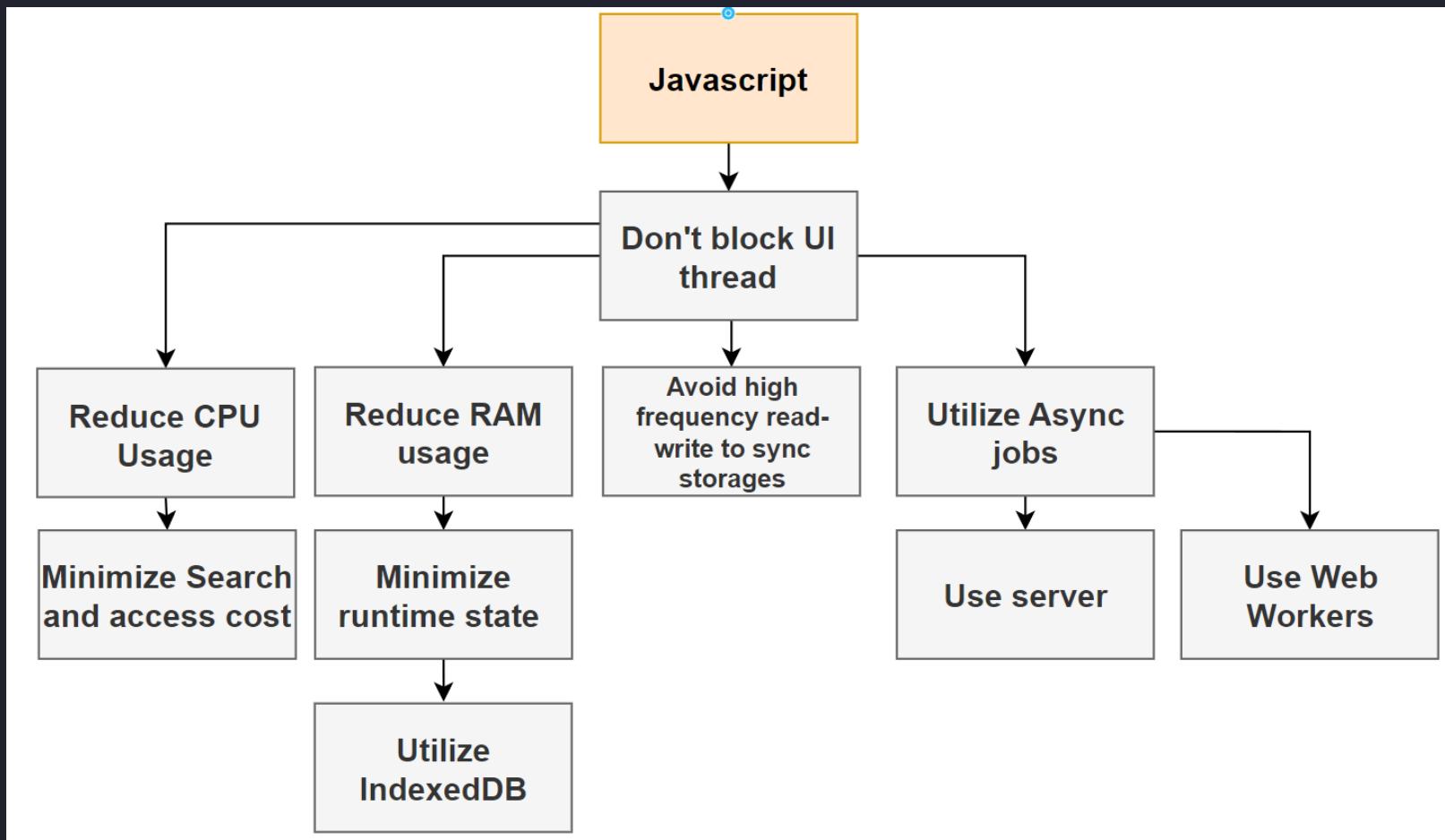


# Rendering Performance - Summary



# Javascript Performance - Summary

The main rule of thumb in building UI apps - Don't block a UI thread.



# Workshop Summary

## Bonus Section - System Design Time!

Let's build **News Feed!**