Building blocks: JavaScript and D3

CS594: Big Data Visualization & Analytics

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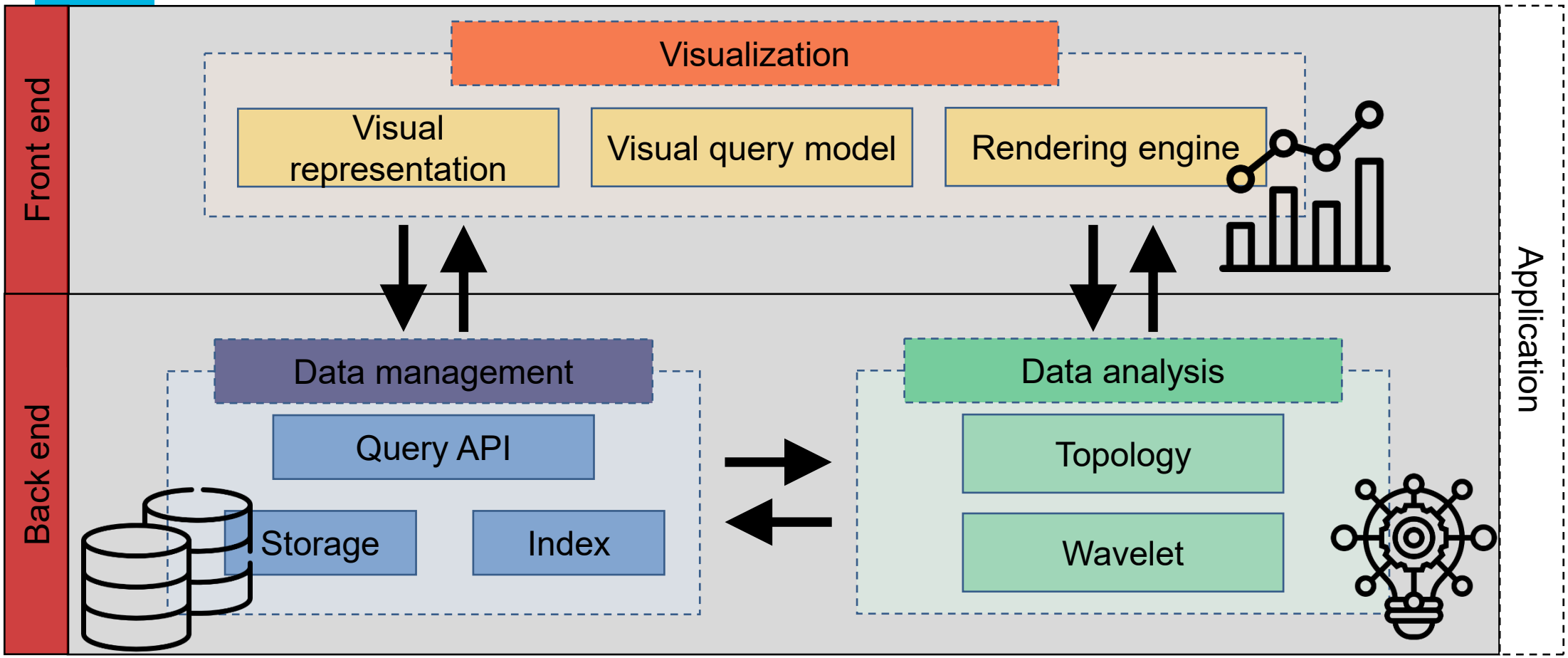
Big data visualization system



Big data visualization system

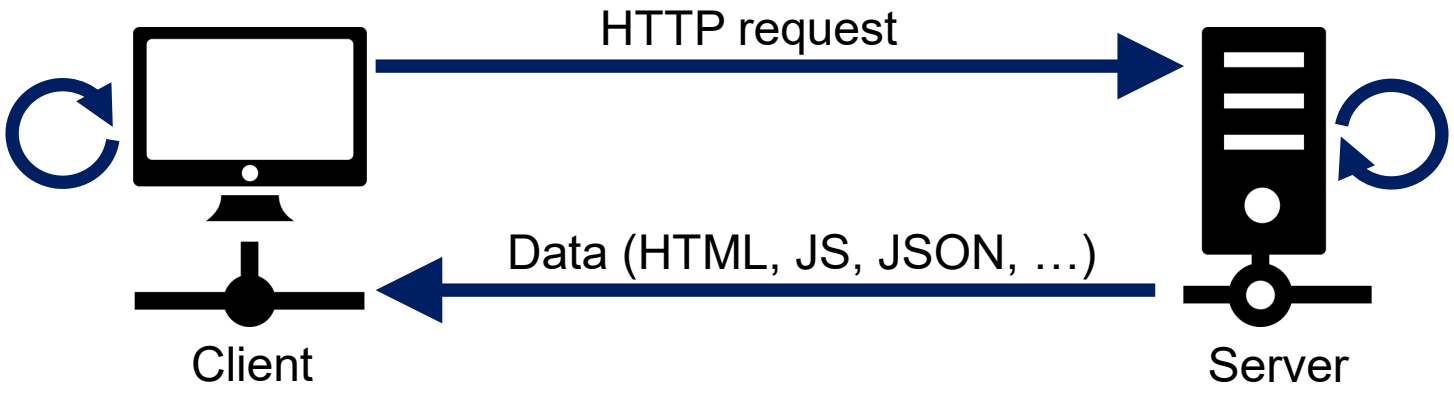
- Why separate front-end and back-end development?
  - Separation of concerns between presentation layer (front end) and data layer (back end).
  - Easily mapped to a client-server model.
    - Client: front end
    - Server: back end
  - Easy deployment.

Building blocks: front-end technologies

- Web technologies
- Web environment
- JavaScript
- D3
- TypeScript
- Angular

Client and server

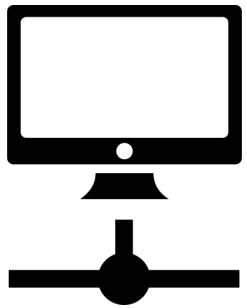
Client-side:
- Rendering
- Interaction
- Light-weight aggregation
- Filtering



Server-side:
- Database query
- Feature extraction
- Data mining

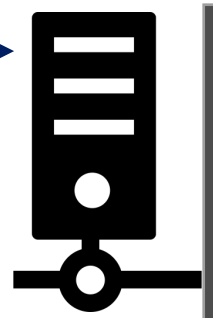
Client and server

Application



HTTP request

Data



HTTP Server

- Serve HTML, JS, CSS files
- Serve geometries
- Compute tiles
- Extract features

- HTML, JS, CSS files
- Geometry files
- Tiles
- Features

Simple server

```
user@DESKTOP MINGW64 ~/example
$ python -m http.server
Serving HTTP on 0.0.0.0 port 8000 (http://0.0.0.0:8000/) ...
```

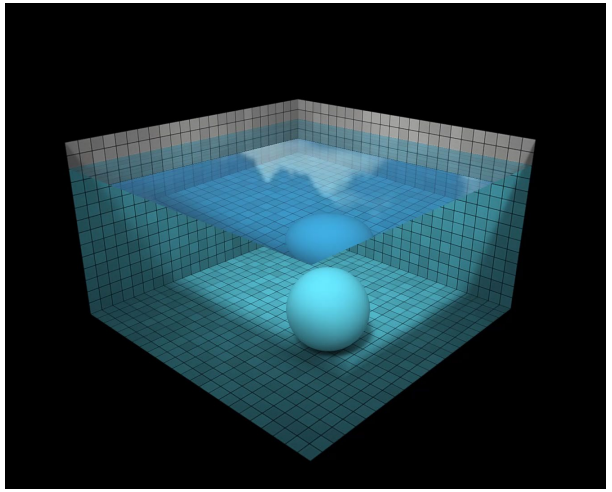
Detailed steps: https://mzl.la/3bSLff0

JavaScript: a client-side programming language

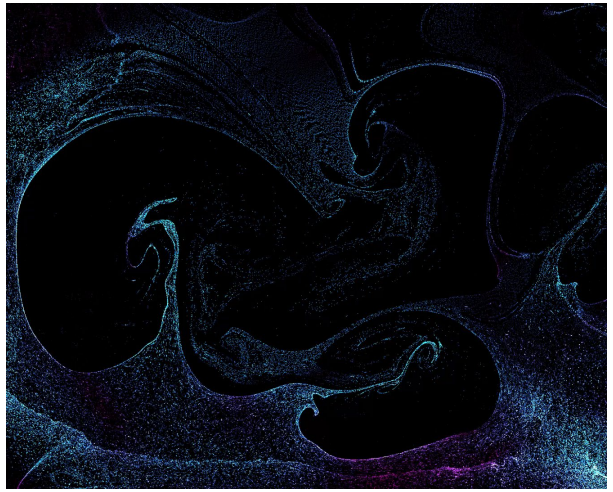
- Interpreted object-oriented language.
- Loosely typed language.
  - Does not require a variable type to be specified.
- Add, delete, and modify nodes from the document tree.
- Integration with other frameworks and toolkits:
  - Qt
  - Swift

JavaScript: a client-side programming language

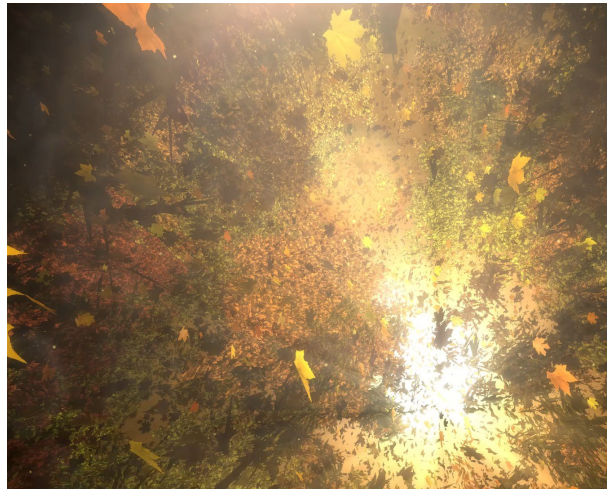
- Is JavaScript slow?
  - JavaScript engines in browsers are getting much faster.
  - Not an issue for graphics, since we transfer the data to the GPU with WebGL.



http://madebyevan.com/webgl-water/



https://haxiomic.github.io/projects/webgl-fluid-and-particles/



http://oos.moxiecode.com/js_webgl/autumn/

JavaScript basics

- Two scopes:
  - Local
  - Global
- Variable created inside a function with ‘var’ keyword: local to function.
  - Created and destroyed every time function is called.
  - BUT: variables declared without ‘var’ keyword are always global.
- Variable created outside a function: global

JavaScript basics

- Inserting JavaScript code in a web page:
  - Inside an HTML tag script.
  - In an external file.
  - As an HTML attribute value.

```
<script type="text/javascript">
    alert("Here is an example.");
</script>
```

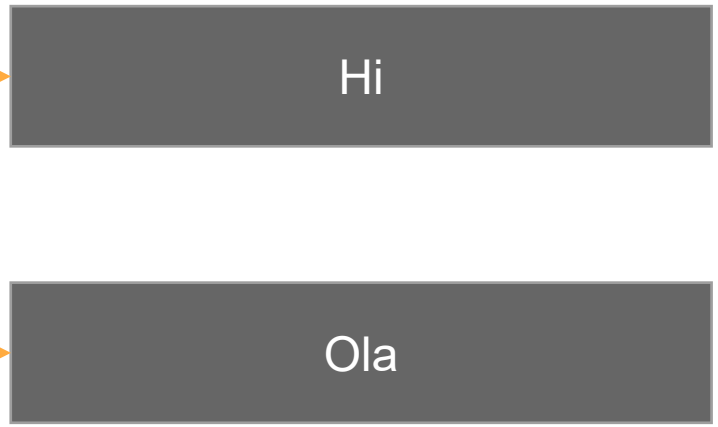
```
<script type="text/javascript" src="file.js"></ script>
```

Statements, comments, and variables

- Statements: separated by new line or semicolon.
- Comment:
  - Single line: // here is a comment
  - Multi line: /* here is a comment */
- Loops and iteration:
  - for, for…in, for…of, do…while, while.
- Variables:
  - Assignment operator (=) to assign values.

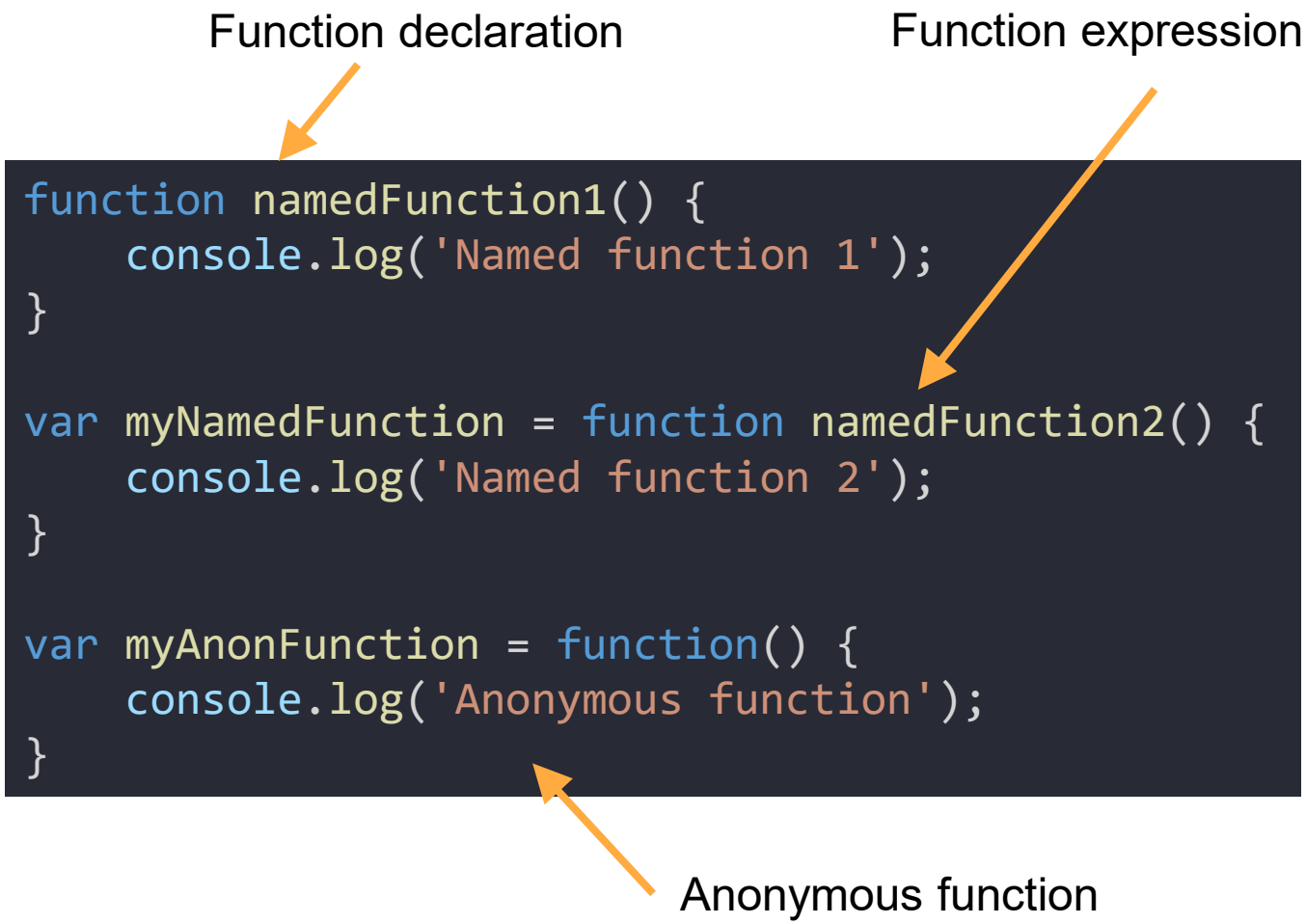
Variable scope

```
var message = 'Hi';

function modify1(){
    var message = 'Hello';
}

function modify2(){
    message = 'Ola';
}

modify1();
console.log(message);

modify2();
console.log(message);
```



Functions

- Different ways to define functions:
  - Named
  - Anonymous
- Function expressions cannot be used before they appear in the code.



Functions

- Function declarations load before any code is executed, while function expressions load only when the interpreter reaches that line.
- Function expressions: closures, arguments to other functions

```
alert(foo());
function foo() { return 5; }
```

Function declaration: error in this case, as foo wasn't loaded yet.

```
alert(foo());
var foo = function() { return 5; }
```

Function expression: alerts 5. Declarations are loaded before any code can run.

Functions

- Functions are first-class objects:
  - Supports passing functions to other functions.
  - Returning them as values from other functions.
  - Assigning them to variables or data structures.
- Closure:
  - Function that maintains the local variables of a function, after the function has returned.

Closure example

```
function sayHi(name){
    var whatToSay = 'Hi '+name;

   return function(){
        console.log(whatToSay);
    }
}

var say = sayHi('Bob');
say();
```

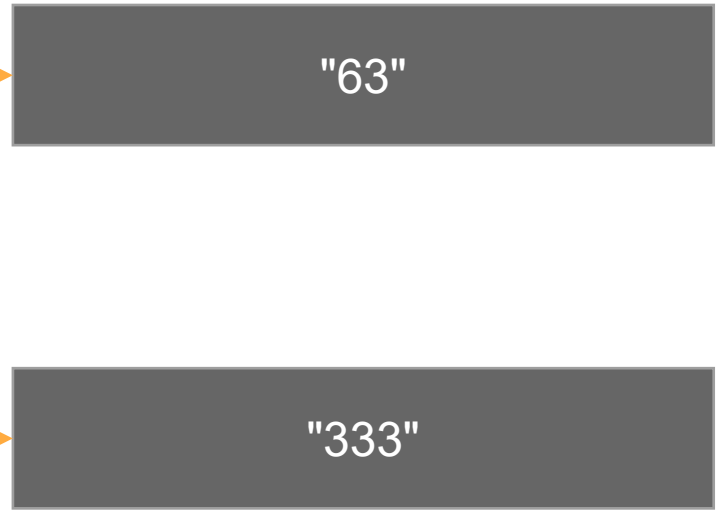
A closure: a function inside a function

No matter where it is executed, closure function will always remember variables from sayHi.

Data types: numbers and strings

- Numbers: a primitive data type (32-bit float).
- String: sequence of characters.
- Booleans.

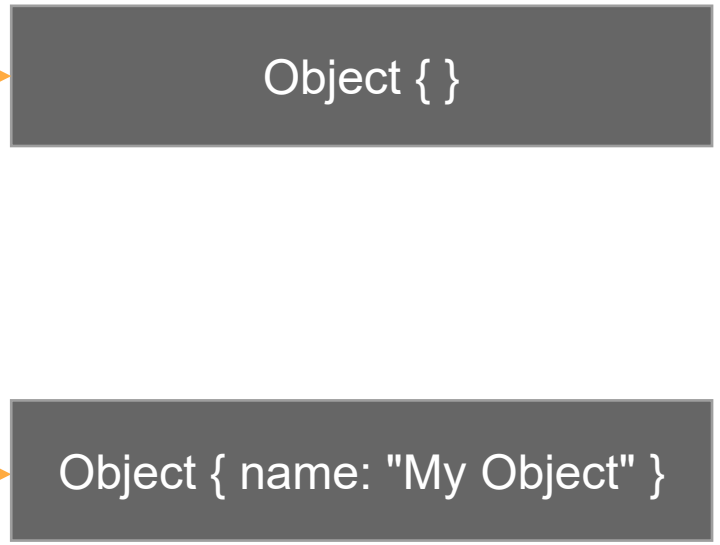
```
var aux1 = 3.0;
var aux2 = 3;
var aux3 = '3';

console.log(aux1+aux2+aux3);
console.log(aux3+aux2+aux1);
```



Objects

- In JavaScript, objects are a collection of properties with a name and a value.

```
var myObject = new Object();
console.log(myObject);

myObject.name = "My Object";
console.log(myObject);
```



Arrays

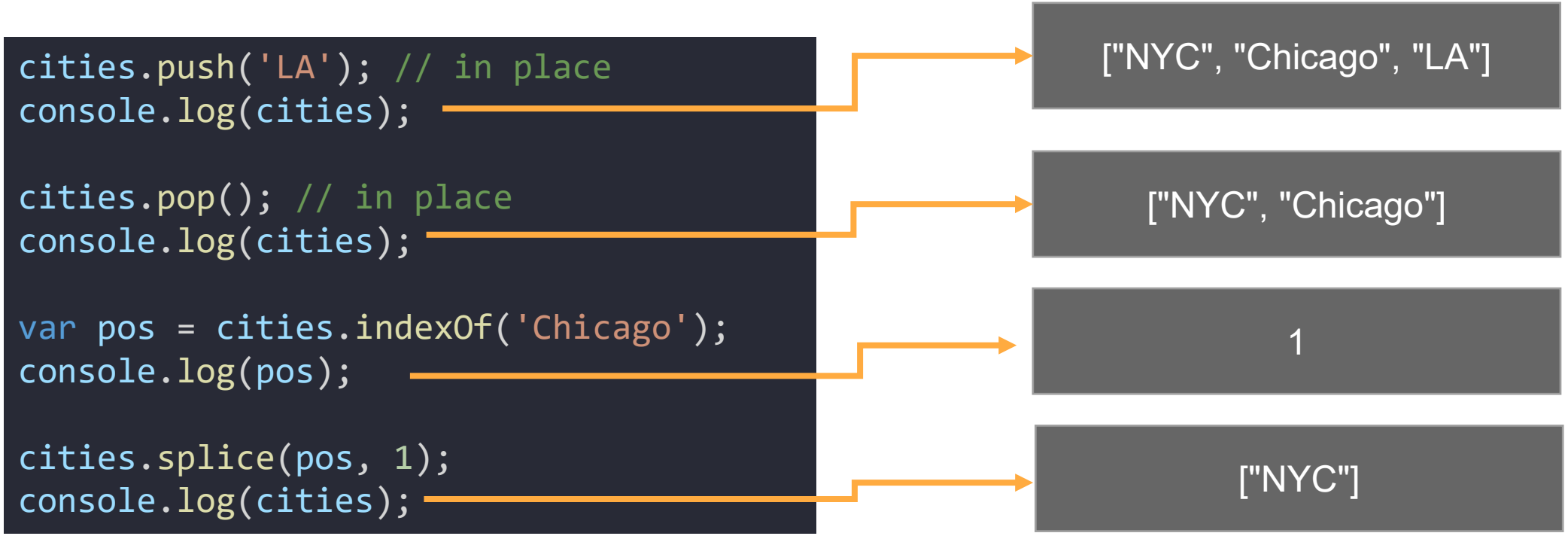
- List-like objects.

```
var cities = ['NYC', 'Chicago'];

console.log(cities[0]);
console.log(cities[cities.length-1]);

cities.forEach(function(item, index)) {
    console.log(item, index);
}
```

Arrays

- List-like objects.

```
cities.push('LA'); // in place
console.log(cities);

cities.pop(); // in place
console.log(cities);

var pos = cities.indexOf('Chicago');
console.log(pos);

cities.splice(pos, 1);
console.log(cities);
```



Example: map

```
var a = [1, 2, 3];

for(var i=0; i<a.length; i++){
    a[i] = a[i] * 2;
}

for(var i=0; i<a.length; i++){
    console.log(a[i]);
}
```

```
var a = [1, 2, 3];

function map(f, a){
    for(var i=0; i<a.length; i++){
        a[i] = f(a[i]);
    }
}

map(function(x){return x * 2;}, a);
map(alert, a);
```

Example: reduce

```
var nums = [1, 2, 3, 4];

function sum(a){
    var sum = 0;
    for(var i=0; i<a.length; i++)
        sum += a[i];
    return sum;
}

function mult(a){
    var mult=1;
    for(var i=0; i<a.length; i++)
        mult *= a[i];
    return mult;
}

console.log(sum(nums));
console.log(mult(nums));
```

```
var nums = [1, 2, 3, 4];

function reduce(f, a, init){
    var s = init;
    for(var i=0; i<a.length; i++)
        s = f(s, a[i]);
    return s;
}

function add(a, b){
    return a+b;
}
function mult(a, b){
    return a*b;
}

console.log(reduce(add, nums, 0));
console.log(reduce(mult, nums, 1));
```

Manipulating documents

- So far: HTML, CSS, JavaScript.
- But how can we use JavaScript to modify nodes from DOM?
- Answer: **document object**.
- When an HTML document is loaded by a browser, it becomes a **document object**, containing the root node of the HTML document.

Document object

```
» document
← ▼ HTMLDocument https://www.google.com/
    URL: "https://www.google.com/"
  ▶ __wizdispatcher: Object { La: trigger(c) ↱≡ , Fa: {…}, Aa: false, … }
  ▶ __wizmanager: Object { w0: false, JN: (1) […], Ha: 10, … }
  ▶ activeElement: <body id="gsr" class="hp vasq big" jsmodel="TvHxbe" jsaction="VM8bg:.CLIENT;hWT9Jb:.CL…:.CLIENT;kWlxhc:.CLIENT"> ⊡
    alinkColor: ""
  ▶ all: HTMLAllCollection { 0: html ⊡ , 1: head ⊡ , 2: meta ⊡ , … }
  ▶ anchors: HTMLCollection { length: 0 }
  ▶ applets: HTMLCollection { length: 0 }
    baseURI: "https://www.google.com/"
    bgColor: ""
  ▶ body: <body id="gsr" class="hp vasq big" jsmodel="TvHxbe" jsaction="VM8bg:.CLIENT;hWT9Jb:.CL…:.CLIENT;kWlxhc:.CLIENT"> ⊡
    characterSet: "UTF-8"
    charset: "UTF-8"
    childElementCount: 1
```

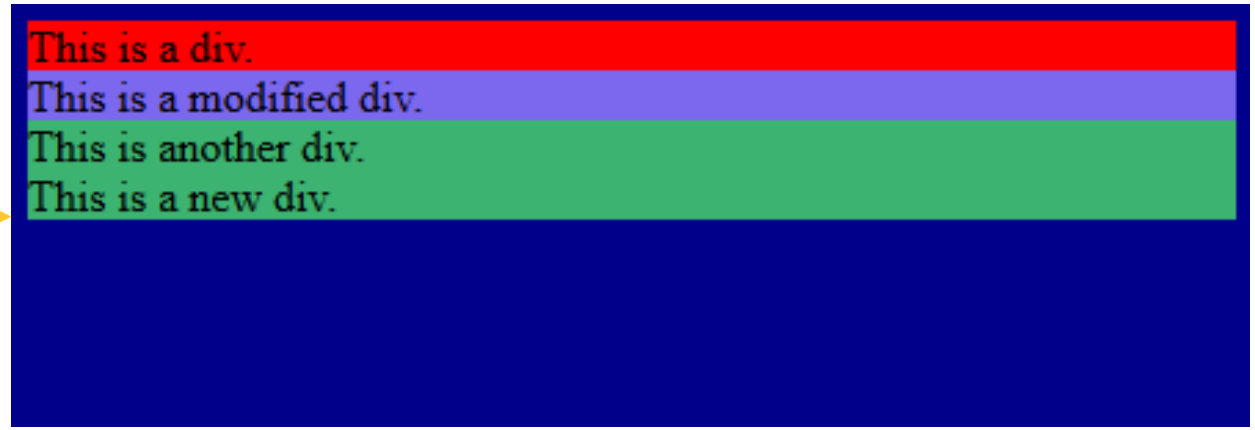
DOM elements using selectors

```
var allDivs = document.querySelector('div');
var myDiv = document.querySelector('#mydiv');
var mySecondDiv = document.querySelector('#myseconddiv');
var myClass = document.querySelector('.myclass');
```

```
mySecondDiv.textContent = 'This is a modified div.';
```

DOM elements using selectors

```
var newDiv = document.createElement('div');
newDiv.textContent = 'This is a new div.';
newDiv.className = 'myclass';
document.querySelector('body').appendChild(newDiv);
```



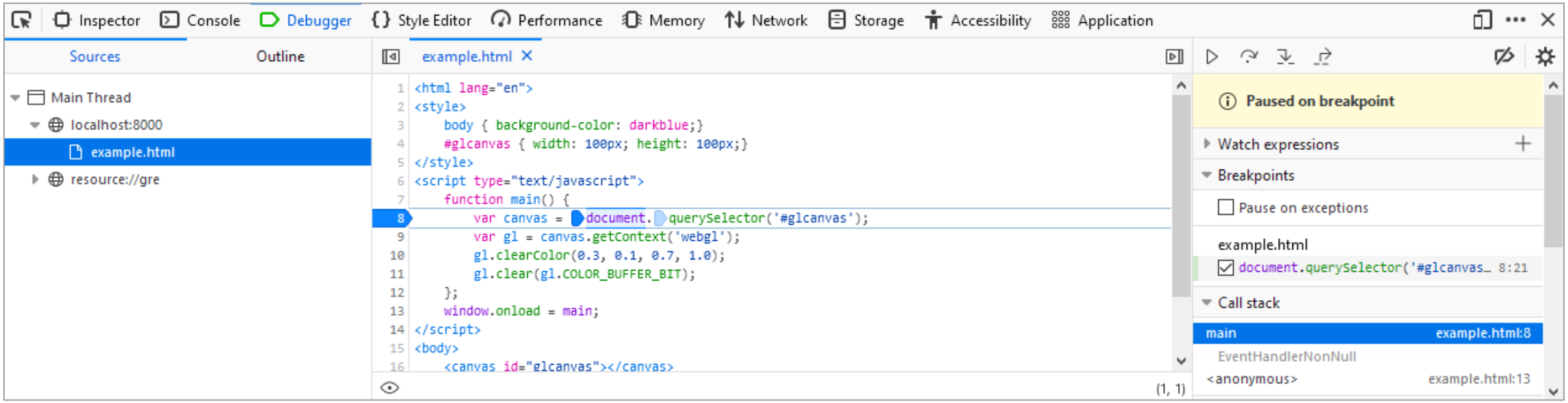
Event handlers

- Events are actions like being clicked, pressed keys, getting focus, etc.
- Different ways to specify handlers for a particular event:

```
<button onclick="handleClick()">
```

```
document.querySelector("button").onclick = function(event) {}
```

Debugging JavaScript



Finally drawing something

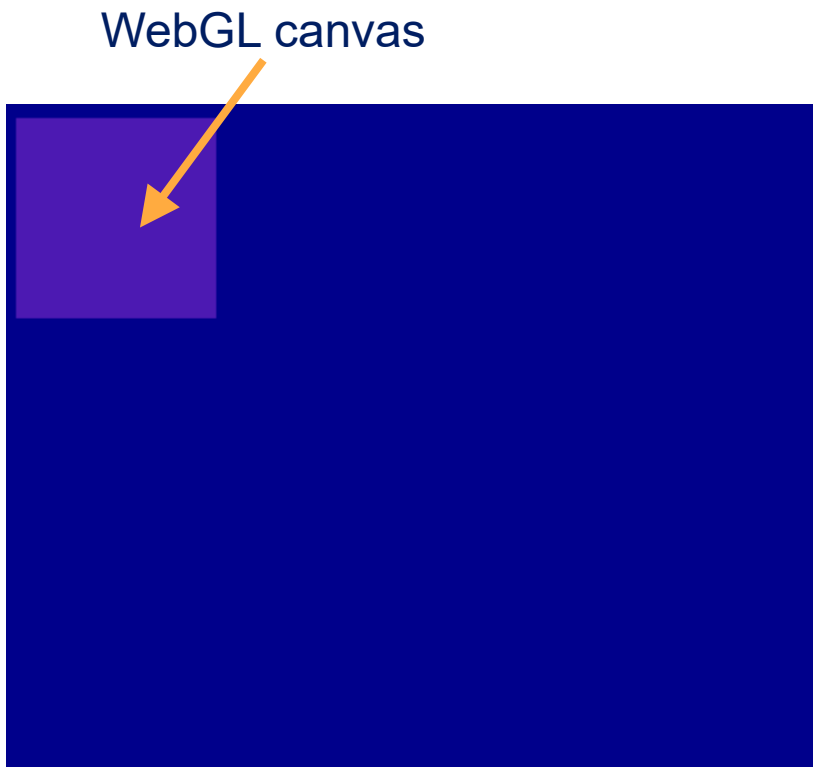
- Several ways to draw graphics on the web:
  - SVG
    - XML-based format for vector images.
    - Simple option for small data.
    - Easy event and CSS integration.
  - Canvas
    - HTML element.
    - No object-level interaction.
  - WebGL
    - Complex 3D geometries.
    - Uses rendering pipeline.
    - Hardware acceleration.

WebGL: a bird's-eye view

- API for rendering graphics within a web browser without plug-ins.
- Hardware accelerated.
- Shader based (no fixed-function API).
  - Fixed function pipeline: set of calls for matrix transformation, lighting.
  - Programmable pipeline: shaders for vertex and fragment processing.
- WebGL 2.0 based on OpenGL ES 3.0.

WebGL: a bird's-eye view

```
<html lang="en">
<style>
    body { background-color: darkblue;}
    #glcanvas { width: 100px; height: 100px;}
</style>
<script type="text/javascript">
    function main() {
        var canvas = document.querySelector('#glcanvas');
        var gl = canvas.getContext('webgl2');
        gl.clearColor(0.3, 0.1, 0.7, 1.0);
        gl.clear(gl.COLOR_BUFFER_BIT);
    };
    window.onload = main;
</script>
<body>
    <canvas id="glcanvas"></canvas>
</body>
</html>
```



D3.js: a bird's-eye view

- Library for manipulating documents based on data.
- Facilitates DOM manipulation to visualize data.
- D3 is not:
  - a visualization library (but you can visualize data using it).
  - a map library (but you can visualize maps using it).
  - restricted to DOM manipulation (there are several others auxiliary functions).

D3.js: first steps

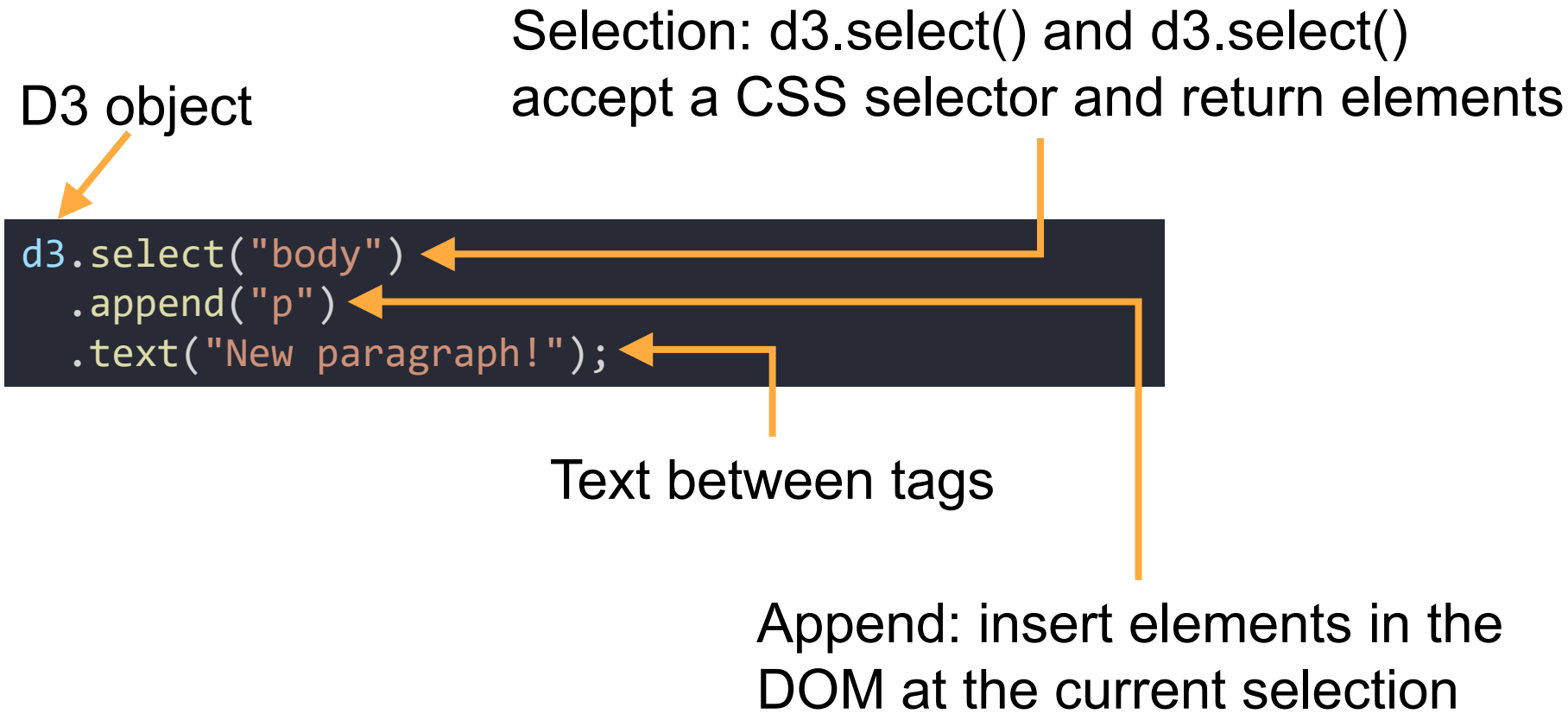
Creating a paragraph

```
var body = d3.select("body");
var p = body.append("p");
p.text("New paragraph!");
```

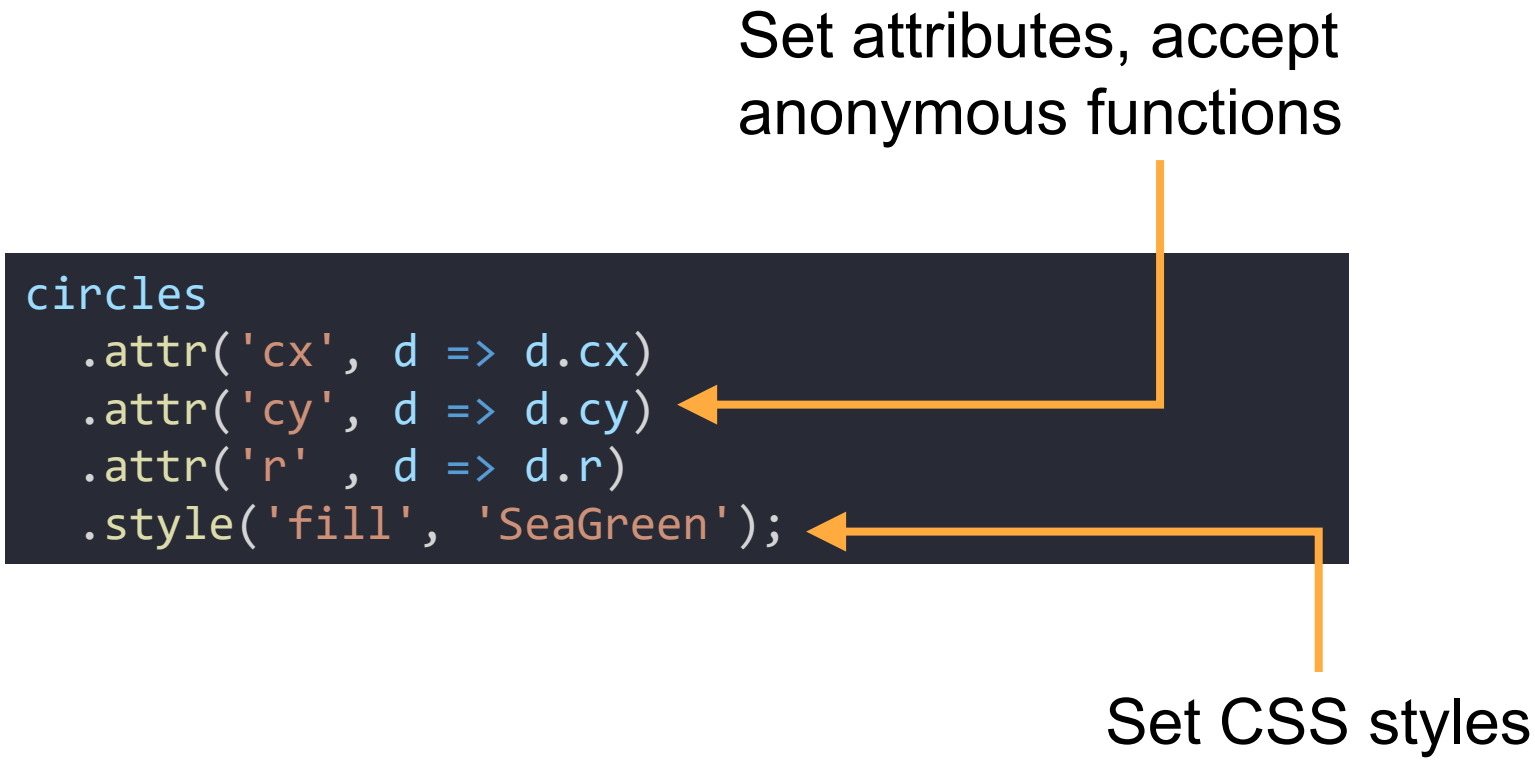
Creating a paragraph with D3.js

```
d3.select("body")
  .append("p")
  .text("New paragraph!");
```

D3.js: selecting elements



D3.js: setting attributes



D3.js: binding data

- Given a selection in D3, one can bind data to it using `.data()`
- This will create a mapping between *each* element in the selection and *each* data element.
  - Default is sequential, i.e, element `i` is mapped to data at index `i`.
- Once bound, one can use data to define attributes:

```
circles
  .attr('r', function(d,i) {
     return d * 100;
  });
```

D3.js: virtual selections

- D3 data operator returns three virtual selections: `enter`, `update`, and `exit`.
- Enter selection: placeholder for missing elements.
- Update selection: update existing elements, bound to data.
- Exit selection: remove remaining elements.

D3.js: virtual selections

```
var data = [5,10,15,20,15]

var ps = d3.select('body')
  .selectAll('p')
  .data(data);
  .enter()
```

Add placeholder elements for each data element without DOM element correspondent

D3.js: virtual selections

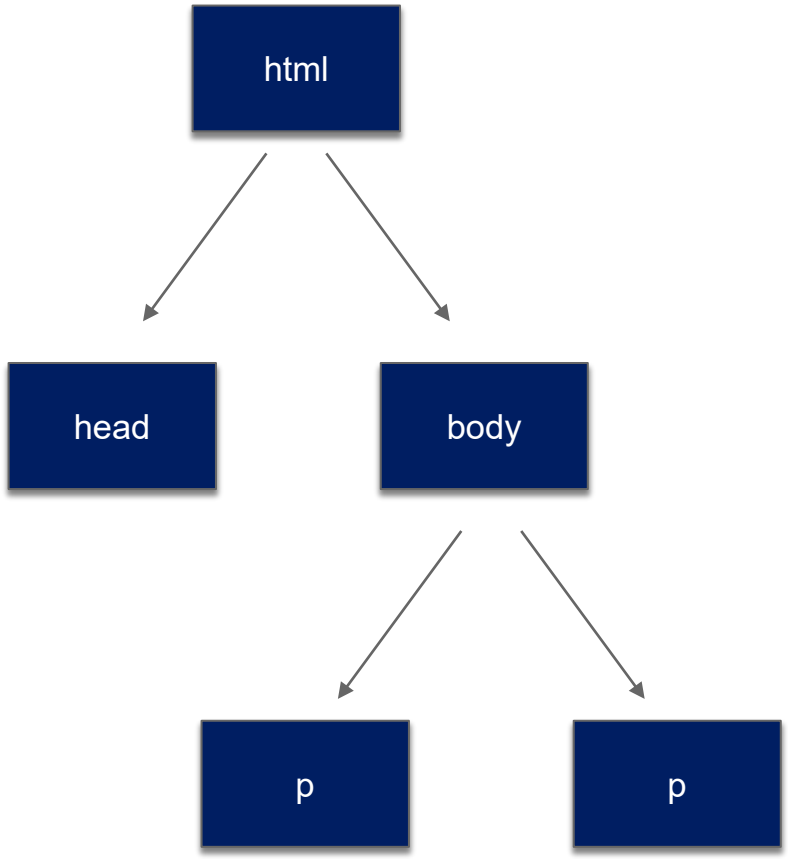
```
var data = [5,10,15,20,15]

var ps = d3.select('body')
  .selectAll('p')
  .data(data);

ps.text('New paragraph');
```

If no previous <p> element inside <body> then this is an **empty** selection

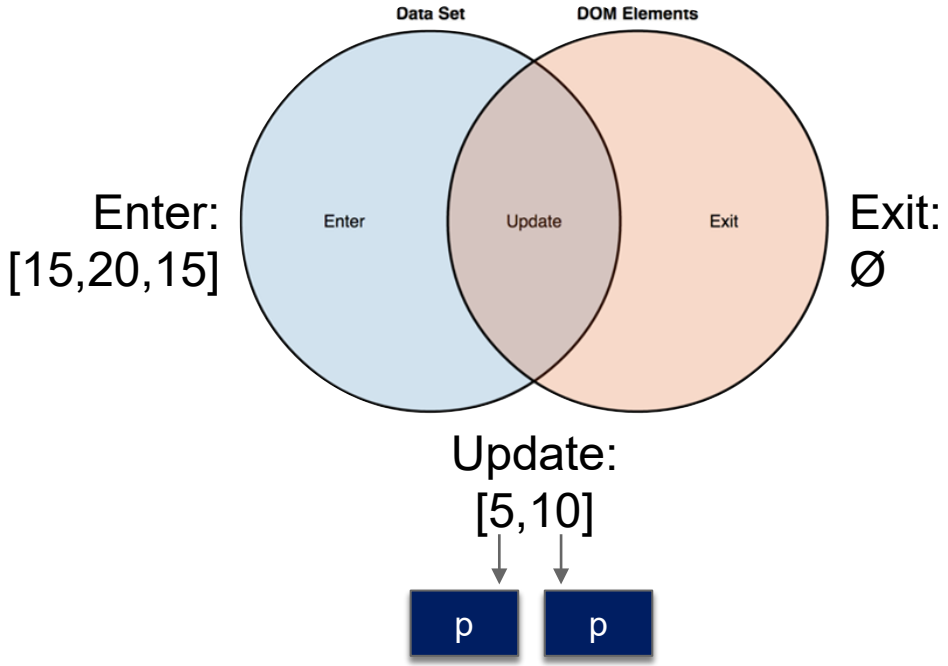
```
var data = [5,10,15,20,15]

var ps = d3.select('body')
  .selectAll('p')
  .data(data);

ps.enter()
  .append('p')
  .text('New paragraph');
```

Creating placeholder elements

D3.js: virtual selections

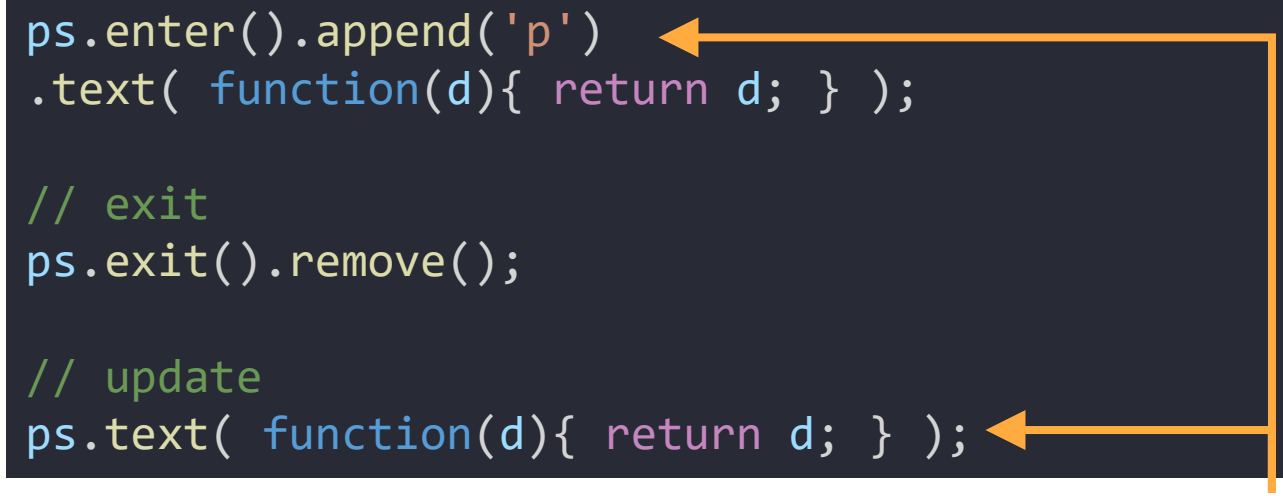



```
var data = [5,10,15,20,15]
var ps = d3.select('body')
  .selectAll('p')
  .data(data);
```



D3.js: virtual selections

```
var data = [5,10,15,20,15]
var ps = d3.select('body').selectAll('p').data(data);

// enter
ps.enter().append('p')
.text( function(d){ return d; } );

// exit
ps.exit().remove();

// update
ps.text( function(d){ return d; } );
```



Data access