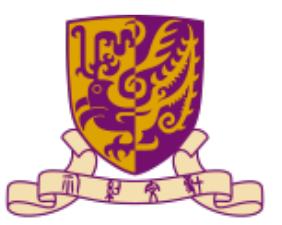

DDA 2003 / MDS 6112

Visual Analytics / Data Visualization

Lecture 7

D3



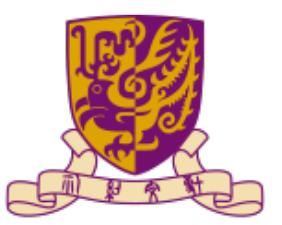


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Outline

- Introduction to D3
- Making a chart



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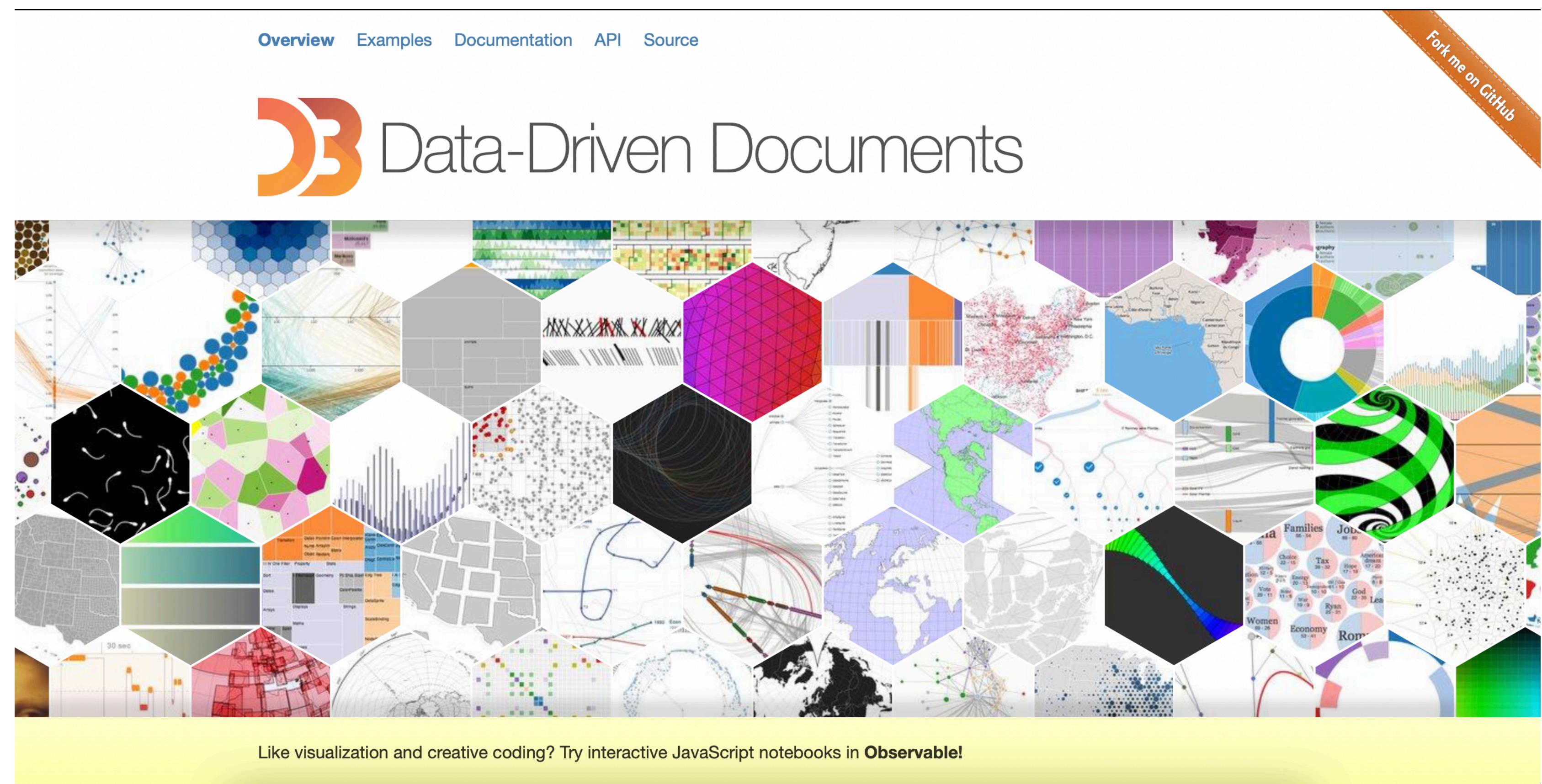
The Chinese University of Hong Kong, Shenzhen

Outline

- Introduction to D3
- Making a chart

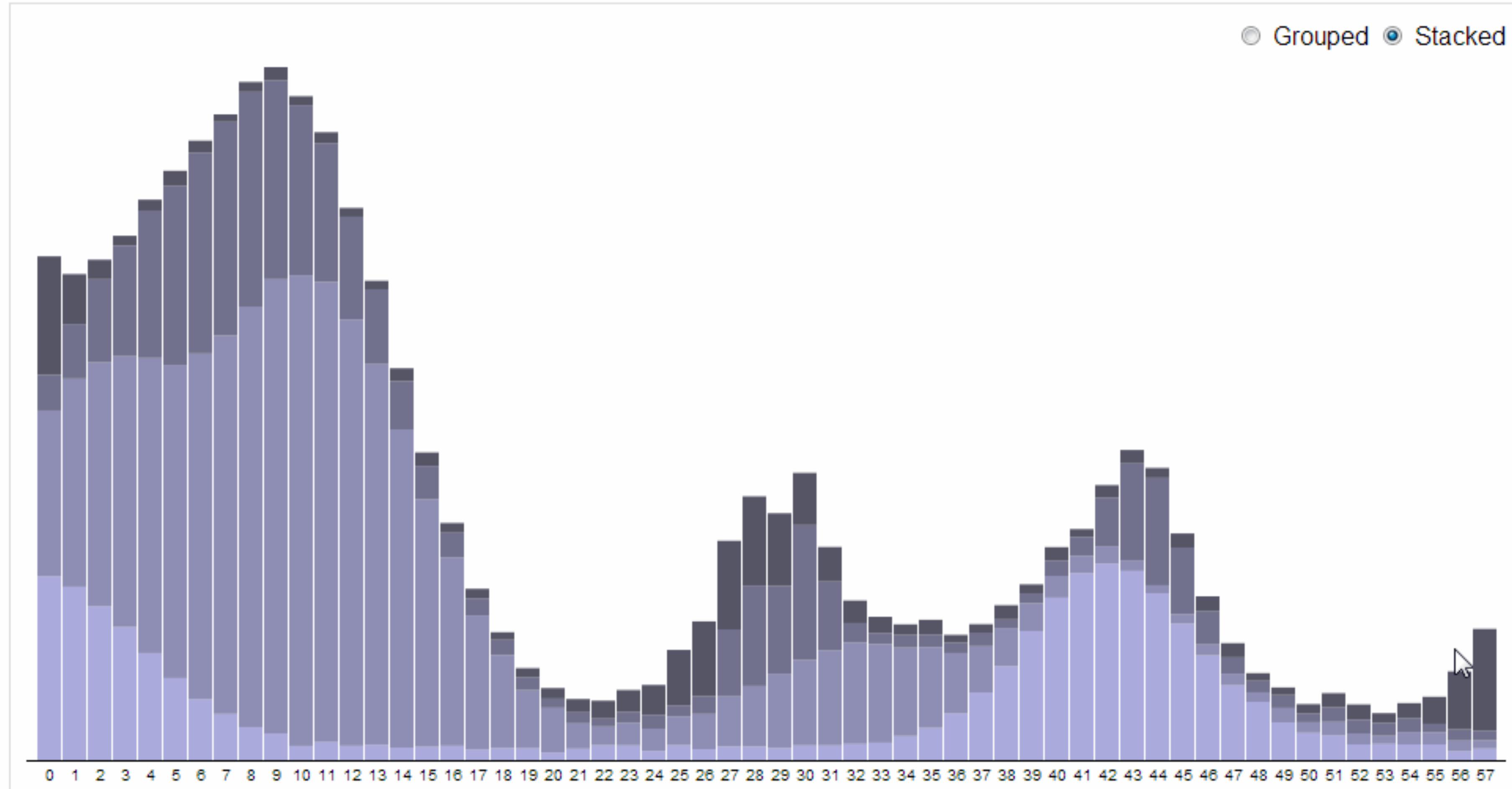
Introduction to D3

- D3 allows you to bind arbitrary data to a Document Object Model (DOM), and then apply data-driven transformations to the document.

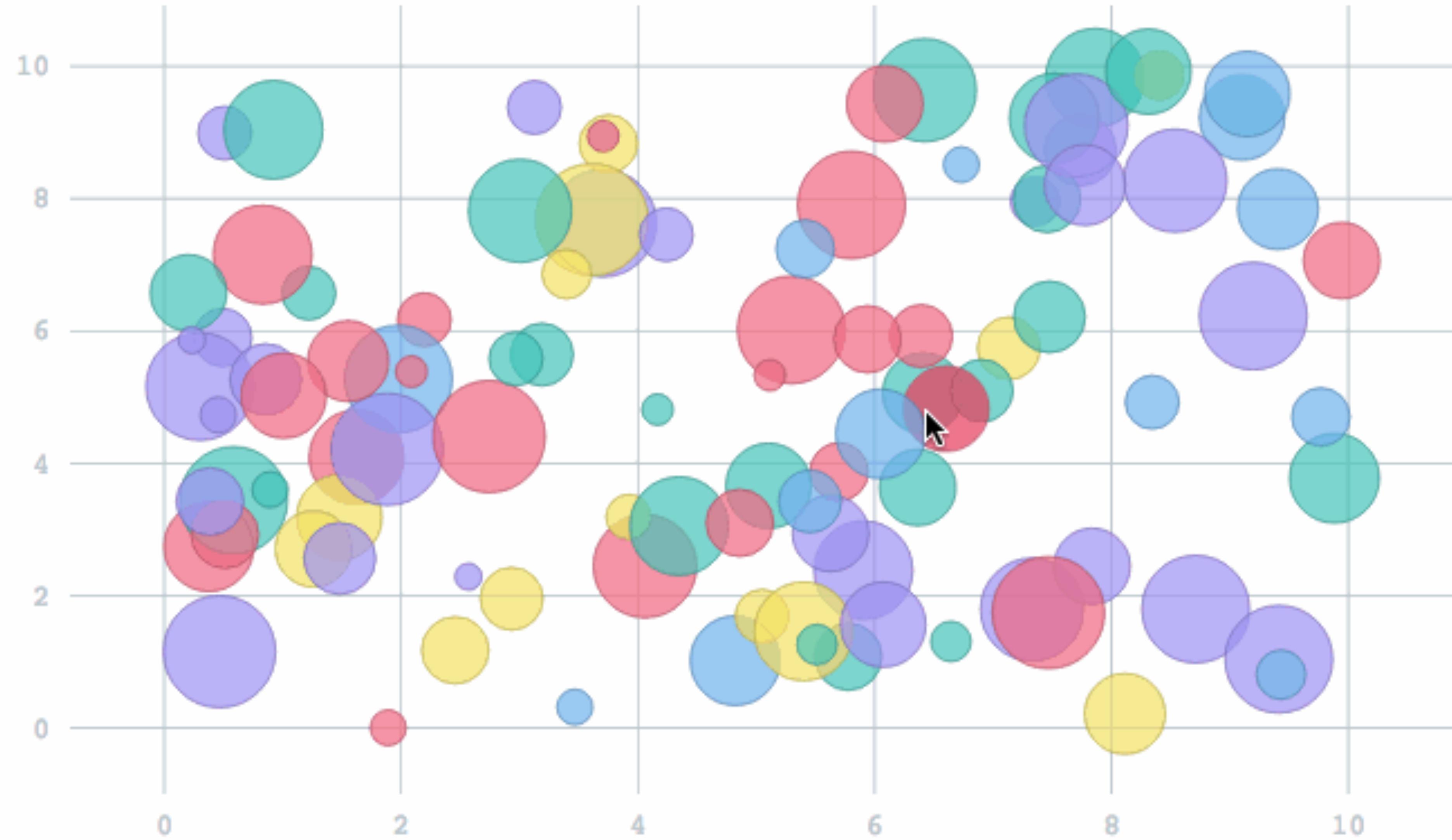


Introduction to D3

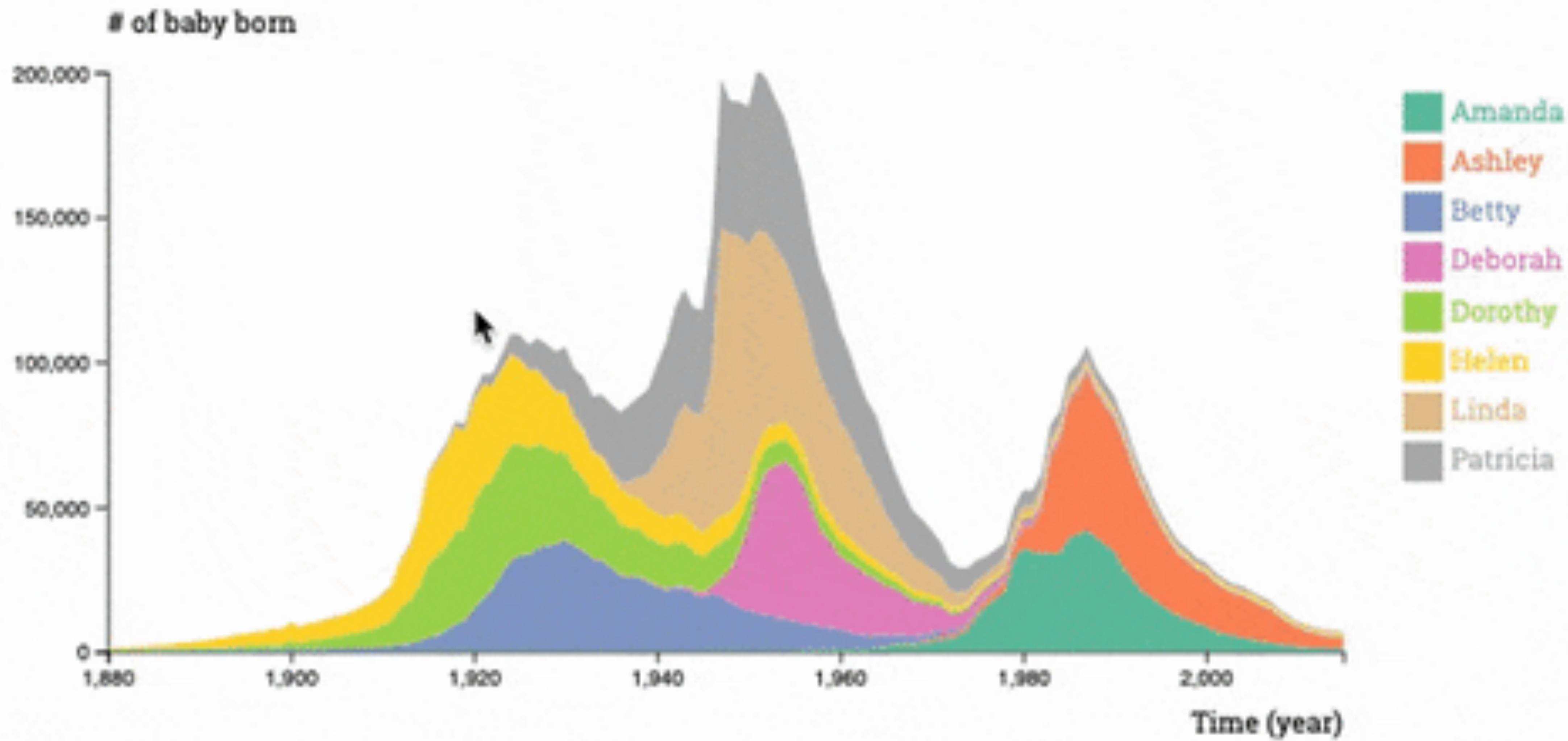
Stacked-to-Grouped Bars



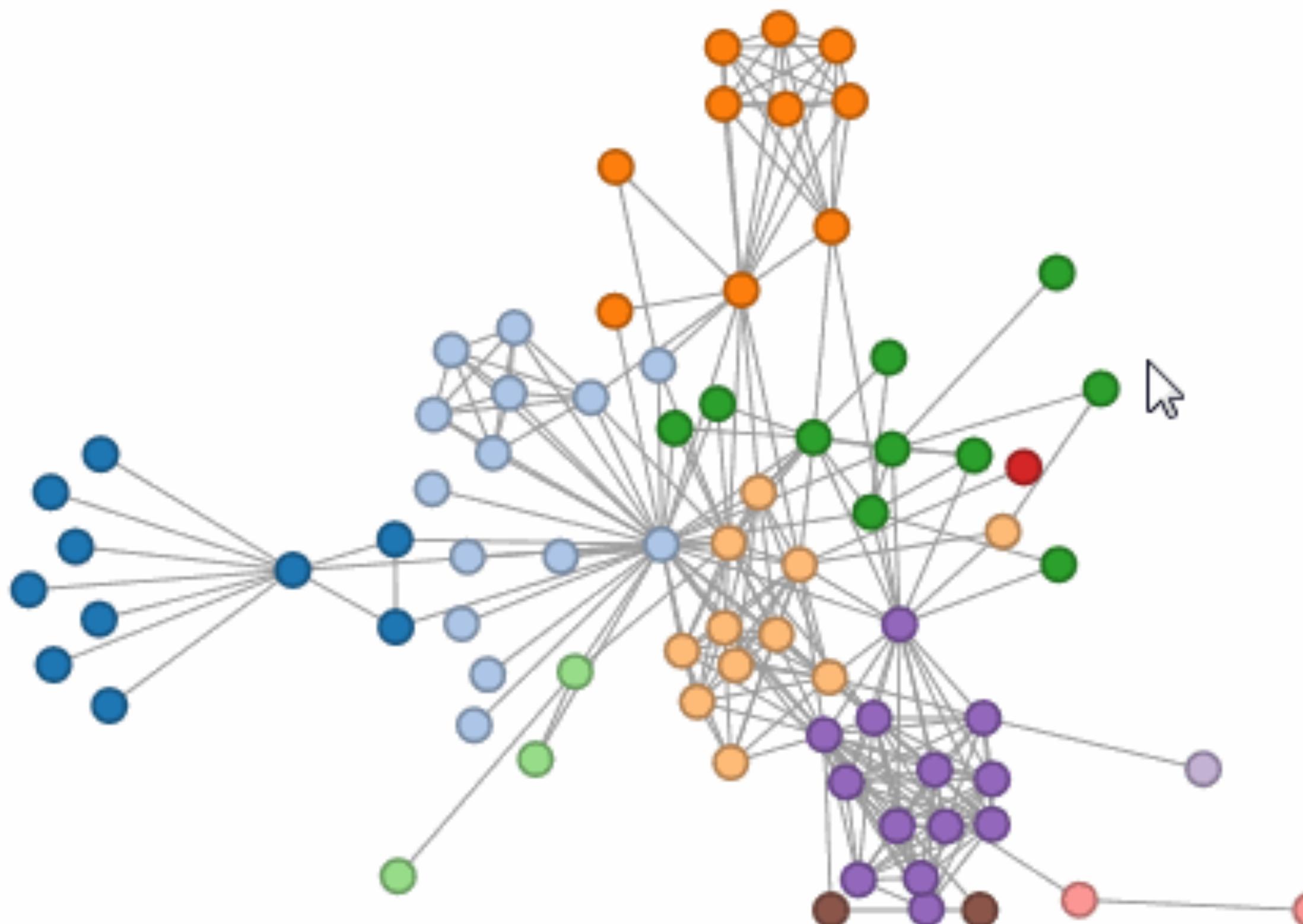
Introduction to D3

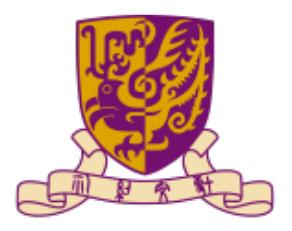


Introduction to D3



Introduction to D3





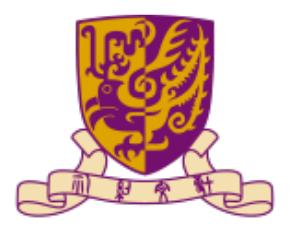
Introduction to D3

- D3 integration

project/
index.html
css/
 style.css
js/
 d3.min.js
main.js

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="UTF-8">
  <title>D3 Project</title>
  <link rel="stylesheet" href="css/style.css">
</head>
<body>

<script src="js/d3.min.js"></script>
<script src="js/main.js"></script>
</body>
</html>
```

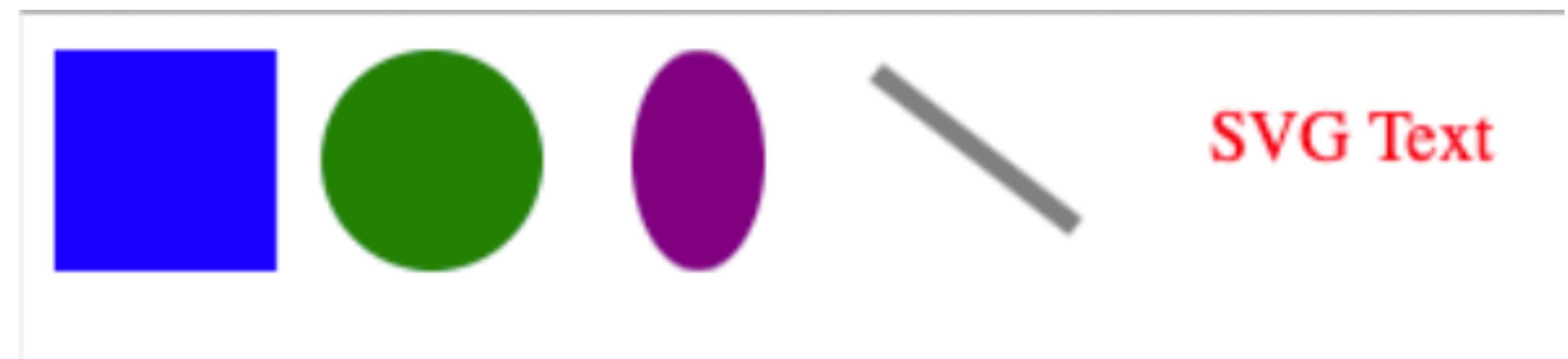


Introduction to D3

- Overview of SVG
 - SVG is defined using markup code similar to HTML
 - SVG elements don't lose any quality when they are resized
 - SVG elements can be included directly within any HTML document or dynamically inserted into the DOM with JS
 - Before you can draw SVG elements, you have to add an `<svg>` element
 - The SVG coordinate system places the origin (0/0) in the top-left corner of the `svg` element

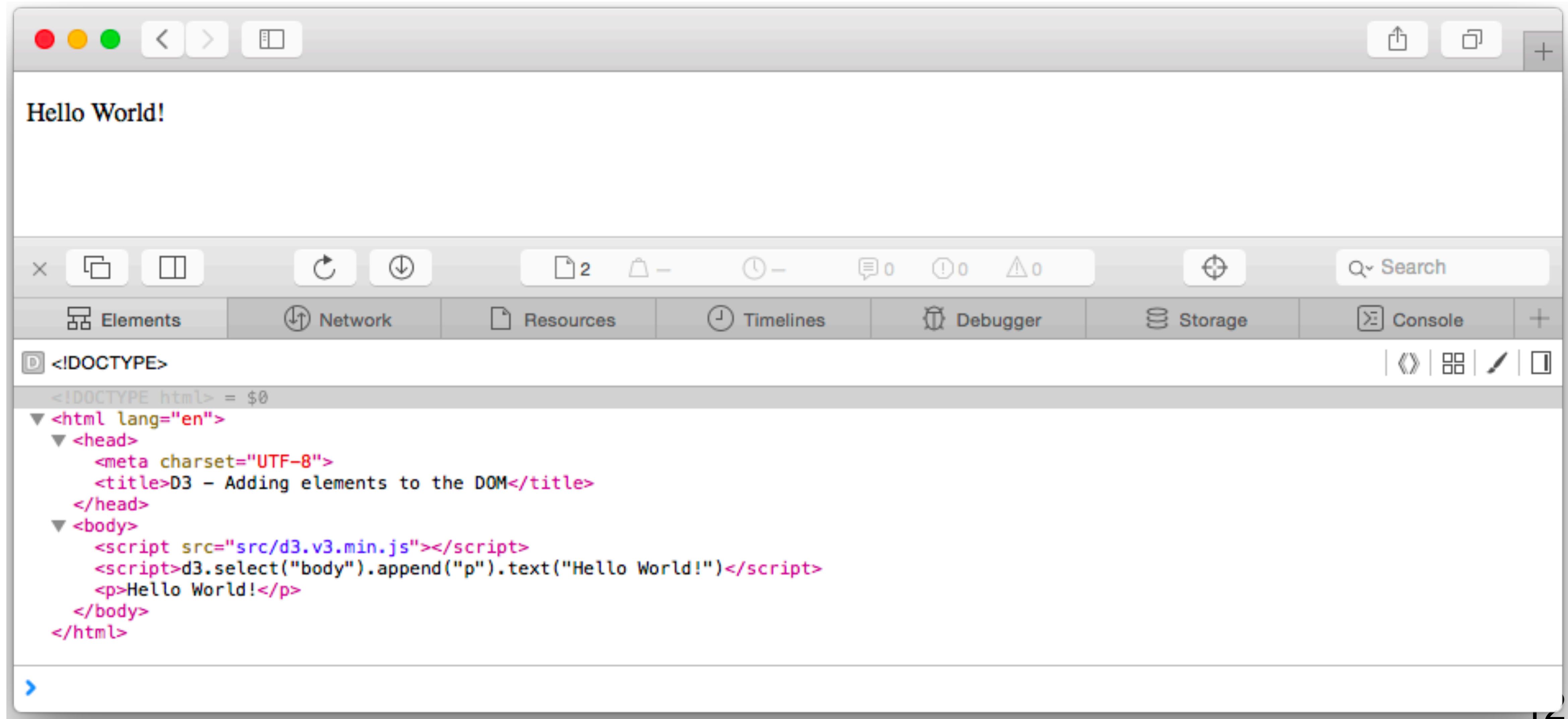
Introduction to D3

```
<svg width="400" height="50">  
  
<!-- Rectangle (x and y specify the coordinates of the upper-left corner -->  
<rect x="0" y="0" width="50" height="50" fill="blue" />  
  
<!-- Circle: cx and cy specify the coordinates of the center and r the radius -->  
<circle cx="85" cy="25" r="25" fill="green" />  
  
<!-- Ellipse: rx and ry specify separate radius values -->  
<ellipse cx="145" cy="25" rx="15" ry="25" fill="purple" />  
  
<!-- Line: x1,y1 and x2,y2 specify the coordinates of the ends of the line -->  
<line x1="185" y1="5" x2="230" y2="40" stroke="gray" stroke-width="5" />  
  
<!-- Text: x specifies the position of the left edge and y specifies the vertical position of the baseline -->  
<text x="260" y="25" fill="red">SVG Text</text>  
  
</svg>
```



Introduction to D3

- Add a DOM Element with D3



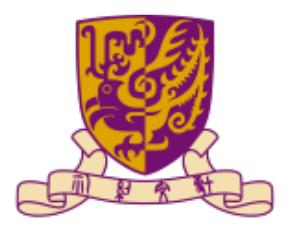
The screenshot shows a web browser window with the title "Hello World!" displayed. Below the browser window is the developer tools interface, specifically the "Elements" tab. The DOM tree is visible, showing the following structure:

```
<!DOCTYPE html> = $0
<html lang="en">
  <head>
    <meta charset="UTF-8">
    <title>D3 - Adding elements to the DOM</title>
  </head>
  <body>
    <script src="src/d3.v3.min.js"></script>
    <script>d3.select("body").append("p").text("Hello World!")</script>
    <p>Hello World!</p>
  </body>
</html>
```

The "Console" tab in the developer tools is also visible at the bottom.

Introduction to D3

- D3 select
 - The `select()` method uses CSS selectors as input to grab page elements. It will return a reference to the first element in the DOM that matches the selector
 - Alternatively, if you need to select more than one element, use `selectAll()`



Introduction to D3

- D3 append
 - After selecting a specific element, we can apply an operator, such as `.append('p')`
 - The `append()` operator adds a new element as the last child of the current selection. We specified "p" as the input argument, so an empty paragraph has been added to the end of the *HTML body*. The new paragraph is automatically selected for further operations

Introduction to D3

- Binding data to visual elements

```
const provinces = ['AB', 'BC', 'MB', 'NB', 'NL', 'NT', 'NS', 'NU', 'ON', 'PE', 'QC', 'SK',  
'YT'];
```

```
const p = d3.select('body').selectAll('p')  
    .data(provinces)
```

```
    .enter()
```

```
    .append('p')
```

```
    .text('Array Element');
```

Reference to the target container

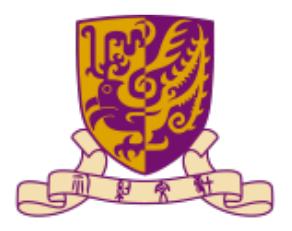
Selection representing the elements (paragraphs) we want to create

Loads the dataset (array of strings).

Creates new data-bound elements/placeholder

Takes the empty placeholder selection and appends a paragraph to the DOM for each element

Adds a string to each newly created paragraph

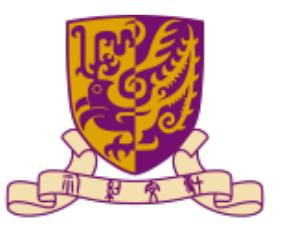


Introduction to D3

- Dynamic properties
 - Access to the corresponding values from the dataset, you have to use *anonymous functions*

```
// Our preferred option: ES6 arrow function syntax  
.text(d => d);
```

```
// Alternative: Traditional function syntax  
.text( function(d) { return d; } );
```



Introduction to D3

• HTML attributes and CSS properties

```
const provinces = ['AB', 'BC', 'MB', 'NB', 'NL', 'NT', 'NS', 'NU', 'ON', 'PE', 'QC', 'SK', 'YT'];
```

```
// Append paragraphs and highlight one element
```

```
let p = d3.select('body').selectAll('p')
  .data(provinces)
  .enter()
  .append('p')
  .text(d => d)
  .attr('class', 'custom-paragraph')
  .style('font-weight', 'bold')
  .style('color', d => {
    if(d == 'BC')
      return 'blue';
    else
      return 'red';
  });
}
```

Introduction to D3

- HTML attributes and CSS properties

```
const numericData = [1, 2, 4, 8, 16];
```

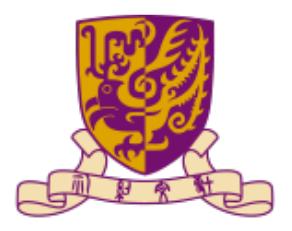
```
// Add <svg> element (drawing space)
const svg = d3.select('body').append('svg')
  .attr('width', 300)
  .attr('height', 50);
```

```
// Add rectangle
svg.selectAll('rect')
  .data(numericData)
  .enter()
  .append('rect')
  .attr('fill', 'red')
  .attr('width', 50)
  .attr('height', 50)
  .attr('y', 0)
  .attr('x', (d, index) => index * 60);
```

Introduction to D3

- Create a new D3 project
- Append a new SVG element to your HTML document with D3 (width: 500px, height: 500px)
- Draw circles with D3
- Define dynamic properties
 - Set the x/y coordinates and make sure that the circles don't overlap each other
 - Radius: *large sandwiches* should be twice as big as small ones
 - Colours: use two different circle colours. One colour (fill) for cheap products < 7.00 USD and one for more expensive products
 - Add a border to every circle (SVG property: stroke)

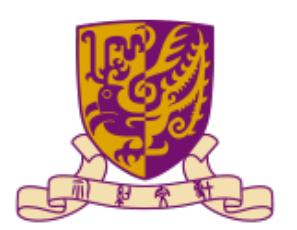
```
const sandwiches = [  
  { name: "Thesis", price: 7.95, size: "large" },  
  { name: "Dissertation", price: 8.95, size: "large" },  
  { name: "Highlander", price: 6.50, size: "small" },  
  { name: "Just Tuna", price: 6.50, size: "small" },  
  { name: "So-La", price: 7.95, size: "large" },  
  { name: "Special", price: 12.50, size: "small" }];
```



Introduction to D3

- Loading external data
 - Instead of typing the data in a local variable, which is only convenient for very small datasets, we can load data *asynchronously* from external files. The D3 built-in methods make it easy to load JSON, CSV, and other files
 - d3.csv()
 - d3.json()

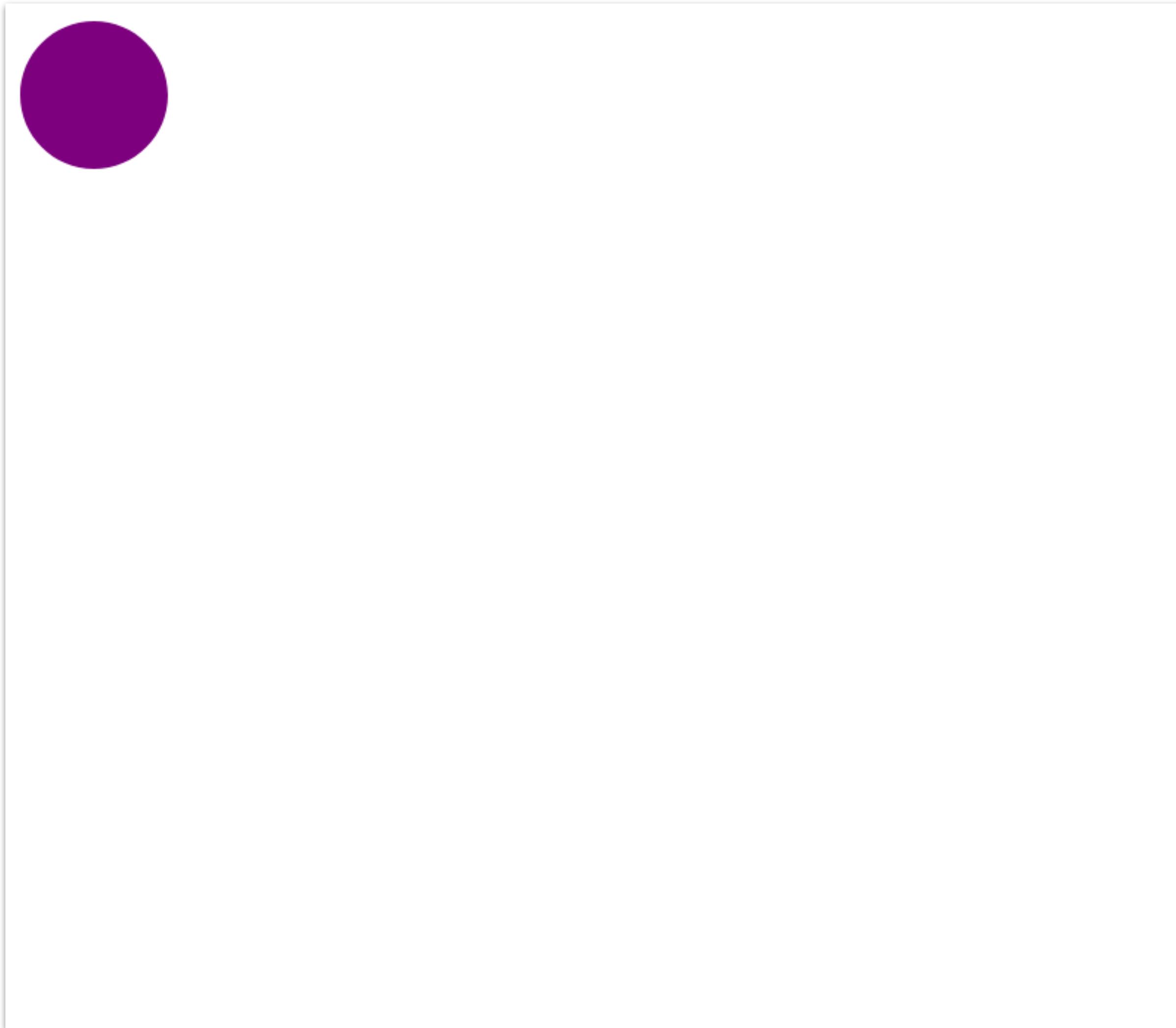
```
d3.csv('data/sandwiches.csv')
  .then(data => {
    console.log(data);
  })
  .catch(error => {
    console.error('Error loading the data');
 });
```



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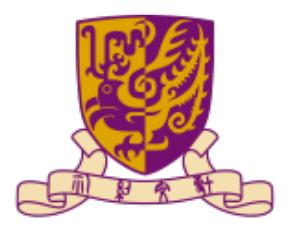
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D3 SVG exercise



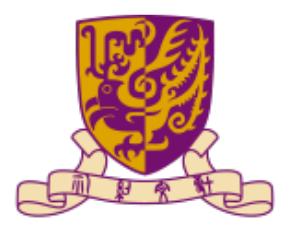
D3 SVG exercise

```
d3.select("body")
  .append("svg")
  .attr("width", 50)
  .attr("height", 50)
  .append("circle")
  .attr("cx", 25)
  .attr("cy", 25)
  .attr("r", 25)
  .style("fill", "purple");
```



Outline

- Introduction to D3
- Making a chart



Making a chart

- SVG groups
 - The group element (<g> </g>) helps us to organize other elements and to apply *transformations*. In this way, we can create hierarchical structures

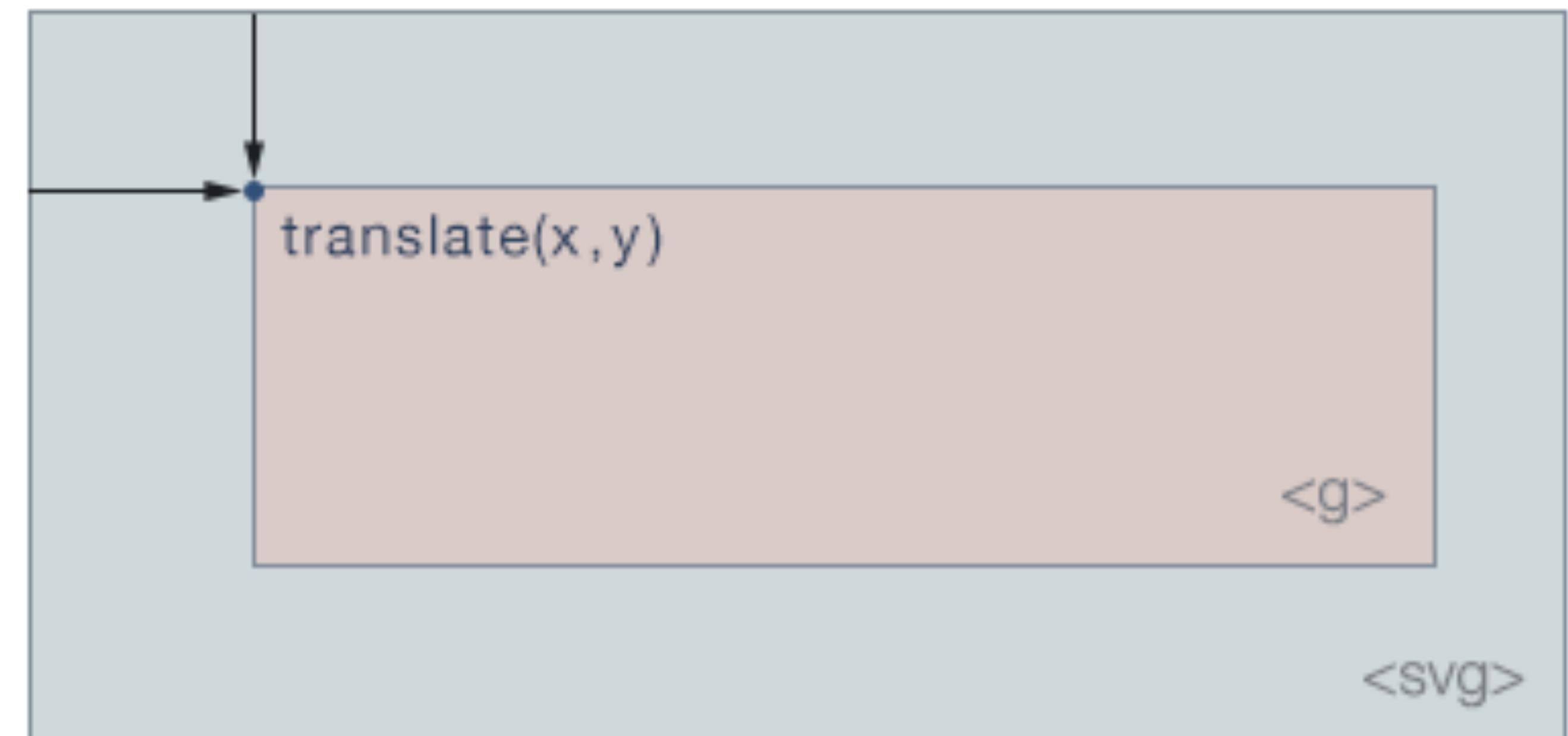
```
// Create group element
const group = svg.append('g');
```

```
// Append circle to the group
const circle = group.append('circle')
    .attr('r', 4)
    .attr('fill', 'blue');
```

Making a chart

- SVG groups
 - Invisible but we can apply transformations, for example *translate()* or *rotate()*, to the group and it will affect the rendering of all child elements

```
const group = svg.append("g")
  .attr("transform", "translate(70, 50)");
```

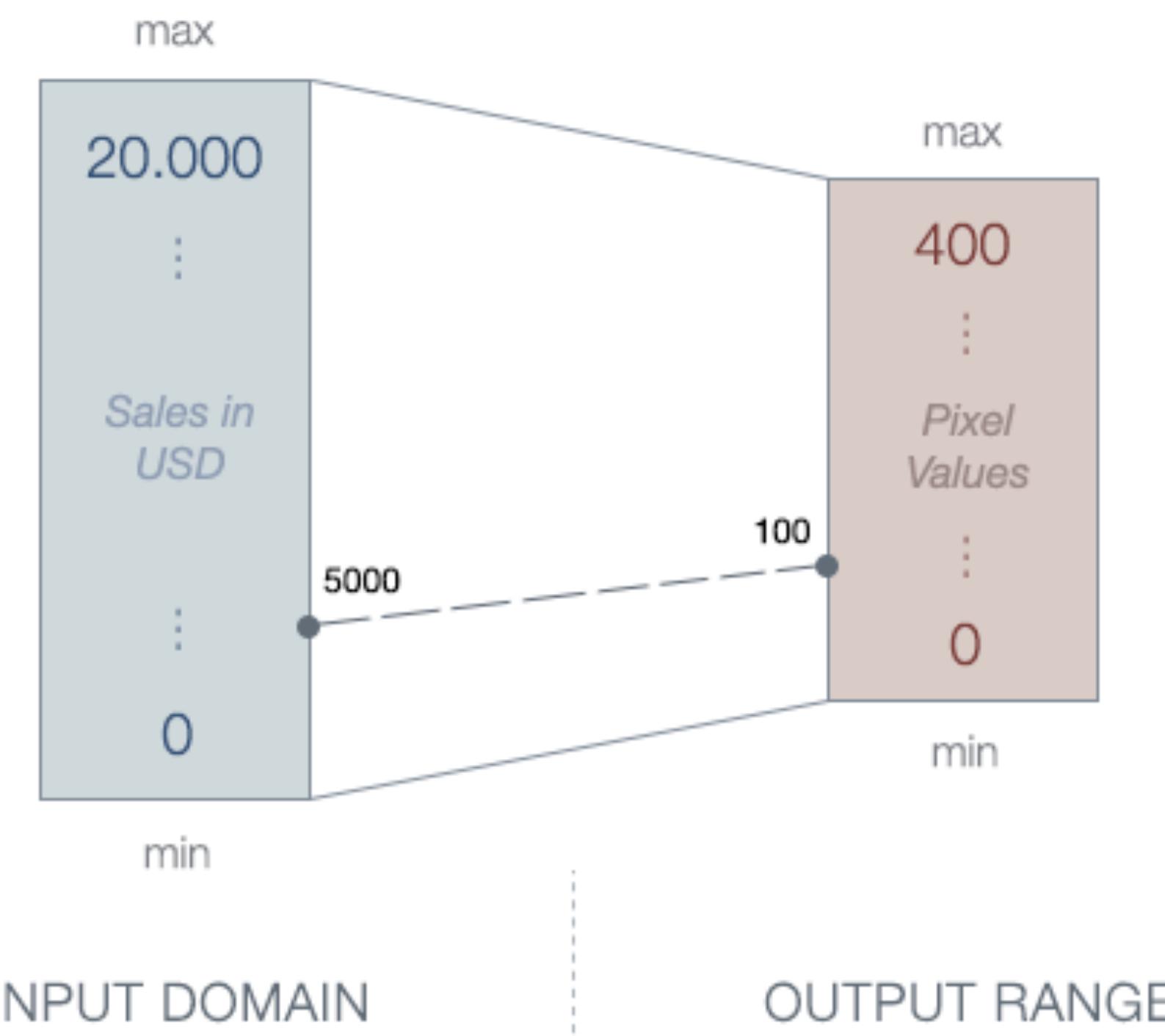


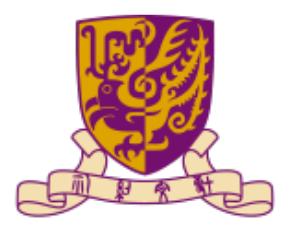
Making a chart

- Scales
 - Scales are functions that map from an input domain to an output range
 - D3 provides built-in methods for many different scales: linear, ordinal, logarithmic, square root, and so on. Most of the time you will use *linear scale functions*, so we will focus on learning this type of scale
 - You can read more about D3 scales here: <https://github.com/d3/d3-scale/blob/master/README.md>

Making a chart

- Scales
- Visualize the monthly sales of an ice cream store. The input data are numbers between 0 and 20,000 USD and the maximum height of the chart is 400px. We take an input interval (called **domain**) and transform it into a new output interval (called **range**).





Making a chart

- Scales

```
// Creating a linear scale function
const iceCreamScale = d3.scaleLinear()
  .domain([0, 20000])
  .range([0, 400]);

// Call the function and pass an input value
iceCreamScale(5000);    // Returns: 100
```

Making a chart

- **Scales**

```
const quarterlyReport = [  
    { month: 'May', sales: 6900 },  
    { month: 'June', sales: 14240 },  
    { month: 'July', sales: 25000 },  
    { month: 'August', sales: 17500 }  
];
```

```
// Returns the maximum value in a given array (= 25000)  
const max = d3.max(quarterlyReport, d => d.sales);
```

```
// Returns the minimum value in a given array (= 6900)  
const min = d3.min(quarterlyReport, d => d.sales);
```

```
// Returns the min. and max. value in a given array (= [6900,25000])  
const extent = d3.extent(quarterlyReport, d => d.sales);
```

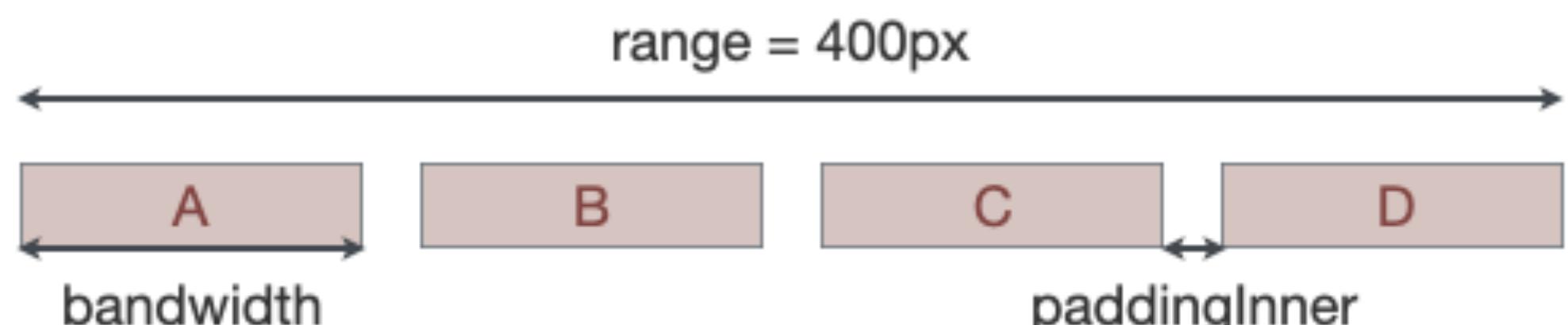
Making a chart

- Scales
 - Time scales: time scales are a variant of linear scales that have a temporal domain. They require JS date objects
 - Ordinal scales: create ordinal scales with a discrete domain

```
// Create an ordinal scale function
const xScale = d3.scaleBand()
    .domain(['Vanilla', 'Cookies', 'Chocolate', 'Pistachio'])
    .range([0, 400])          // D3 fits n (=4) bands within a 400px space
    .paddingInner(0.05); // Adds spacing between bands
```

```
// By definition all bands have the same width
// and you can get it with `xScale.bandwidth()`
```

```
// We can use JS .map() instead of manually specifying all possible values
const months = quarterlyReport.map(d => d.month);
months // Returns: ['May', 'June', 'July', 'August']
```



Making a chart

- Scales
 - Colour scales: built-in color palettes that work like ordinal scales and can also be accessed like other scales

```
// Construct a new ordinal scale with a range of ten categorical colours
```

```
var colorPalette = d3.scaleOrdinal(d3.schemeCategory10);
```

```
// We can log the color range and see 10 distinct hex colours
```

```
console.log(colorPalette.range());
```

```
// ["#1f77b4", "#ff7f0e", "#2ca02c", "#d62728", "#9467bd", "#8c564b", "#e377c2", "#7f7f7f", "#bcbd22", "#17becf"]
```

```
// Specify domain (optional)
```

```
colorPalette.domain(['Vanilla', 'Cookies', 'Chocolate', 'Pistachio']);
```

```
// Use color palette
```

```
colorPalette("Chocolate") // Returns: #2ca02c
```



Making a chart

- Refine axis
 - Automatically adjust the spacing and labels for a given scale and range

```
var xAxis = d3.axisBottom()  
    .scale(xScale)  
    . .... // Add options here
```

- Number of ticks: .ticks(5)
- Tick format, e.g. as percentage: .tickFormat(d3.format(".0%"))
- Predefined tick values: .tickValues([0, 10, 20, 30, 40])
- Remove tick marks at the beginning and end of an axis: .tickSizeOuter(0)

Making a chart

- Axes
 - Provide four methods to create axes with different orientations and label placements (`d3.axisTop`, `d3.axisBottom`, `d3.axisLeft`, and `d3.axisRight`) which can display reference lines for D3 scales automatically
 - Use `call()` to add into svg

```
// Create a horizontal axis with labels placed below the axis
```

```
const xAxis = d3.axisBottom();
```

```
// Pass in the scale function
```

```
xAxis.scale(xScale);
```

```
svg.append('g')
  .attr('class', 'axis x-axis')
  .call(xAxis);
```

Making a chart

- Draw a bar chart

```
const margin = {top: 5, right: 5, bottom: 20, left: 50};
```

```
// Width and height as the inner dimensions of the chart area
```

```
const width = 500 - margin.left - margin.right,
```

```
height = 140 - margin.top - margin.bottom;
```

```
// Define 'svg' as a child-element (g) from the drawing area and include spaces
```

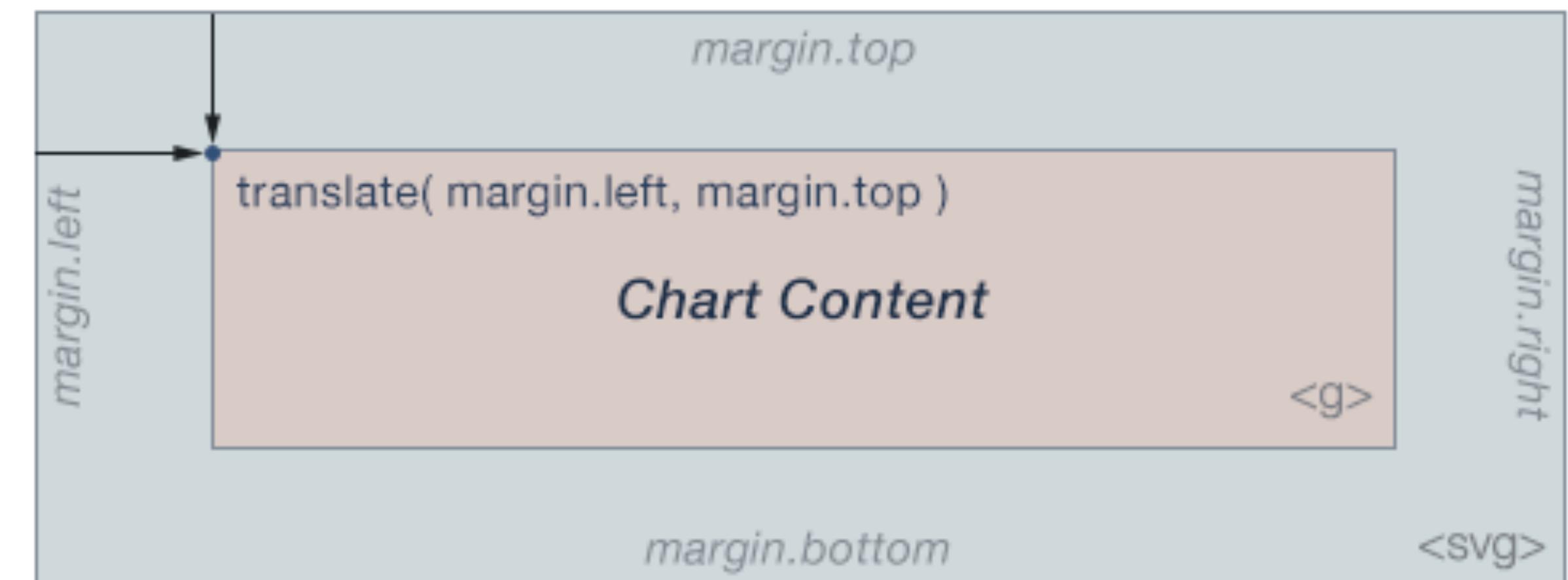
```
const svg = d3.select('#chart').append('svg')
```

```
    .attr('width', width + margin.left + margin.right)
```

```
    .attr('height', height + margin.top + margin.bottom)
```

```
    .append('g')
```

```
    .attr('transform', `translate(${margin.left}, ${margin.top})`);
```



Making a chart

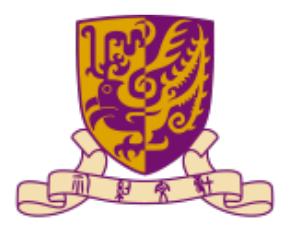
- Draw a bar chart

```
// Initialize linear and ordinal scales (input domain and output range)
const xScale = d3.scaleLinear()
  .domain([0, d3.max(data, d => d.sales)])
  .range([0, width]);

const yScale = d3.scaleBand()
  .domain(data.map(d => d.month))
  .range([0, height])
  .paddingInner(0.15);

// Initialize axes
const xAxis = d3.axisBottom(xScale)
  .ticks(6)
  .tickSizeOuter(0);

const yAxis = d3.axisLeft(yScale)
  .tickSizeOuter(0);
```



Making a chart

- Draw a chart

```
// Draw the axis (move xAxis to the bottom with 'translate')
```

```
const xAxisGroup = svg.append('g')
  .attr('class', 'axis x-axis')
  .attr('transform', `translate(0, ${height})`)
  .call(xAxis);
```

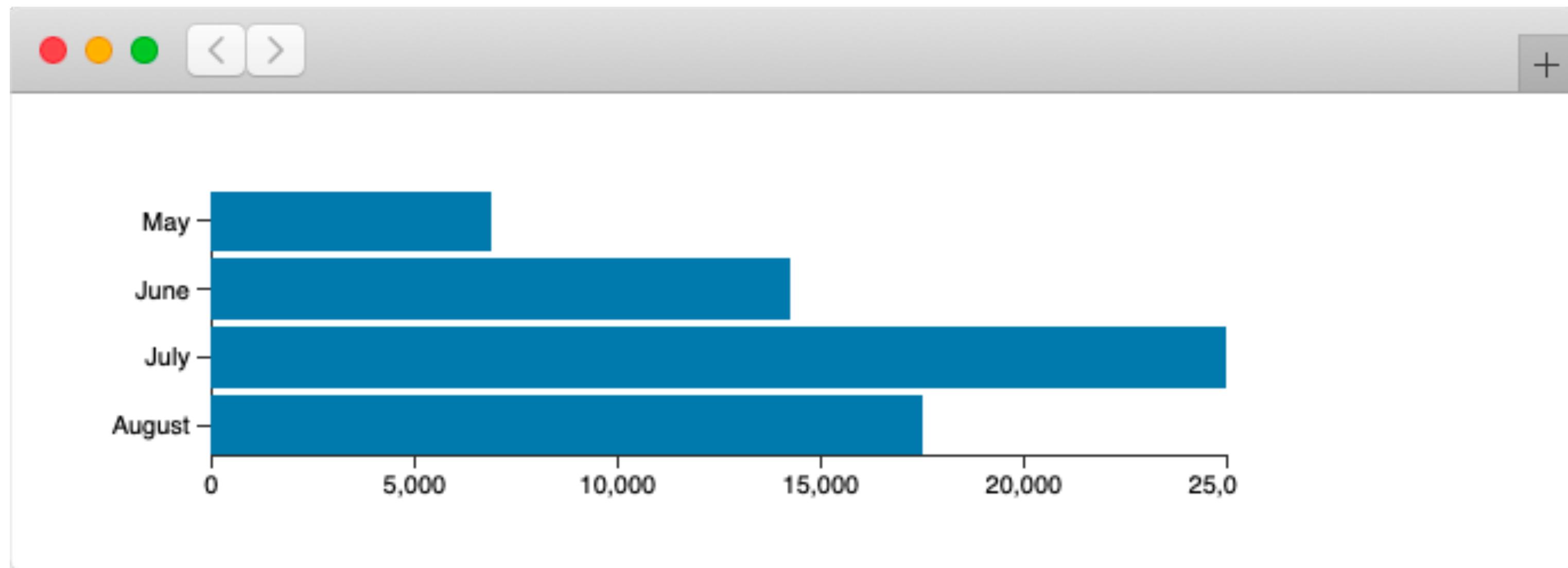
```
const yAxisGroup = svg.append('g')
```

```
  .attr('class', 'axis y-axis')
  .call(yAxis);
```

Making a chart

- Draw a bar chart

```
// Add rectangles
svg.selectAll('rect')
  .data(data)
  .enter()
  .append('rect')
  .attr('class', 'bar')
  .attr('width', d => xScale(d.sales))
  .attr('height', yScale.bandwidth())
  .attr('y', d => yScale(d.month))
  .attr('x', 0);
```

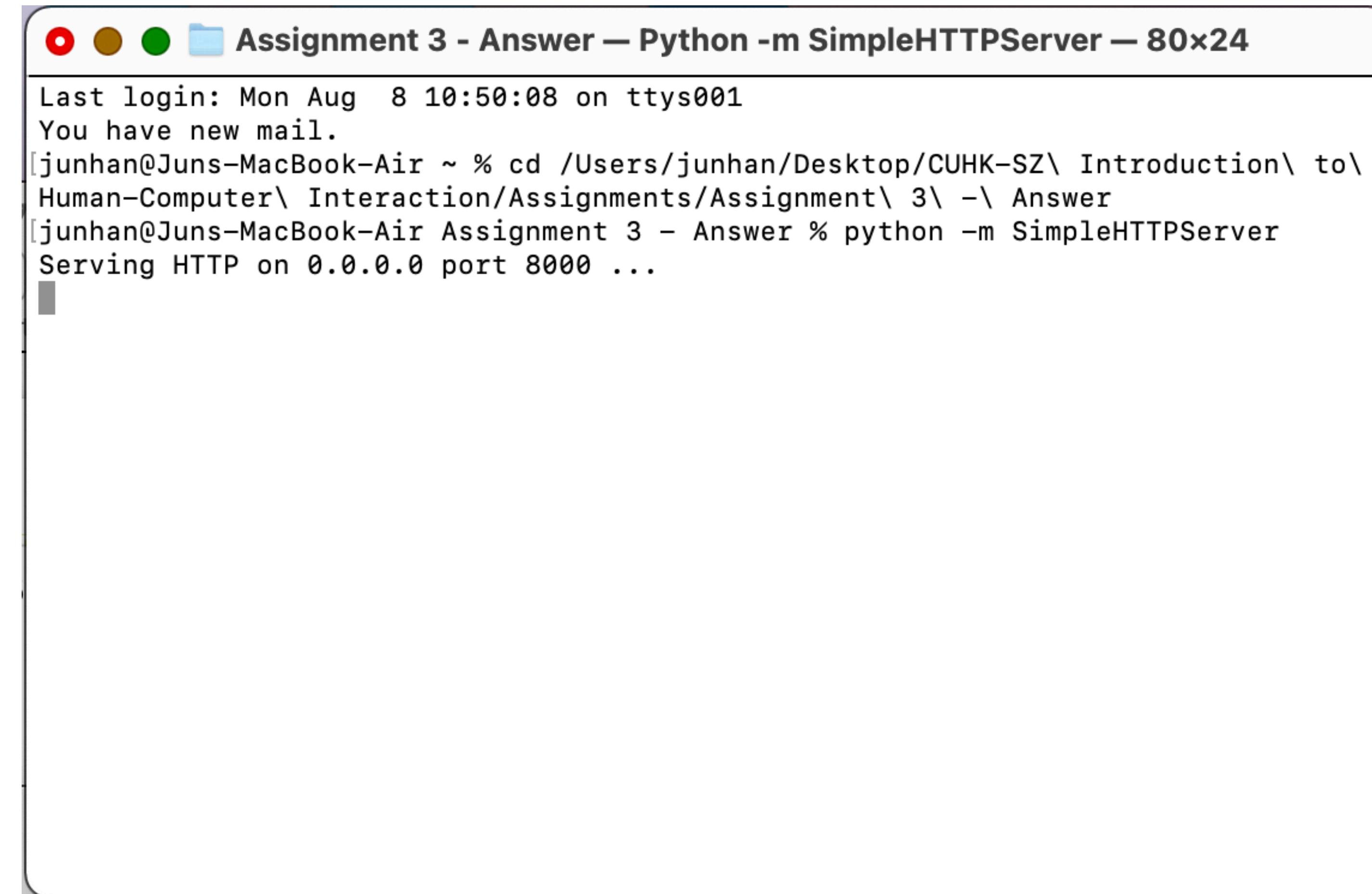


How to access local files

- Build a local server
- Change security permission in browser

How to access local files (using python)

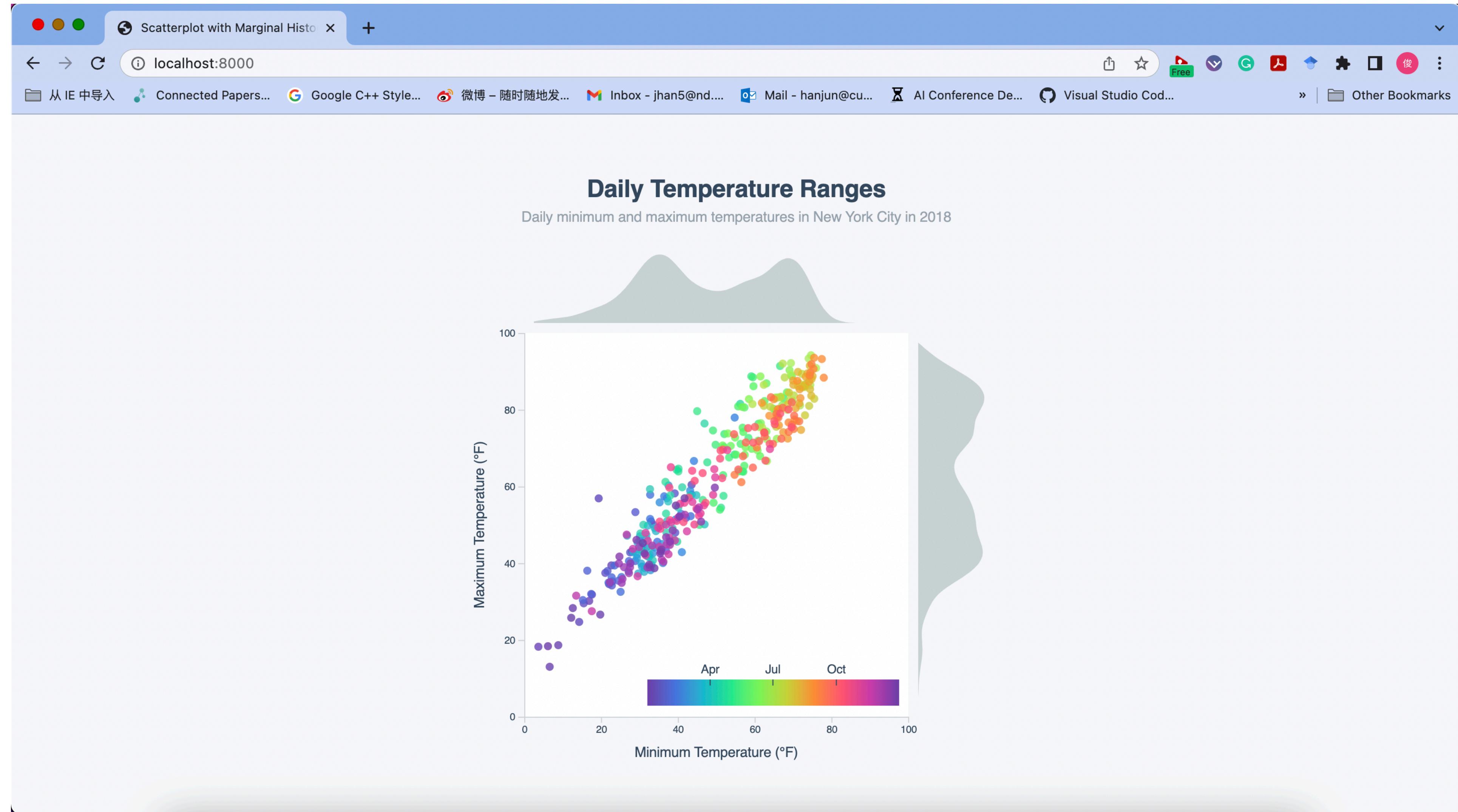
- Go to the folder including html file(s) and type `python -m SimpleHTTPServer` in terminal



```
Assignment 3 - Answer — Python -m SimpleHTTPServer — 80x24
Last login: Mon Aug  8 10:50:08 on ttys001
You have new mail.
[junhan@Juns-MacBook-Air ~ % cd /Users/junhan/Desktop/CUHK-SZ\ Introduction\ to\ ]
Human-Computer\ Interaction/Assignments/Assignment\ 3\ -\ Answer
[junhan@Juns-MacBook-Air Assignment 3 - Answer % python -m SimpleHTTPServer
Serving HTTP on 0.0.0.0 port 8000 ...]
```

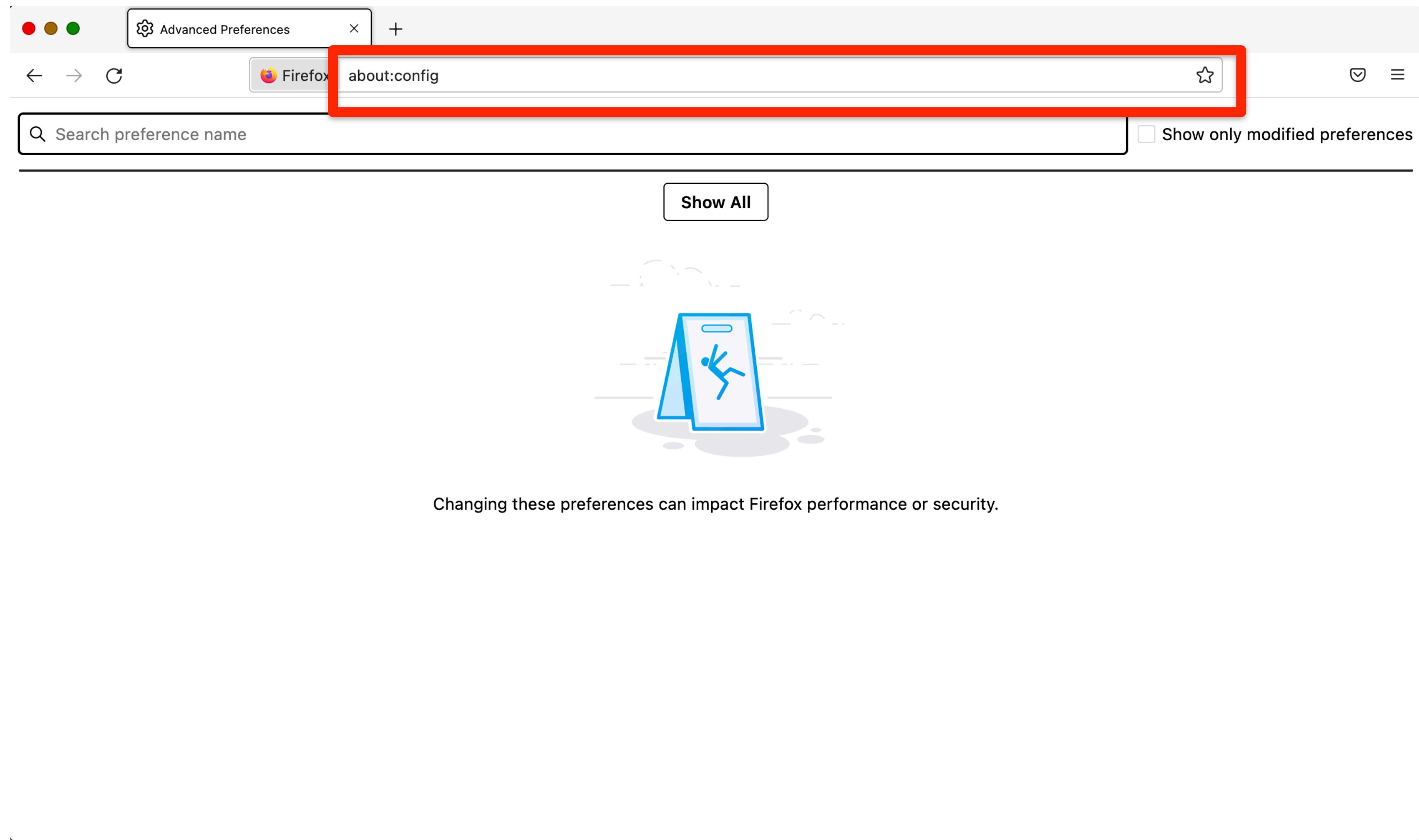
How to access local files (using python)

- Open a browser and go to <http://localhost:8000>



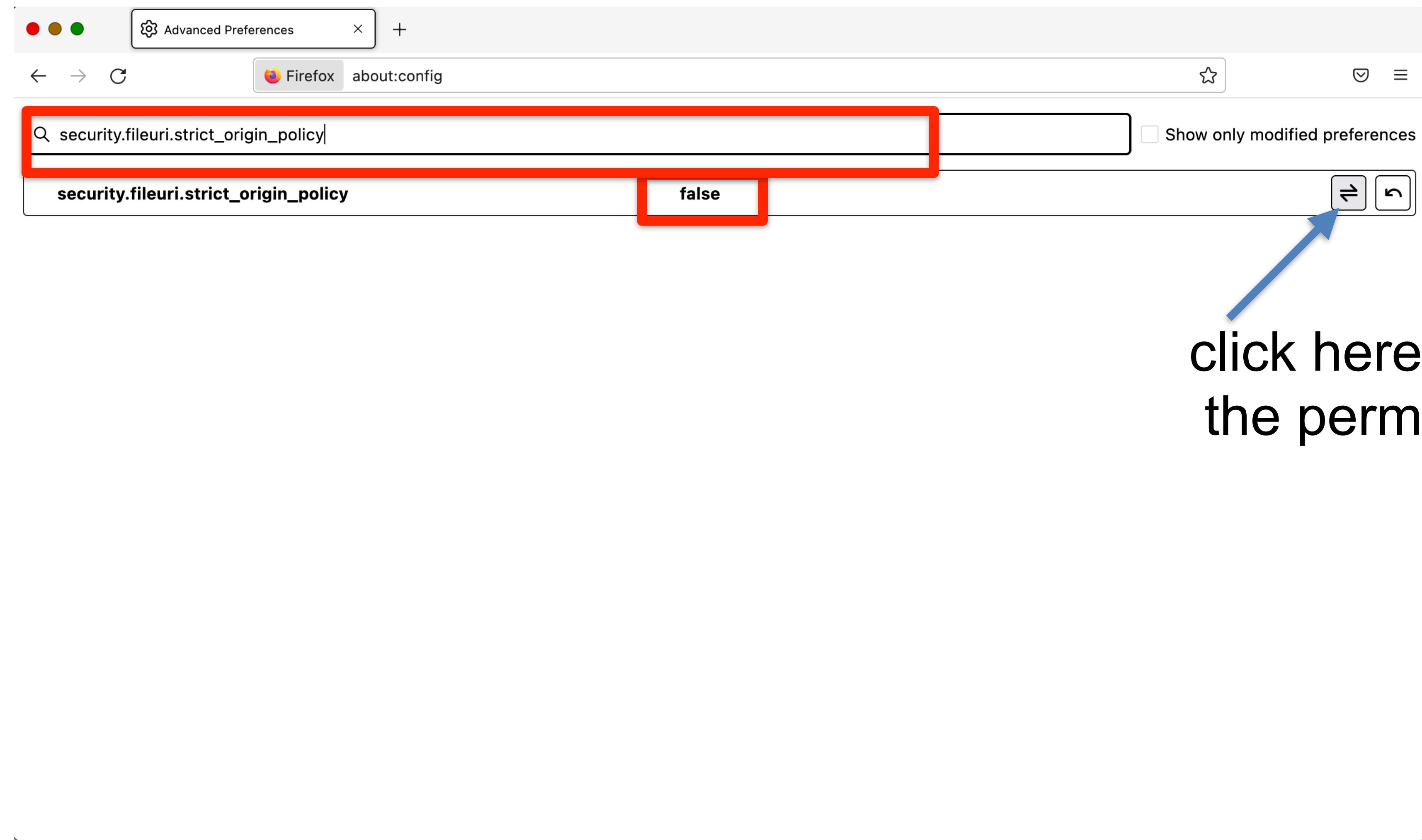
How to access local files (FireFox)

- Type about:config



How to access local files (FireFox)

- Search `security.fileuri.strict_origin_policy` and change true to false



D3 exercise bar chart

- In html, create a div that will be modified by D3 later
- In Javascript, set a svg area and specify the chart size and its margin
- Read data from a .csv file
- This numeric variable is provided to the d3.histogram() function that will compute the binning and returns the coordinates of each bar
- These bars can thus be drawn using a classic .append("rect") approach

Bar chart

- In html, create a div that will be modified by D3 later

```
<!DOCTYPE html>
<html>

</html>
<meta charset="utf-8">

<!-- Create a div where the graph will take place -->
<div id="my_dataviz"></div>

<!-- Load .js -->
<script src="https://d3js.org/d3.v6.js"></script>
<script src="src/bar-chart.js"></script>
</html>
```

Bar chart

- In Javascript, set a svg area and specify the chart size and its margin

```
const margin = {top: 30, right: 30, bottom: 70, left: 60},  
width = 460 - margin.left - margin.right,  
height = 400 - margin.top - margin.bottom;
```

```
// append the svg object to the body of the page  
const svg = d3.select("#my_dataviz")  
  .append("svg")  
    .attr("width", width + margin.left + margin.right)  
    .attr("height", height + margin.top + margin.bottom)  
  .append("g")  
    .attr("transform", `translate(${margin.left},${margin.top})`);
```

Bar chart

- Read data from a .csv file

```
d3.csv("https://raw.githubusercontent.com/holtzy/data_to_viz/master/  
Example_dataset/1_OneNum.csv").then(function(data){
```

Bar chart

- This numeric variable is provided to the d3.histogram() function that will compute the binning and returns the coordinates of each bar

```
// X axis: scale and draw:
```

```
const x = d3.scaleLinear()  
    .domain([0, 1000]) // can use this instead of 1000 to have the max of data: d3.max(data,  
function(d) { return +d.price })  
    .range([0, width]);  
svg.append("g")  
    .attr("transform", `translate(0, ${height})`)  
    .call(d3.axisBottom(x));
```

```
// set the parameters for the histogram
```

```
const histogram = d3.histogram()  
    .value(function(d) { return d.price; }) // I need to give the vector of value  
    .domain(x.domain()) // then the domain of the graphic  
    .thresholds(x.ticks(70)); // then the numbers of bins
```

Bar chart

- This numeric variable is provided to the d3.histogram() function that will compute the binning and returns the coordinates of each bar

```
// And apply this function to data to get the bins  
const bins = histogram(data);
```

```
// Y axis: scale and draw:  
const y = d3.scaleLinear()  
  .range([height, 0]);  
  y.domain([0, d3.max(bins, function(d) { return d.length; })]); // d3.hist has to be called  
before the Y axis obviously  
svg.append("g")  
  .call(d3.axisLeft(y));
```

Bar chart

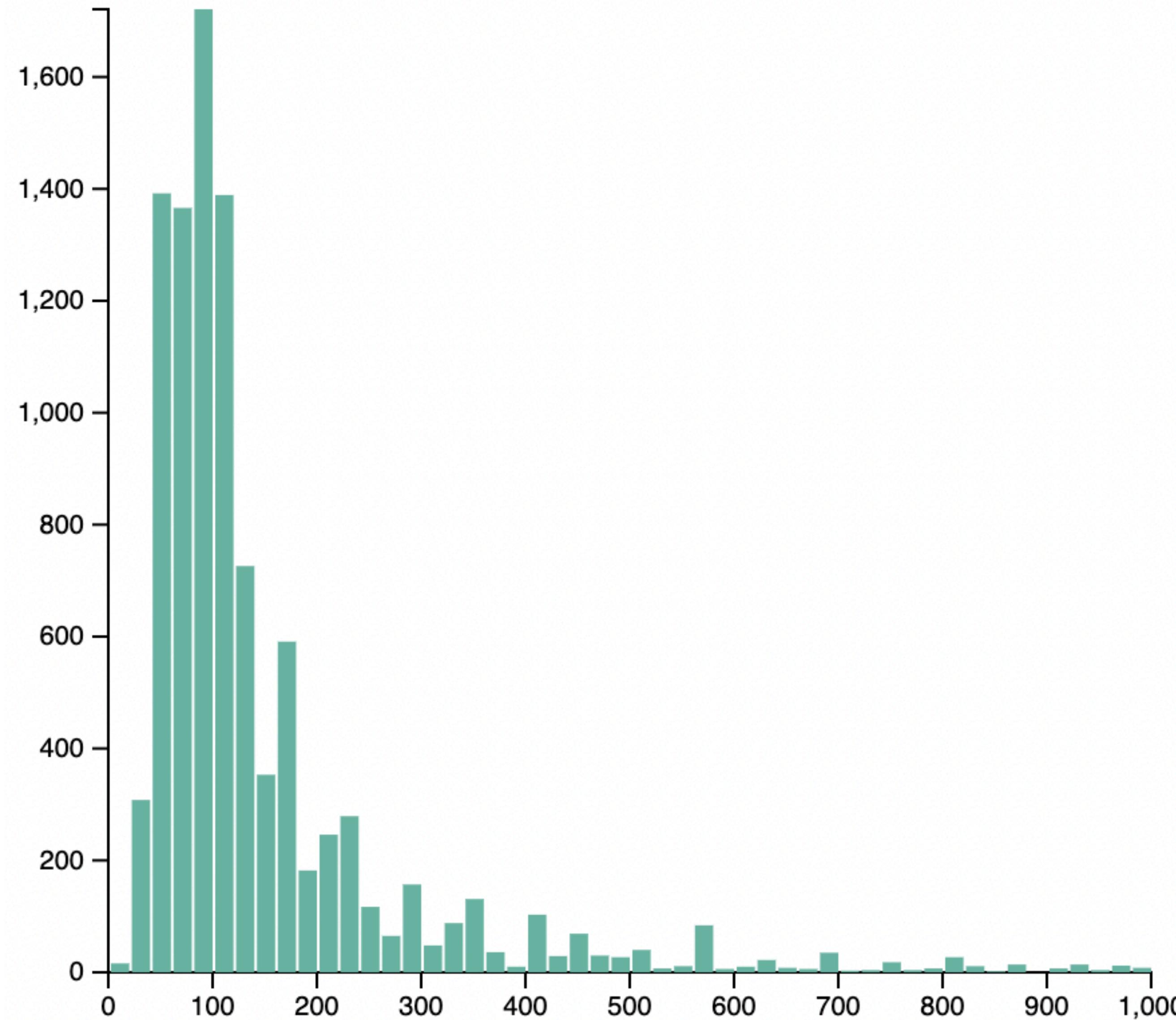
- These bars can thus be drawn using a classic `.append("rect")` approach

```
// append the bar rectangles to the svg element
```

```
svg.selectAll("rect")
  .data(bins)
  .join("rect")
    .attr("x", 1)
    .attr("transform", function(d) { return `translate(${x(d.x0)} , ${y(d.length)})`})
    .attr("width", function(d) { return x(d.x1) - x(d.x0)-1})
    .attr("height", function(d) { return height - y(d.length); })
    .style("fill", "#69b3a2")

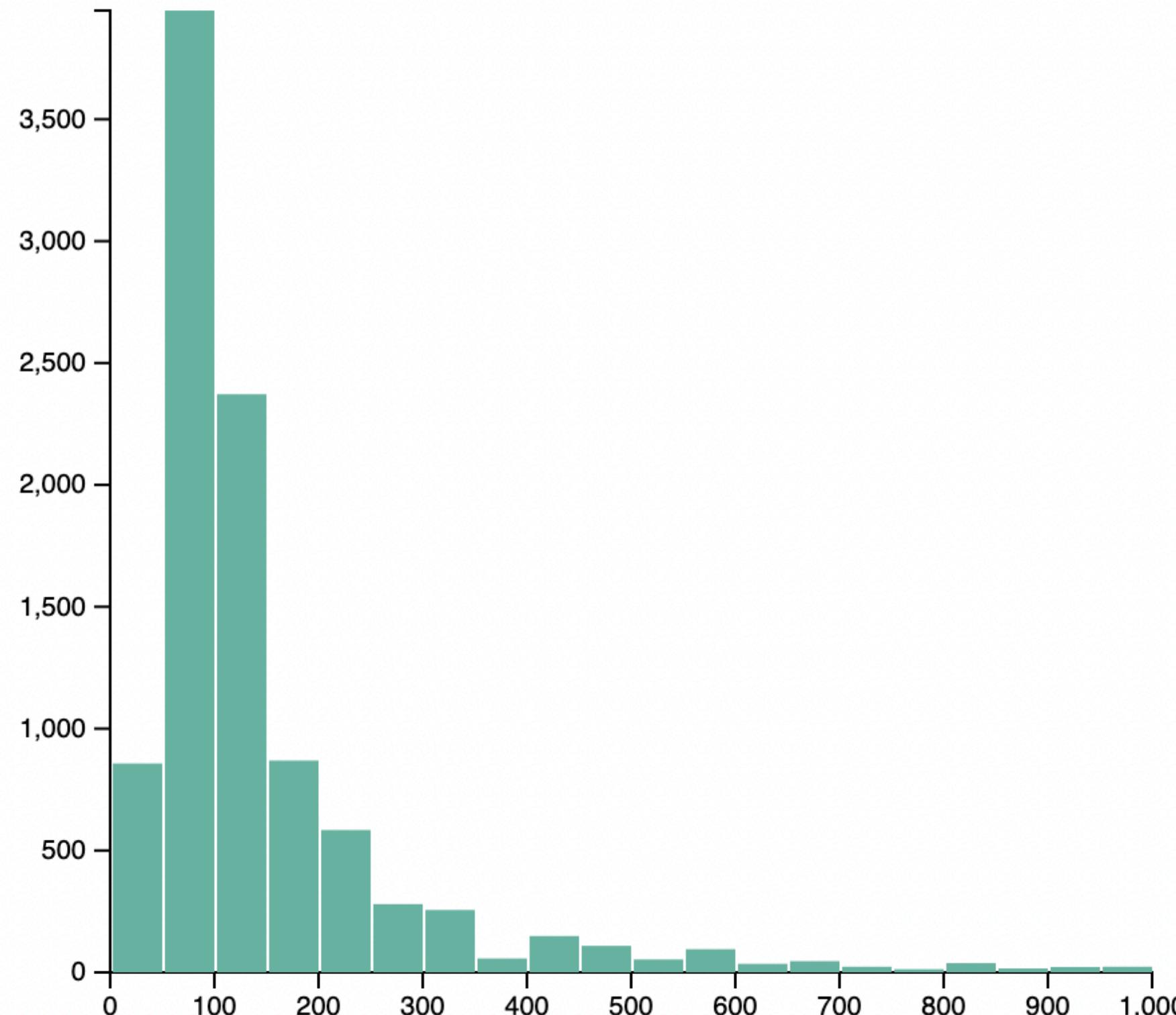
});
```

Bar chart

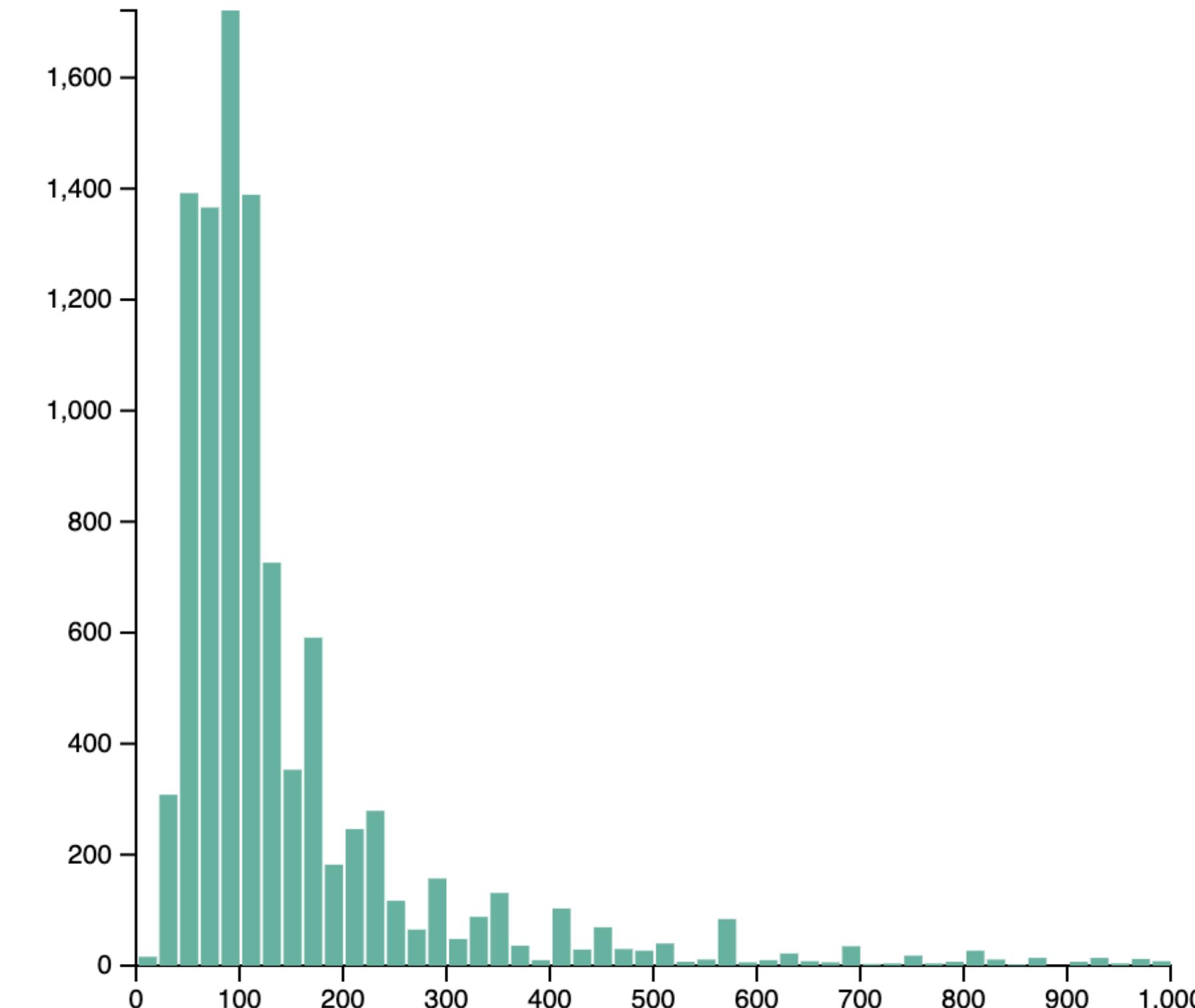


Bar chart interaction exercise

- Based on the previous example, add a controller that users can choose the number of bins when drawing a bar chart



bins 

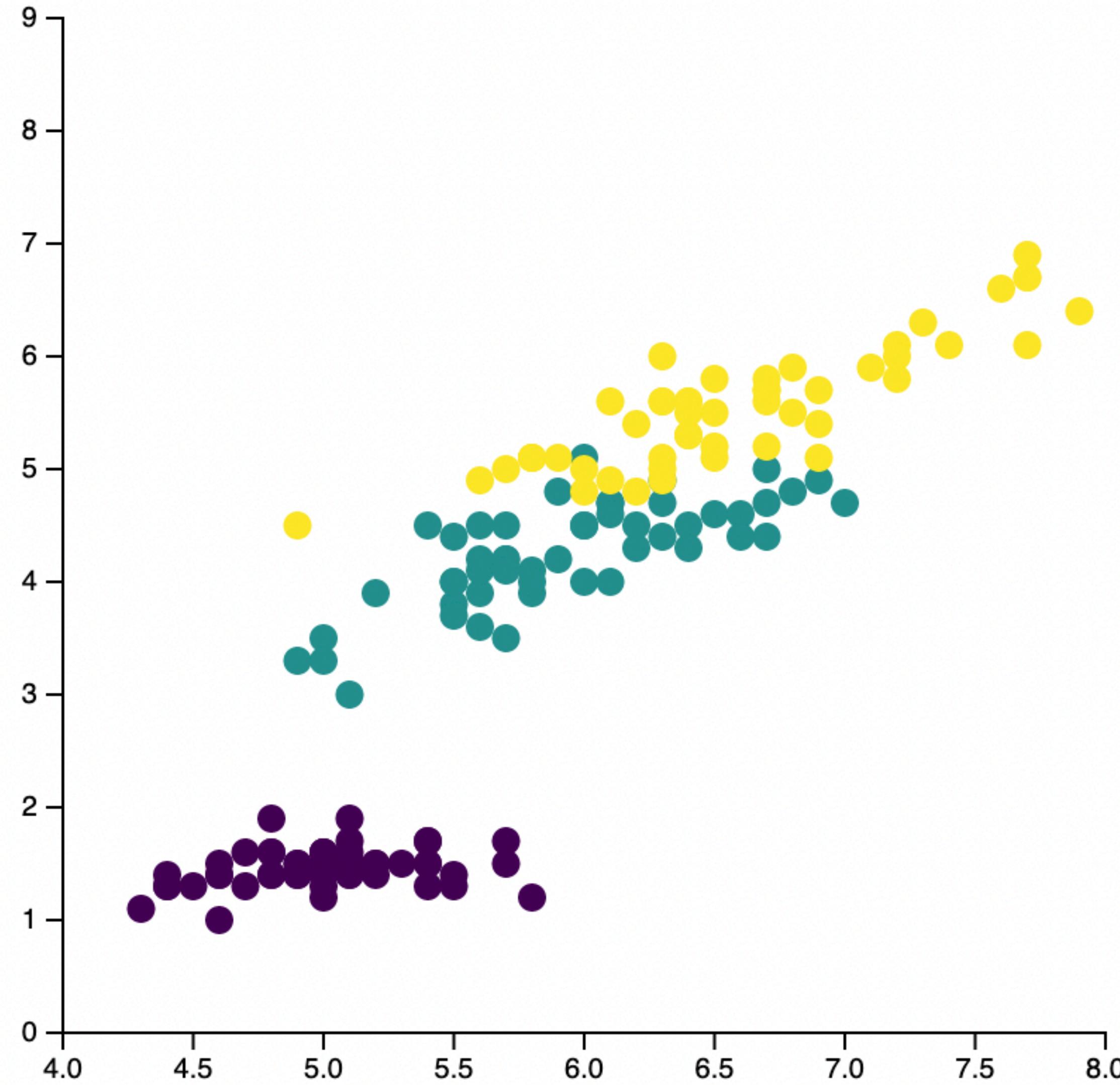


bins 

D3 exercise: scatter chart

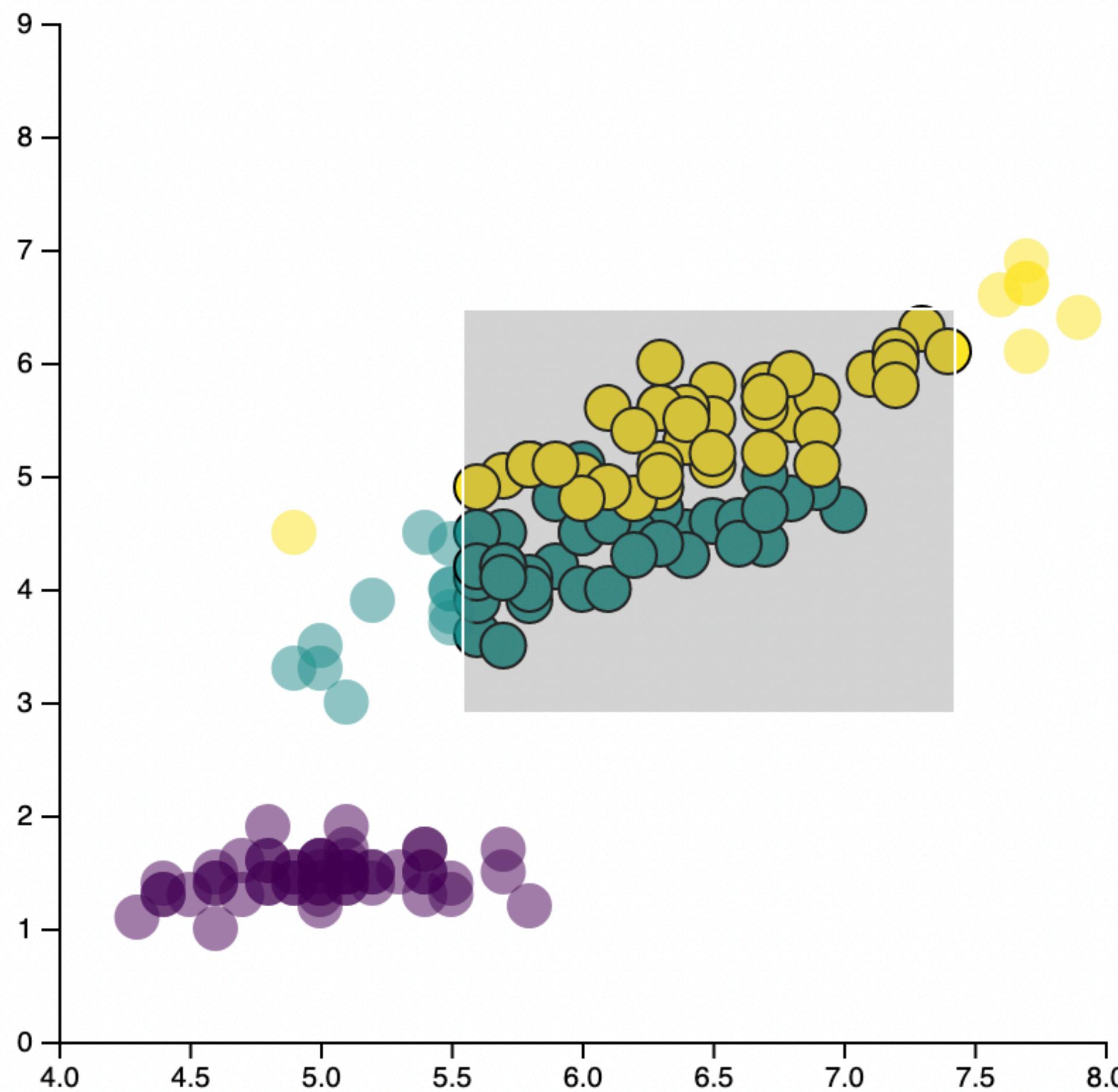
- Create a div that will be modified by D3 it defines a svg area with margins
- Read data using d3.csv() and scale x and y axis points
- Create a color scale with scaleOrdinal, attributing a different color for each group
- Points add by appending circle to the svg

Scatter chart



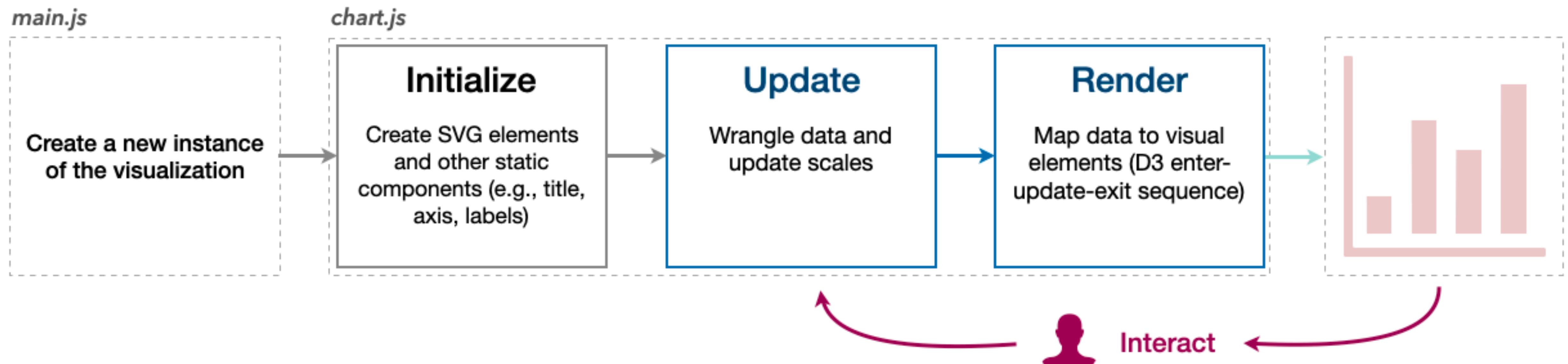
Scatter chart interaction exercise

- Based on the previous example, add a mouse brush function that users can brush dots in the scatter and highlight the selected dots



Making a chart

- Reuse D3 component



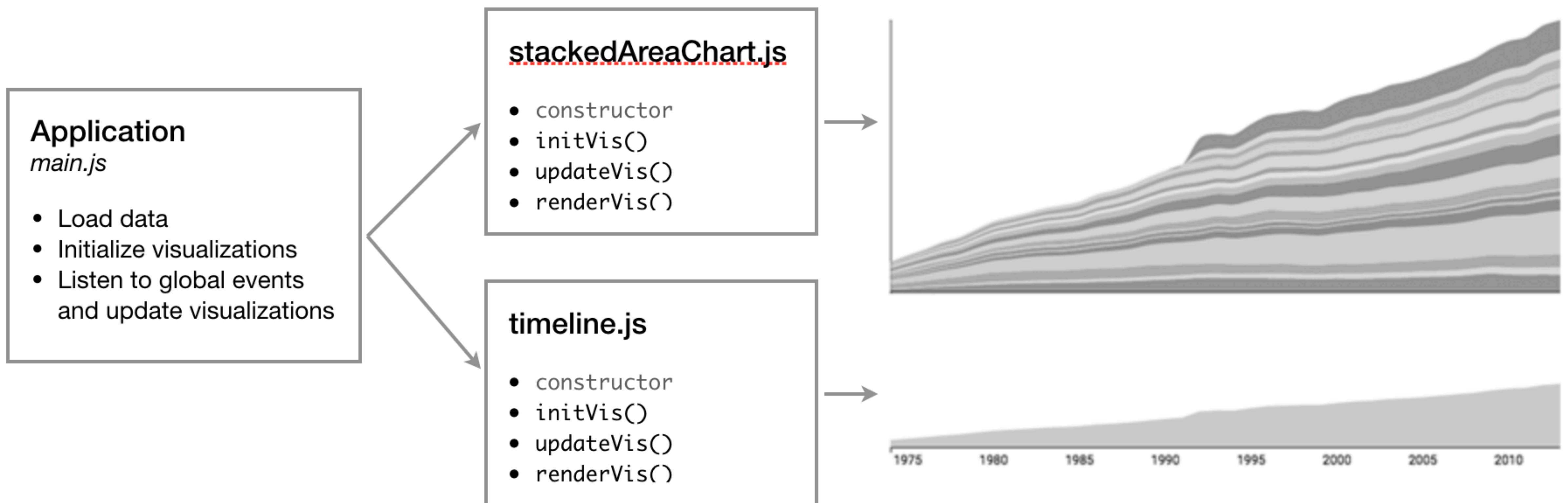
Making a chart

- Introduce classes to better support object-oriented programming
that you should use // Create an instance (for example in main.js)

```
// Create an instance (for example in main.js)
let barchart = new BarChart({
  'parentElement': '#bar-chart-container',
  'containerHeight': 400
});
```

```
barchart.data = data;
```

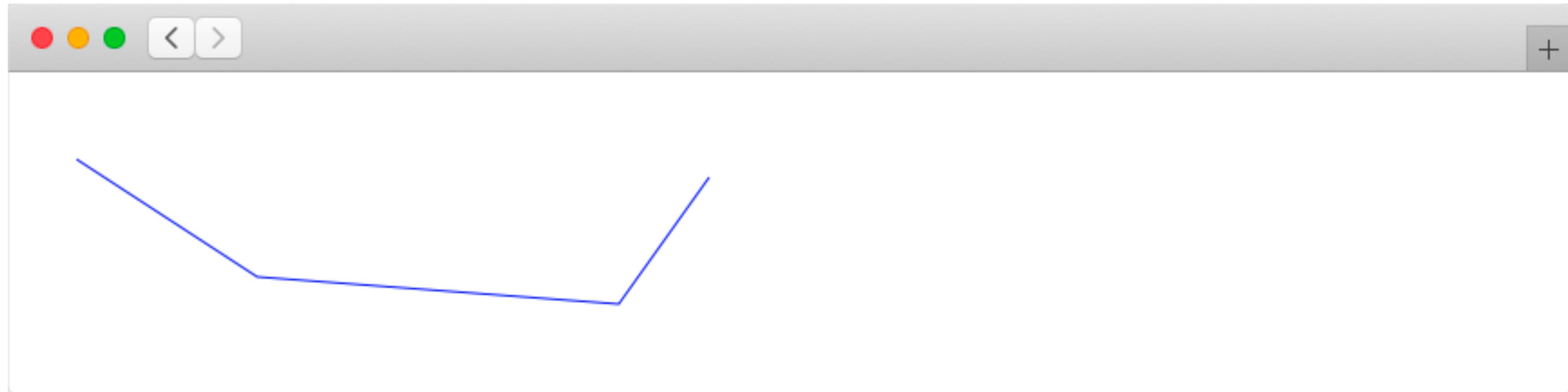
Making a chart



Making a chart

- Making line and area charts

```
<svg width="500" height="200">
  <path style="fill: none; stroke: blue" d="M0 10 L100 75 L300 90 L350 20"></path>
</svg>
```



Making a chart

- Making line and area charts

```
const data = [{x: 0, y: 10}, {x: 100, y: 75}, {x: 300, y: 90}, {x: 350, y: 20}]
```

```
// Prepare a helper function
const line = d3.line()
  .x(d => d.x)
  .y(d => d.y);
```

```
// Add the <path> to the <svg> container using the helper function
d3.select('svg').append('path')
  .attr('d', line(data))
  .attr('stroke', 'red')
  .attr('fill', 'none');
```



Making a chart

- Making line and area charts

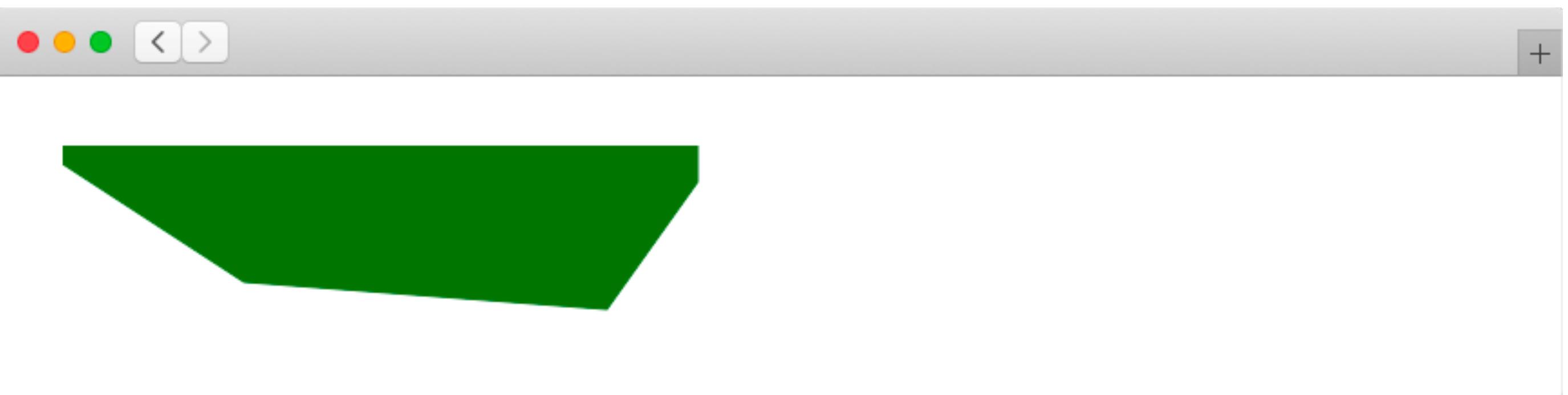
```
const data = [{x: 0, y: 10}, {x: 100, y: 75}, {x: 300, y: 90}, {x: 350, y: 20}]
```

```
// Prepare a helper function
```

```
const area = d3.area()  
.x(d => d.x)    // Same x-position  
.y1(d => d.y)   // Top line y-position  
.y0(0)          // Bottom line y-position
```

```
// Add the area path using this helper function
```

```
d3.select('svg').append('path')  
.attr('d', area(data))  
.attr('stroke', 'green')  
.attr('fill', 'green');
```



Making a chart

- Making line and area charts

```
const data = [{x: 0, y: 10}, {x: 100, y: 75}, {x: 300, y: 90}, {x: 350, y: 20}]
```

```
// Prepare a helper function
```

```
const area = d3.area()  
.x(d => d.x)    // Same x-position  
.y1(d => d.y)   // Top line y-position  
.y0(150)         // Bottom line y-position  
.curve(d3.curveNatural)
```

```
// Add the area path using this helper function
```

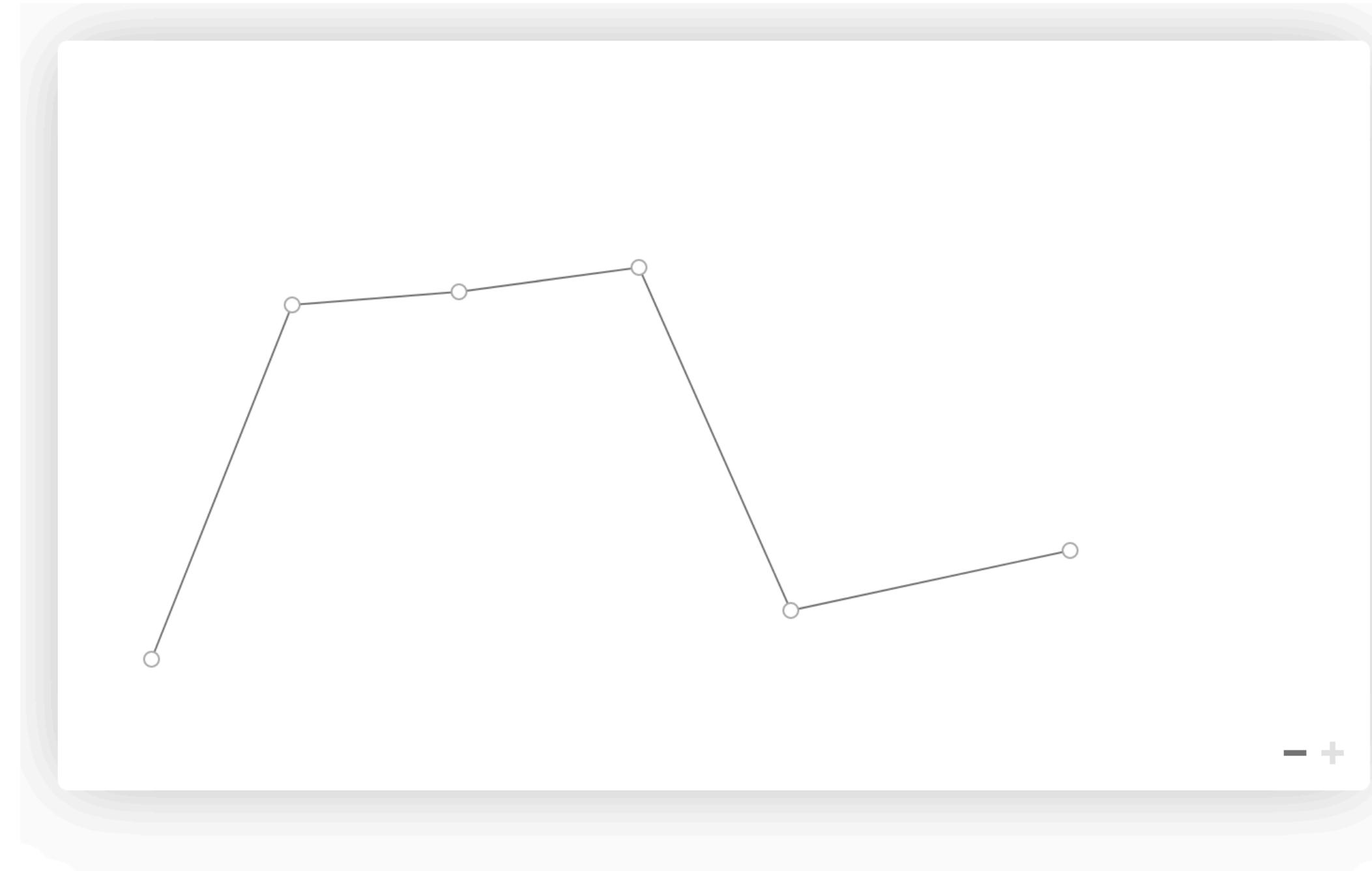
```
d3.select('svg').append('path')  
.attr('d', area(data))  
.attr('stroke', 'green')  
.attr('fill', 'green');
```



Making a chart

- Compare different curve interpolation types interactively

D3 curve explorer



D3 CURVE EXPLORER

curveLinear

curveBasis

curveBasisClosed

curveBundle ($\beta=0$)

curveBundle ($\beta=0.5$)

curveBundle ($\beta=1$)

curveCardinal ($tension=0$)

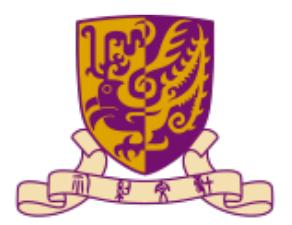
curveCardinal ($tension=0.5$)

curveCardinal ($tension=1$)

curveCatmullRom ($\alpha=0$)

curveCatmullRom ($\alpha=0.5$)

curveCatmullRom ($\alpha=1$)



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Thank Dr. Michael Oppermann for many of the slides!