Data Visualization on the Web with D3 and Leaflet

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Today's Plan

- Brief overview of Data Visualization
- Where does D3 fit in?
- Whirlwind introduction to Web Development
- Explore D3 Core Concepts and build a bar chart
- Web mapping with Leaflet
- Discussion (Visualization, Web Development, Learning, Deeper dive into some examples, etc.)

Brief Overview of Data Visualization

What is Data Visualization?

- Graphical display of abstract information for communication and sense-making
- Modern equivalent of Visual Communication

Goals

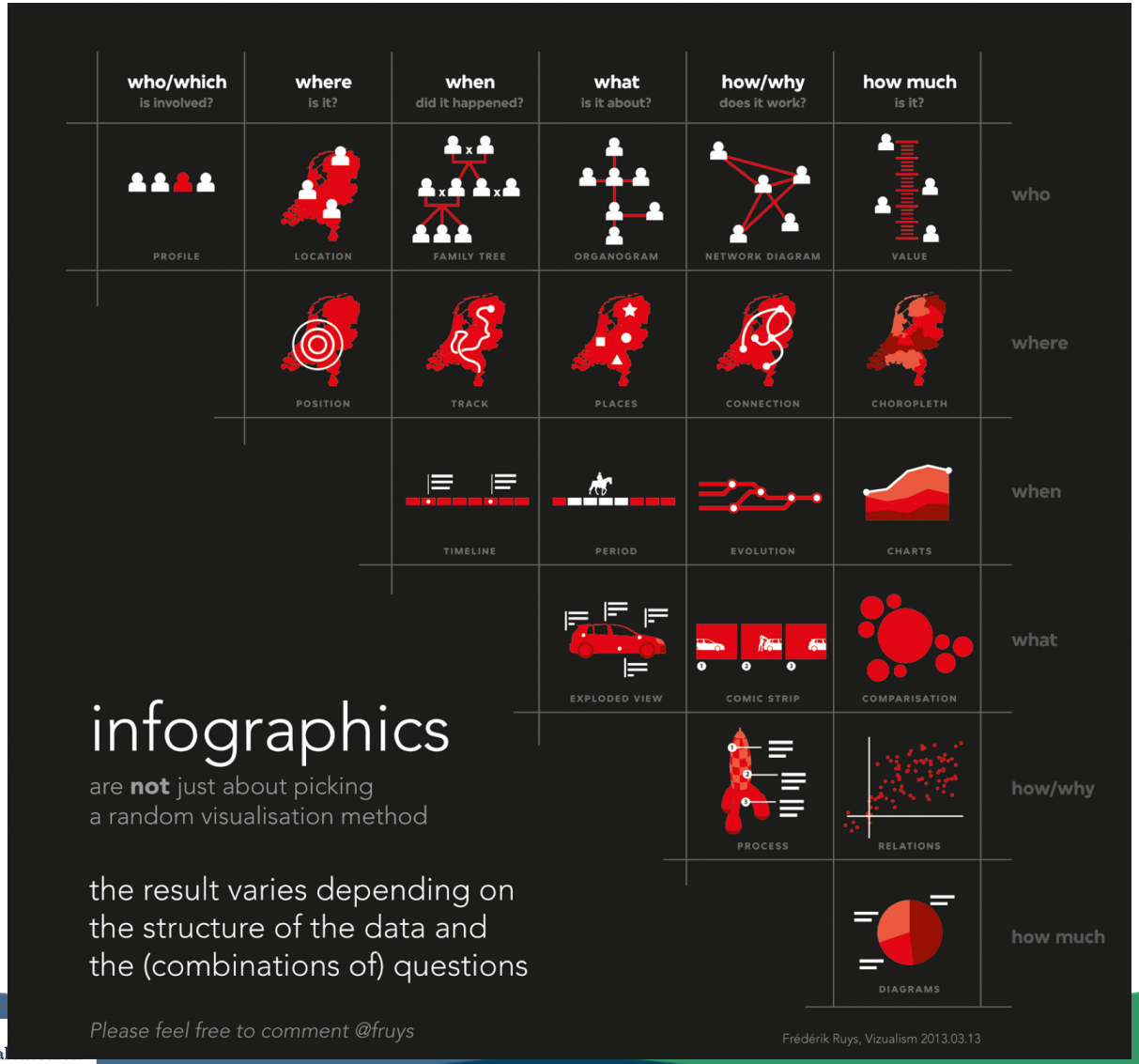
- Using graphics with or without explanatory texts for Communication
- Displaying data for Analysis
- The Changing Goals of Data Visualization

Types of Quantitative Messages (Stephen Few)

- Timeseries: A single variable is captured over a period of time
- Ranking: Categorical subdivisions are ranked in ascending or descending order
- Part-to-whole: Categorical subdivisions are measured as a ratio to the whol
- Deviation: Categorical subdivisions are compared against a reference
- Frequency Distribution: Number of observations of a particular variable for given interval
- Correlation: Comparison between observations represented by two variables
- Nominal Comparison: Comparing categorical subdivisions in no particular order
- Geographic: Comparison of a variable across a map or layout

Form follows function

Link



Why publish on the web?

- Fastest way to reach a larger audience
- Working with web-standard technologies means that your work can be seen and experienced by anyone using a recent web browser, regardless of the operating system and device type.
- Avoiding proprietary software (e.g. GIS)

Technology Strategy

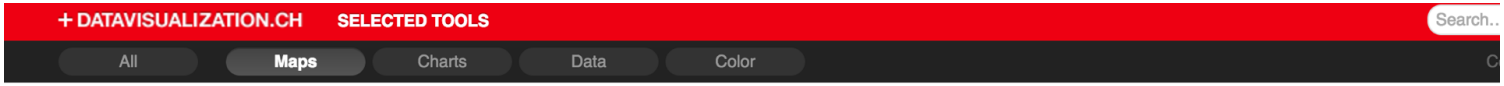
- Who's your target audience?
- How much data to you have? Where is it?
- Is the web map/dataviz going to part of an existing website?
- Do you need to support tablets and mobiles?
- Do you need to support offline access?
- Public or private?

Data Strategy

- Data has a longer life-cycle
- Web presentations of data age quickly

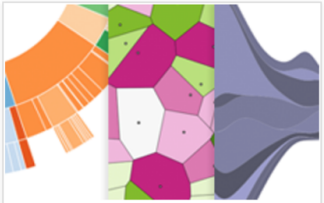
Visualization Tools

Link



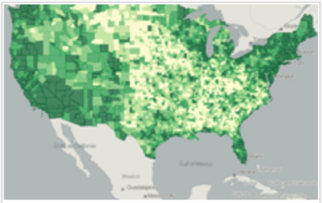
CartoDB

A web service for mapping, analyzing and building applications with data.



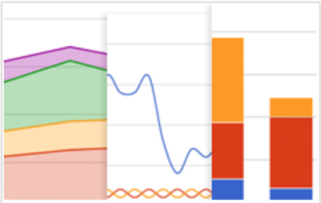
D3.js

An small, flexible and efficient library to create and manipulate interactive documents based on data.



GeoCommons

A public community and set of tools to access, visualize and analyze data with compelling map visualizations.



Google Chart Tools

A collection of simple to use, customizable and free to use interactive charts and data tools.

Google Fusion Tables

A web application that makes it easy to host, manage, collaborate on, visualize, and publish data tables.

Kartograph

A simple and lightweight framework for creating beautiful, interactive vector maps.

Leaflet

A lightweight JavaScript library for making tile-based interactive maps for desktop and mobile browsers.

Many Eyes

A web application to build, share and discuss graphic representation of user uploaded data.

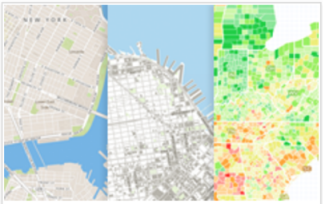
Visualization Tools

Link

↑ DATAVISUALIZATION.CH SELECTED TOOLS

Search...

All | Maps | Charts | Data | Color | Co

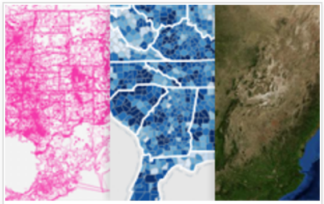


MapBox

A web platform for hosting custom designed map tiles and a set of open source tools to produce them.

Modest Maps

A display and interaction library for tile-based maps in Flash, JavaScript and Python.



Polymaps

A library for making dynamic, interactive maps with image- and vector-based tiles.

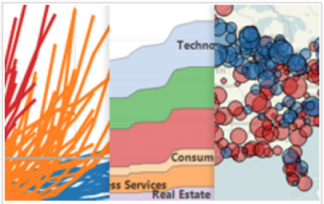


Tableau Public

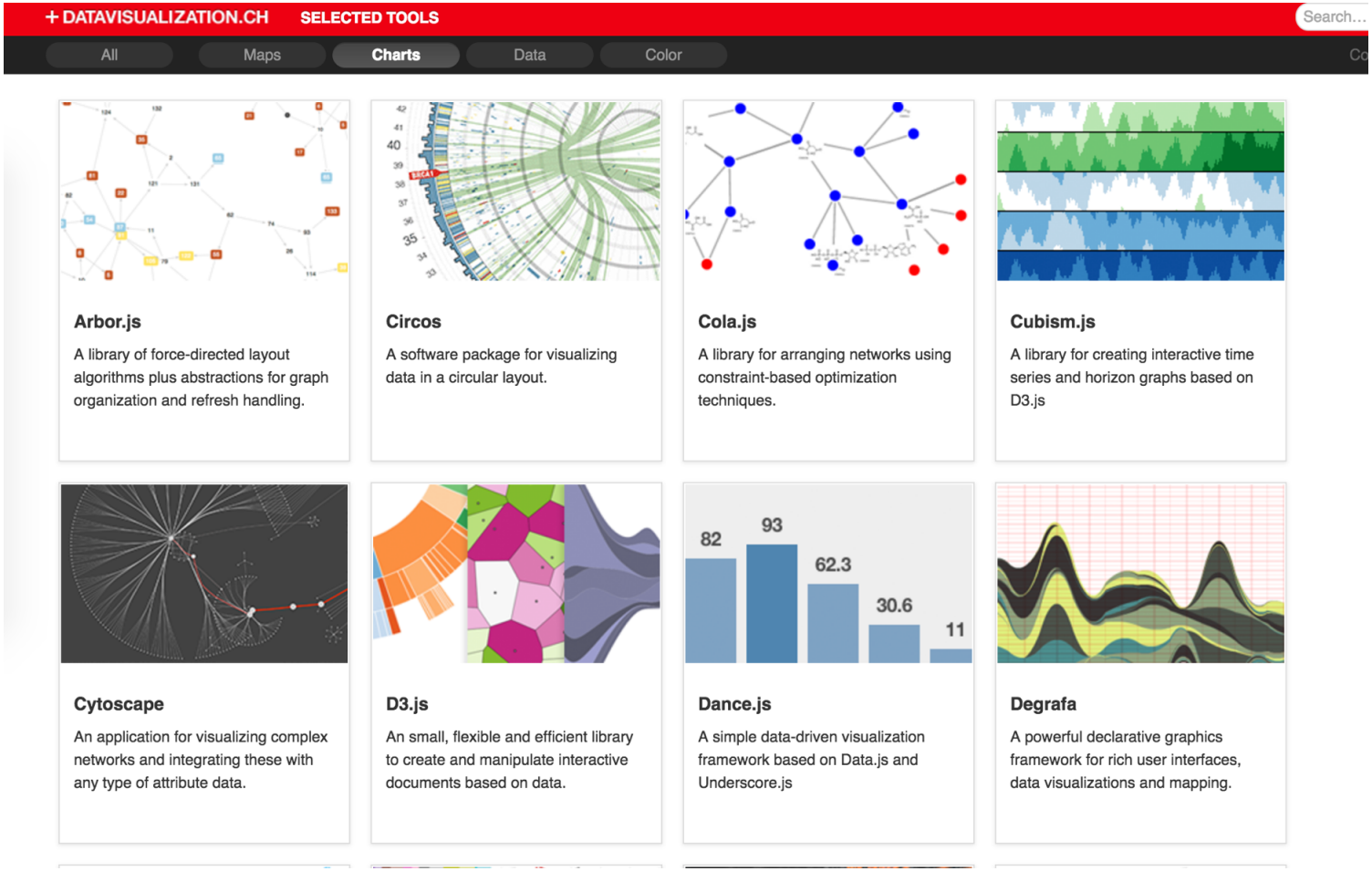
A desktop application to build and post interactive graphs, dashboards, maps and tables to the web.

Unfolding

A library to create interactive maps and geovisualizations in Processing and Java.

Visualization Tools

Link



Visualization Tools

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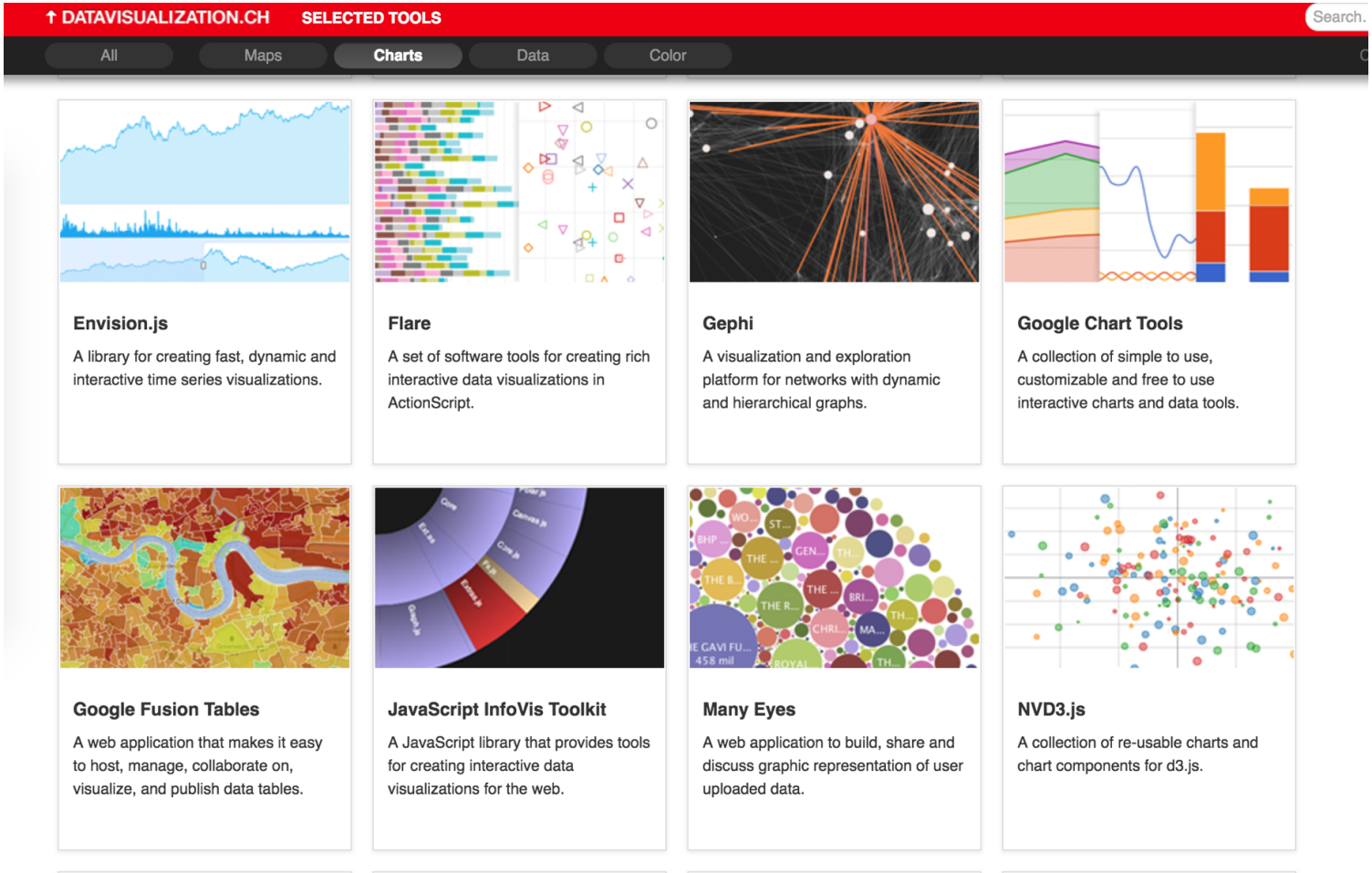

Visualization Tools

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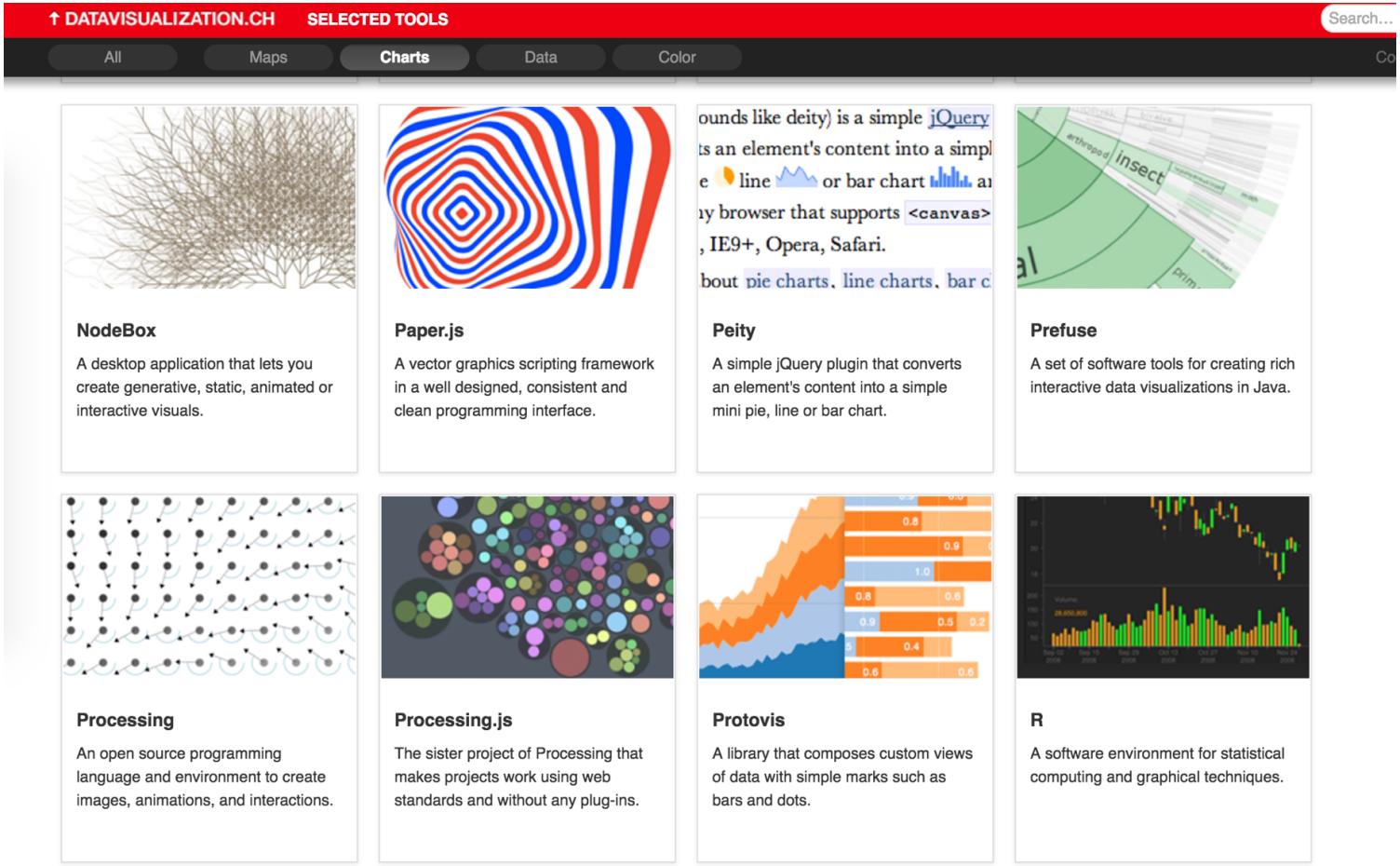


Where does D3 fit in?

What is D3?

- From d3js.org:
  - D3.js is a JavaScript library for manipulating documents based on data. D3 helps you bring data to life using HTML, SVG and CSS. D3's emphasis on web standards gives you the full capabilities of modern browsers without tying yourself to a proprietary framework, combining powerful visualization components and a data-driven approach to DOM manipulation.

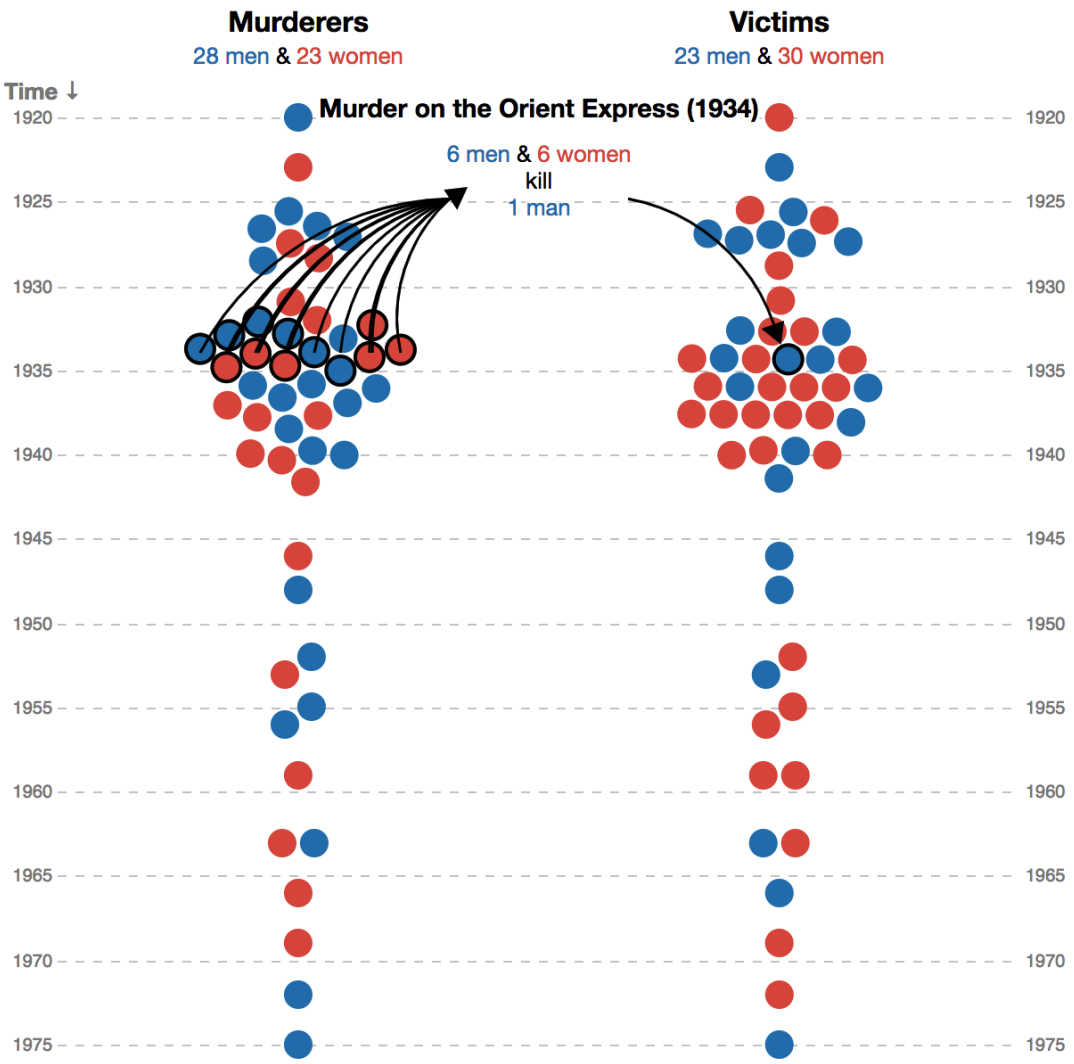
Why learn D3?

- Create highly customizable and interactive visualizations on the web
- Knowing D3 = Hirable skills
- Opportunity to learn web development
- Thousands of examples and a great open source community
- 5 reasons to learn D3

Linked Beeswarm Plot

Link

Each **circle** represents a murderer or a victim. Earlier stories are on **top**; later ones are on **bottom**. **Hover or tap** on a circle for more information.

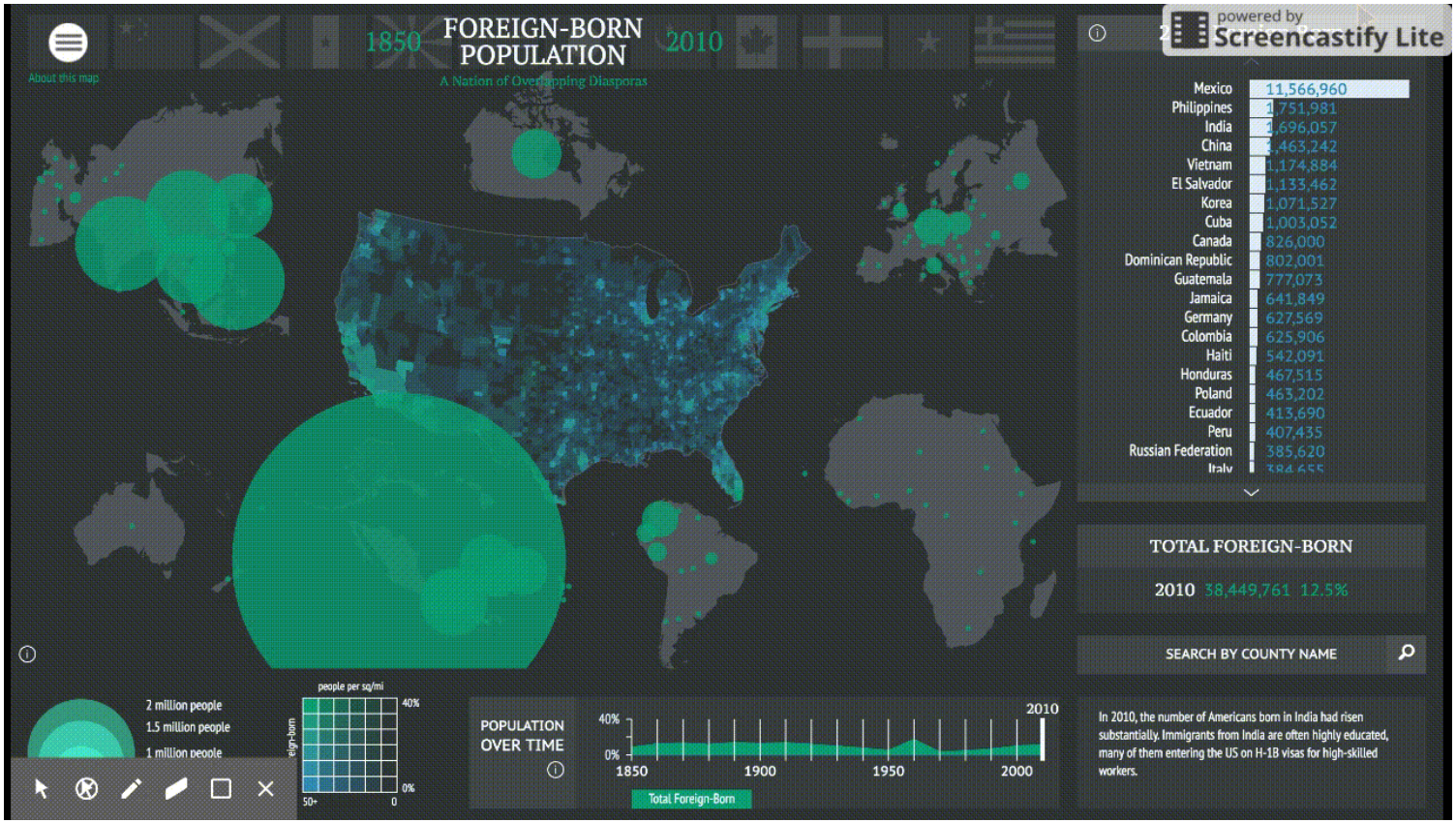


Face of Fracking

Link

American Panorama - Foreign Born Population

Link



Simpson's Paradox

Link

Proper Pooling

By "properly pooled," the investigators at Berkeley meant "broken down by department." Men more often applied to science departments, while women inclined towards humanities. Science departments require special technical skills but accept a large percentage of qualified applicants. In contrast, humanities departments only require a standard undergrad curriculum but have fewer slots.

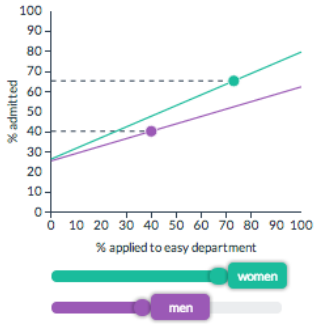
The authors concluded that any sexism occurred before Berkeley ever saw the applications:

> Women are shunted by their socialization and education toward fields of graduate study that are generally more crowded, less productive of completed degrees, and less well funded, and that frequently offer poorer professional employment prospects.
>
> — (p. 403)

To the right are data on the six largest departments, but the names have been changed to protect the innocent.

Illustration

Suppose there are two departments: one easy, one hard ('hard' as in 'hard to get into'). The sliders below set what percentage each gender applies to the easy department. Both departments prefer women, but if too many women apply to the hard one, their acceptance rate drops below the men's.



	# applied		# admitted		% admitted	
departments	men	women	men	women	men	women
"Easy"	1,076	1,340	672	1,068	62% 38%	20% 80%
"Hard"	1,615	495	413	131	26% 74%	27% 74%
Combined	2,691	1,835	1,085	1,199	40% 60%	35% 65%

Simpson's paradox? no

Generative Art with D3

Link

Optionally…

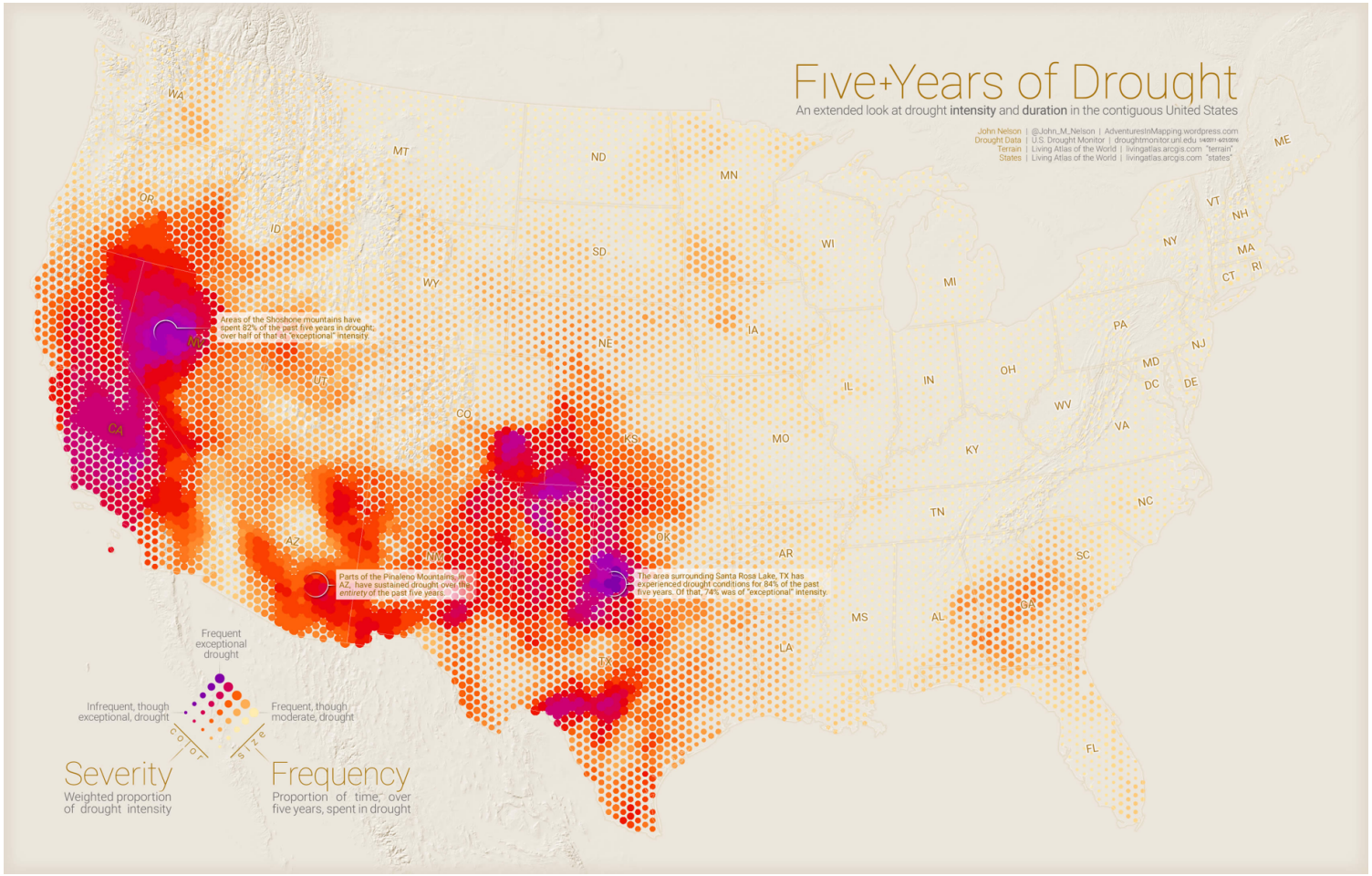
- Use software and data visualization servies like Tableau, Excel, Qlik Sense, Datawrapper, Raw
- GIS Software
- Use R or Python and associated visualization packages such as ggvis, rCharts, and Shiny
    - Create interactive graphics but less customization options and/or limited pre-existing graphics types (e.g., bar charts).

Visualizing Friendships - R

Link

Five Years of Drought - ArcGIS Pro

Link



Whirlwind Introduction to Web Technology

Technology Considerations

- Frontend
  - HTML5, CSS3, JavaScript
  - Frontend frameworks
  - SVG, Canvas, WebGL
  - Mobile
- Backend
  - Python, Java
  - Backend frameworks
  - Web Servers

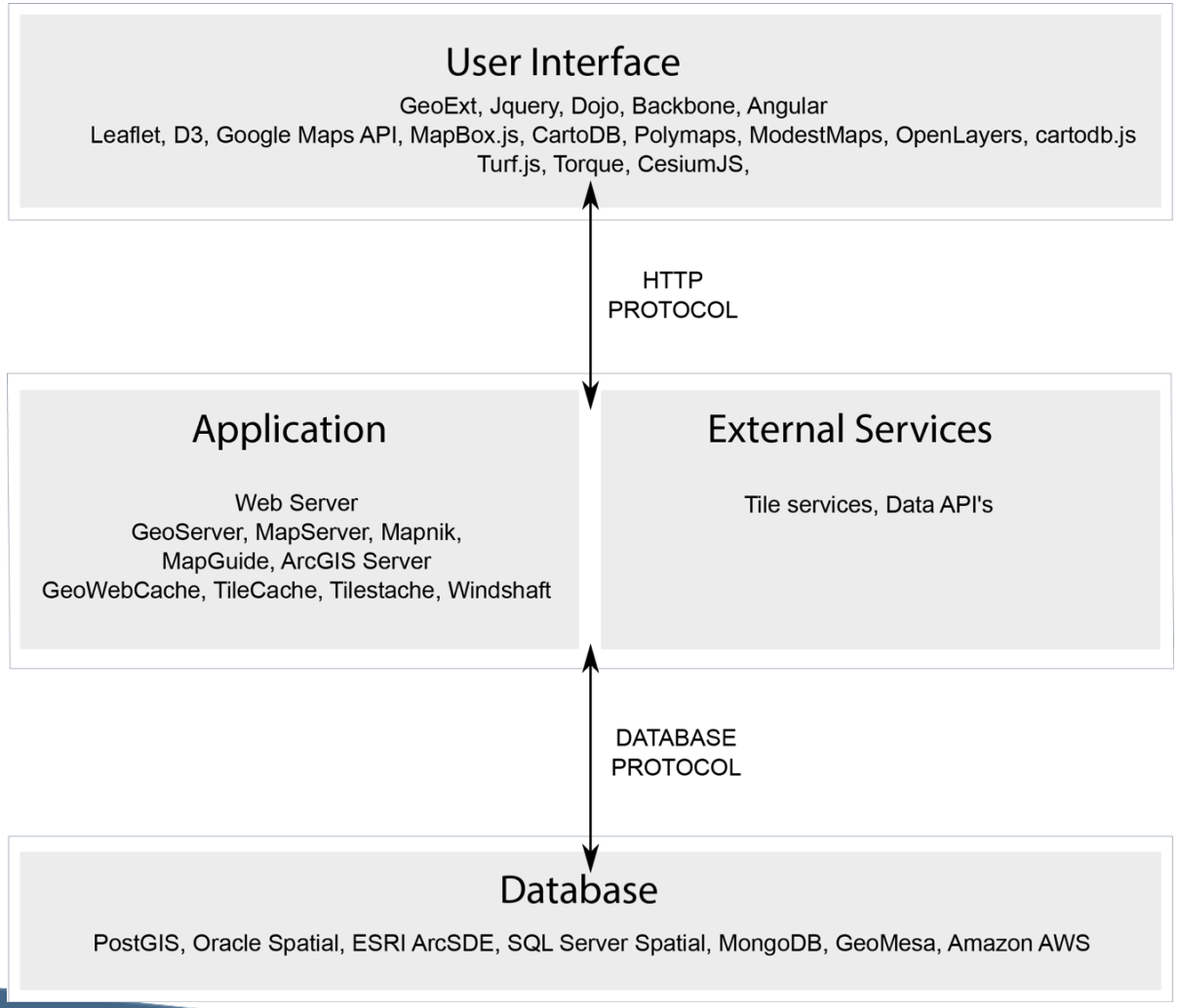
Quick Start Technology Stack

- Data, Middleware & User Interface
  - ArcGIS Online
  - CARTO
  - MapBox
  - Google
  - Tableau, RStudio
- Embed widgets into your own website

Hybrid Technology Stack

- Don’t want to maintain database/mapping servers?
  - Use data and other web services from ArcGIS Online, CARTO, MapBox, Google, etc.
  - Build custom user interface with JavaScript libraries
- Don’t want to write Javascript/HTML/CSS?
  - Build your web app with Rshiny; host your data and app on a server running Shiny Server
  - Build your web app with Python packages (Folium, Bokeh), deploy on a web server
- Interactive maps and data with Google Sheets

Custom Technology Stack



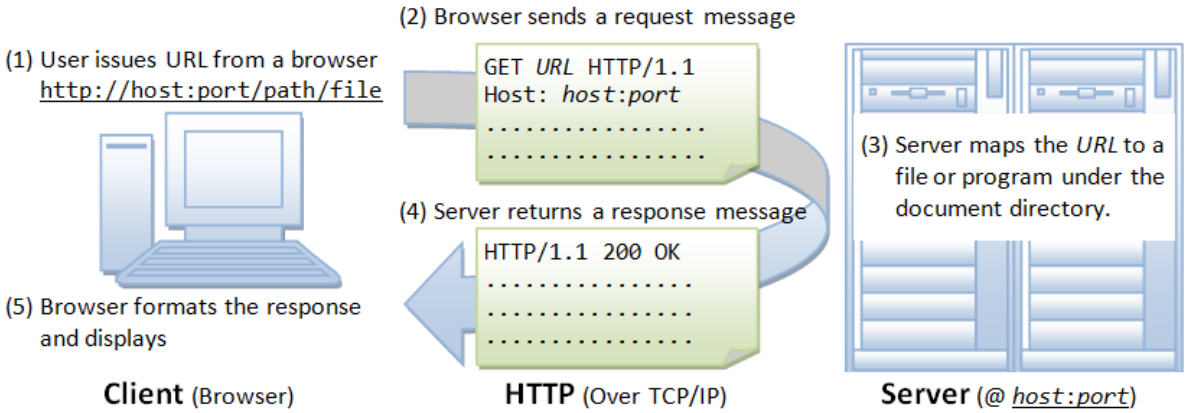
Where to begin?

- Tools: Code Editor, Browser & Browser's Developer Tools
- HTML
- CSS
- DOM
- JavaScript
- Web formats for displaying graphics: SVG and Canvas

Tools for Web Development

- Code Editor
  - Sublime Text, Atom, PyCharm, Vim, Notepad++, IDLE, Gedit, TextMate
  - Syntax highlighting, indentation, autocomplete, bracket matching
  - Run interpreters, debuggers
- Browser
  - Developer Tools - press `Ctrl+Shift+I` (or `F12`) in Chrome
  - More info on Chrome Developer tools here

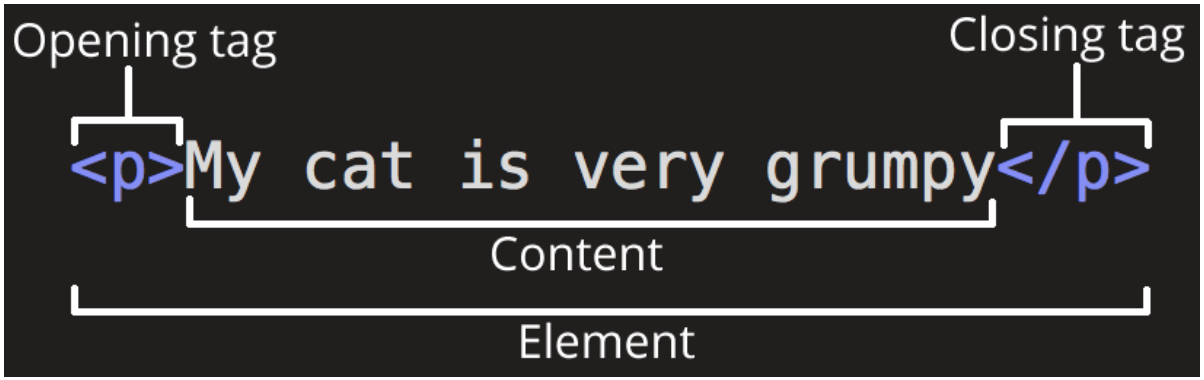
Quick Review of Client & Server



- HTTP, language of the web
- Browser sends HTTP GET Request. Server sends response for each request with content and/or status message.
- HTTP Basics

Hyper Text Markup Language (HTML)

- HTML is not a programming language; it is a markup language
- Role » Describes content
- HTML Elements consist of a opening tag, the content, and a closing tag




```
<ul>
  <li><a href="gif.berkeley.edu">Home Page</a></li>
  <li><a href="gif.berkeley.edu/people">Staff</a></li>
</ul>
<div id="map" class="center" style="height:500px;"></div>
```

- HTML5 Resources
  - Dive into HTML5
  - Mozilla Developer Network

Cascading Style Sheet (CSS)

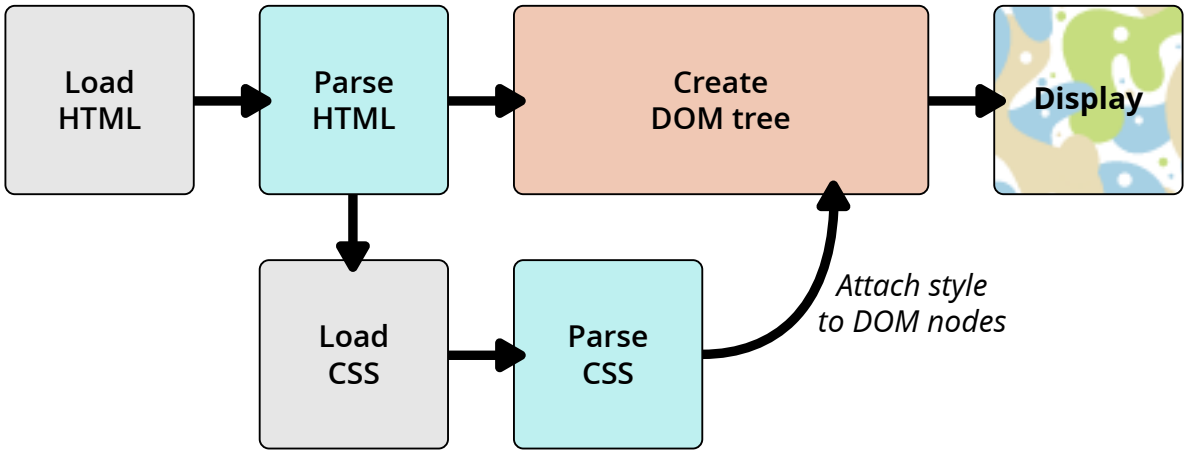
- Not a programming or markup language
- Role » Describes presentation of a document written in HTML or XML (e.g. SVG)
- Selectors, properties, and values
- Properties and Attributes

```
#map {
  height: 500px;
}
h1 {
  font-family: "Helvetica", "sans-serif";
  font-weight: bold;
  background-color: #000;
}
.chart {
  float: left;
}
```

- CSS3 Resources
  - Mozilla Developer Network

Document Object Model (DOM)

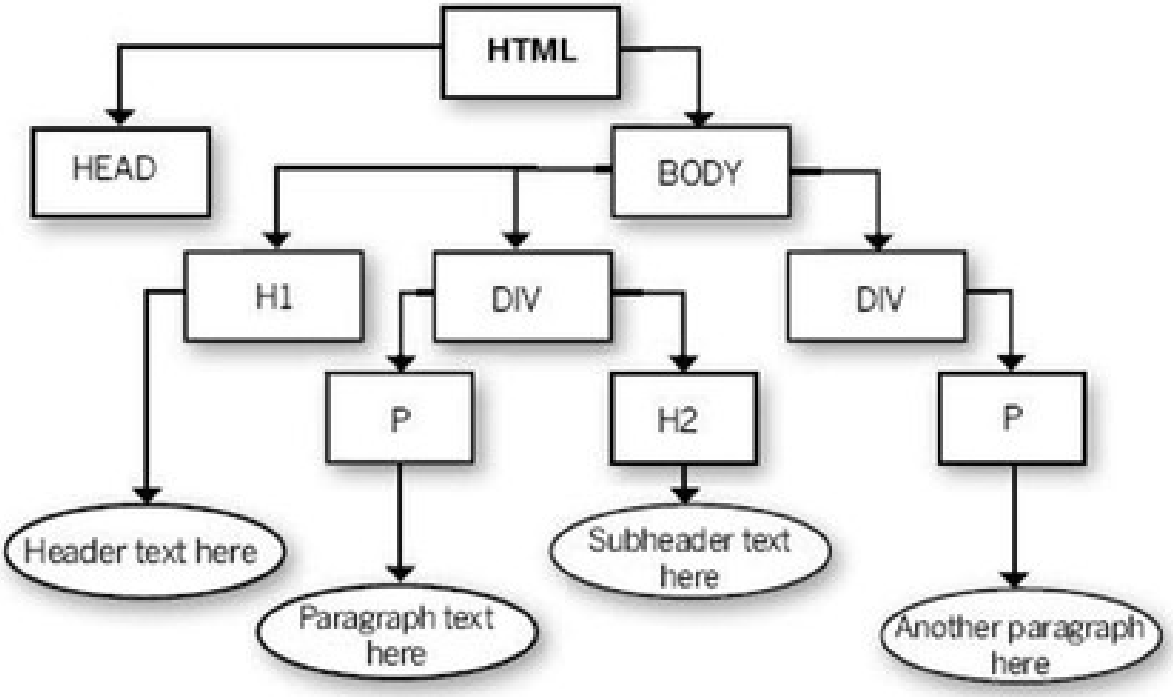
- Structured representation of the document (a tree) created by the browser
- HTML you write is parsed by the browser and turned into the DOM
- Programming interface for HTML and SVG documents
- JavaScript manipulates the DOM



Conceptual Web Page

```
<!DOCTYPE html>
<html>
<head>
    <!-- head content -->
    <style type="text/css">
      div {
        color: red;
      }
    </style>
</head>
<body>
    <h1>Header text here</h1>
    <div>
        <h2>Subheader text here</h2>
        <p>Paragraph text here</p>
    </div>
    <div>
        <p>Another paragraph here</p>
    </div>
    <script>
        <!-- JavaScript content -->
    </script>
</body>
</html>
```

The DOM for conceptual web page



- Understading the DOM

JavaScript

- "Easy to learn, hard to master"
- Role » Creating interaction
- Interpreted by your browser
- Asychronous (code executes in background after client-browser recieves data from server)
- Get familiar with
  - Working with json objects
  - Array functions (forEach, filter, map)
  - Method chaining, Callbacks, Closures, Modules
- JS Resources
  - Mozilla Developer Network

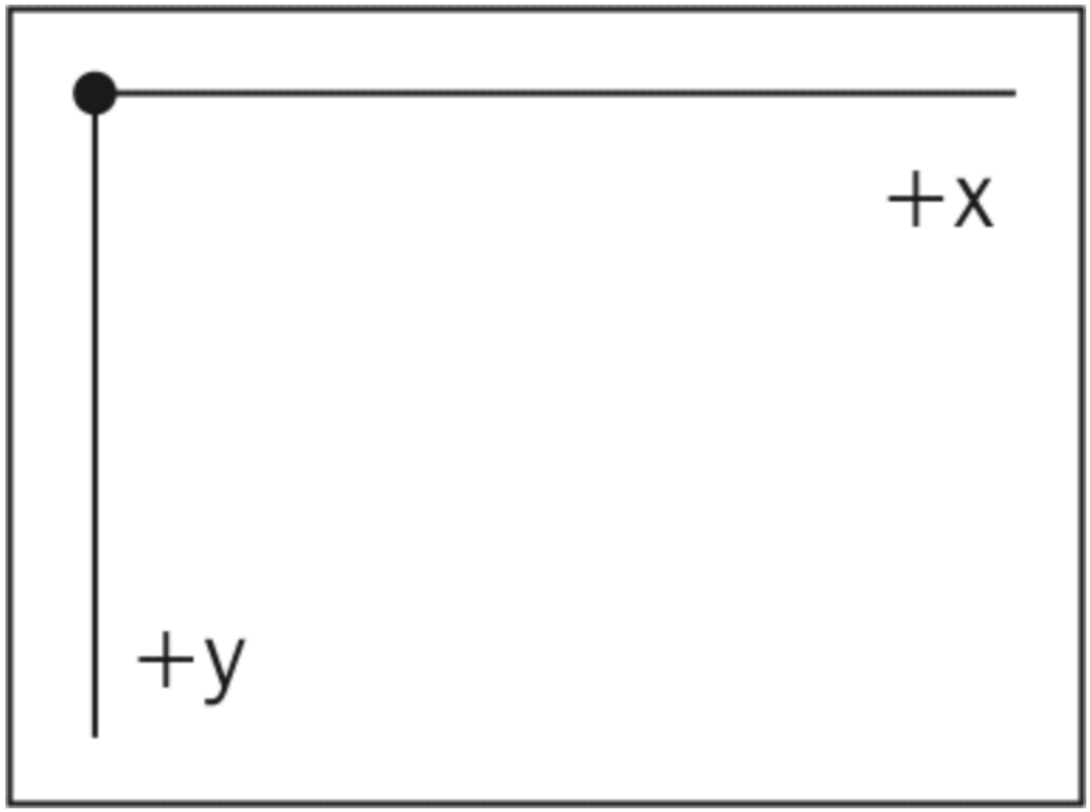
SVG

```
<svg width="300" height="180">
  <rect x="10" y="20" width="20" height="50" fill="blue"
             stroke="red" stroke-width="1"/>

  <circle cx="100" cy="100" r="25" fill="red"
             stroke="#ddd" stroke-width="5"></circle>

  <g transform="translate(5, 15)">
    <text x="0" y="0">My graphic</text>
  </g>

  <g transform="translate(5, 55)">
    <!-- M: move to (jump)
         L: line to
         Q: curve to (quadratic) -->
    <path d="M0,50 L50,0 Q100,0 100,50"
      fill="none" stroke-width="3" stroke="black" />
  </g>

  <g transform="translate(5, 105)">
    <!-- C: curve to (cubic)
         Z: close shape -->
    <path d="M0,100 C0,0 25,0 125,100 Z" fill="black" />
  </g>
</svg>
```

- Play with this code on SVG Graphic Primitives - JSFiddle

SVG (contd.)

- Coordinate system, top-left is (0, 0)
- Depth depends on order in which shapes are drawn



SVG v/s Canvas

- HTML5 Canvas is a raster based format for drawing on the web
  - You can draw raster graphcis with D3
  - You can only get pixel values on click event
  - Faster
- SVG (Scalable Vector Graphics) is a vector based format for drawing on the web
  - HTML has div and span, etc.; SVG has circle and rect, etc.
  - SVG is a DOM for graphical elements
  - You can attach events to SVG elements
  - Most D3 examples work with SVG

Codepen.io

- Playground for the front-end web developmet
- Open this link in a new tab to explore how HTML, CSS and JavaScript work together.
- Some other playgrounds
  - JSFiddle
  - JS Bin
  - Blockbuilder - D3

Web Development Resources

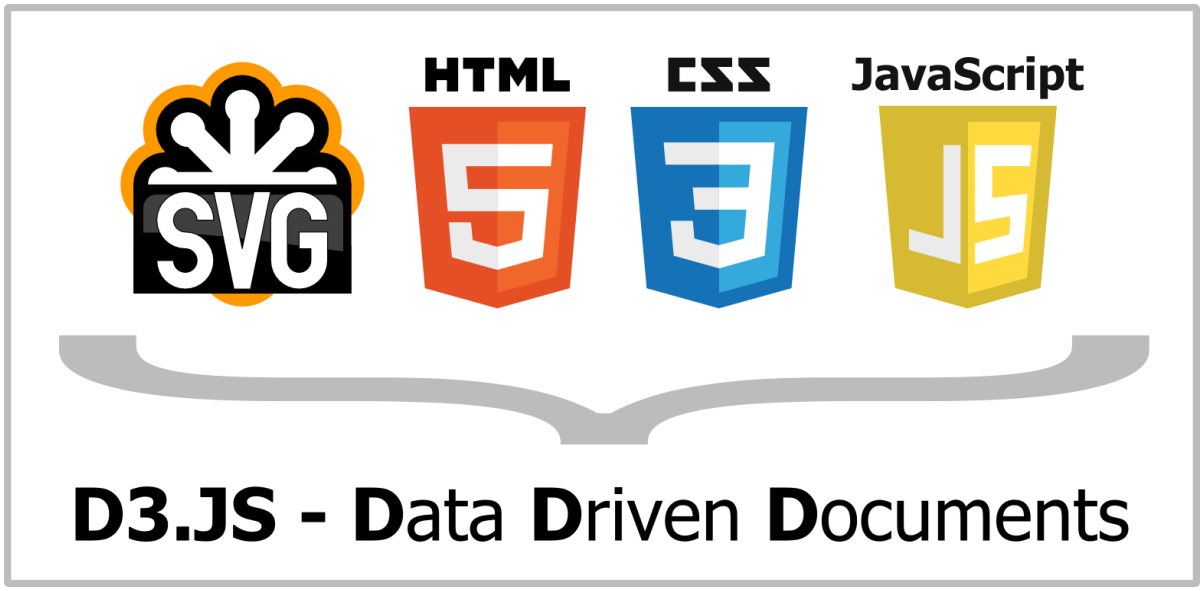
- If you are going to develop medium to large scale web apps learn more about using front-end development tools.
  - Getting Started Web Development Guide
  - Front-end Handbook
- Google Search
  - Favor results from Stack Exchange, Mozilla Developer Network, CSS-Tricks
- caniuse - Check which browsers support what features
- Web Design
  - A List Apart
  - Webdesigner News - curated stories
- Eloquent Javascript
- Egghead.io - Bite size web dev video training
- Lynda.com, Frontend Masters, CodeAcademy, Udacity, Coursera, etc.

Explore D3 Core Concepts and build a bar chart

Data-Driven Documents

D3 (Data Driven Documents)

- D3.js is a javascript for producing dynamic, interactive data visualizations in web browsers.
- Built on the fundamental web standards of HTML, CSS, SVG, and JavaScript.



- Created by Mike Bostock, Vadim Ogievetsky and Jeffrey Heer (all at that time were part of the Stanford Visualization Group).

What does it do?

- It is *not* a graphics library, it is *not* a charting library, it is a general purpose data visualization library
- Has everything you need for visualizing complex data BUT you will not find commands like barchart, scatterplot, or piechart, or even map
- Visualizes data using web standards (HTML, Javascript, CSS, SVG)
- Heavily used in data journalism and visualization. New York Times has been the pioneer in data visualization and data journalism.
- Most and foremost a DOM manipulation library (in this regard similar to jquery).
- Provides handy utilities for processing data (array, time series, geo data)
- Comes with a lot of functions and methods to create mapping functions that will map your data directly to properties on html elements
- Filled with algorithms (voronoi, quadtrees, circle fitting, convex hull, projections)

Learning D3

One of the most interesting aspects about d3 is that it is the intersection between design and code, math and art, data and story - Ian Johnson

- Very active user community in Bay Area.
- Bay Area d3 User Group.
- Rich ecosystem of examples showing visualization types, coding techniques:
  - blockbuilder.org/
  - bl.ocks.org/
- Navigating the D3 Ecosystem
- How do I learn D3.js? Quora thread
- D3 version 3 not the same as D3 version 4

Resources

- Books
  - Interactive Data Visualization for the Web
  - D3 Tips and Tricks
- Curated lists of data viz and data viz research
  - visualisingdata.com
  - The Chartmaker Directory
- Mike Bostock Blog
- For geographic visualizations
  - Learning D3.js 4 Mapping
  - Jason Davies, Jason Davies Code Blocks
- API documentation

Core Concepts - Declarative API

- Declarative: Tell D3 what you want, not how you want it done
- API: Methods and objects you use to interact with software
  - e.g. keyboard interface for a computer
- Describe a relationship between data and UI (User Interface) elements, D3 handles implementation details

```
d3.selectAll('p').style('color', 'red');
```

- Example: JS Fiddle

Core Concepts - Selections

- D3 provides shorthand for selecting and manipulating DOM objects (similar to jQuery)

```
// Anywhere on the page, one or multiple items
d3.select('#hero');       // selects the element with an id="foo" attribute
d3.selectAll('.primary'); // selects all elements with CSS class primary
d3.selectAll('p');     // select all divs on the page

// Within an existing selection
d3.select('#hero').selectAll('p');
```

- Create/Read/Update/Delete (CRUD) properties of selections
- Getters and setters
- selection.attr(name[, value])

```
d3.select('a').attr('href'); // get the href value of the first link on the page
d3.select('a').attr('href', 'http://cal-adapt.org'); // set the first link's href to Cal-Adapt
```

```
d3.selectAll('p').attr('href', function(d, i, nodes) {
  // the first parameter is named d and is the node's data point, or datum
  // the second parameter is named i and is the node's index in the selection
  // the third parameter is an array of the nodes in the selection
})
```

Core Concepts - Selections (contd.)

- selection.style(name[, value])

```
d3.select('a').style('color'); // get the text color of the first link
d3.select('a').style('color', 'red'); // set the first link's text color to red
d3.select('a').style('color', function(d, i, nodes) {
  return getColorByURL(this.href); // this is the native DOM element
});
```

- selection.classed(names[, value])

```
d3.select('#submitBtn').classed('btn-lg'); // does submitBtn's classList include btn-lg?
d3.select('#submitBtn').classed('btn btn-lg', true); // apply the btn and btn-lg classes
d3.selectAll('button').classed('btn', function(d, i, nodes) {
  return i < 3; // apply the btn class to the first 3 buttons
});
```

```
// selection.classed similar to selection.attr('class'[, value])
selection.attr('class', 'btn btn-lg')
```

Core Concepts - Selections (contd.)

- selection.text([value]) && selection.html([value])

```
d3.select('#someDiv').text(); // get the innerText of #someDiv
d3.select('#someDiv').text('Hello World!'); // set the innerText of #someDiv
d3.select('#someDiv').html(); // get the innerHTML of #someDiv
d3.select('#someDiv').html('<h2>Hello World!</h2>'); // set the innerHTML of #someDiv
```

- selection.append(type) && selection.insert(type[, before])

```
d3.select('body').append('p');
```

- selection.remove()

```
d3.select('body').remove('p');
```

- Handle events - selection.on()

```
d3.selectAll('button').on('click', handleButtonClicks);
d3.select('body').on('mousemover', trackMousePosition);
```

Core Concepts - Data Joins

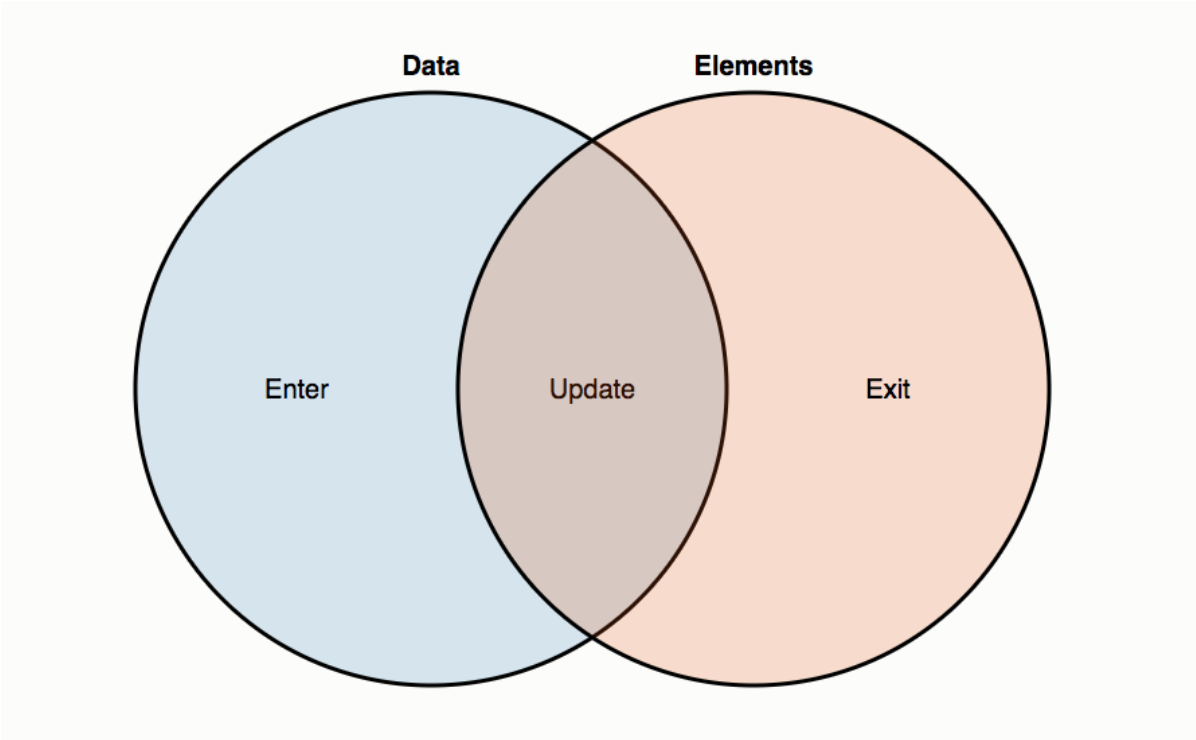
- Real power of D3 is joining data and selections
- `selection.data()` - accepts an array of data items and joins them to the DOM elements in the selection

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

```
const data = [90, 70, 50, 30, 10];

d3.select('#chart')
  .selectAll('div')
  .data(data) // pair each number in the array with an empty div
    .attr('class', 'bar') // color, height, and spacing via CSS
    .style('width', function(d) {
      return d + 'px' // use the data items as pixel widths
    });
```

Core Concepts - Data Joins (contd.)

- ENTER, UPDATE and EXIT SELECTIONS
  - Mike Bostock - Thinking with Joins
  - Mike Bostock - General Update Pattern examples
  - Also D3 In Depth book (in progress) is great!



Core Concepts - Data Joins (contd.)

- selection.data() is followed by selection.enter() and selection.append()

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

```
const data = [90, 70, 50, 30, 10];

d3.select('#chart')
  .selectAll('div')
  .data(data) // returns an empty selection
  .enter()
    .append('div')
    .attr('class', 'bar') // color, height, and spacing via CSS
    .style('width', function(d) {
      return d + 'px' // use the data items as pixel widths
    });
```

Core Concepts - Data Joins (contd.)

- Use with dynamic data

```
const data = [
  { name: 'Alice', math: 93, science: 84 },
  { name: 'Bobby', math: 81, science: 97 },
  { name: 'Carol', math: 74, science: 88 },
  { name: 'David', math: 64, science: 76 },
  { name: 'Emily', math: 80, science: 94 }
];

function render(subject) {
  d3.select('#chart') // within the #chart container...
    .selectAll('div') // select all the divs
    .remove();         // and remove them, clearing the #chart div

  // now just repeat our creation pattern from the first example
  d3.select('#chart')
  .selectAll('div')
  .data(data)
  .enter()
    .append('div')
    .attr('class', 'bar')
    .style('width', function(d) {
      return d[subject] + 'px' // use the subject passed in to grab the correct property
    });
}

render('math'); // render the math data when the page first loads
```

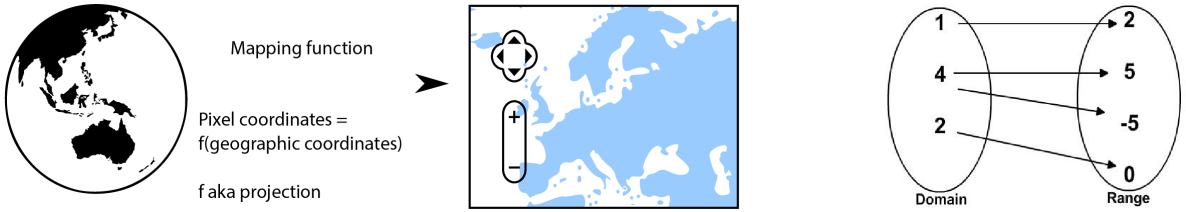
Core Concepts - Data Joins (contd.)

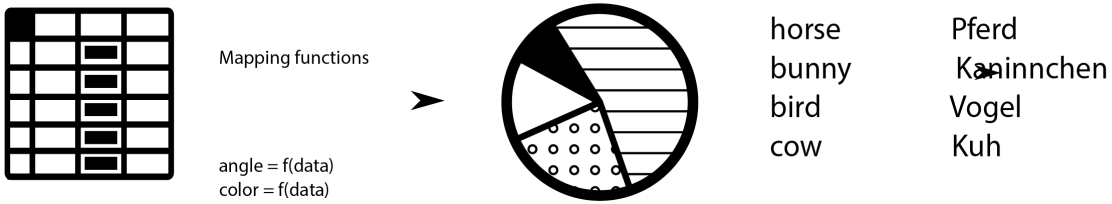
- Use `selection.transition()` to animate

```
function render(subject) {
  // store a reference to the bars already on the chart
  const bars = d3.select('#chart')
    .selectAll('div') // this won't be empty after the first time this function runs
    .data(data, function(d) {
      return d.name // use the name property to match across updates
    });

  const newBars = bars.enter() // use the enter selection
    .append('div') // to add new bars for any data items without an existing DOM element
      .attr('class', 'bar')
      .style('width', 0); // set the initial width to 0

  // combine the selections of new and existing bars
  // so you can act on them together
  newBars.merge(bars)
    .transition() // animate everything that comes after this line!
    .style('width', function(d) {
      return d[subject] + 'px' // set the width like normal!
    });
}
```

Core Concepts - Scales

- Mapping: An operation that associates each element of a given set (the domain) with one or more elements of a second set (range)
- Any (computer) visualization problem can be described as a mapping problem.






```
const percentToDecimal = d3.scaleLinear()
  .domain([0, 100])
  .range([0, 1])

percentToDecimal(0)   // 0
percentToDecimal(50)  // 0.5
percentToDecimal(100) // 1
```

Core Concepts - Scales (contd.)

- Scales in practice

```
// specify chart dimensions
const width = 600;
const height = 400;

// create a scale to map scores to bar widths
// test scores are stored as percentages
// a score of 100 should create a full-width bar
const xScale = d3.scaleLinear()
  .domain([0, 100])
  .range([0, width]);

d3.select('#chart')
  .selectAll('div')
  .data(data)
  .enter()
    .append('div')
    .style('width', function(d) {
      // pass the score through the linear scale function
      return xScale(d[subject]) + 'px'
    });
```

Core Concepts - Scales (contd.)

- Lot of other scales, e.g. `d3.bandScale()`

```
// specify chart dimensions
const width = 600;
const height = 400;

// create a scale to map scores to bar widths
// test scores are stored as percentages
// a score of 100 should create a full-width bar
const xScale = d3.scaleLinear()
  .domain([0, 100])
  .range([0, width]);

const yScale = d3.scaleBand()
  .domain(data.map(function(d) { return d.name }))
  .range([0, height]);

d3.select('#chart')
  .selectAll('div')
  .data(data)
  .enter()
    .append('div')
    .style('width', function(d) {
      // pass the score through the linear scale function
      return xScale(d[subject]) + 'px'
    })
    .style('height', function(d) {
      return yScale.bandwidth() + 'px'
    });
```

D3 - Other concepts

- Lots of convenience functions for loading and manipulating data, working with arrays
- Axes, Scales, Colors
- Manipulate structure of your data - d3.nest()
- D3 API Reference
- Writing reusable components
    - A good place to start is by reading Towards Resuable Charts where Mike Bostock proposes a convention for creating reusable charts.
    - This blog post and this book do a great job on clarifying the resuable charts api with examples and explanations.

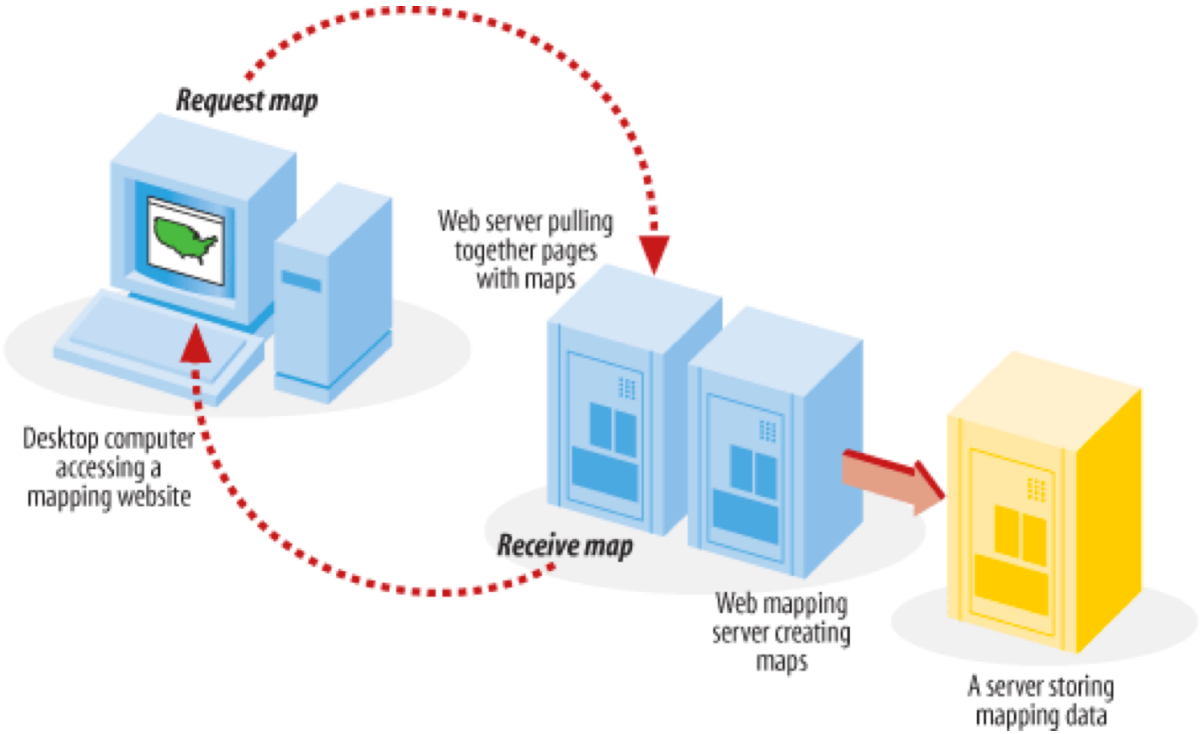
Other options for using D3

- Rickshaw, Highcharts, NVD3 are libraries built on top of D3
- D3 and Crossfilter (Fast Multidimensional Filtering for Coordinated Views)
- Open-source tools binding D3 to R, Python
- Vega - higher-level visualization specification language on top of D3

Web Mapping

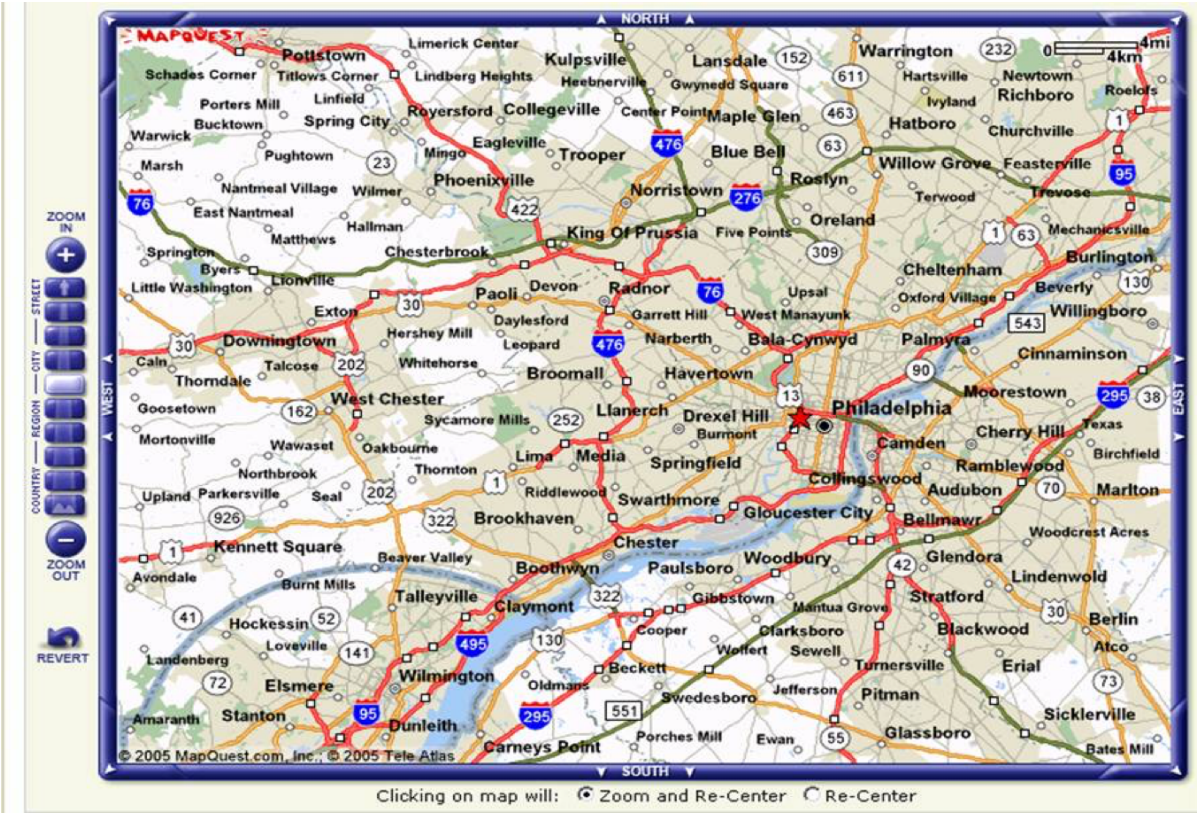
What is a Web Map?

- Digital map that works in a web browser (as opposed to PDF/Image files)
  - Interactive
  - Developed using web application technologies – Not specialized mapping software



A Quick Recap of Web Mapping History

- 1996 MapQuest

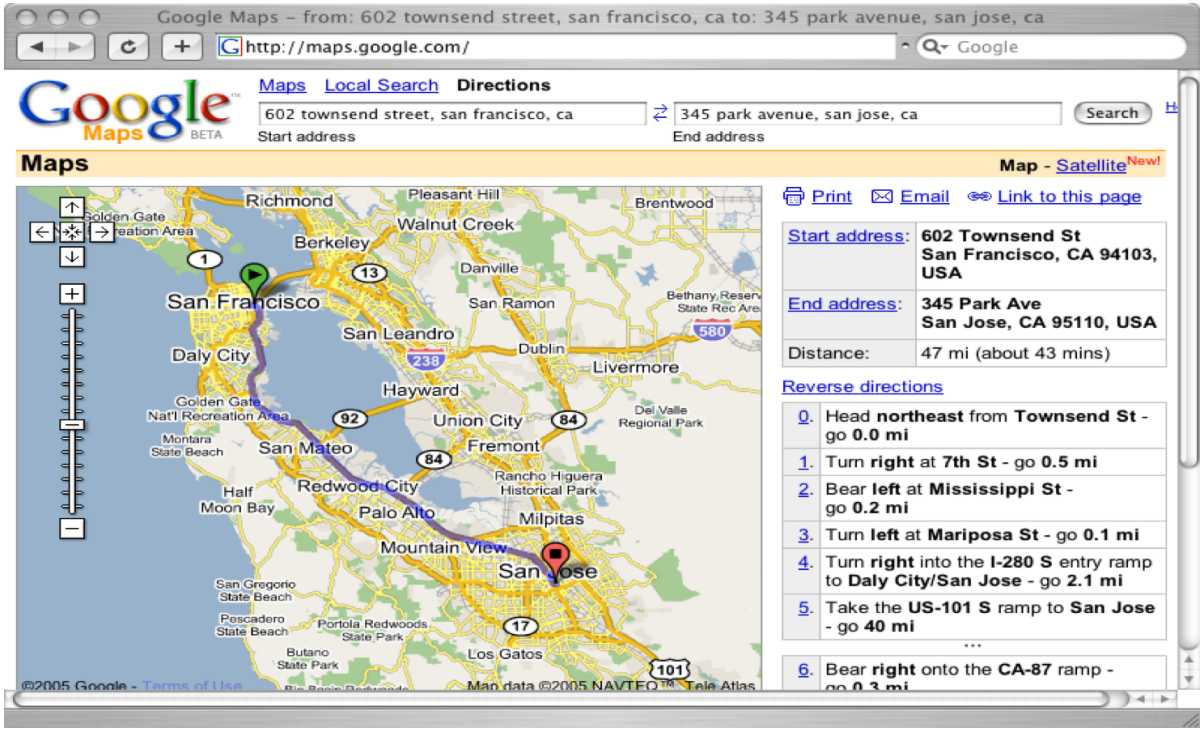


A Quick Recap of Web Mapping History (contd.)

- 1997 - 2004
  - MapInfo, AOL buys MapQuest
  - GPS Selective Availability ends (2000)
  - Microsoft MapPoint
  - Open Street Map (OSM) founded in UK (2004)
  - NASA releases WorldWind
  - Yahoo! Maps
  - Google buys Where2, Keyhold & ZipDash

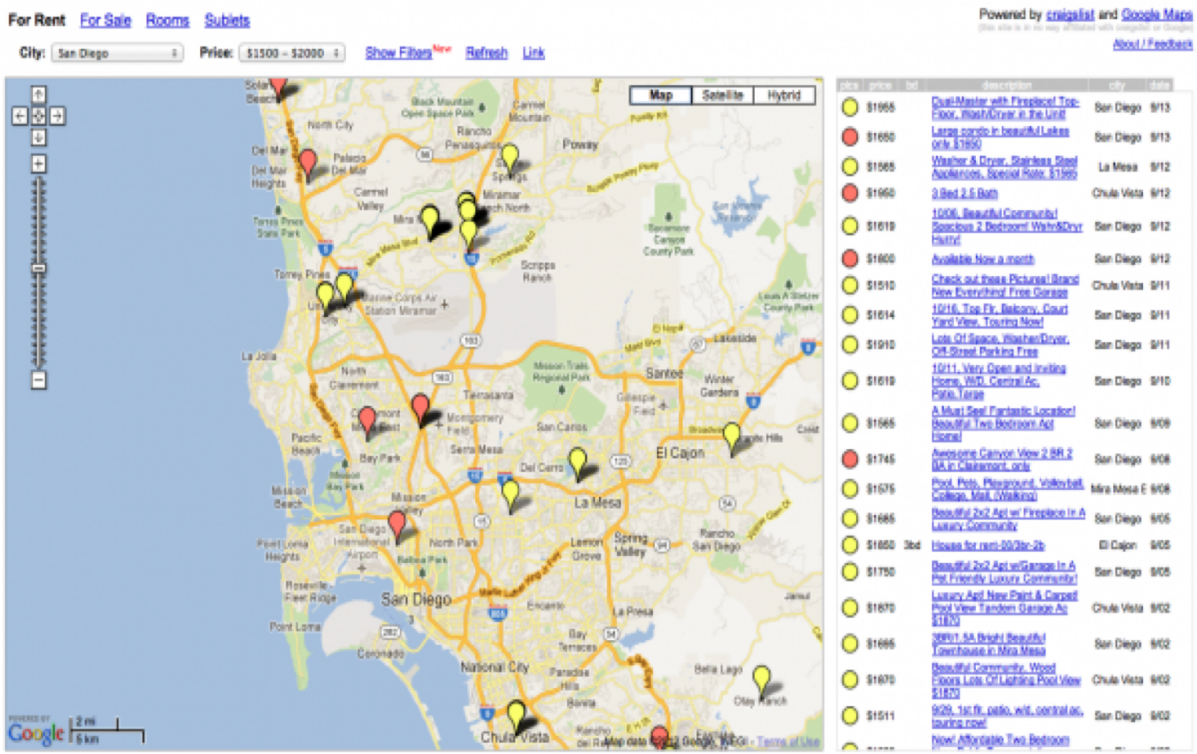
A Quick Recap of Web Mapping History (contd.)

- 2005 - Google Maps



A Quick Recap of Web Mapping History (contd.)

- 2005 - First Google Maps Mashup

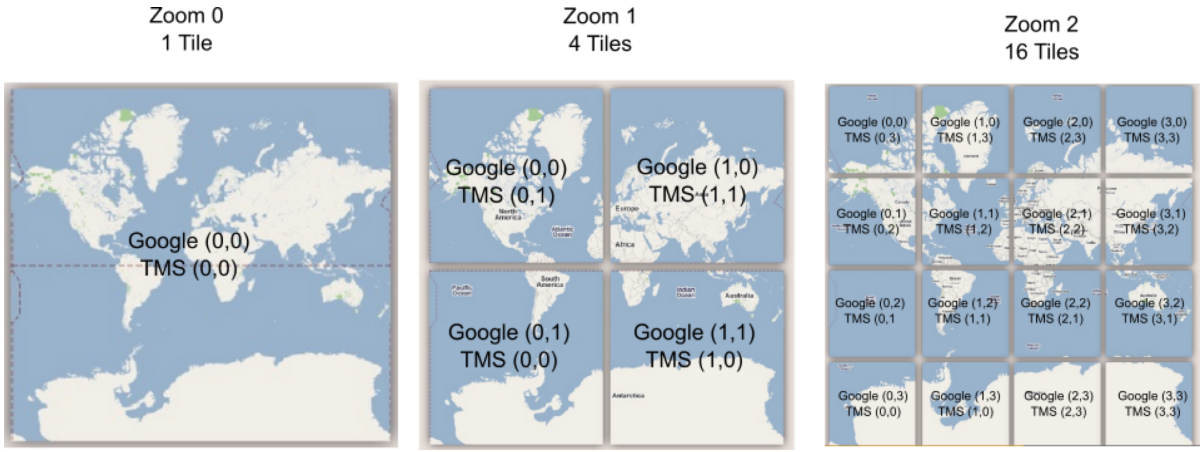


Technological Breakthroughs

- Slicing a square map into smaller square image tiles – Web Mercator projection
- Slippy maps with smooth zoom and pan – Web development techniques (AJAX) used for requesting data (map tiles) from server asynchronously (in the background)
- Open API
- No plugins, seamless user experience
- Mapping as a service

Map Tiles

- 256 pixels x 256 pixels image files
- Pre-rendered or rendered on the fly
- 360 billion tiles to cover the whole world at 20 zoom levels



Fast forward to present

- Web Services, Open Data, Open Standards and Formats, Free and Open Source Software

Web Services

- APIs (Application Programming Interface)
  - Basemaps, Data, Geocoding, Navigation, Spatial Analysis • Commercial
  - Google, ESRI, CARTO, MapBox, Planet … many more – Free and paid tiers
- Non-commercial
  - Data.gov, NPMap, SF Open Data, NASA
  - Cal-Adapt, Landcarbon, Ecoengine @berkeleyGIF

Open Data

- Free
- Limited or no copyright restrictions
- Contributed by government, researchers, non-profits, citizens
  - World Bank, OpenStreetMap, NASA
- Pay attention to:
  - Attribution requirements
  - Restrictions on redistribution
  - Data Quality

Data - OpenStreetMap

- Collaborative project to create a free and editable map of the world
- Volunteered geographic information
- Primary output = DATA not the map
- Open Database License (ODBL)
  - License/Use cases
- Getting the data (planet.osm.org & other)
  - Planet extract (666 GB uncompressed; 30-40 GB compressed)
  - Smaller extracts for countries, metro areas available
  - Updated regularly
  - Tools for importing into PostgreSQL/PostGIS

Open Standards

- Data Formats
  - GeoJSON, TopoJSON, KML, Shapefile, WaterML, NetCDF…
- Specifications
  - Web Map Services, Web Feature Services, Vector Tiles

Open Standards - GeoJSON

- File format for spatial data common on the web
- Subset of JSON format (JavaScript Object Notation)
- Converting to GeoJSON
  - GDAL, geojson.io, fiona (python package), QGIS, ArcGIS
- TopoJSON
  - Extension that encodes topology – More compact than GeoJSON

Open Standards - Vector Tiles

- Instead of raster images data is returned in vector format
- More efficient
- Contains
  - Data and geometry
  - Instructions on styling, instructions on stitching data back together
- Style on the fly in browser instead of server (no need to pre- render)
- Formats
  - Mapbox Vector Tile (MVT), GeoJSON/TopoJSON vector tiles

FOSS (Free and Open Source Software)

- Dekstop
  - GRASS, QGIS
- Geo-enabled databases
  - PostgreSQL/PostGIS
- Software for exposing spatial data to the web
  - MapServer, Mapnik, GeoServer, Tilecache
- JavaScript mapping and data visualization libraries
- System libraries
  - GDAL, PROJ4

Leaflet

- Lightweight, simple & flexible open source JavaScript mapping library
- Created by Vladimir Agafonkin. Great speaker, checkout some of his talks on Leaflet
- Mobile-friendly. Well documented API, huge amount of plugins.
- Use with other JS mapping libraries (like Esri-Leaflet) or by itself. Similar libraries - OpenLayers, ModestMaps, Polymaps.
- Carto.js and Mapbox.js libraries are built on top of Leaflet.
- Leaflet FAQ

What does it do?

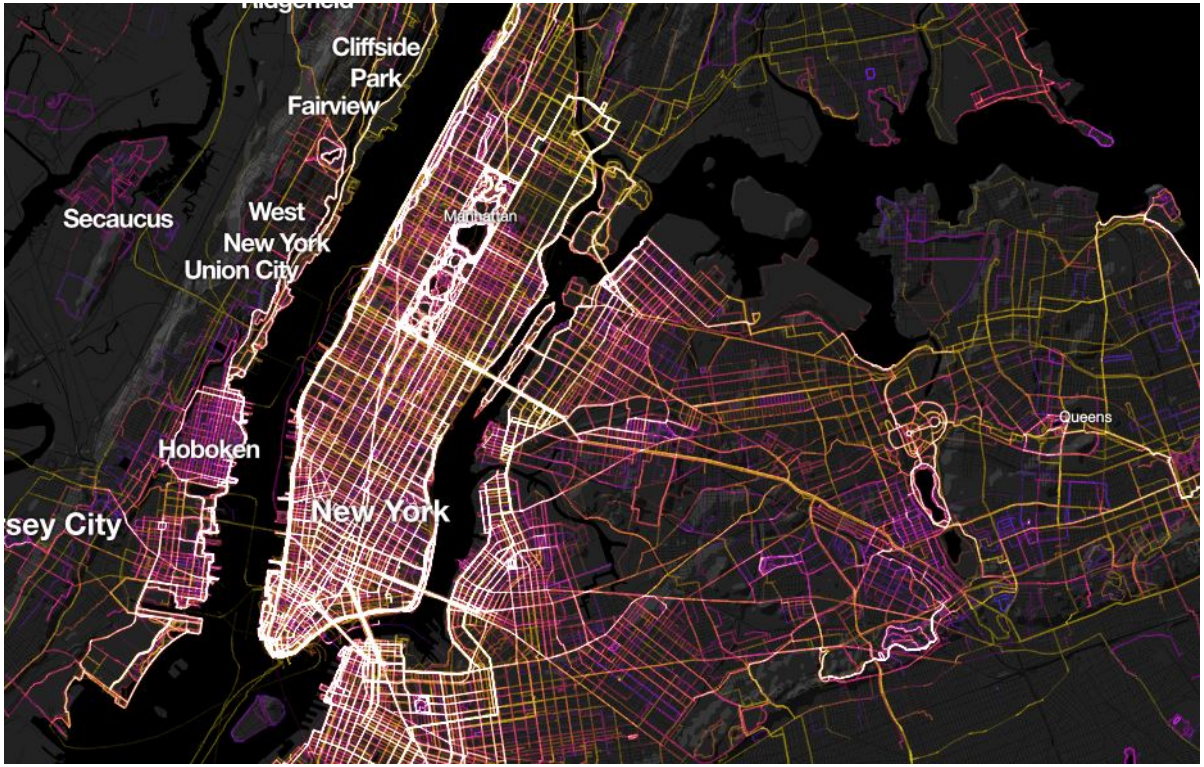
- Slippy maps with panning and zooming
- Provides functions for converting data into map layers
- Provides mouse interaction
- Does not provide any data
- You provide tile basemaps and data for overlays
- Easy to extend with plugins

Overlays - GeoJSON

```
var obj =
{ "type": "FeatureCollection",
    "features": [
      { "type": "Feature",
        "geometry": {"type": "Point", "coordinates": [102.0, 0.5] },
        "properties": {"prop0": "value0"}
       },
      { "type": "Feature",
         "geometry": {
           "type": "Polygon",
           "coordinates": [
             [ [100.0, 0.0], [101.0, 0.0], [101.0, 1.0],
               [100.0, 1.0], [100.0, 0.0] ]
             ]
         },
         "properties": {
           "prop0": "value0",
           "prop1": {"this": "that"}
           }
      }
    ]
}
```

- GeoJSON Specification, Validate your geojson
- Convert from shapefile - geojson.io, Mapshaper, GIS
- GeoJSON data coordinates should be in latitude, longitude (WGS 84)!!!

Basemaps & Overlays - Map Tiles



- How Web Maps Work
- Web Mercator - Standard projection for map tiles

Leaflet Exercises

- Link to Github Repo
- Before we begin:
  - Start a local server
  - Code Editor and Browser
  - Workflow for the exercises

Exercise 01 - Make a map

- This exercise covers the basics for creating a Leaflet map element and adding a basemap to it.
- Four things you absolutely need for adding Leaflet map to a web page
  - Leaflet CSS file
  - Leaflet JavaScript file
  - A div element with an `id` attribute
  - A `css` height for your map div

Exercise 02 - Add Overlay

- Adding an overlay of tick collection point locations

Exercise 03 - Style Overlay

- Experiment with applying custom styles to geojson overlay
- Leaflet allows you to pass a variety of options to `L.geoJson` to style your layer. The options are written as callback functions.
- An example of a callback function

```
// Callback Example

function mySandwich(param1, param2, callback) {
  alert('Started eating my sandwich.\n\nIt has: ' + param1 + ', ' + param2);
  callback();
}

mySandwich('ham', 'cheese', function() {
  alert('Finished eating my sandwich.');
});
```

Exercise 04 - Working with Larger Datasets

- Geojson files with lots of data can take longer to load depending on size and network speed. And on the web you never want to keep your user waiting :-) There are couple of ways you can deal with larger files.
- Option 1 - Use the topojson format. Topojson is an extension of GeoJSON that encodes topology.
    - Convert geojson to topojson using mapshaper.org. You can also further reduce file size by simplifying the geometry. It depends on your app, how much detail you need to show.
- Option 2 - Host the data on service providers like CARTO, ArcGIS Online, Mapbox. These companies also provide their own web mapping libraries (some built on top of Leaflet)
- Great mapmakers cheatsheet on other options for dealing with large files with Leaflet and web maps in general.

Exercise 05 - Add a Leaflet plugin for Geocoding

- Huge list of Leaflet plugins to extend functionality.
- We will add a geocoding plugin called Leaflet Control Geocoder

Exercise 06 - Spatial Analysis in your Browser

- Experiment with doing some spatial analysis directly in your browser using Turf.js
- Turf.js is a javascript library for spatial analysis. MapBox has a great intro on using Turf that you can check out here.

Leaflet Review

- Adding content and styling to make it look like a real website
- Adding legends
- An example of using the MarkerCluster Leaflet plugin
- An example of using the Turf.js buffer functionality

Discussion

You Pick!

Visualization, Web Development, Learning,

Deeper dive into some examples, ...