Data Visualization (CSCI 627/490)

Web Programming

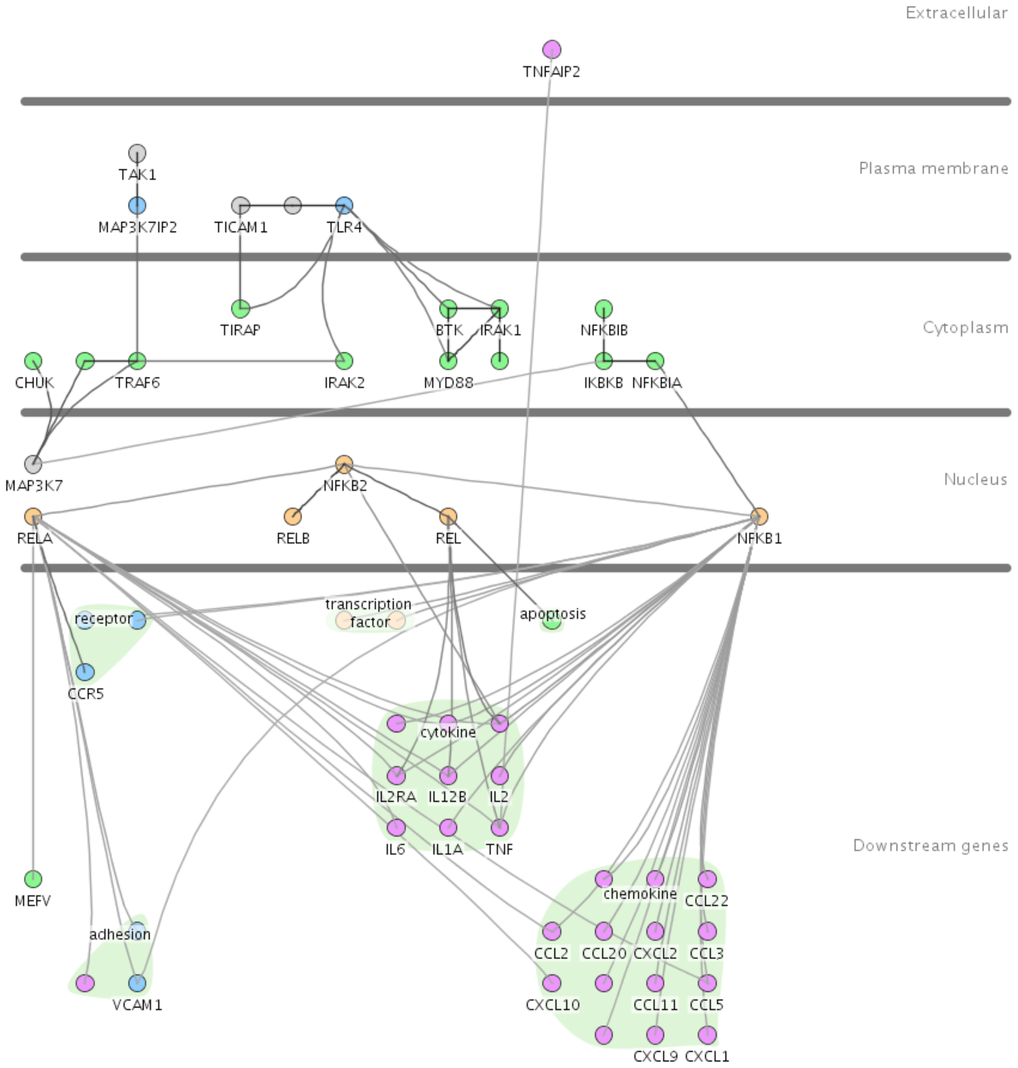
Dr. David Koop

Definition of Visualization

"Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively."

— T. Munzner

Why Computers?



[Cerebral, Barsky et al., 2007]

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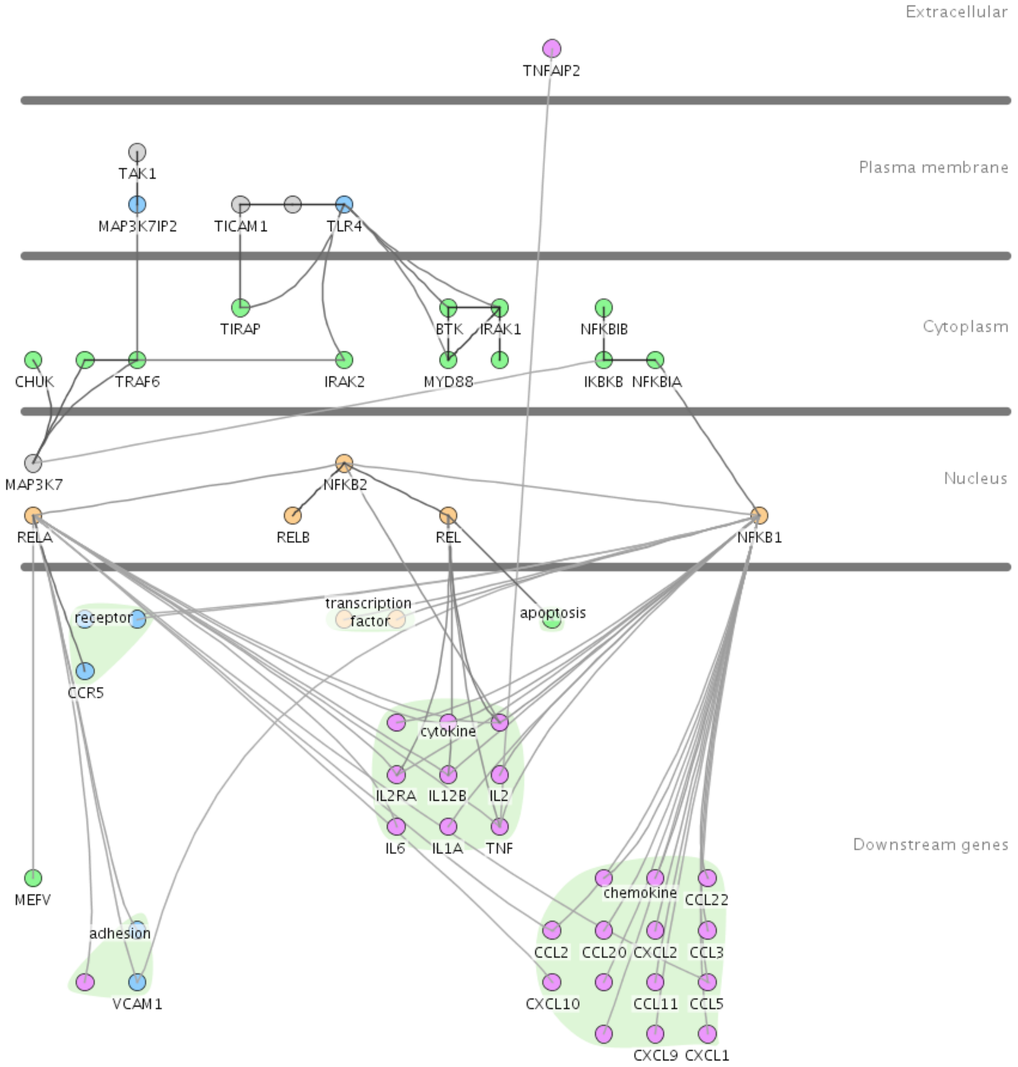

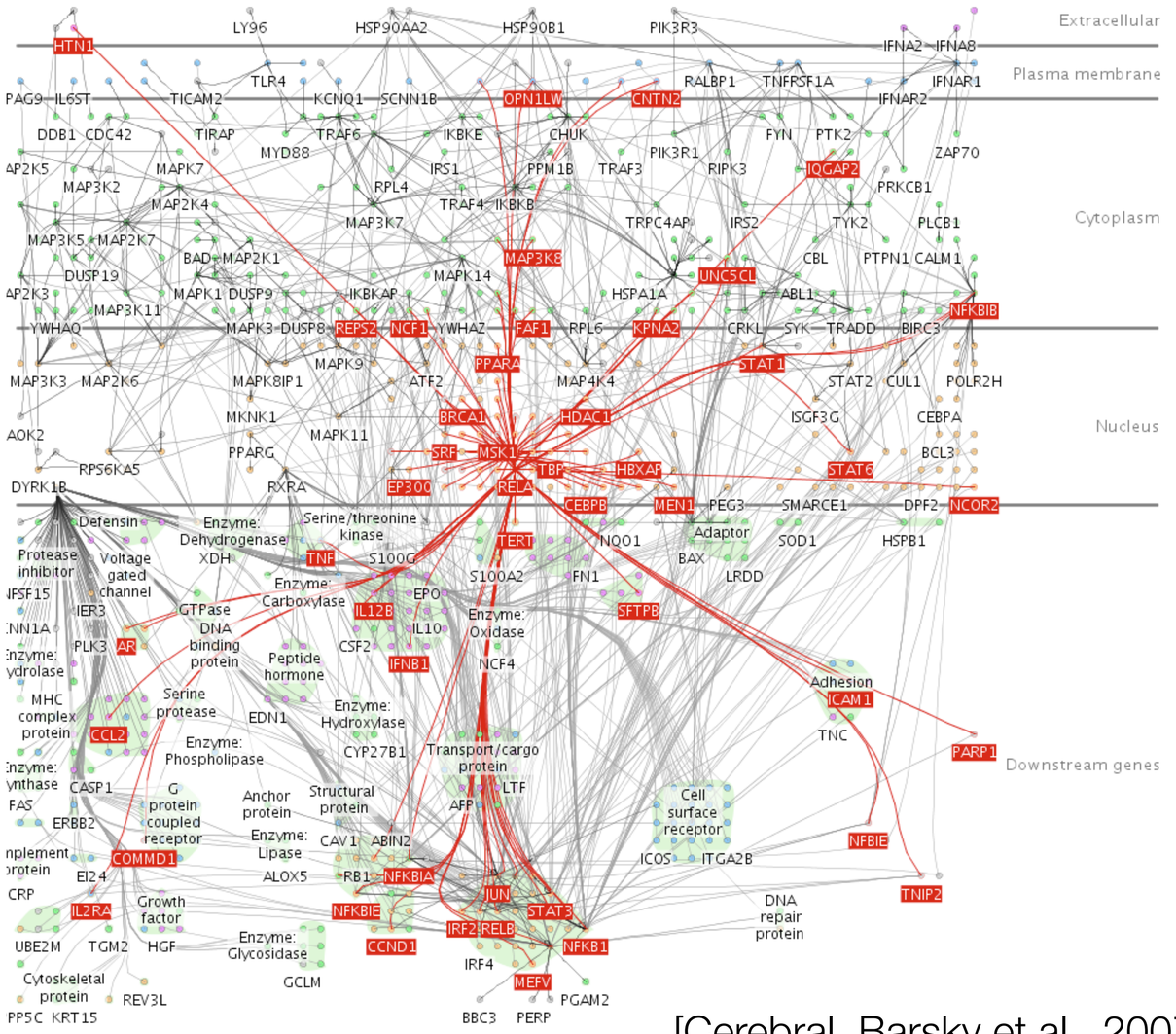

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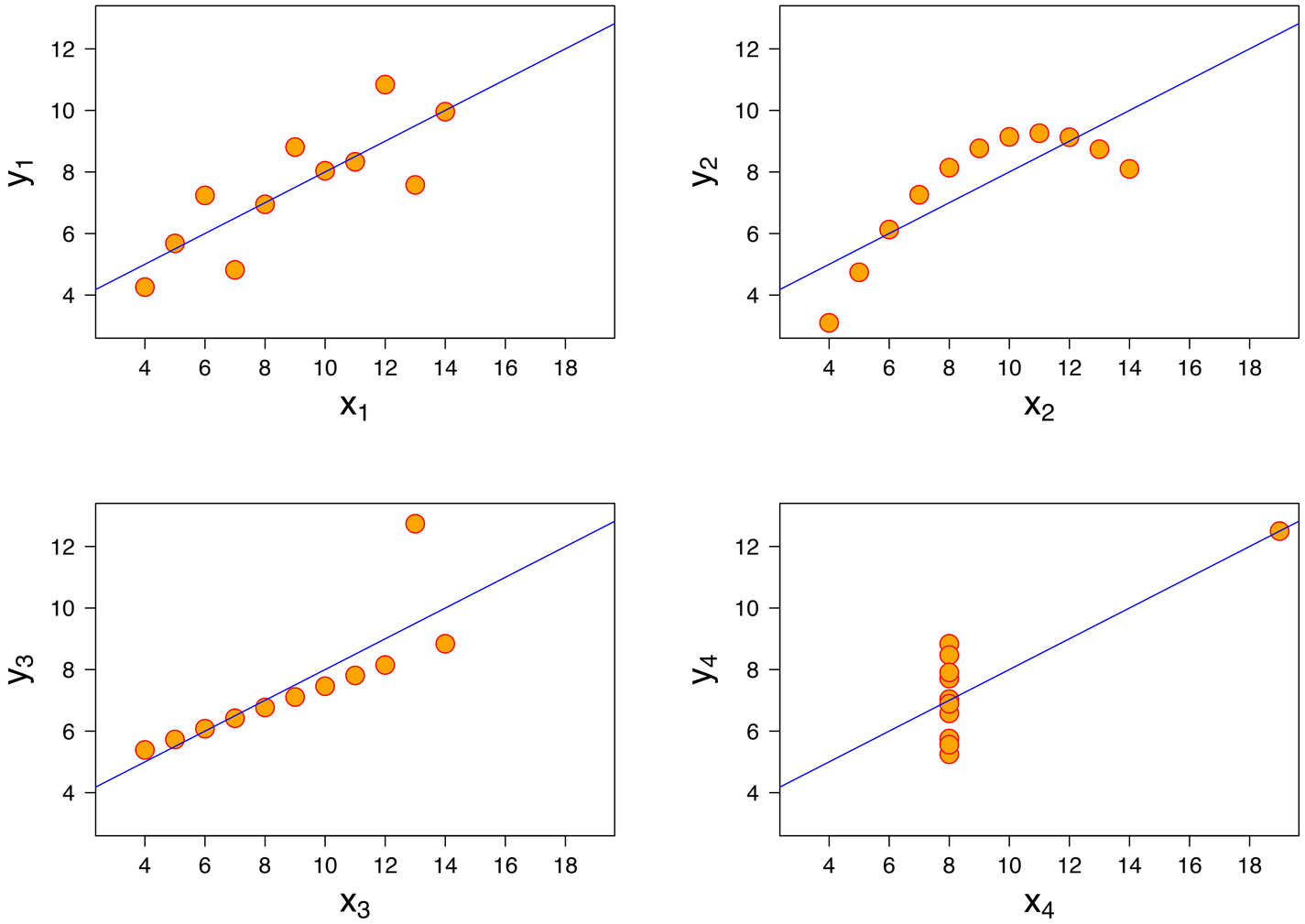
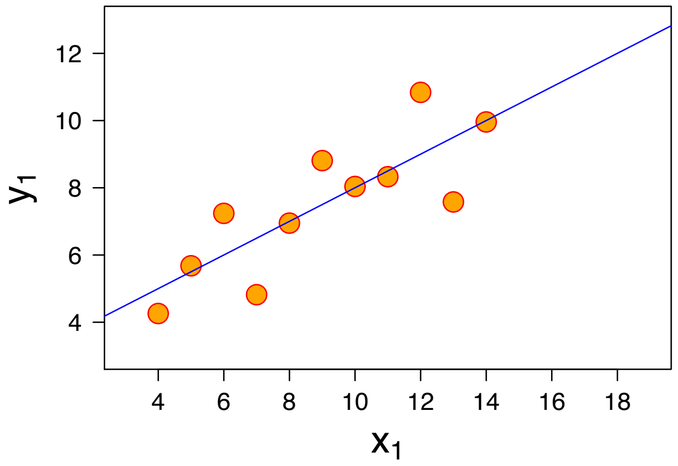
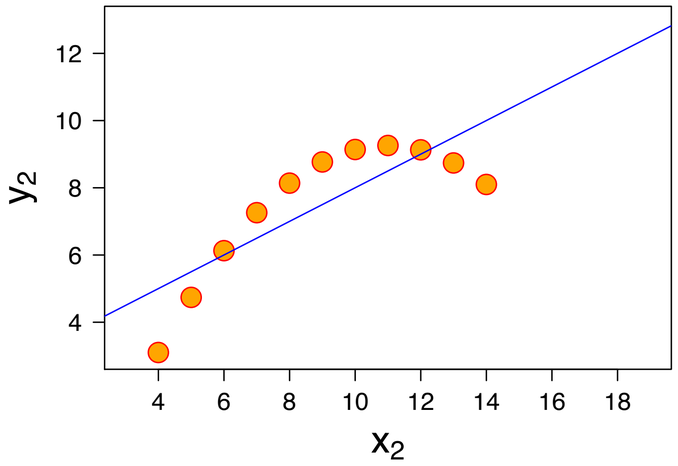
Why Visual?

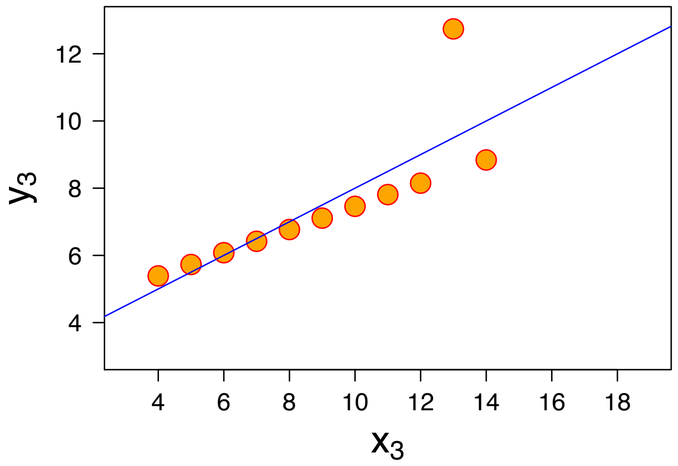


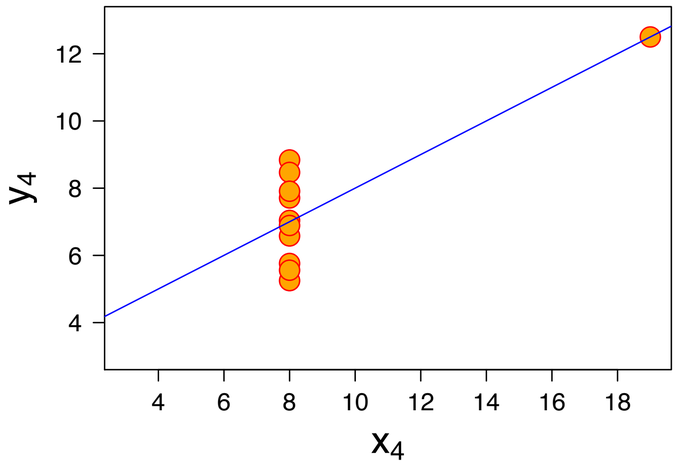
[F. J. Anscombe]

Why Visual?





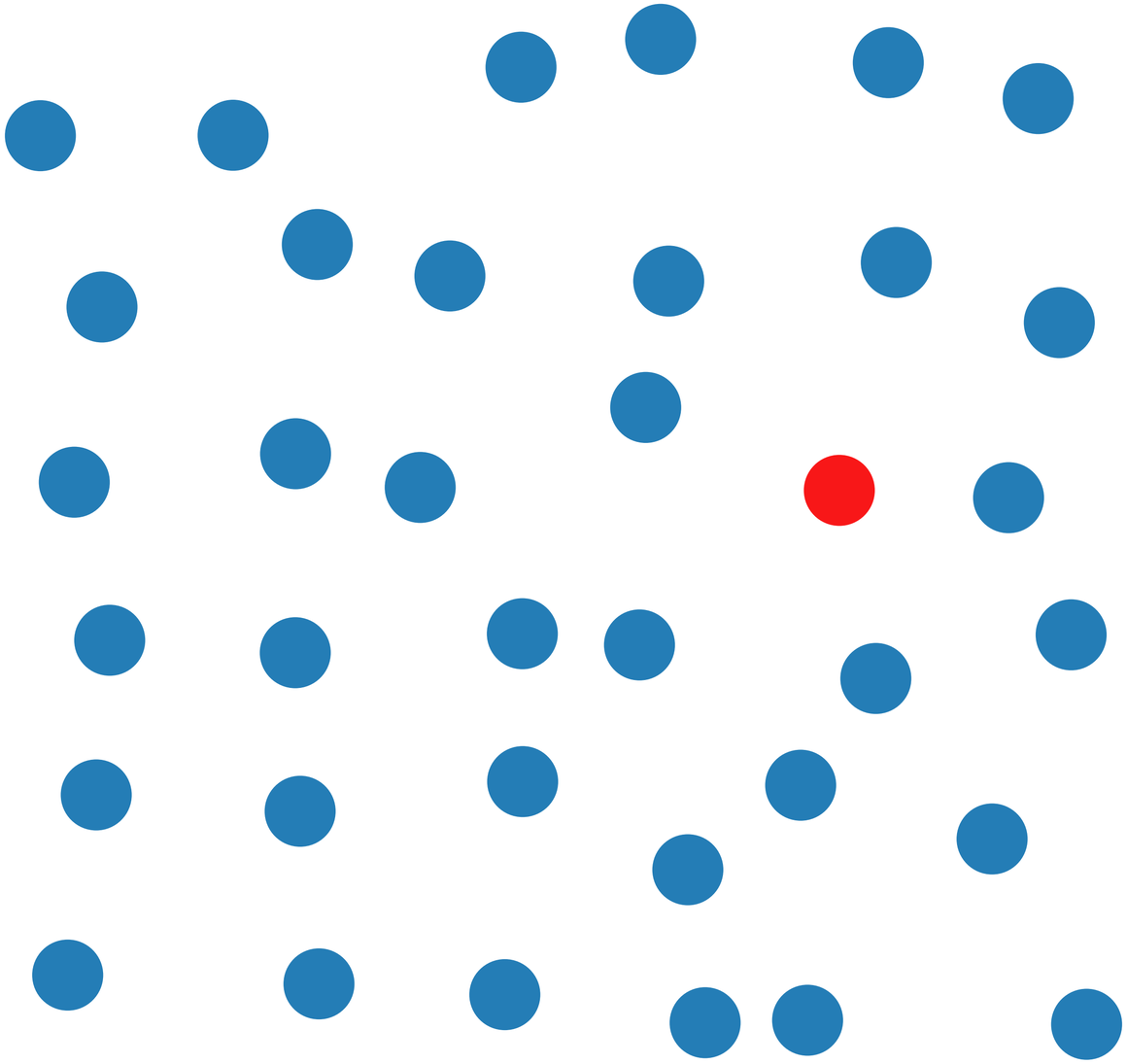




Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

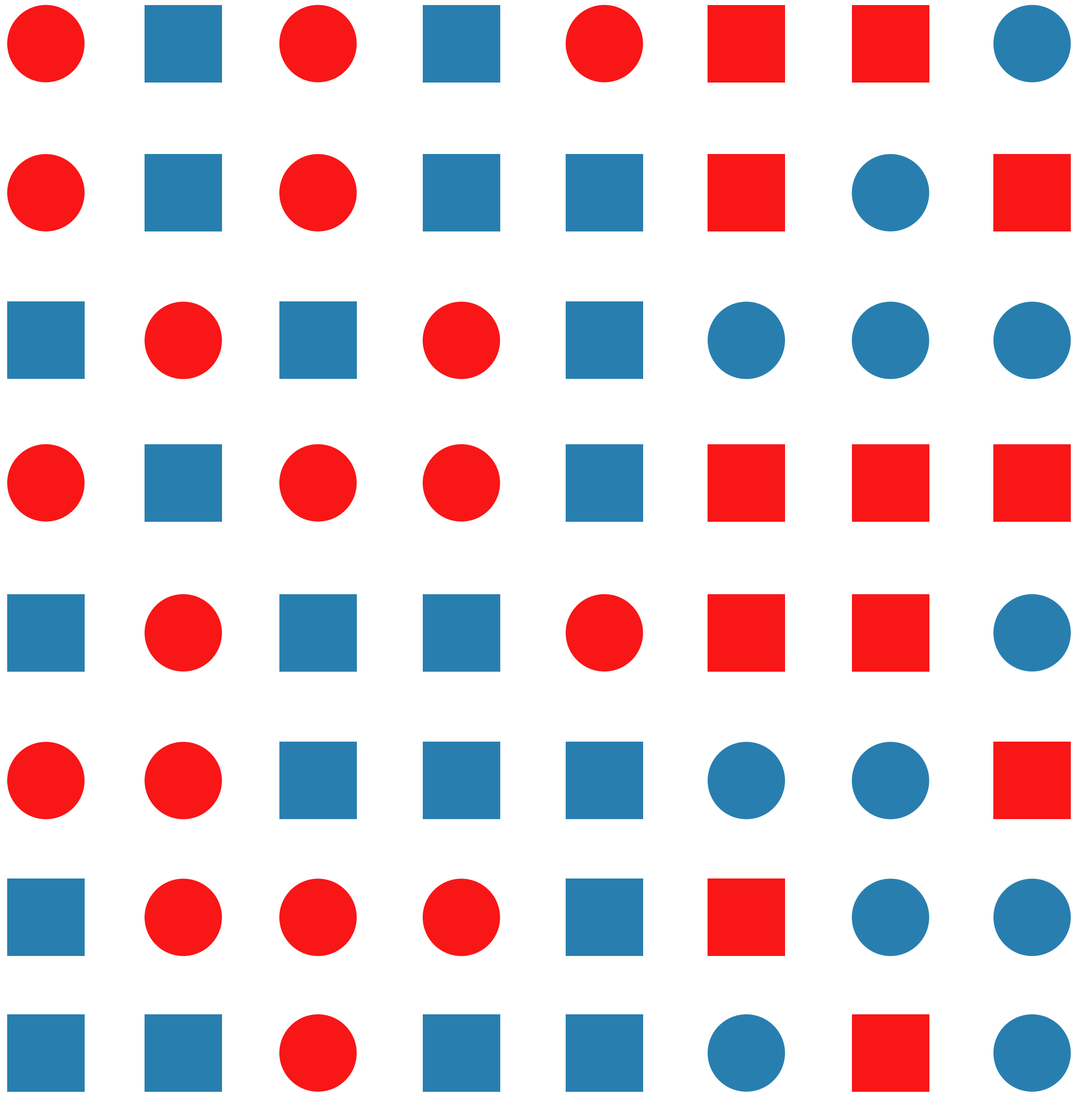
[F. J. Anscombe]

Visual Pop-out



[C. G. Healey]

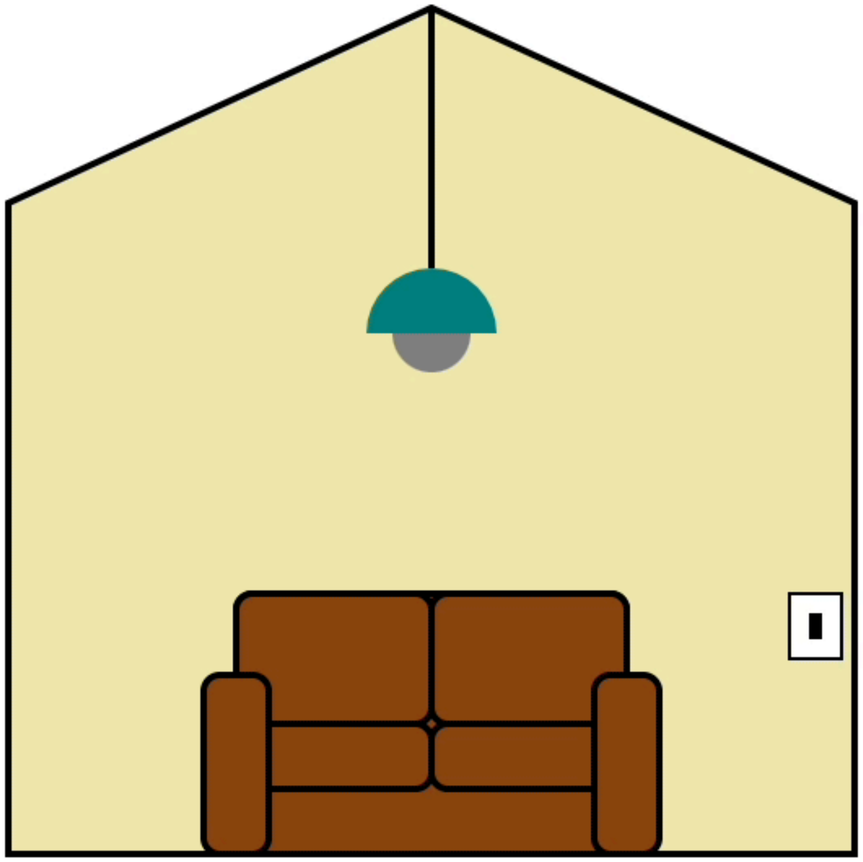
Visual Perception Limitations



[C. G. Healey]

Assignment 1

- Write HTML, CSS, and SVG
- Text markup and styling (information)
- Drawing markup and styling (room)
- Draw Bar chart using Plot library
- Due Tuesday, Sept. 11



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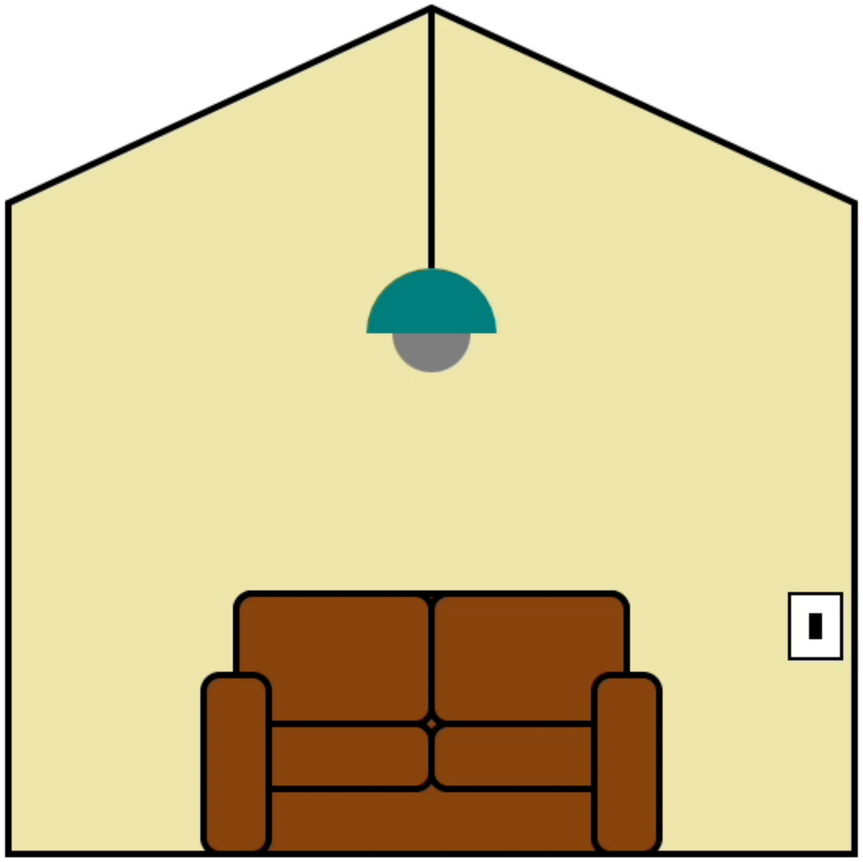

Languages of the Web

- HTML
- CSS
- SVG
- JavaScript
  - ECMAScript is a JavaScript standard
  - Versions of Javascript: ES6 (ECMAScript 2015), ECMAScript 2024…
  - Specific frameworks: react, jQuery, bootstrap, Plot, D3

Web Programming Tools

- Basic: Text editor and Modern Browser
- Developer Tools: Built in to browsers (e.g. Chrome Developer Tools)
- Web Environments: Observable, CodePen, JSFiddle, etc.
- IDEs: WebStorm, VSCode

Observable

- Observable is a platform that allows users to create notebooks using JavaScript, Markdown, and HTML
- Strong support of data visualization (company and community interests)
- Introduction: A Taste of Observable
- Type markup/code,"execute" the cell, and results appear **above** the code
- Pin the cell to keep the code visible
- Can choose the type of cell (JavaScript, Markdown, or HTML)
- Can create an output (variable) in each cell that can be used in other cells
- Content is all **global scope**!

Other Platforms

- CodePen
- deno.land

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Hyper Text Markup Language (HTML)

- Markup languages allow users to encode the **semantics** of text
- Tags define the boundaries of the structures of the content
  - Tags are enclosed in angle brackets (e.g. `<html>`)
  - Most of the time, you have a start and end tag
  - End tags are just like start tags except that they have forward slash after the open bracket (e.g. `</html>`)
  - Tags may be nested but not mismatched
    - `<p>A <strong><em>very</em></strong> cool example</p>`
    - `<p>A <strong>very <em>cool</strong></em> example</p>`
  - What about `<img src="mypicture.png" alt="My Image">`?

HTML Elements and Attributes

- Tags denote **elements** of the content (e.g. sections, paragraphs, images)
- Each element may have **attributes** which define other information
  - An attribute has a **key** and **value** (`key="value"`)
  - e.g. `<img src="mypicture.png" alt="My Image">`
- Many different elements available
  - Common: headers (`h1`, …, `h6`), paragraph (`p`), lists (`ul`, `ol`, `li`), emphasis (`em`, `strong`), link (`a`), spans & divisions (`span`, `div`)
  - Lots more (e.g. `abbr`): see MDN Documentation
- Many different attributes available
  - See MDN Documentation: note that some are legacy due to CSS

HTML Element Structure & Naming

- Elements structure a document
  - Document Object Model (DOM)
  - We can visualize this information
  - More importantly, we can **navigate** this tree
- Identifying and Classifying elements: `id` and `class` attributes
  - `id` identifies a **single** element—use for a unique case
  - `class` may identify **multiple** elements—use for common cases
  - Each element may have multiple classes, separate by spaces
  - Use normal identifiers: don't start the name with a number

Other HTML Trivia

- `<`, `>`, `&`, and `"` are special characters, escape with `<`, `>`, `&`, and `&quot;` (note the semi-colon)
- Comments are enclosed by `<!--` and `-->`
  - `<!-- This is a comment -->`
- HTML Documents begin with a `DOCTYPE` declaration
  - For HTML5, this is easier `<!DOCTYPE html>`
- meta tag: `<meta charset="UTF-8"/>`
- HTML has audio and video tags, math equation support, and more

Basic HTML File

```
<!DOCTYPE html>
<html>
  <head>
  <title>A Basic Web Page</title>
</head>
<body>
  <h1>Da Bears</h1>
  <p><em>This is <strong>cool</strong>. What about
<u><strong>this?</strong></u></em></p>
  <img alt="Caleb Williams" src="https://upload.wikimedia.org/
wikipedia/commons/thumb/1/10/Caleb_Williams_Oklahoma.jpg/253px-
Caleb_Williams_Oklahoma.jpg" width="300px">
</body>
</html>
```

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wikipedia/commons/thumb/1/10/Caleb_Williams_Oklahoma.jpg/253px-
Caleb_Williams_Oklahoma.jpg" width="300px">
</body>
</html>
```

In many environments (e.g. Observable), only need this part

What is CSS?

Cascading Style Sheets (CSS)

- Separate from content, just specifies how to style the content
- Style information can appear in three places:
  - External file
  - In a style element at the beginning of the HTML file
  - In a specific element in the body of a document (least preferable)
- Why Cascading?
  - Don’t want to have to specify everything over and over
  - Often want to use the same characteristics in a region of the DOM
  - Use inheritance: properties that apply to children cascade down

CSS Selectors

- How do we specify what part(s) of the page we want to style?
- The **element types** themselves (the HTML tag)
  - `strong { color: red; }`
- **Classes** of elements (ties to HTML `class` attribute)
  - `.cool { color: blue; }`
- A **specific** element (ties to HTML `id` attribute)
  - `#main-section { color: green; }`
- Relationships
  - Descendant: `p em { color: yellow; }`
  - Child: `p > em { color: orange; }`
- Pseudo-classes: `a:hover { color: purple; }`

Other CSS Bits

- Comments: `/* This is a comment in CSS */`
- Grouping Selectors: `p, li { font-size: 12pt; }`
- Multiple Classes: `.cool.temp { color: blue; }`
- Colors:
  - Names (Level 1, 2, & 3): `red, orange, antiquewhite`
  - Dash notation (3- & 6-character): `#fff, #00ff00`
  - Integer or % RGB and HSL Functions: `rgb( 255, 0, 0), rgb(50%, 50%, 0%), hsl(120, 100%, 50%)`
  - Also `background-color`
- Watch out for multiple rules (look at how a web browser parses)
- Again, much more documentation at MDN

Example CSS

```
body {
   font-face: sans-serif;
   font-size: 12pt;
}
em { color: green; }
em u { color: red; }
em > strong { color: blue; }
img { border: 4px solid red; }
```

- What colors are displayed for this HTML (with the above stylesheet)?
  - `<em>This is <strong>cool</strong>. What about <u><strong>this?</strong></u></em>`

CSS Specificity

- Example:
  - CSS:

```
p.exciting { color: red; }
p { color: blue; }
```

  - What is the color of the paragraph

```
<p class="exciting">Cool</p>?
```

- Generally, last rule listed overrides previous rules
- …but anytime a selector is **more specific**, it has precedence
- `p.exciting` is a more specific selector
- When in doubt, **test it** in a browser

How to add CSS to HTML

- External: a separate file via a link element (in the `<head>` section):
  - `<link rel="stylesheet" href="styles.css">`
- Embedded: in the header:
  - `<style type="text/css"> … </style>`
- Inline: for a specific element: (**Discouraged!**)
  - `<p style="font-weight: bold;">Some text</p>`

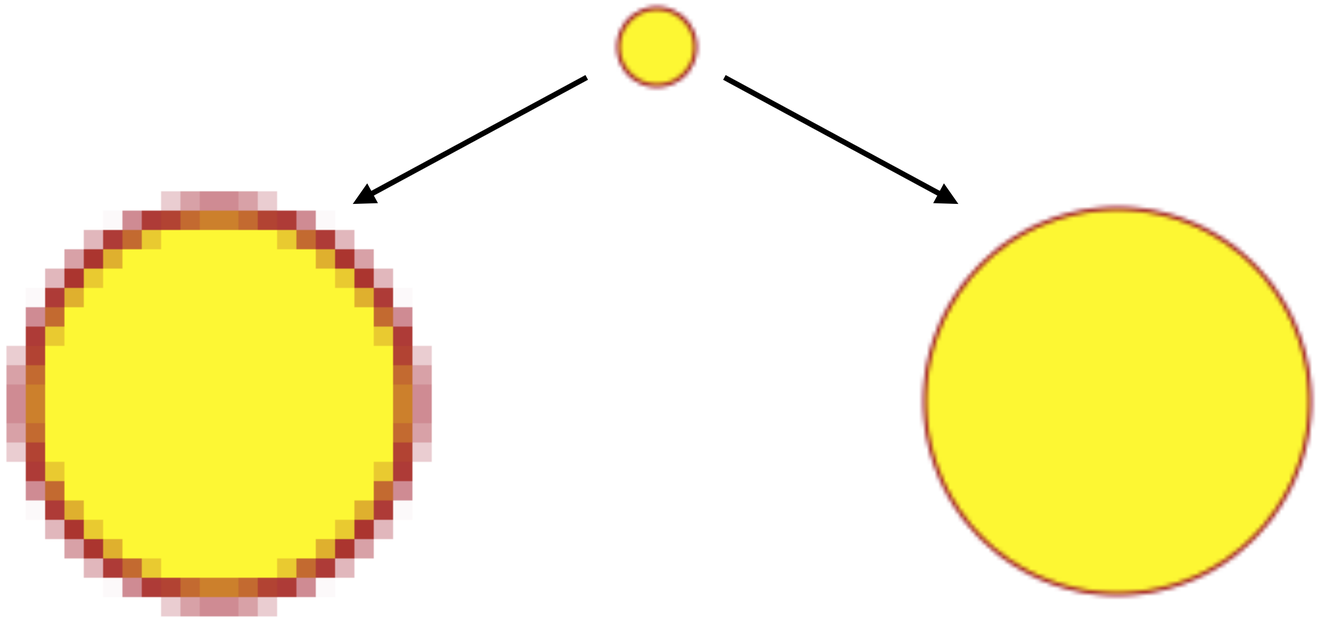
Observable

- Style rules are **global**
- Make sure you scope the rules
  - Add a `<style>` block to the cell for the rules for that cell
  - Put everything in a `<div>` with an `id` attribute
    - `<div id="mydiv">…</div>`
  - CSS rules should start with the div id unless you want to have rules apply to the entire notebook
    - `#mydiv p { font-family: sans-serif };`

What is the difference between vector and raster graphics?

Scalable Vector Graphics (SVG)

- Vector graphics vs. Raster graphics
- Drawing commands versus a grid of pixels
- Why vector graphics?

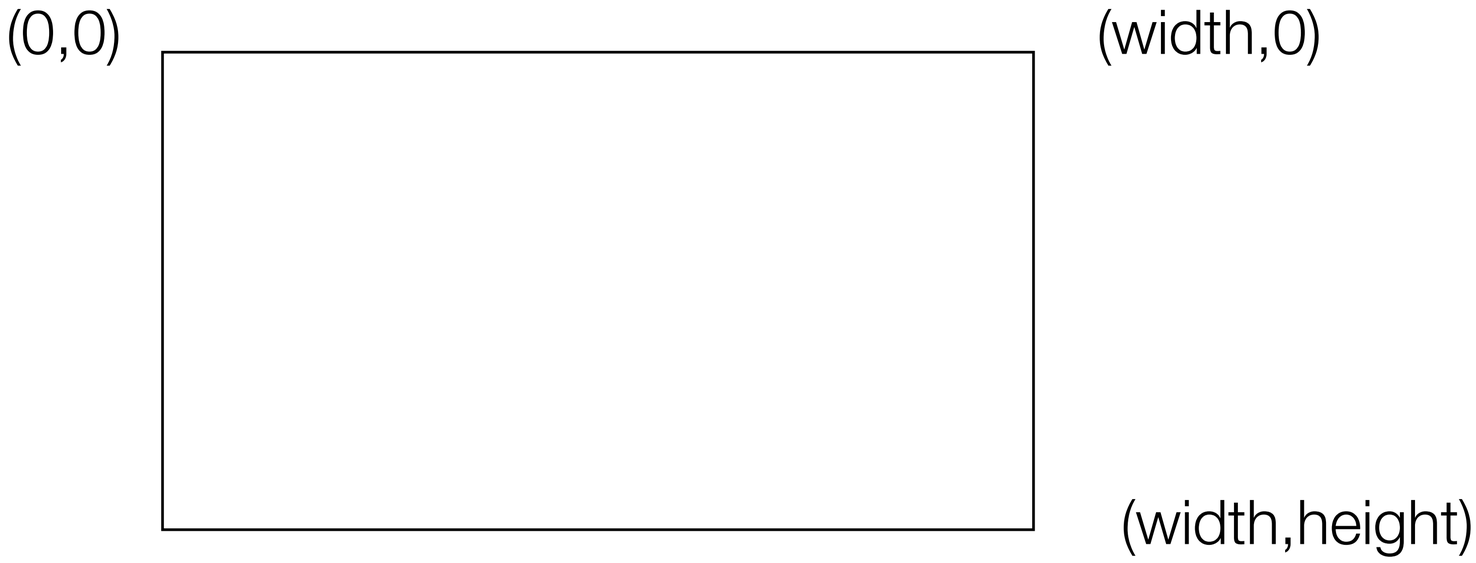


Raster

Vector

SVG Background

- Another markup language:
  - Describe the shapes and paths by their endpoints, characteristics
- SVG can be embedded into HTML5 documents!
- Pixel Coordinates: **Top-left** origin



SVG Elements

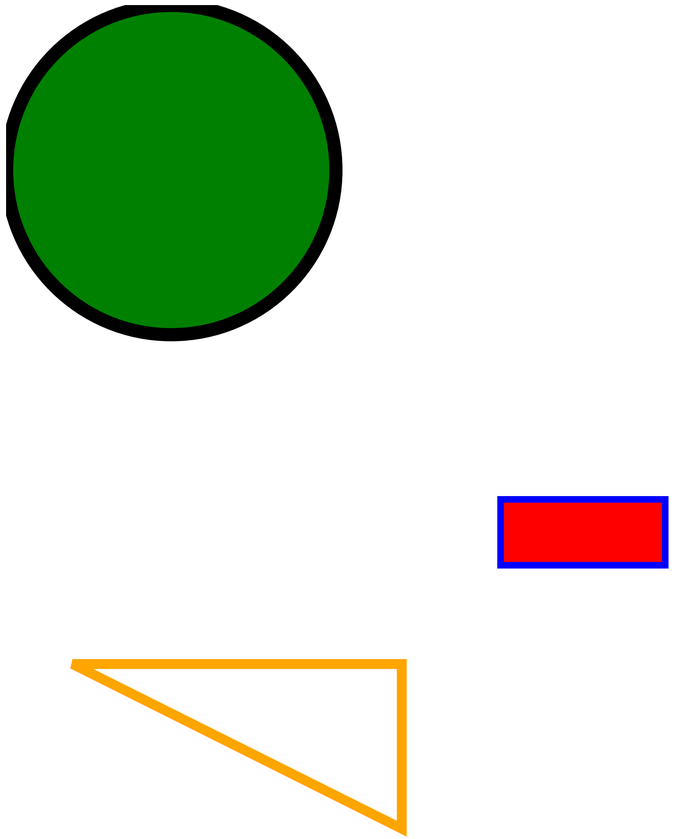
- Drawing primitives:
  - Lines, Circles, Rects, Ellipses, Text, Polylines, Paths
  - Work by specifying information about **how** to draw the shape
  - Lots more: see MDN Documentation
- Ordering/Stacking:
  - SVG Elements are drawn in the order they are specified
- Paths: directions for drawing
  - https://developer.mozilla.org/en-US/docs/Web/SVG/Tutorial/Paths

SVG Styles

- We can specify styles of SVG elements in CSS!
- Example:

```
circle { fill: green; stroke: black;
         stroke-width: 4px; }
.normal { fill: red; stroke: blue;
          stroke-width: 2px; }
#p1 { fill: none; stroke: red; stroke-width: 3px; }
```

SVG Example



```
<svg id="mysvg" width="300" height="600">
  <circle cx="50" cy="50" r="50"/>
  <rect class="lego" x="150" y="150"
        width="50" height="20"/>
  <path id="triangle" d="M 20 200
        L 120 200 L 120 250 Z"/>
</svg>
```

```
circle { fill: green; stroke: black;
         stroke-width: 4px; }
.lego { fill: red; stroke: blue;
        stroke-width: 2px; }
#triangle { fill: none; stroke: orange;
            stroke-width:3px; }
```

SVG Grouping

- Very powerful, useful for animations and transformations
- `<g> <circle …/> <circle … /> <circle … /></g>`
- Can add transforms to the group:

```
<svg width="200" height="200">
    <g transform="translate(0, 200) scale(1, -1)">
        <circle cx="50" cy="50" r="10"/>
        <circle cx="80" cy="80" r="10"/>
        <circle cx="110" cy="50" r="10"/>
        <circle cx="140" cy="90" r="10"/>
    </g>
</svg>
```

[SVG Example, Scheidegger, 2016]

JavaScript in one slide

- Interpreted and Dynamically-typed Programming Language
- Statements end with semi-colons, normal blocking with brackets
- Variables: `var a = 0; let b = 2; const d = 4;`
- Operators: `+, -, *, /, [ ]`
- Control Statements: `if (<expr>){…} else {…}, switch`
- Loops: `for, while, do-while`
- Arrays: `var a = [1,2,3]; a[99] = 100; console.log(a.length);`
- Functions: `function myFunction(a,b) { return a + b; }`
- Objects: `var obj = {x: 2, y: 4}; obj.x = 3; obj.y = 5;`
  - Prototypes for instance functions
- Comments are `/* Comment */` or `// Single-line Comment`

JavaScript References

- Learn Just Enough JavaScript: Introduction, P. Boffa
- Eloquent JavaScript, M. Haverbeke
- MDN Tutorials
- Interactive Data Visualization for the Web, Murray