E6895 Advanced Big Data Analytics Lecture 13:

Big Data Visualization

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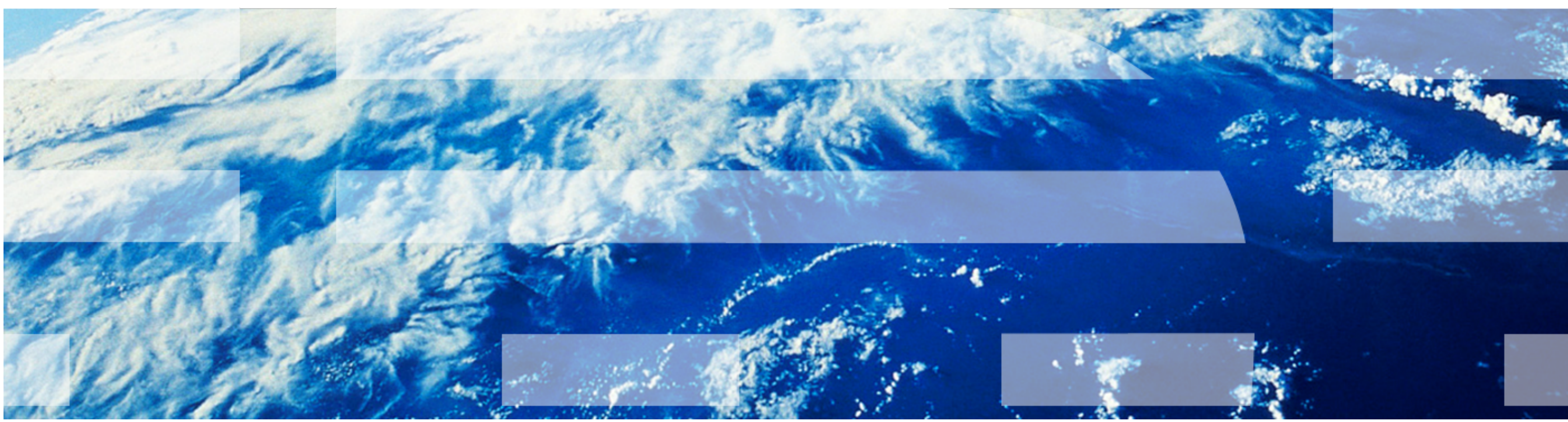


April 24th, 2020

COLUMBIA UNIVERSITY

MUST DO for a DATA SCIENTIST

Write Webpages to present results:

- Write HTML
- Write Javascript
- Write CSS

==> Extremely Important. If you cannot write them, then you are not ready to work.

Do Not Only Live in the World of Jupyter Notebook!!!

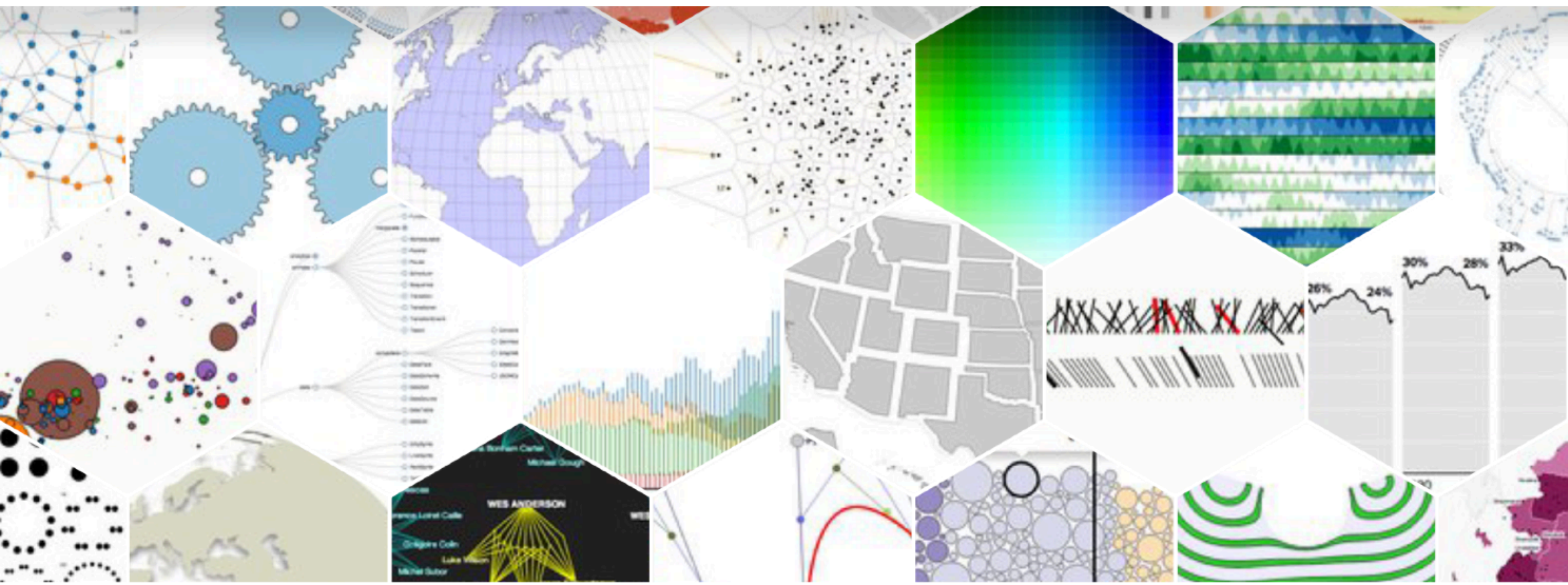
==> Lots of new graduates in the latest 1~3 years are terrible in doing real world work! They do not understand or experience real world system context!!

Using D3 for Visualization — Introduction and Examples

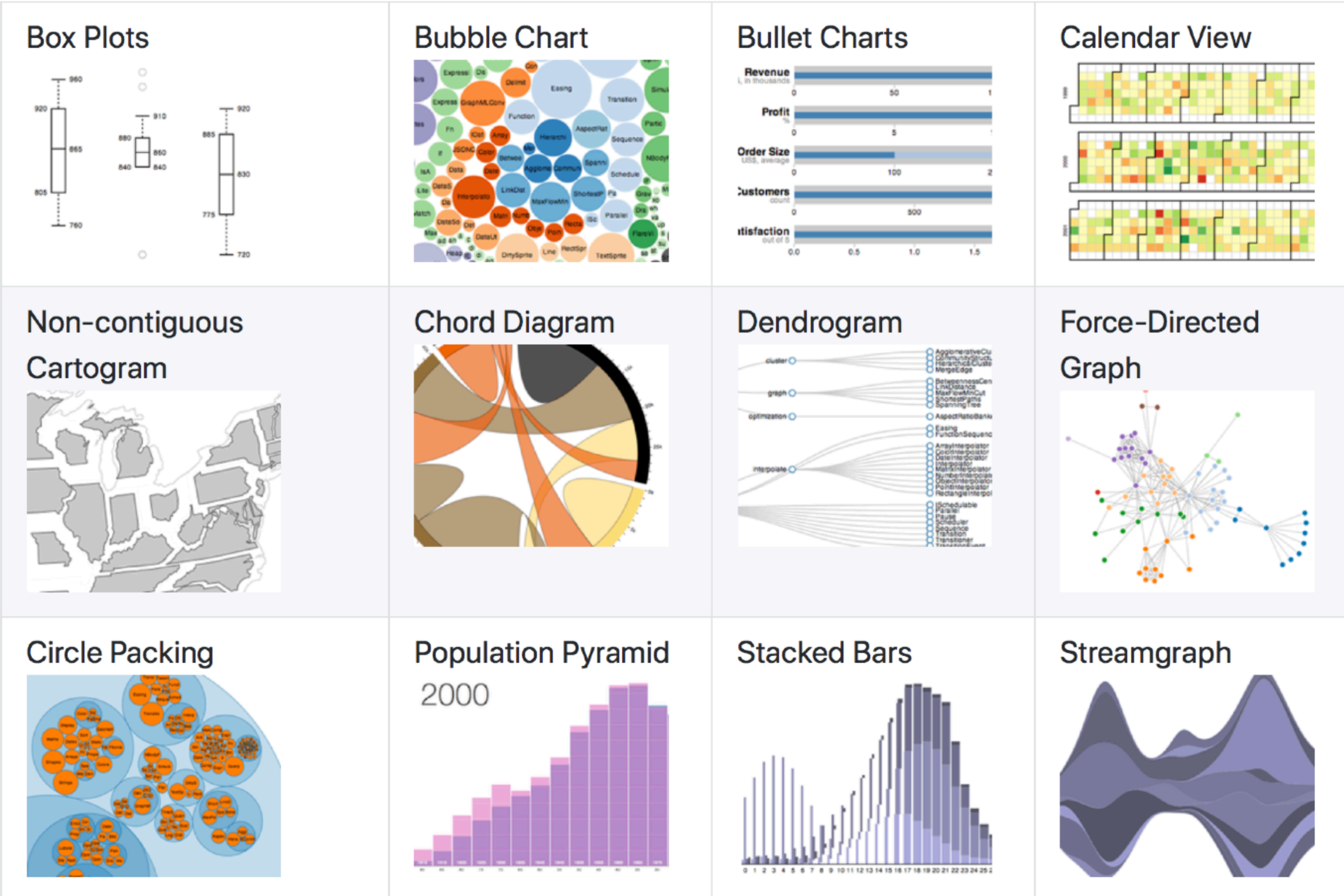
D3 Website

http://d3js.org

Data-Driven Documents

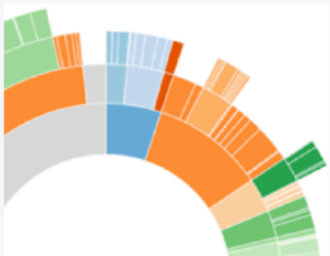


D3 Gallery


Box Plots
Bubble Chart
Bullet Charts
Calendar View
Non-contiguous Cartogram
Chord Diagram
Dendrogram
Force-Directed Graph
Circle Packing
Population Pyramid
2000
Stacked Bars
Streamgraph

D3 Gallery

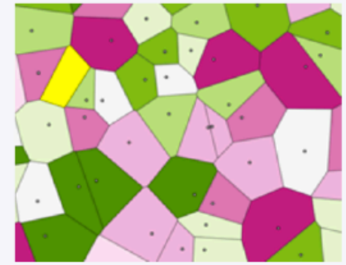
Sunburst



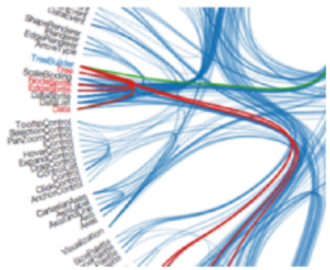
Node-Link Tree

Treemap

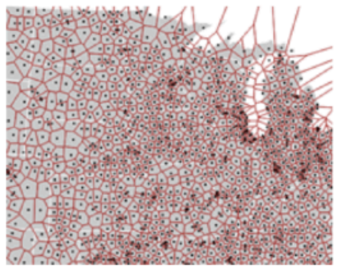
Voronoi Diagram



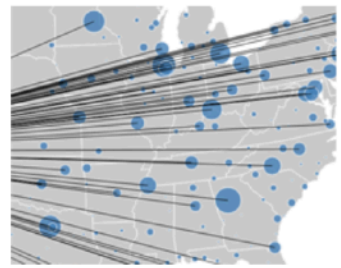
Hierarchical Edge Bundling



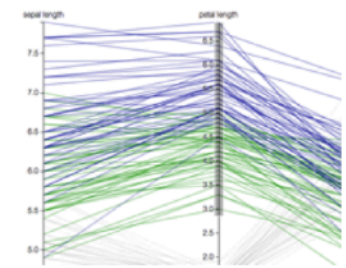
Voronoi Diagram



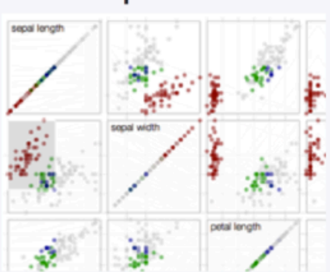
Symbol Map



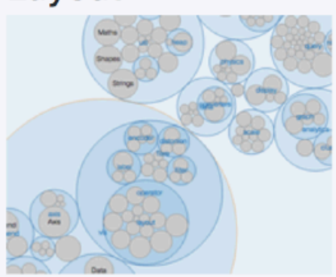
Parallel Coordinates



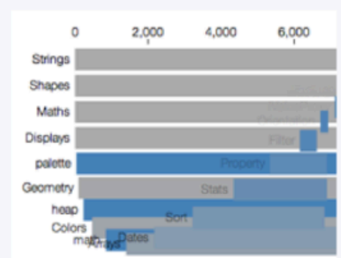
Scatterplot Matrix



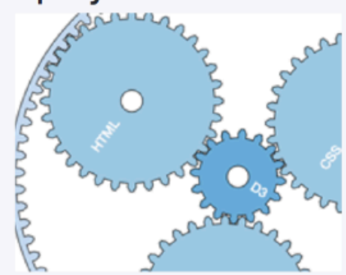
Zoomable Pack Layout



Hierarchical Bars



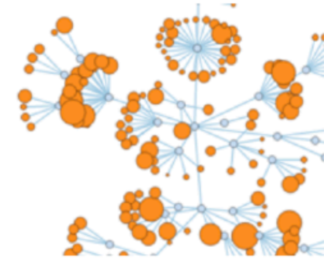
Epicyclical Gears



D3 Gallery

Collision Detection

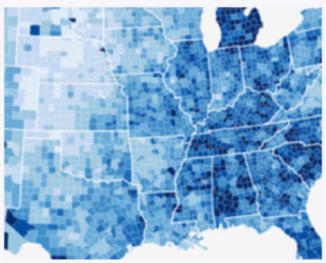
Collapsible Force Layout



Force-Directed States

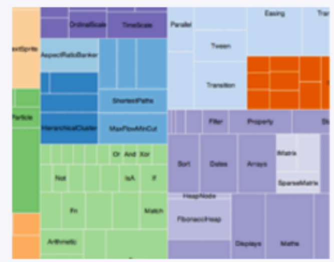
Azimuthal Projections

Choropleth

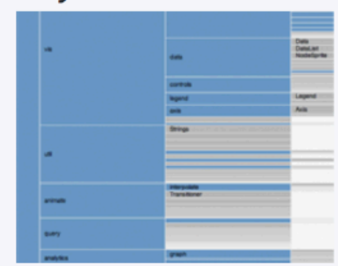


Collapsible Tree Layout

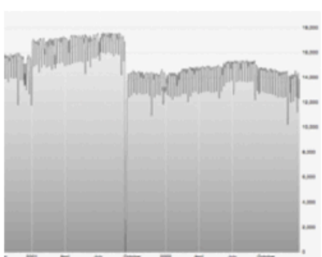
Zoomable Treemap



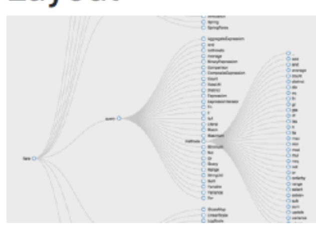
Zoomable Partition Layout



Zoomable Area Chart

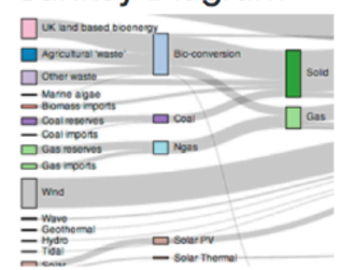


Drag and Drop Collapsible Tree Layout



Radial Cluster Layout

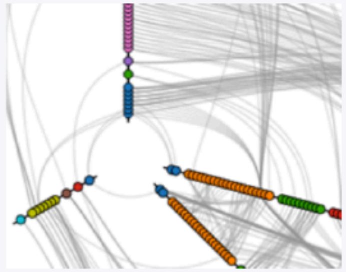
Sankey Diagram



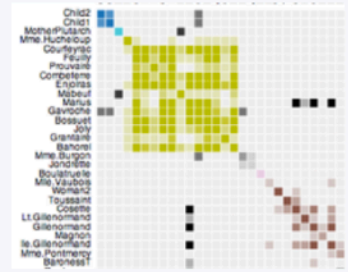
D3 Gallery

Fisheye Distortion

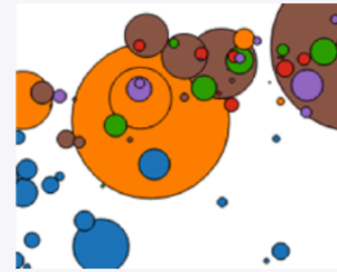
Hive Plot



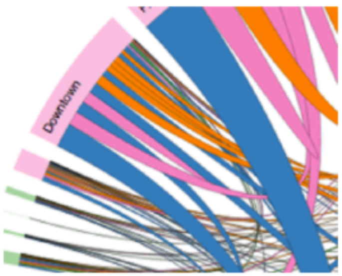
Co-occurrence Matrix



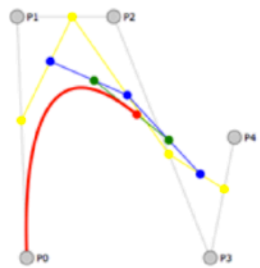
Motion Chart



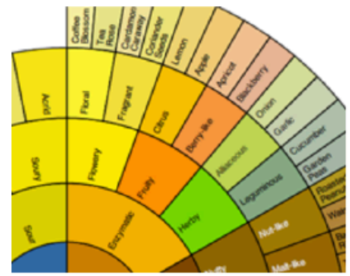
Chord Diagram



Animated Béziers

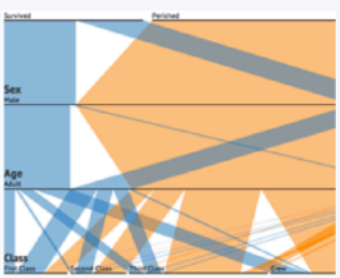


Zoomable Sunburst



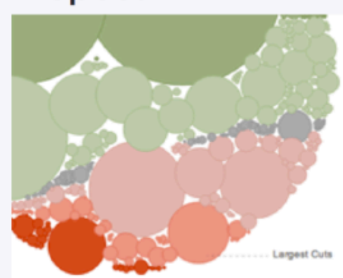
Collatz Graph

Parallel Sets



Word Cloud

Obama's Budget Proposal



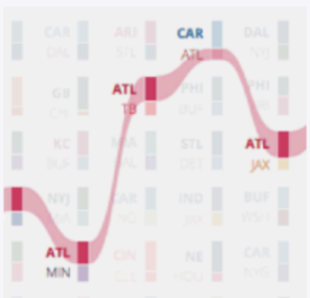
Facebook IPO

D3 Gallery

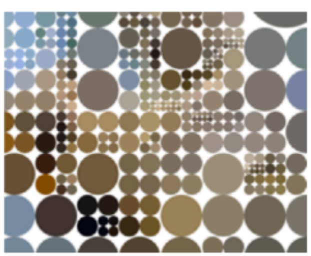
US Trade Deficit

Sequences sunburst

NFL Predictions

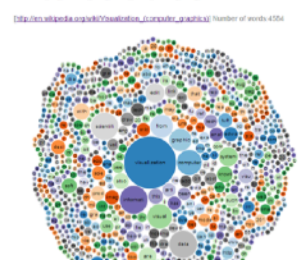


Koalas to the Max

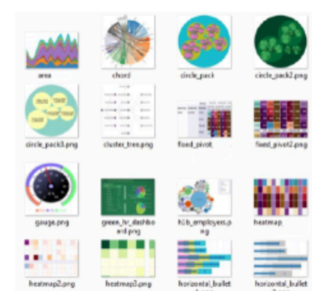


Sankey Creator

Convert any page into bubbles



D3 Builder



Installing

For NPM, `npm install d3`. For Yarn, `yarn add d3`. Otherwise, download the latest release. The released bundle supports AMD, CommonJS, and vanilla environments. Create a custom bundle using Rollup or your preferred bundler. You can also load directly from d3js.org:

```
<script src="https://d3js.org/d3.v5.js"></script>
```

For the minified version:

```
<script src="https://d3js.org/d3.v5.min.js"></script>
```

You can also use the standalone D3 microlibraries. For example, d3-selection:

```
<script src="https://d3js.org/d3-selection.v1.min.js"></script>
```

D3 Selections

In Javascript:

```
var paragraphs = document.getElementsByTagName("p");
for (var i = 0; i < paragraphs.length; i++) {
  var paragraph = paragraphs.item(i);
  paragraph.style.setProperty("color", "white", null);
}
```

D3 employs a declarative approach, operating on arbitrary sets of nodes called *selections*. For example, you can rewrite the above loop as:

```
d3.selectAll("p").style("color", "white");
```

D3 Dynamic Properties

Randomly color paragraphs:

```
d3.selectAll("p").style("color", function() {
  return "hsl(" + Math.random() * 360 + ",100%,50%)";
});
```

Alternate shades of gray for even and odd nodes:

```
d3.selectAll("p").style("color", function(d, i) {
  return i % 2 ? "#fff" : "#eee";
});
```

D3 Dynamic Properties

Randomly color paragraphs:

```
d3.selectAll("p")
  .data([4, 8, 15, 16, 23, 42])
    .style("font-size", function(d) { return d + "px"; });
```

Computed properties often refer to bound data. Data is specified as an array of values, and each value is passed as the first argument (d) to selection functions. With the default join-by-index, the first element in the data array is passed to the first node in the selection, the second element to the second node, and so on. For example, if you bind an array of numbers to paragraph elements, you can use these numbers to compute dynamic font sizes:

D3 Enter

Using D3’s *enter* and *exit* selections, you can create new nodes for incoming data and remove outgoing nodes that are no longer needed.

When data is bound to a selection, each element in the data array is paired with the corresponding node in the selection. If there are fewer nodes than data, the extra data elements form the enter selection, which you can instantiate by appending to the `enter` selection. For example:

```
d3.select("body")
  .selectAll("p")
  .data([4, 8, 15, 16, 23, 42])
  .enter().append("p")
    .text(function(d) { return "I’m number " + d + "!"; });
```

D3 Exit

```
// Update…
var p = d3.select("body")
  .selectAll("p")
  .data([4, 8, 15, 16, 23, 42])
    .text(function(d) { return d; });

// Enter…
p.enter().append("p")
    .text(function(d) { return d; });

// Exit…
p.exit().remove();
```

D3 Transformation

For example, to fade the background of the page to black:

```
d3.select("body").transition()
    .style("background-color", "black");
```

Or, to resize circles in a symbol map with a staggered delay:

```
d3.selectAll("circle").transition()
    .duration(750)
    .delay(function(d, i) { return i * 10; })
    .attr("r", function(d) { return Math.sqrt(d * scale); });
```

https://bost.ocks.org/mike/bar/

```
var data = [4, 8, 15, 16, 23, 42];
```

Selecting an Element

Javascript:

```
var div = document.createElement("div");
div.innerHTML = "Hello, world!";
document.body.appendChild(div);
```

D3:

```
var body = d3.select("body");
var div = body.append("div");
div.html("Hello, world!");
```

Chaining Methods

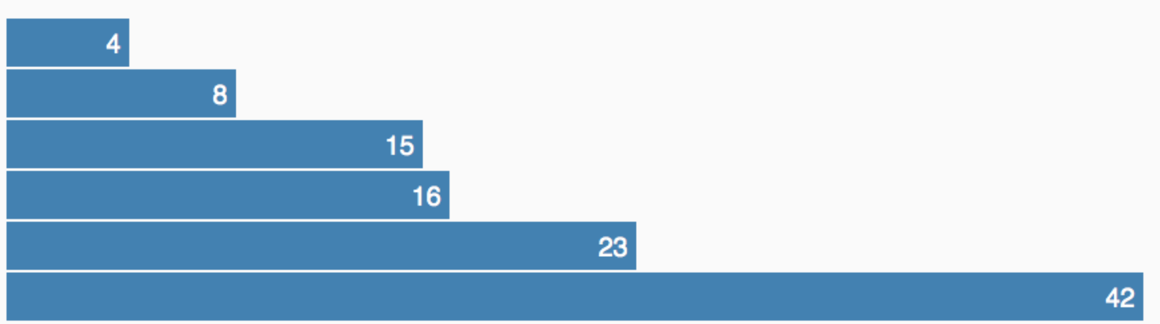
```
var body = d3.select("body");
body.style("color", "black");
body.style("background-color", "white");
```

```
d3.select("body")
    .style("color", "black")
    .style("background-color", "white");
```

```
var section = d3.selectAll("section");

section.append("div")
    .html("First!");

section.append("div")
    .html("Second.");
```

Coding a Chart, Manually

```
<!DOCTYPE html>
<style>

.chart div {
  font: 10px sans-serif;
  background-color: steelblue;
  text-align: right;
  padding: 3px;
  margin: 1px;
  color: white;
}

</style>
<div class="chart">
  <div style="width: 40px;">4</div>
  <div style="width: 80px;">8</div>
  <div style="width: 150px;">15</div>
  <div style="width: 160px;">16</div>
  <div style="width: 230px;">23</div>
  <div style="width: 420px;">42</div>
</div>
```



Columbia University

Coding a Chart, Automatically

```
d3.select(".chart")
  .selectAll("div")
    .data(data)
  .enter().append("div")
    .style("width", function(d) { return d * 10 + "px"; })
    .text(function(d) { return d; });
```

First, we select the chart container using a class selector.

```
var chart = d3.select(".chart");
```

Next we initiate the data join by defining the selection to which we will join data.

```
var bar = chart.selectAll("div");
```

Coding a Chart, Automatically

```
var barUpdate = bar.data(data);
```

```
var barEnter = barUpdate.enter().append("div");
```

```
barEnter.style("width", function(d) { return d * 10 + "px"; });
```

```
barEnter.text(function(d) { return d; });
```

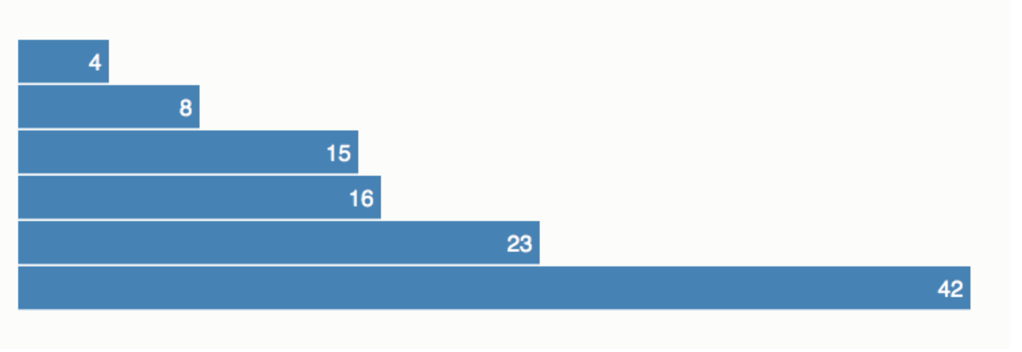
Scaling to Fit

```
var x = d3.scale.linear()
    .domain([0, d3.max(data)])
    .range([0, 420]);
```

D3 Bar Chart Tutorial

```
<!DOCTYPE html>
<style>

.chart rect {
  fill: steelblue;
}

.chart text {
  fill: white;
  font: 10px sans-serif;
  text-anchor: end;
}

</style>
<svg class="chart" width="420" height="120">
  <g transform="translate(0,0)">
    <rect width="40" height="19"></rect>
    <text x="37" y="9.5" dy=".35em">4</text>
  </g>
  <g transform="translate(0,20)">
    <rect width="80" height="19"></rect>
    <text x="77" y="9.5" dy=".35em">8</text>
  </g>
  <g transform="translate(0,40)">
    <rect width="150" height="19"></rect>
    <text x="147" y="9.5" dy=".35em">15</text>
  </g>
  <g transform="translate(0,60)">
    <rect width="160" height="19"></rect>
    <text x="157" y="9.5" dy=".35em">16</text>
  </g>
  <g transform="translate(0,80)">
    <rect width="230" height="19"></rect>
    <text x="227" y="9.5" dy=".35em">23</text>
  </g>
  <g transform="translate(0,100)">
    <rect width="420" height="19"></rect>
    <text x="417" y="9.5" dy=".35em">42</text>
  </g>
</svg>
```

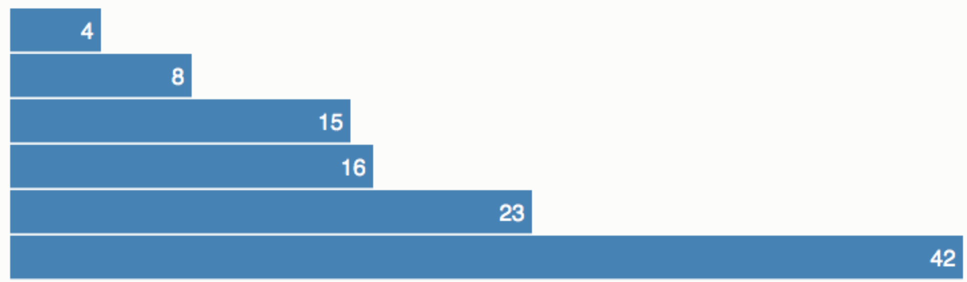
Full code to do it manually



D3 Bar Chart Tutorial

Full code to do it automatically

```
<!DOCTYPE html>
<meta charset="utf-8">
<style>

.chart rect {
  fill: steelblue;
}

.chart text {
  fill: white;
  font: 10px sans-serif;
  text-anchor: end;
}

</style>
<svg class="chart"></svg>
<script src="//d3js.org/d3.v3.min.js" charset="utf-8"></script>
```



Full code to do it automatically

```
<script>

var data = [4, 8, 15, 16, 23, 42];

var width = 420,
    barHeight = 20;

var x = d3.scale.linear()
    .domain([0, d3.max(data)])
    .range([0, width]);

var chart = d3.select(".chart")
    .attr("width", width)
    .attr("height", barHeight * data.length);

var bar = chart.selectAll("g")
    .data(data)
  .enter().append("g")
    .attr("transform", function(d, i) { return "translate(0," + i * barHeight + ")"; });

bar.append("rect")
    .attr("width", x)
    .attr("height", barHeight - 1);

bar.append("text")
    .attr("x", function(d) { return x(d) - 3; })
    .attr("y", barHeight / 2)
    .attr("dy", ".35em")
    .text(function(d) { return d; });

</script>
```

Load data

```
// 1. Code here runs first, before the download starts.

d3.tsv("data.tsv", function(error, data) {
  // 3. Code here runs last, after the download finishes.
});

// 2. Code here runs second, while the file is downloading.
```

```
name        value
Locke       4
Reyes       8
Ford        15
Jarrah      16
Shephard    23
Kwon        42
```

The equivalent of Javascript code:

```
var data = [
  {name: "Locke",    value:  4},
  {name: "Reyes",    value:  8},
  {name: "Ford",     value: 15},
  {name: "Jarrah",   value: 16},
  {name: "Shephard", value: 23},
  {name: "Kwon",     value: 42}
];
```

D3 Bar Chart Tutorial

```
<!DOCTYPE html>
<meta charset="utf-8">
<style>

.chart rect {
  fill: steelblue;
}

.chart text {
  fill: white;
  font: 10px sans-serif;
  text-anchor: end;
}

</style>
<svg class="chart"></svg>
<script src="//d3js.org/d3.v3.min.js" charset="utf-8"></script>
```

D3 Bar Chart Tutorial

```
<script>

var width = 420,
    barHeight = 20;

var x = d3.scale.linear()
    .range([0, width]);

var chart = d3.select(".chart")
    .attr("width", width);

d3.tsv("data.tsv", type, function(error, data) {
  x.domain([0, d3.max(data, function(d) { return d.value; })]);

  chart.attr("height", barHeight * data.length);

  var bar = chart.selectAll("g")
      .data(data)
    .enter().append("g")
      .attr("transform", function(d, i) { return "translate(0," + i * barHeight + ")"; });

  bar.append("rect")
      .attr("width", function(d) { return x(d.value); })
      .attr("height", barHeight - 1);

  bar.append("text")
      .attr("x", function(d) { return x(d.value) - 3; })
      .attr("y", barHeight / 2)
      .attr("dy", ".35em")
      .text(function(d) { return d.value; });
});

function type(d) {
  d.value = +d.value; // coerce to number
  return d;
}

</script>
```

D3 Example Circles

https://bost.ocks.org/mike/circles/

```
<svg width="720" height="120">
  <circle cx="40" cy="60" r="10"></circle>
  <circle cx="80" cy="60" r="10"></circle>
  <circle cx="120" cy="60" r="10"></circle>
</svg>
```

```
var circle = d3.selectAll("circle");
```

```
circle.style("fill", "steelblue");
circle.attr("r", 30);
```

D3 Example Circles

https://bost.ocks.org/mike/circles/

```
<svg width="720" height="120">
  <circle cx="40" cy="60" r="10"></circle>
  <circle cx="80" cy="60" r="10"></circle>
  <circle cx="120" cy="60" r="10"></circle>
</svg>
```

```
var circle = d3.selectAll("circle");
```

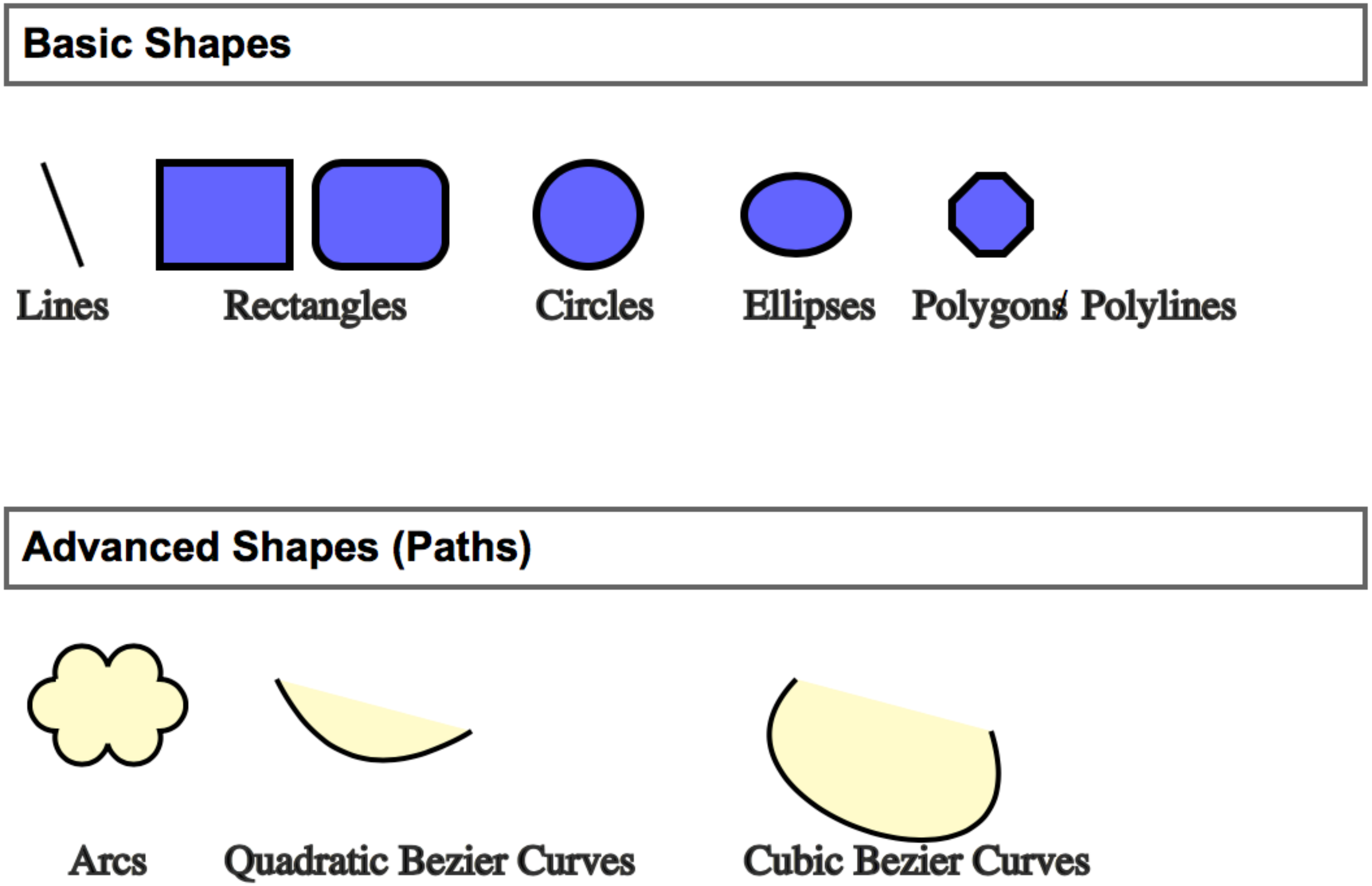
```
circle.style("fill", "steelblue");
circle.attr("r", 30);
```

```
circle.attr("cx", function() { return Math.random() * 720; });
```

SVG Introduction

Reference: http://tutorials.jenkov.com/svg/svg-examples.html

SVG Examples

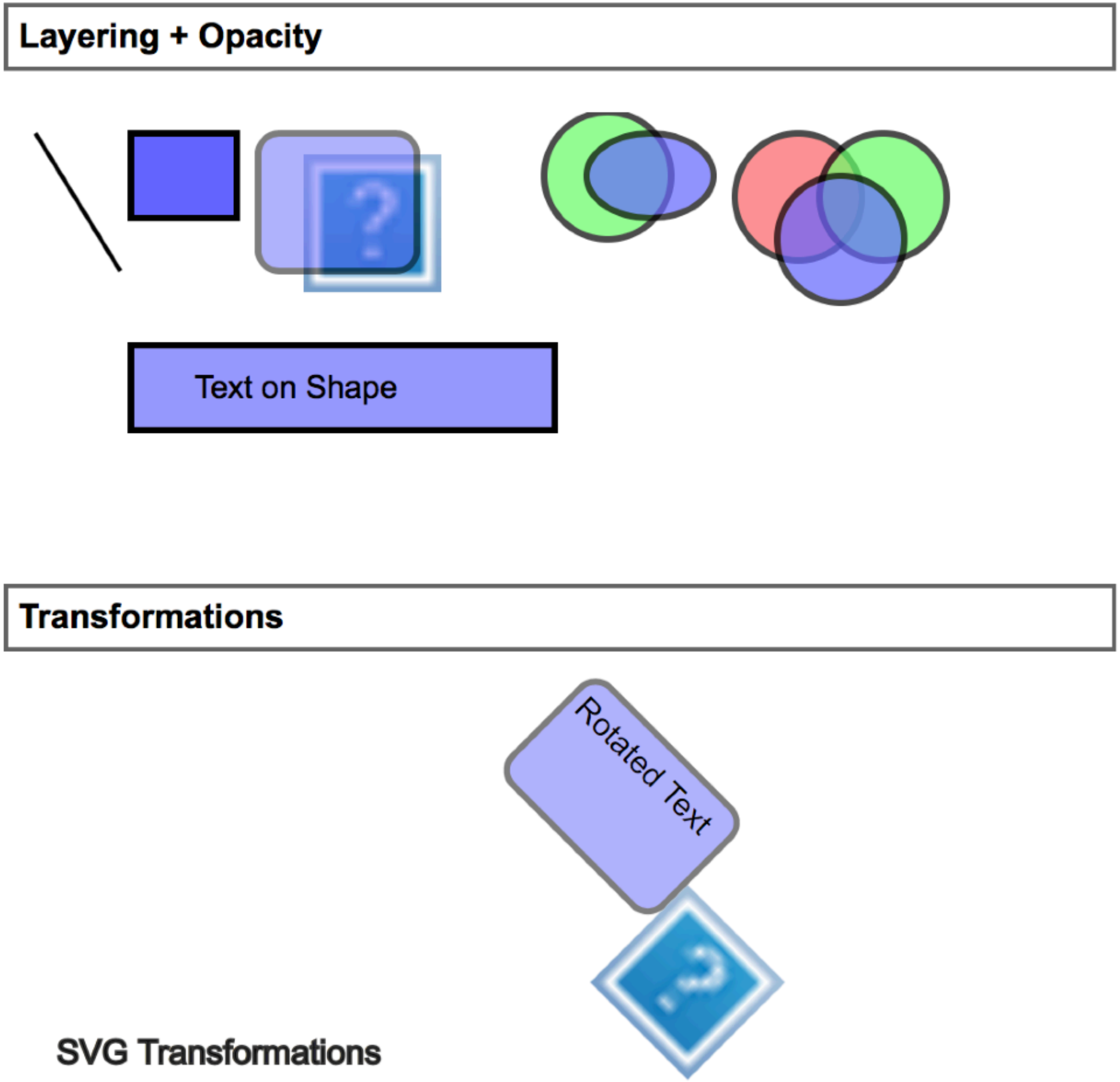


SVG Examples

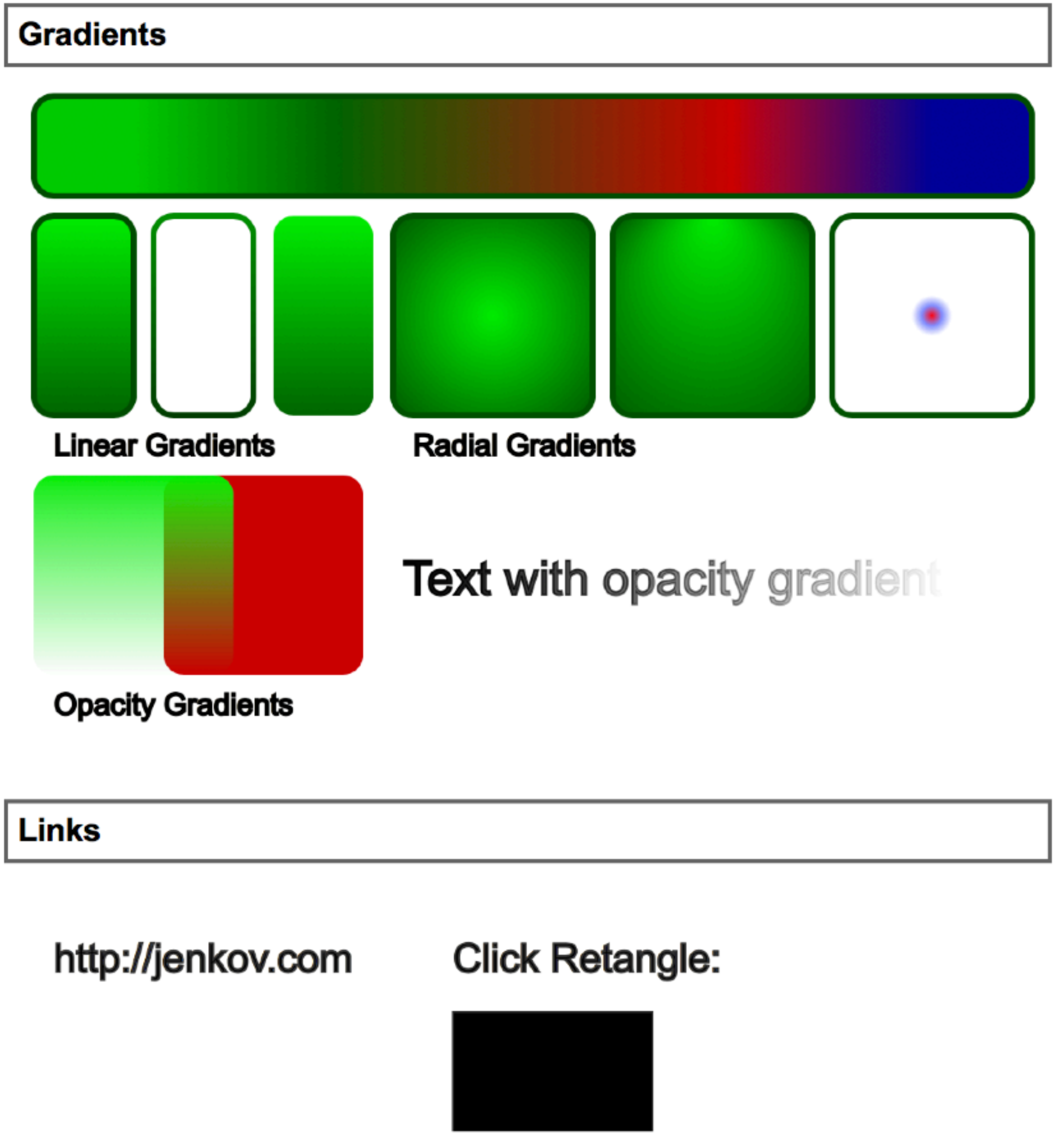
Text

Images

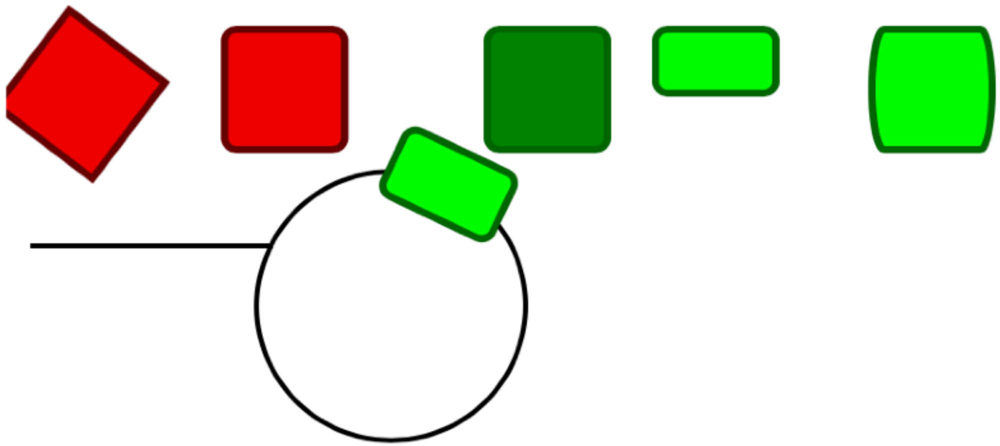
SVG Examples



SVG Examples



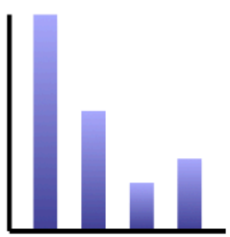
Animations



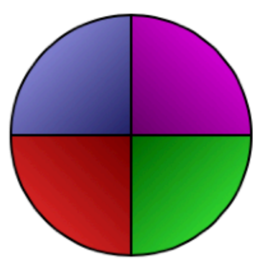
Animation

Use Cases

Graphs



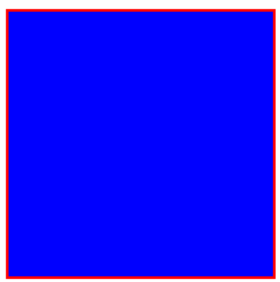
Bar Charts



Pie Charts

A Simple SVG Example

```
<svg  xmlns="http://www.w3.org/2000/svg"
      xmlns:xlink="http://www.w3.org/1999/xlink">
    <rect x="10" y="10" height="100" width="100"
          style="stroke:#ff0000; fill: #0000ff"/>
</svg>
```



SVG as Background Images

Since the browsers treat SVG images just like bitmap images, you can use SVG images as background images via CSS. Here is an example:

```
div {
    background-image: url('my-svg-image.svg');
    background-size : 100px 100px;
}
```

svg Element Inside HTML

Embedding an SVG image using the `svg` element can be done by embedding an `svg` element directly in an HTML page, like this:

```
<div>
<svg>
    <circle cx="40" cy="40" r="24" style="stroke:#006600; fill:#00cc00"/>
    </svg>
</div>
```

SVG g, line, rect, and text Elements

```
<svg xmlns="http://www.w3.org/2000/svg"
    xmlns:xlink="http://www.w3.org/1999/xlink">

    <g>
      <line x1="10" y1="10" x2="85" y2="10"
          style="stroke: #006600;"/>

      <rect x="10" y="20" height="50" width="75"
          style="stroke: #006600; fill: #006600"/>

      <text x="10" y="90" style="stroke: #660000; fill: #660000">
        Text grouped with shapes</text>
    </g>

</svg>
```

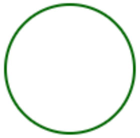
SVG strokes and fill

```
<circle cx="40" cy="40" r="24"
    style="stroke:#006600;
           stroke-width: 3;
           fill:#00cc00"/>
```

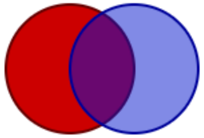
```
<circle cx="40" cy="40" r="24"
    style="stroke:#006600;
           stroke-width: 3;
           stroke-dasharray: 10 5;
           fill:#00cc00"/>
```

```
<circle cx="40" cy="40" r="24"
    style="stroke: none;
           fill:#00cc00"/>
```

```
<circle cx="40" cy="40" r="24"
    style="stroke: #00600;
           fill:none"/>
```



```
<circle cx="40" cy="40" r="24"
    style="stroke: #660000;
           fill: #cc0000" />
<circle cx="64" cy="40" r="24"
    style="stroke: #000066;
           fill: #0000cc"
           fill-opacity: 0.5/>
```



SVG path Element

```
<svg xmlns="http://www.w3.org/2000/svg"
    xmlns:xlink="http://www.w3.org/1999/xlink">

    <path d="M50,50
             A30,30 0 0,1 35,20
             L100,100
             M110,110
             L100,0"
          style="stroke:#660000; fill:none;"/>
</svg>
```

A: Arc
M: Move
L: Line

SVG arc

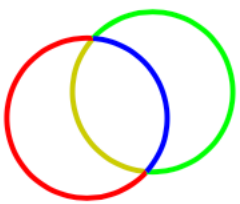
```
<svg xmlns="http://www.w3.org/2000/svg"
    xmlns:xlink="http://www.w3.org/1999/xlink">

    <path d="M50,50
             A30,50 0 0,1 100,100"
          style="stroke:#660000; fill:none;"/>
</svg>
```

The radius of the arc is set by the two first parameters set on the `A` command. The first parameter is `rx` (radius in x-direction) and the second is `ry` (radius in y-direction). Setting `rx` and `ry` to the same value will result in a circular arc. Setting `rx` and `ry` to different values will result in an elliptical arc. In the example above `rx` was set to `30` and `ry` to `50`.

The third parameter set on the `A` command is the `x-axis-rotation`. This sets the rotation of the arc's x-axis compared to the normal x-axis. In the above example the `x-axis-rotation` is set to `0`. Most of the time you will not need to change this parameter.

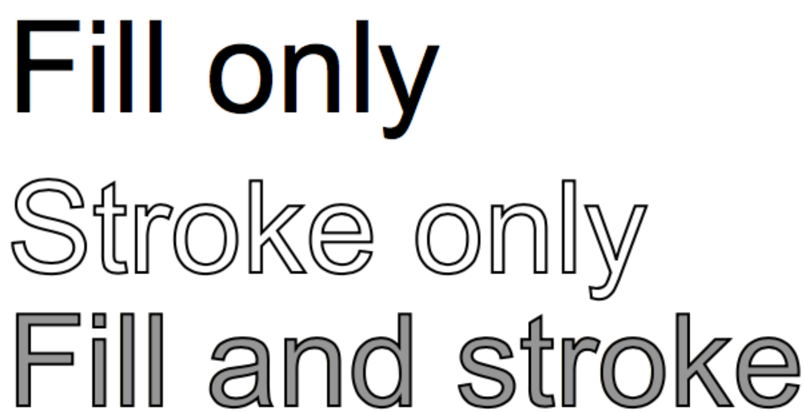
The fourth and fifth parameters are the `large-arc-flag` and `sweep-flag` parameters. The `large-arc-flag` determines whether to draw the smaller or bigger arc satisfying the start point, end point and `rx` and `ry`.

```
<path d="M40,20  A30,30 0 0,0 70,70"
    style="stroke: #cccc00; stroke-width:2; fill:none;"/>

<path d="M40,20  A30,30 0 1,0 70,70"
    style="stroke: #ff0000; stroke-width:2; fill:none;"/>

<path d="M40,20  A30,30 0 1,1 70,70"
    style="stroke: #00ff00; stroke-width:2; fill:none;"/>

<path d="M40,20  A30,30 0 0,1 70,70"
    style="stroke: #0000ff; stroke-width:2; fill:none;"/>
```



SVG text Element

```
<text x="20" y="40"
      style="fill: #000000; stroke: none; font-size: 48px;">
    Fill only
</text>
<text x="20" y="100"
      style="fill: none; stroke: #000000;  font-size: 48px;">
    Stroke only
</text>
<text x="20" y="150"
      style="fill: #999999; stroke: #000000;  font-size: 48px;">
    Fill and stroke
</text>
```



SVG text Element

```
<svg xmlns="http://www.w3.org/2000/svg"
     xmlns:xlink="http://www.w3.org/1999/xlink">

    <text x="20"  y="40"
         transform="rotate(30 20,40)"
         style="stroke:none; fill:#000000;"
         >Rotated SVG text</text>
</svg>
```

Rotated SVG text

```
<text x="10" y="20" style="writing-mode: tb;">
    Vertical
</text>
```

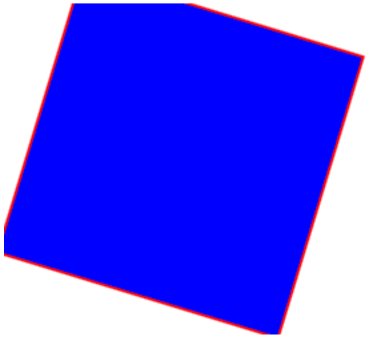
Vertical

SVG Transformation

```
<svg xmlns="http://www.w3.org/2000/svg"
    xmlns:xlink="http://www.w3.org/1999/xlink">

    <rect x="50" y="50" height="110" width="110"
          style="stroke:#ff0000; fill: #ccccff"
          transform="translate(30) rotate(45 50 50)"
            >
    </rect>
    <text x="70" y="100"
          transform="translate(30) rotate(45 50 50)"
    >Hello World</text>
</svg>
```

SVG Animation

```
<svg xmlns="http://www.w3.org/2000/svg"
    xmlns:xlink="http://www.w3.org/1999/xlink">

    <rect x="10" y="10" height="110" width="110"
         style="stroke:#ff0000; fill: #0000ff">

        <animateTransform
            attributeName="transform"
            begin="0s"
            dur="20s"
            type="rotate"
            from="0 60 60"
            to="360 60 60"
            repeatCount="indefinite"
        />
    </rect>

</svg>
```



Overview of Animation Options

1. <set>
2. <animate>
3. <animateColor>
4. <animateTransform>
5. <animateMotion>

set

```
<circle cx="30" cy="30" r="25" style="stroke: none; fill: #0000ff;">
    <set attributeName="r" attributeType="XML"
         to="100"
         begin="0s"  />

</circle>
```

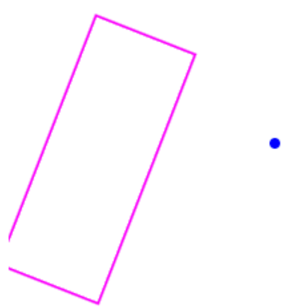
SVG Animation

animate

```
<circle cx="30" cy="30" r="25" style="stroke: none; fill: #0000ff;">
    <animate attributeName="cx" attributeType="XML"
             from="30"  to="470"
             begin="0s" dur="5s"
             fill="remove" repeatCount="indefinite"/>

</circle>
```

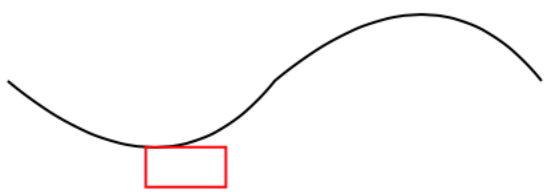
animateTransform

```
<rect x="20" y="20" width="100" height="40"
    style="stroke: #ff00ff; fill:none;" >
  <animateTransform attributeName="transform"
                    type="rotate"
                    from="0 100 100" to="360 100 100"
                    begin="0s" dur="10s"
                    repeatCount="indefinite"
          />
</rect>
```



animateMotion

```
<rect x="0" y="0" width="30" height="15"
      style="stroke: #ff0000; fill: none;">
    <animateMotion
            path="M10,50 q60,50 100,0 q60,-50 100,0"
            begin="0s" dur="10s" repeatCount="indefinite"
            />
</rect>
```

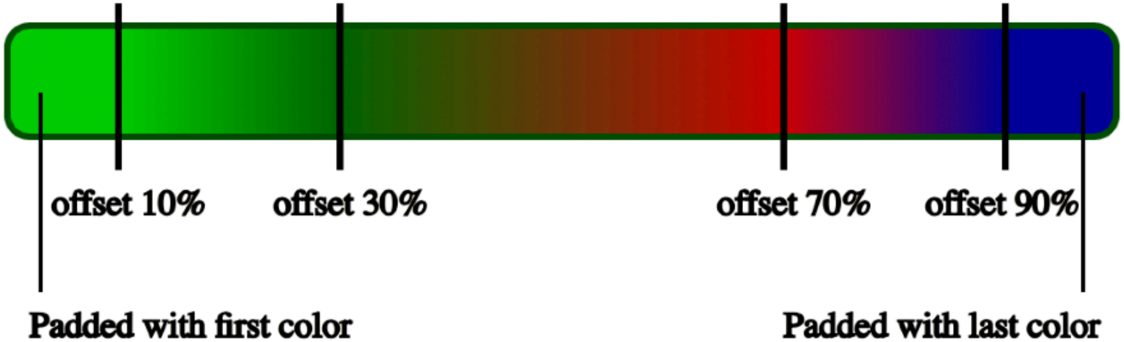


Linear Gradients

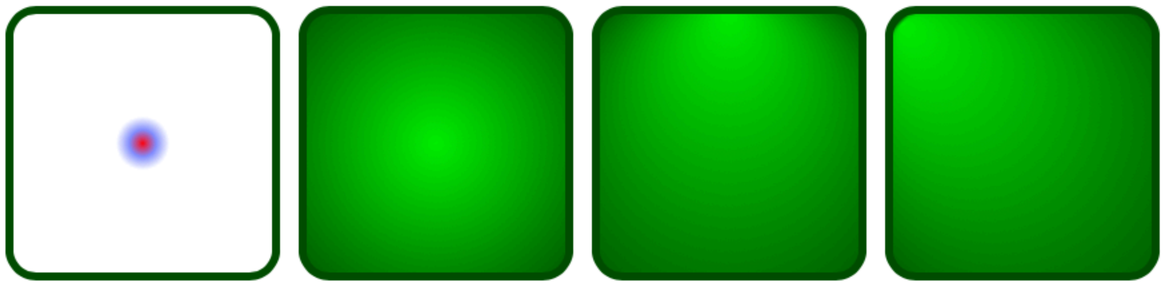
```
<svg xmlns="http://www.w3.org/2000/svg"
     xmlns:xlink="http://www.w3.org/1999/xlink">

  <defs>
    <linearGradient id="myLinearGradient1"
                    x1="0%" y1="0%"
                    x2="0%" y2="100%"
                    spreadMethod="pad">
      <stop offset="0%"   stop-color="#00cc00" stop-opacity="1"/>
      <stop offset="100%" stop-color="#006600" stop-opacity="1"/>
    </linearGradient>
  </defs>

  <rect x="10" y="10" width="75" height="100" rx="10" ry="10"
     style="fill:url(#myLinearGradient1);
            stroke: #005000;
            stroke-width: 3;" />

</svg>
```

SVG Gradients

```
<svg xmlns="http://www.w3.org/2000/svg"
     xmlns:xlink="http://www.w3.org/1999/xlink">


<defs>
  <linearGradient id="myLinearGradient1"
                  x1="0%" y1="0%"
                  x2="100%" y2="0%"
                  spreadMethod="pad">
    <stop offset="10%" stop-color="#00cc00" stop-opacity="1"/>
    <stop offset="30%" stop-color="#006600" stop-opacity="1"/>

    <stop offset="70%" stop-color="#cc0000" stop-opacity="1"/>
    <stop offset="90%" stop-color="#000099" stop-opacity="1"/>

  </linearGradient>

</defs>

<rect x="10" y="10" width="500" height="50" rx="10" ry="10"
   style="fill:url(#myLinearGradient1); stroke: #005000;
          stroke-width: 3;" />

</svg>
```



Radial Gradients



```
<svg xmlns="http://www.w3.org/2000/svg"
        xmlns:xlink="http://www.w3.org/1999/xlink">

    <defs>
        <radialGradient id="myRadialGradient4"
           fx="5%" fy="5%" r="65%"
           spreadMethod="pad">
          <stop offset="0%"   stop-color="#00ee00" stop-opacity="1"/>
          <stop offset="100%" stop-color="#006600" stop-opacity="1" />
        </radialGradient>
    </defs>

    <rect x="340" y="10" width="100" height="100" rx="10" ry="10"
           style="fill:url(#myRadialGradient4);
                  stroke: #005000; stroke-width: 3;" />
</svg>
```

SVG Image

```
<svg xmlns="http://www.w3.org/2000/svg"
    xmlns:xlink="http://www.w3.org/1999/xlink">

  <rect x="10" y="10" height="130" width="500" style="fill: #000000"/>

  <image x="20" y="20" width="300" height="80"
     xlink:href="http://jenkov.com/images/layout/top-bar-logo.png" />

  <line x1="25" y1="80" x2="350" y2="80"
            style="stroke: #ffffff; stroke-width: 3;"/>
</svg>
```

SVG Maps

https://www.tutorialspoint.com/svg/maps.htm