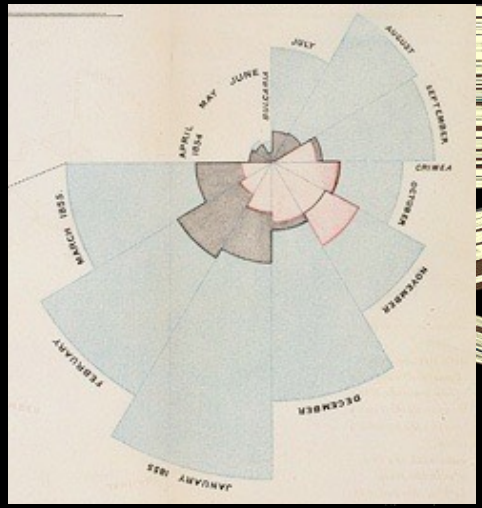
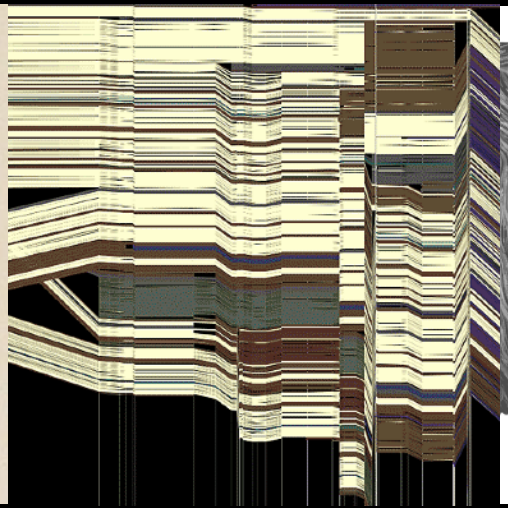
CSE 512 - Data Visualization

Visualization Tools, Part 1





Jeffrey Heer University of Washington

Tools & Trade-Offs

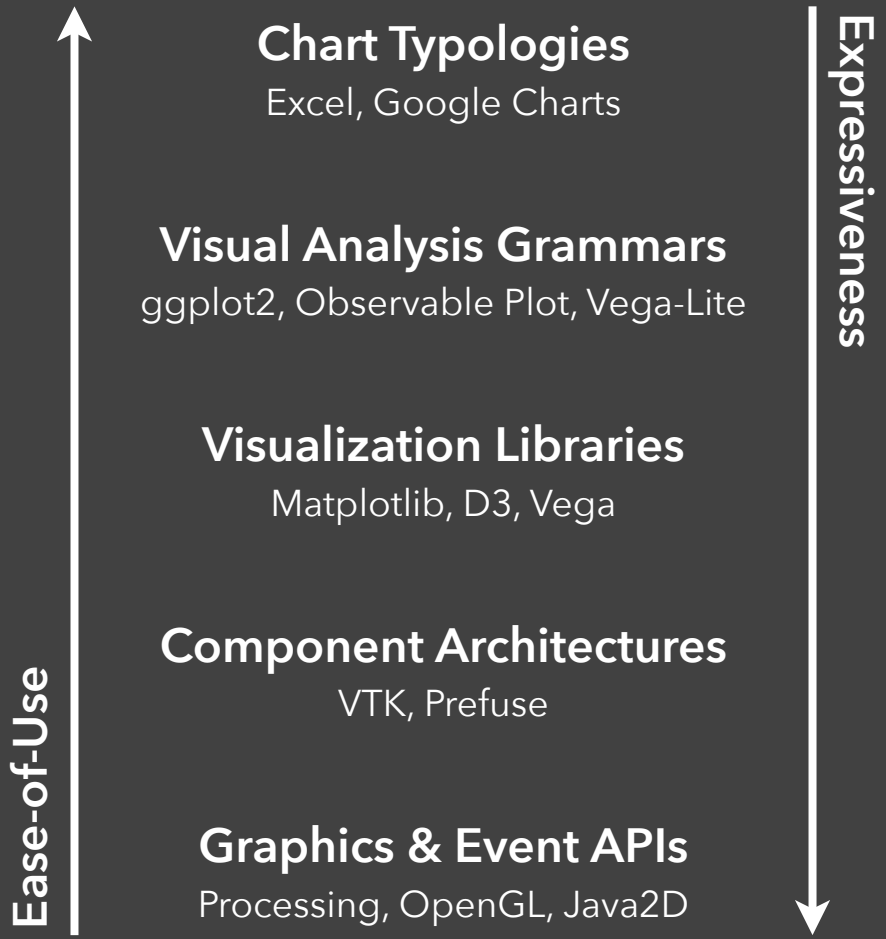


Chart Typologies
Excel, Google Charts
Visual Analysis Grammars
ggplot2, Observable Plot, Vega-Lite
Visualization Libraries
Matplotlib, D3, Vega
Component Architectures
VTK, Prefuse
Graphics & Event APIs
Processing, OpenGL, Java2D
Ease-of-Use
Expressiveness

Ease-of-Use

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Excel, Google Charts

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Graphics & Event APIs
Processing, OpenGL, Java2D

Expressiveness

Offer **fine-grained control** for composing interactive graphics.

But require **verbose** specifications and technical expertise.

Ease-of-Use

Expressiveness

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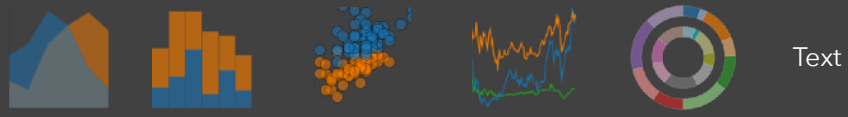
Grammar Building Blocks

Data	Input data to visualize
Transforms	Filter, aggregate, stats, layout
Scales	Map data values to visual values
Guides	Axes & legends to visualize scales
Marks	Data-representative graphics



Ease-of-Use

Expressiveness

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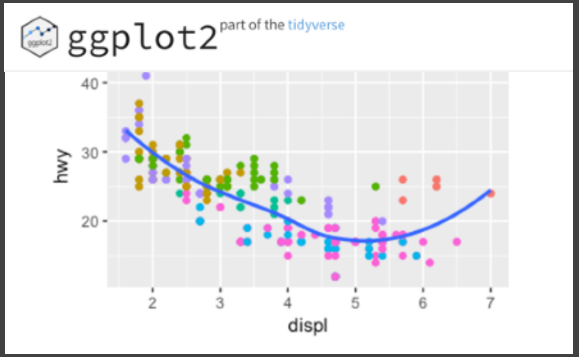

Facilitate **rapid exploration** with **concise** specifications by omitting low-level details.

Infer **sensible defaults** and customize by overriding defaults.

Ease-of-Use

Chart Typologies
Excel, Google Charts

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Component Architectures
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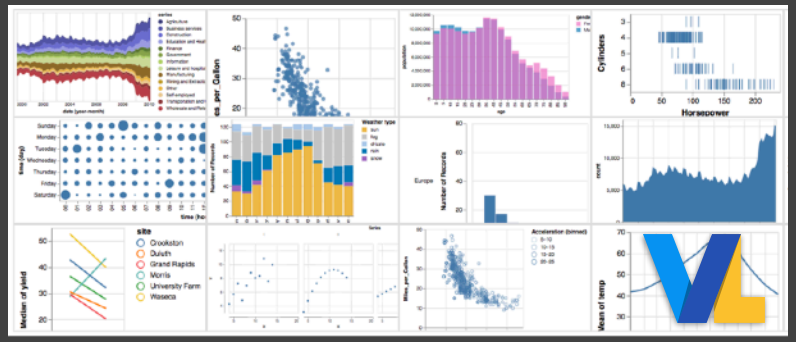
Expressiveness



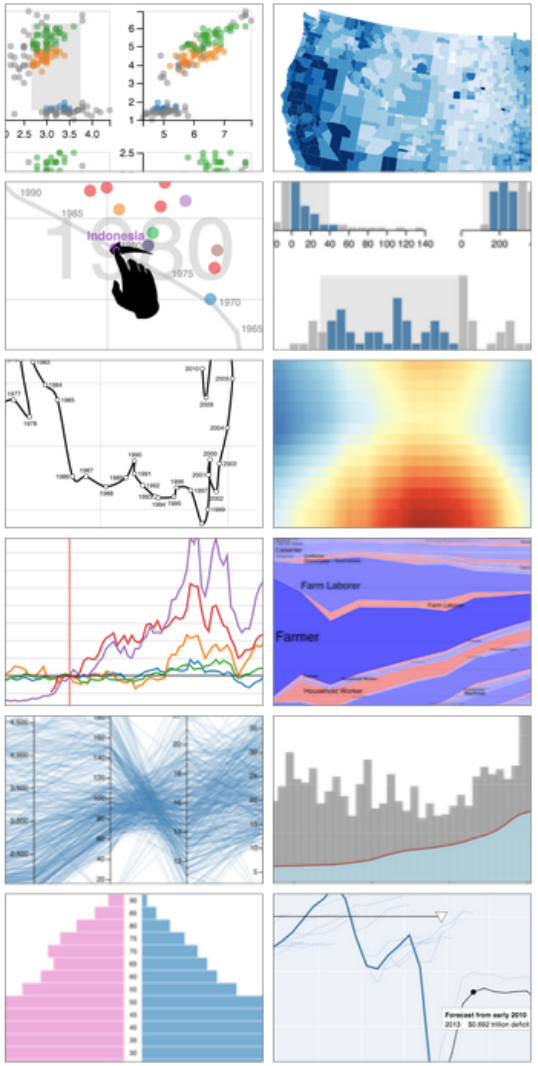
Facilitate **rapid exploration**
with **concise** specifications
by omitting low-level details.

Infer **sensible defaults** and
customize by overriding defaults.

A Dive Into Vega-Lite

Vega-Lite is a *Visual Analysis Grammar*

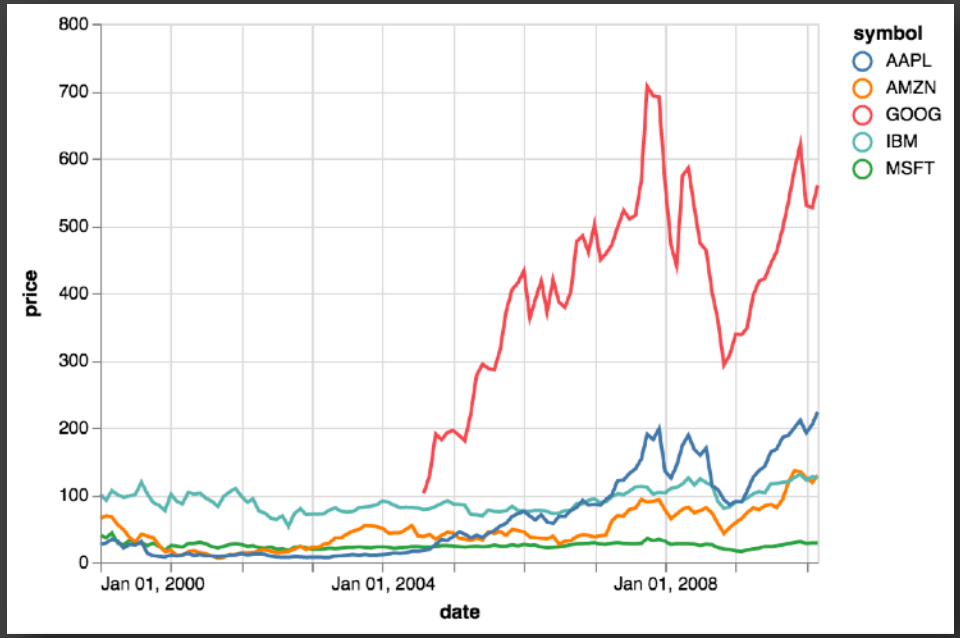
Similar in spirit to how SQL provides a language for expressing database queries, Vega-Lite is a high-level language for describing visualizations.



Vega-Lite is a *Visual Analysis Grammar*

Vega Altair Python API

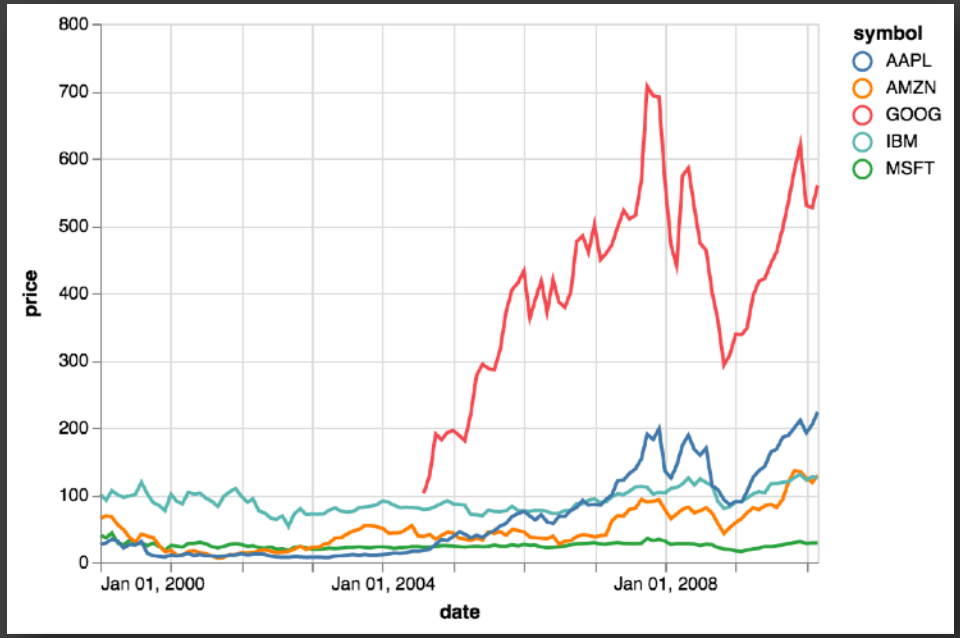
```
alt.Chart('stocks.csv')
  .mark_line()
  .encode(
    x='date',
    y='price',
    color='symbol'
  )
```



Vega-Lite is a *Visual Analysis Grammar*

Vega-Lite JavaScript API

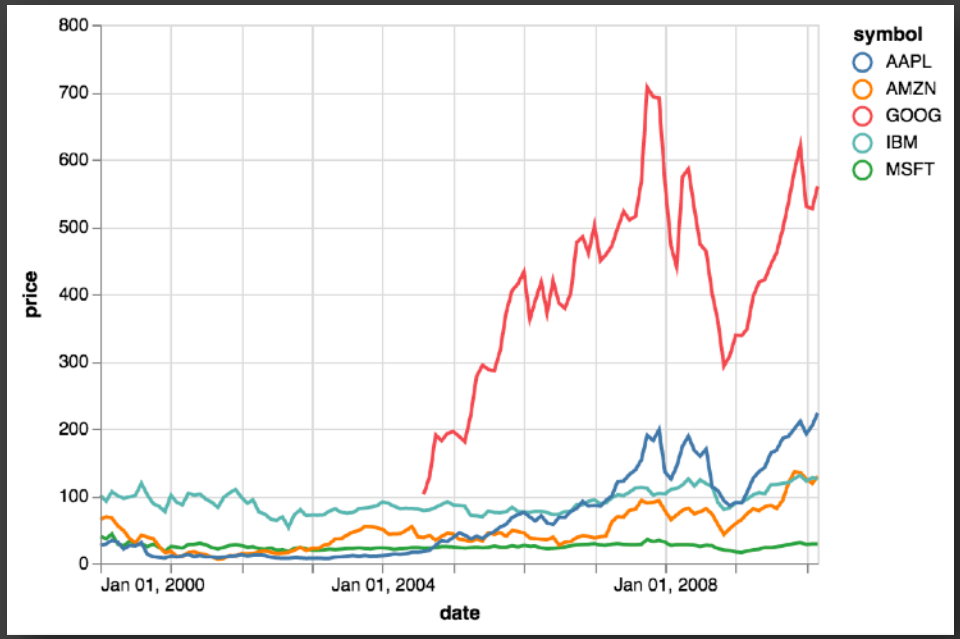
```
vl.data('stocks.csv')
  .markLine()
  .encode(
    vl.x().fieldT('date'),
    vl.y().fieldQ('price'),
    vl.color().fieldN('symbol')
  )
```



Vega-Lite is a *Visual Analysis Grammar*

Vega-Lite JSON Specification

```
{
  data: {url: "stocks.csv"},
  mark: "line",
  encoding: {
    x: {
      type: "temporal",
      field: "date"
    },
    y: {
      type: "quantitative",
      field: "price"
    },
    color: {
      type: "nominal",
      field: "symbol"
    }
  }
}
```



Specifying Single Views

Abstract Data  Visual Representation

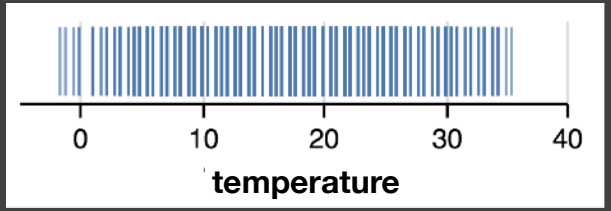
Specifying Single Views

Abstract Data → Visual Representation

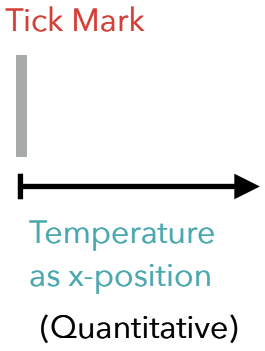
Weather Data for Seattle

date	temperature	precipitation	weather
1/1	10.6	10.9	"rain"
1/2	11.7	0.8	"drizzle"
1/3	12.2	10.2	"rain"
…	…	…	…

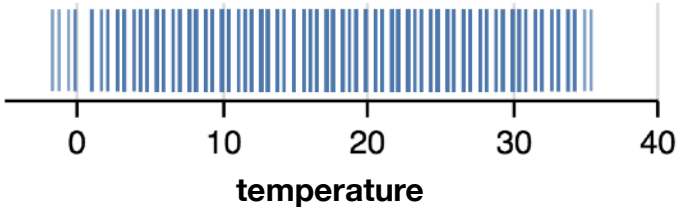
Strip Plot of Temperature



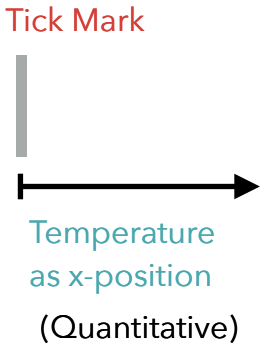
Strip Plot = (Tick with x=field)




```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      field: "temperature",
      type: "quantitative"
    }
  }
}
```



Strip Plot = (Tick with x=field)




```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
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    x: {
      field: "temperature",
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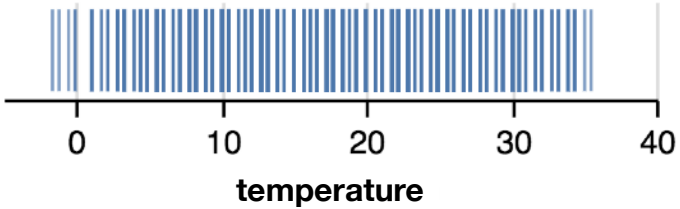
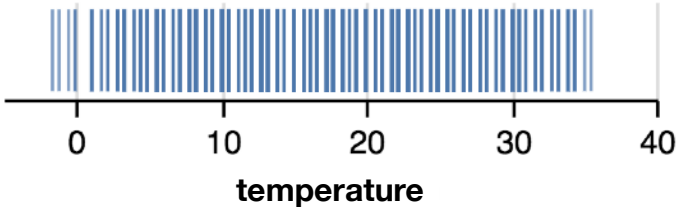
    }
  }
}
```



Vega-Lite is portable JSON specification

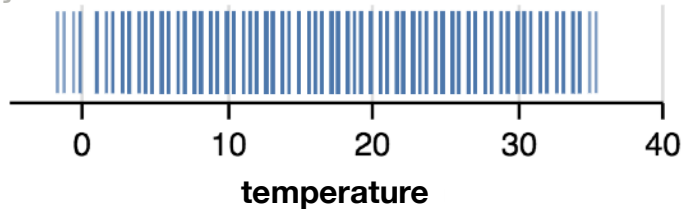
Strip Plot = (Tick with x=field)

```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      field: "temperature",
      type: "quantitative"
    }
  }
}
```



Strip Plot: Default Scales and Axes

```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      field: "temperature",
      type: "quantitative",
      scale: {type: "linear", domain: [-10, 40], ...}
      axis: {title: "temperature", grid: true, ...}
    }
  }
}
```



Strip Plot

```
{
  data: {url: "weather-seattle.json"},
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  encoding: {
    x: {
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  }
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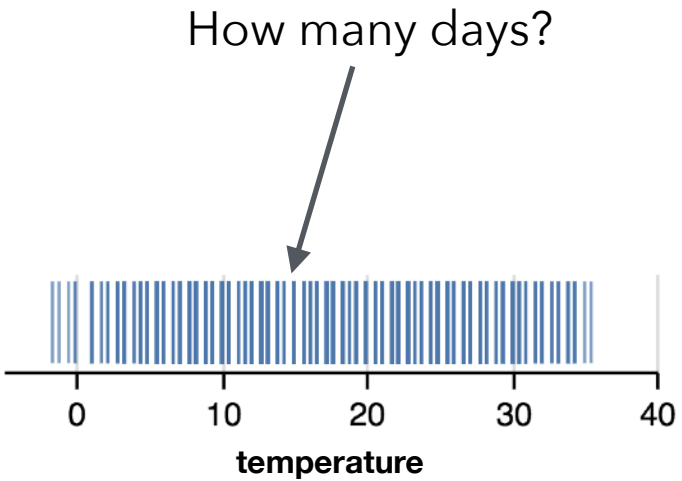
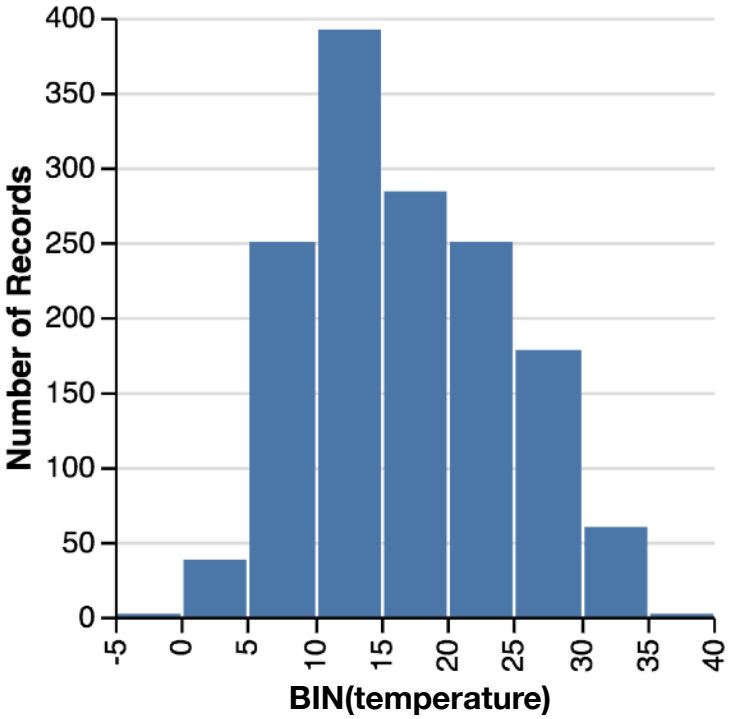


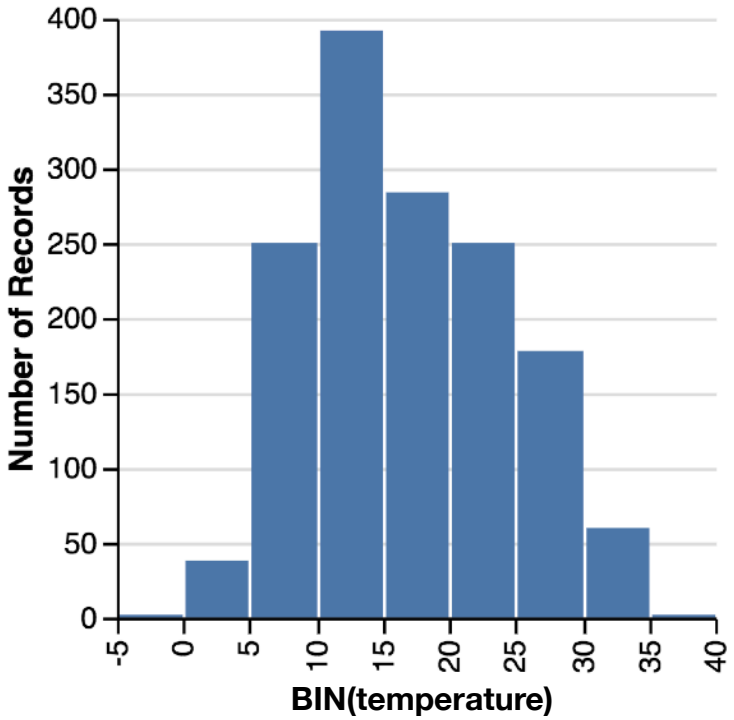
Histogram

Goal



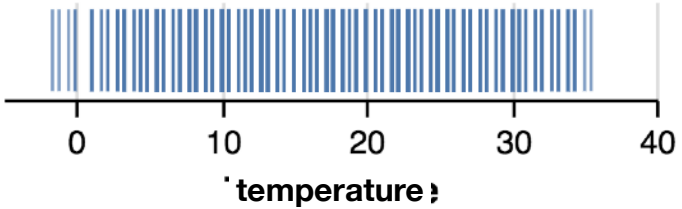
Histogram = (Bar with x=binned field, y=count)

Goal



Histogram = (Bar with x=binned field, y=count)

```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      field: "temperature",
      type: "quantitative"
    }
  }
}
```



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  data: {url: "weather-seattle.json"},
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    x: {
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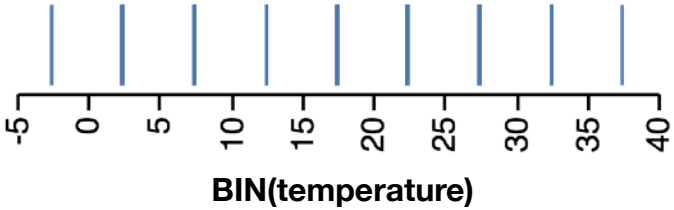

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  data: {url: "weather-seattle.json"},
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      aggregate: "count",
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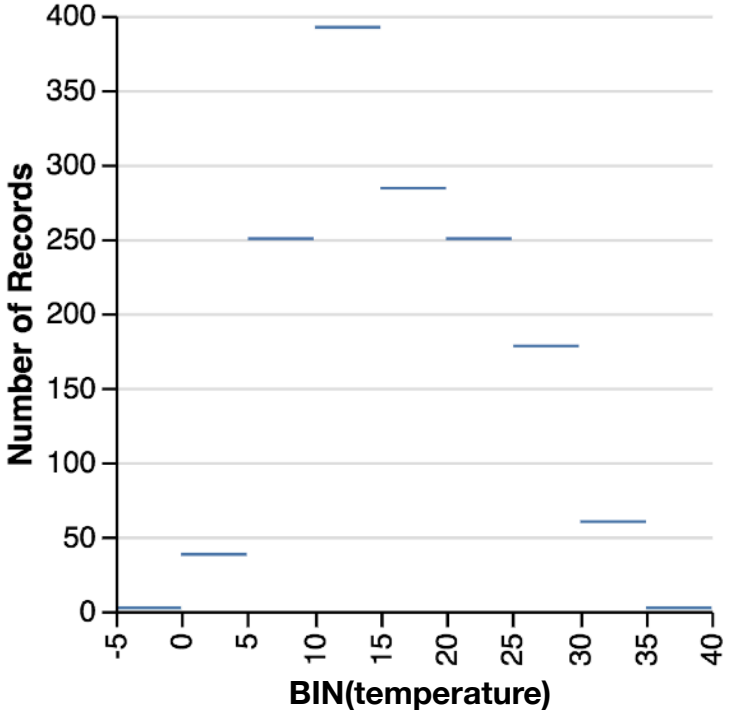
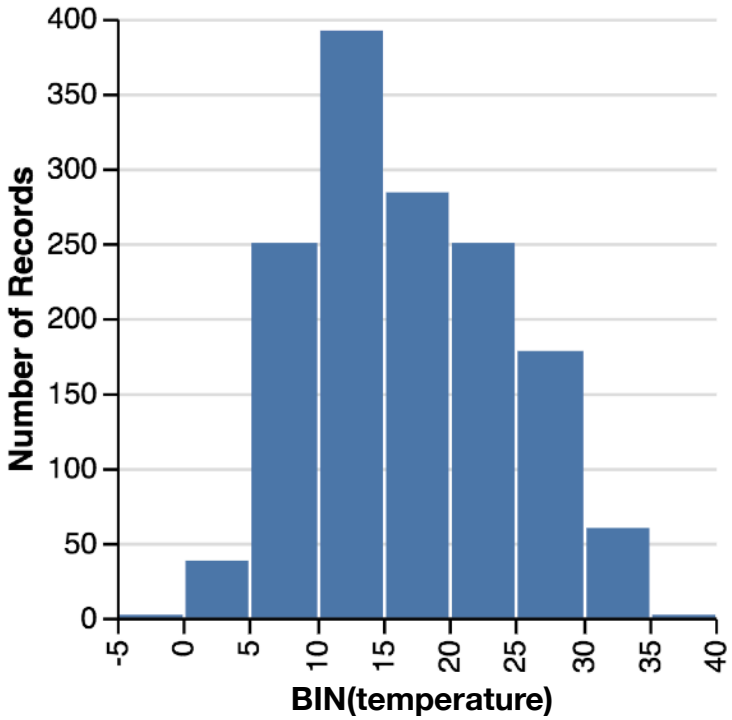
    }
  }
}
```



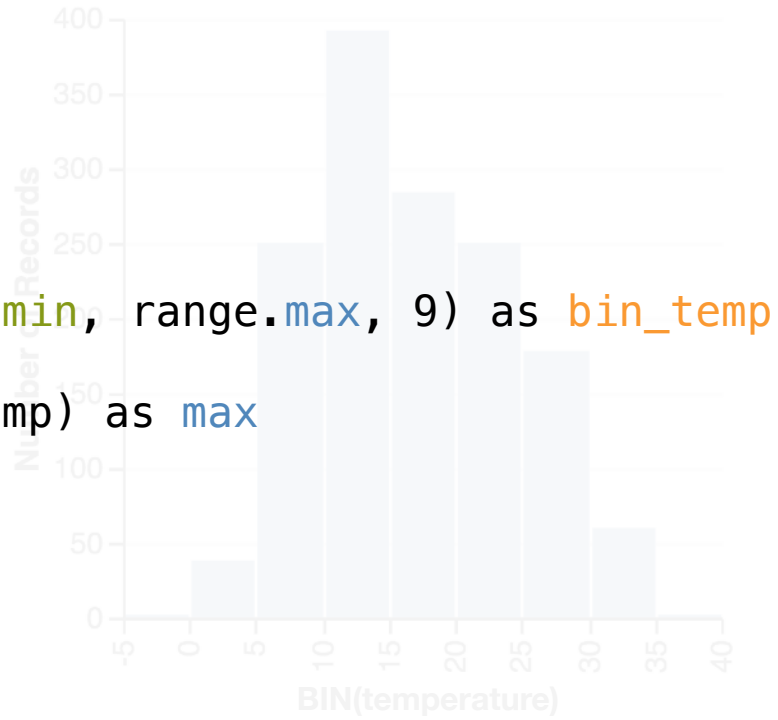
Histogram = (Bar with x=binned field, y=count)

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    }
  }
}
```



Histogram = (Bar with x=binned field, y=count)

```
SELECT bin_temp, count(*)
FROM (
  SELECT floor(weather.temp, range.min, range.max, 9) as bin_temp
  FROM weather, (
    SELECT min(temp) as min, max(temp) as max
  ) range
)
```



Histogram

```
{
  data: {url: "weather-seattle.json"},
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    x: {
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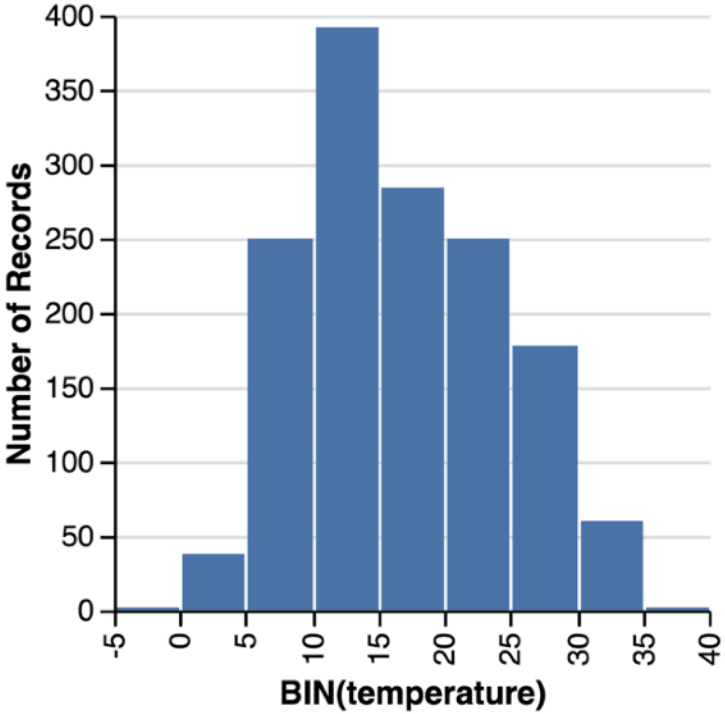
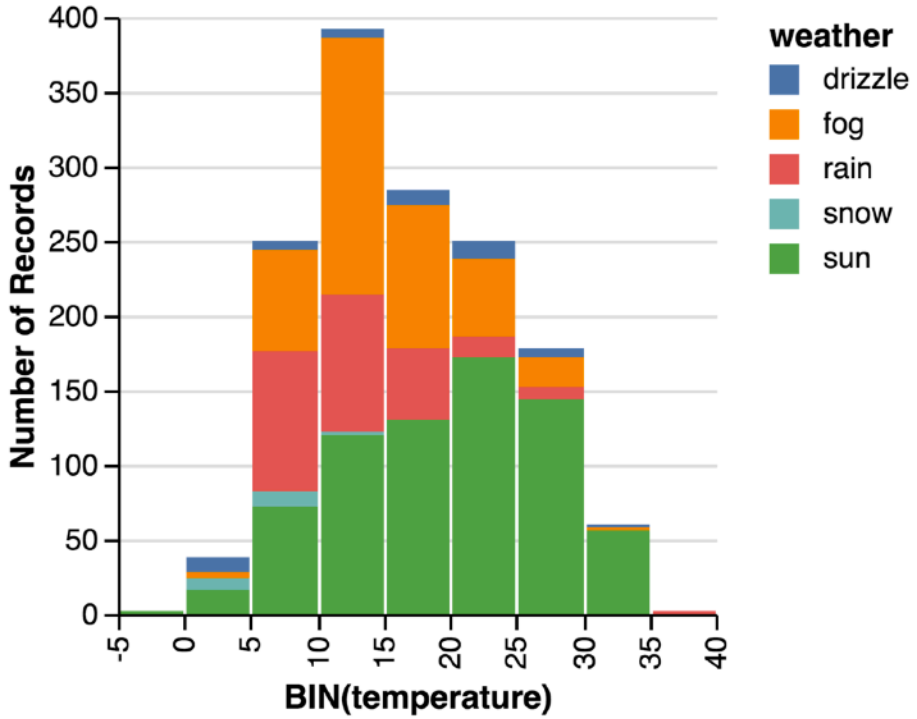


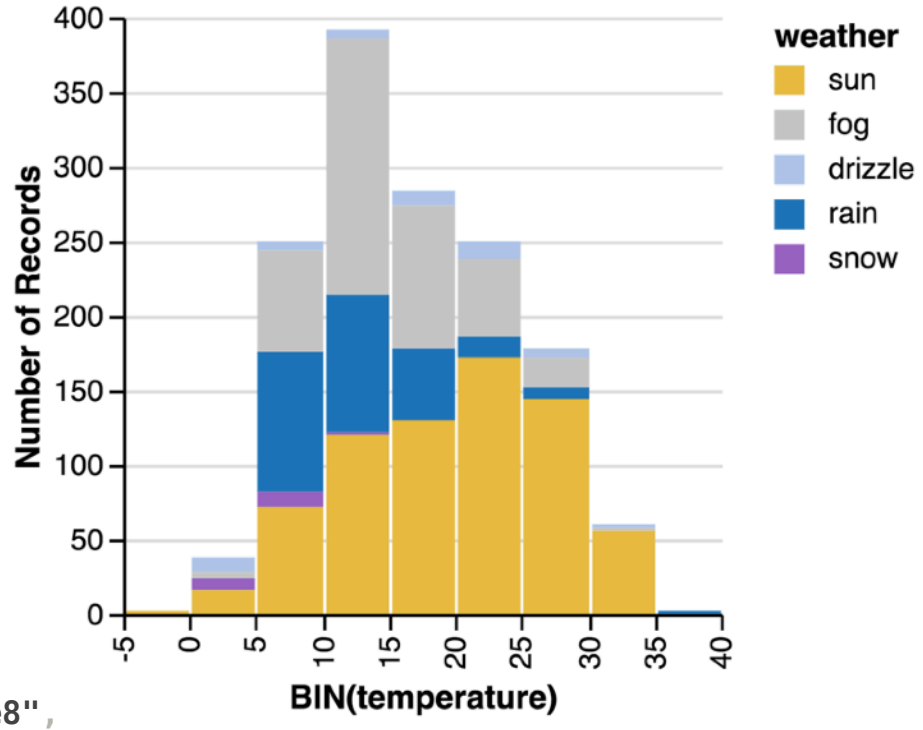
Histogram + Color

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    },
    color: {
      field: "weather",
      type: "nominal"
    }
  }
}
```



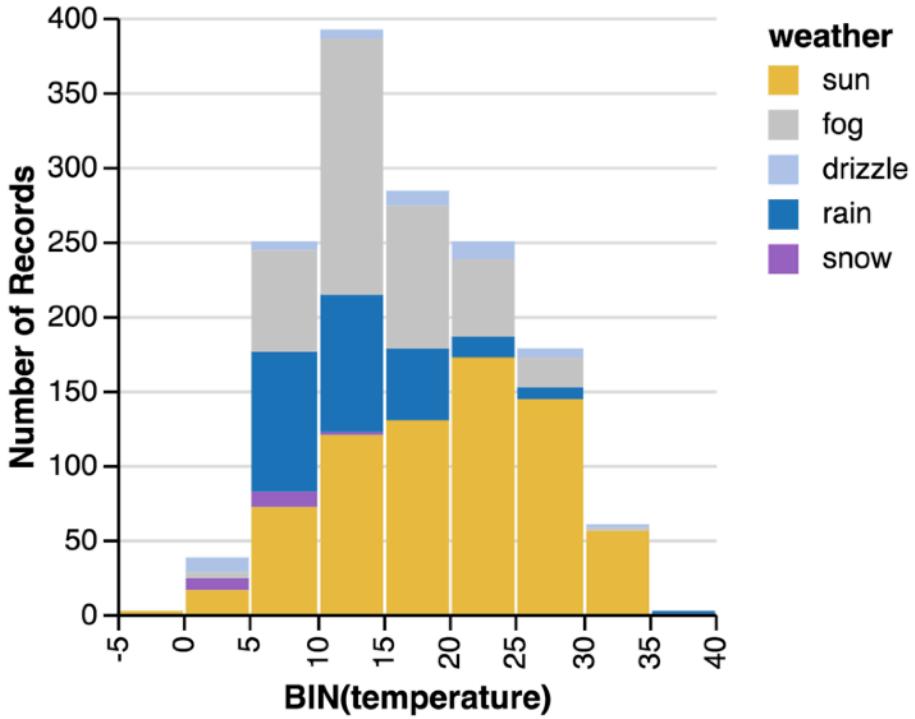
Histogram + Color

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    },
    color: {
      field: "weather",
      type: "nominal",
      "scale": {
        "domain": ["sun","fog","drizzle",
                   "rain","snow"],
        "range": ["#e7ba52","#c7c7c7","#aec7e8",
                  "#1f77b4","#9467bd"]
      }
    }
```



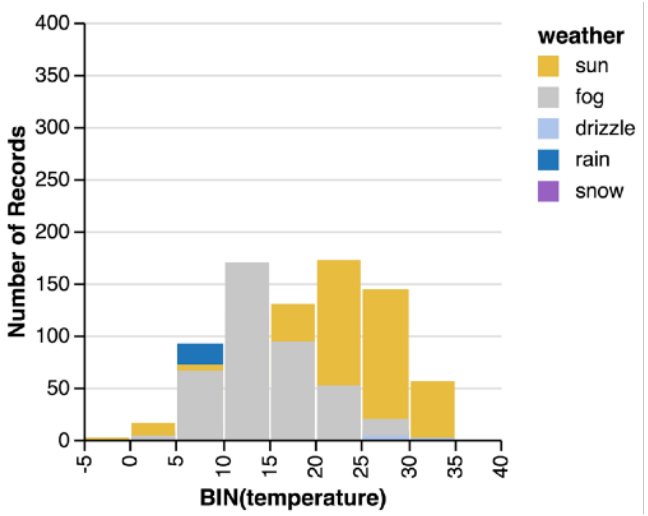
Histogram + Color = Stacked Histogram

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    },
    color: {
      field: "weather",
      type: "nominal",
      ...
      }
    }
  }
}
```

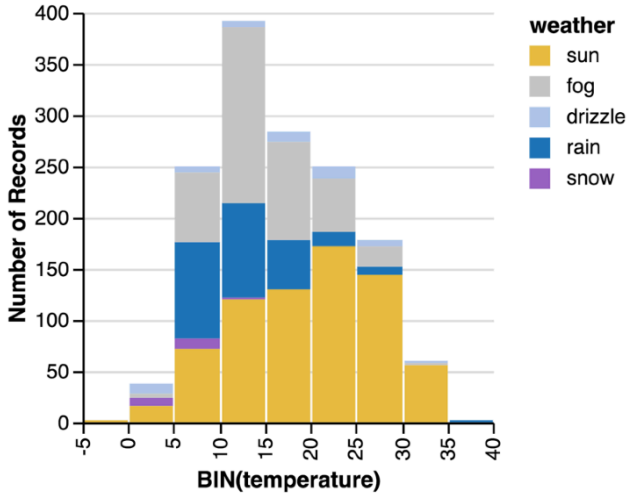


Stacked Histogram: Sensible Defaults

no stack



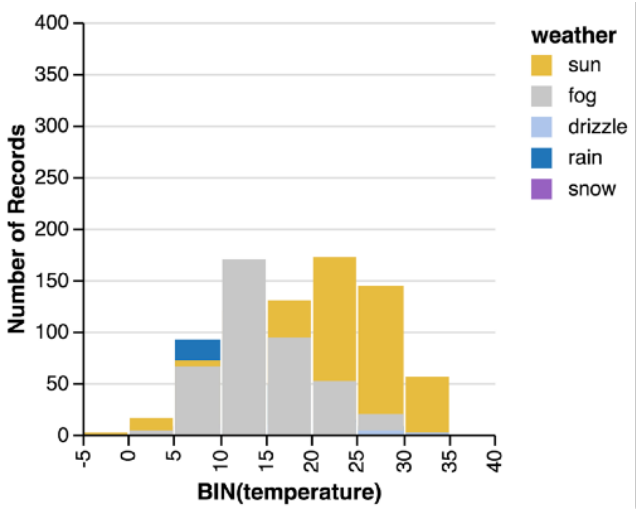
stack (default)



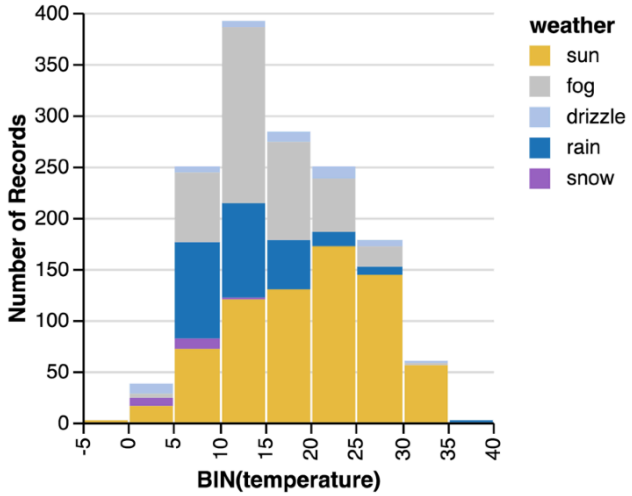
Stacked Histogram: Sensible Defaults

Channel (color) + Mark (bar) automatically enables stacking: a layout transform.

no stack



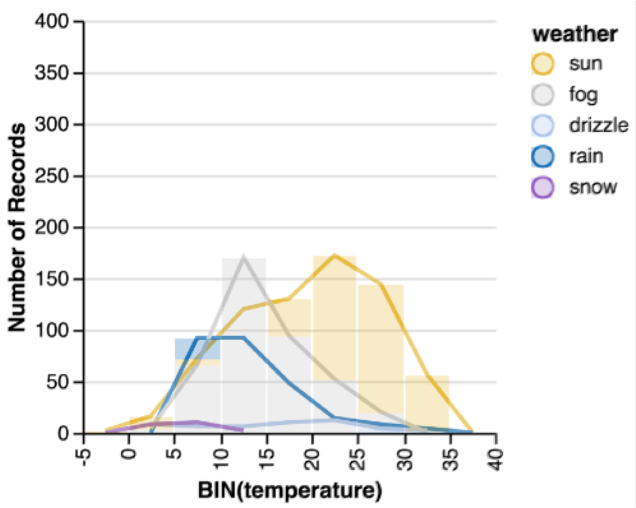
stack (default)



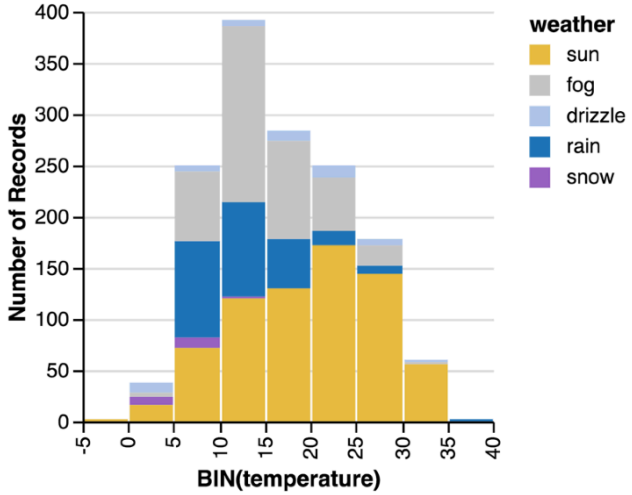
Stacked Histogram: Sensible Defaults

Channel (color) + Mark (bar) automatically enables stacking: a layout transform.

no stack → overlap

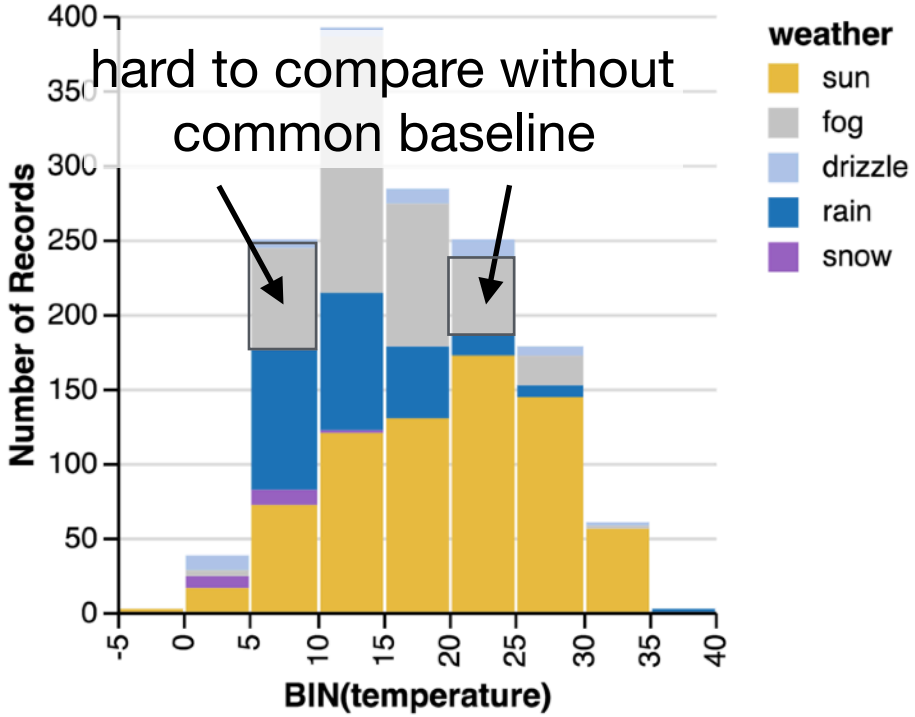


stack (default)



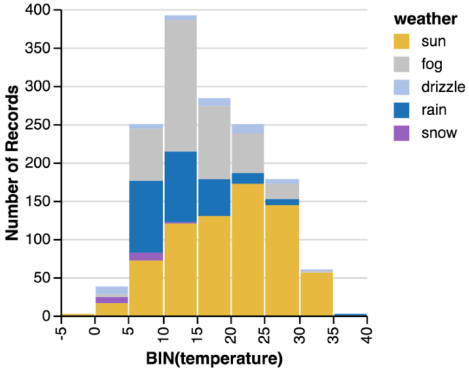
Histogram + Color = Stacked Histogram

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    },
    color: {
      field: "weather",
      type: "nominal"
    }
  }
}
```



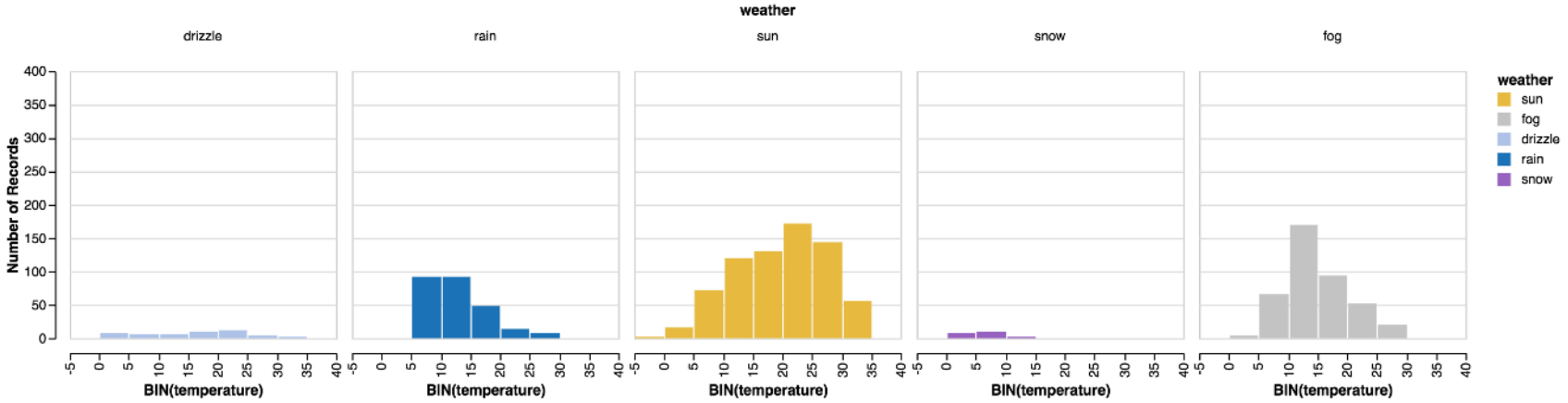
Histogram + Color = Stacked Histogram

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {bin: true, field: "temperature", type: "quantitative"},
    y: {aggregate: "count",              type: "quantitative"},
    color: {       field: "weather",     type: "nominal"}
  }
}
```



Histogram + Column = Trellis Histogram

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {bin: true, field: "temperature", type: "quantitative"},
    y: {aggregate: "count",              type: "quantitative"},
    column: {      field: "weather",     type: "nominal"}
  }
}
```



Ease-of-Use

Chart Typologies
Excel, Google Charts

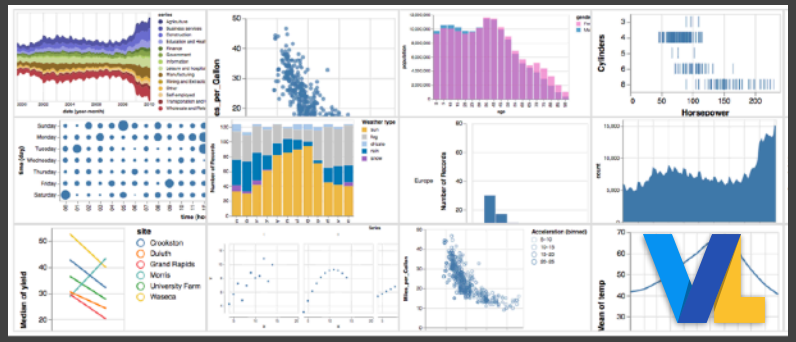
Visual Analysis Grammars
ggplot2, Observable Plot, Vega-Lite

Visualization Libraries
Matplotlib, D3, Vega

Component Architectures
VTK, Prefuse

Graphics & Event APIs
Processing, OpenGL, Java2D

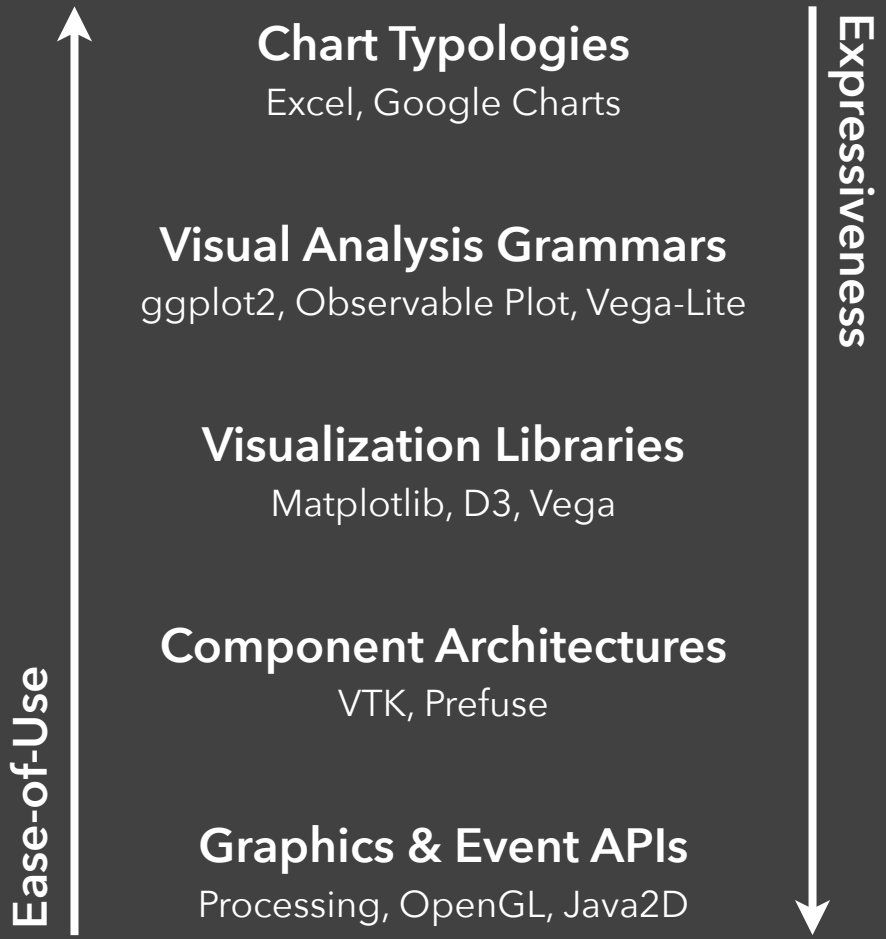
Expressiveness



Facilitate **rapid exploration** with **concise** specifications by omitting low-level details.

Infer **sensible defaults** and customize by overriding defaults.

With **native** support for ***interaction!***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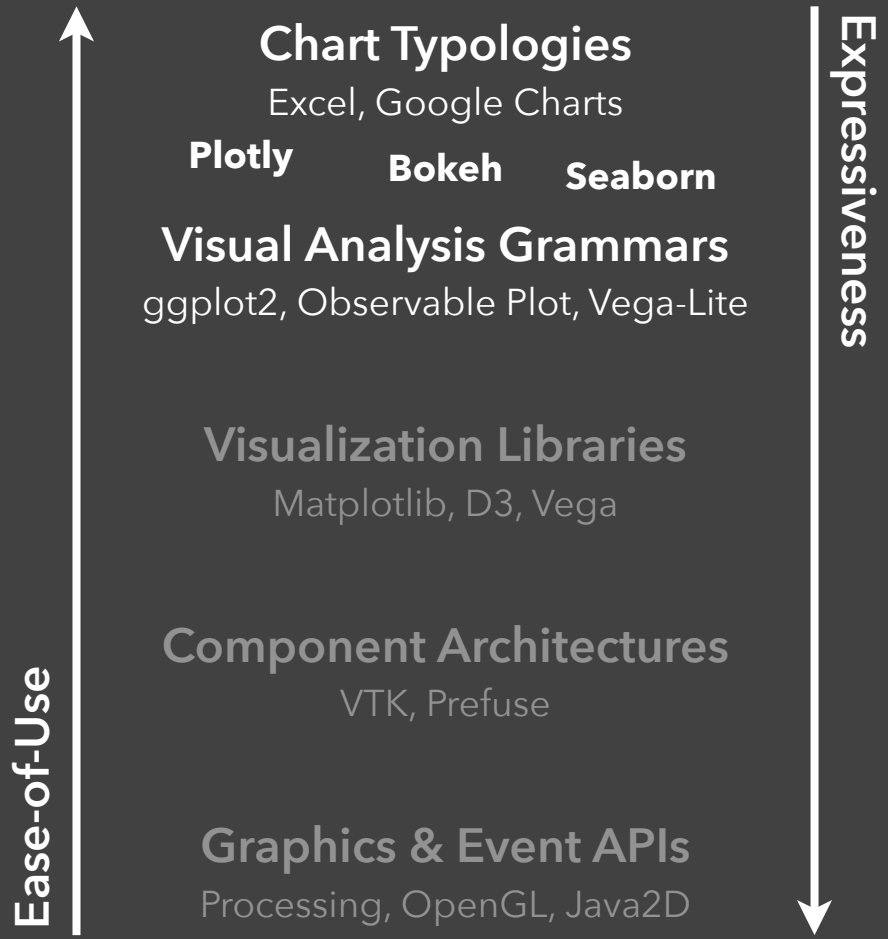
Chart Typologies
Excel, Google Charts
Plotly
Bokeh
Seaborn
Visual Analysis Grammars
ggplot2, Observable Plot, Vega-Lite
Visualization Libraries
Matplotlib, D3, Vega
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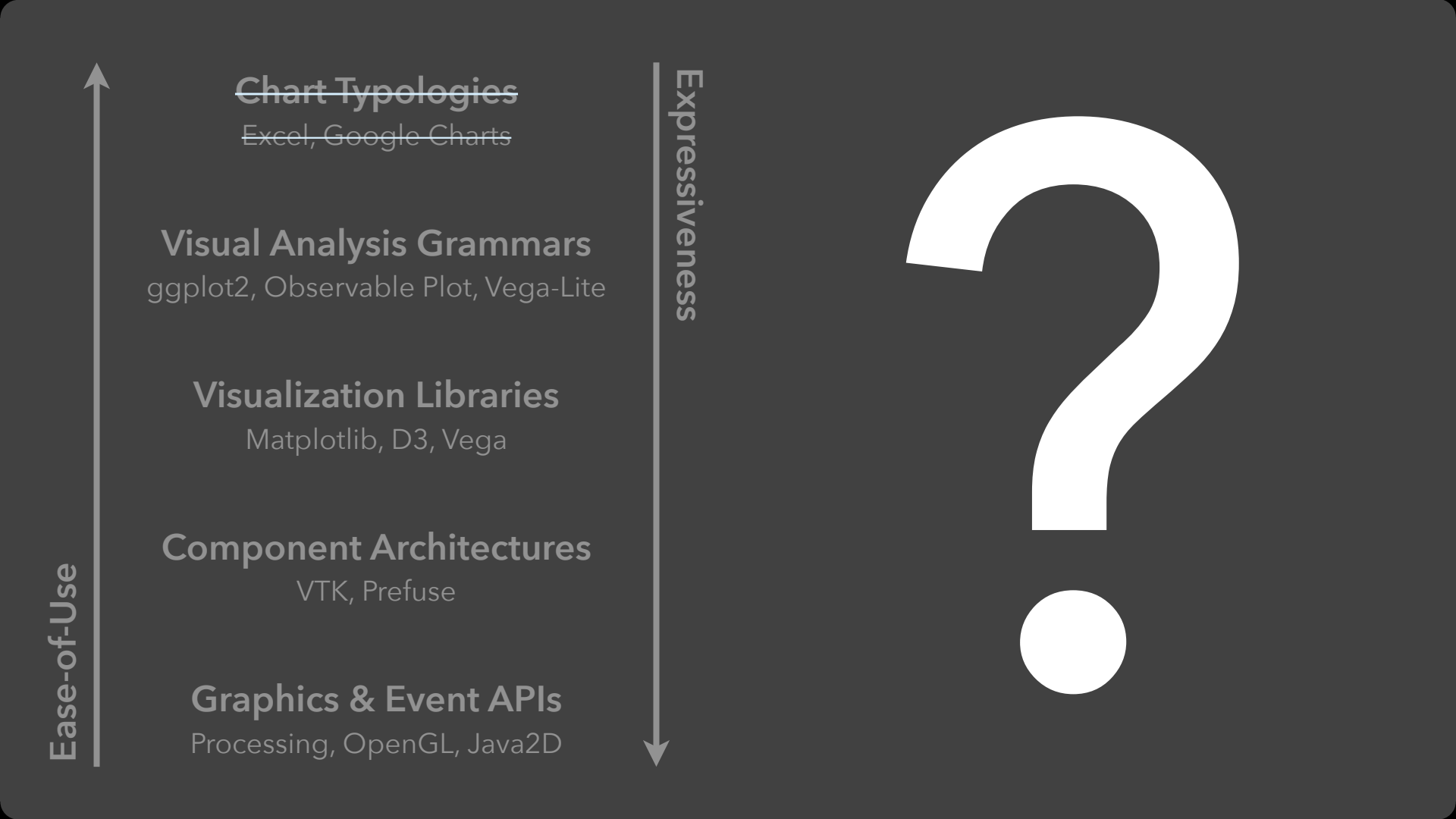
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Ease-of-Use
Expressiveness
?

Ease-of-Use

Expressiveness

Visualization Guidance

Tableau, Voyager, Lux, LLMs, ...

Visual Analysis Grammars

ggplot2, Observable Plot, Vega-Lite

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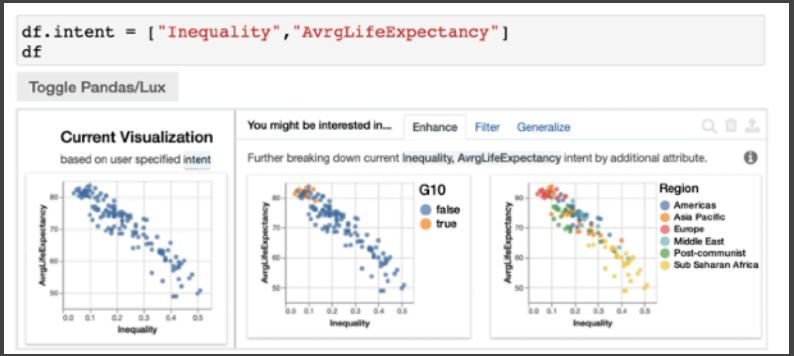
Voyager, Wongsuphasawat et al. 2017



Lux, Lee et al. 2021

Example: U.S. Census

Example: U.S. Census Data

People Count: # of people in group
Year: 1850 – 2000 (every decade)
Age: 0 – 90+
Sex: Male, Female
Marital Status: Single, Married, Divorced, …

Example: U.S. Census Data

People Count
Year
Age
Sex
Marital Status

2,348 data points

	A	B	C	D	E
1	year	age	marst	sex	people
2	1850	0	0	1	1483789
3	1850	0	0	2	1450376
4	1850	5	0	1	1411067
5	1850	5	0	2	1359668
6	1850	10	0	1	1260099
7	1850	10	0	2	1216114
8	1850	15	0	1	1077133
9	1850	15	0	2	1110619
10	1850	20	0	1	1017281
11	1850	20	0	2	1003841
12	1850	25	0	1	862547
13	1850	25	0	2	799482
14	1850	30	0	1	730638
15	1850	30	0	2	639636
16	1850	35	0	1	588487
17	1850	35	0	2	505012
18	1850	40	0	1	475911
19	1850	40	0	2	428185
20	1850	45	0	1	384211
21	1850	45	0	2	341254
22	1850	50	0	1	321343
23	1850	50	0	2	286580
24	1850	55	0	1	194080
25	1850	55	0	2	187208
26	1850	60	0	1	174976
27	1850	60	0	2	162236
28	1850	65	0	1	106827
29	1850	65	0	2	105534
30	1850	70	0	1	73677
31	1850	70	0	2	71762
32	1850	75	0	1	40834
33	1850	75	0	2	40229
34	1850	80	0	1	23449
35	1850	80	0	2	22949
36	1850	85	0	1	8186
37	1850	85	0	2	10511
38	1850	90	0	1	5259
39	1850	90	0	2	6569
40	1860	0	0	1	2120846
41	1860	0	0	2	2092162

Exercise & Assignment

Hours of Sunshine

The climate of a place can have a tremendous impact on people's lived experience. You will examine average monthly climate measurements for six major U.S. cities, roughly covering the edges of the continental United States.

Our in-class ***exercise*** is to get hands-on experience creating and publishing visualizations. You will create and revise a line chart of average monthly sunshine hours for six U.S. cities.

The ***assignment*** is to then design your own graphic.

Hours of Sunshine Exercise

Complete the exercises in the activity document. Submit your results using the provided form link.

You may collaborate in groups of 1-3 people.

The course staff is here to help! Don’t hesitate to ask us questions spanning design, tech, or more.

A1: Expository Visualization

Using the given climate data set…

Pick a **guiding question**, use it to title your vis.

Design a **static visualization** for that question.

You are free to **use visualization tool**.

Deliverables via Gradescope

Image of your visualization (PNG or JPG format)

Short description + design rationale (≤ 4 paragraphs)

Due by **EOD, Tue April 8**.