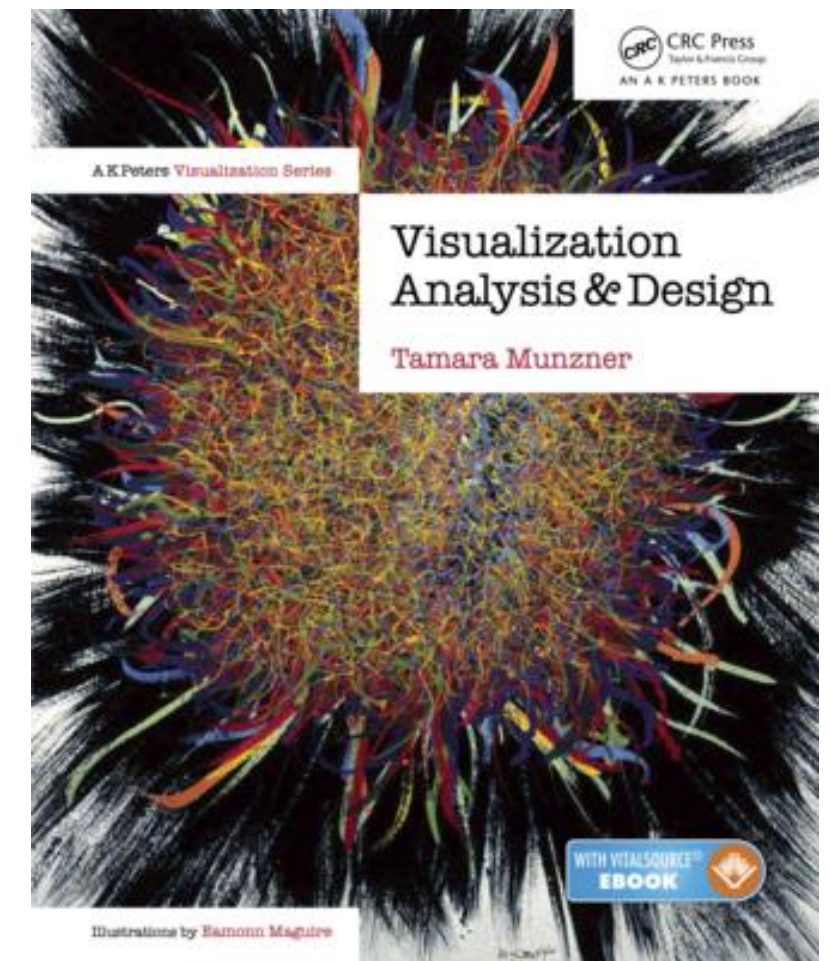


# Information Visualization

## Spatial Layout (a) Arrange Tables

- Slides refer to <https://www.cs.ubc.ca/~tmm/>



# Spatial Layout

- **Arrange Tables (ch. 7)**
- Arrange Spatial Data (ch. 8)
- Arrange Networks and Trees (ch. 9)

# How?

## Encode

### ➔ Arrange

➔ Express



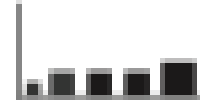
➔ Separate



➔ Order



➔ Align



➔ Use



### ➔ Map

from **categorical** and **ordered** attributes

➔ Color

➔ Hue



➔ Saturation



➔ Luminance



➔ Size, Angle, Curvature, ...



➔ Shape



➔ Motion

Direction, Rate, Frequency, ...

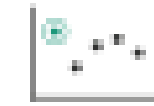


## Manipulate

### ➔ Change



### ➔ Select



### ➔ Navigate



## Facet

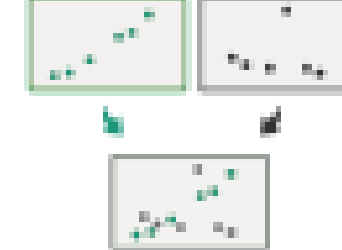
### ➔ Juxtapose



### ➔ Partition

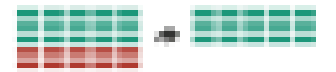


### ➔ Superimpose



## Reduce

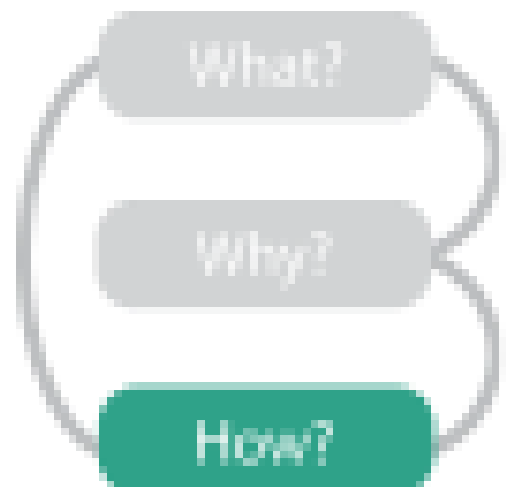
### ➔ Filter



### ➔ Aggregate



### ➔ Embed



# Encode tables: Arrange space

## Encode

---

### ➔ Arrange

➔ Express



➔ Separate



➔ Order



➔ Align



➔ Use



# Arrange tables

## ➔ Express Values



## ➔ Separate, Order, Align Regions

➔ Separate



➔ Order



➔ Align



-> 0 key

➔ 1 Key  
*List*



➔ 2 Keys  
*Matrix*



➔ 3 Keys  
*Volume*



➔ Many Keys  
*Recursive Subdivision*



## ➔ Axis Orientation

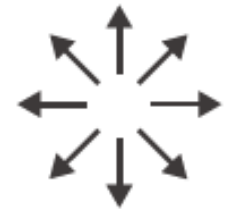
➔ Rectilinear



➔ Parallel

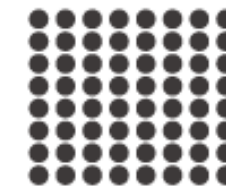


➔ Radial



## ➔ Layout Density

➔ Dense



➔ Space-Filling



# Keys and Values

- **key**

- independent attribute
- used as unique index to look up items
- simple tables: 1 key
- multidimensional tables: multiple keys

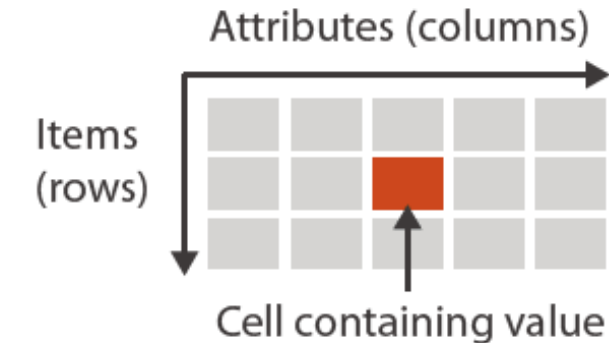
- **value**

- dependent attribute, value of cell

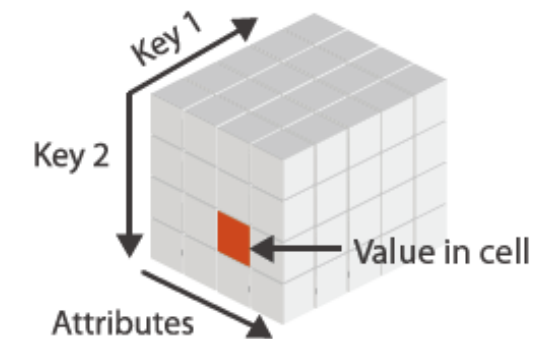
- **classify arrangements by key count**

- 0, 1, 2, many...

→ Tables



→ *Multidimensional Table*



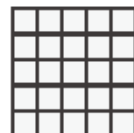
➔ Express Values



➔ 1 Key  
*List*



➔ 2 Keys  
*Matrix*



➔ 3 Keys  
*Volume*



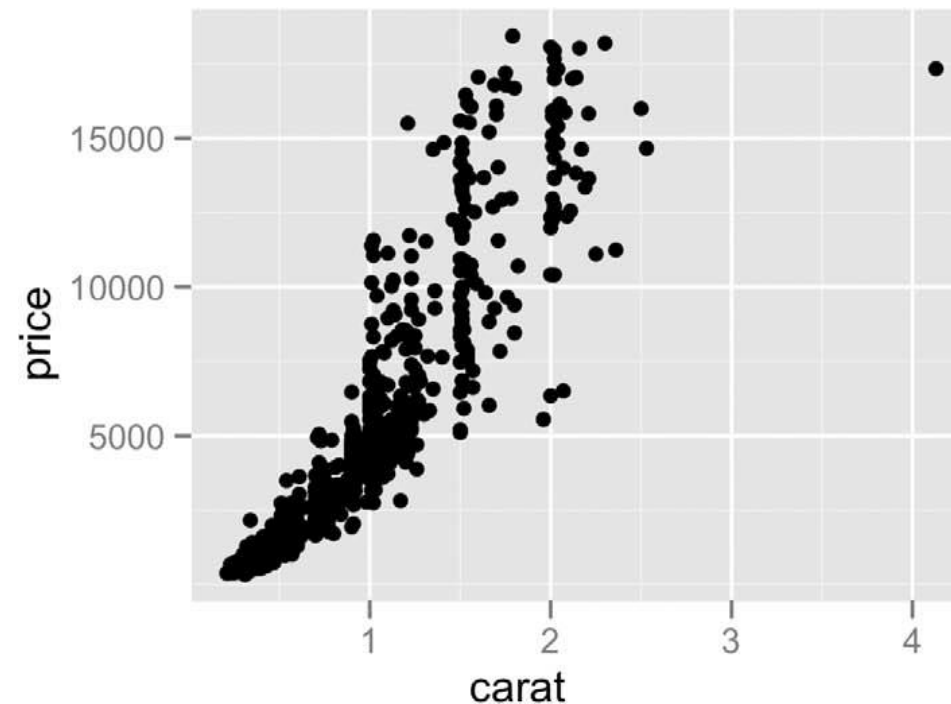
➔ Many Keys  
*Recursive Subdivision*



# Idiom: **scatterplot**

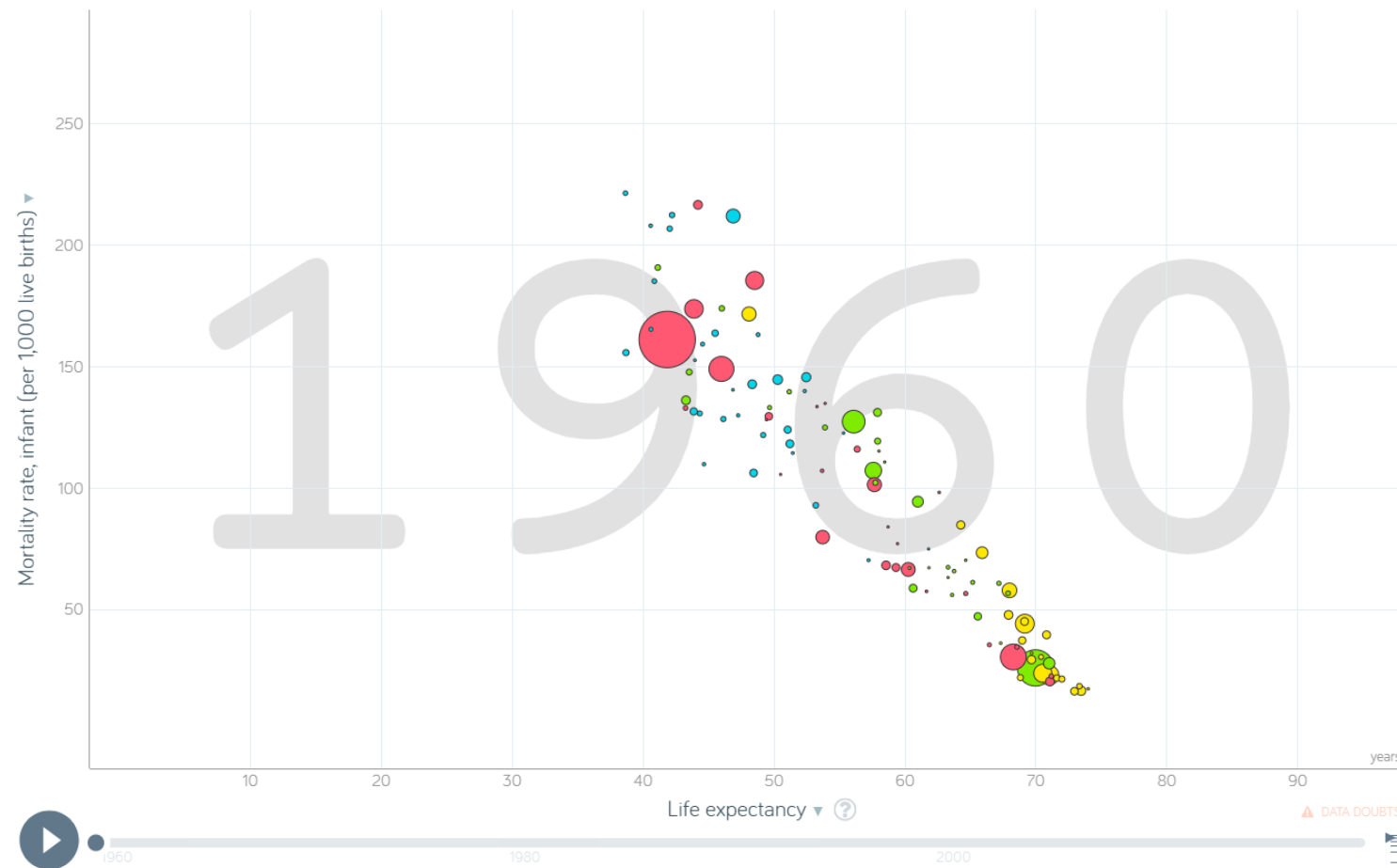
- *express* values
  - quantitative attributes
- **no keys**, only values
  - data
    - 2 quant attribs
  - mark: points
  - channels
    - horiz + vert position
  - tasks
    - find trends, outliers, distribution, correlation, clusters
  - scalability
    - hundreds of items

➞ Express Values



# Scatterplots: Encoding more channels

- *additional channels viable since using point marks*
  - *color*
  - *size (bubbleplots)*
    - *radius is misleading, take square root since area grows quadratically*
  - *shape*

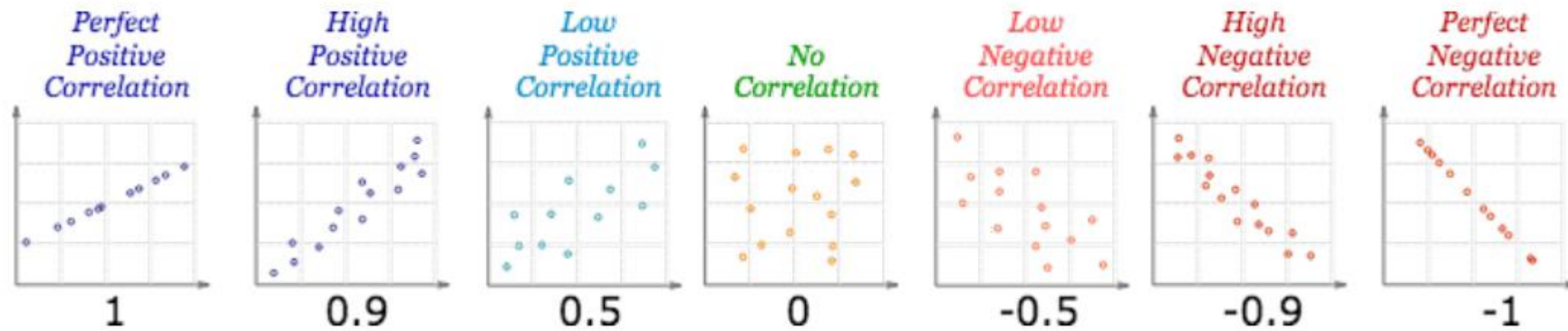


<https://www.gapminder.org/>



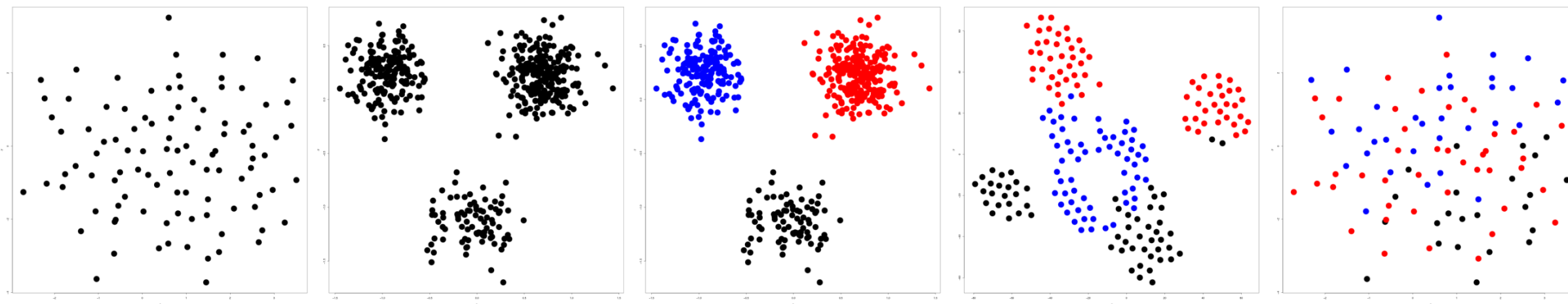
# Scatterplot tasks

- Correlation



<https://www.mathsisfun.com/data/scatter-xy-plots.html>

- clusters/groups, and clusters vs classes



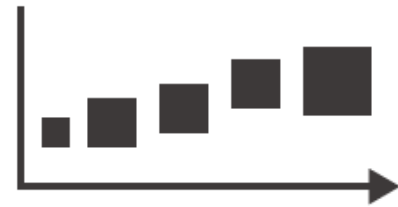
<https://www.cs.ubc.ca/labs/imager/tr/2014/DRVisTasks/>

# Some keys: Categorical regions

→ Separate



→ Order



→ Align

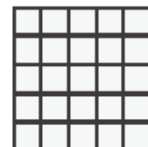


- regions: contiguous bounded areas distinct from each other
  - using space to *separate* (proximity)
  - following expressiveness principle for categorical attributes
- use ordered attribute to *order* and *align* regions

→ 1 Key  
*List*



→ 2 Keys  
*Matrix*



→ 3 Keys  
*Volume*



→ Many Keys  
*Recursive Subdivision*



# Idiom: **bar chart**

- one key, one value

- data

- 1 categ attrib, 1 quant attrib

- mark: lines

- channels

- length to express quant value
    - spatial regions: one per mark
      - separated horizontally, aligned vertically
      - ordered by quant attrib

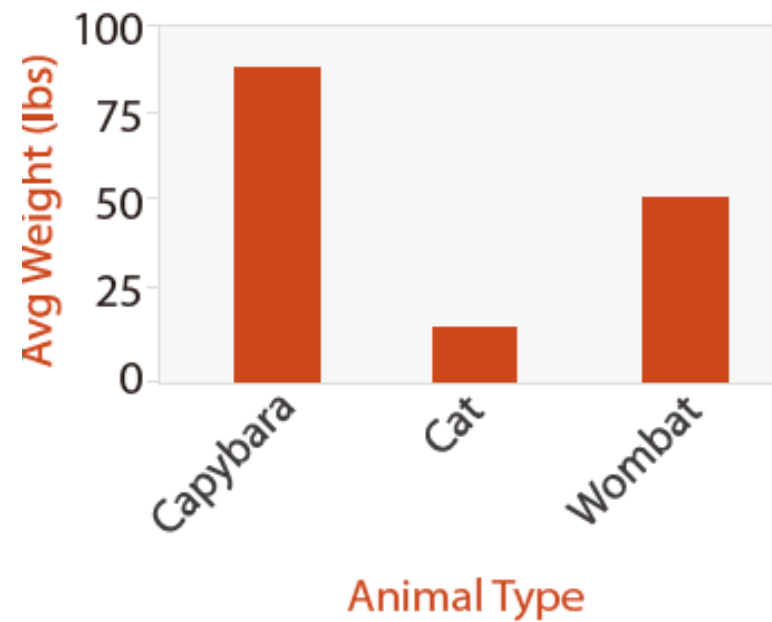
- » by label (alphabetical), by length attrib (data-driven)

- task

- compare, lookup values

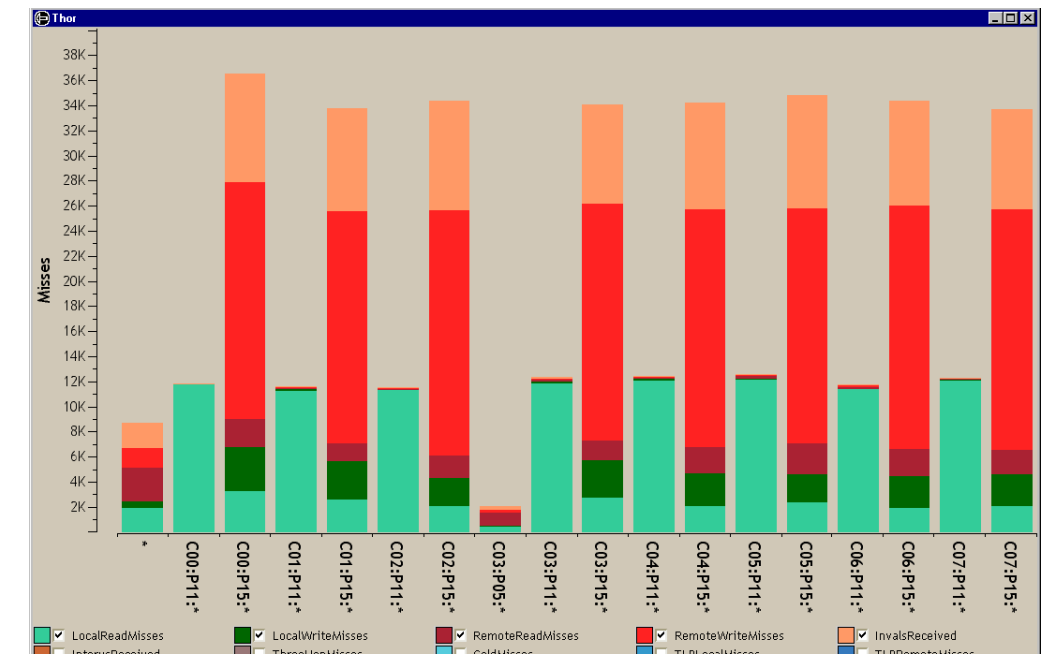
- scalability

- dozens to hundreds of levels for key attrib



# Idiom: **stacked bar chart**

- one more key
  - data
    - 2 categ attrib, 1 quant attrib
  - mark: vertical stack of line marks
    - glyph: composite object, internal structure from multiple marks
  - channels
    - length and color hue
    - spatial regions: one per glyph
      - aligned: full glyph, lowest bar component
      - unaligned: other bar components
  - task
    - part-to-whole relationship
  - scalability
    - several to one dozen levels for stacked attrib



[\[Using Visualization to Understand the Behavior of Computer Systems. Bosch. Ph.D. thesis, Stanford Computer Science, 2001.\]](#)

# Idiom: **streamgraph**

- generalized stacked graph

- emphasizing horizontal continuity

- vs vertical items

- data

- 1 categ key attrib (artist)
    - 1 ordered key attrib (time)
    - 1 quant value attrib (counts)

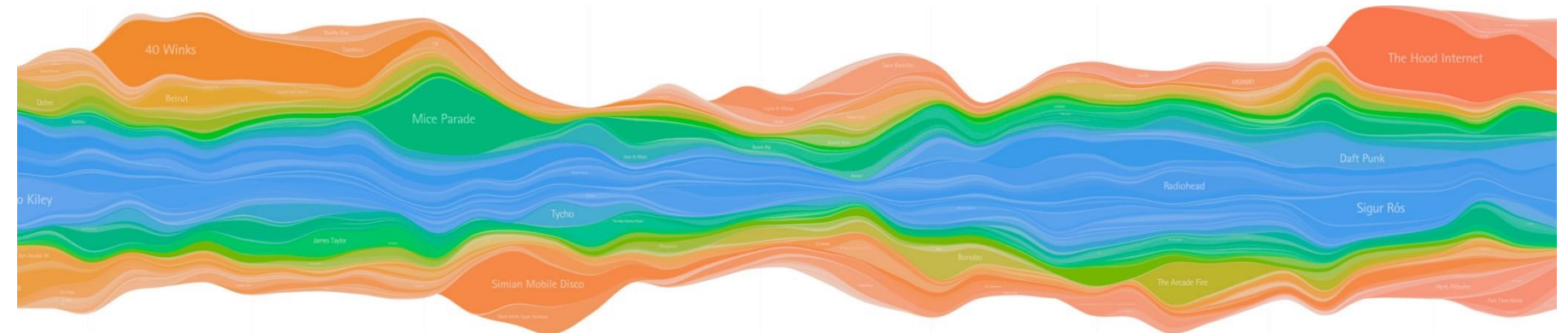
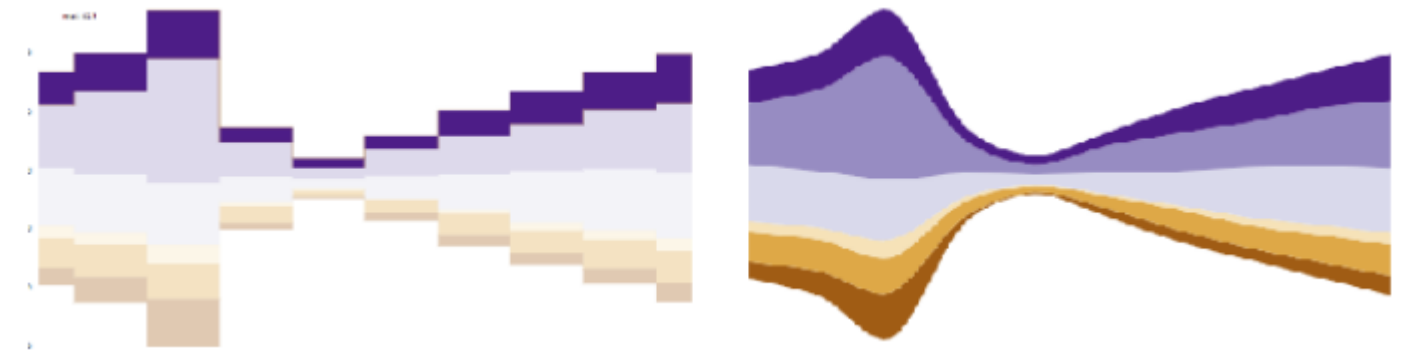
- derived data

- geometry: layers, where height encodes counts
    - 1 quant attrib (layer ordering)

- scalability

- hundreds of time keys
    - dozens to hundreds of artist keys

- more than stacked bars, since most layers don't extend across whole chart



*[Stacked Graphs Geometry & Aesthetics. Byron and Wattenberg. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14(6): 1245–1252, (2008).]*

# Idiom: **line chart**

- one key, one value

- data

- 2 quant attribs

- mark: points

- line connection marks between them

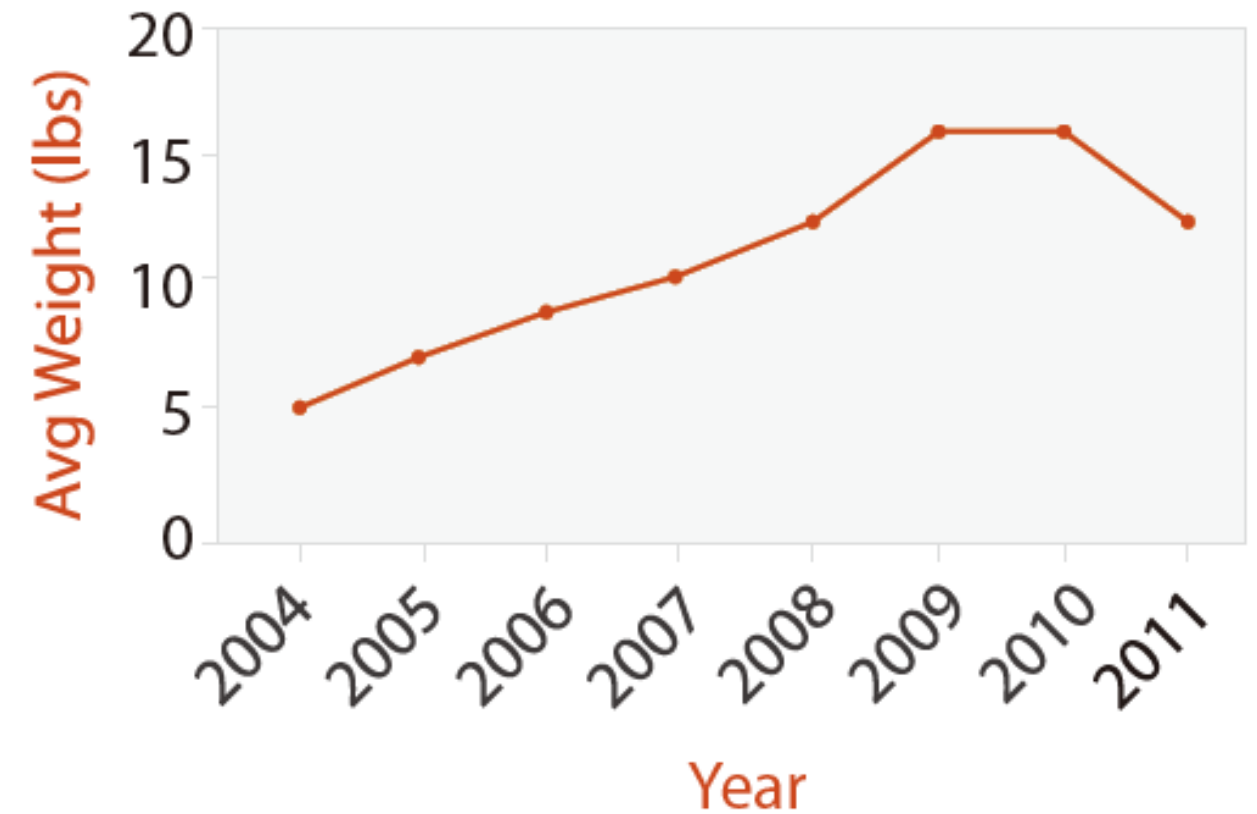
- channels

- aligned lengths to express quant value
    - separated and ordered by key attrib into horizontal regions

- task

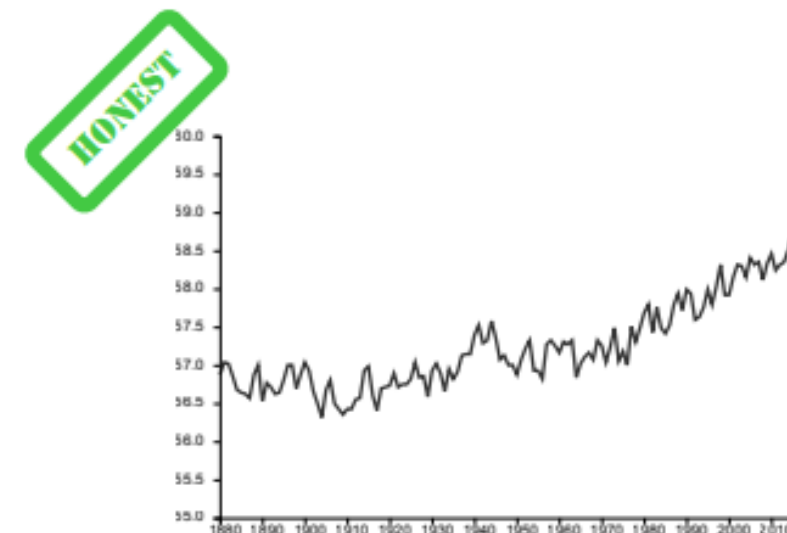
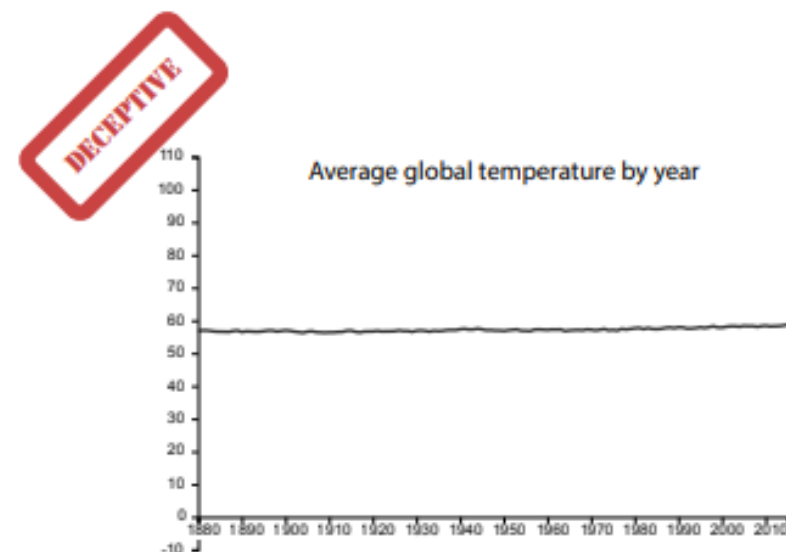
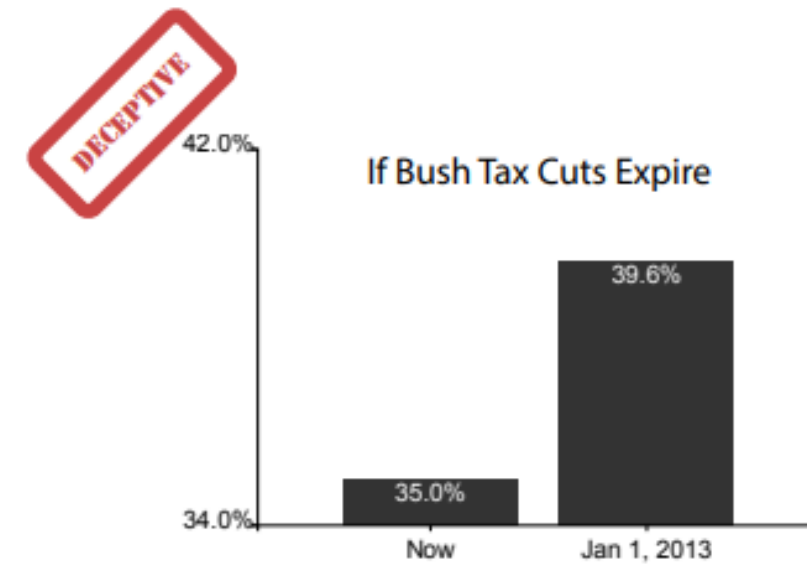
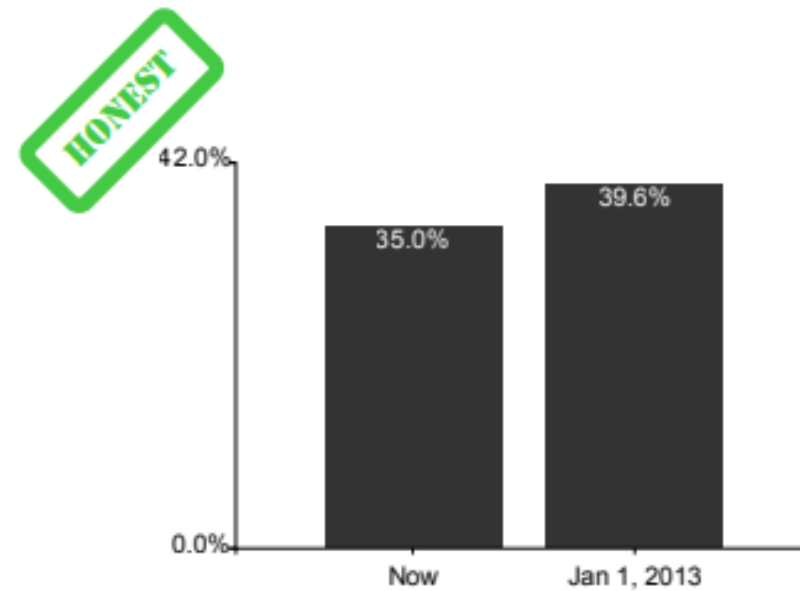
- find trend

- connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next



# Chart axes: avoid cropping y axis

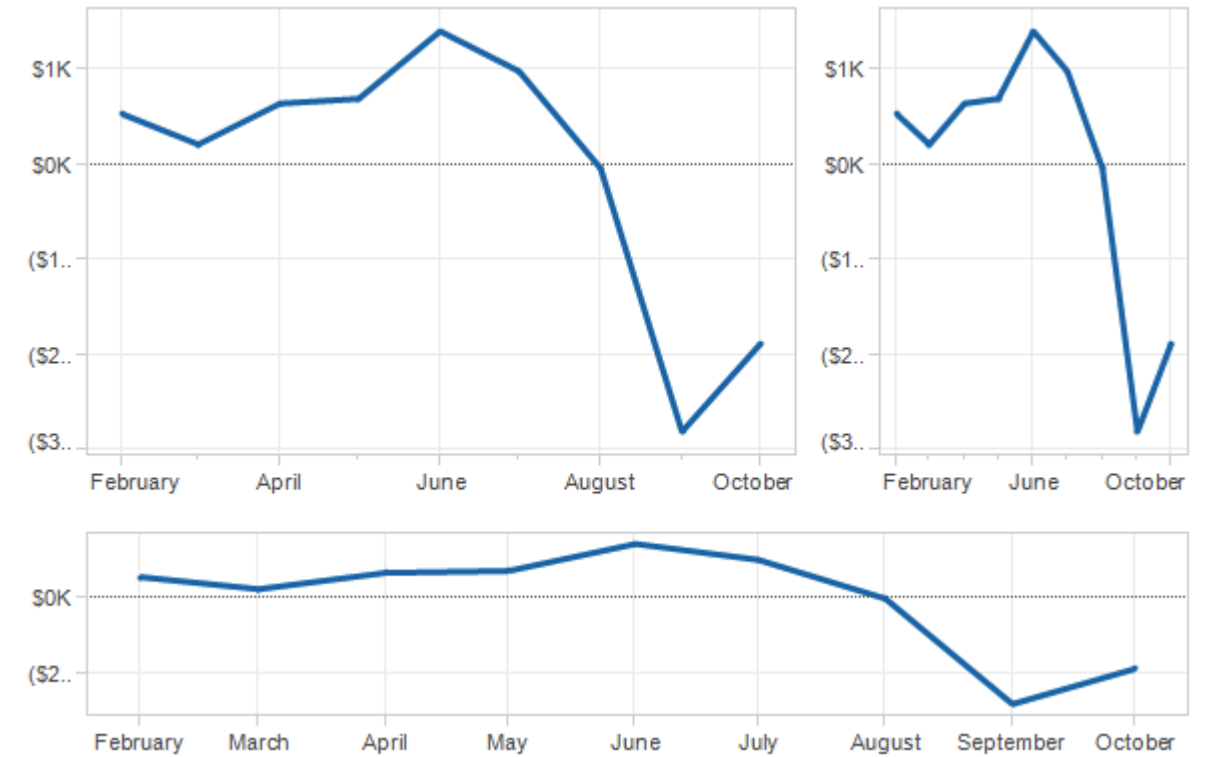
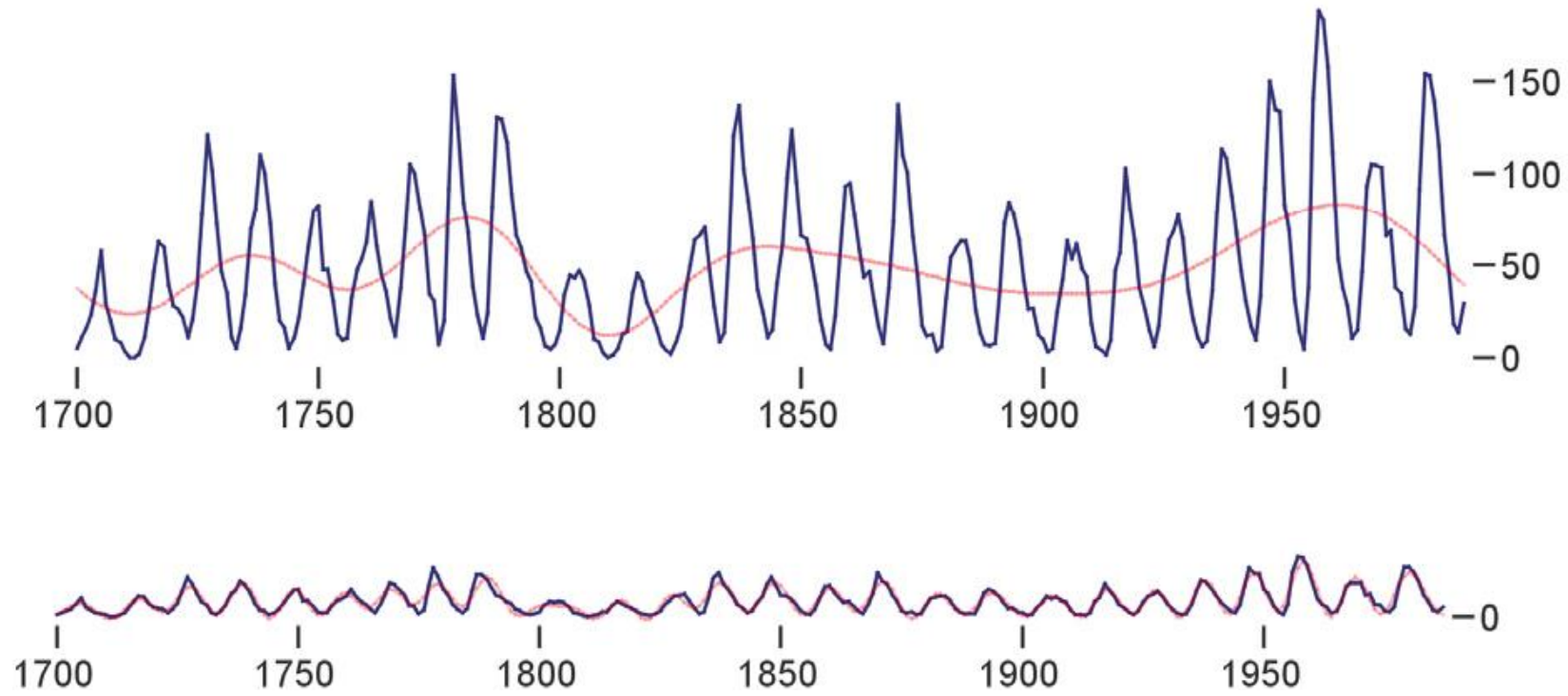
- include 0 at bottom left or slope misleads
  - some exceptions (arbitrary 0, small change matters)





# Idiom: line chart

- Banking to 45 degrees

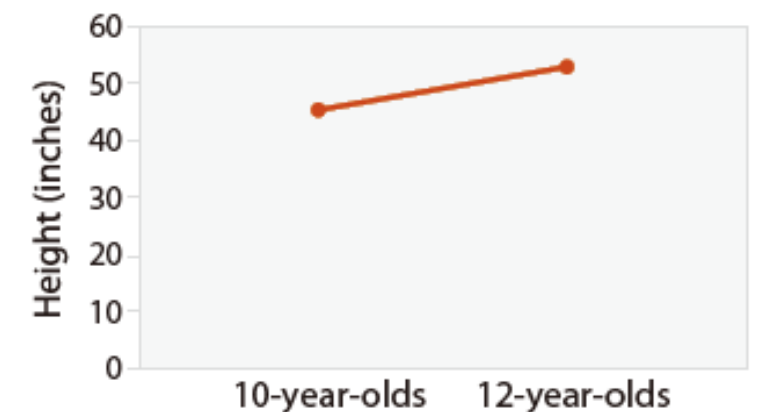
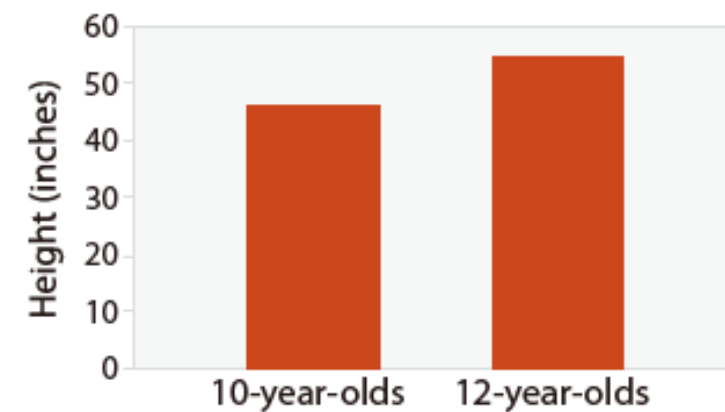
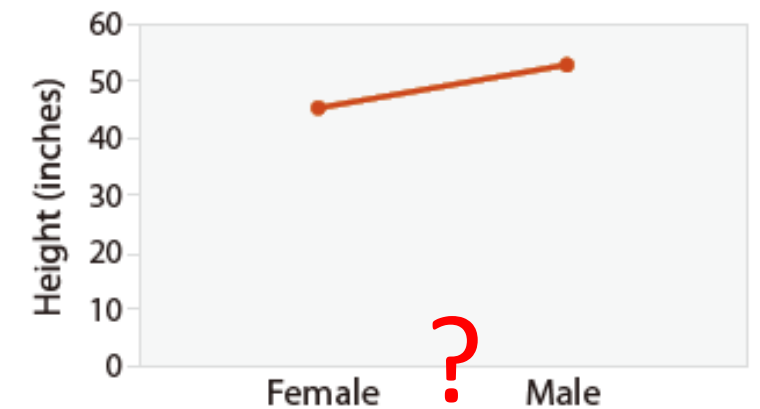
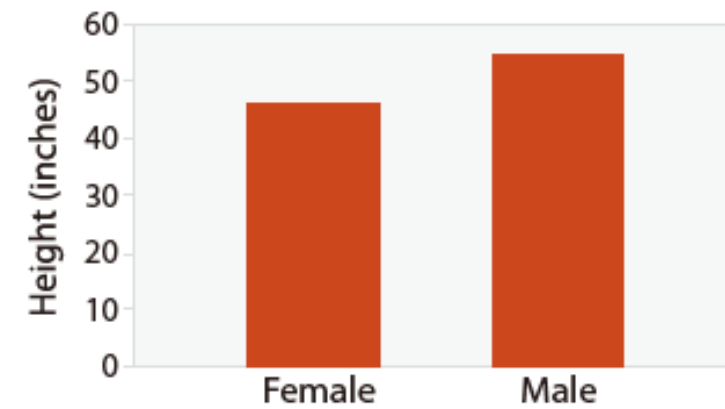


[Heer and Agrawala 06]



# Choosing bar vs line charts

- depends on type of key attrib
  - bar charts if categorical
  - line charts if ordered
- do not use line charts for categorical key attribs
  - violates expressiveness principle
    - implication of trend so strong that it overrides semantics!
      - “The more male a person is, the taller he/she is”



*after [Bars and Lines: A Study of Graphic Communication. Zacks and Tversky. Memory and Cognition 27:6 (1999), 1073–1079.]*

# Idiom: **heatmap**

- two keys, one value

- data

- 2 categ attribs (gene, experimental condition)
    - 1 quant attrib (expression levels)

- marks: area

- separate and align in 2D matrix
      - indexed by 2 categorical attributes

- channels

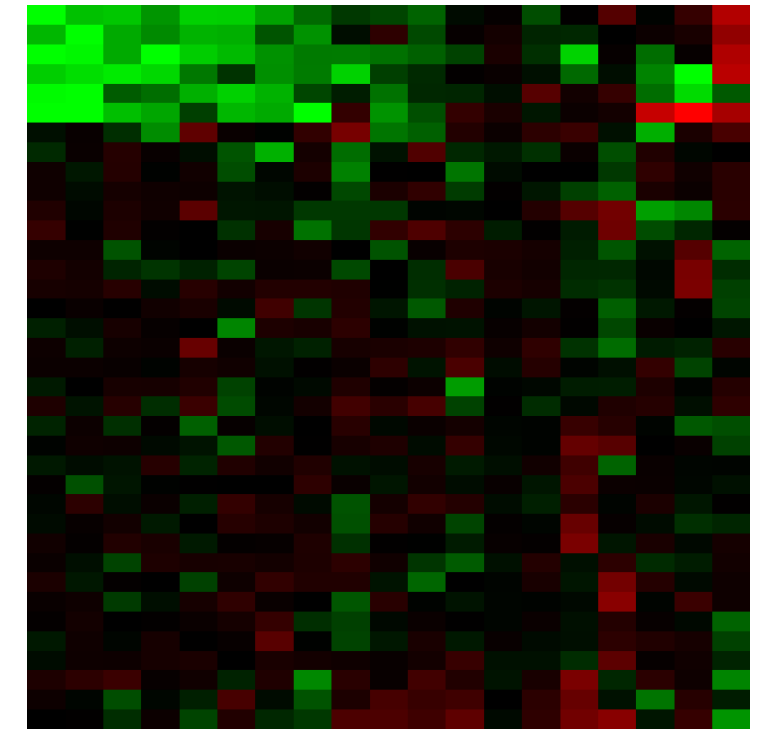
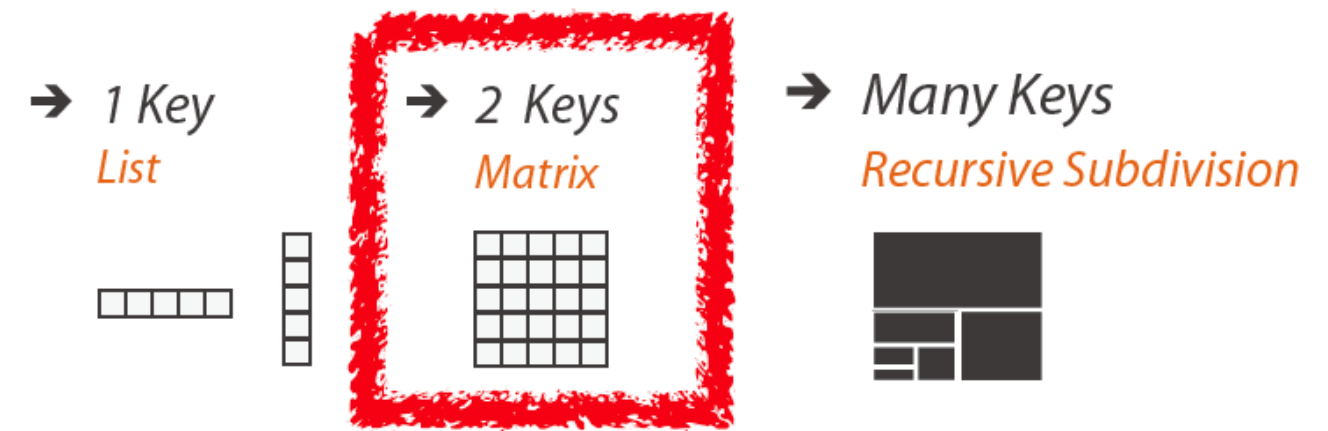
- color by quant attrib
      - (ordered diverging colormap)

- task

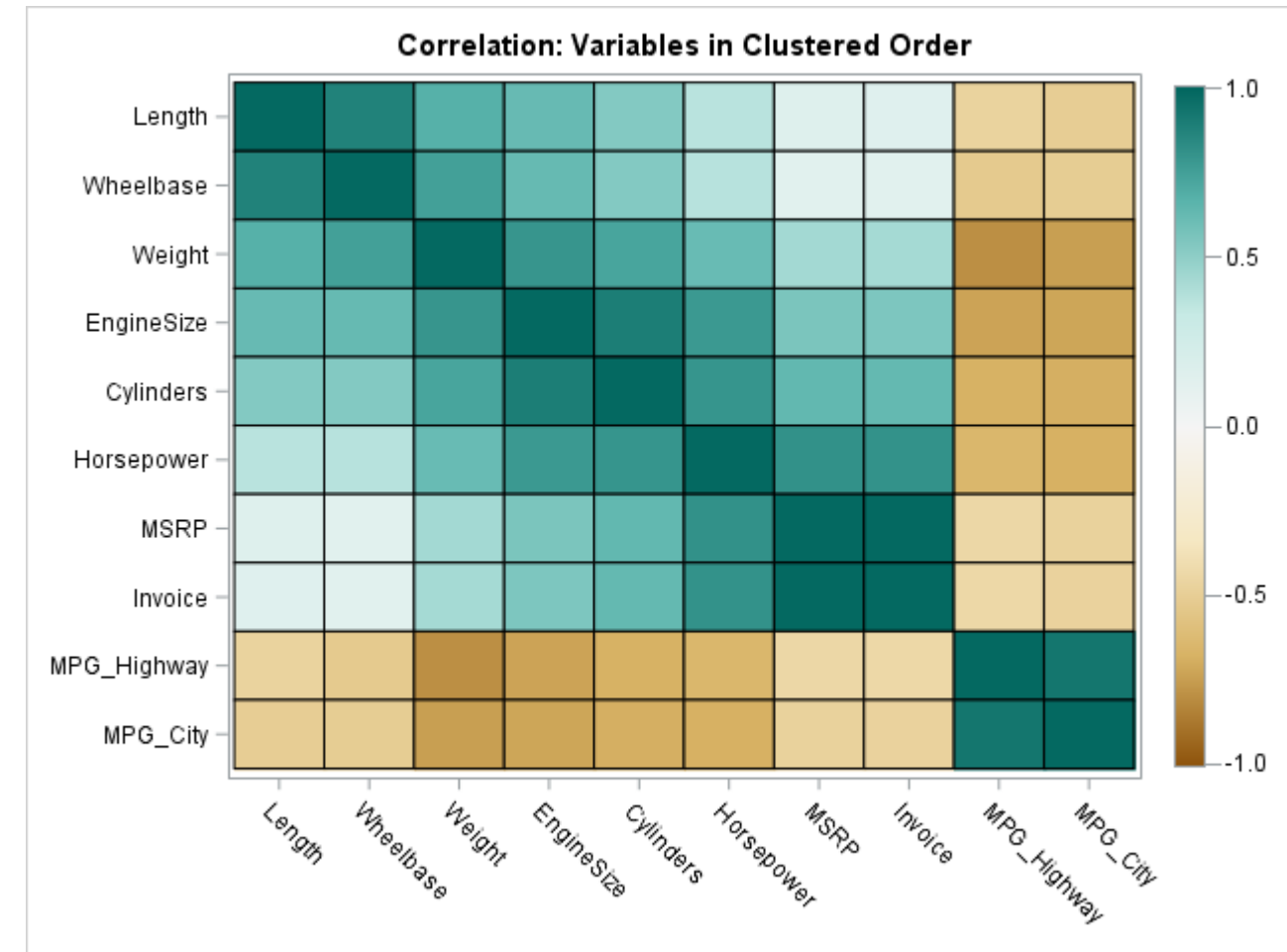
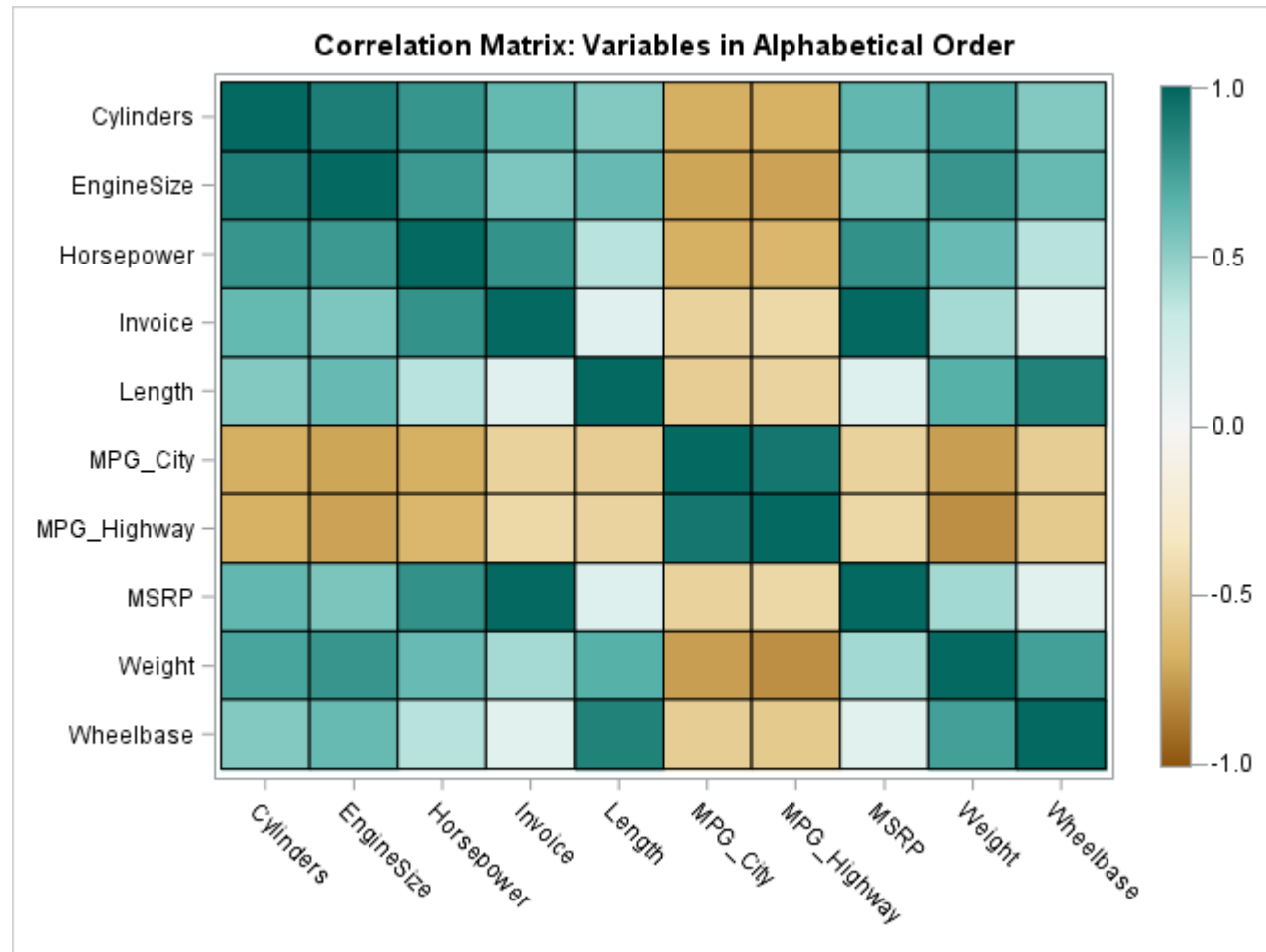
- find clusters, outliers

- scalability

- 1M items, 100s of categ levels, ~10 quant attrib levels

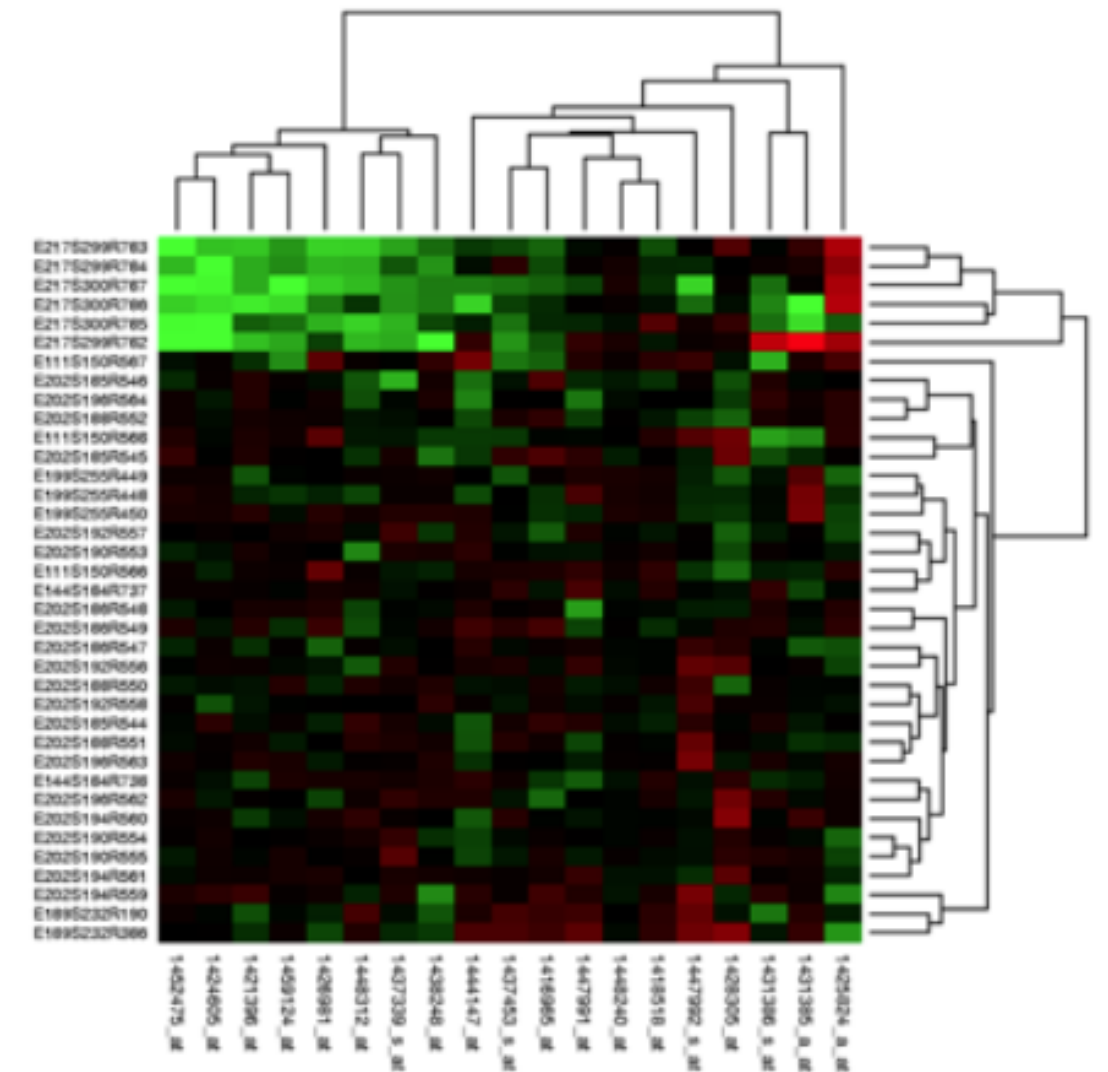


# Heatmap reordering



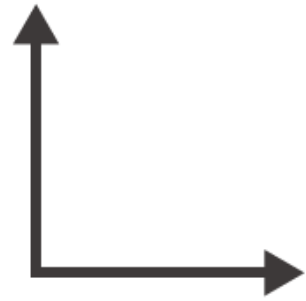
# Idiom: **cluster heatmap**

- in addition
  - derived data
    - 2 cluster hierarchies
  - dendrogram
    - Parent-child relationships in tree with connection line marks
    - Leaves aligned so interior branch heights easy to compare
  - heatmap
    - Marks (re-)ordered by cluster hierarchy traversed



## ➔ **Axis Orientation**

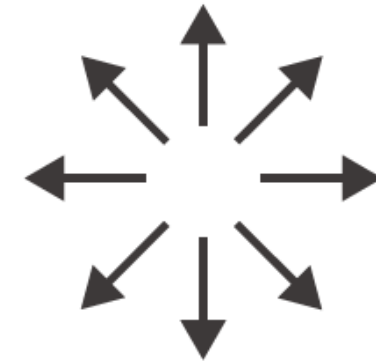
➔ Rectilinear



➔ Parallel



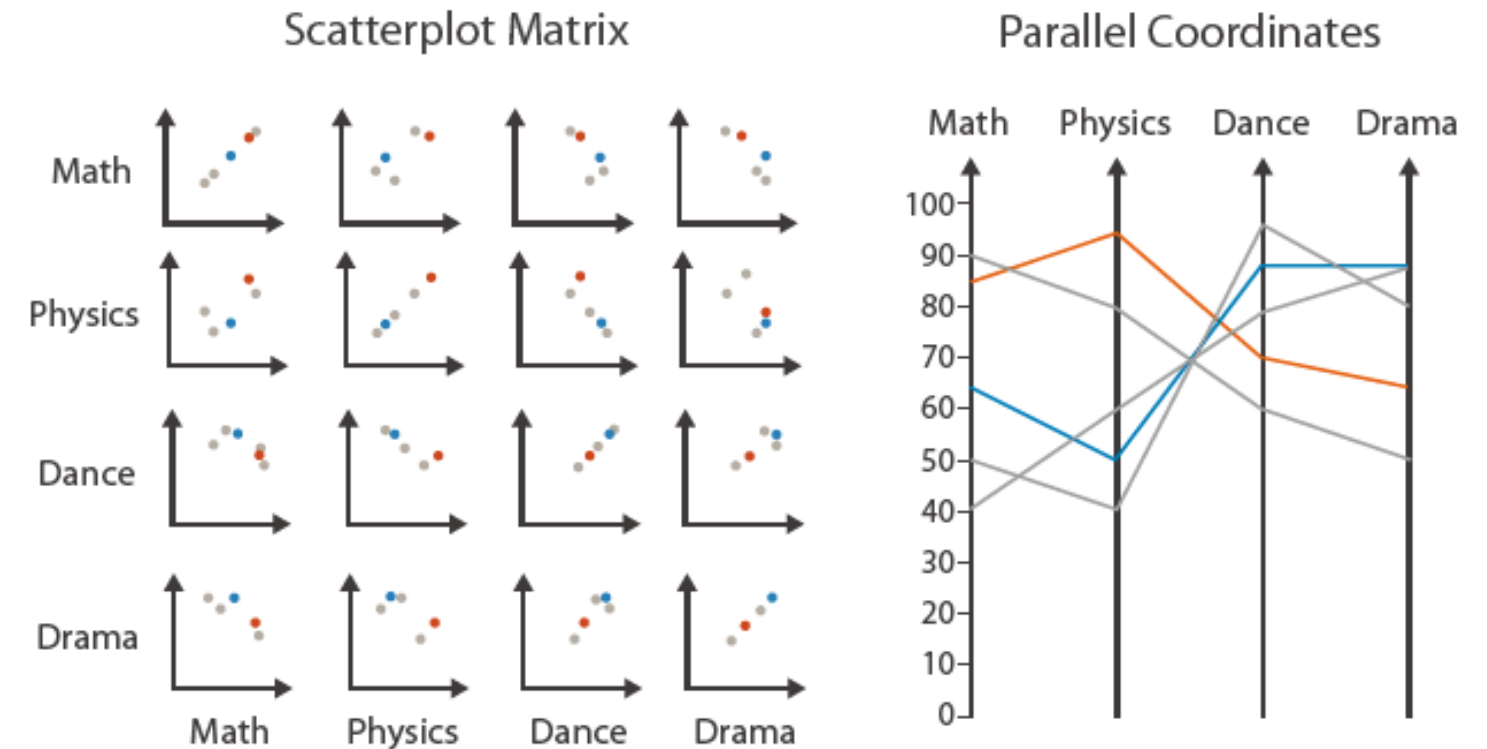
➔ Radial



# Idioms: scatterplot matrix, parallel coordinates

- **scatterplot matrix (SPLOM)**

- rectilinear axes, point mark
- all possible pairs of axes
- scalability
  - one dozen attribs
  - dozens to hundreds of items



- **parallel coordinates**

- parallel axes, jagged line representing item
- rectilinear axes, item as point
  - axis ordering is major challenge
- scalability
  - dozens of attribs
  - hundreds of items

Table

Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

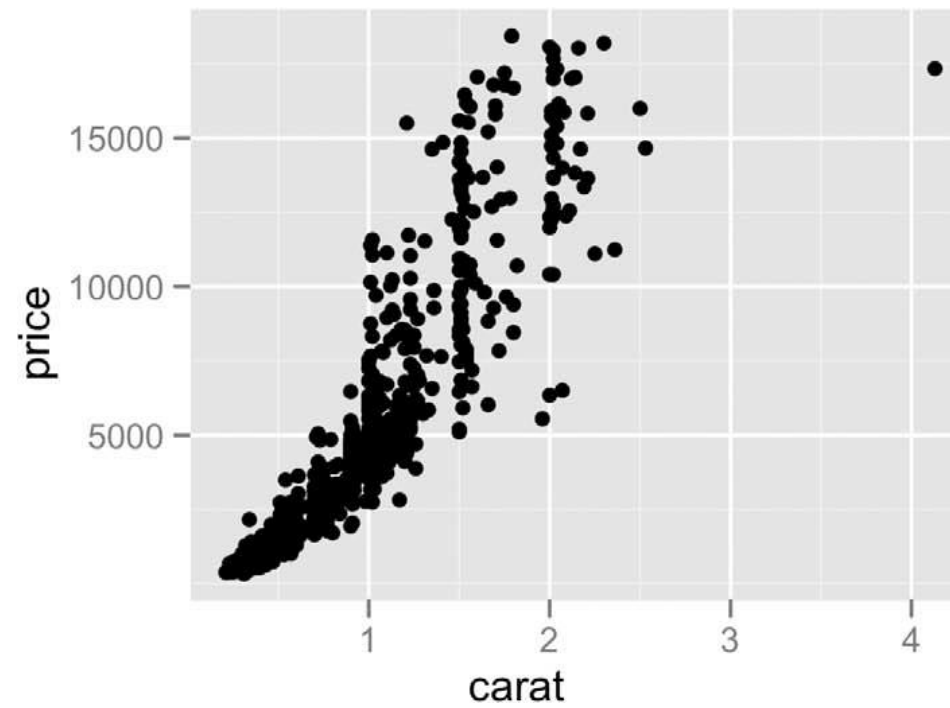
after [Visualization Course Figures. McGuffin, 2014.

<http://www.michaelmcguffin.com/courses/vis/>]



# Task: Correlation

- scatterplot matrix
  - positive correlation
    - diagonal low-to-high
  - negative correlation
    - diagonal high-to-low
  - uncorrelated
- parallel coordinates
  - positive correlation
    - parallel line segments
  - negative correlation
    - all segments cross at halfway point
  - uncorrelated
    - scattered crossings



[A layered grammar of graphics. Wickham. *Journ. Computational and Graphical Statistics* 19:1 (2010), 3–28.]

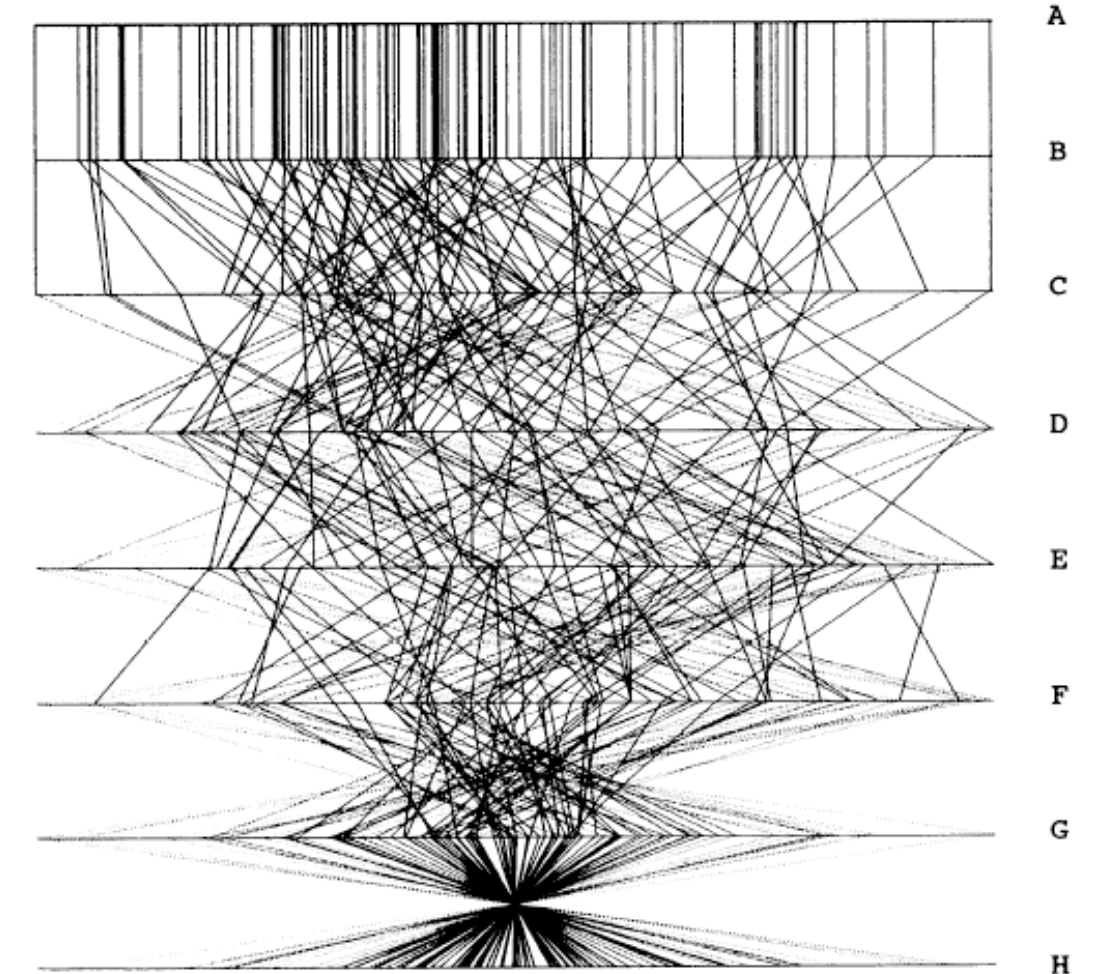
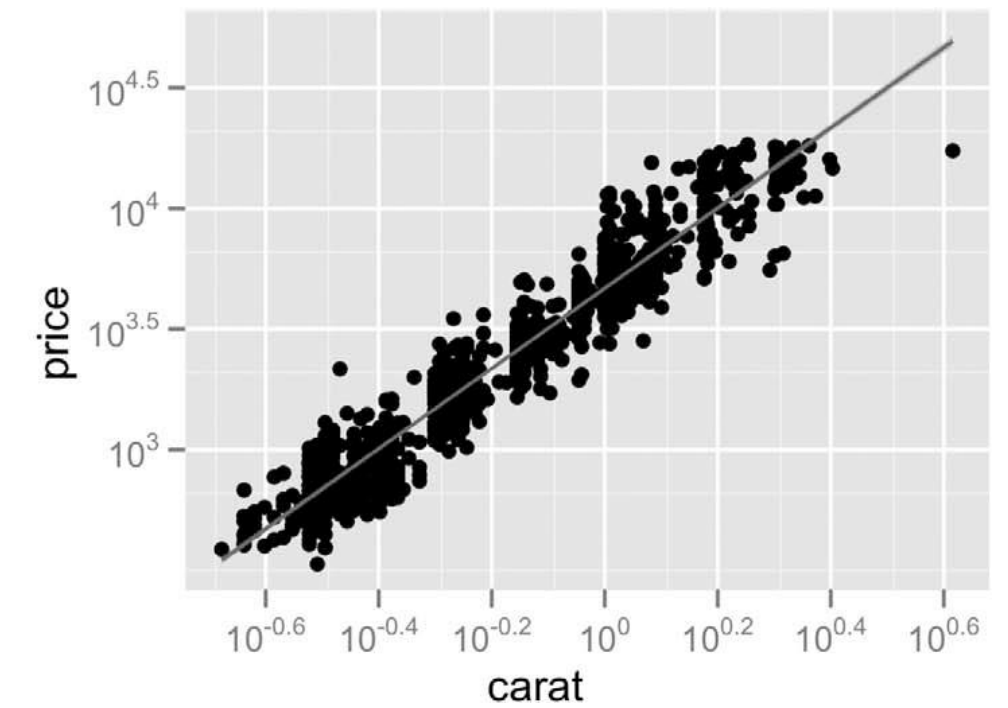
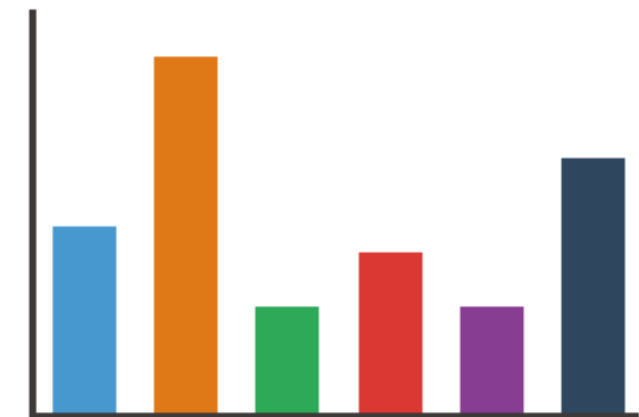


Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of  $\rho = 1, .8, .2, 0, -.2, -.8,$  and  $-1$ .

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. *Journ. American Statistical Association* 85:411 (1990), 664–675.]

# Idioms: **radial bar chart**, **star plot**

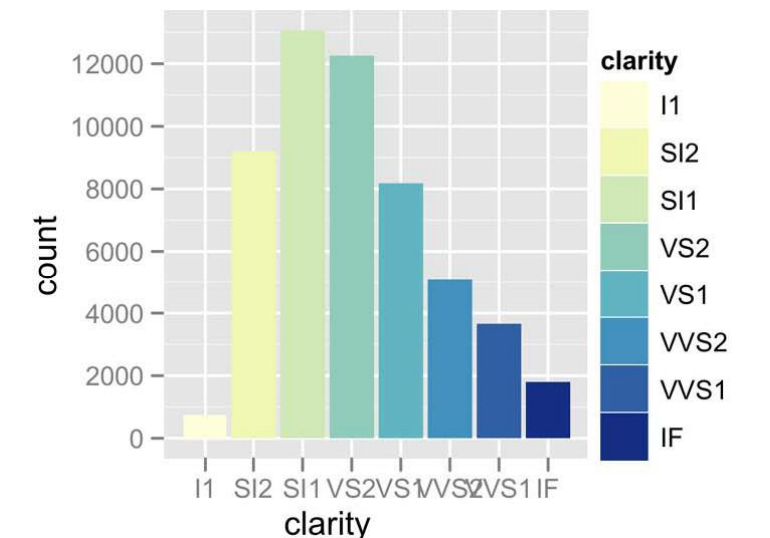
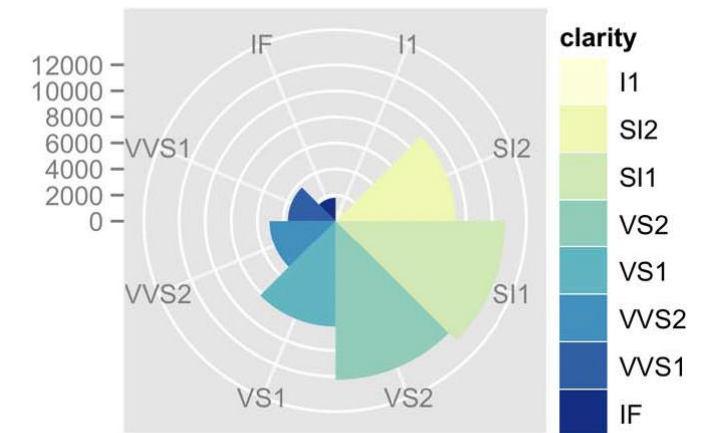
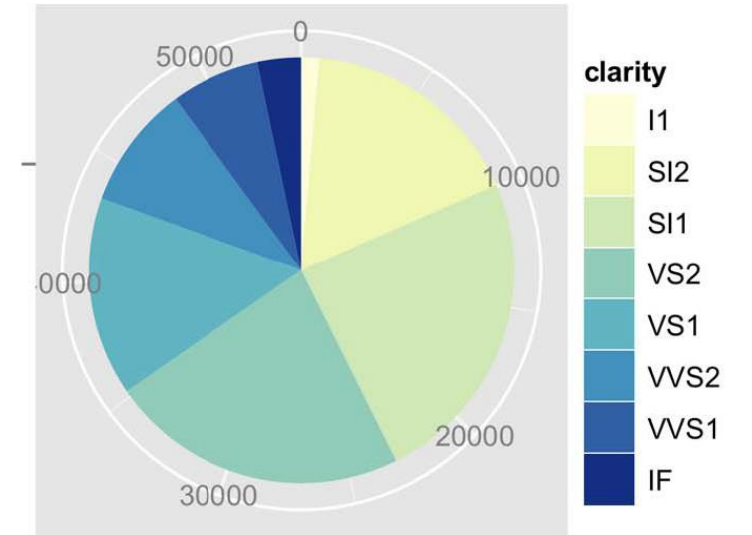
- radial bar chart
  - radial axes meet at central ring, line mark
- star plot
  - radial axes, meet at central point, line mark
- bar chart
  - rectilinear axes, aligned vertically
- accuracy
  - length unaligned with radial
    - less accurate than aligned with rectilinear





# Idioms: pie chart, polar area chart

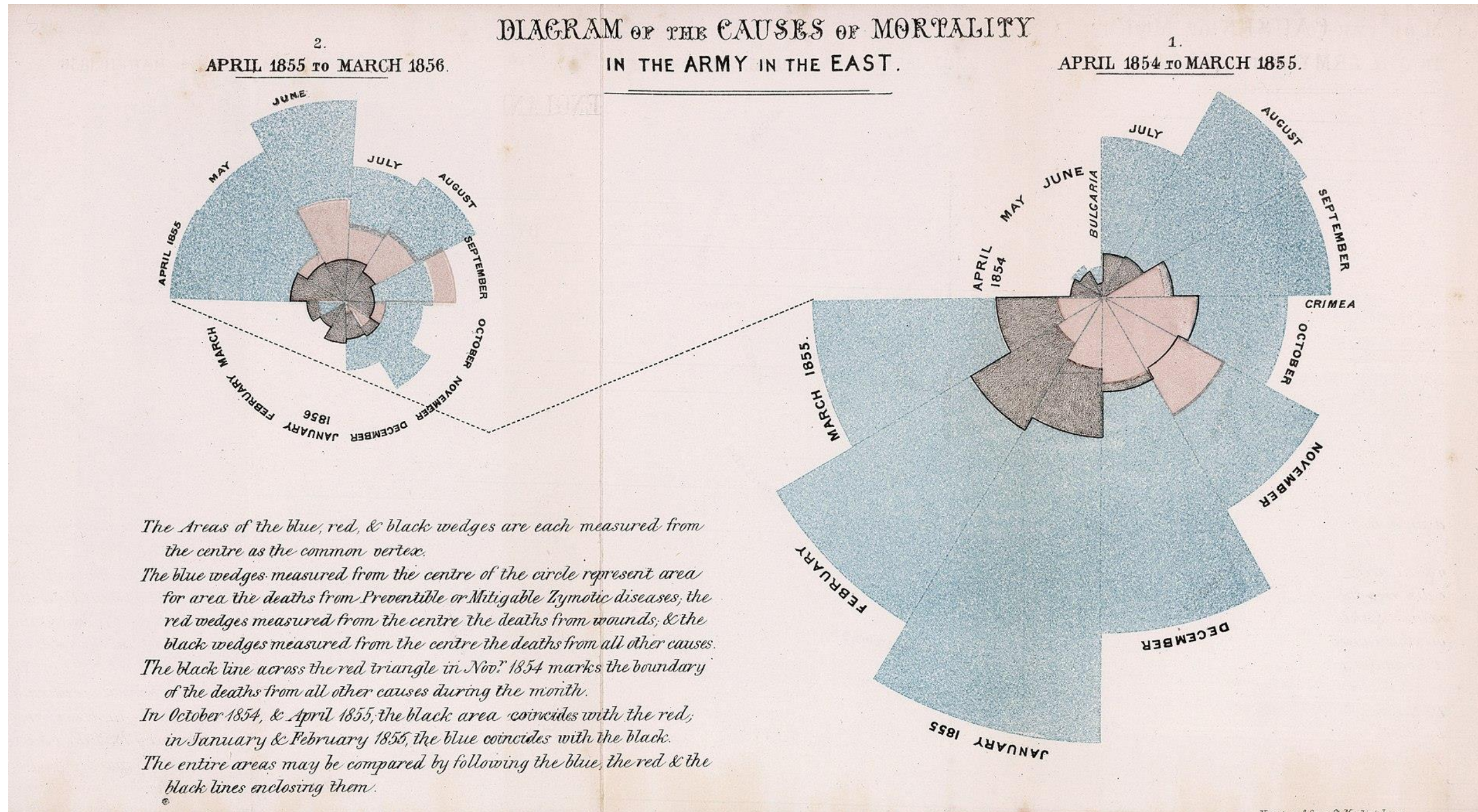
- pie chart
  - area marks with angle channel
  - accuracy: angle/area less accurate than line length
    - arclength also less accurate than line length
- polar area chart
  - area marks with length channel
  - more direct analog to bar charts
- data
  - 1 categ key attrib, 1 quant value attrib
- task
  - part-to-whole judgements





# Coxcomb / nightingale rose / polar area chart

- invented by Florence Nightingale

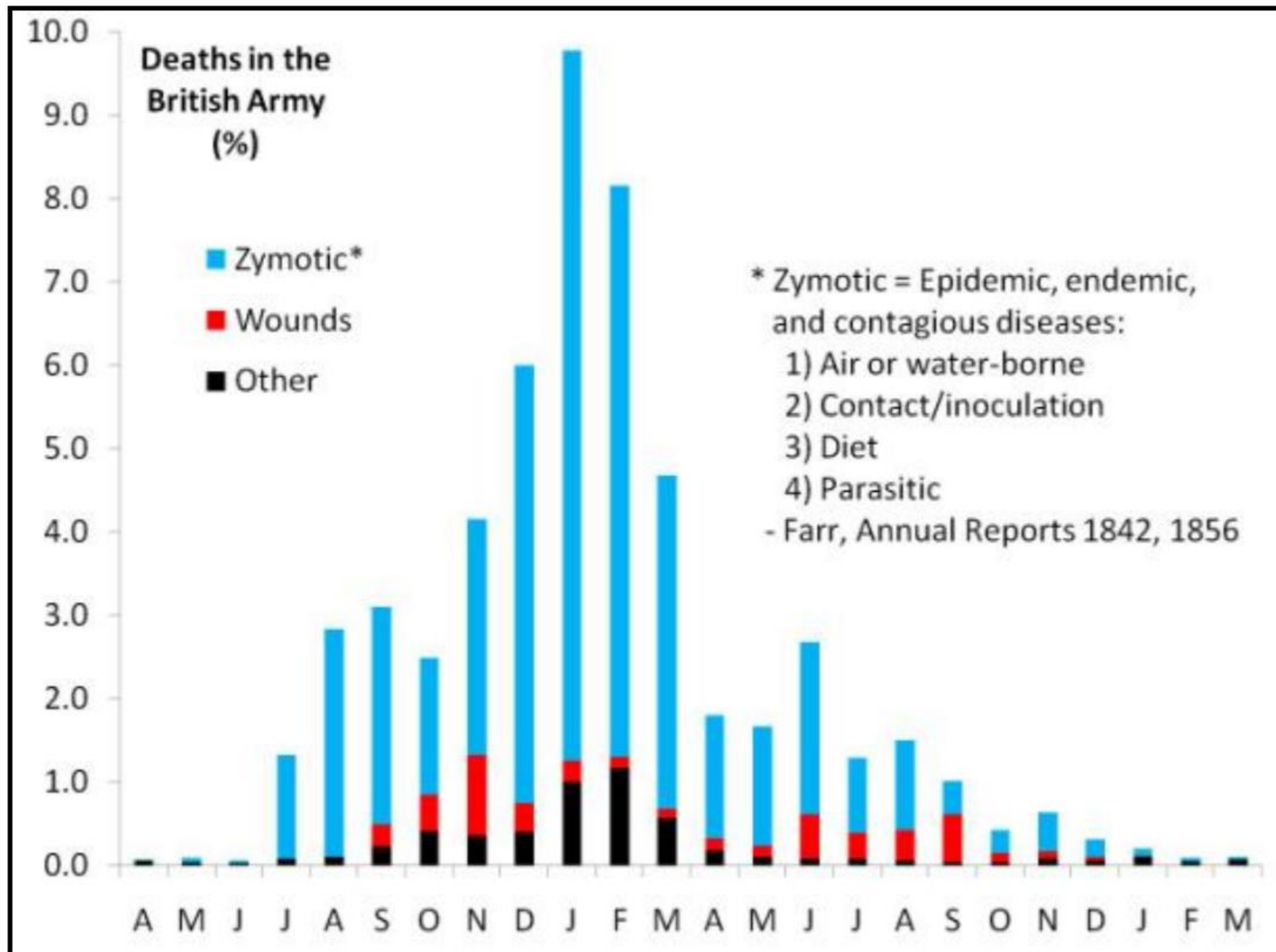


Blue: epidemic

Red: wounds

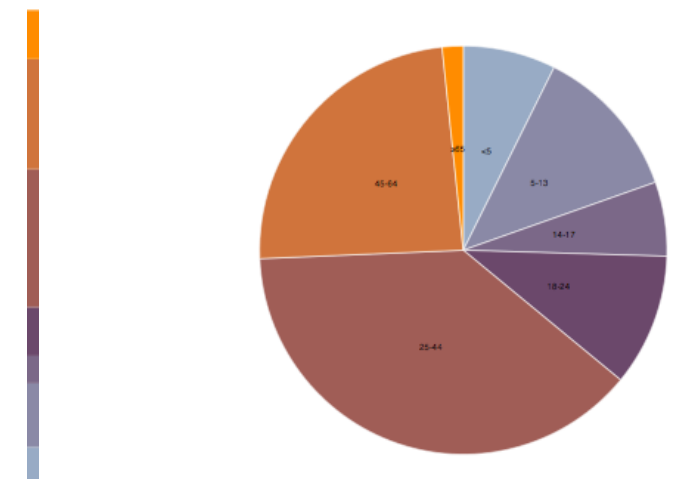
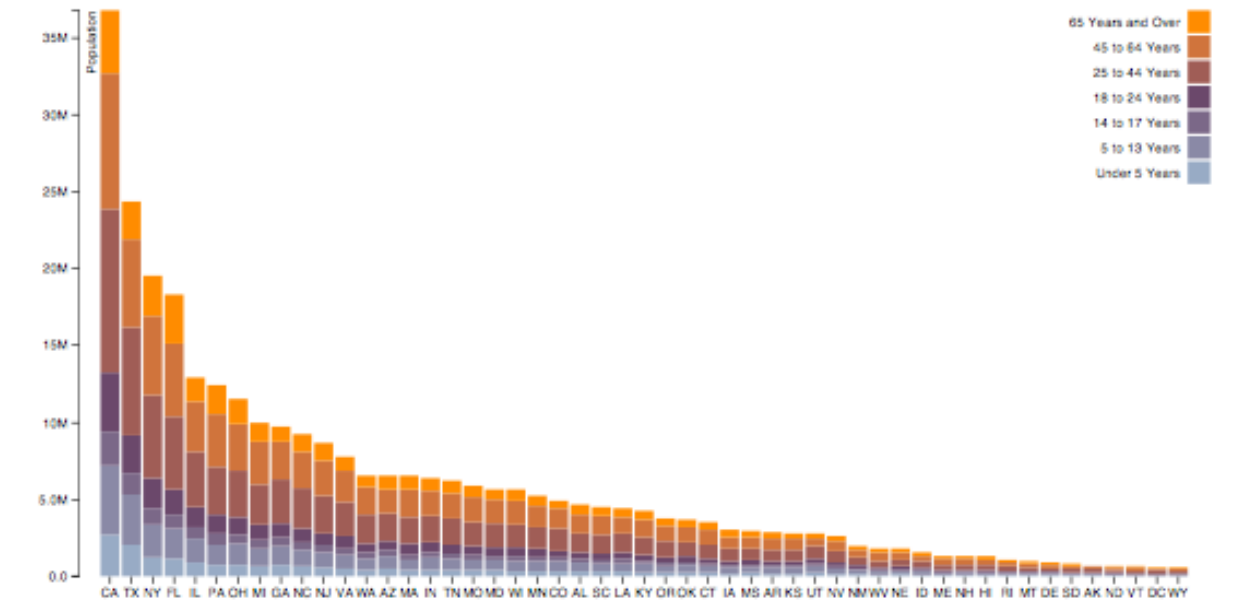
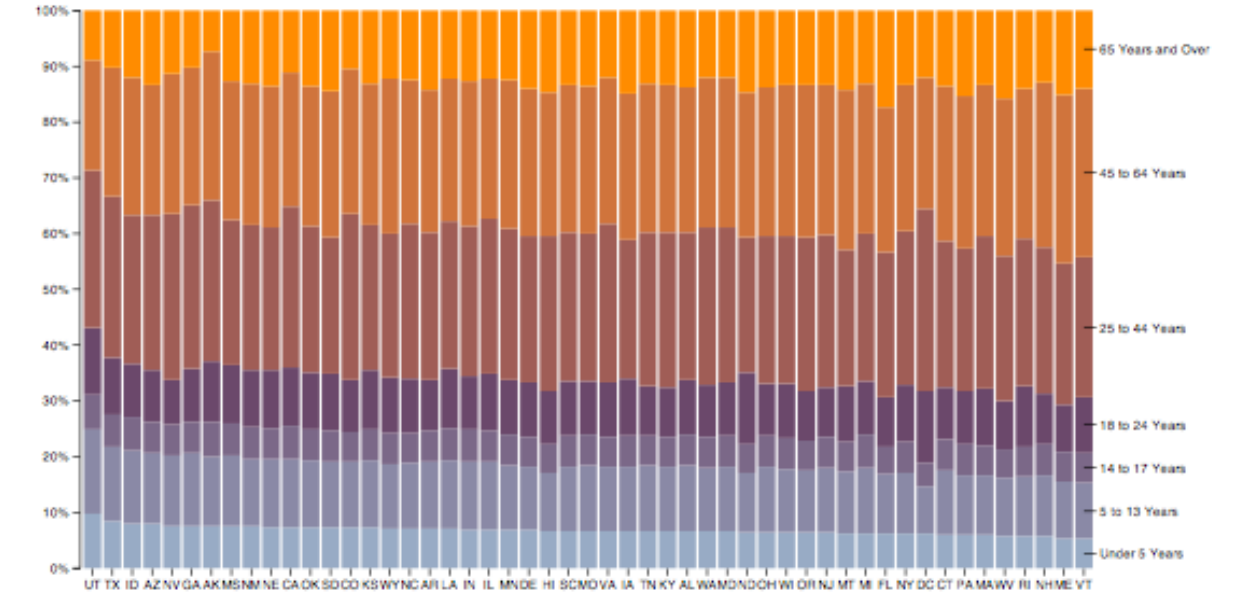
Black: other





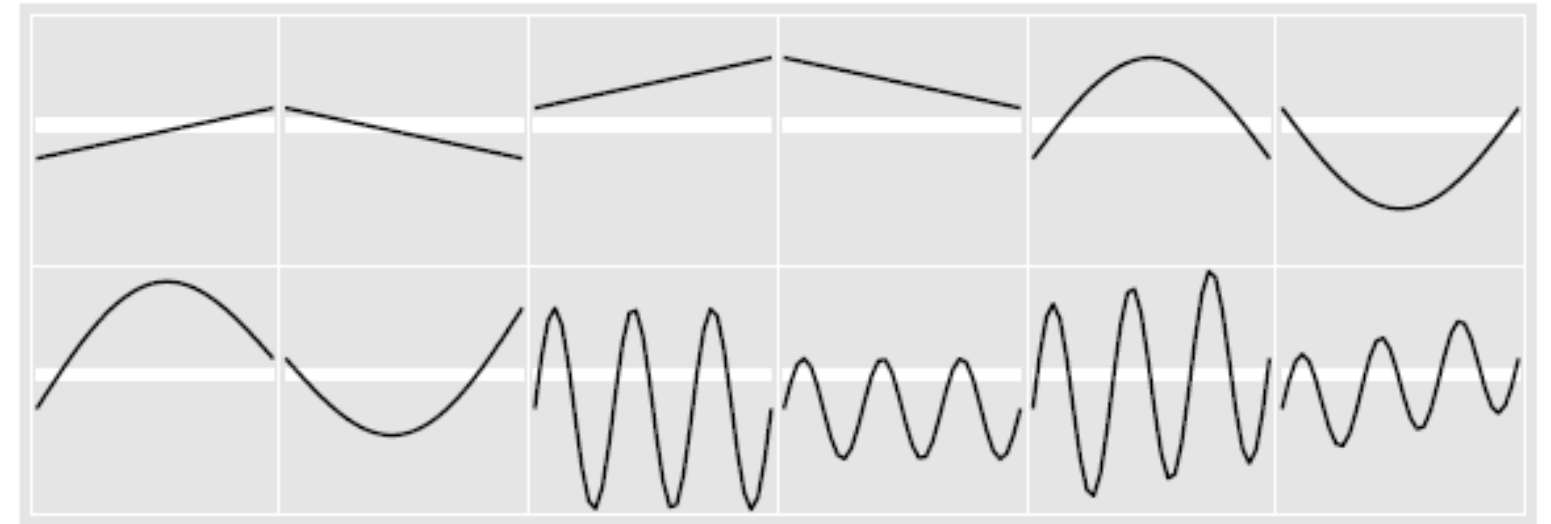
# Idioms: **normalized stacked bar chart**

- task
  - part-to-whole judgements
- **normalized stacked bar chart**
  - stacked bar chart, normalized to full vert height
  - single stacked bar equivalent to full pie
    - high information density: requires narrow rectangle
- **pie chart**
  - information density: requires large circle



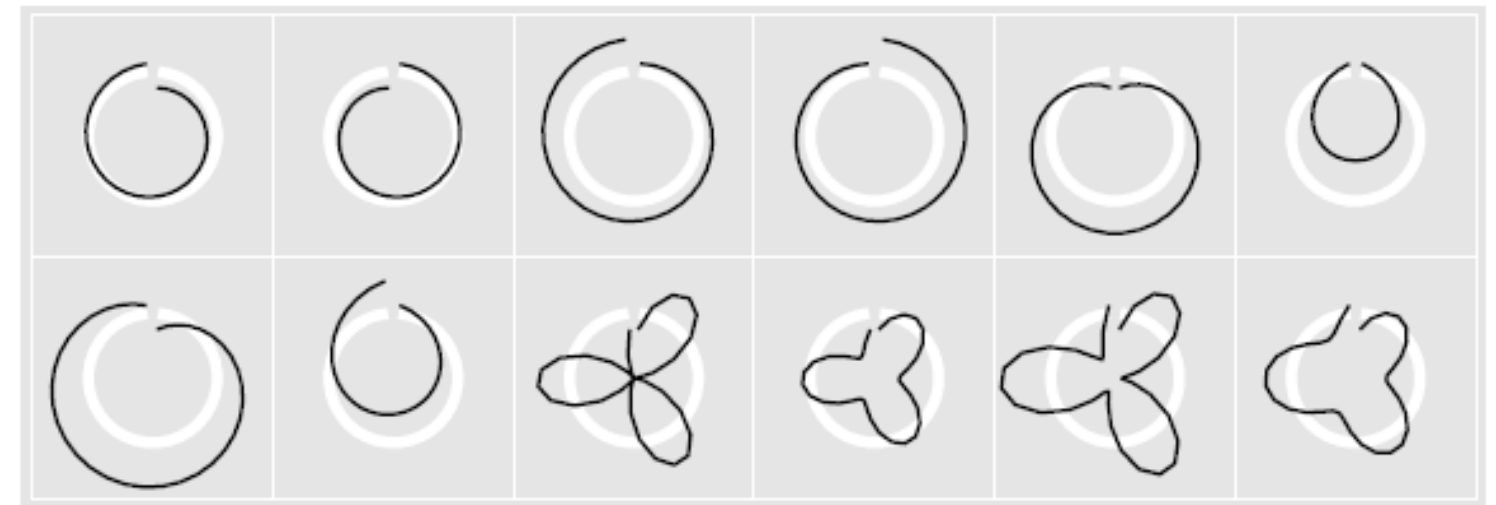
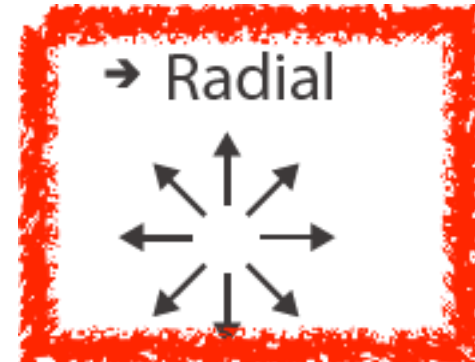
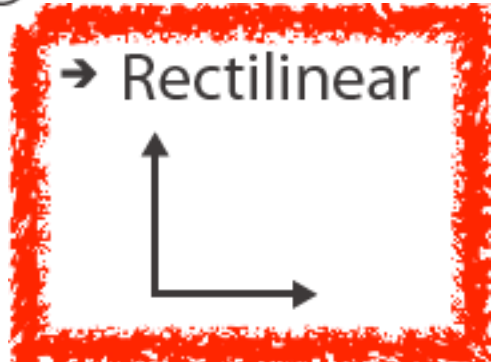
# Idiom: **glyphmaps**

- rectilinear good for linear vs nonlinear trends



- radial good for cyclic patterns

➔ Axis Orientation



*[Glyph-maps for Visually Exploring Temporal Patterns in Climate Data and Models. Wickham, Hofmann, Wickham, and Cook. Environmetrics 23:5 (2012), 382–393.]*

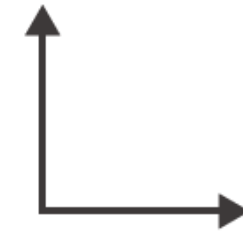
# Orientation limitations

- **rectilinear: scalability wrt #axes**
  - 2 axes best
  - 3 problematic
    - more in afternoon
  - 4+ impossible
- **parallel: unfamiliarity, training time**
- **radial: perceptual limits**
  - angles lower precision than lengths
  - asymmetry between angle and length
    - can be exploited!

*[Uncovering Strengths and Weaknesses of Radial Visualizations - an Empirical Approach. Diehl, Beck and Burch. IEEE TVCG (Proc. InfoVis) 16(6):935--942, 2010.]*

## ➔ Axis Orientation

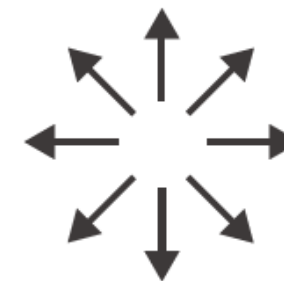
➔ Rectilinear



➔ Parallel



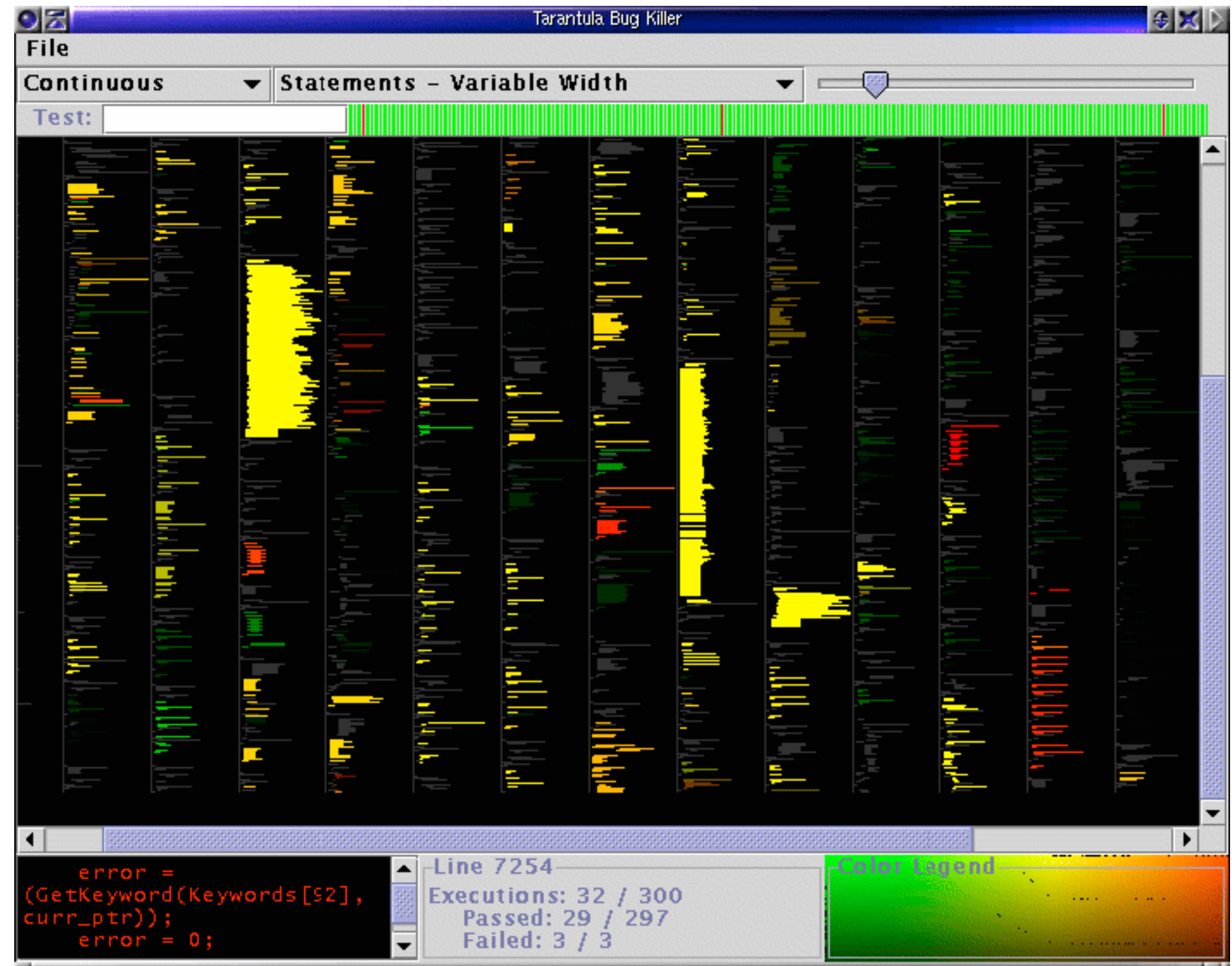
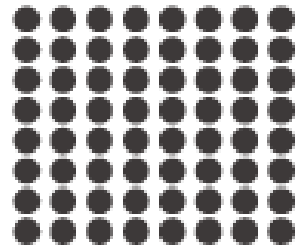
➔ Radial



# dense software overviews

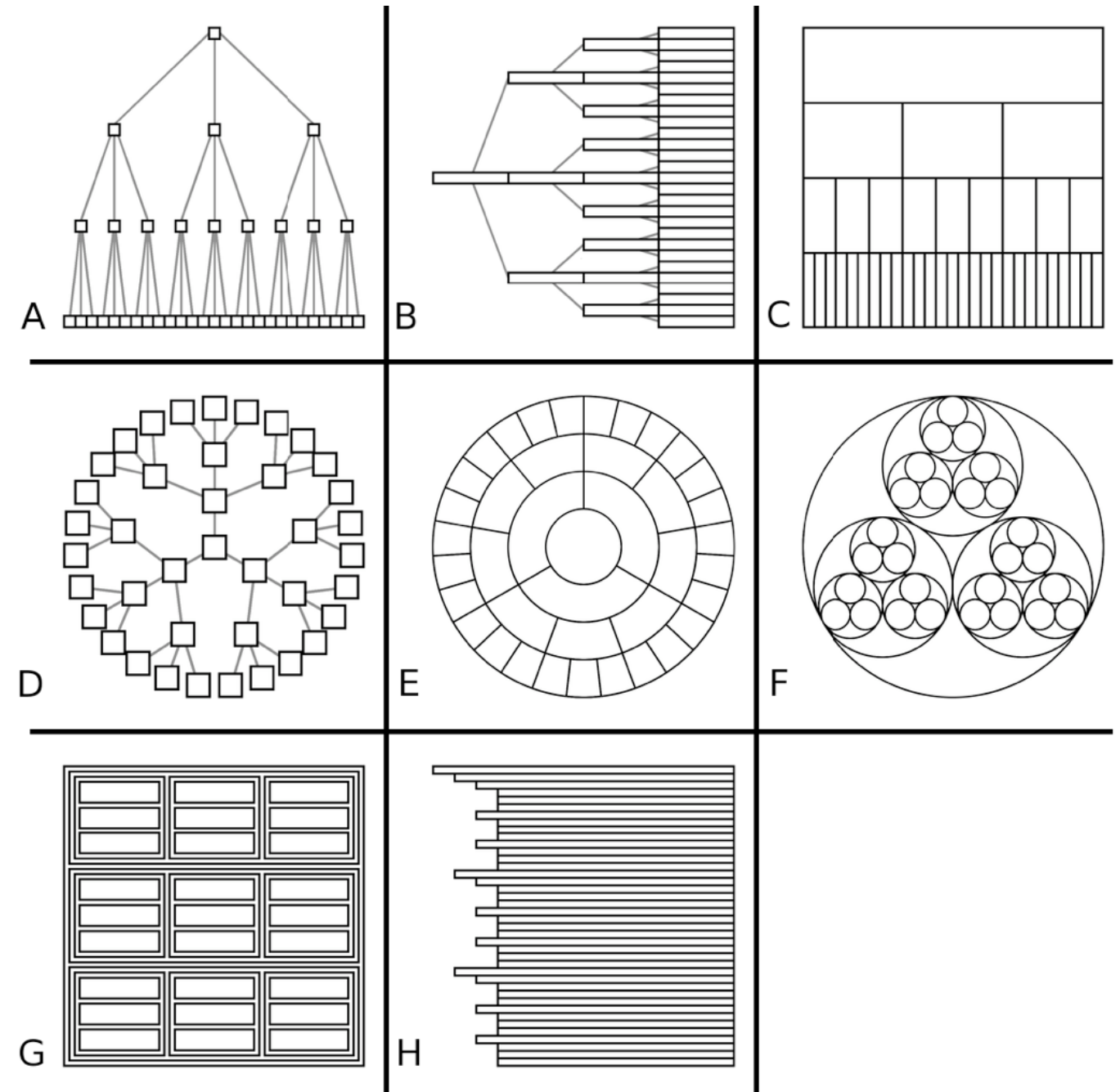
## ➔ Layout Density

### ➔ Dense



# Layout density

- Space-Filling
  - It fills all available space in the view
- Marks
  - Area
  - Containment





# Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.  
–*Chap 7: Arrange Tables*
- Visualizing Data. Cleveland. Hobart Press, 1993.
- *A Brief History of Data Visualization*. Friendly. 2008.  
<http://www.datavis.ca/milestones>