Intro to Data Visualization

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REU Site 2023
Old Dominion University

Many slides courtesy Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14
Based on Tamara Munzner, *Visualization Analysis and Design*, AK Peters / CRC Press, Oct 2014

Slides adapted from Module-03 InfoVis from ODU CS 432/532 Web Science

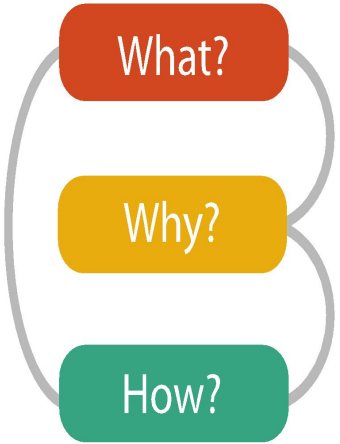
Roadmap

- Discuss Submitted Charts
  - https://piazza.com/class/liggjhb5nrb1wd/post/14
- Data and Basic Principles
- Intro to Creating Charts in Python
- Chart Types (Idioms) w/example code and exercises
  - Google Colab notebook

Visualization Analysis and Design by Tamara Munzner, available via ODU MIDAS login at https://go.oreilly.com/old-dominion-university/library/view/visualization-analysis-and/9781466508910/

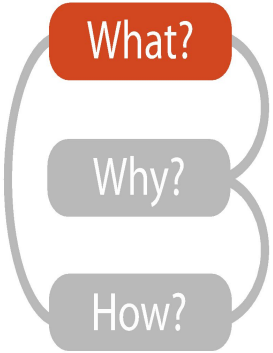
Analysis: What, why, and how

- what is shown?
  - **data** abstraction
- why is the user looking at it?
  - **task** abstraction
- how is it shown?
  - **idiom**: visual encoding and interaction



- what-why-how analysis framework as scaffold to think systematically about design space

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14



What?

Datasets

Data Types

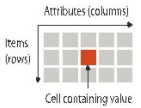
- Items
- Attributes
- Links
- Positions
- Grids

Data and Dataset Types

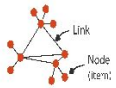
Tables	Networks & Trees	Fields	Geometry	Clusters, sets, lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

Dataset Types

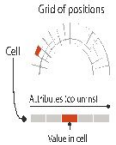
- Tables



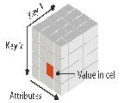
- Networks



- Fields (Continuous)



- *Multidimensional Table*



- *Trees*

- Geometry (Spatial)

Dataset Availability

- Static

- Dynamic

Attributes

Attribute Types

- Categorical

- Ordered
  - *Ordinal*

  - *Quantitative*

Ordering Direction

- Sequential

- Diverging

- Cyclic

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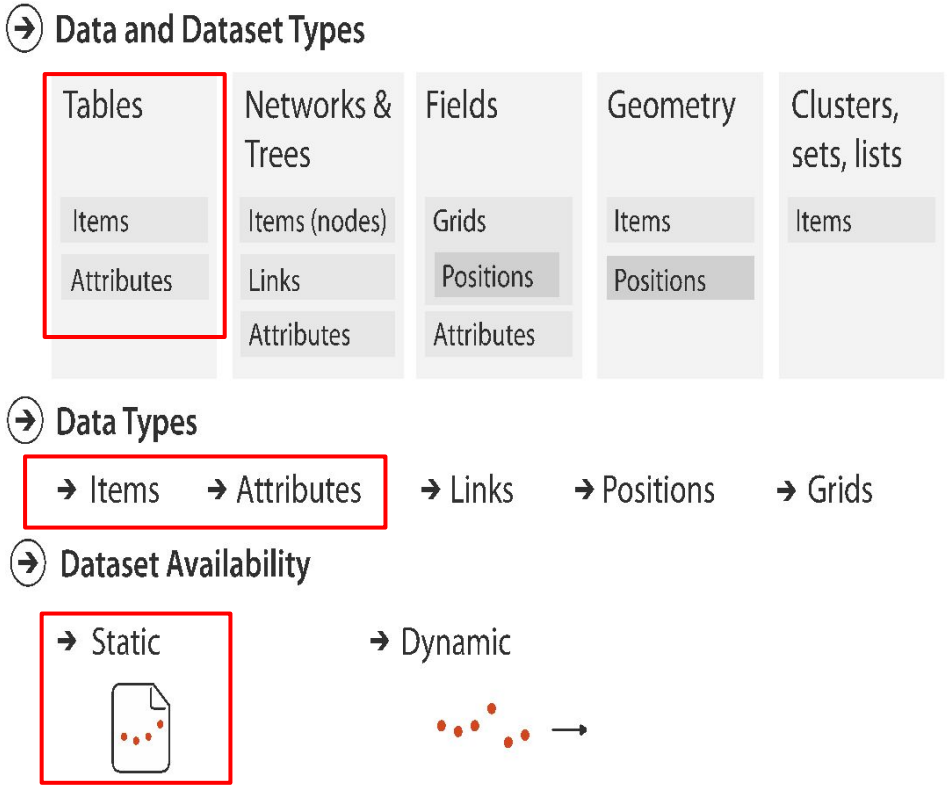
Dataset and data types



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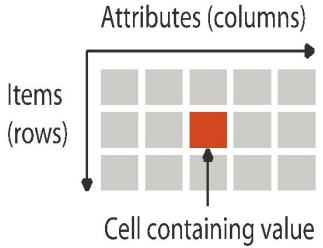
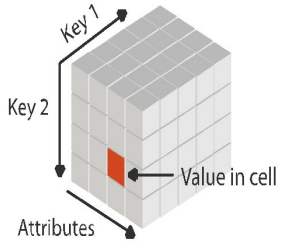
Keys and values

- 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

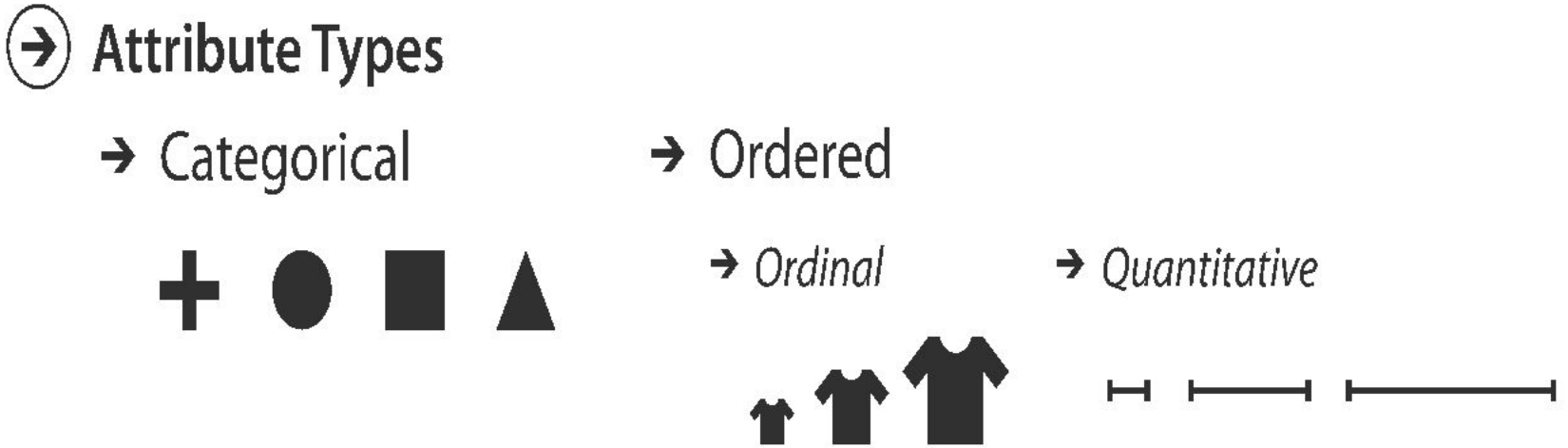


→ *Multidimensional Table*



Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Attribute types



Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Identify items, attributes, keys, types

date	precipitation	temp_max	temp_min	wind	weather
2012-01-01	0.0	12.8	5.0	4.7	drizzle
2012-01-02	10.9	10.6	2.8	4.5	rain
2012-01-03	0.8	11.7	7.2	2.3	rain
2012-01-04	20.3	12.2	5.6	4.7	rain
2012-01-05	1.3	8.9	2.8	6.1	rain
2012-01-06	2.5	4.4	2.2	2.2	rain
2012-01-07	0.0	7.2	2.8	2.3	rain

https://github.com/vega/vega-datasets/blob/next/data/seattle-weather.csv

"Graphics reveal data" -Edward Tufte

- Vis tools can allow people to explore data to find patterns or to determine if a statistical model actually fits the data

- ***But***, look out for questionable data
  - "just because it's numbers doesn't mean it's true"
  - is it a typo or something interesting?

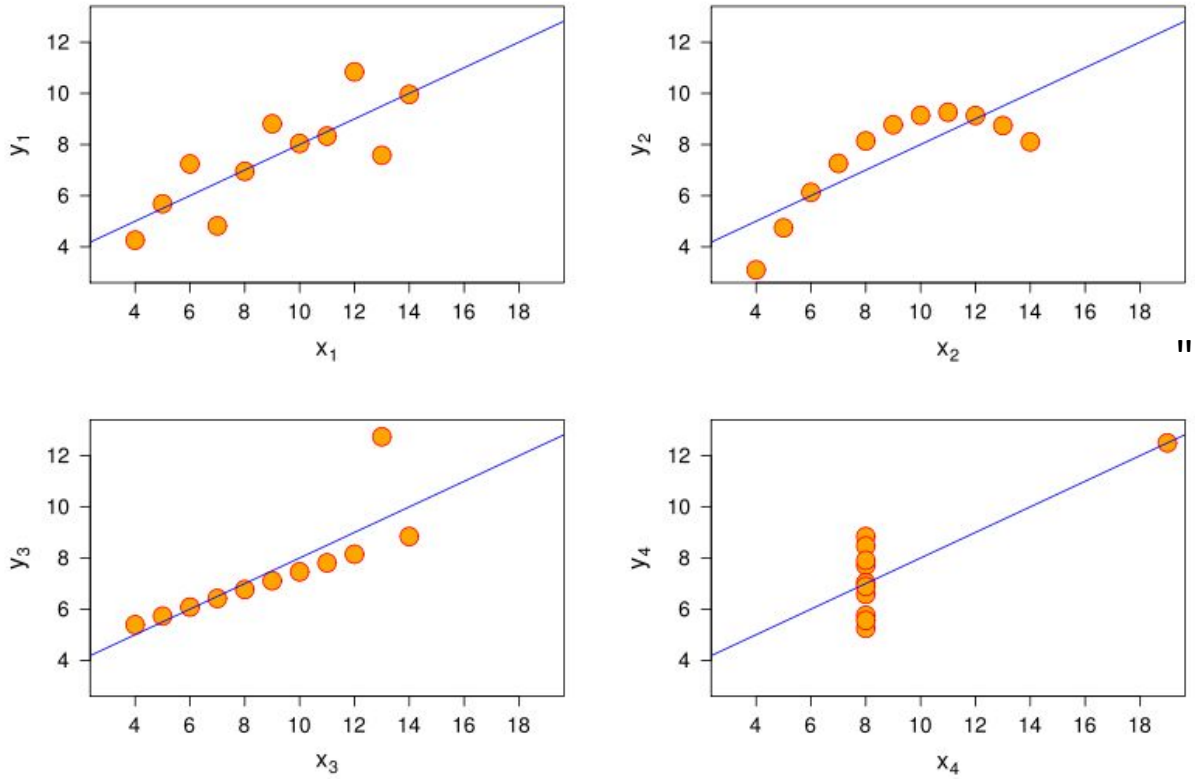
    "make sure you know which one it is"

Anscombe's Quartet

	I		II		III		IV	
	x	y	x	y	x	y	x	y
	10	8,04	10	9,14	10	7,46	8	6,58
	8	6,95	8	8,14	8	6,77	8	5,76
	13	7,58	13	8,74	13	12,74	8	7,71
	9	8,81	9	8,77	9	7,11	8	8,84
	11	8,33	11	9,26	11	7,81	8	8,47
	14	9,96	14	8,1	14	8,84	8	7,04
	6	7,24	6	6,13	6	6,08	8	5,25
	4	4,26	4	3,1	4	5,39	19	12,5
	12	10,84	12	9,13	12	8,15	8	5,56
	7	4,82	7	7,26	7	6,42	8	7,91
	5	5,68	5	4,74	5	5,73	8	6,89
SUM	99,00	82,51	99,00	82,51	99,00	82,50	99,00	82,51
AVG	9,00	7,50	9,00	7,50	9,00	7,50	9,00	7,50
STDEV	3,32	2,03	3,32	2,03	3,32	2,03	3,32	2,03

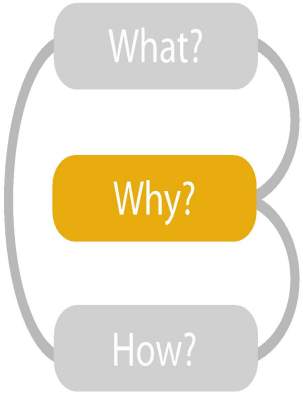
F.J. Anscombe, "Graphs in Statistical Analysis", *American Statistician*, Feb 1973
Image from https://medium.com/datadriveninvestor/anscombes-quartet-12649db7eac0, Munzner, Figure 1.3

The four data sets are *not* the same

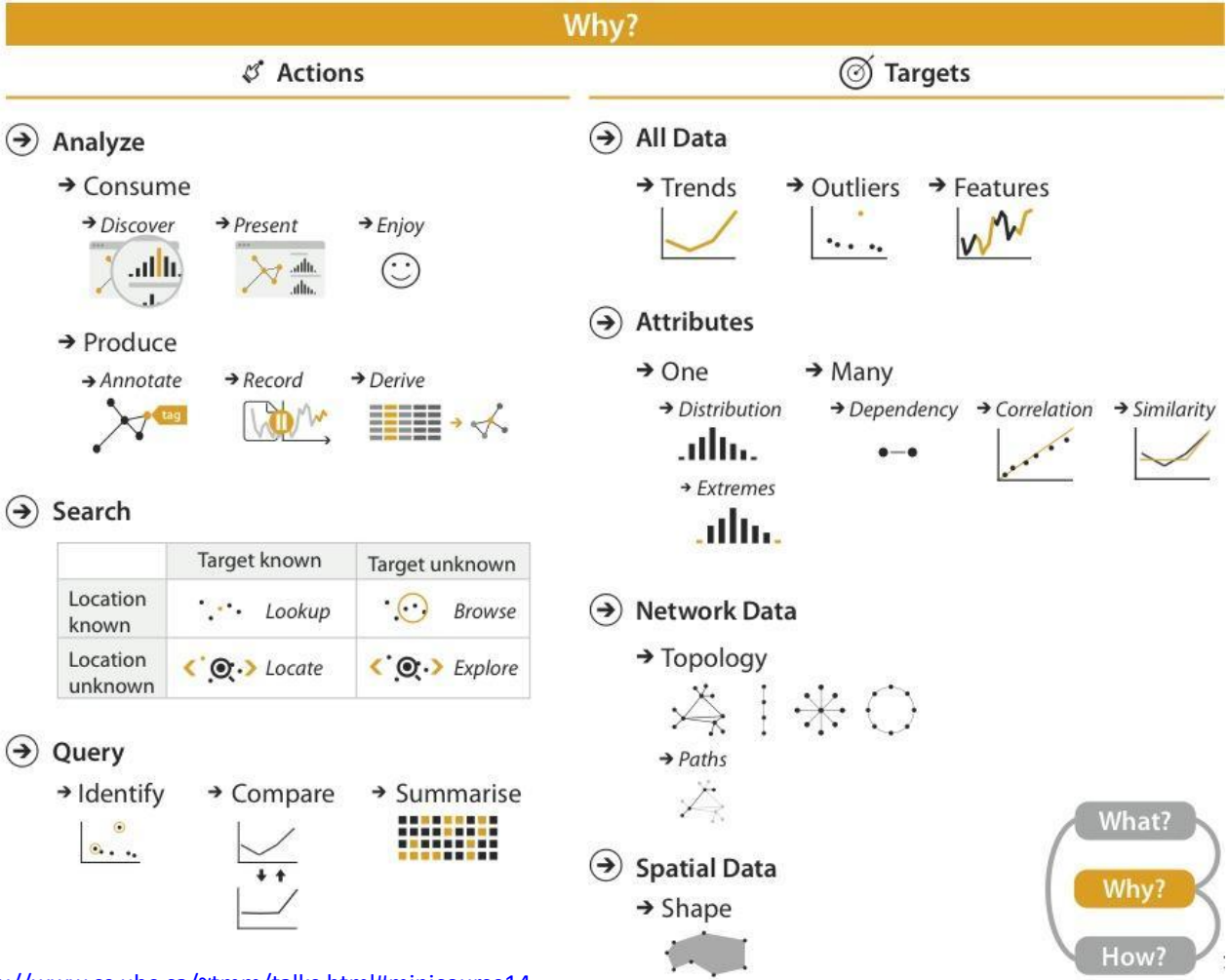


"Graphics *reveal* data"

http://en.wikipedia.org/wiki/File:Anscombe.svg



- {action, target} pairs
  - *discover distribution*
  - *compare trends*
  - *locate outliers*
  - *browse topology*



Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

High-level actions: Analyze

- consume
  - discover vs present
    - aka explore vs explain
  - enjoy
    - aka casual, social

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Actions: Mid-level search, low-level query

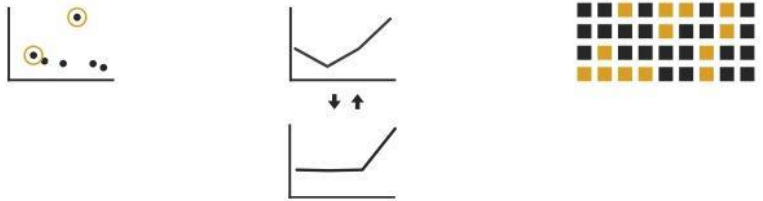
- what does user know?
  - target, location
- how much of the data matters?
  - one, some, all

Search

	Target known	Target unknown
Location known	Lookup	Browse
Location unknown	Locate	Explore

Query

→ Identify → Compare → Summarise



Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Why: Targets

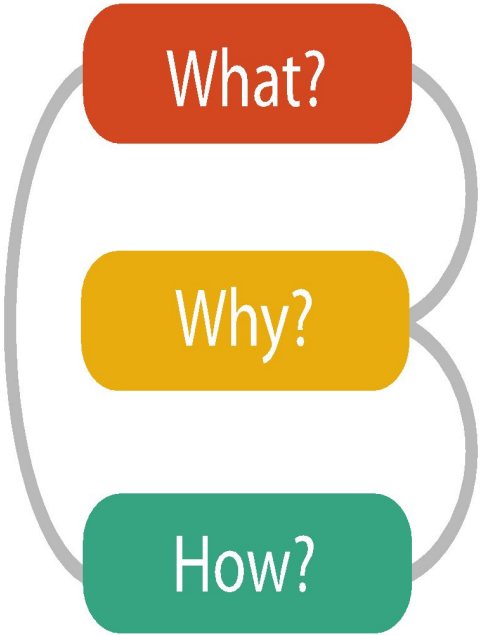
- ALL DATA
  - Trends
  - Outliers
  - Features

- ATTRIBUTES
  - One
    - Distribution
    - Extremes
  - Many
    - Dependency
    - Correlation
    - Similarity

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Workflow

- What
  - data gathering
  - data wrangling
- Why
  - developing questions
  - initial analysis
- How
  - charts for analysis
  - charts for presentation

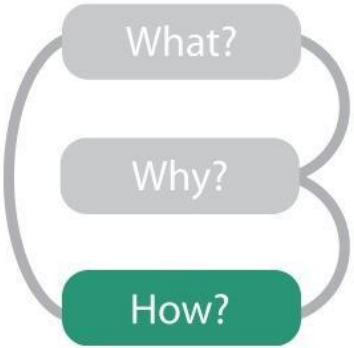


How?

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**

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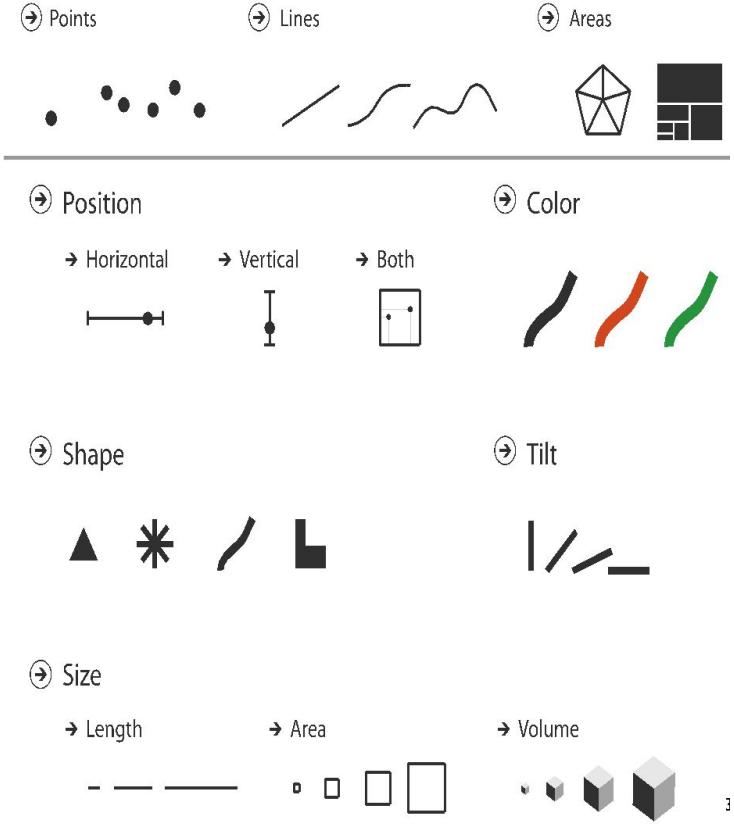
Definitions: Marks and channels

- marks
  - geometric primitives
- channels
  - control appearance of marks
  - can redundantly code with multiple channels

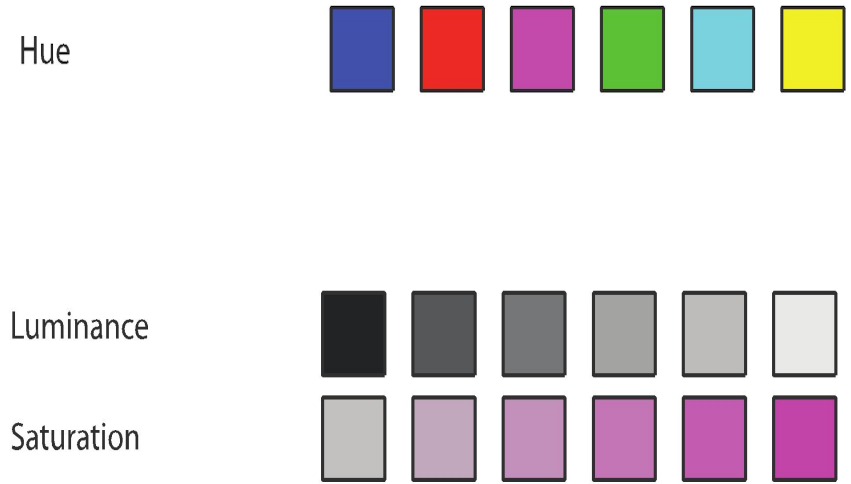
- interactions
  - point marks only convey position; no area constraints
    - can be size and shape coded
  - line marks convey position and length
    - can only be size coded in 1D (width)
  - area marks fully constrained
    - cannot be size or shape coded



Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Color: Luminance, saturation, hue

- 3 channels
  - identity channel for categorical
    - hue
  - magnitude channels for ordered
    - luminance
    - saturation



Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Color Spaces

- Six different hues ordered by luminance
  - computed lightness *L* values same (HSL color space)
  - true luminance is closer to what we perceive
  - *L** is computed perceptually linear luminance - best match to what we see

Fig 10.3, *VAD*

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Spectral Sensitivity to Luminance

We are much more sensitive to middle wavelengths of green and yellow than to outer wavelengths of red and blue

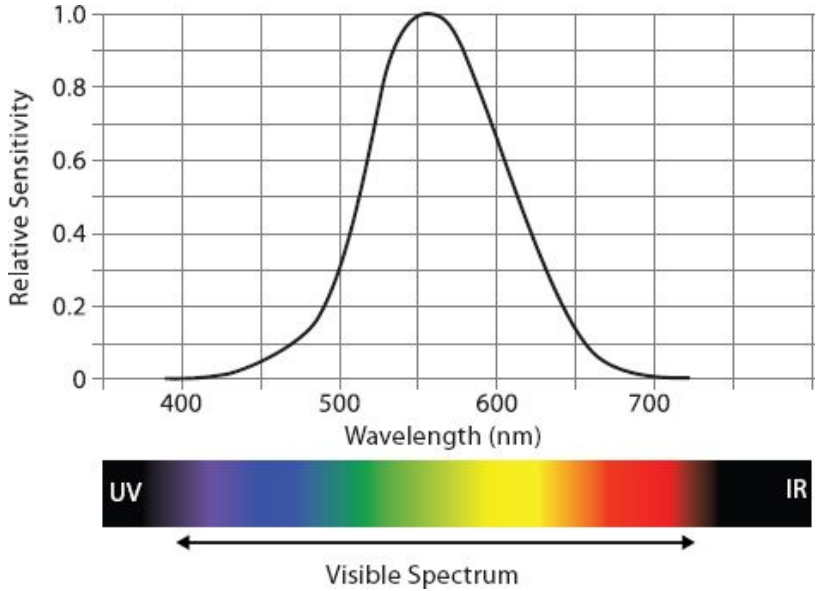


Fig 10.4, *VAD*

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Rainbow Colormaps

- Standard rainbow colormap is perceptually non-linear
- Perceptually linear rainbow colormap
  - seems dingy, rarely used
- Segmented rainbow, good for categorical data

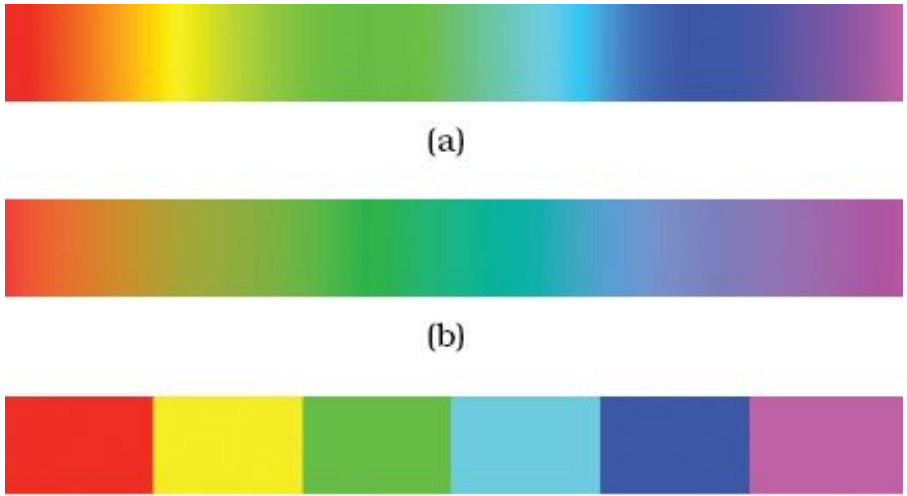
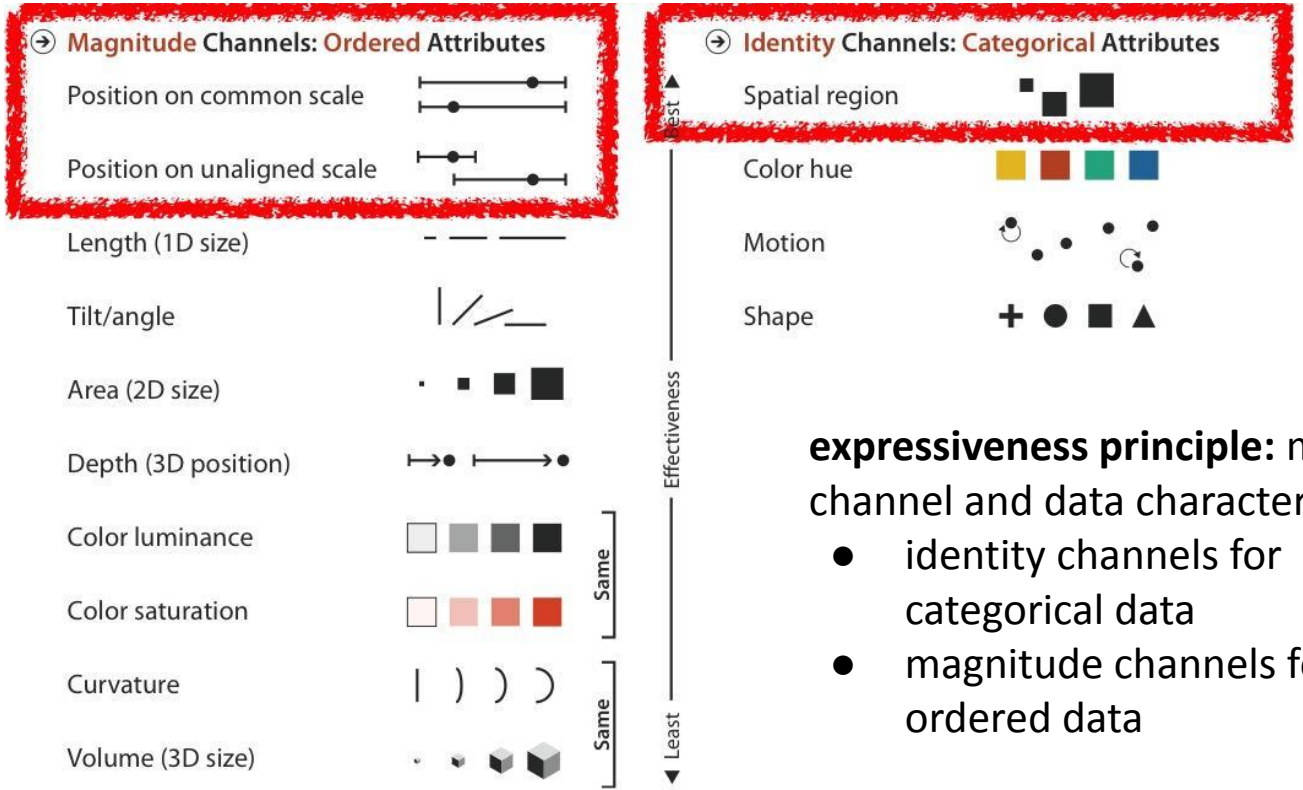


Fig 10.13, *VAD*

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Channels: Expressiveness types and effectiveness rankings

effectiveness principle: encode most important attributes with highest ranked channels



expressiveness principle: match channel and data characteristics

- identity channels for categorical data
- magnitude channels for ordered data

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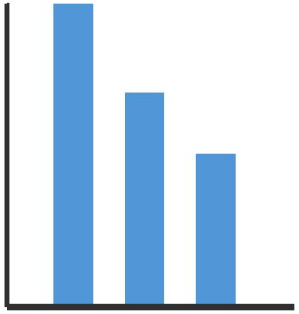
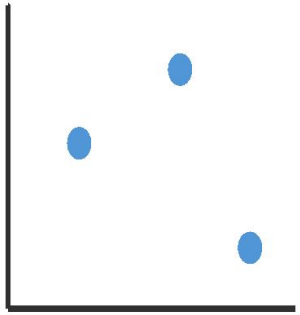
Visual encoding



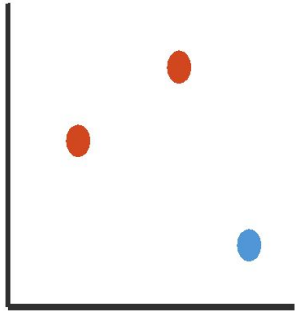
1:
vertical position

mark: line



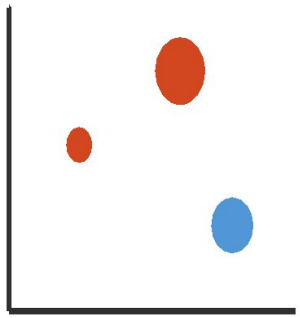
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point



4:
vertical position
horizontal position
color hue
size (area)

mark: point

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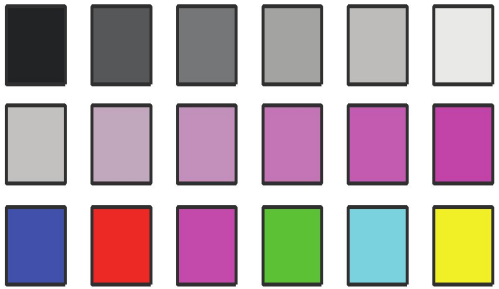
Discriminability

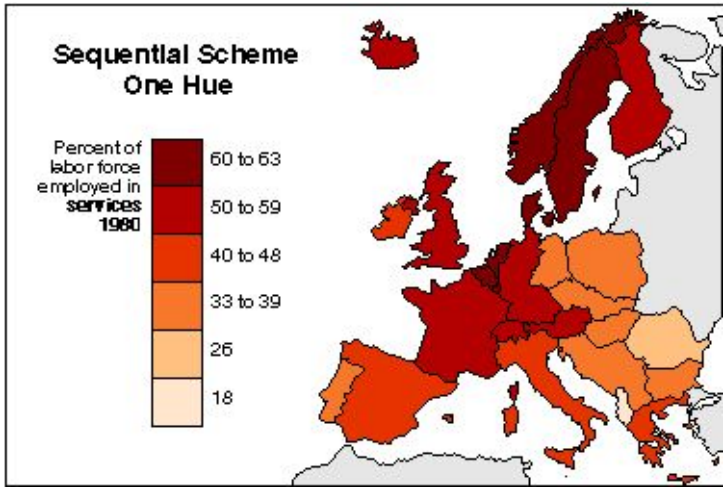
In a single channel, how many bins (distinguishable steps/levels) are there?

- luminance: < 5
- saturation: about 3
- hue: 6-7
- linewidth: only a few



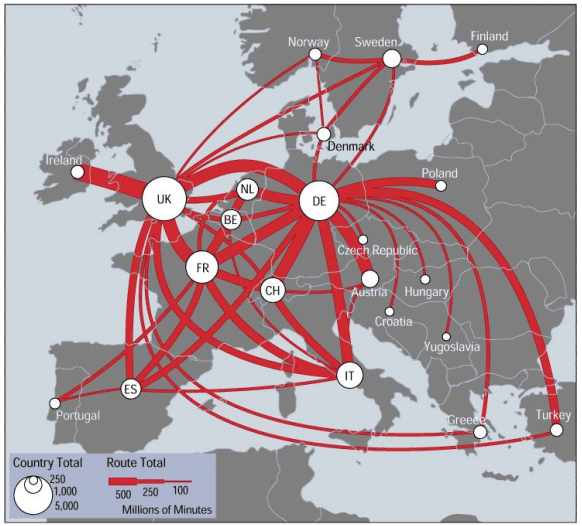
Can you discriminate between the different levels in each channel?

channel: saturation



https://web.natur.cuni.cz/~langhamr/lectures/vtfg1/mapinfo_2/barvy/colors.html

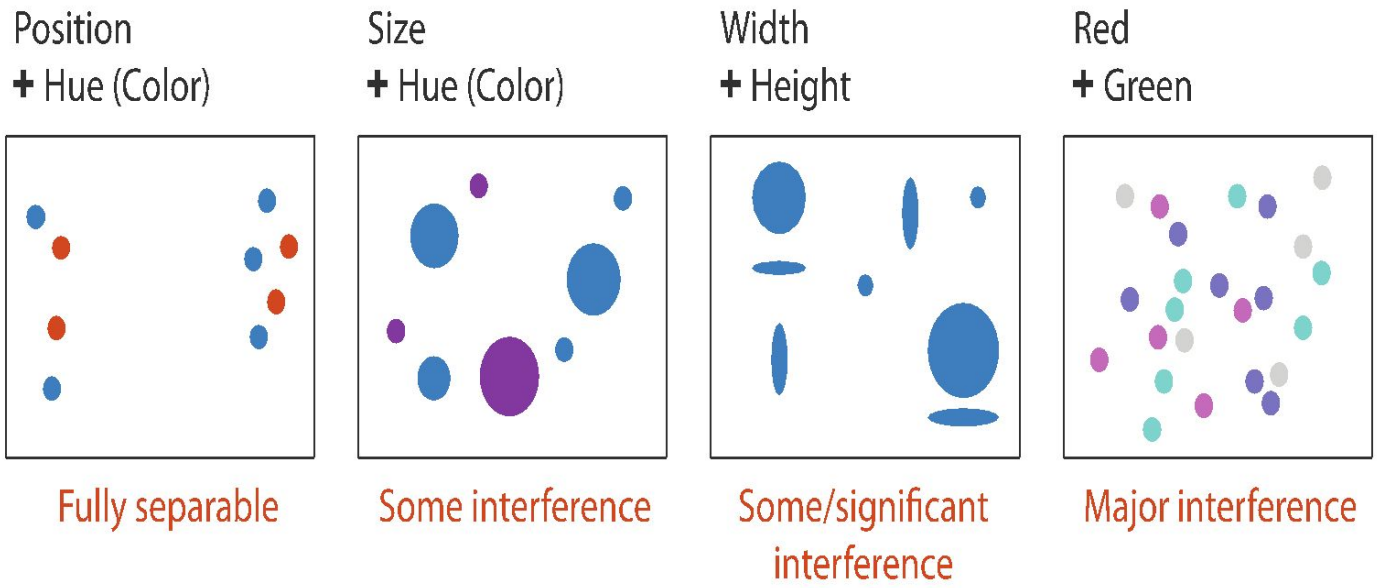
channel: linewidth



source: *Telecommunications Traffic Flow Map*

Separability vs. Integrality

When combining multiple channels, can the viewer separate the values mapped to each channel?



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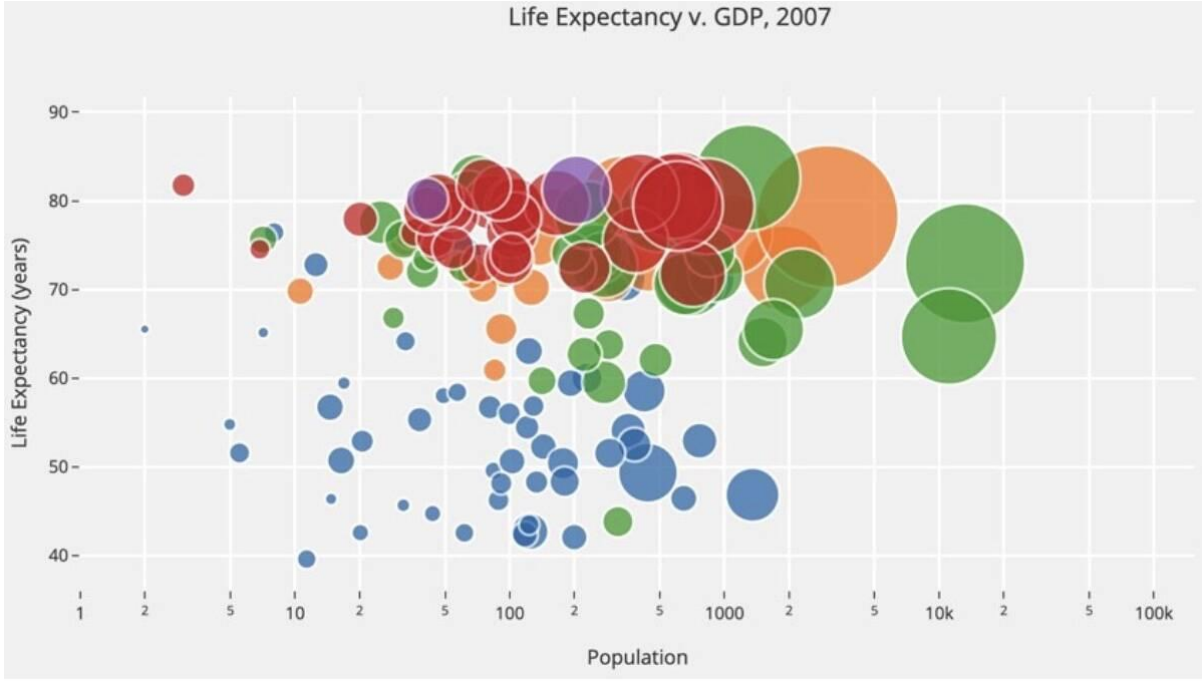
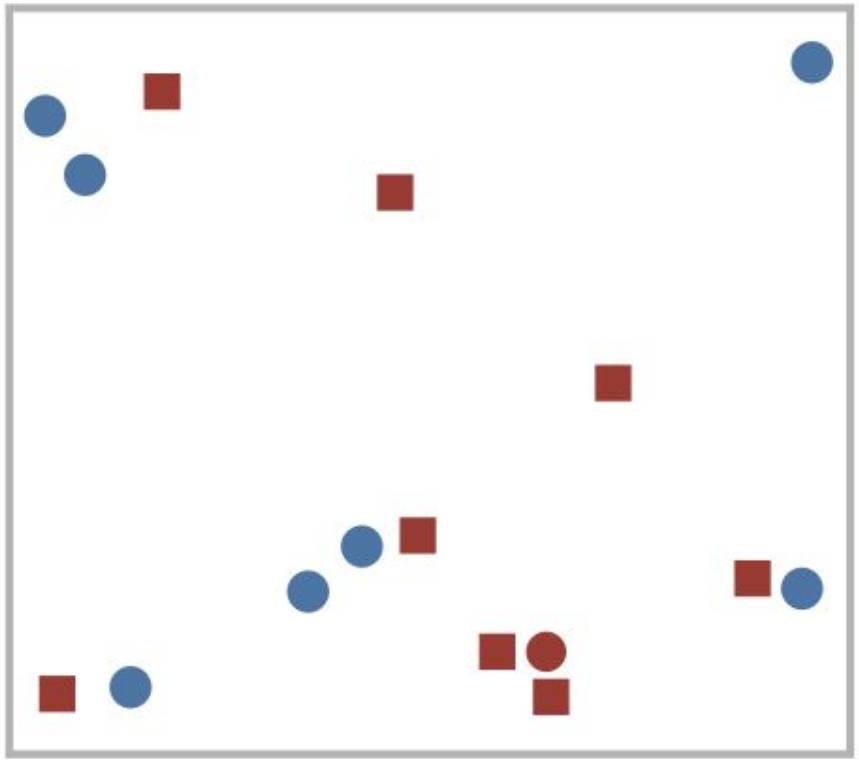
Can you group the bubbles of the same size apart from their color?



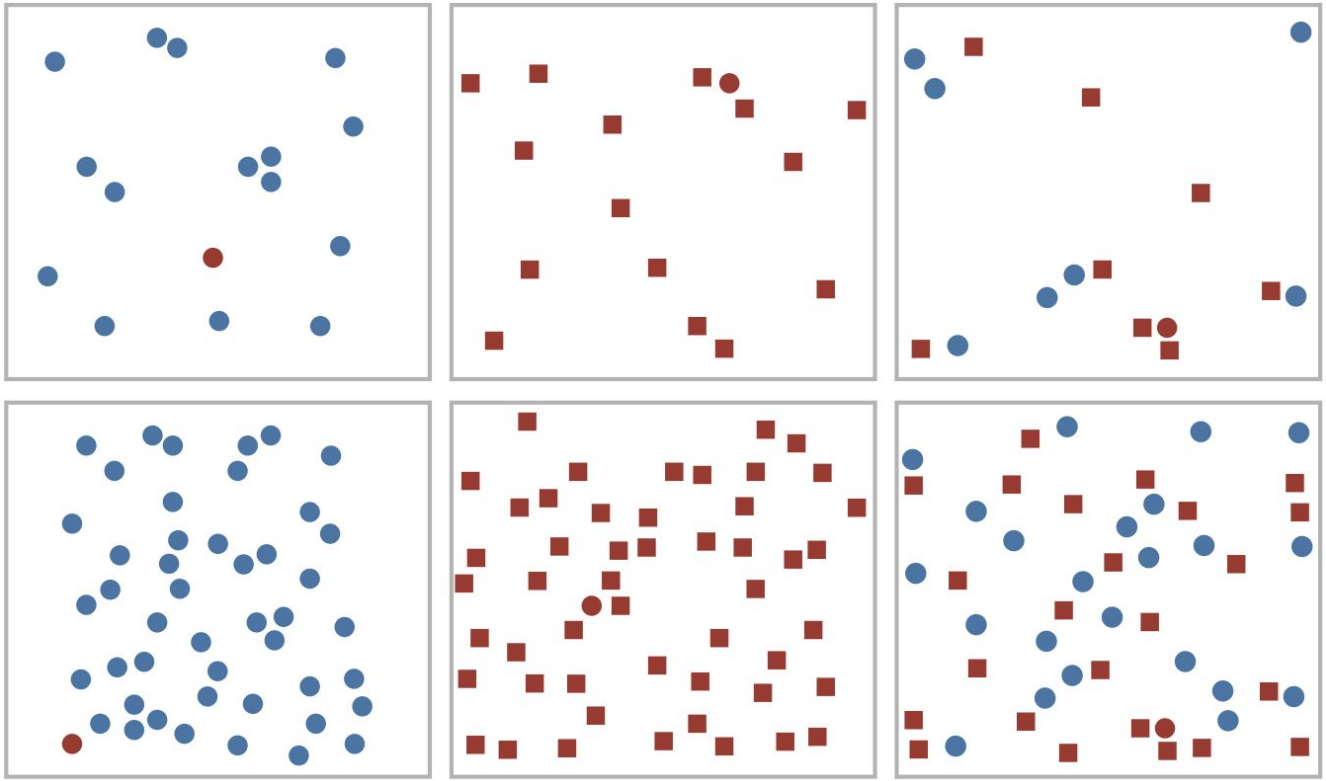
https://www.spiritedpuddlejumper.com/the-history-of-bubble-charts/

Popout: How long does it take to find the red dot?



https://www.csc2.ncsu.edu/faculty/healey/PP/

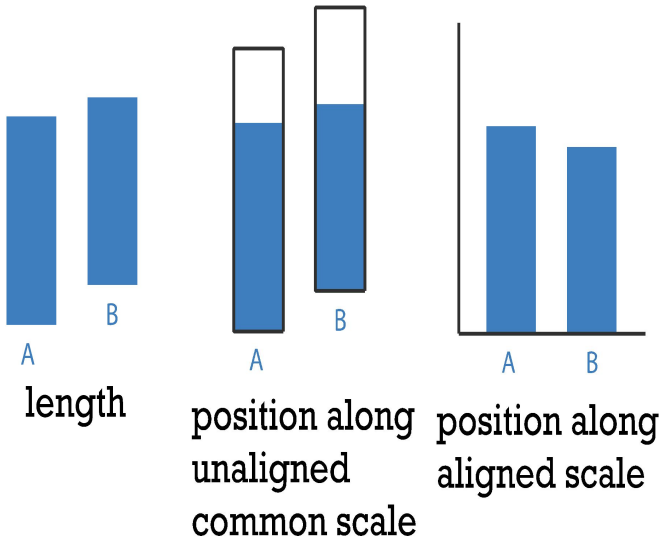
Popout (aka preattentive processing)



https://www.csc2.ncsu.edu/faculty/healey/PP/

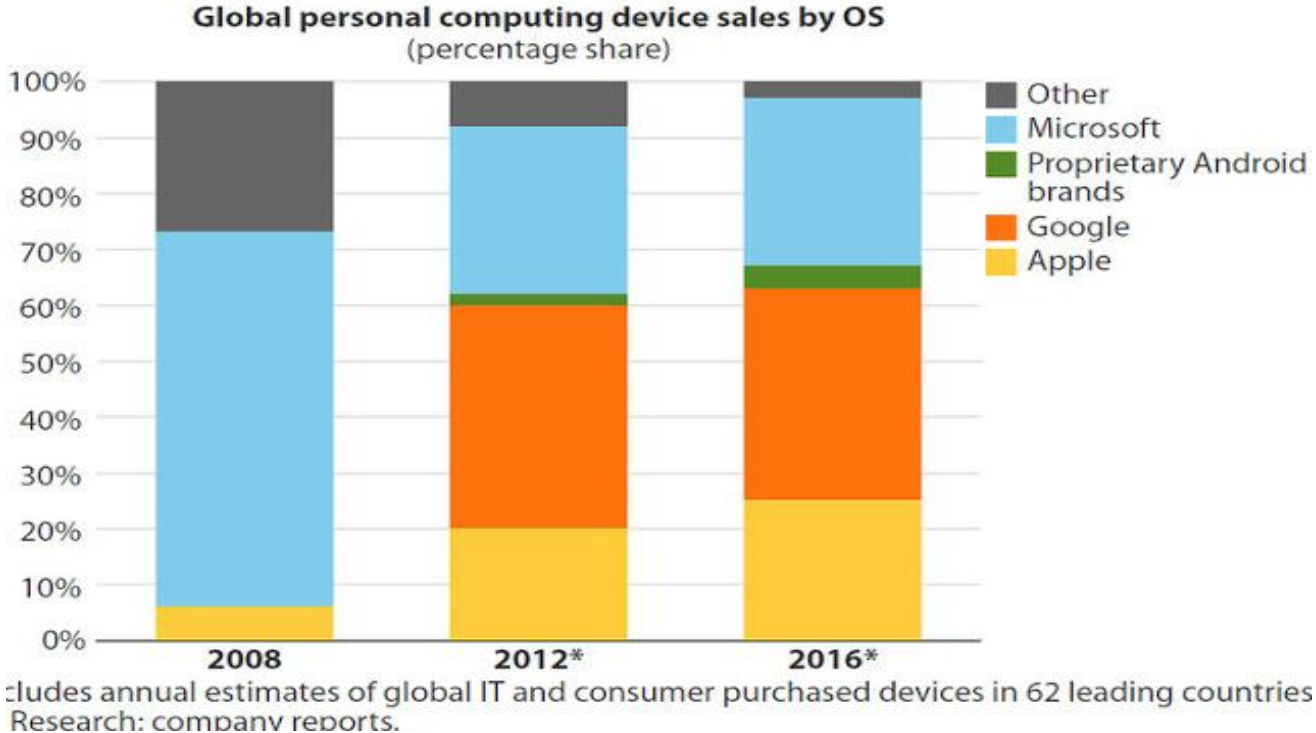
Relative vs. absolute judgments

- perceptual system mostly operates with relative judgments, not absolute
  - accuracy increases with common frame/scale and alignment
  - adding frame allows us to judge the length of the unfilled bar
    - sizes have a larger difference than the filled bars
  - aligning achieves the same effect without using a frame



after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Which bars is it easier to compare?



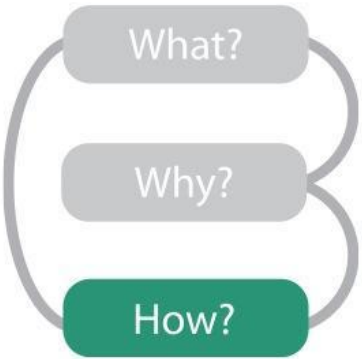
https://www.storytellingwithdata.com/blog/2012/11/to-stack-or-not-to-stack

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**

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

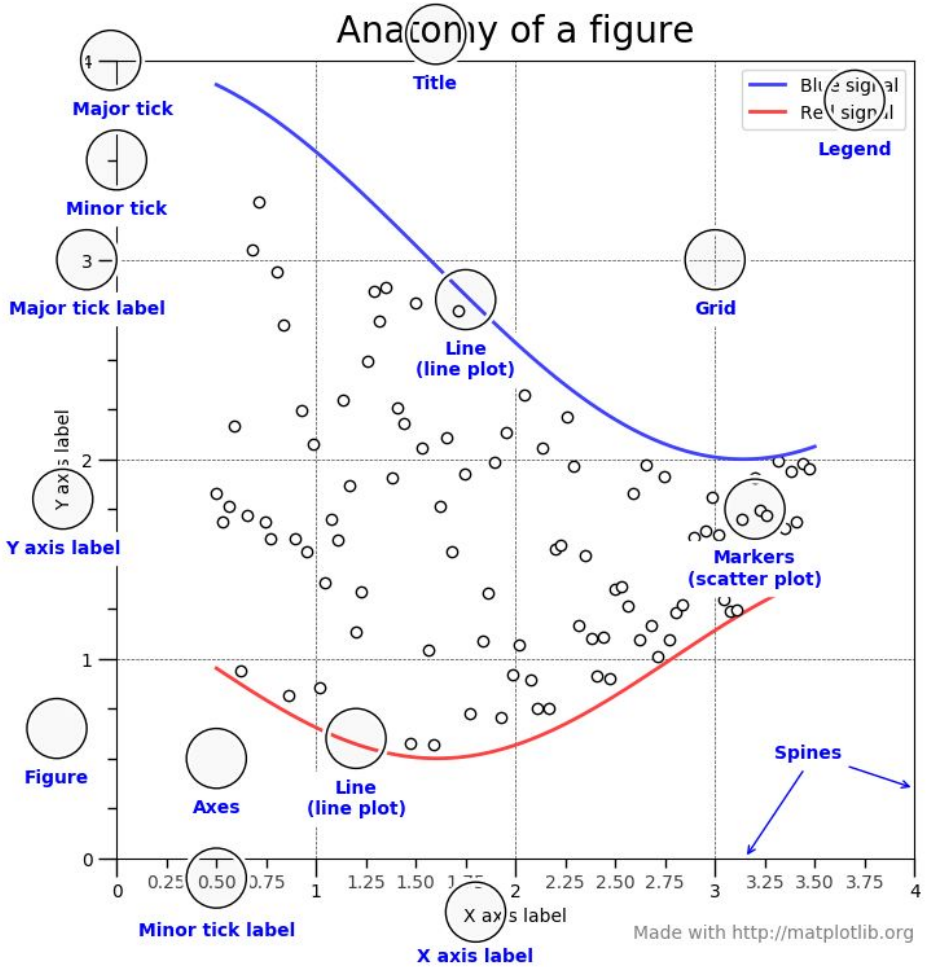
Creating Charts in Python

- Matplotlib, https://matplotlib.org/
  - most popular Python plotting library, similar to MATLAB
  - provides full control over the plot
  - developed way before Pandas, so harder to integrate
- Pandas, https://pandas.pydata.org/docs/user_guide/visualization.html
  - visualization in Pandas is a wrapper around Matplotlib
- Seaborn, https://seaborn.pydata.org/
  - high-level interface to Matplotlib
  - closely integrated with Pandas
  - allows for more complex charts than Pandas plot()
  - can still use Matplotlib for advanced chart customization

https://towardsdatascience.com/matplotlib-seaborn-pandas-an-ideal-amalgamation-for-statistical-data-visualisation-f619c8e8baa3

A Few Python Charting Resources

- Matplotlib API reference, https://matplotlib.org/stable/api/index
- Matplotlib Tutorials, https://matplotlib.org/stable/tutorials/index.html
- Seaborn API reference, https://seaborn.pydata.org/api.html
- Seaborn user guide and tutorial, https://seaborn.pydata.org/tutorial.html
- Pandas plot API reference, https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.plot.html
- Matplotlib + Seaborn + Pandas: An Ideal Amalgamation for Statistical Data Visualisation, https://towardsdatascience.com/matplotlib-seaborn-pandas-an-ideal-amalgamation-for-statistical-data-visualisation-f619c8e8baa3
- Visualization with Seaborn, https://jakevdp.github.io/PythonDataScienceHandbook/04.14-visualization-with-seaborn.html
- Data Visualization with Pandas and Seaborn, https://levelup.gitconnected.com/data-visualization-with-pandas-and-seaborn-5de444b567a0

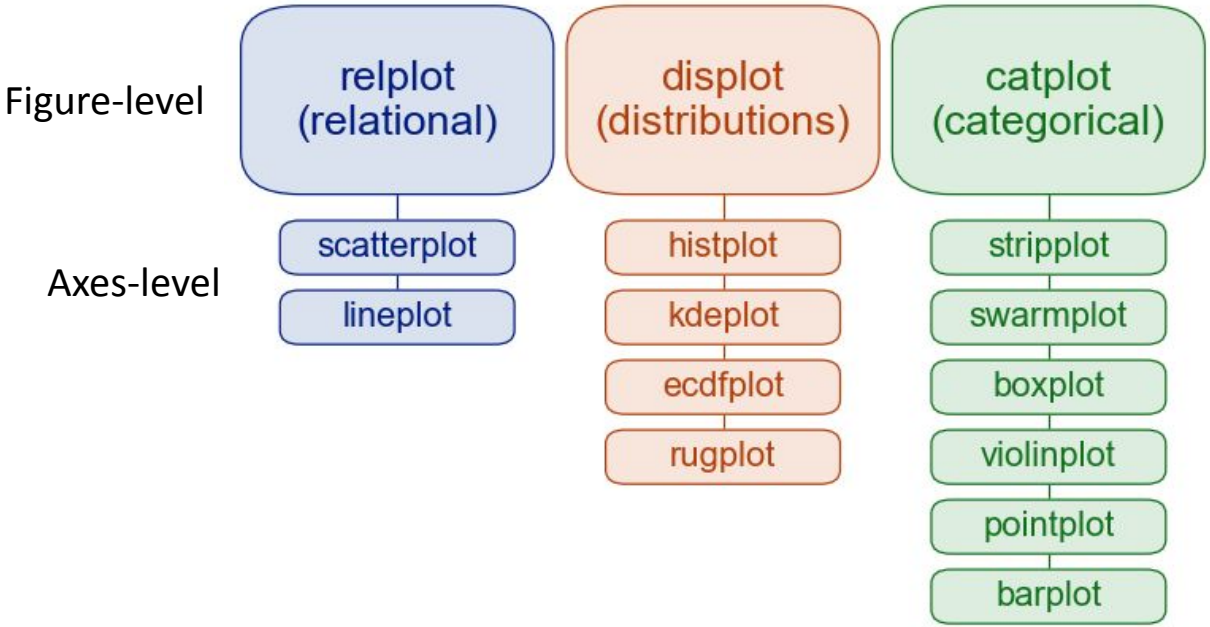


- Figure
  - the whole figure
- Axes
  - an actual plot in the figure
  - can be multiple of these (subplots) in a single figure
- Axis
  - an actual x/y axis in a specific plot

*Functions in Seaborn are either **Figure**-level or **Axes**-level*

https://towardsdatascience.com/matplotlib-seaborn-pandas-an-ideal-amalgamation-for-statistical-data-visualisation-f619c8e8baa3

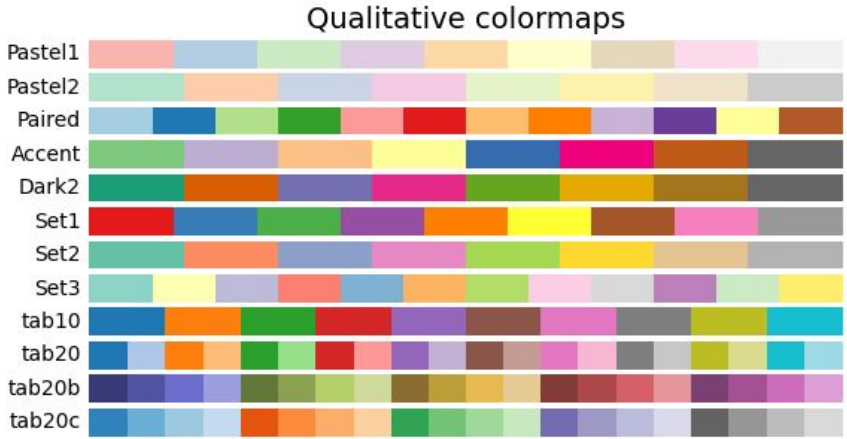
Seaborn Figure-Level vs. Axes-Level



https://seaborn.pydata.org/tutorial/function_overview.html#figure-level-vs-axes-level-functions

Colormaps in Matplotlib

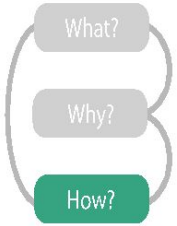
Qualitative = categorical

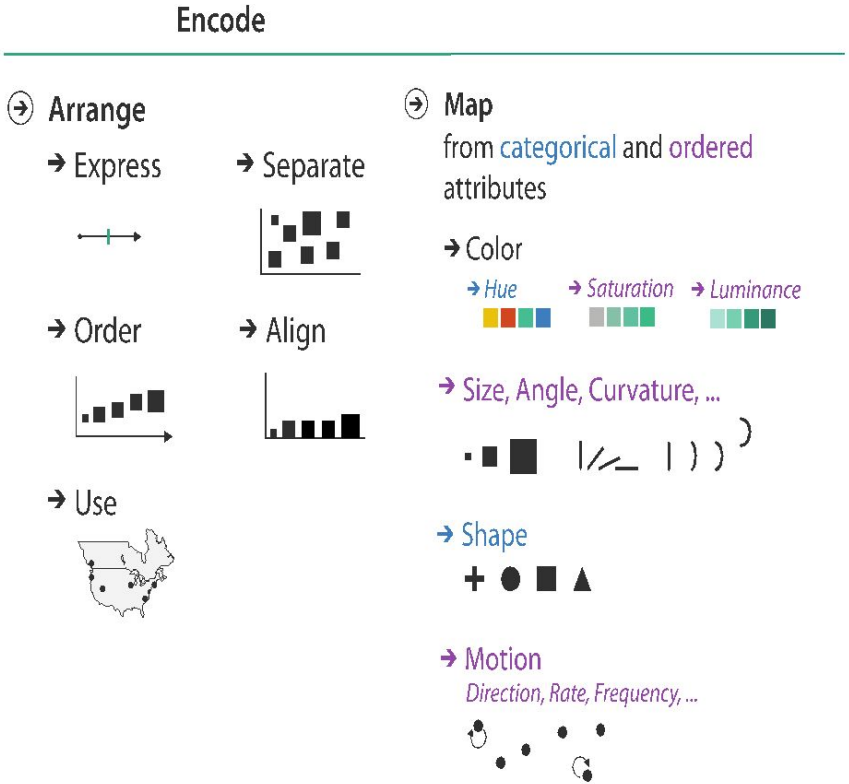


https://matplotlib.org/stable/tutorials/colors/colormaps.html

Idiom design choices: Part 1

idiom: distinct approach to creating or manipulating visual representation





Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Arrange tables

- Express Values

- Separate, Order, Align Regions
  - Separate

  - Order

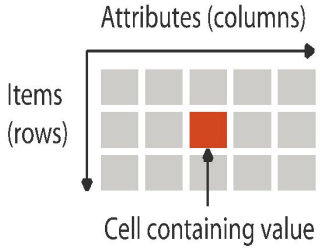
  - Align

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

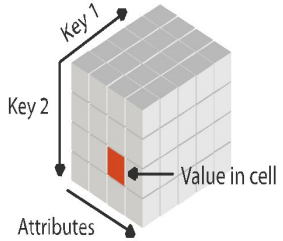
Reminder: Keys and values

- 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



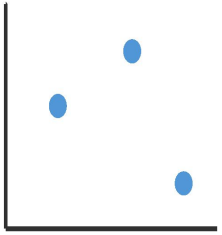
→ *Multidimensional Table*

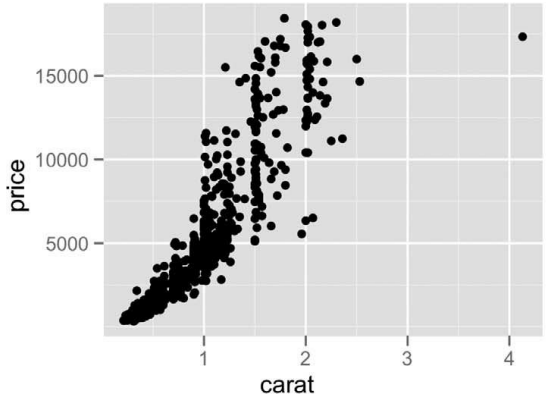


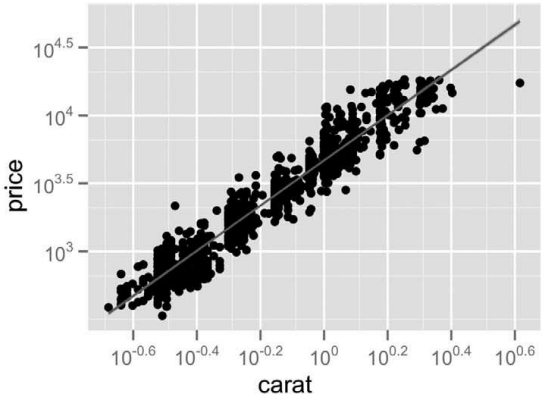
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

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







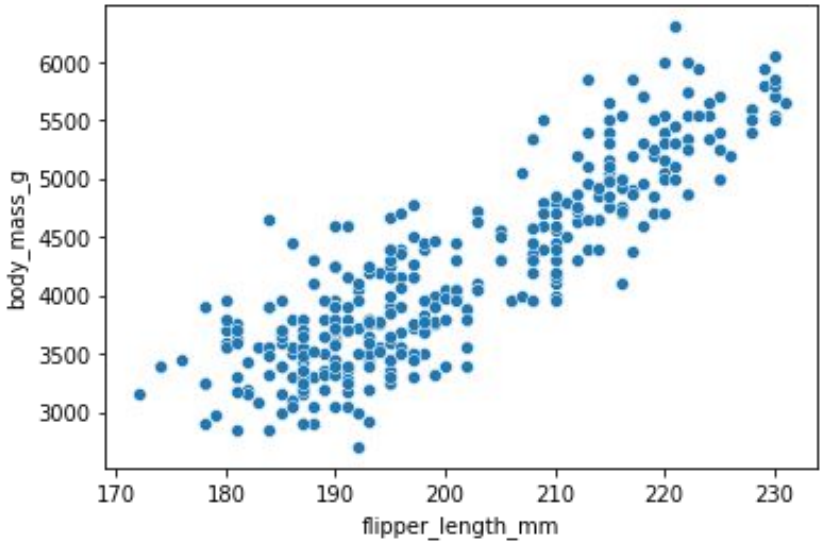
source: [A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Basic Scatterplot using Seaborn

```
sns.scatterplot(data=penguins, x="flipper_length_mm", y="body_mass_g")
```

```
penguins = sns.load_dataset("penguins")
penguins.head()
```

	species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g
0	Adelie	Torgersen	39.1	18.7	181.0	3750.0
1	Adelie	Torgersen	39.5	17.4	186.0	3800.0
2	Adelie	Torgersen	40.3	18.0	195.0	3250.0



notebook with exercise:
https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=PsnBm1atRBuS

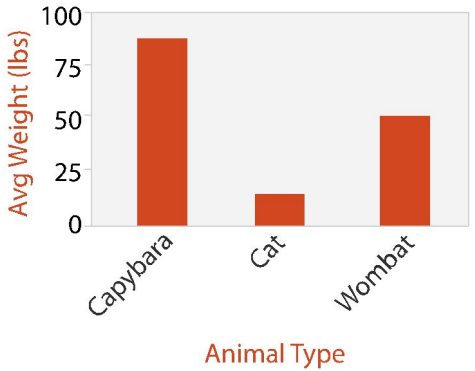
Some keys: Categorical regions

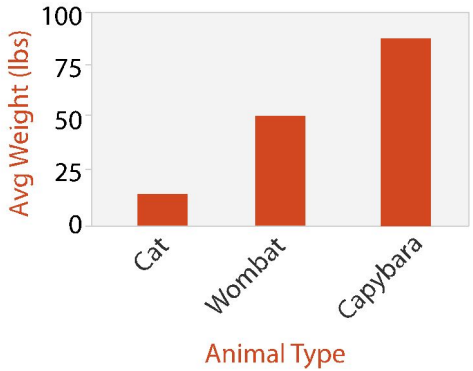
- **regions**: contiguous bounded areas distinct from each other
  - using space to ***separate*** (proximity)
  - following expressiveness principle for categorical attributes
- use ordered attribute to ***order*** and ***align*** regions

Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

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
      - **separate**d horizontally, **align**ed vertically
      - **order**ed by quant attrib
        - » by label (alphabetical), by length attrib (data-driven)
  - task
    - compare, lookup values
  - scalability
    - dozens to hundreds of levels for key attrib





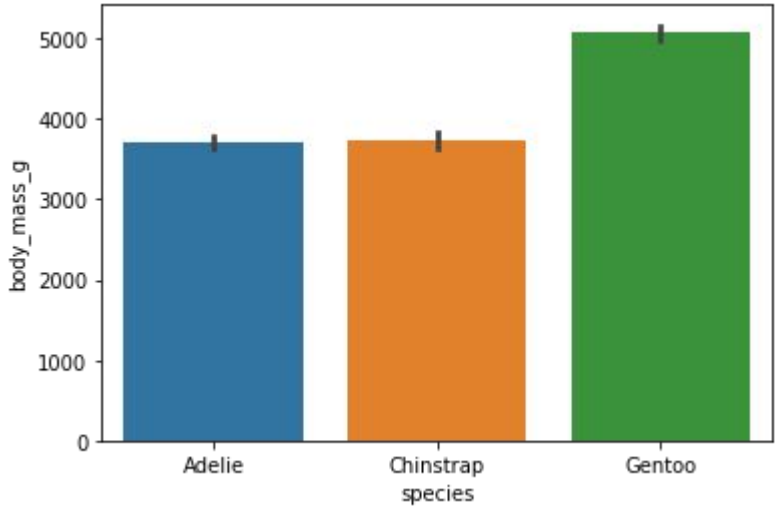
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Basic Bar Chart using Seaborn

```
sns.barplot(data=penguins, x="species", y="body_mass_g");
```

```
penguins = sns.load_dataset("penguins")
penguins.head()
```

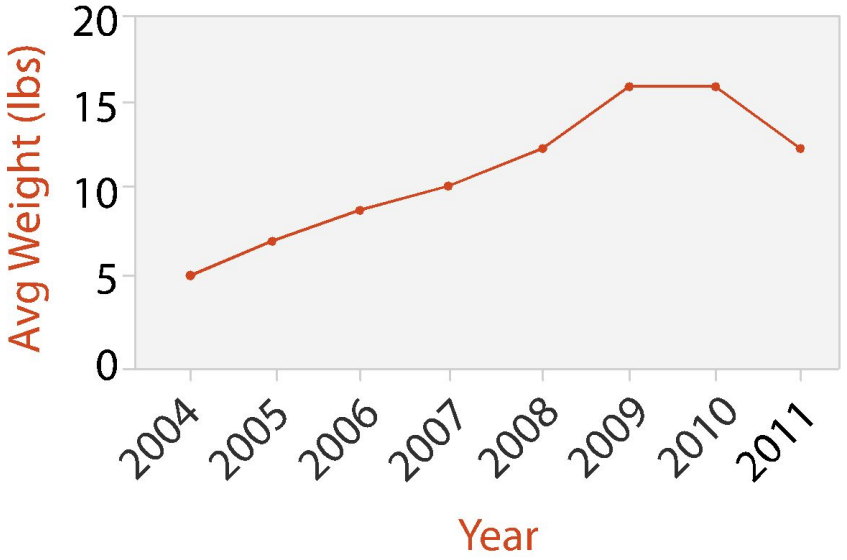
	species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g
0	Adelie	Torgersen	39.1	18.7	181.0	3750.0
1	Adelie	Torgersen	39.5	17.4	186.0	3800.0
2	Adelie	Torgersen	40.3	18.0	195.0	3250.0



notebook with exercise:
https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=_pzMwxshRDRM

Idiom: **line chart**

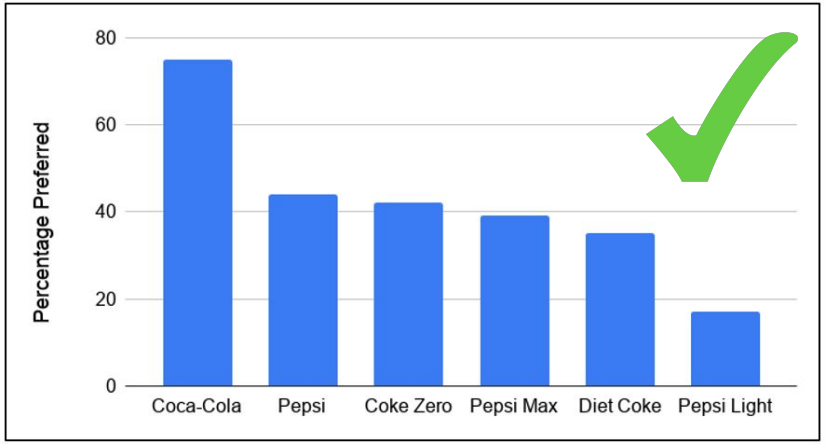
- one key, one value
  - data
    - 1 quant attrib, 1 ordered attrib
  - mark: points
    - line connection marks between them
  - channels
    - aligned vertical position
    - separated and ordered by key attrib into horizontal regions
  - task
    - find trend
      - connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next



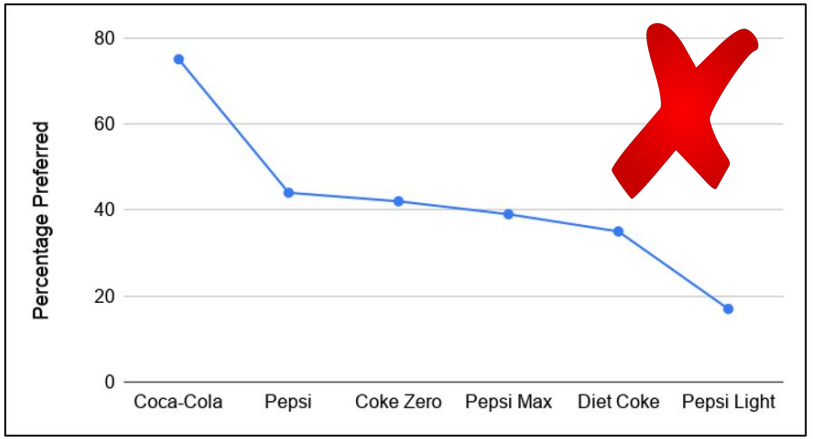
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

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!

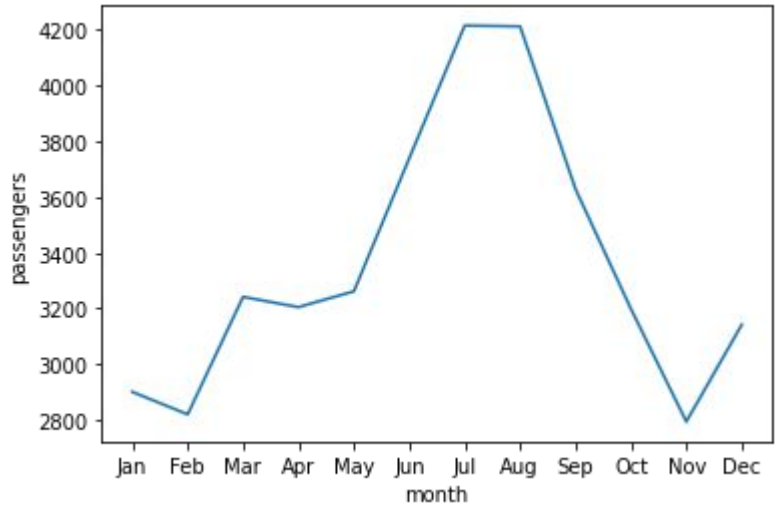


Basic Line Chart using Seaborn

```
sns.lineplot(data=per_month, x="month", y="passengers")
```

per_month

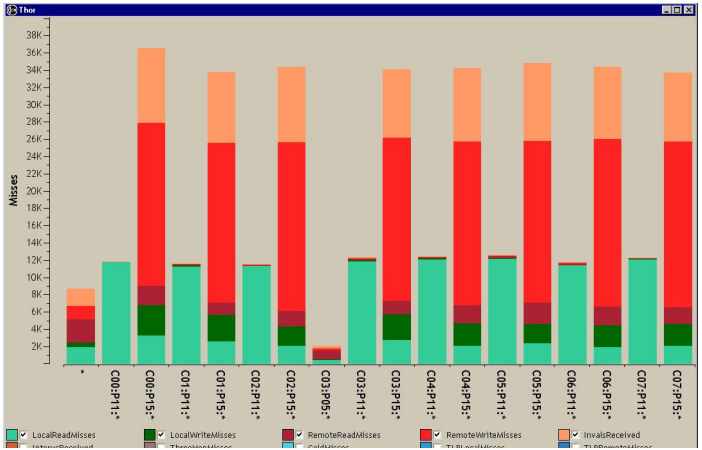
	month	passengers
0	Jan	2901
1	Feb	2820
2	Mar	3242
3	Apr	3205
4	May	3262



notebook: https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=2viXqJtwREmc

Idiom: **stacked bar chart**

- 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



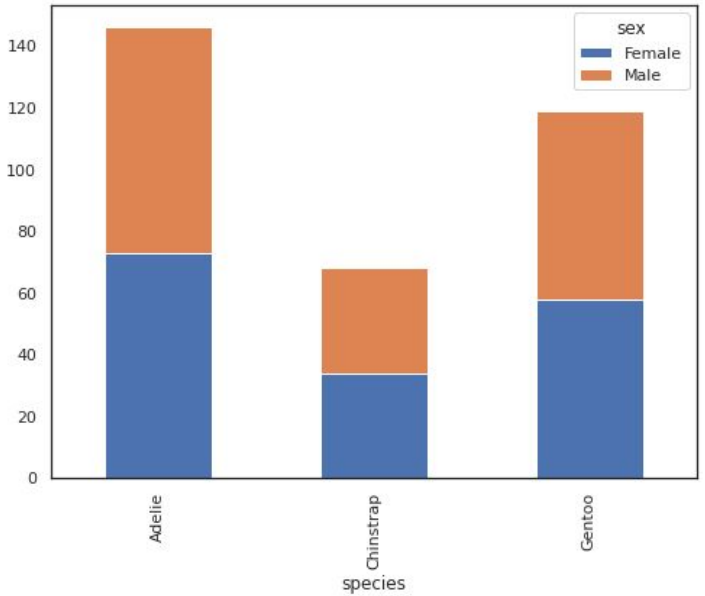
source: [Using Visualization to Understand the Behavior of Computer Systems. Bosch. Ph.D. thesis, Stanford Computer Science, 2001.]

Stacked Bar Chart using Pandas Plot

```
penguin_pivot.plot.bar(stacked=True)
```

penguin_pivot

species	sex Female	Male
Adelie	73	73
Chinstrap	34	34
Gentoo	58	61



for your review after the workshop

notebook: https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=tsfGoH85-byP

Idiom: Grouped Bar Chart

- data: 2 categ attrib, 1 quant attrib
- mark: multibar glyph in each region
- channels
  - length and color hue
  - spatial regions: one per glyph
- task: compare, lookup values (same as bar chart)

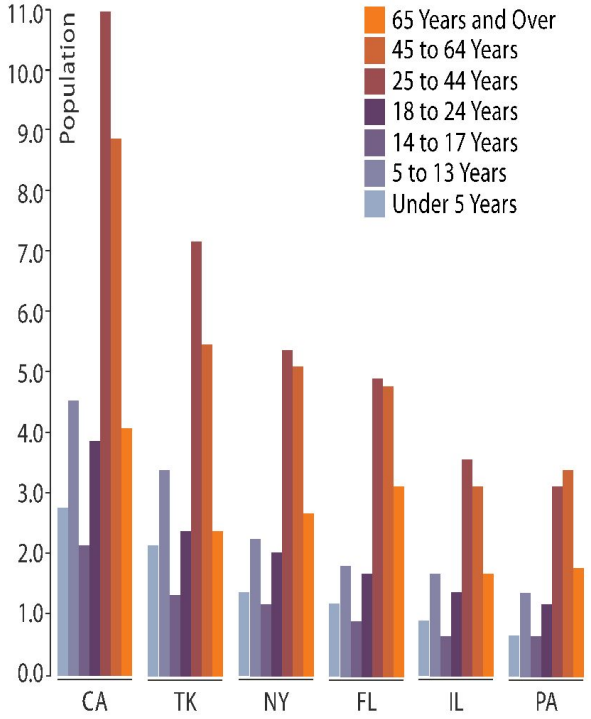


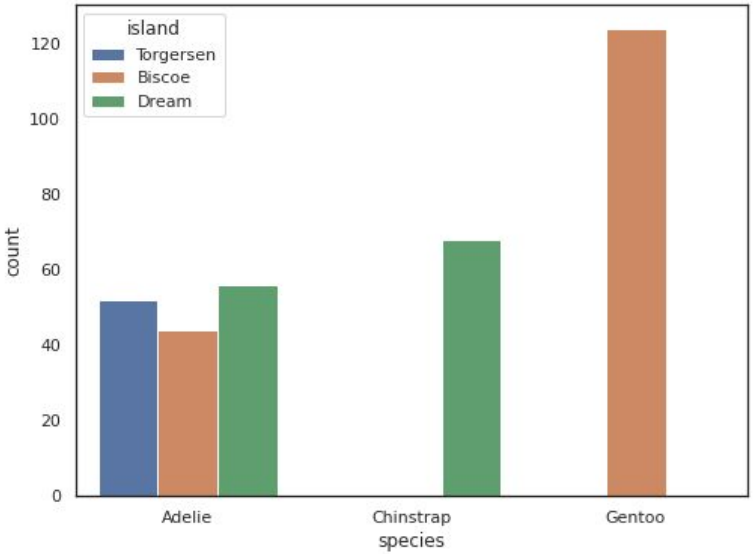
Fig 12.8a, *VAD*

Grouped Bar Chart using Seaborn

```
sns.countplot(data=penguins, x="species", hue="island")
```

```
penguins = sns.load_dataset("penguins")
penguins.head()
```

	species	island	bill_length_mm	bill_depth_mm
0	Adelie	Torgersen	39.1	18.7
1	Adelie	Torgersen	39.5	17.4
2	Adelie	Torgersen	40.3	18.0

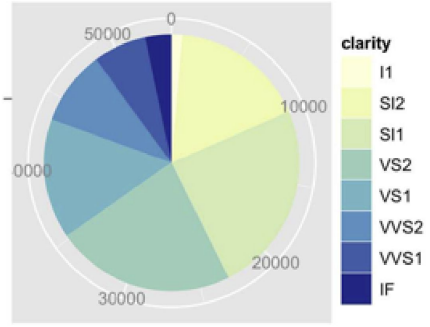


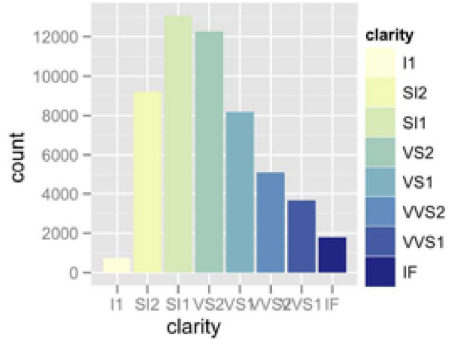
notebook: https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=3zHUIj1uAGAy

Idioms: **pie chart**

- pie chart
  - area marks with angle channel
  - accuracy: angle/area much less accurate than line length
- data
  - 1 categ key attrib, 1 quant value attrib
- task
  - part-to-whole judgments

Think carefully before choosing pie charts when there are more than 3-4 categories.





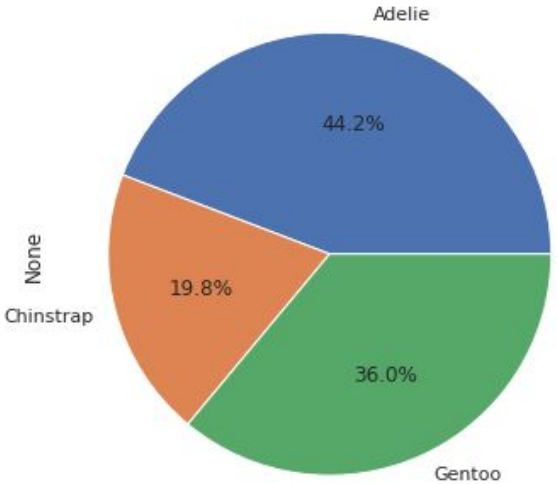
[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Pie Chart using Pandas Plot

```
data.plot.pie(autopct="%.1f%%")
```

```
data = penguins.groupby("species").size()
data
```

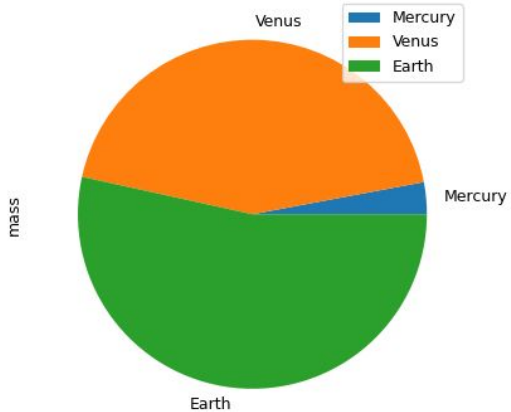
```
species
Adelie       152
Chinstrap     68
Gentoo       124
dtype: int64
```

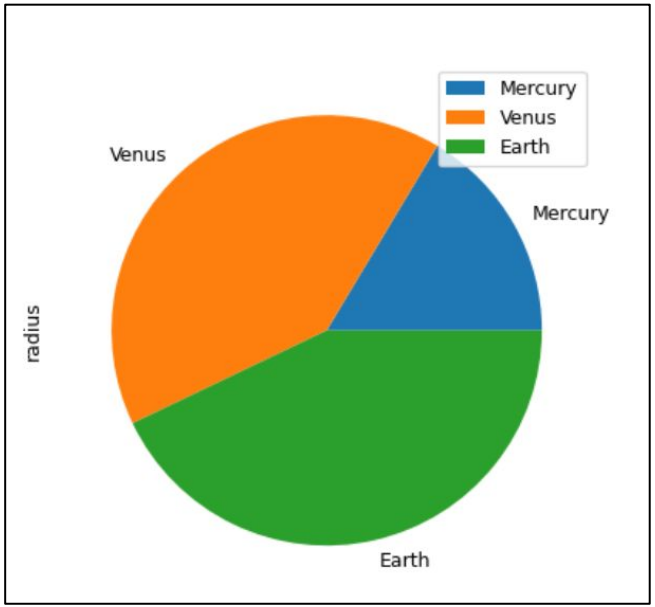


for your review after the workshop
notebook: https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=Kakoma6aEaBL

Be careful with pie charts

```
>>> df = pd.DataFrame({'mass': [0.330, 4.87 , 5.97],
...                    'radius': [2439.7, 6051.8, 6378.1]},
...                   index=['Mercury', 'Venus', 'Earth'])
>>> plot = df.plot.pie(y='mass', figsize=(5, 5))
```

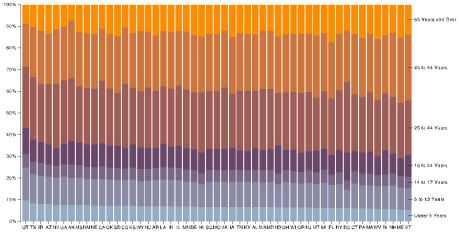


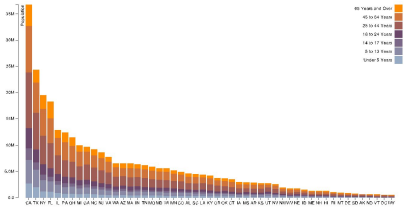


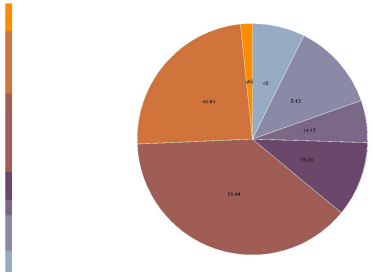
https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.plot.pie.html

Idioms: **normalized stacked bar chart**

- task
  - part-to-whole judgments
- 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



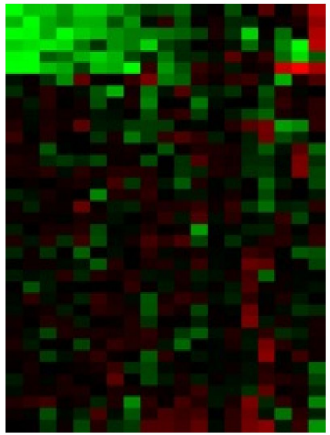


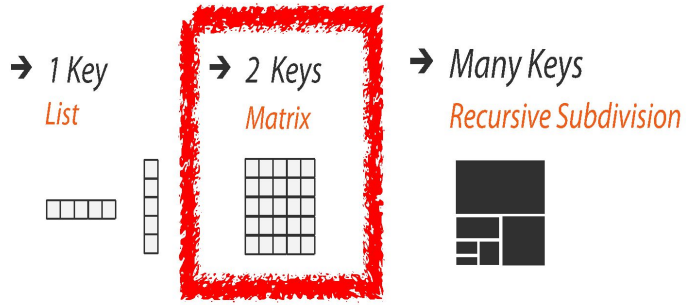


Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

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





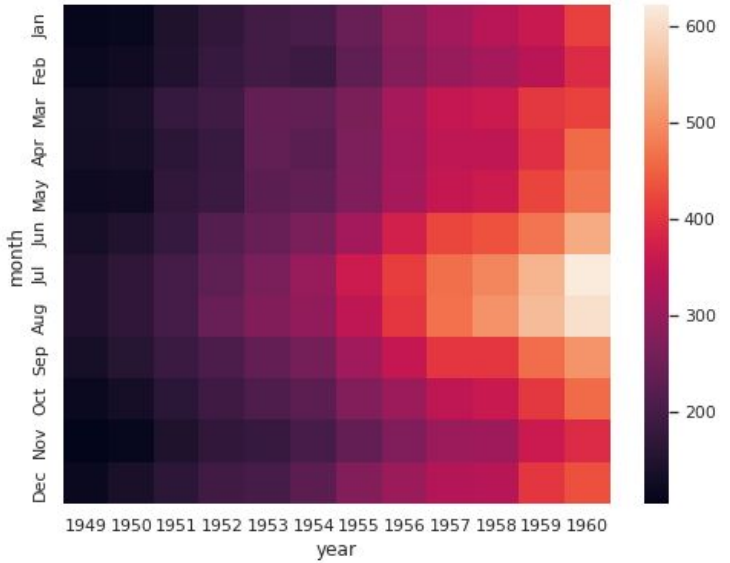
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Heatmap using Seaborn

```
sns.heatmap(pivot)
```

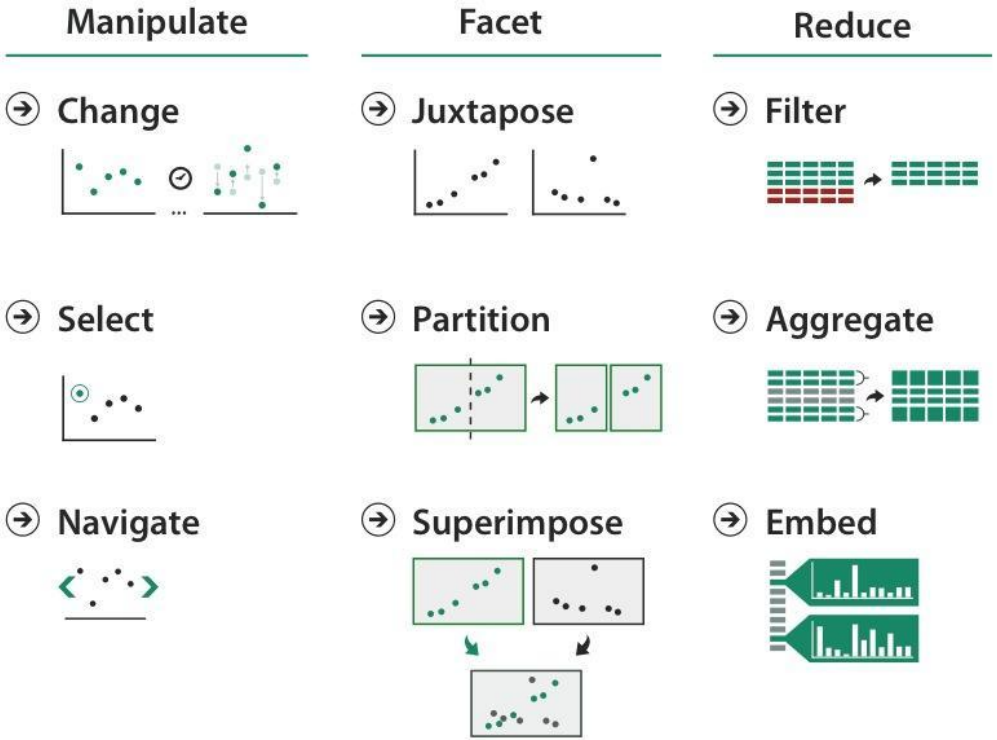
```
pivot = flights.pivot("month", "year", "passengers")
pivot.head()
```

month	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Jan	112	115	145	171	196	204	242	284	315	340	360	417
Feb	118	126	150	180	196	188	233	277	301	318	342	391
Mar	132	141	178	193	236	235	267	317	356	362	406	419
Apr	129	135	163	181	235	227	269	313	348	348	396	461
May	121	125	172	183	229	234	270	318	355	363	420	472



notebook: https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=vpXW3p9dFtyE

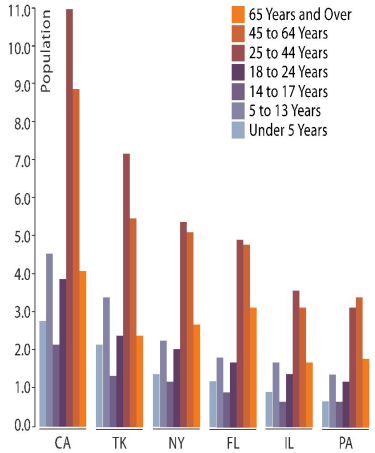
Idiom design choices: Part 2



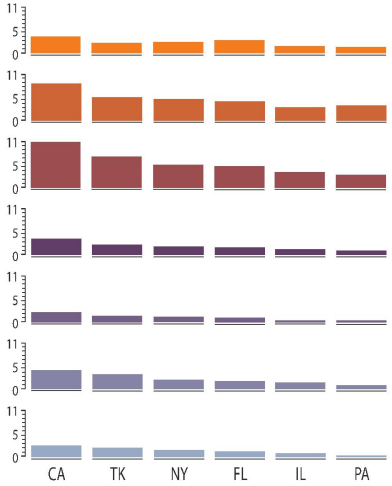
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Partitioning: List alignment

- single bar chart with grouped bars
  - split by state into regions
    - complex glyph within each region showing all ages
  - compare: easy within state, hard across ages



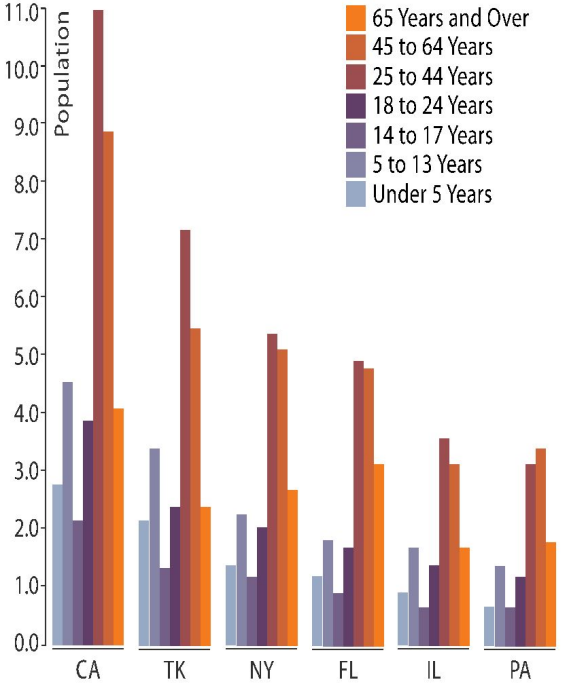
- small-multiple bar charts
  - split by age into regions
    - one chart per region
  - compare: easy within age, harder across states



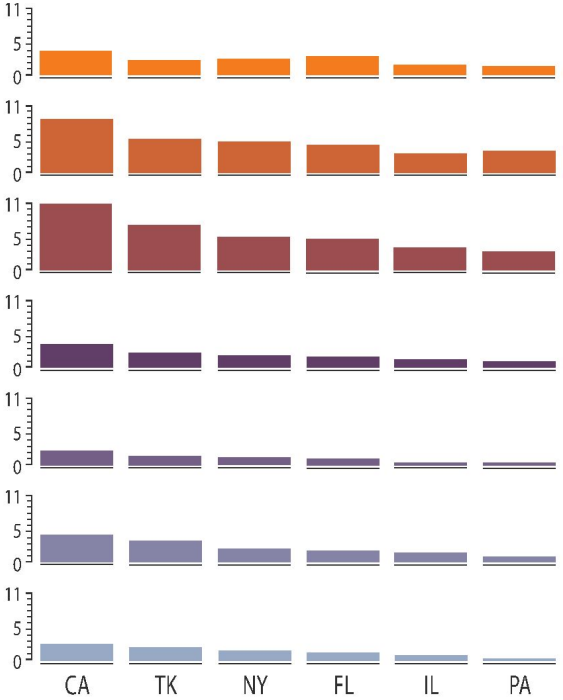
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Partitioning: List alignment and comparison

easy within state, hard across ages

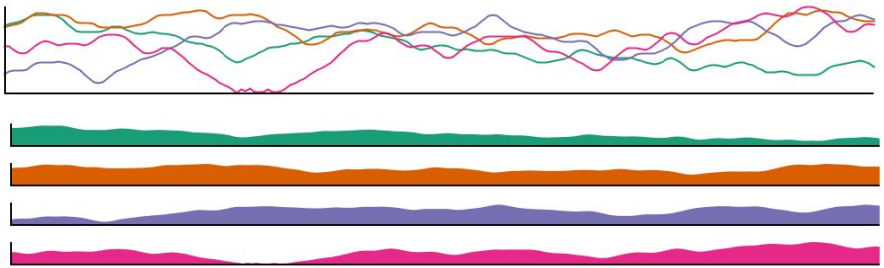


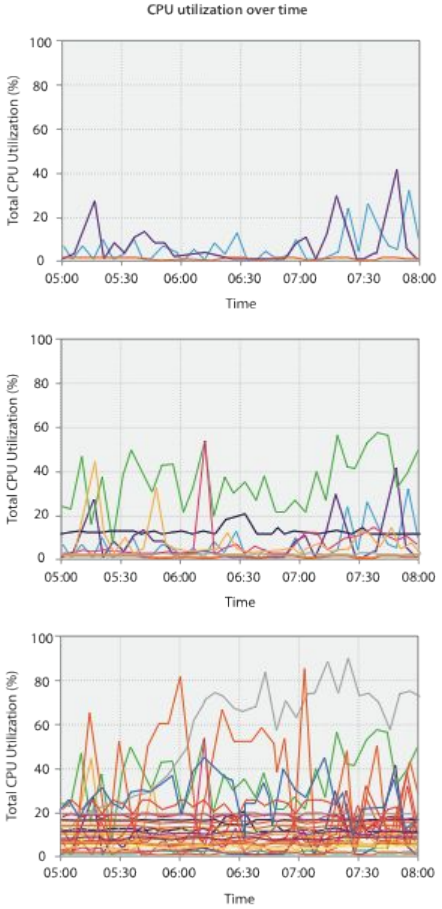
easy within age, harder across states



Superimposing limits

- few layers, but many lines
  - up to a few dozen, but not hundreds
- superimpose vs juxtapose: empirical study
  - superimposed for local visual, multiple for global
  - same screen space for all multiples, single superimposed
  - tasks
    - local: maximum, global: slope, discrimination





[Graphical Perception of Multiple Time Series. Javed, McDonnel, and Elmqvist. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE InfoVis 2010) 16:6 (2010), 927–934.]

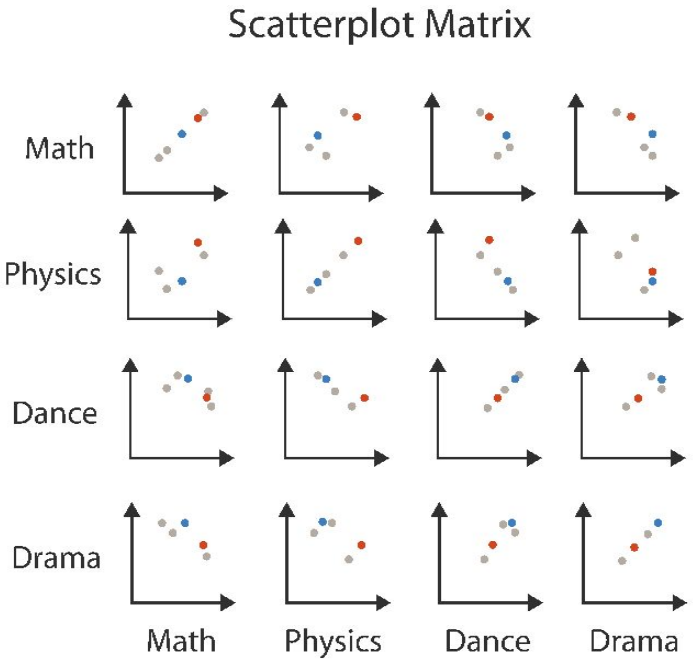
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Idiom: **scatterplot matrix**

- scatterplot matrix (SPLOM)
  - rectilinear axes, point mark
  - all possible pairs of axes
  - scalability
    - one dozen attribs
    - dozens to hundreds of items
  - task: correlation
    - positive correlation: diagonal low-to-high
    - negative correlation: diagonal high-to-low
    - uncorrelated

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



source: [Visualization Course Figures. McGuffin, 2014]

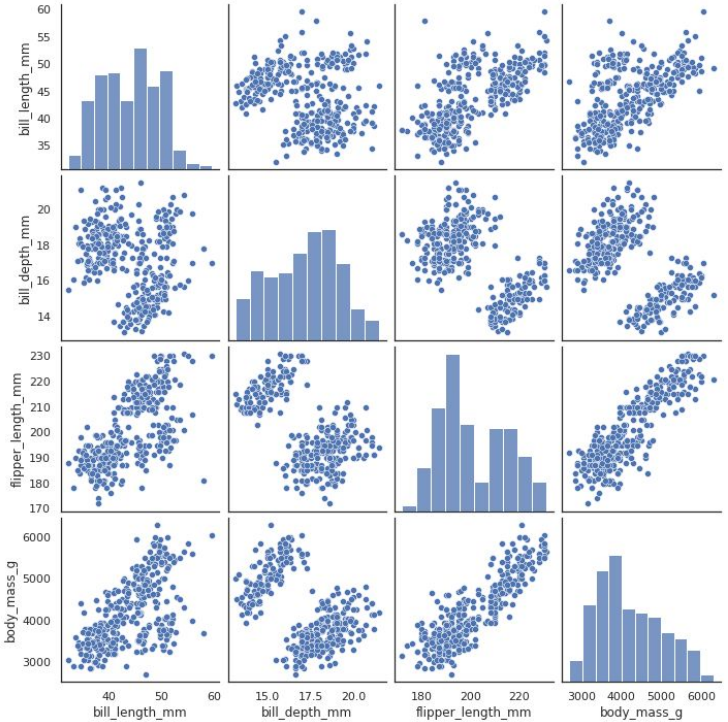
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Scatterplot Matrix using Seaborn

```
sns.pairplot(penguins)
```

```
penguins = sns.load_dataset("penguins")
penguins.head()
```

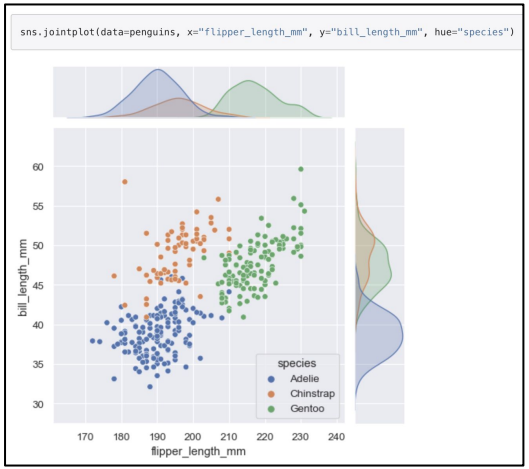
	species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g
0	Adelie	Torgersen	39.1	18.7	181.0	3750.0
1	Adelie	Torgersen	39.5	17.4	186.0	3800.0
2	Adelie	Torgersen	40.3	18.0	195.0	3250.0



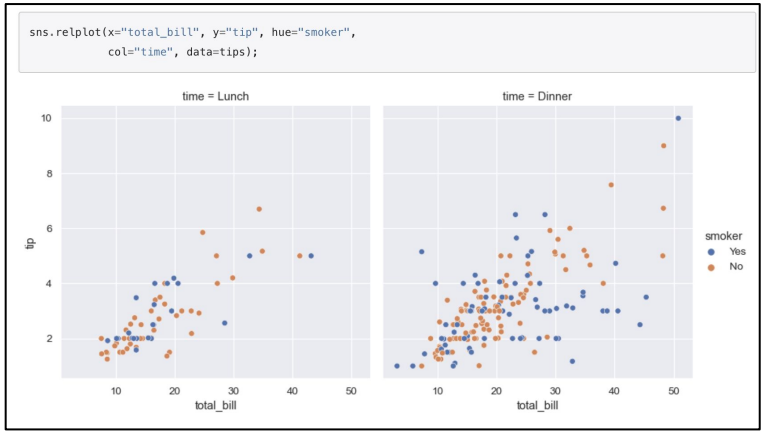
notebook: https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=qM1518i8RGv5

More Multiple Views in Seaborn

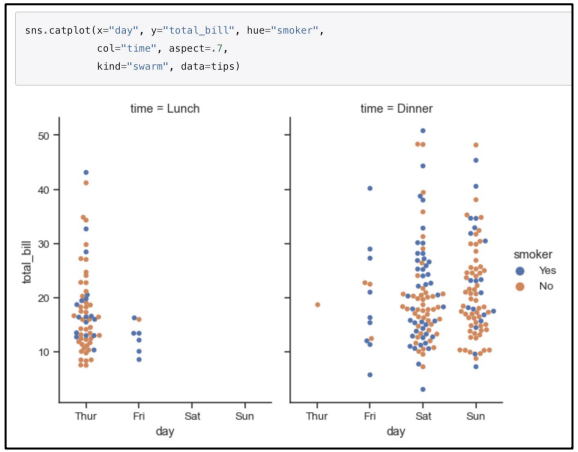
jointplot()



relplot()



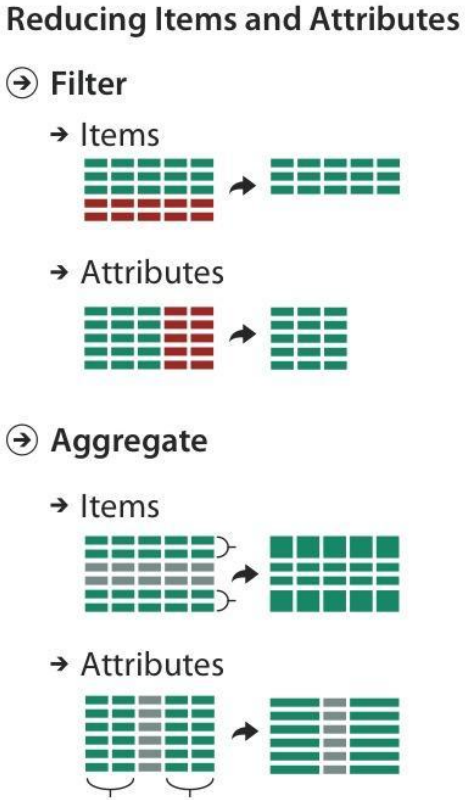
catplot()

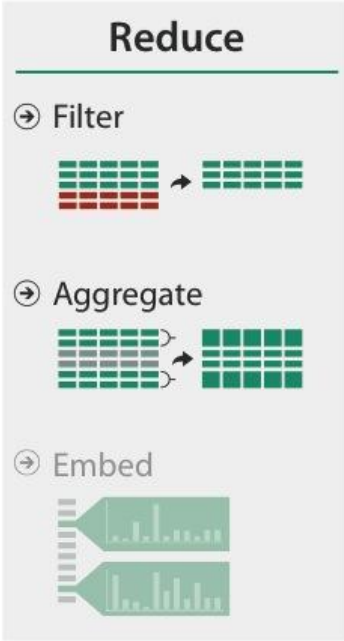


https://seaborn.pydata.org/tutorial/function_overview.html#combining-multiple-views-on-the-data
https://seaborn.pydata.org/tutorial/relational.html#showing-multiple-relationships-with-facets
https://seaborn.pydata.org/tutorial/categorical.html#showing-multiple-relationships-with-facets

Reduce items and attributes

- filter
  - pro: straightforward and intuitive
    - to understand and compute
  - con: out of sight, out of mind
- aggregation
  - pro: inform about whole set
  - con: difficult to avoid losing signal
- not mutually exclusive
  - combine filter, aggregate
  - combine reduce, change, facet

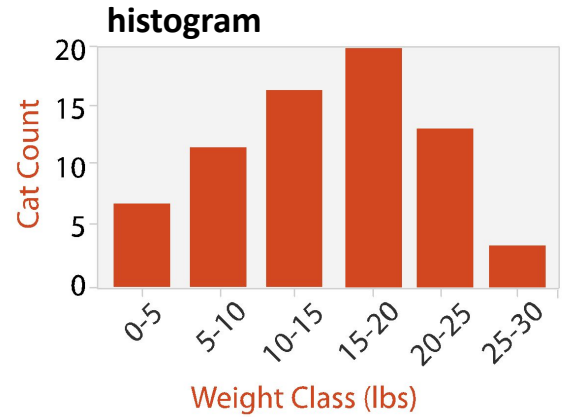


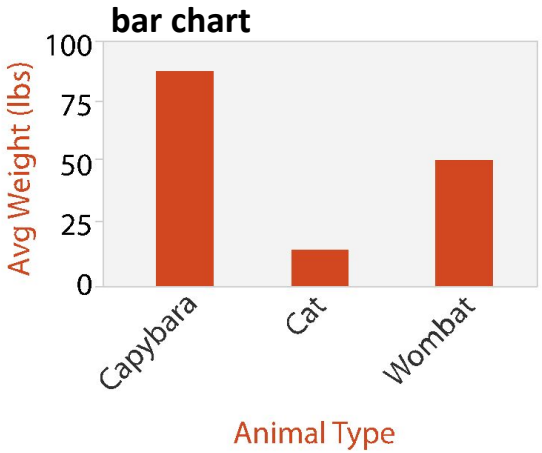


Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Idiom: **histogram**

- static item aggregation
- task: find distribution
- data: table
- derived data
  - new table: keys are bins, values are counts
- bin size crucial
  - pattern can change dramatically depending on discretization (bin size)





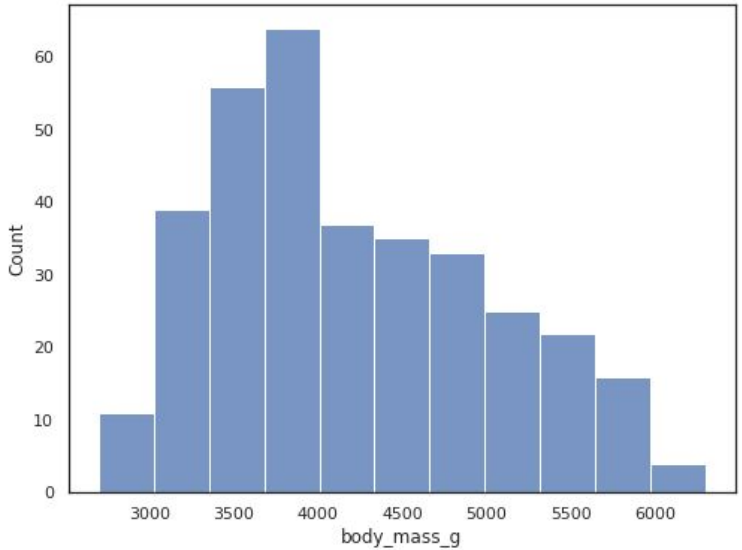
Tamara Munzner, VAD minicourse, June 2014, http://www.cs.ubc.ca/~tmm/talks.html#minicourse14

Histogram using Seaborn

```
sns.histplot(penguins['body_mass_g'])
```

```
penguins = sns.load_dataset("penguins")
penguins.head()
```

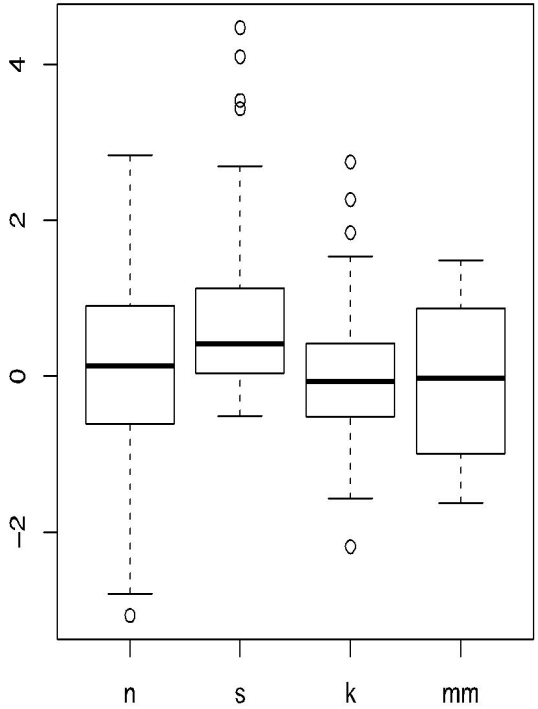
	species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g
0	Adelie	Torgersen	39.1	18.7	181.0	3750.0
1	Adelie	Torgersen	39.5	17.4	186.0	3800.0
2	Adelie	Torgersen	40.3	18.0	195.0	3250.0



notebook and exercise:
https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=NneMJx2ZRIL1

Idiom: **boxplot**

- static item aggregation
- task: find distribution
- data: table
- derived data
  - 5 quant attribs
    - median: central line
    - lower and upper quartile: boxes
    - lower upper fences: whiskers
      - values beyond which items are outliers
  - outliers beyond fence cutoffs explicitly shown



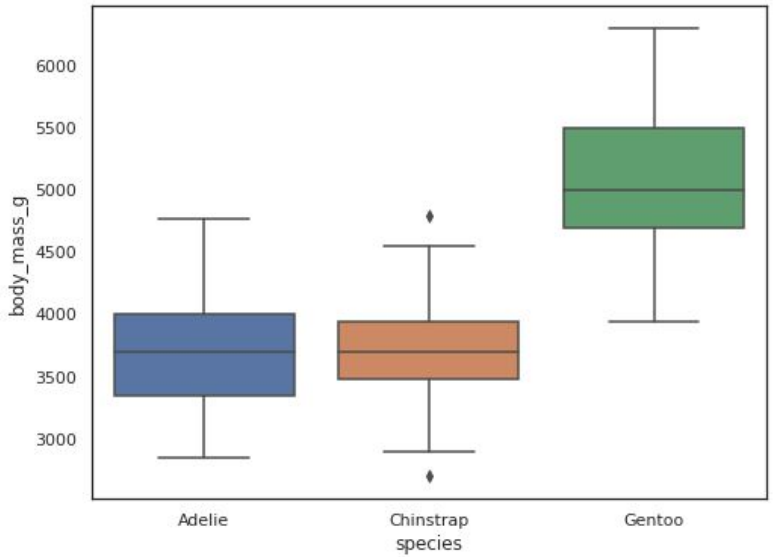
source: [40 years of boxplots. Wickham and Stryjewski. 2012]

Boxplot using Seaborn

```
sns.boxplot(data=penguins, x="species", y="body_mass_g")
```

```
penguins = sns.load_dataset("penguins")
penguins.head()
```

	species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g
0	Adelie	Torgersen	39.1	18.7	181.0	3750.0
1	Adelie	Torgersen	39.5	17.4	186.0	3800.0
2	Adelie	Torgersen	40.3	18.0	195.0	3250.0



notebook and exercise:
https://colab.research.google.com/drive/1Y2lJFV4NqzLc2J3pxvP34VtqUw7jKmEe#scrollTo=V2RG95LkRKQe

Interested in learning more?

Watch Tamara Munzner's D3 Unconference 2015 Keynote (55 min), https://youtu.be/jVC6SQS23ak or her full-day tutorial at IEEE VIS 2021 (18 videos), https://www.youtube.com/playlist?list=PLT4XLHmqHJBdB24LAQPk_PV7wrwpJFh5a

Still interested?

Check out ODU CS 625 - Data Visualization

https://github.com/odu-cs625-datavis/public/tree/main/fall21#readme

covers most of Munzner's textbook

Still interested?

Check out ODU CS 725/825 - Information Visualization and Visual Analytics

https://github.com/odu-cs725-infovis/public/tree/main/spr23#readme

more advanced visualizations, research-based, assumes knowledge of all material from CS 625