Applied Data Analysis (CS401)

ada

Lecture 3
Visualizing data
30 Sep 2020

EPFL

Robert West

dlab

Announcements

- You must find 2 team mates and register by today, Wed 30 Sep 23:59
  - Still looking for team members? Immediately contact Ekaterina Svikhnushina (TA) on Zulip!
- Project milestone P0 due Fri 2 Oct 23:50
- Homework 1 released Fri 2 Oct
- Friday's lab session:
  - More on data visualization
  - Working with data from the Web

Feedback

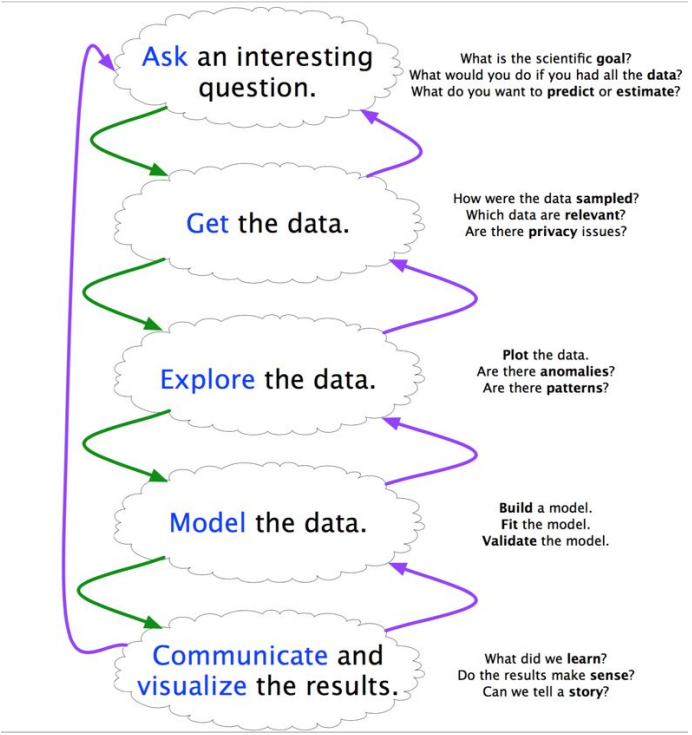
Give us feedback on this lecture here:
https://go.epfl.ch/ada2020-lec3-feedback

- What did you (not) like about this lecture?
- What was (not) well explained?
- On what would you like more (fewer) details?
- What's your favorite color, baby?
- …

Uses for data visualization

Support reasoning about information **(analysis)**

- Finding relationships
- Discover structure
- Quantifying values and influences
- Should be part of a query/analyze cycle ➡



Inform and persuade others **(communication)**

- Capture attention, engage
- Tell a story visually
- Can focus on certain aspects and omit others

Static viz

Great for data exploration, developed throughout the last few centuries…

Interactive viz

More and more common when delivering the results (and also during exploration). New frameworks are the key enabler.

Want to learn more?

Dedicated course:

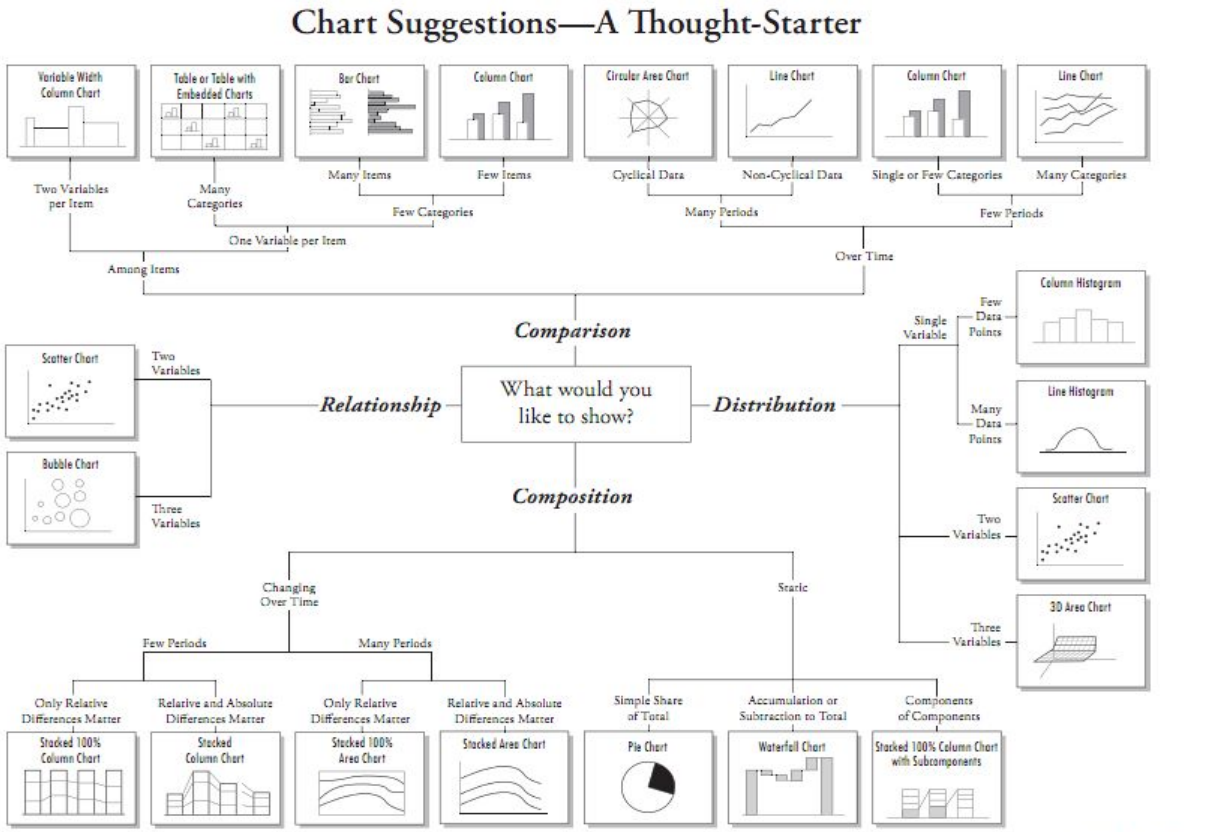
COM-480: Data Visualization

Today’s lecture

- Part 1: Navigating the chart landscape
- Part 2: Principles and best practices
- Part 3: A (small) selection of use cases for data visualization

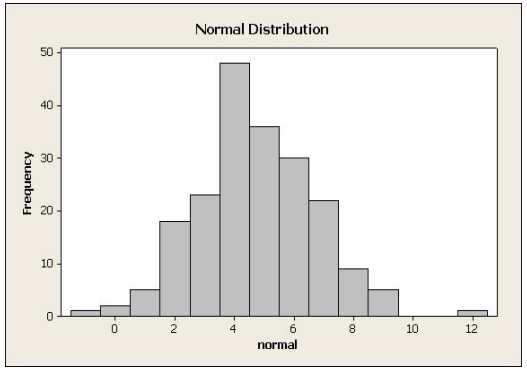
Part 1
Navigating the chart landscape

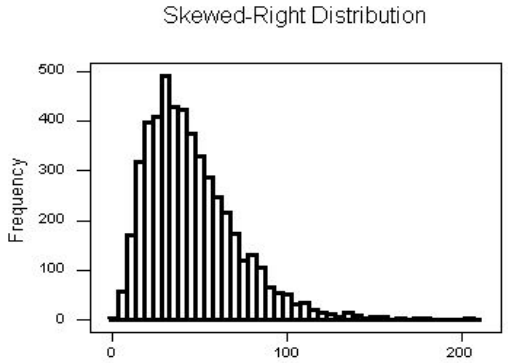
Chart selection

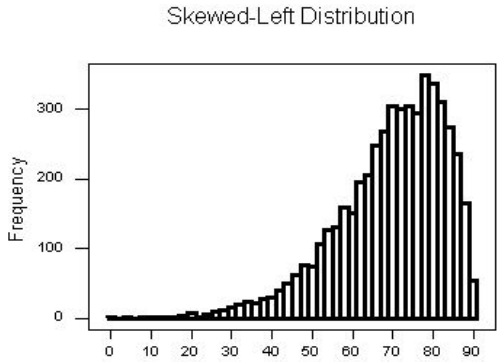


One variable: histograms

Histograms can tell you a lot about a single variable, discrete or continuous

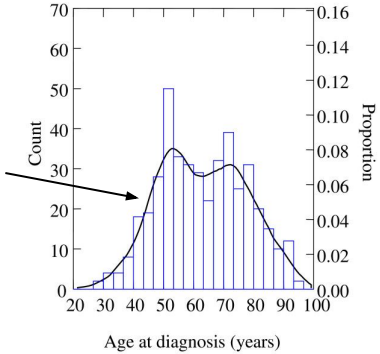




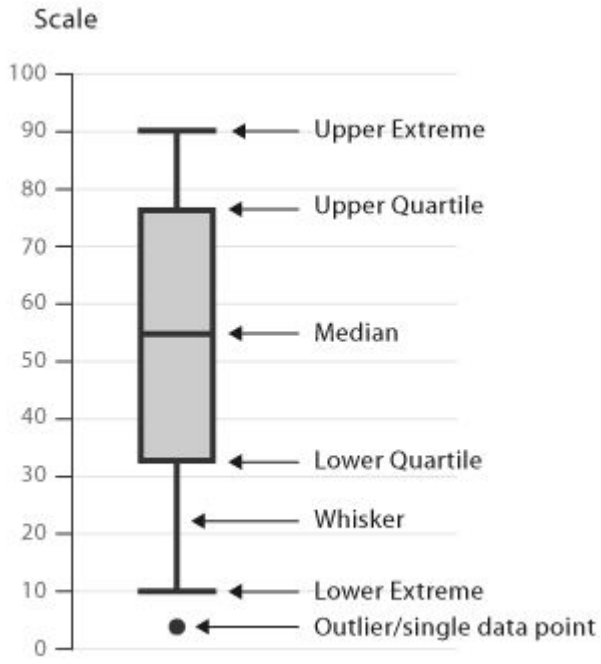


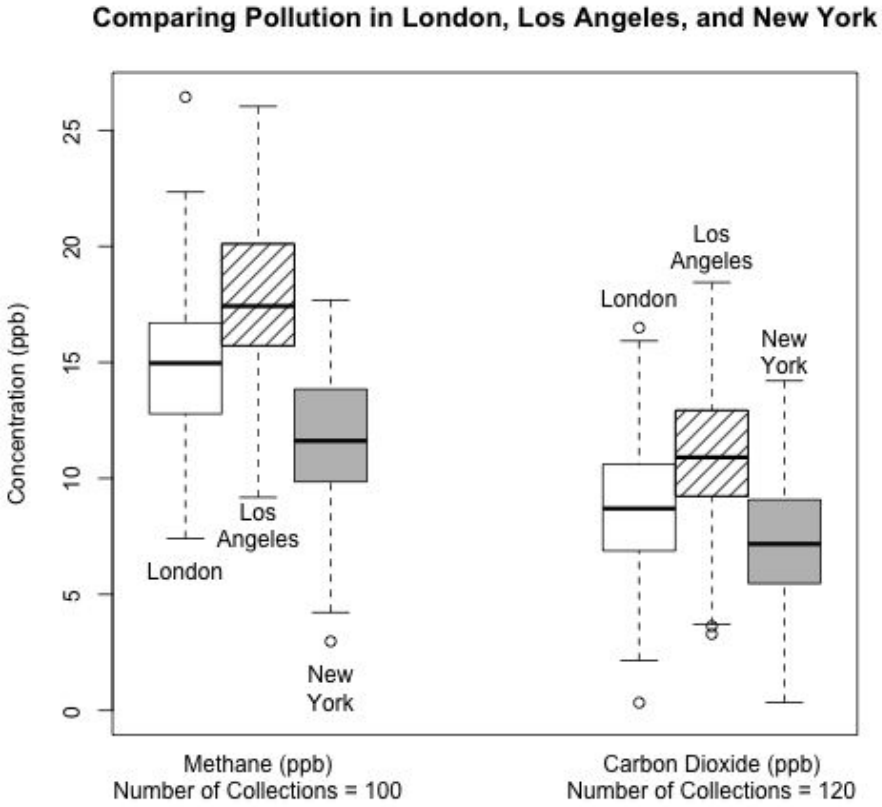
Easy to recognize skewed distributions!

Smoothed histogram (a.k.a. kernel density estimate)



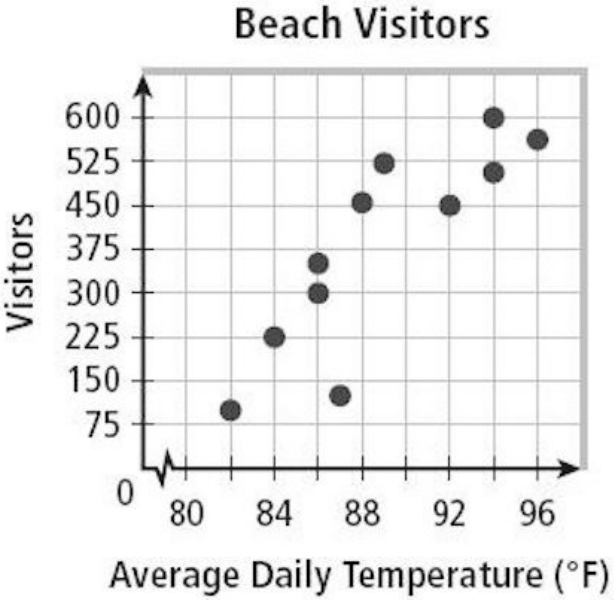
One variable: box plots

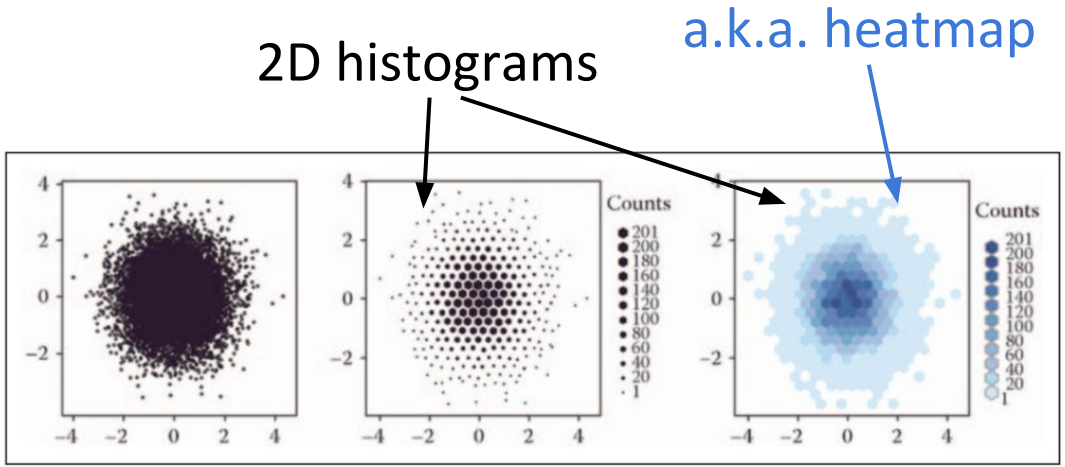




Two variables: scatter plots

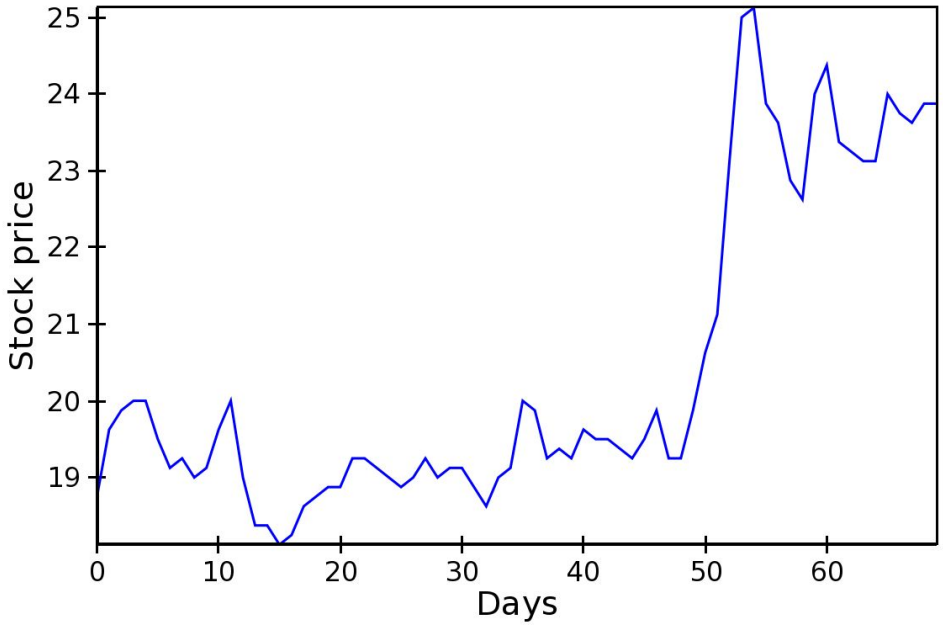
Scatter plots quickly expose the relationships between two variables



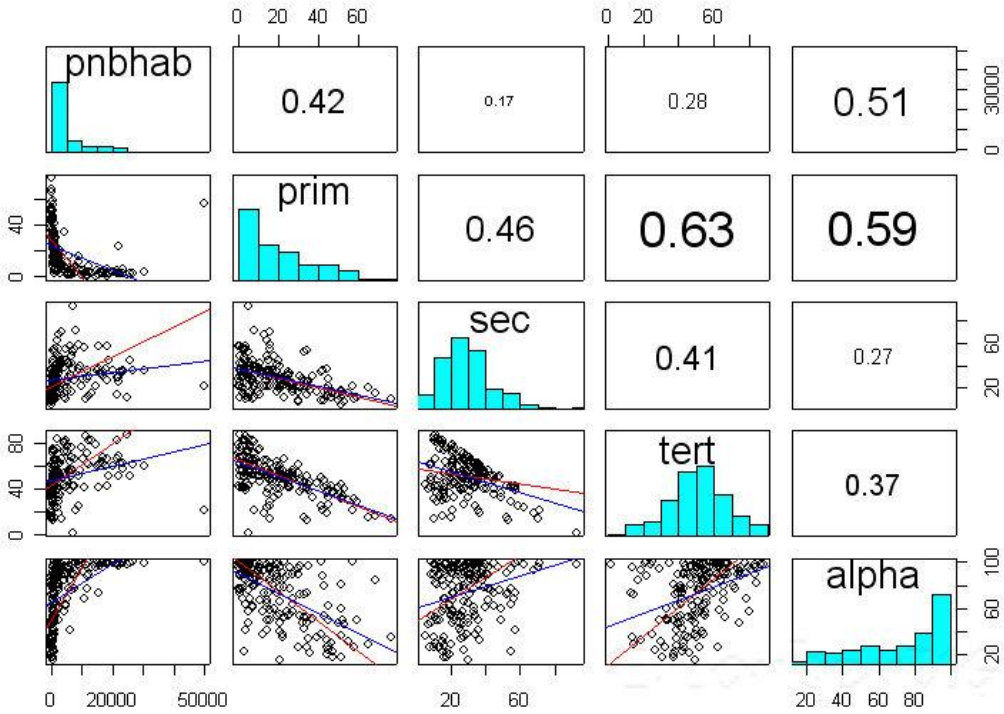


Two variables: line plots

If relationship is functional (e.g., after binning and aggregating)



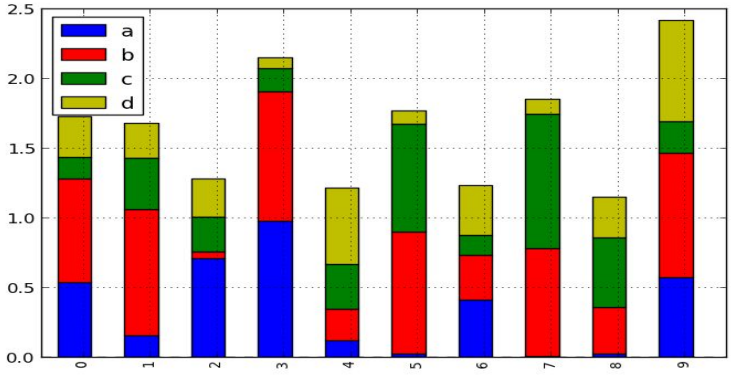
> 2 variables: scatter plot matrix



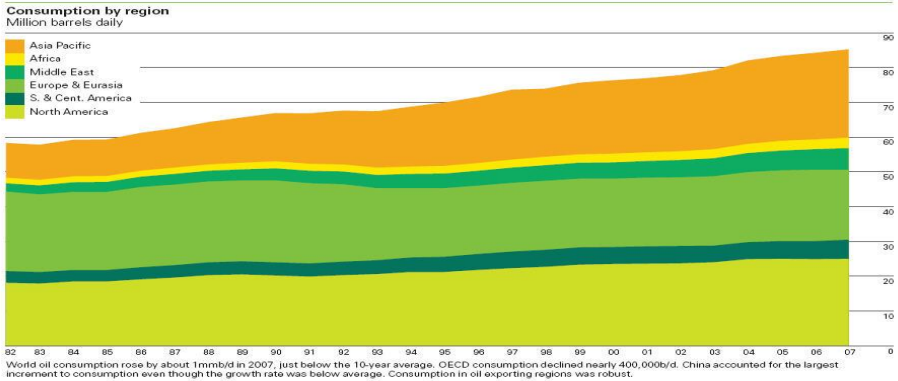
> 2 variables: stacked plots

Here: 3 variables: stack index, color, height

Stack variable and color variables categorical,
height variable continuous:

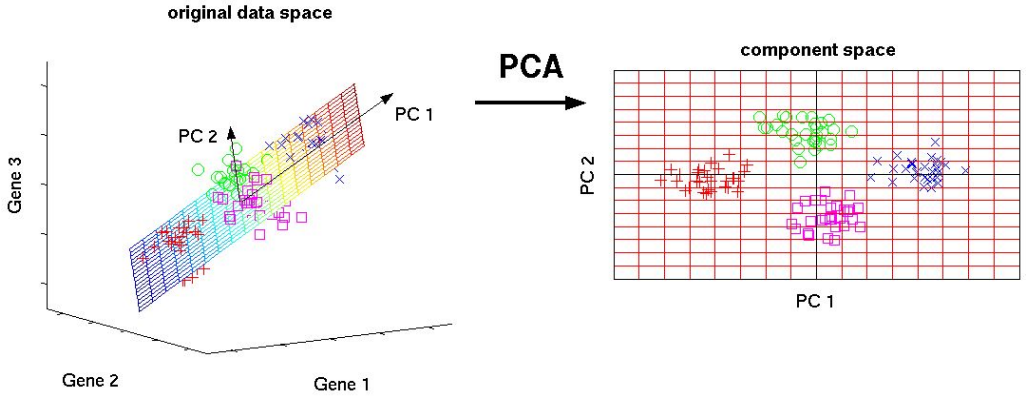


Color variable categorical,
stack and height variables continuous:

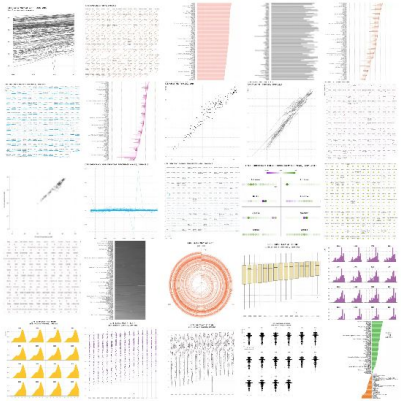


Dimensionality reduction

- For example, **PCA:** allows visualization of high-dimensional continuous data in 2D using principal components
- The principal components are the strongest (highest variation) dimensions in the dataset, and are orthogonal



One dataset, visualized 25 ways

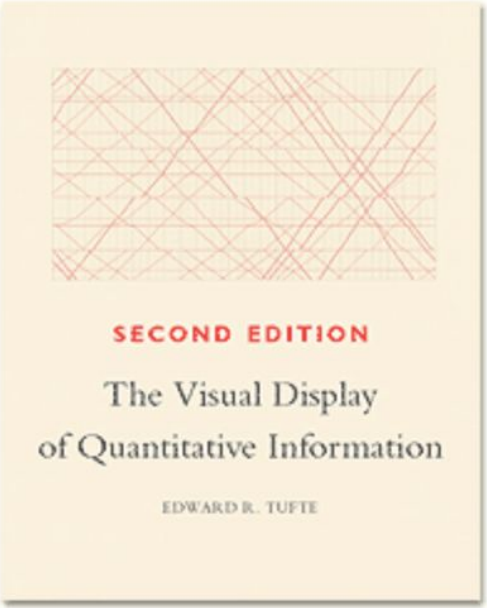


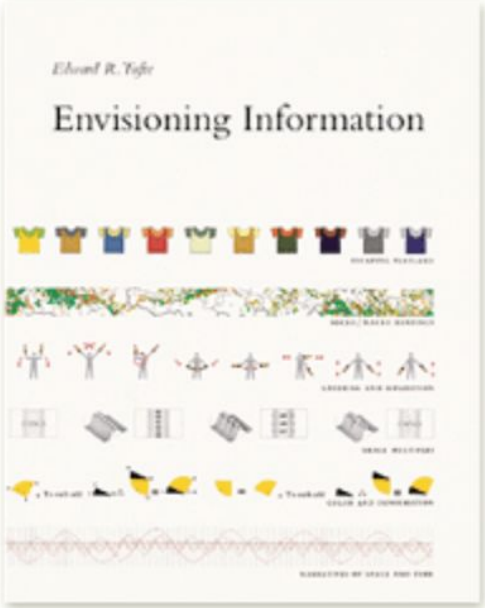
http://flowingdata.com/2017/01/24/one-dataset-visualized-25-ways

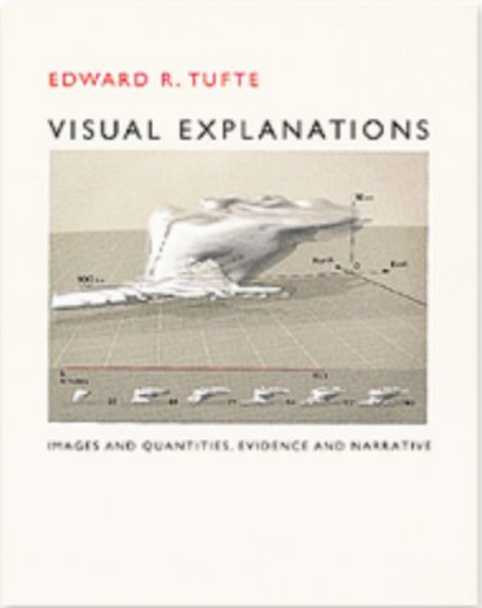
"You must help the data focus and get to the point. Otherwise, it just ends up rambling about what it had for breakfast this morning and how the coffee wasn't hot enough."

Part 2
Principles and best practices

Instructive coffee table books by Edward







[demo] [another great coffee table book]

Perception of magnitudes

(128, 128, 128)

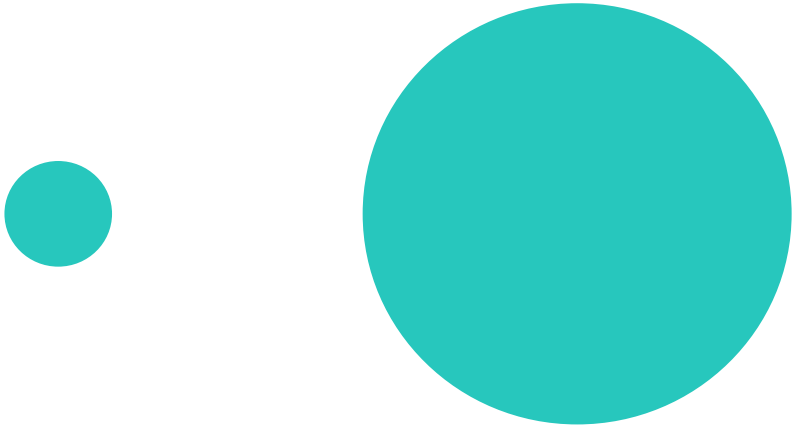
(144, 144, 144)

Which is brighter?

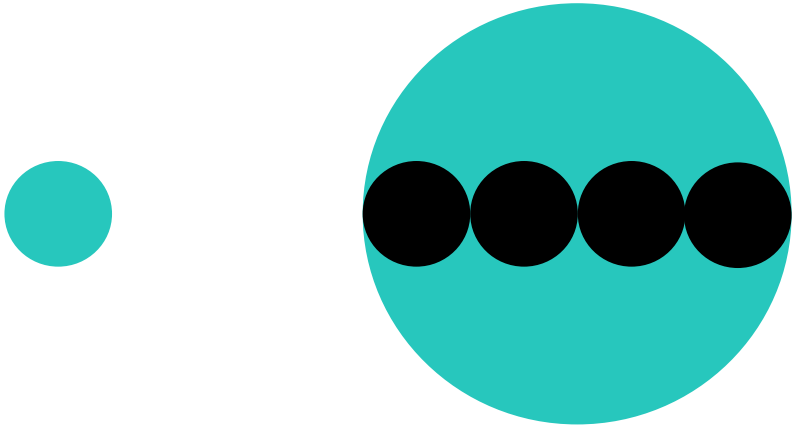
Just noticeable difference (JND)

- Weber's Law: $$\frac{\Delta I}{I} = k,$$

- I: intensity; ΔI: increase from I to notice a difference; k: constant
- Required increase ΔI depends on original intensity I
- Most continuous variations in stimuli are perceived in discrete (multiplicative) steps



Compare area of circles



Compare area of circles

Perception of magnitudes

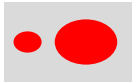
Most accurate

Position

Length

Slope

Angle



Area

Volume

Least accurate

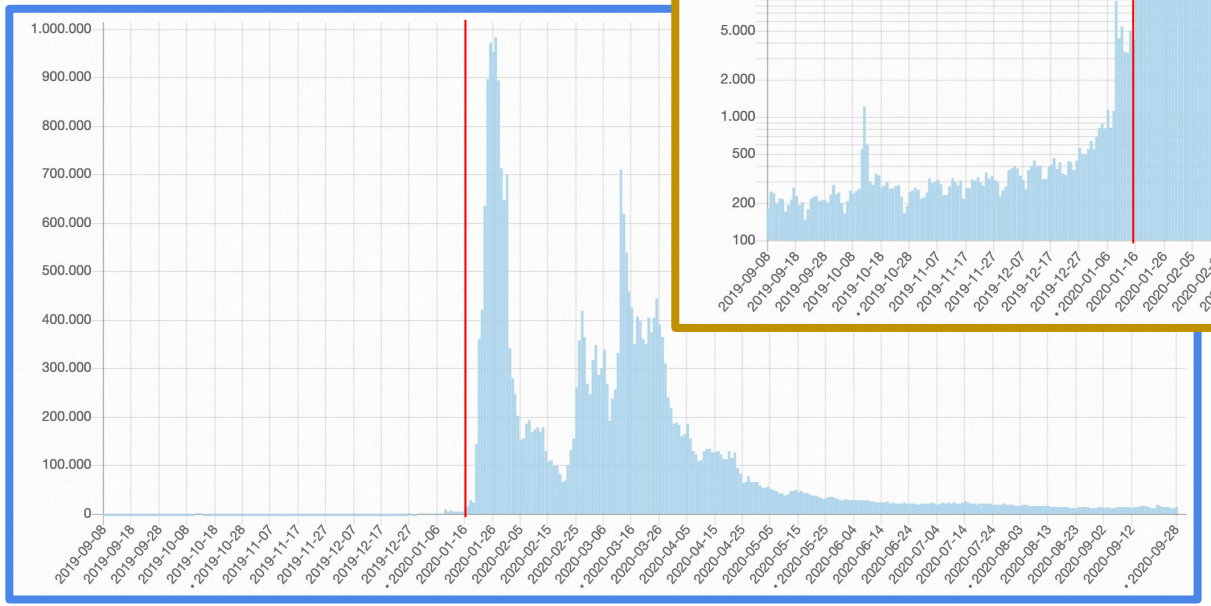
Color hue-saturation-density

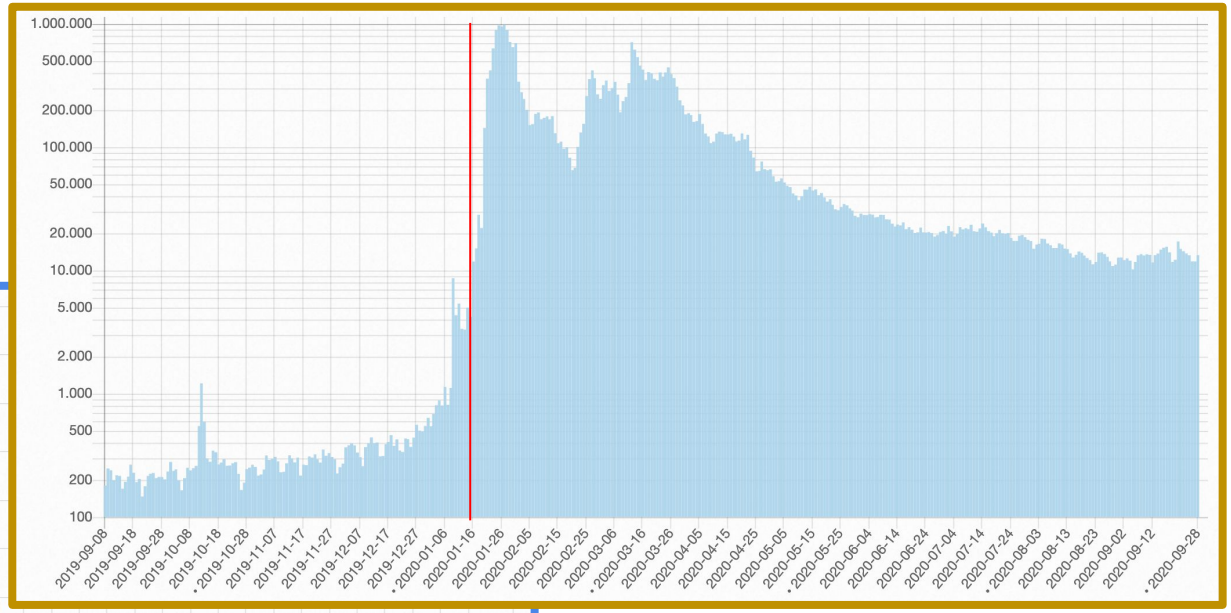
Cleveland & McGill (1984) *Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods*

Choose your axes wisely!

Time series of pageviews of Wikipedia article about "Coronavirus"

(linear y-axis)

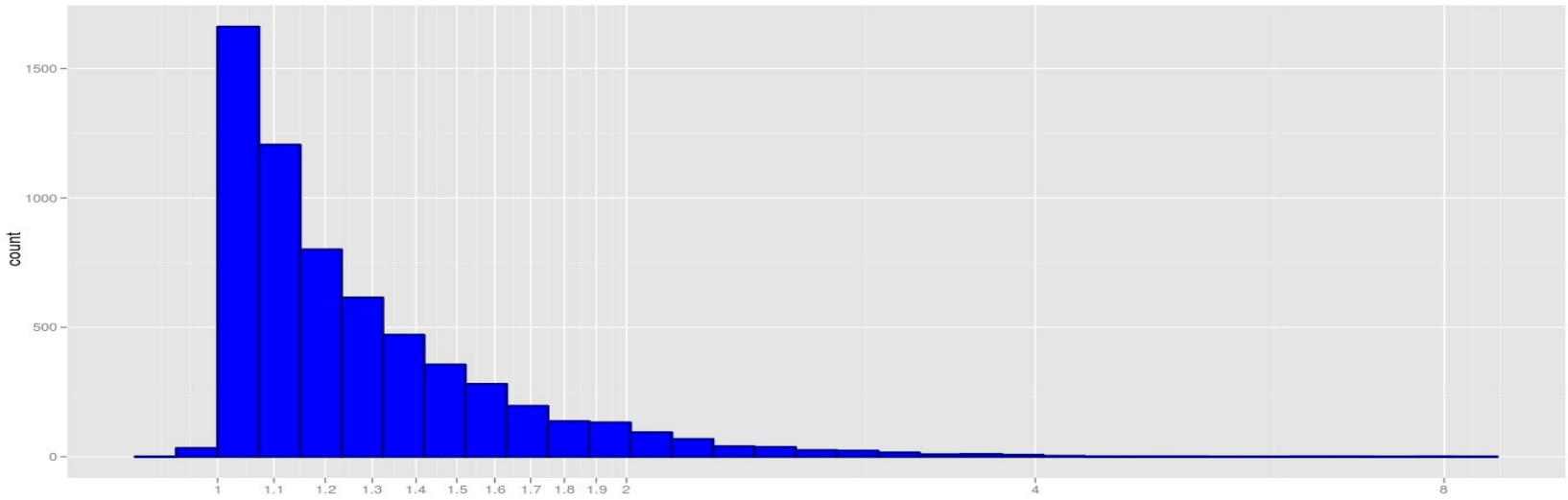




(logarithmic y-axis)

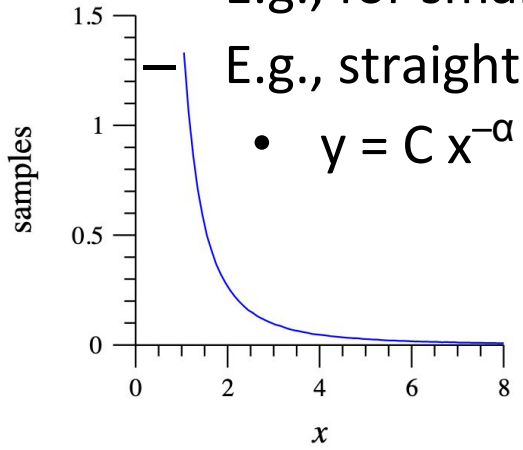
[link]

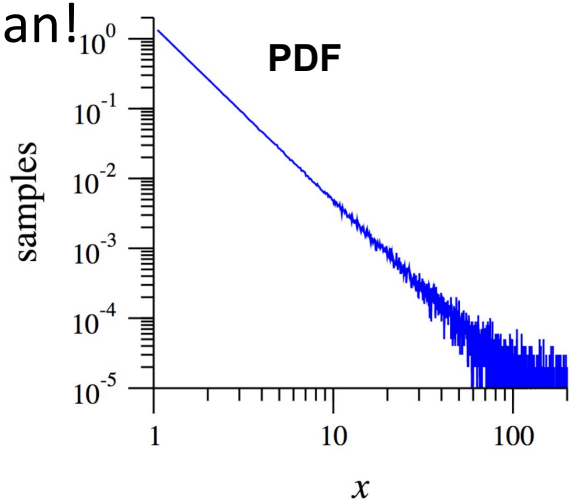
Choose your axes wisely: Visualizing heavy-tailed distributions

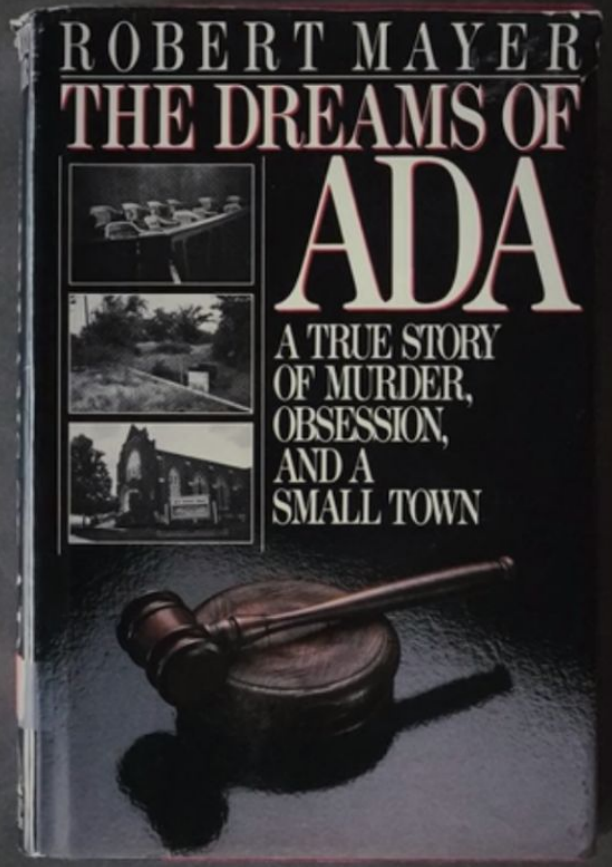


Heavy-tailed data: power laws

- $p(x) = Cx^{-\alpha}$,
  - Very large values are rare, “but not very rare”
  - Body size vs. city size
  - Many natural phenomena are power laws (e.g., # of friends)
  - For dealing with them, need to know some tricks
  - E.g., for small α, mean & var = ∞ → use median!
  - E.g., straight line on log-log axes:
    - $y = C\,x^{-\alpha} \leftrightarrow \underline{\log(y)} = \underline{\log(C)} - \alpha\,\underline{\log(x)}$

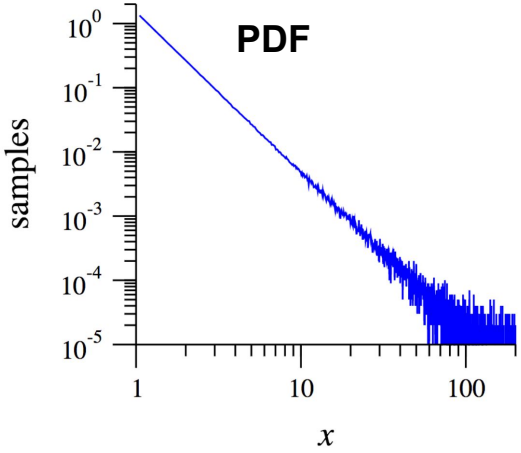


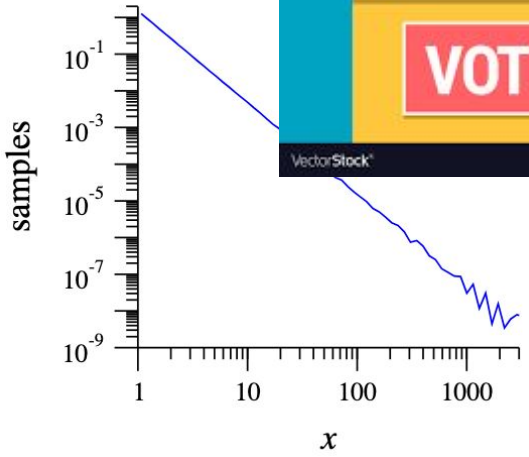



ROBERT MAYER
THE DREAMS OF
ADA
A TRUE STORY
OF MURDER,
OBSESSION,
AND A
SMALL TOWN

Heavy-tailed data: power laws

- Complementary cumulative distribution function (CCDF):
  - P(x) := Pr{X >= x}



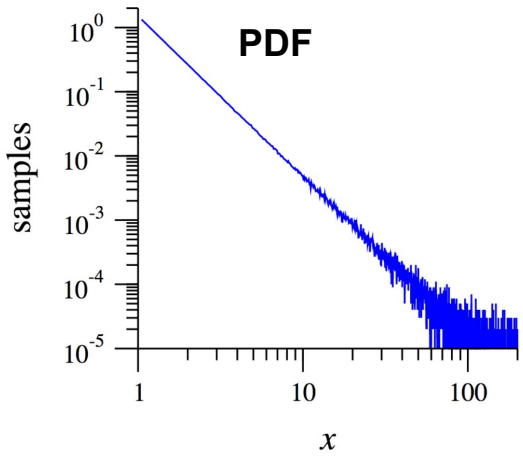


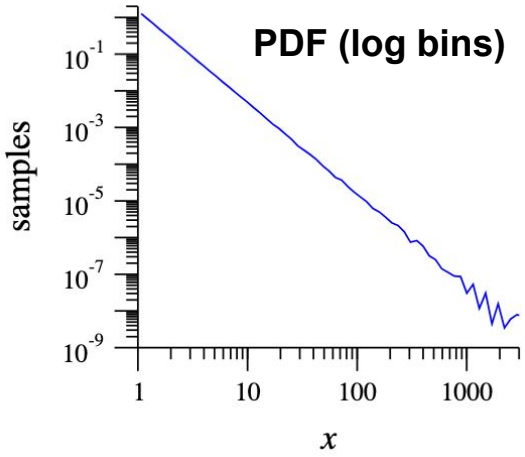
POLLING TIME

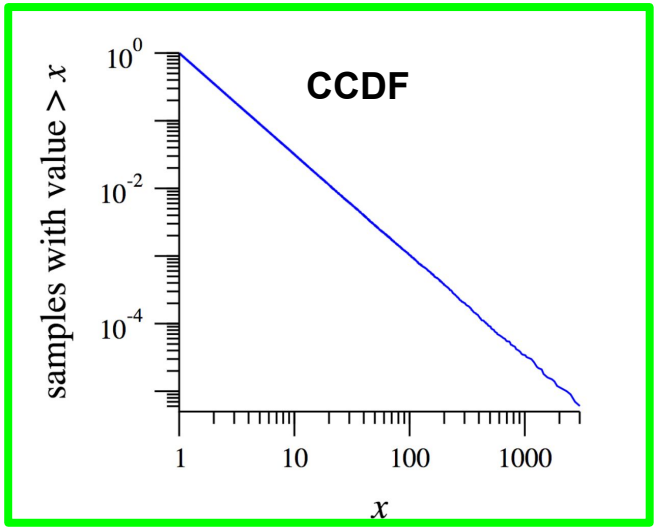
- Everyone: please vote! (Only available via Zoom call)
- Question: What shape does the CCDF of a power law have when plotted on log-log axes?

Heavy-tailed data: power laws

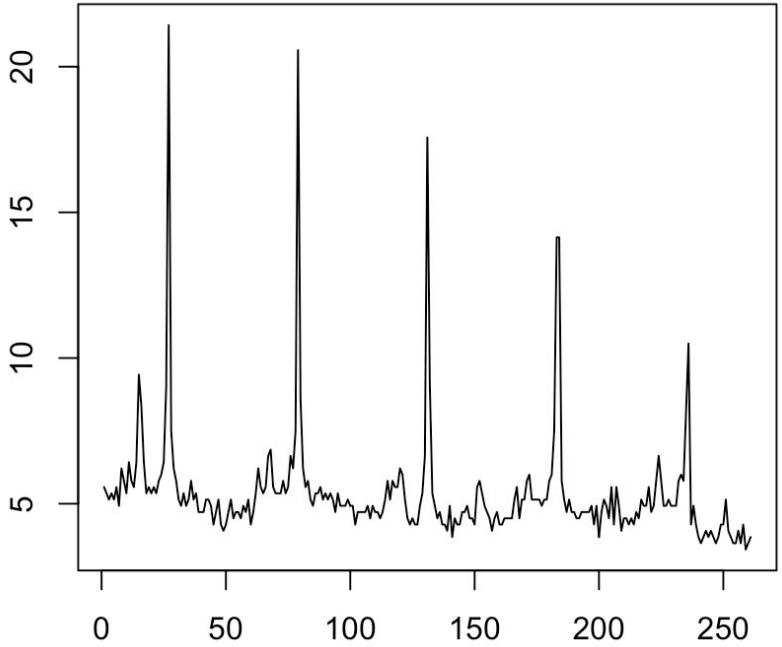
- Complementary cumulative distribution function (CCDF):
  - P(x) := Pr{X >= x}
- CCDF of power law is also a power law (with exponent α – 1)
  - $P(x) = C \int_x^\infty x'^{-\alpha}\,\mathrm{d}x' = \frac{C}{\alpha - 1} x^{-(\alpha-1)}.$

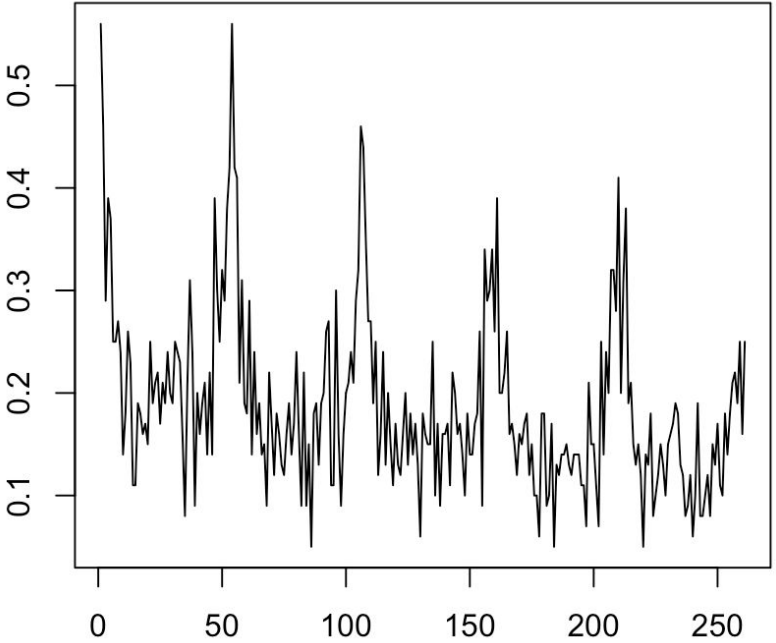






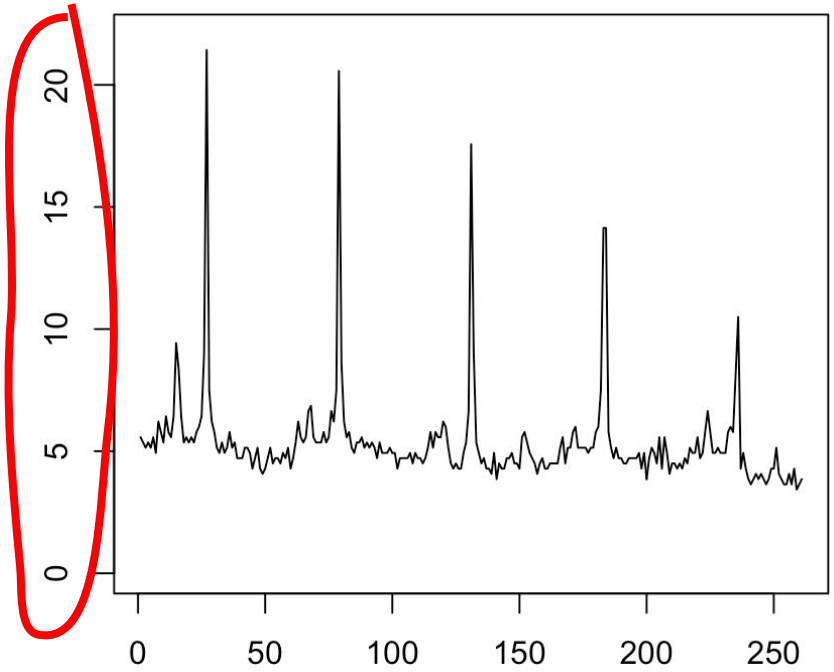
Answer fast: which time series has a higher mean value?

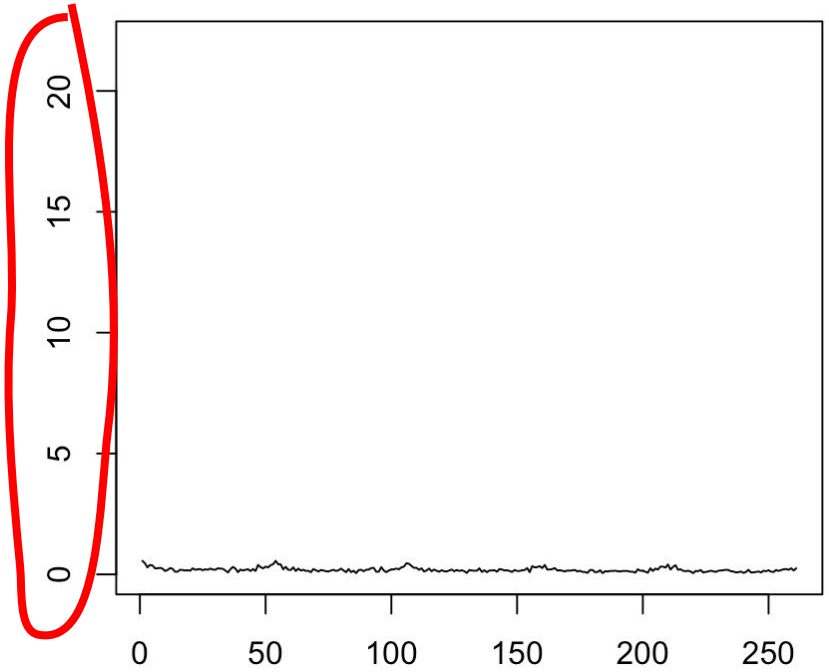




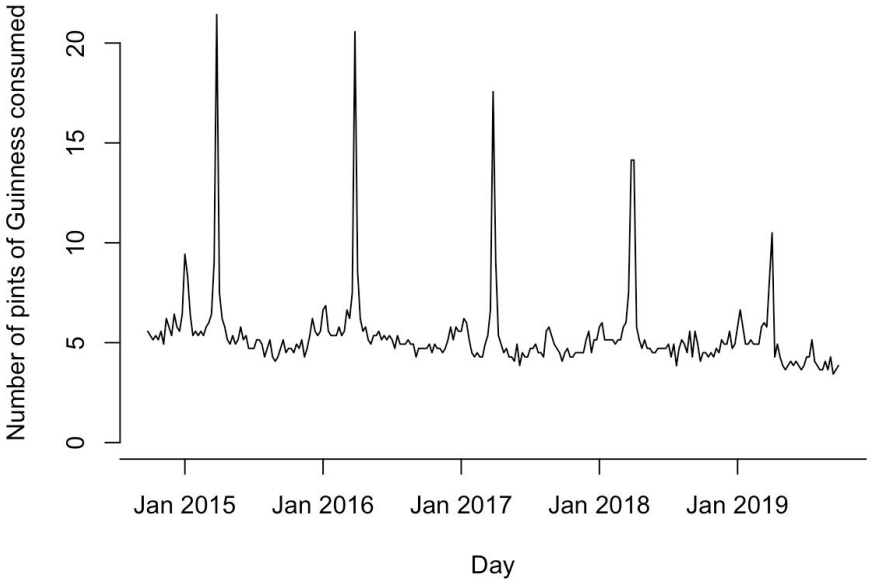
Use consistent axes!

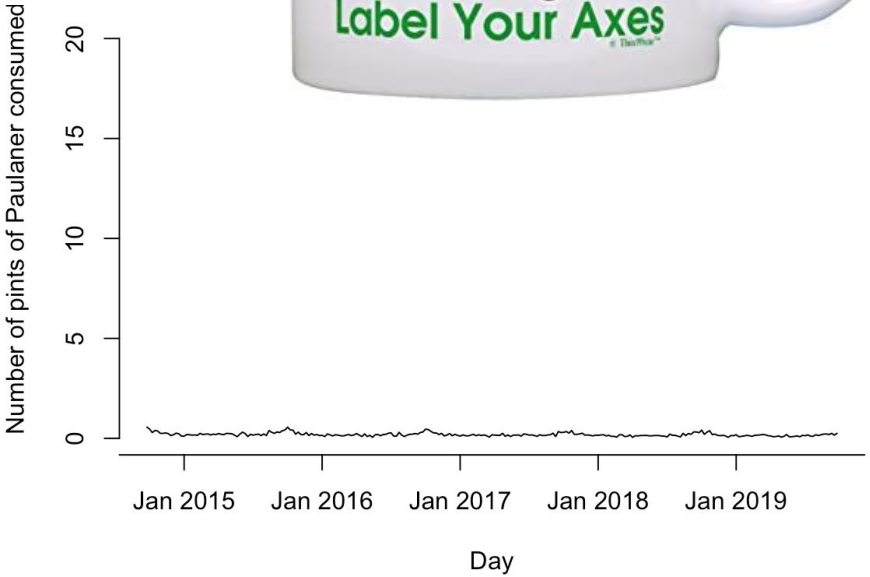
Answer fast: which time series has a higher mean value?

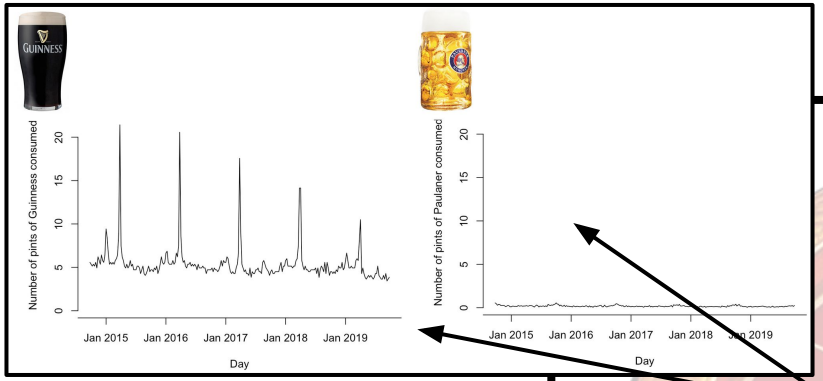




Label your axes!





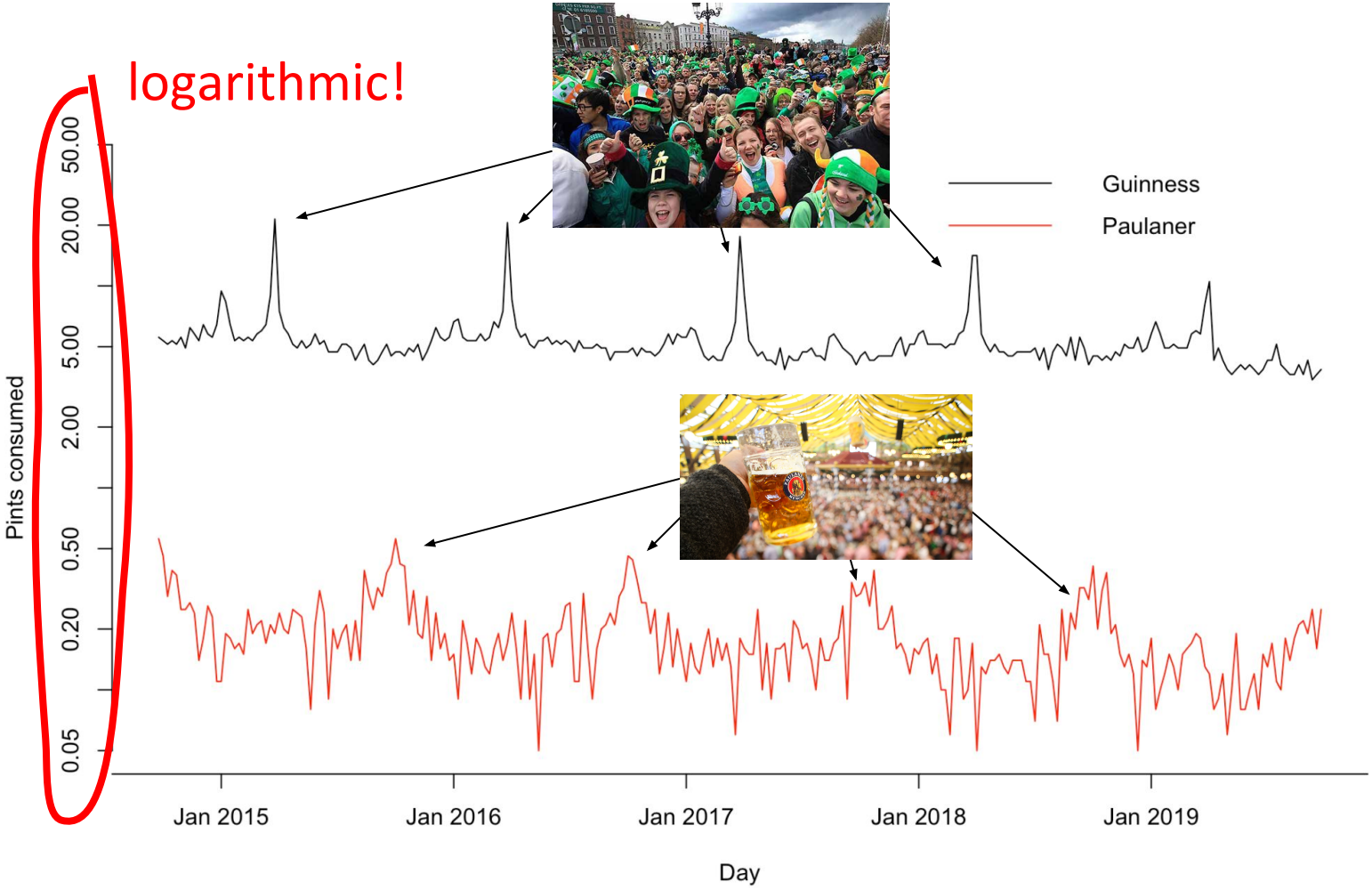


CHAT ROULETTE!

Think for 1 minute:

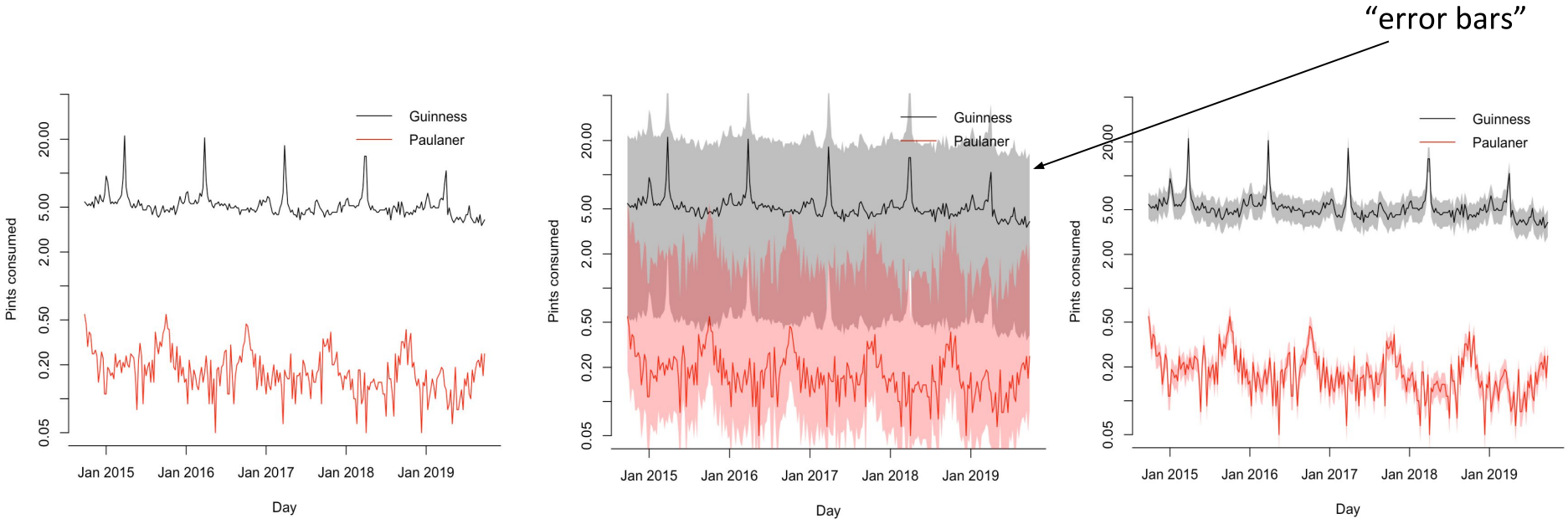
How could we show details of both time series without using different y-axes?

- Then: chat with a fellow student for 3 minutes
  - Rolex Forum: Talk to neighbor (priority: left, right)
  - Zoom: You'll be randomized into small **"breakout rooms"**

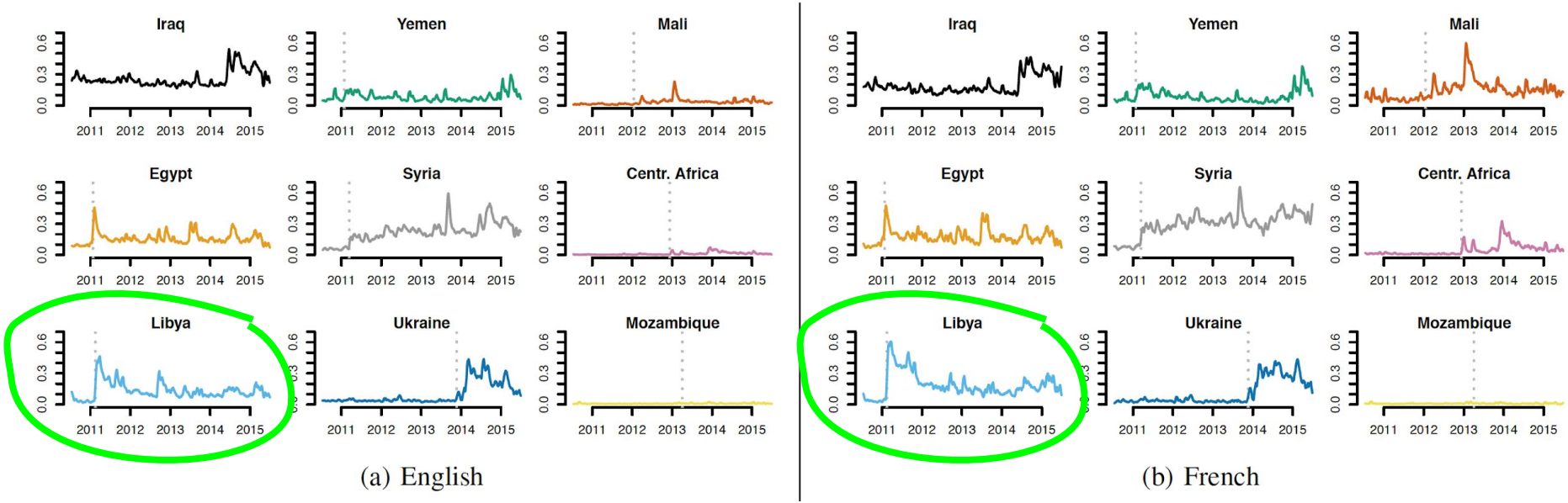

logarithmic!
Pints consumed
50.00
20.00
5.00
2.00
0.50
0.20
0.05
Guinness
Paulaner
Jan 2015
Jan 2016
Jan 2017
Jan 2018
Jan 2019
Day

Show data uncertainty!

Which beer is more popular, Guinness or Paulaner?



Consider using small multiples!



Use colors consistently!

Use colors wisely!

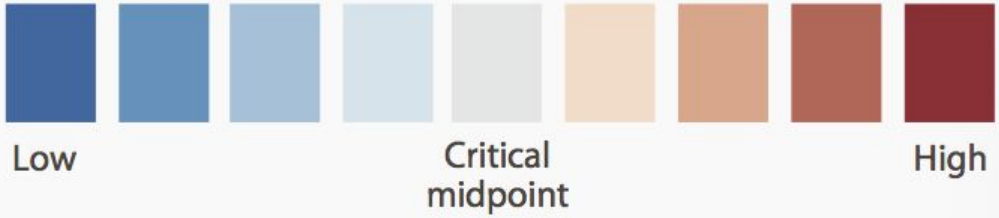
Choose colors based on the information you want to convey

Sequential

Colors can be ordered from low to high

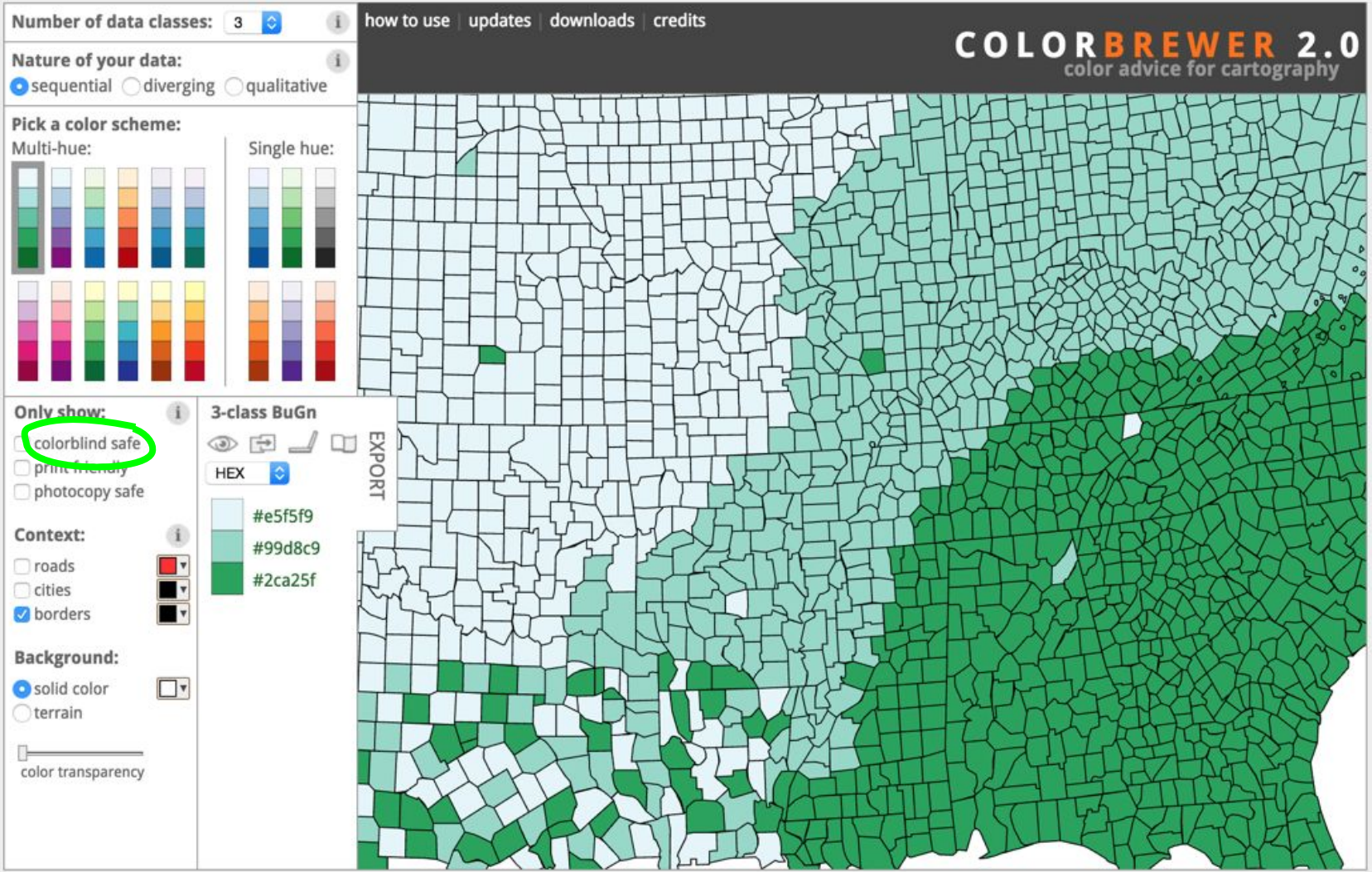
Diverging

Two sequential schemes extended out from a critical midpoint value



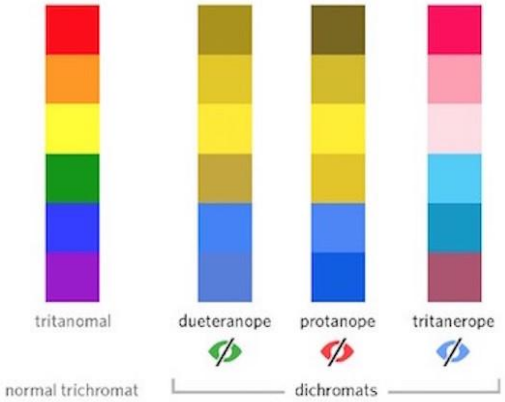
Categorical

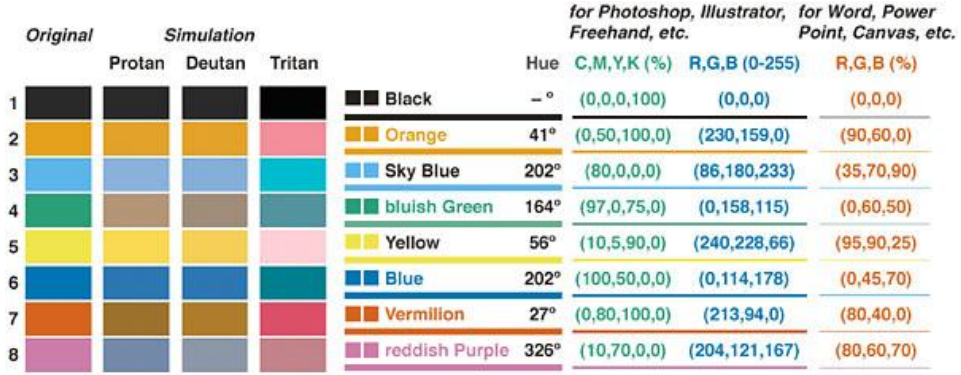
Lots of contrast between each adjacent color


Number of data classes: 3
how to use | updates | downloads | credits
COLORBREWER 2.0
color advice for cartography
Nature of your data:
sequential
diverging
qualitative
Pick a color scheme:
Multi-hue:
Single hue:
Only show:
colorblind safe
photocopy safe
3-class BuGn
HEX
EXPORT
#e5f5f9
#99d8c9
#2ca25f
Context:
roads
cities
borders
Background:
solid color
terrain
color transparency

Use colorblind-safe palettes!

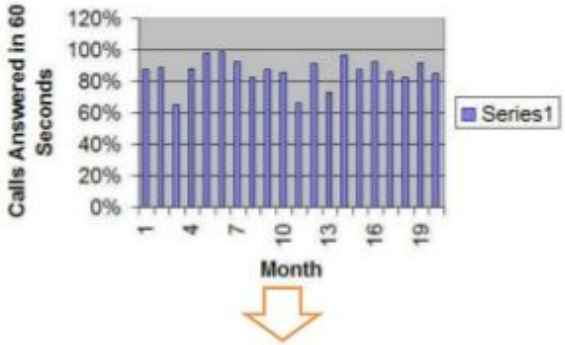
- 10% of males (i.e., ~10% of your reviewers...) have some form of colorblindness



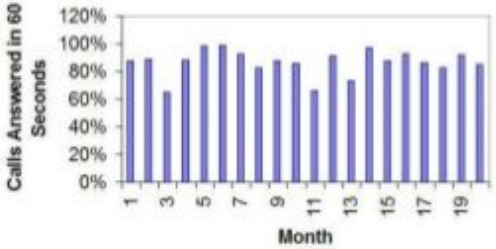


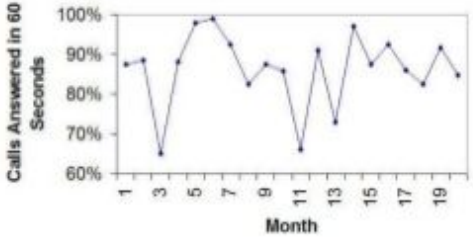
	Original	Simulation: Protan	Simulation: Deutan	Simulation: Tritan		Hue	for Photoshop, Illustrator, Freehand, etc.: C,M,Y,K (%)	for Photoshop, Illustrator, Freehand, etc.: R,G,B (0-255)	for Word, Power Point, Canvas, etc.: R,G,B (%)
1					Black	– °	(0,0,0,100)	(0,0,0)	(0,0,0)
2					Orange	41°	(0,50,100,0)	(230,159,0)	(90,60,0)
3					Sky Blue	202°	(80,0,0,0)	(86,180,233)	(35,70,90)
4					bluish Green	164°	(97,0,75,0)	(0,158,115)	(0,60,50)
5					Yellow	56°	(10,5,90,0)	(240,228,66)	(95,90,25)
6					Blue	202°	(100,50,0,0)	(0,114,178)	(0,45,70)
7					Vermilion	27°	(0,80,100,0)	(213,94,0)	(80,40,0)
8					reddish Purple	326°	(10,70,0,0)	(204,121,167)	(80,60,70)

Use data ink wisely! Avoid chart junk!

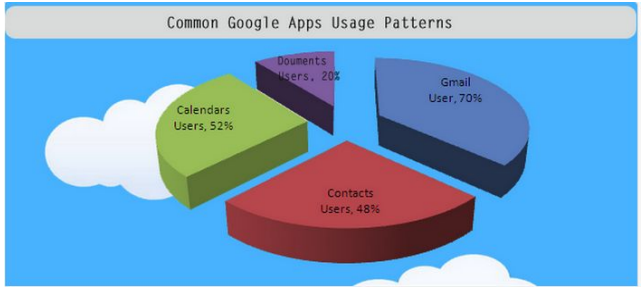


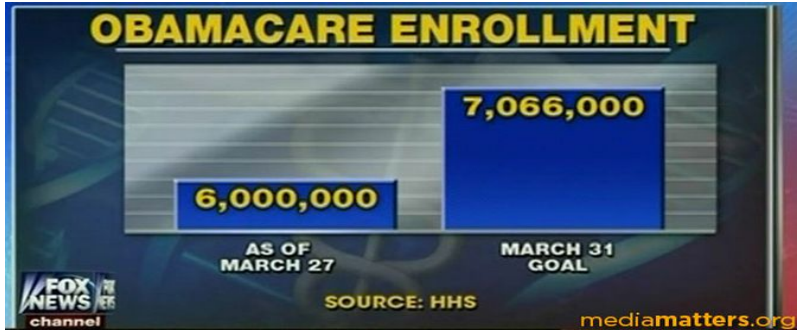
Graphical excellence gives the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.
-Edward Tufte

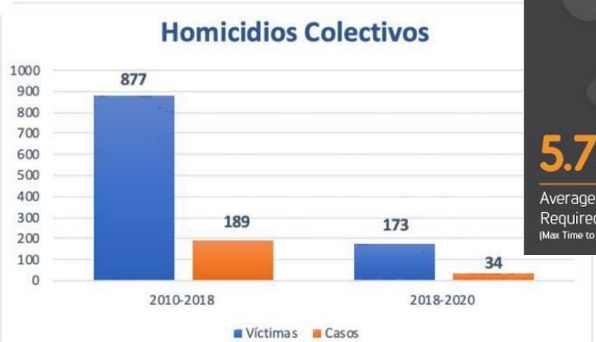


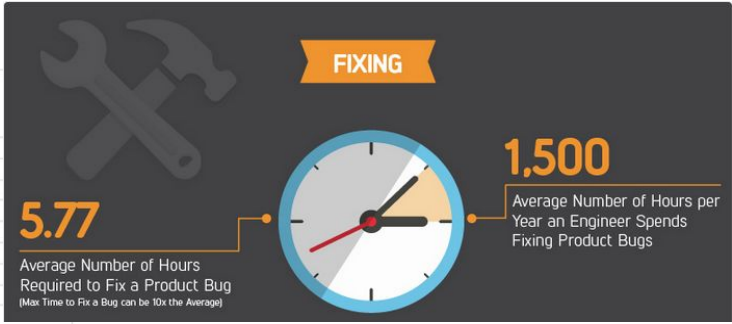


Toilet exercise: Which principles and best practices do these graphics violate?





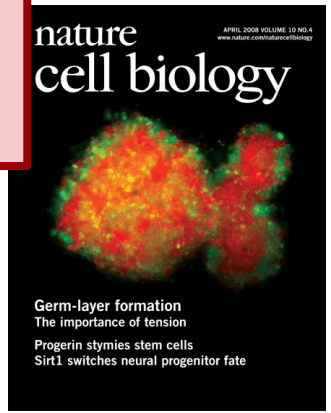


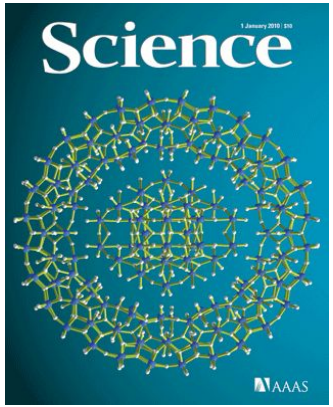


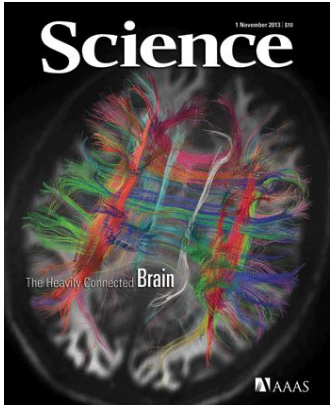
Courtesy of viz.wtf

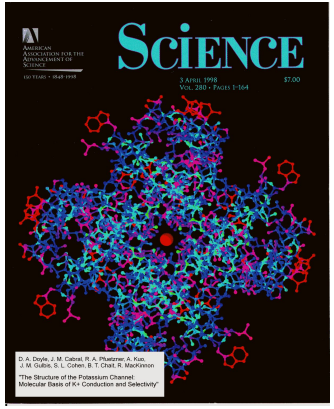
Part 3
A (small) selection of use cases for data visualization

Use case: Presenting scientific results





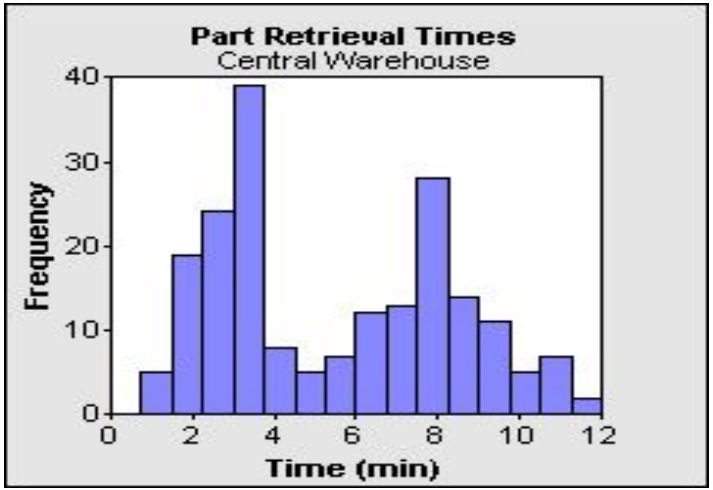




Use case:
Data wrangling

Multimodal data

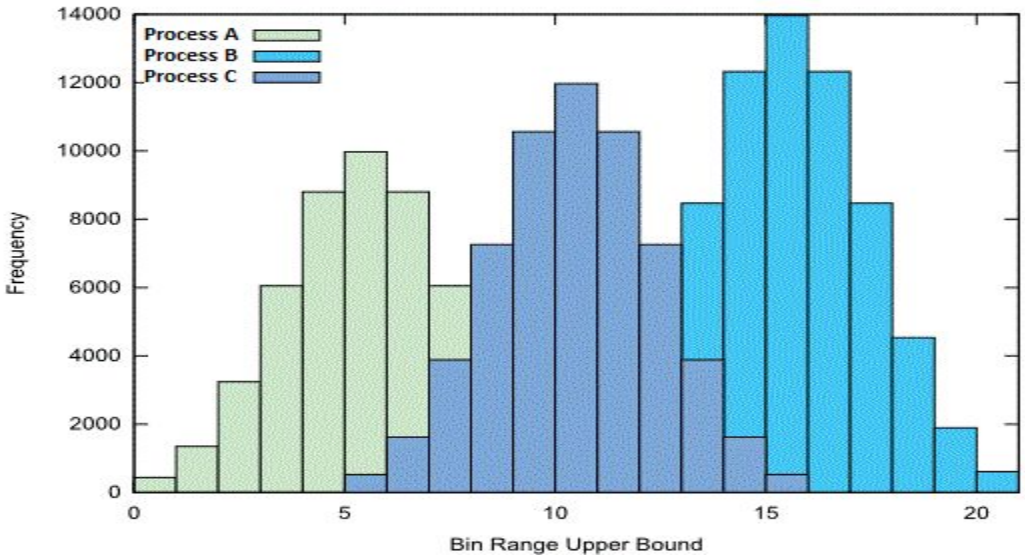
- Two or more distinct peaks in a histogram often **suggest 2 or more distinct populations** of samples.
- Often arises from binary factors such as gender or political views.
- But don't guess! Explore further by using, e.g., color and a histogram of multiple populations (p.t.o.).



Use case:
Data wrangling

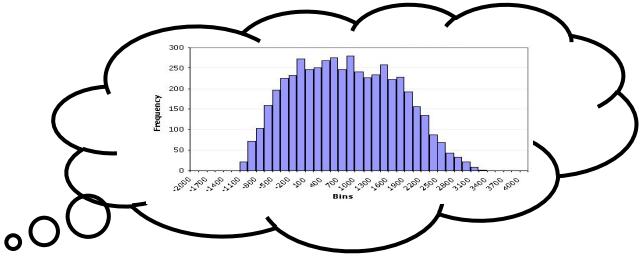
Multimodal data

Explore further by using, e.g., color and a histogram of multiple populations

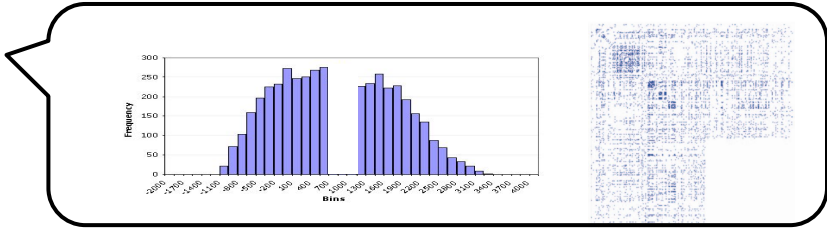


Use case:
Data wrangling

Weird data



- Maintain a **theory of what the data should look like**.
- Some data is **very hard to explain**.
- Never just blink it away!
- First, assume a bug. Try to fix it.
- If not a bug: you might have made an interesting discovery!
- Some of science's most important findings were made by not ignoring weird data, but dwelling on it!



[link]

Use case: Journalism

NY Times interactive visualizations (recession/recovery 2014)

http://www.nytimes.com/interactive/2014/06/05/upshot/how-the-recession-reshaped-the-economy-in-255-charts.html

And 2014 “the year in interactive storytelling”

http://www.nytimes.com/interactive/2014/12/29/us/year-in-interactive-storytelling.html?_r=0

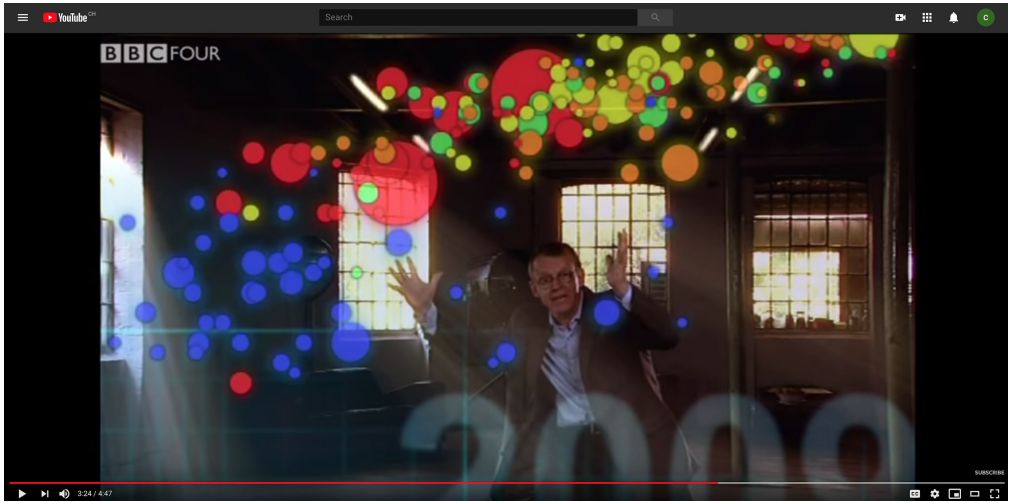
NY Times graphics are a great source of best practices in viz (except for when they’re not…)

Use case: Educating the public

Hans Rosling:

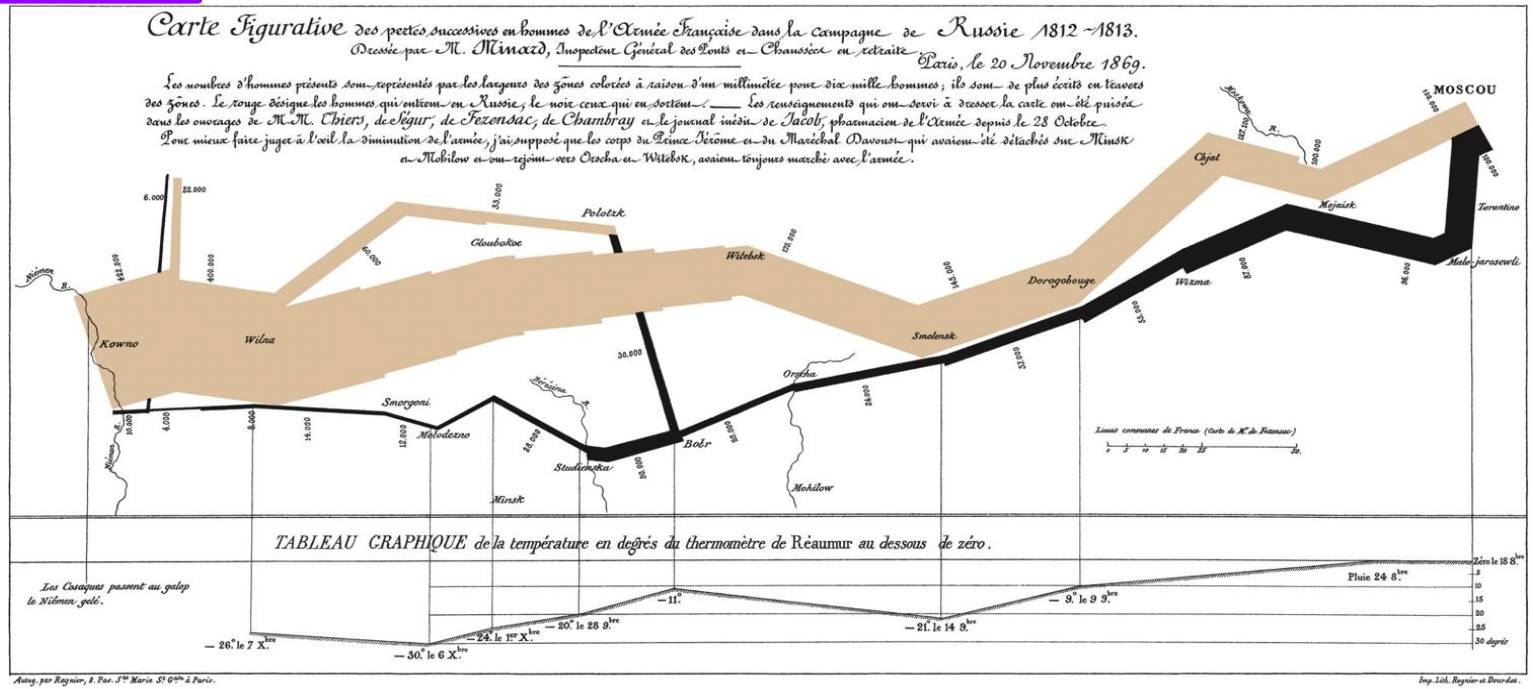
200 countries, 200 years, 4 minutes

https://www.youtube.com/watch?v=jbkSRLYSojo



Use case: Give new perspectives

Charles Joseph Minard 1869 Napoleon's march



According to Tufte: "*It may well be the best statistical graphic ever drawn.*"

5 variables: army size, location, dates, direction, temperature during retreat

Tools

(remaining slides for your personal perusal)

Interactive toolkits: D3

Without doubt, the most widely used interactive visualization framework is **D3**.

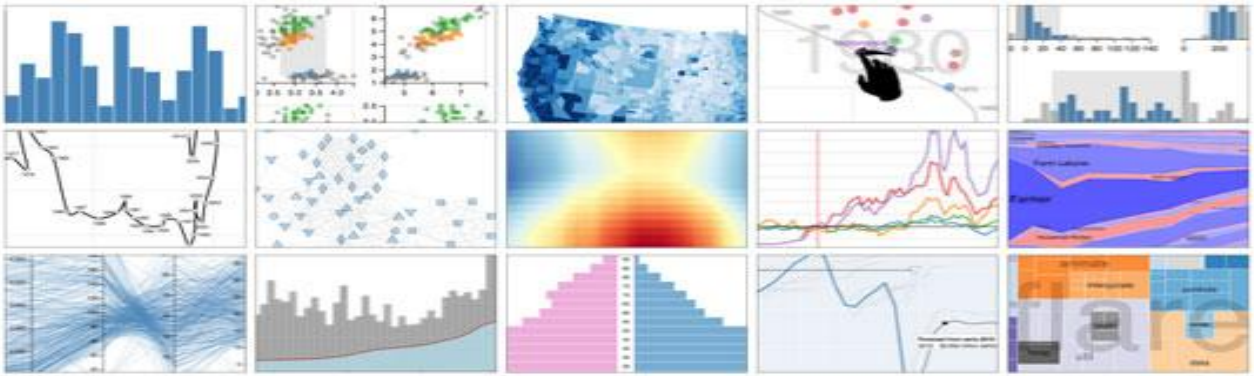
Note from the authors: *D3 is intentionally a low-level system. During the early design of D3, we even referred to it as a "visualization kernel" rather than a "toolkit" or "framework"*

Interactive toolkits: Vega

Vega is a “visualization grammar” developed on top of D3.js

It specifies graphics in JSON format.

vega

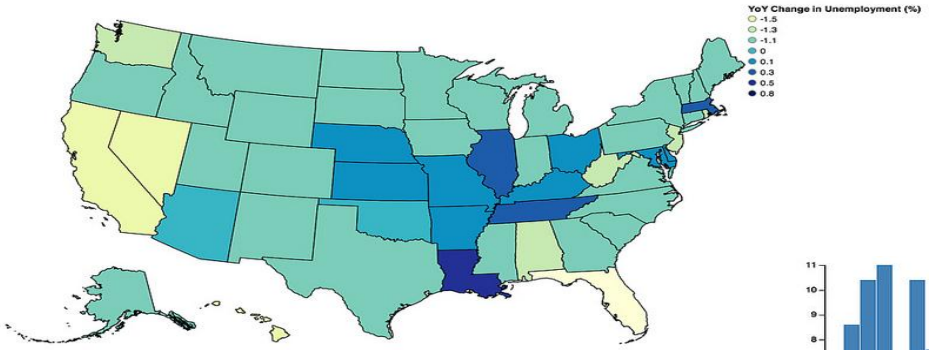


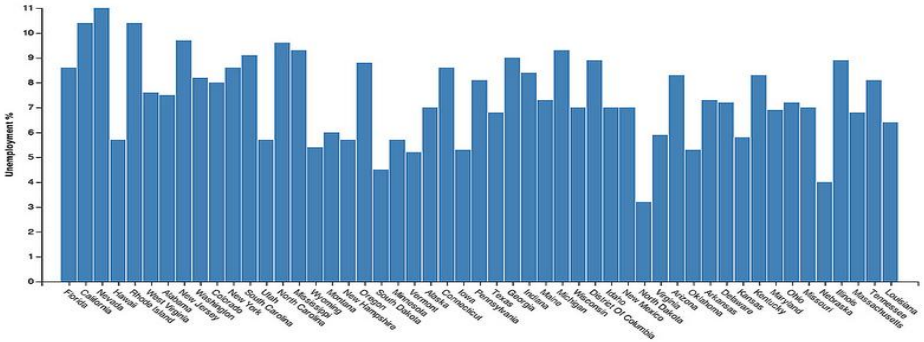
Vega is a *visualization grammar*, a declarative format for creating, saving, and sharing interactive visualization designs.

Interactive toolkits: Vincent

Vincent is a Python-to-Vega translator.

Trivia question: why is it called Vincent? Hint: Vincent+Vega= ?





Interactive toolkits: Vincent

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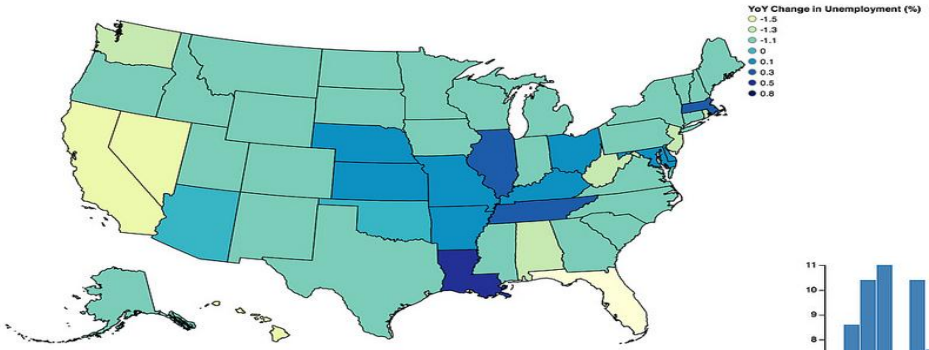
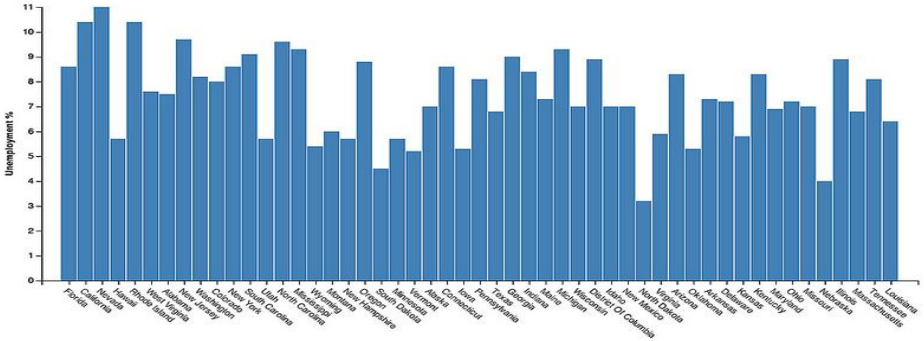


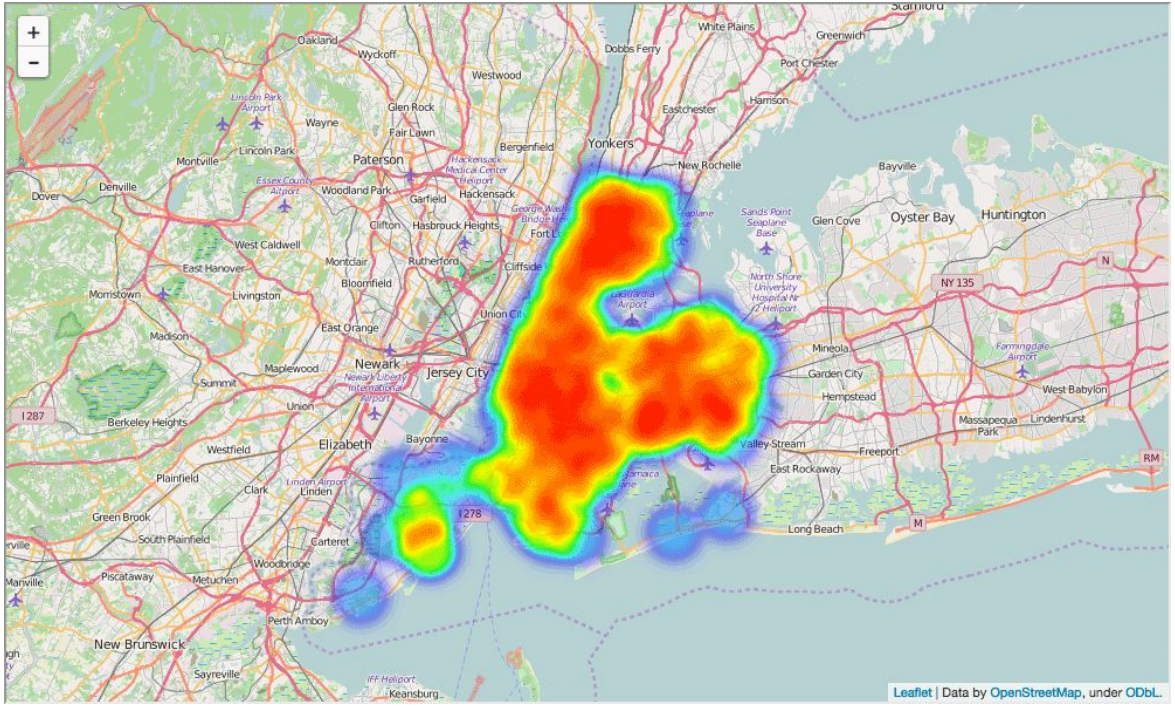


Bokeh: another interactive viz library

Bokeh is an independent Viz library focused more heavily on big data visualization. Has both Python and Scala bindings.

Visualizing maps: Folium

More in tomorrow's lab session!



Feedback

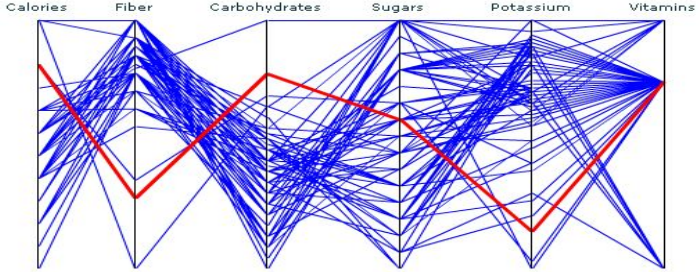
Give us feedback on this lecture here:
https://go.epfl.ch/ada2020-lec3-feedback

- What did you (not) like about this lecture?
- What was (not) well explained?
- On what would you like more (fewer) details?
- What's your favorite color, baby?
- …

> 2 variables: parallel-coord. plots

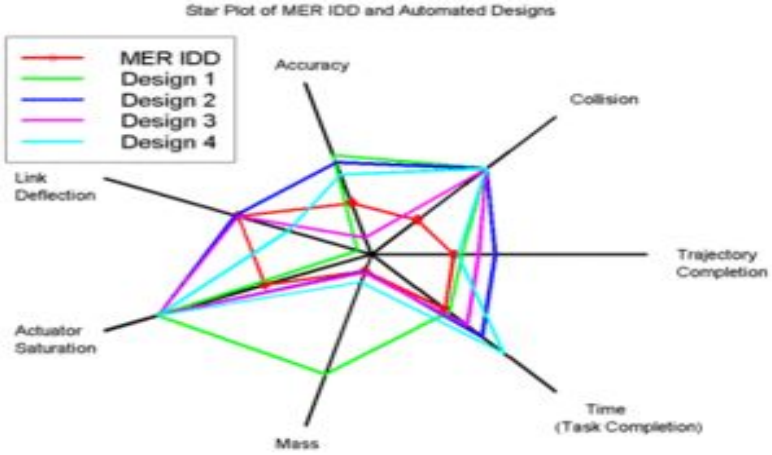
Color, x, y

Color variable is categorical, others arbitrary



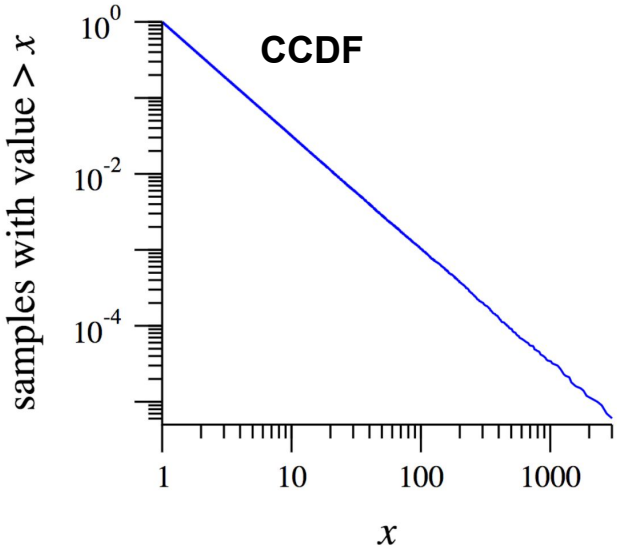
> 2 variables: radar charts

- Similar to parallel-coord. plots
- Doesn't pretend that x axis has meaningful order
- Also good for periodic data



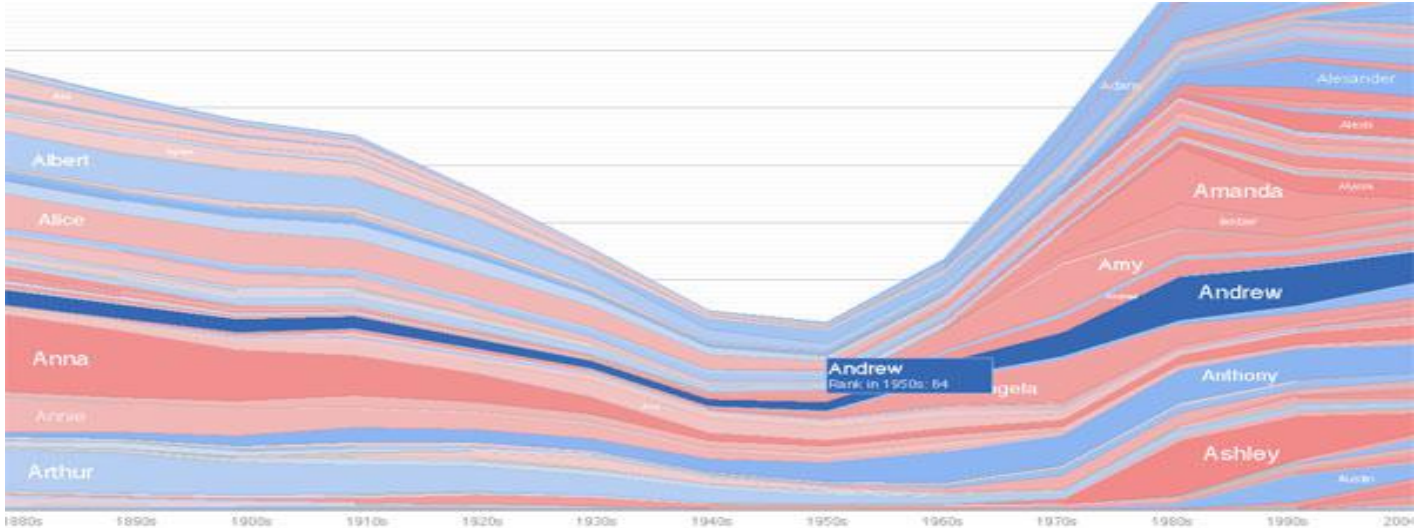
Heavy-tailed data: power laws

- Smart trick for plotting CCDF of any distribution:
  - x-axis: data sorted in ascending order
  - y-axis: (n:1)/n (where n is number of data points)



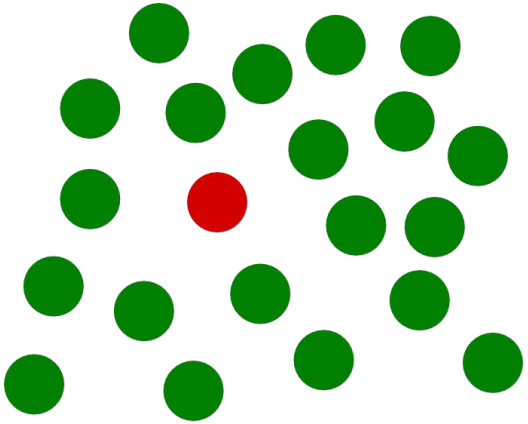
Interactive chart design: simplifying

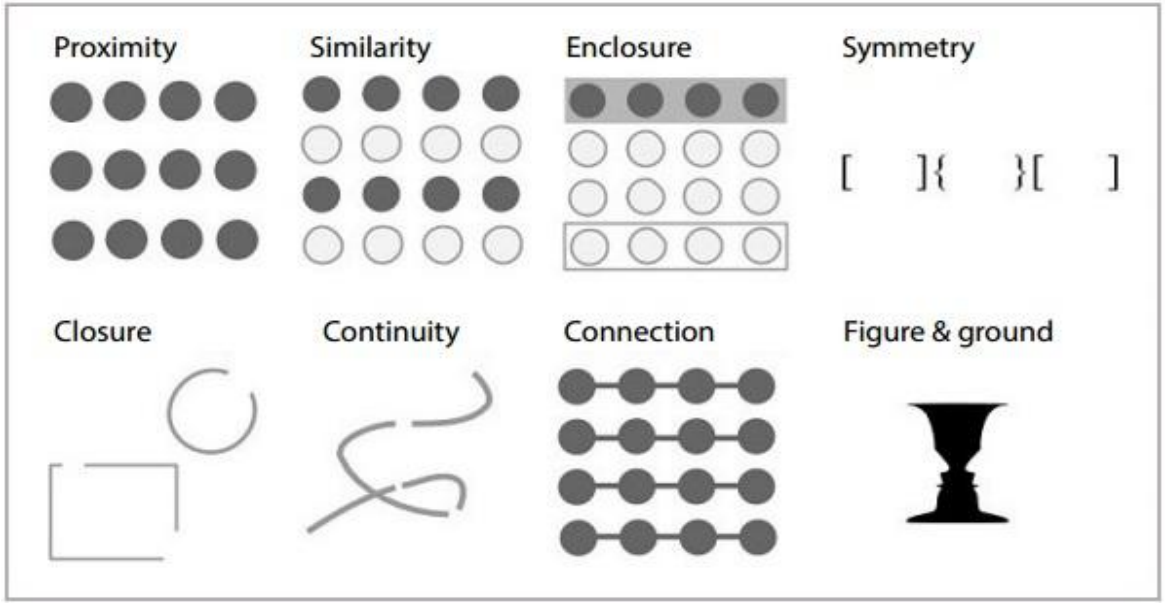
- With interactive charts you can keep things very simple by **hiding** and **dynamically revealing** important structure.
- On an interactive chart, you reveal the information most useful for **navigating** the chart.



Use structure!

Gestalt psychology principles (1912)



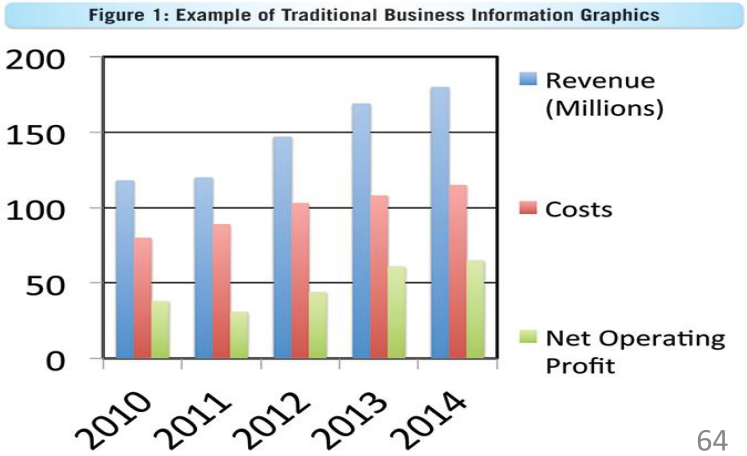
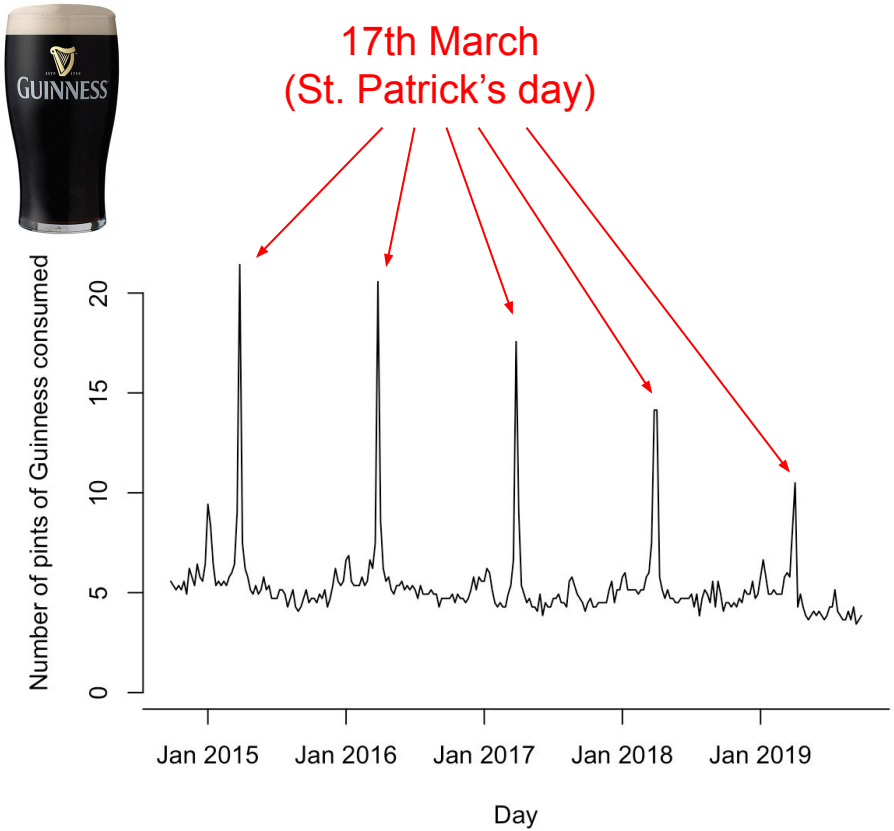


A case for ugly visualizations

People instinctively gravitate to attractive visualizations, and they have a better chance of getting on the cover of a journal.

But does this **conflict with the goals of visualization?**

- Rapid exploration
- Focus on most important details
- Easy and fast to develop and customize



Guide your audience!