ASPP 2022

MONDRAGON UNIBERTSITATEA

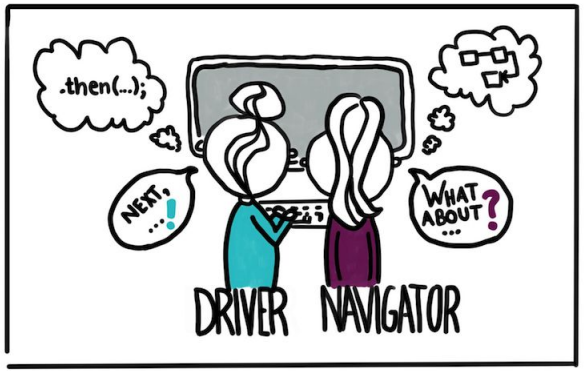
Best practices in data visualization

Guillermo Aguilar, Aina Frau-Pascual, Nicolas P. Rougier

Bilbao, ASPP 2022

Plan for this session

16:30	Principles of data visualization
	Hands-on Exercise 1: **mastering matplotlib**
	Review
~ 17:40	Break 5-10 min
~ 17:50	Visualizations and use of color
	Hands-on Exercise 2: **which visualization should I use?**
	Review of your solutions as PR
	(*) Hands-on Exercise 3: images + **Review** of your solutions as PR
19:00	The End!



Visualization is a method of computing. It transforms the symbolic into geometric, **enabling researchers to observe** their simulations and computations. Visualization offers **a method for seeing the unseen.** It enriches the process of scientific discovery and fosters profound and unexpected insights.

Visualization in Scientific Computing, NSF report, 1987

Classical example: Anscombe's quartet

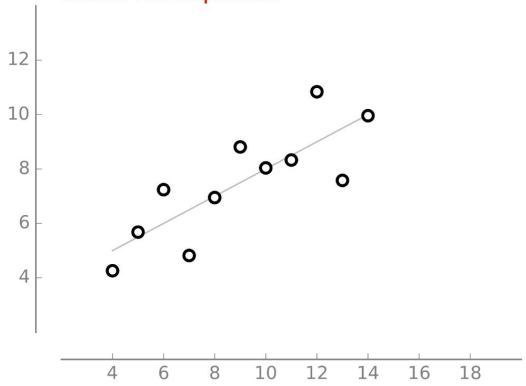
I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

statistic	value
mean of x	9
sample variance of x	11
mean of y	7.50
sample variance of y	4.125
correlation coefficient	0.816
linear regression line	y = 3.00 + 0.500x
coefficient of determination	0.67

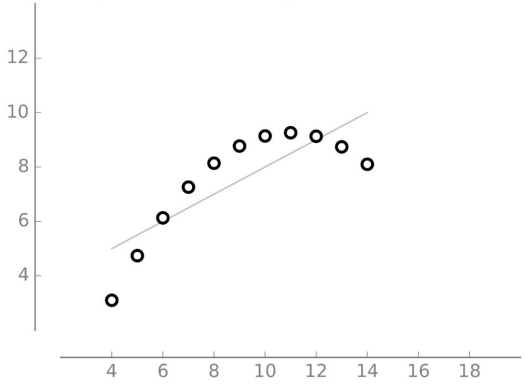
Anscombe (1973)

Classical example: Anscombe's quartet

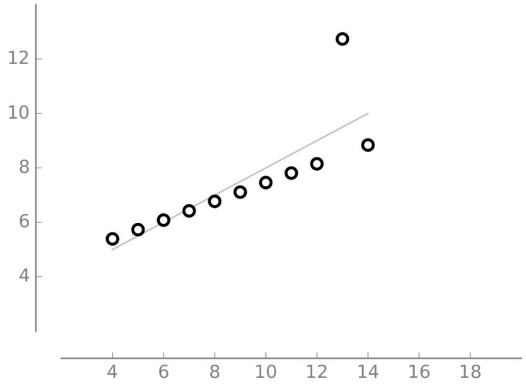
What we expect...



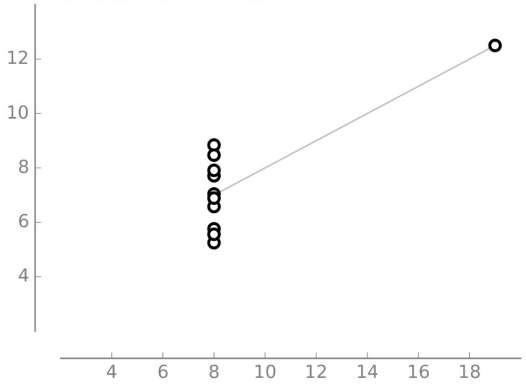
The non-linear case



The Y outlier case



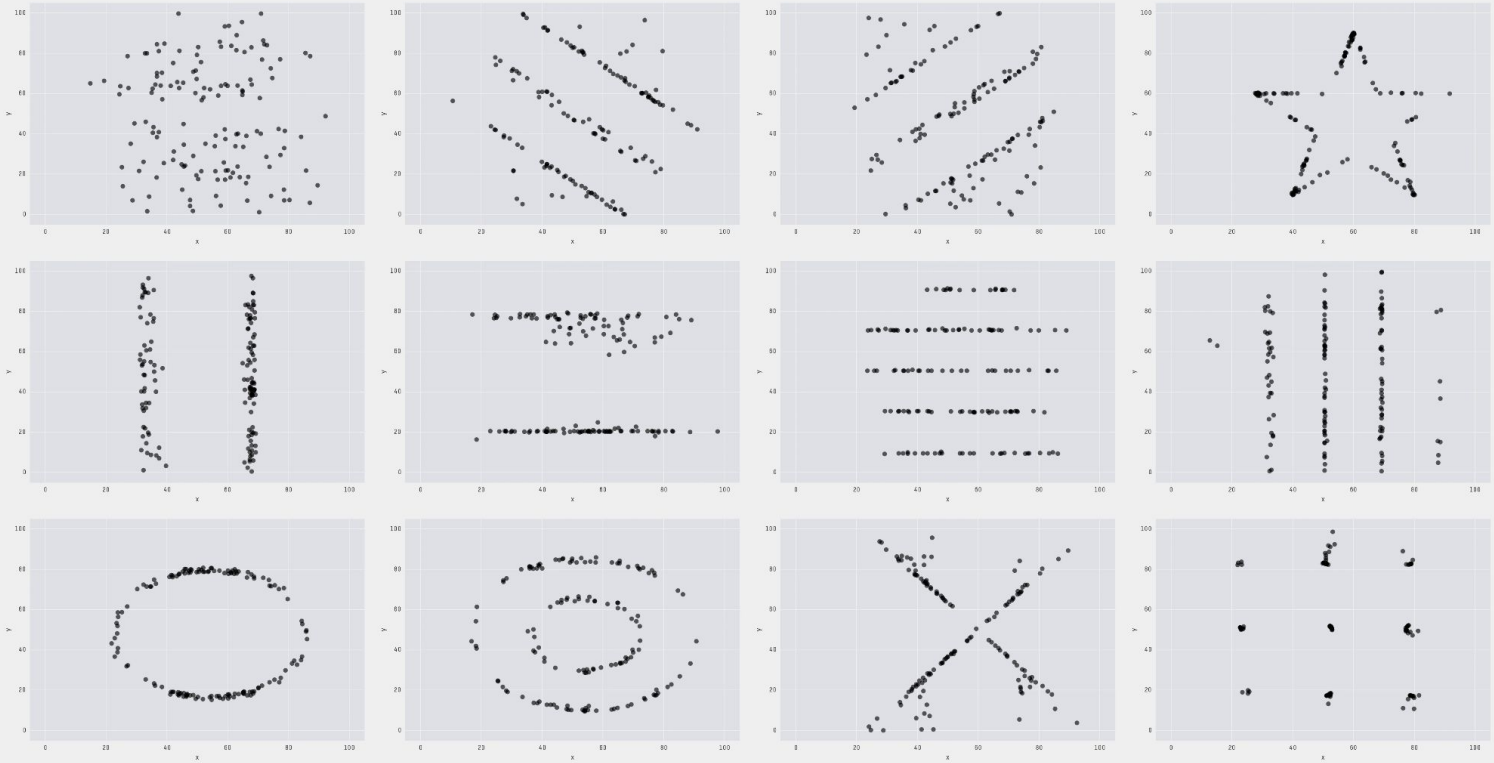
The X outlier case



statistic	value
mean of x	9
sample variance of x	11
mean of y	7.50
sample variance of y	4.125
correlation coefficient	0.816
linear regression line	y = 3.00 + 0.500x
coefficient of determination	0.67

Datasaurus

X Mean: 54.26
Y Mean: 47.83
X SD : 16.76
Y SD : 26.93
Corr. : -0.06



And you will read this last

You will read this first

And you will read this

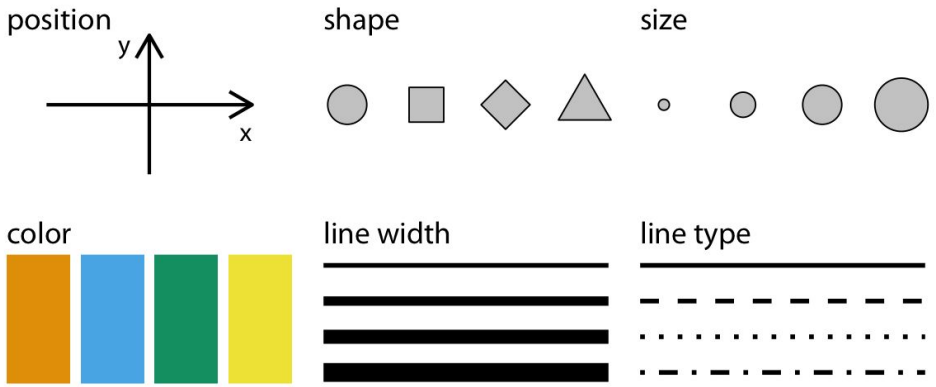
Then this one

Source: UX design

Main challenge on data visualization: the **mapping from..**

Data → Graphical elements

Type of variable	Examples	Appropriate scale
quantitative/numerical continuous	1.3, 5.7, 83, $1.5x10^{-2}$	continuous
quantitative/numerical discrete	1, 2, 3, 4	discrete
qualitative/categorical unordered	dog, cat, fish	discrete
qualitative/categorical ordered	good, fair, poor	discrete
date or time	Jan. 5 2018, 8:03am	continuous or discrete



Claus O. Wilke (2019)

OPEN ACCESS Freely available online

PLOS | COMPUTATIONAL BIOLOGY

Editorial

Ten Simple Rules for Better Figures

Nicolas P. Rougier[1,2,3]*, Michael Droettboom[4], Philip E. Bourne[5]

1 INRIA Bordeaux Sud-Ouest, Talence, France, **2** LaBRI, UMR 5800 CNRS, Talence, France, **3** Institute of Neurodegenerative Diseases, UMR 5293 CNRS, Bordeaux, France, **4** Space Telescope Science Institute, Baltimore, Maryland, United States of America, **5** Office of the Director, The National Institutes of Health, Bethesda, Maryland, United States of America

1) Know your audience

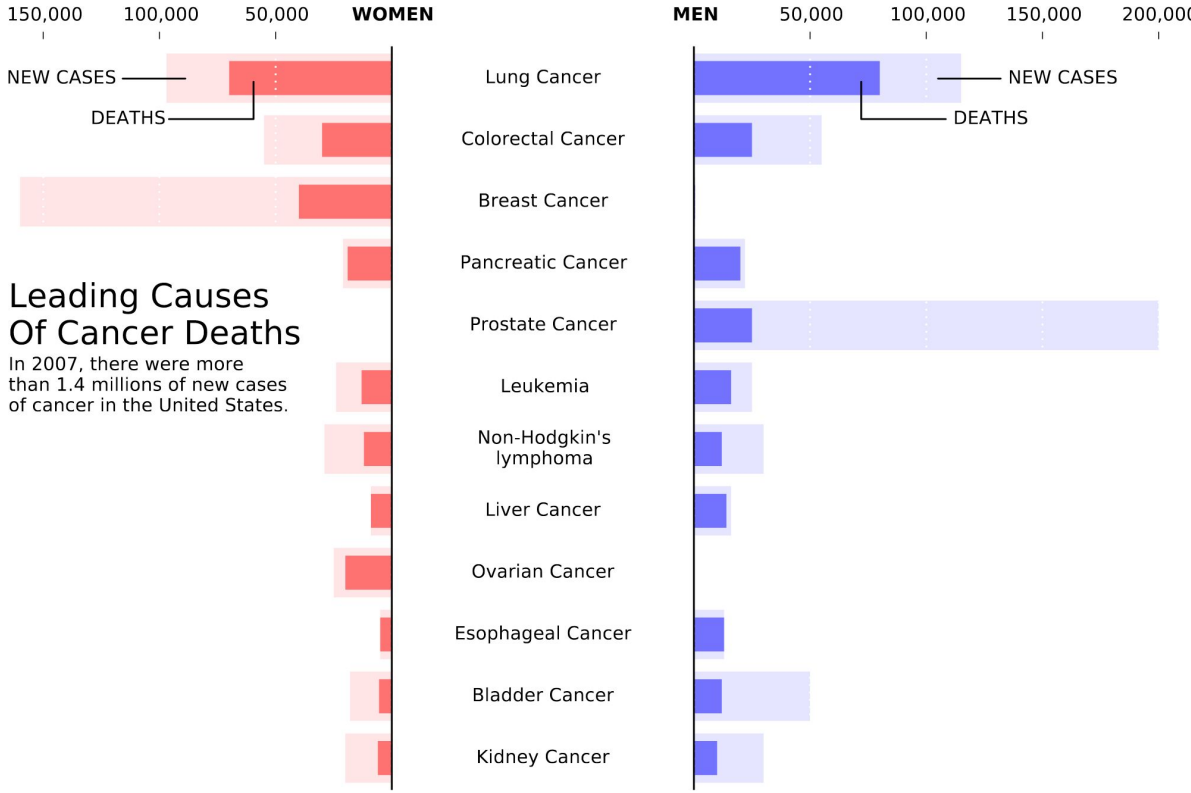
- Complexity +

My colleagues

Scientific community

Student audience

General public



Audience: general public

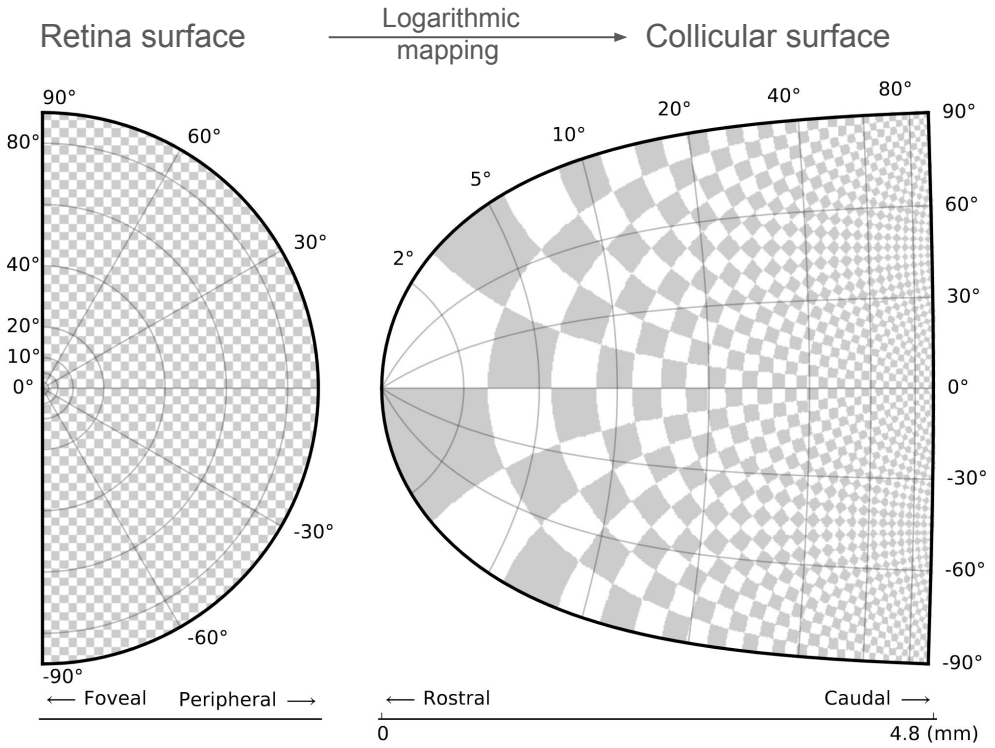
Main message: cancer

Separated in sex groups: Women / Men

2) Identify your message

Audience:
neuroscience
scientific
community

Superior Colliculus

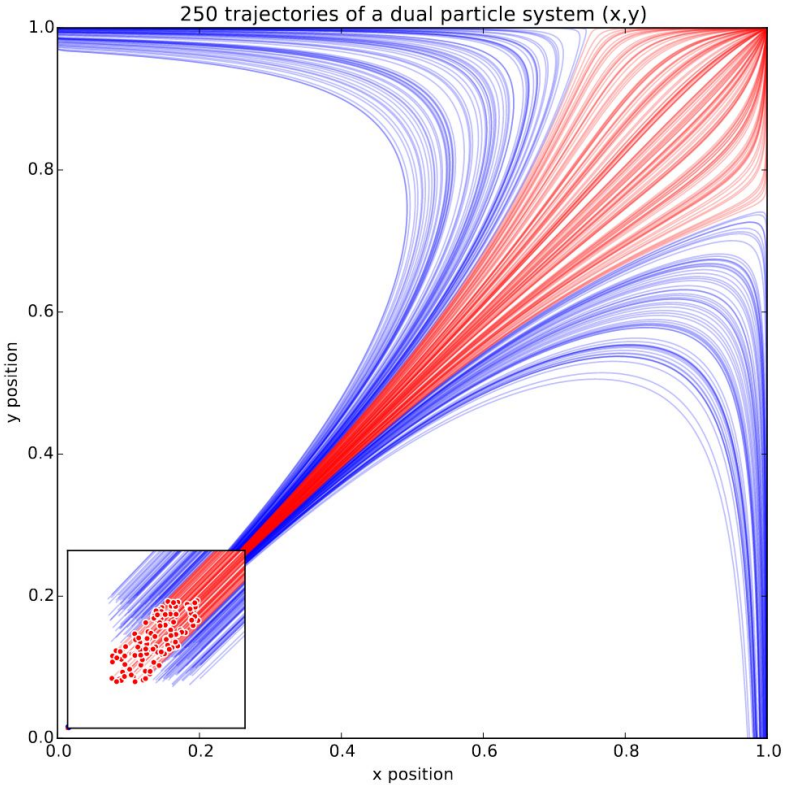


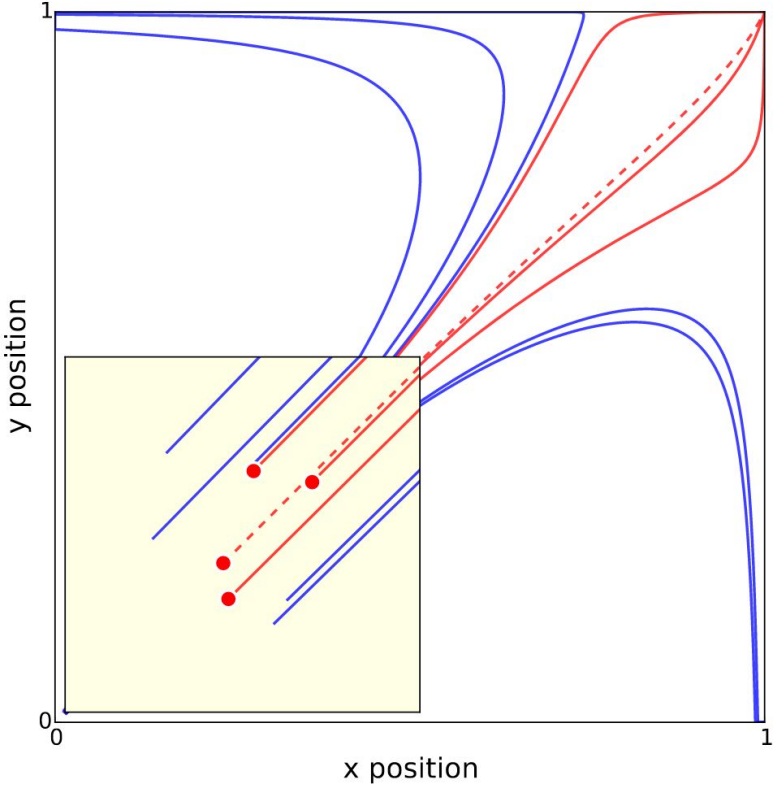
SC regions

Main message: Artificial checkerboard pattern demonstrates the magnification of the foveal region in the superior colliculus (brainstem structure). This has to do with the induction of saccadic eye movement that the SC plays a role in.

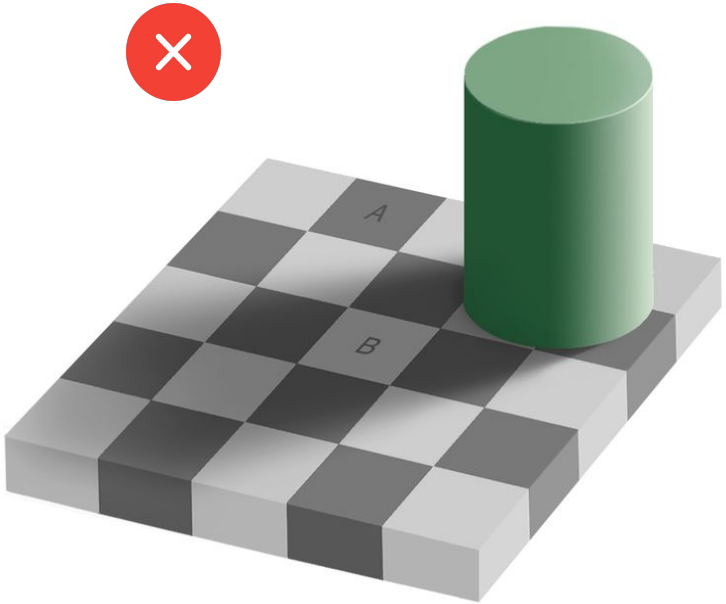
3) Adapt the figure to support medium

Simulation of trajectories of a dual-particle system



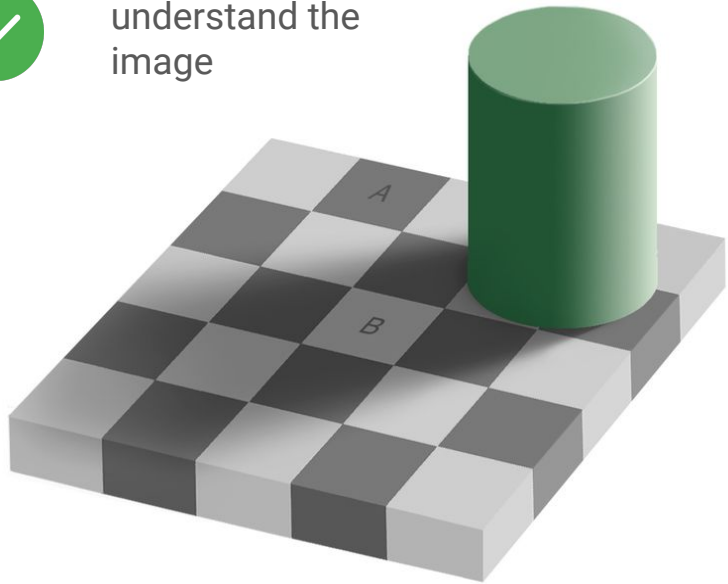


4) Captions are not optional



Optical illusion

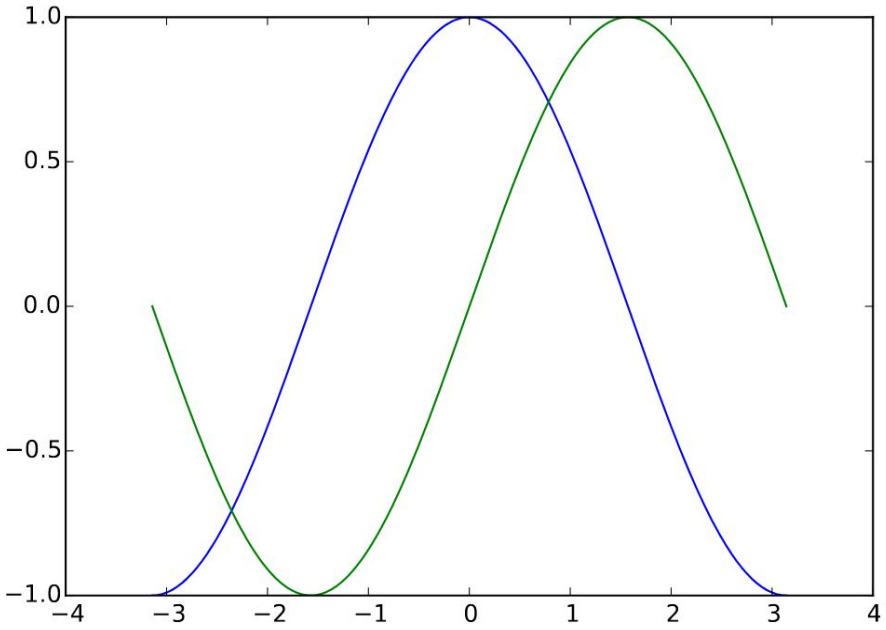
Caption helps you understand the image



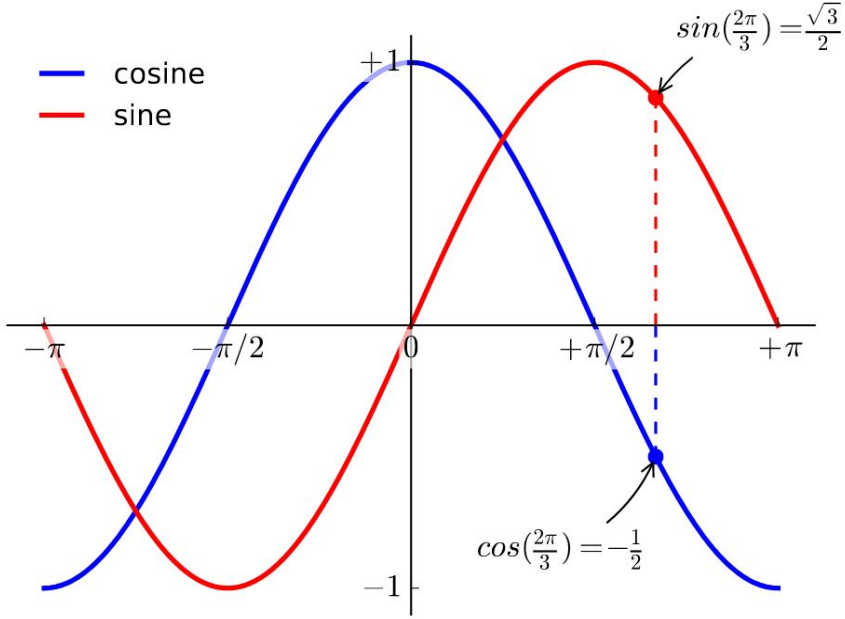
A and B patches are actually the same color even though we perceive them at being different color

5) Do not trust the defaults

Defaults for a matplotlib plot



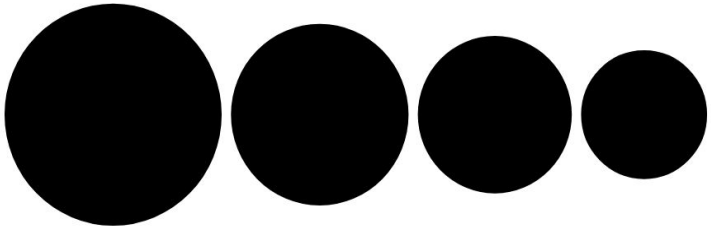
With a bit of work…



6) Use color effectively → more on this later

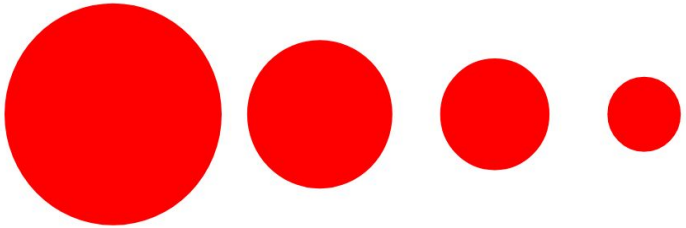
7) Do not mislead the reader

Using the disc area shows a more proportional sizes



Relative size using disc area

Relative size using disc radius



Using the disc radius misleads the reader to think the difference is bigger

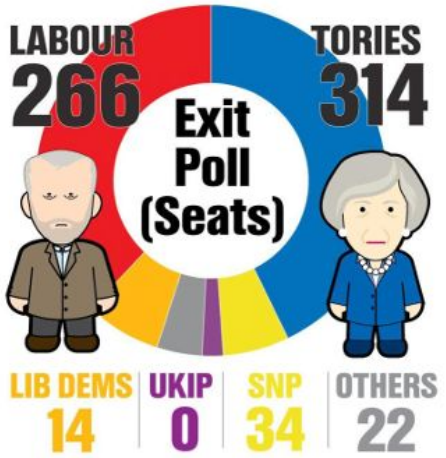
Using full range bars shows a more realistic comparison among them

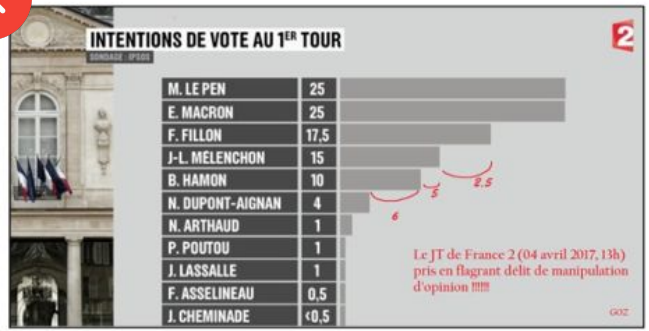
Relative size using full range

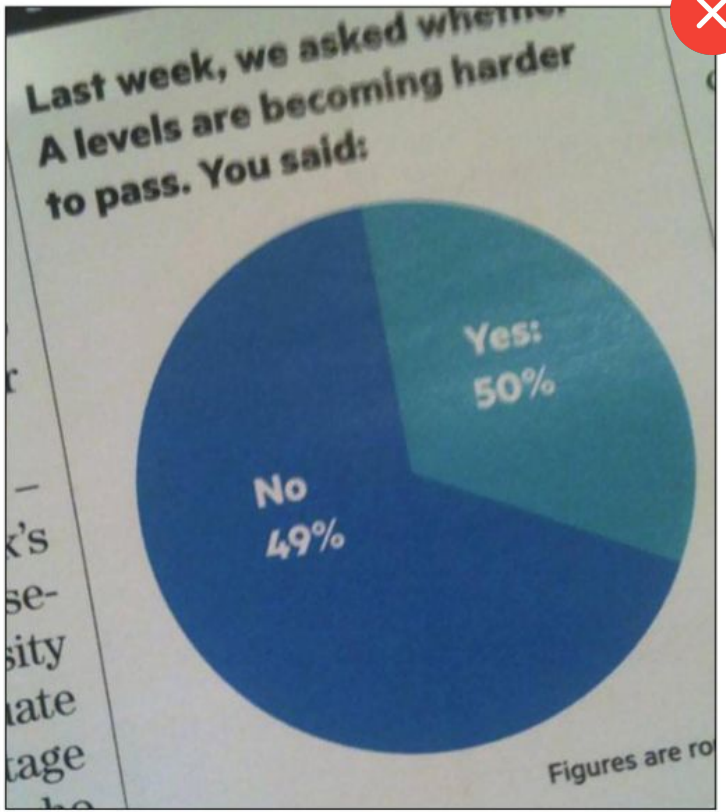
Relative size using partial range

Using partial range bars misleads the reader to think the difference is bigger

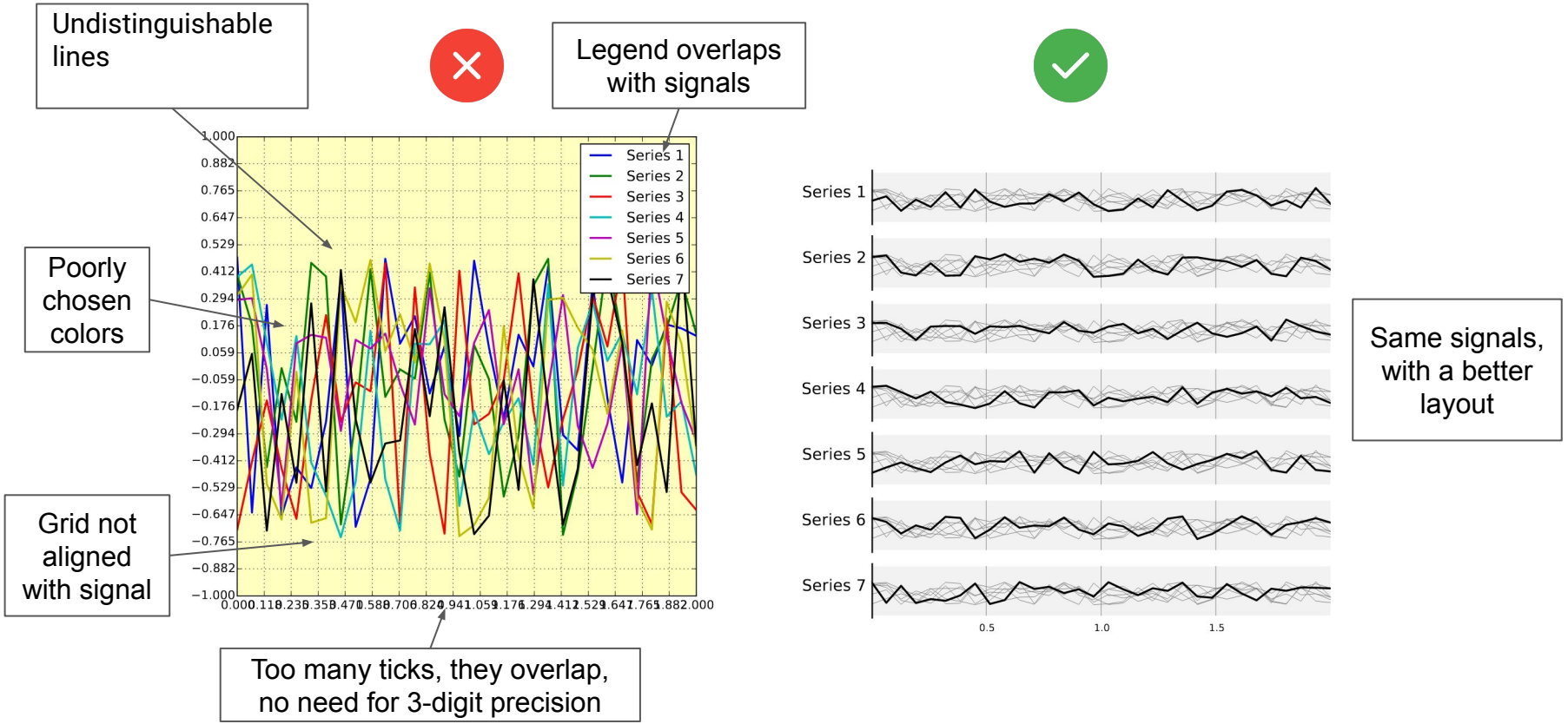
7) Do not mislead the reader. Really.



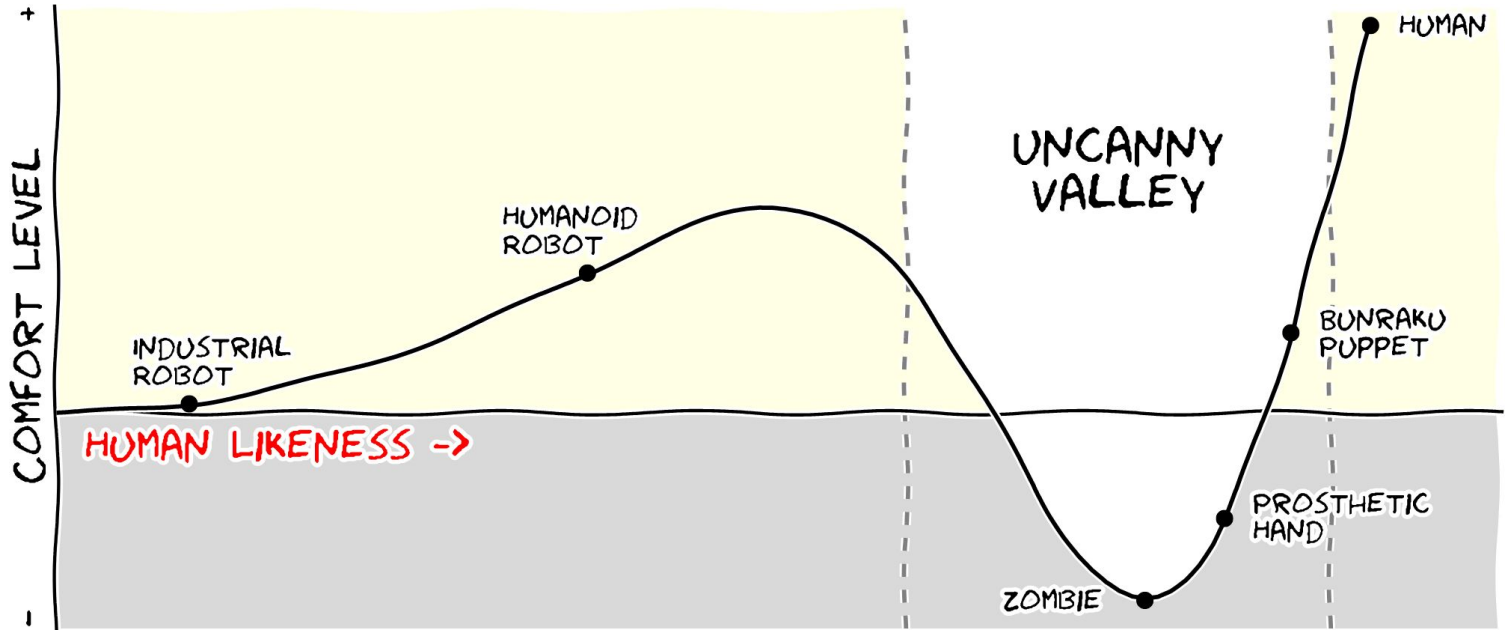




8) Avoid chartjunk



9) Message trumps beauty



10) Get the right tool

PDFCrop to remove white borders

GraphViz for creating easy graphs

ImageMagick for scripted image processing

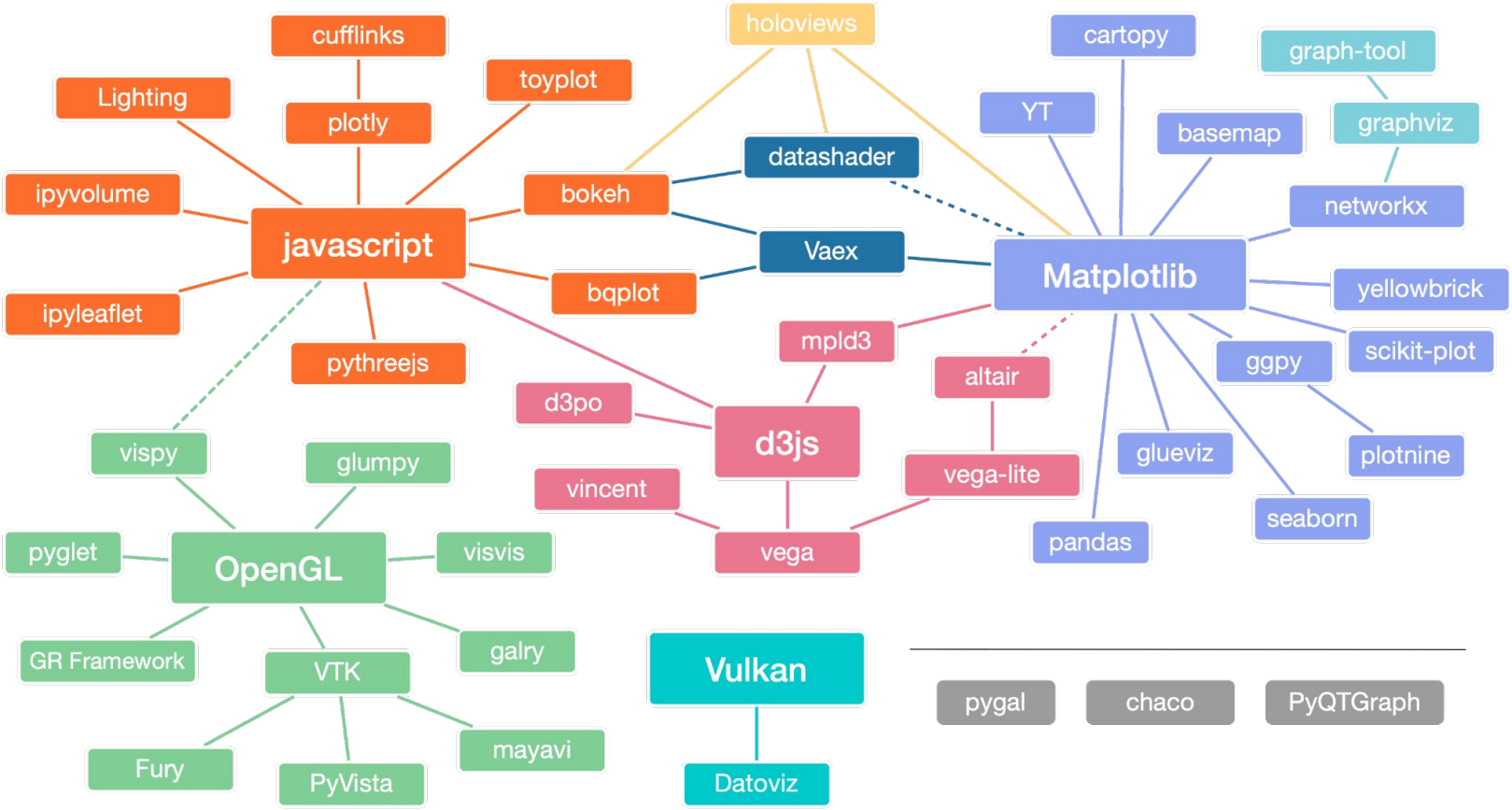
Gimp for bitmap image manipulation

Inkscape for vector image manipulation

Tikz for scripted vector art

And many, many, many others…

Overview of visualization libraries

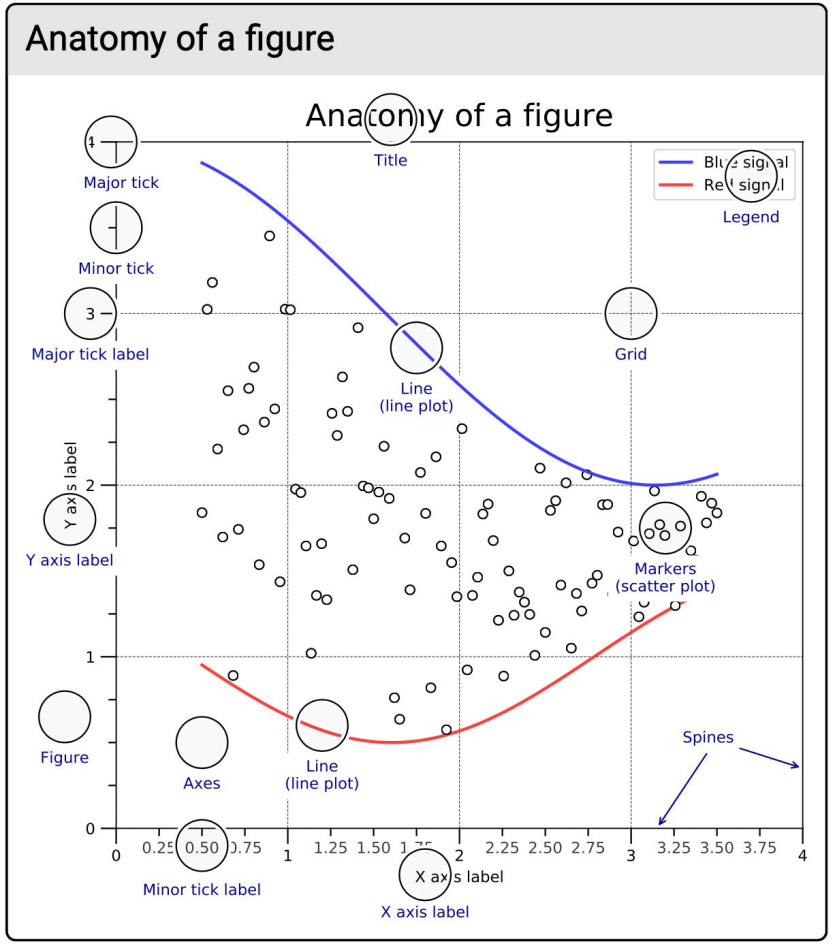


Time for hands-on exercises!

Exercise 1: Mastering matplotlib

Have your cheatsheet at hand!:

https://matplotlib.org/cheatsheets/

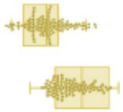


Many types of data visualization tools: datavizcatalogue.com

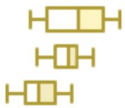
Distributions: one continuous variable

Barcode Plot

Bean Plot

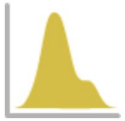


Bee Swarm Box Plot



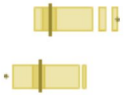
Box Plot

Box-Percentile Plot



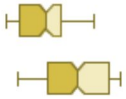
Density Plot

Dot Distribution Plot



HDR Box Plot

Histogram



Notched Box Plot

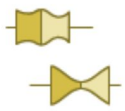
Population Pyramid

Q-Q Plot

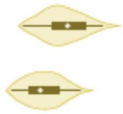
Ridgeline Plot

Sina Plots

Stem & Leaf Plot



Vase Plot



Violin Plot

Proportions, parts-to-a-whole and Flow

Bubble Chart

Bubble Map

Circle Packing

Demers Cartogram

Dorling Map

Marimekko Chart

100% Stacked Bar Chart

Donut Chart

Waffle Chart

Parallel Sets

Pie Chart

Proportional Area Chart

Sankey Diagram

Treemap

Unit Chart (Area)

Alluvial Diagram

Flow Diagram

Comparisons: more than one variable

Bar Chart

Bullet Graph

Column Chart

Dot Graph

Grouped Bar Chart

Lollipop Chart

Pictogram Chart

Radial Column Chart

Side by Side Bar Chart

Slopegraph

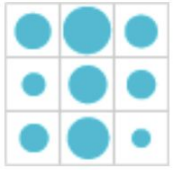
Stacked Bar Chart

Unit Chart

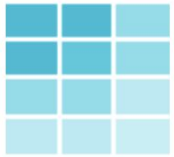
Radar Chart

Correlations and Uncertainty/Error

Bubble Chart



Correlation Matrix

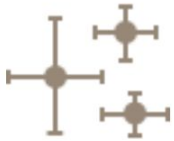


Heatmap

Scatterplot

Area Bands

Confidence Strips



Error Bars

Graded Error Bars

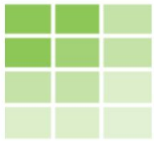
Data over time: timeseries

Area Graph

Connected Scatterplot

Control Chart

Gantt Chart



Heatmap

Horizon Plot

Line Graph

Run Chart

Spiral Plot

Stacked Area Graph

Streamgraph

Timeline

Connections and Hierarchy

Arc Diagram

Circular Tree Diagram

Connection Map

Hive Plot

Network Diagram

Non-ribbon Chord Diagram

Circular Tree Diagram

Circular Treemap

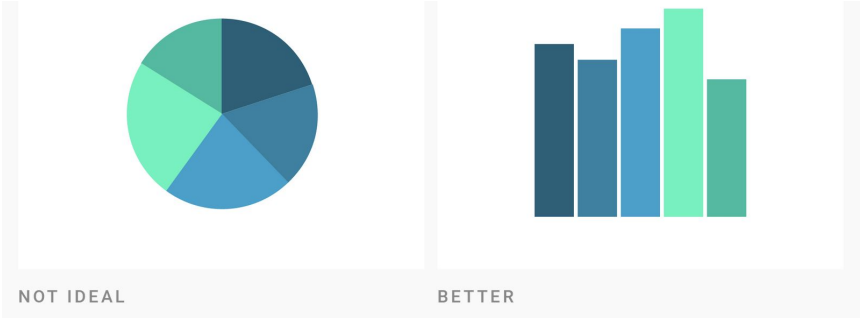
Icicle Chart

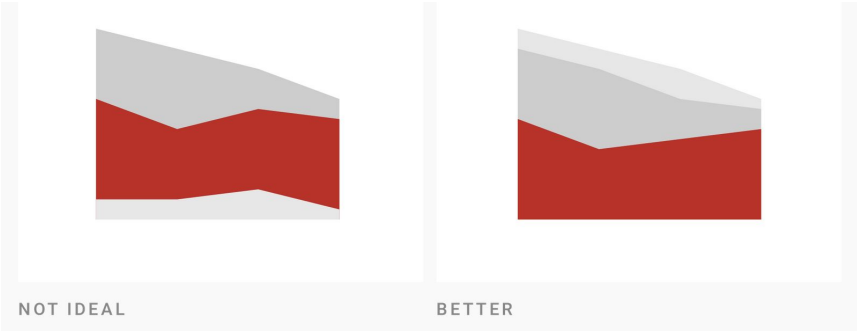
Sunburst Diagram

Tree Diagram

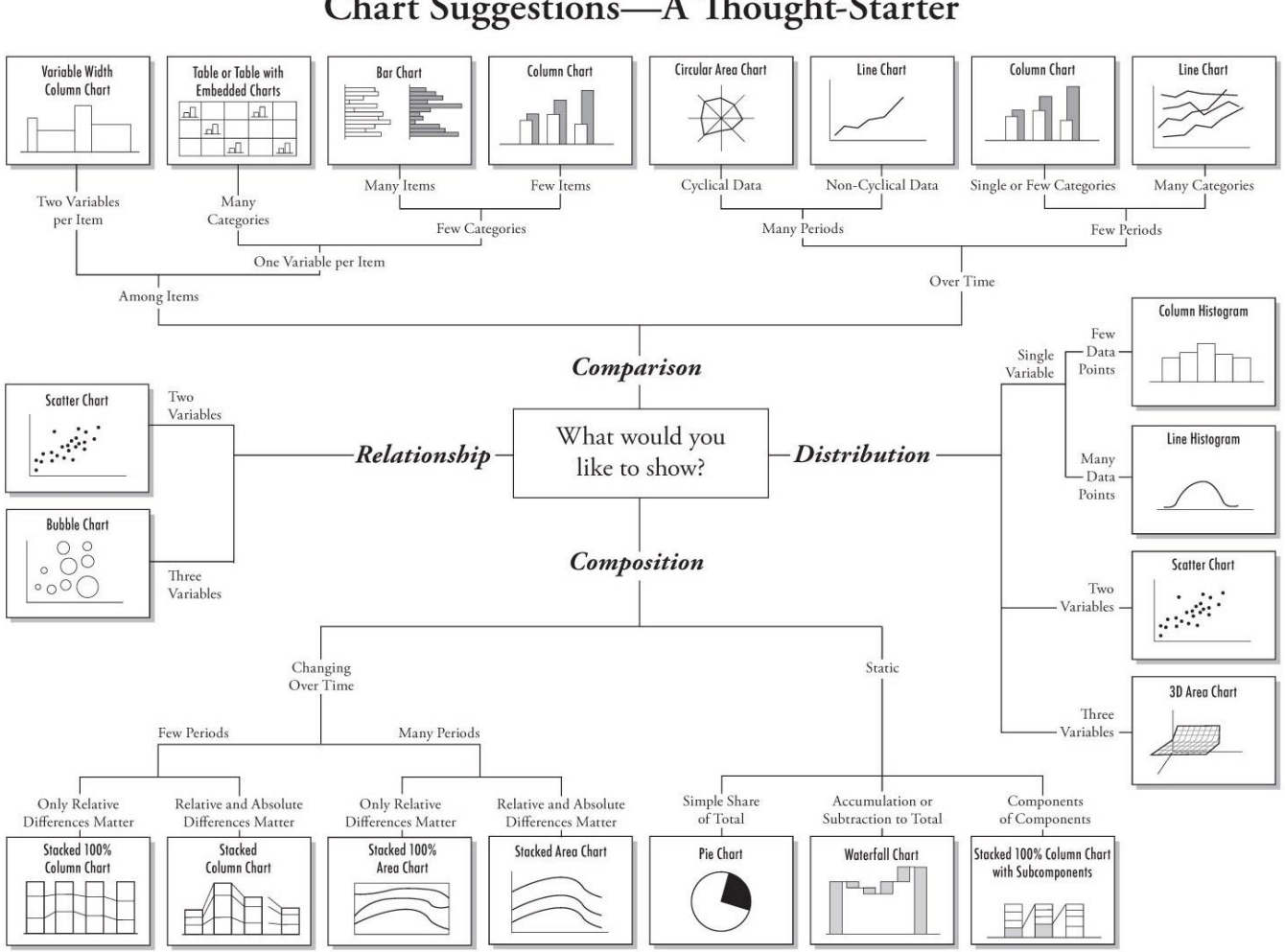
Treemap

Each data structure has a better graphic type to represent it



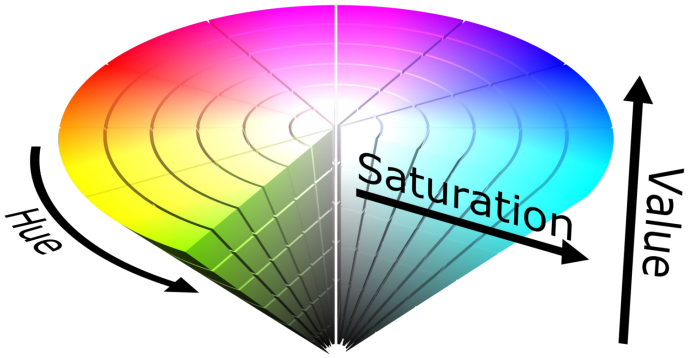


If you're completely overwhelmed by options,
you can use:



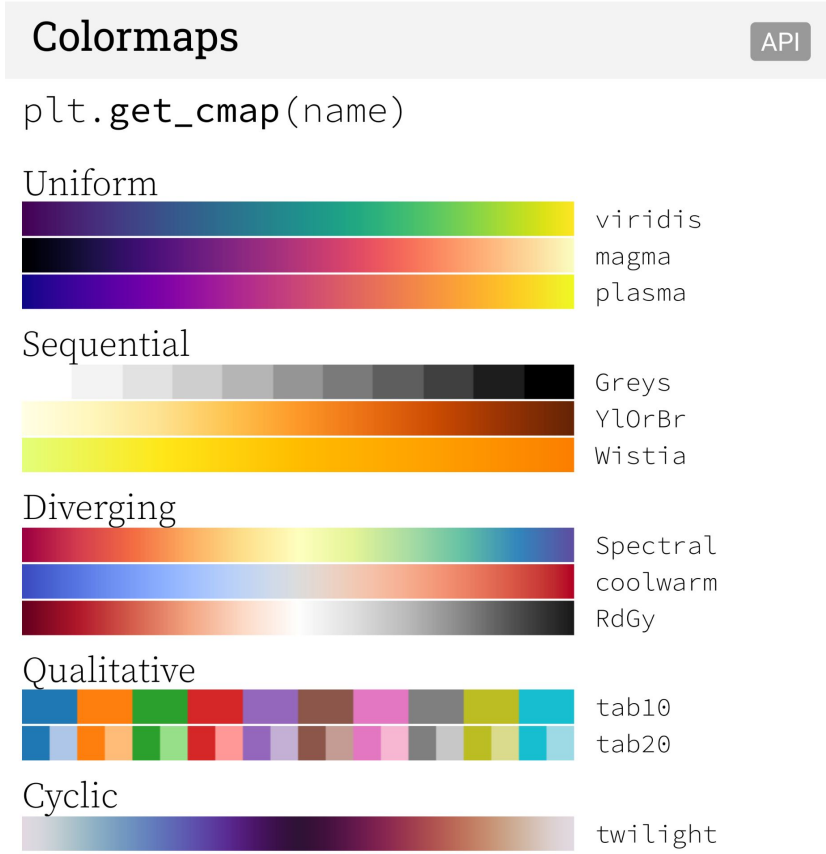
6) Use color effectively

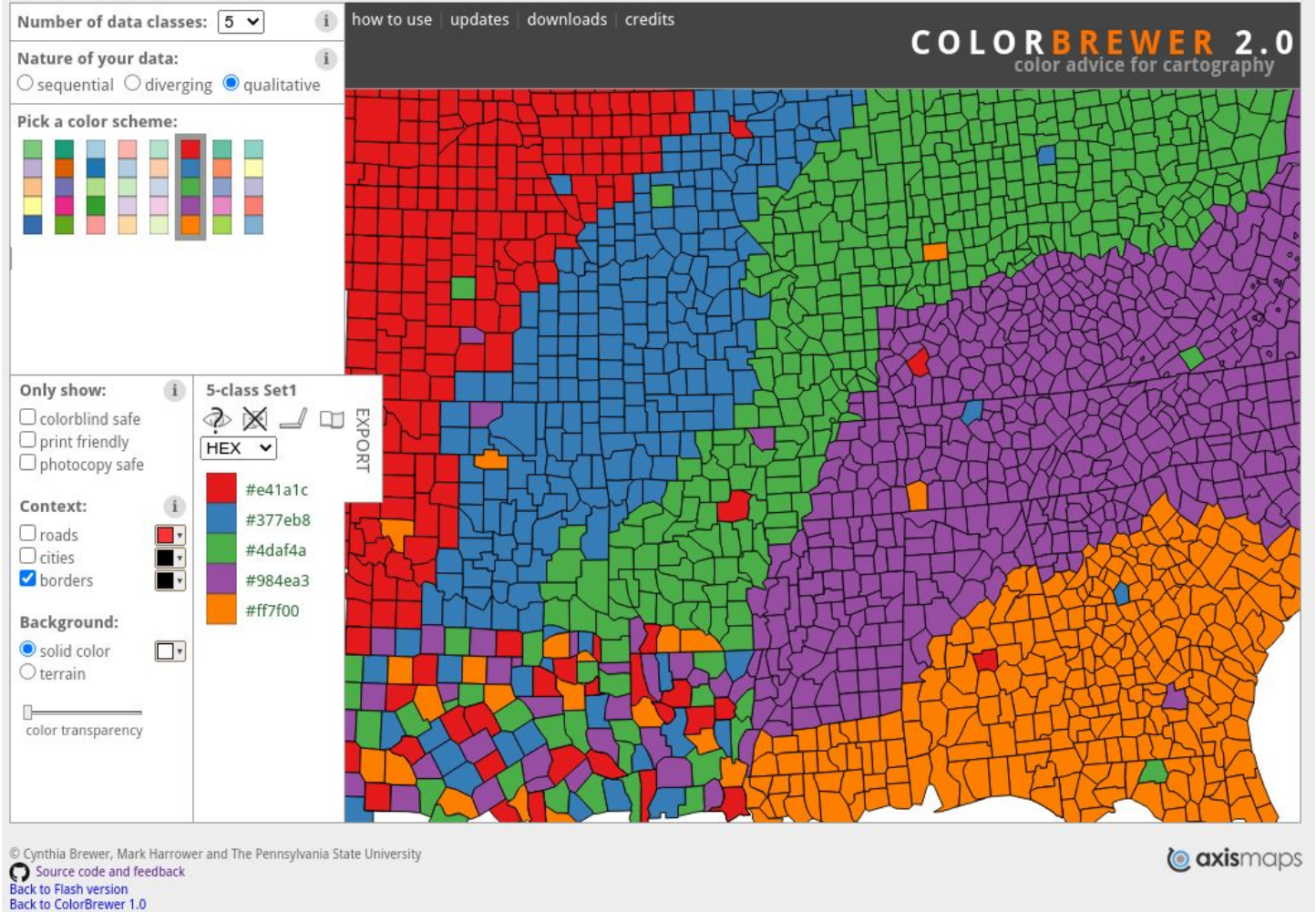
Three dimensions of color: Hue, saturation and brightness



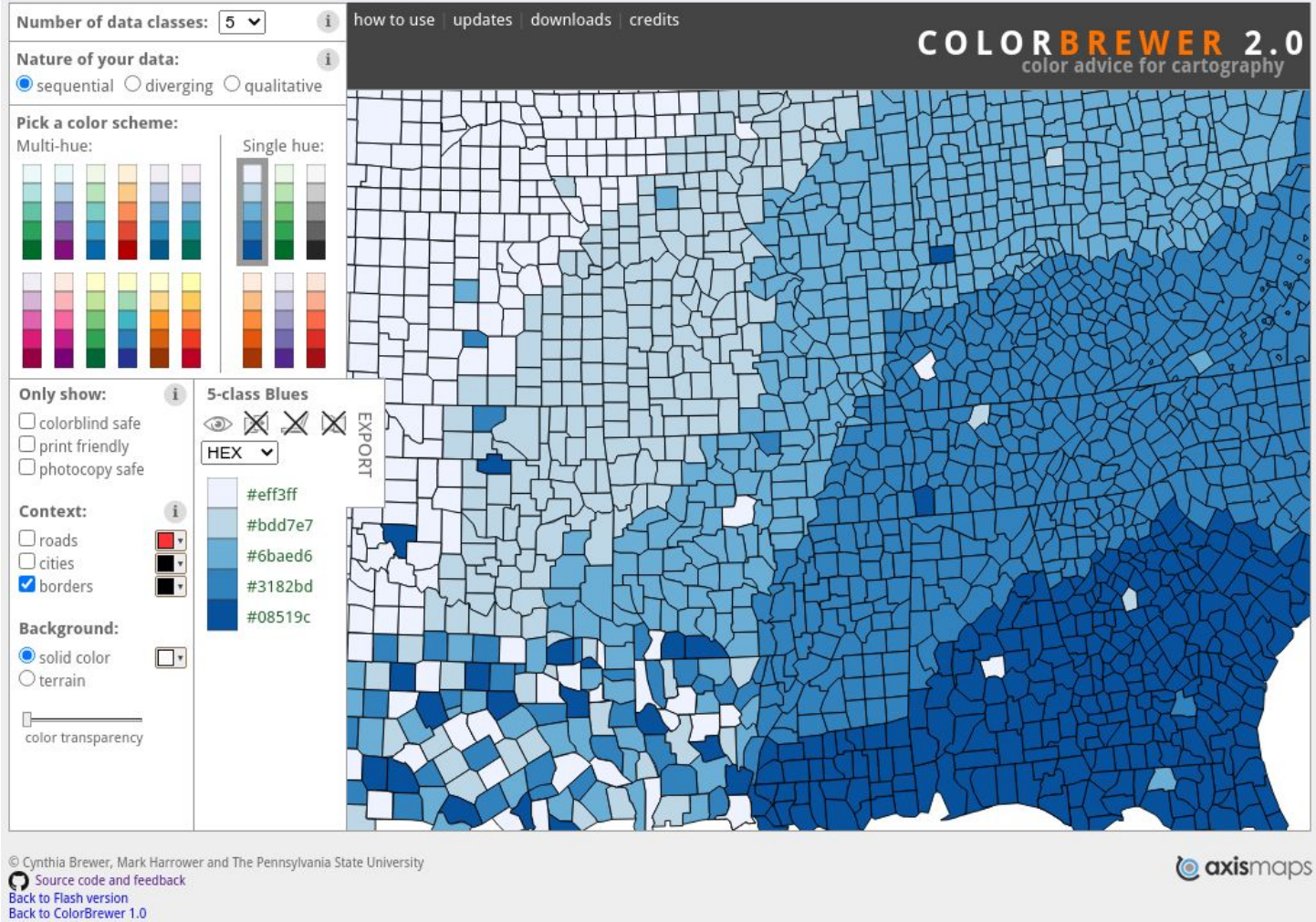
Types of color scales

- **Qualitative/categorical**: data with no order
  - e.g. cities, countries
- **Sequential**: increasing or decreasing data
  - e.g. year
- **Diverging**: data with a natural zero
  - e.g. % change, temperature
- **Circular**
  - e.g. orientation, direction



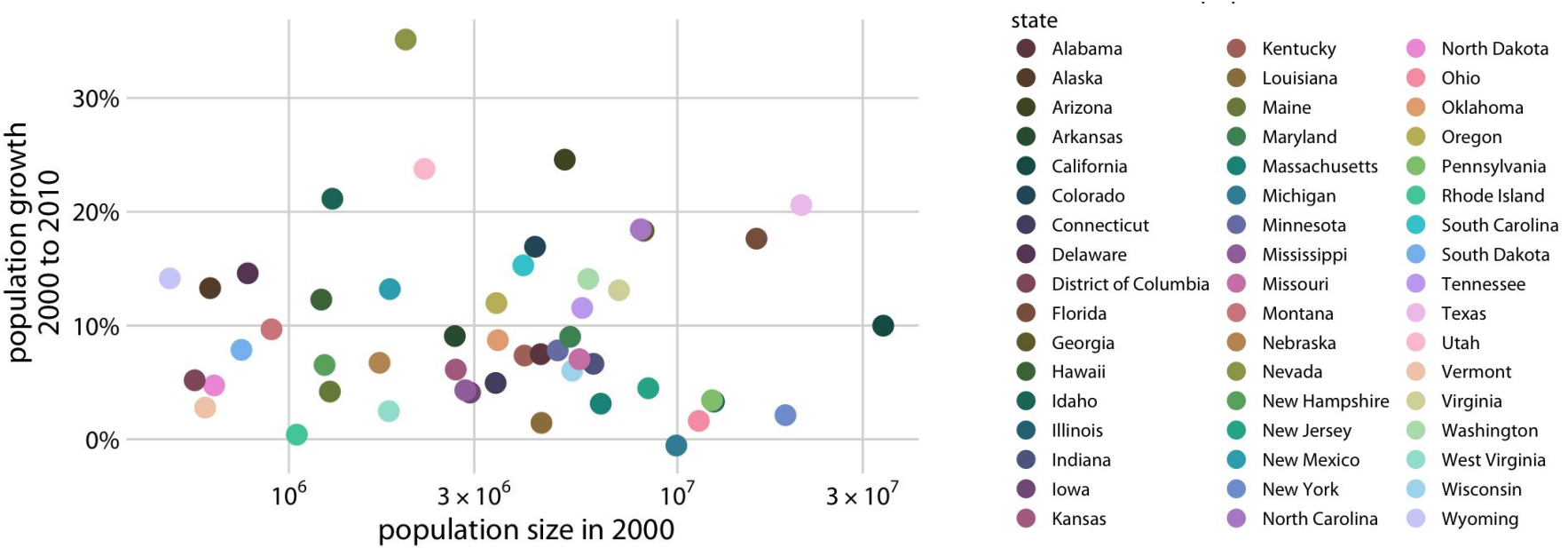


https://colorbrewer2.org



https://colorbrewer2.org

Common pitfall: encoding too much information



Claus O. Wilke (2019)

Common pitfall: using the wrong color scale

rainbow scale

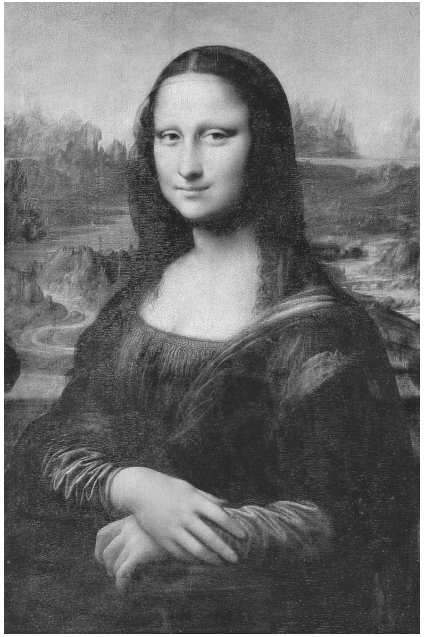
rainbow converted to grayscale

The jet/rainbow color scale is **NOT a sequential** colormap, as our perception of it is NOT linear but **circular!**

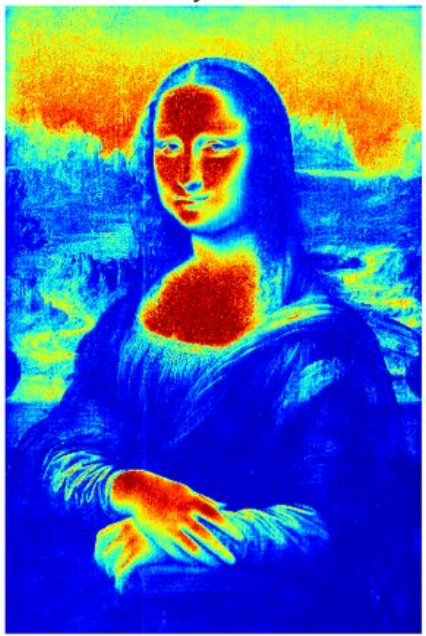
Common pitfall: using the wrong color scale

Colour

Grey

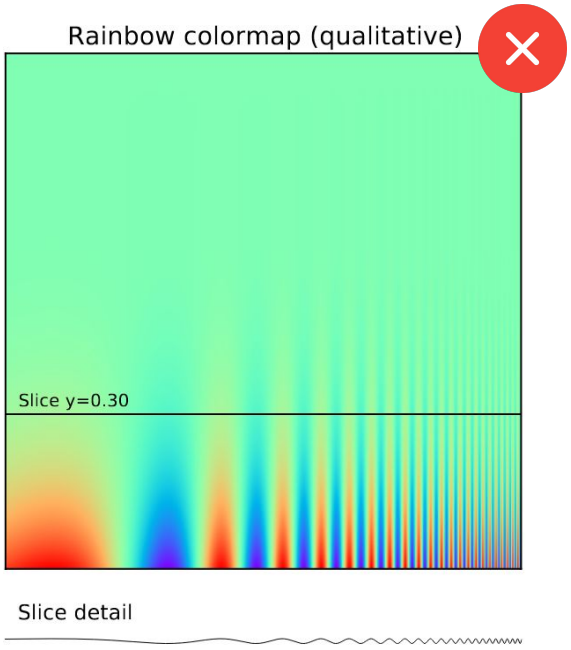


Jet

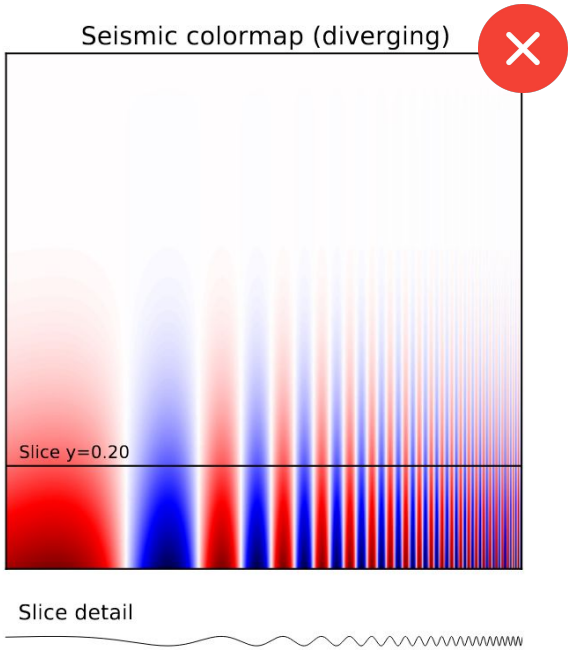


Viridis

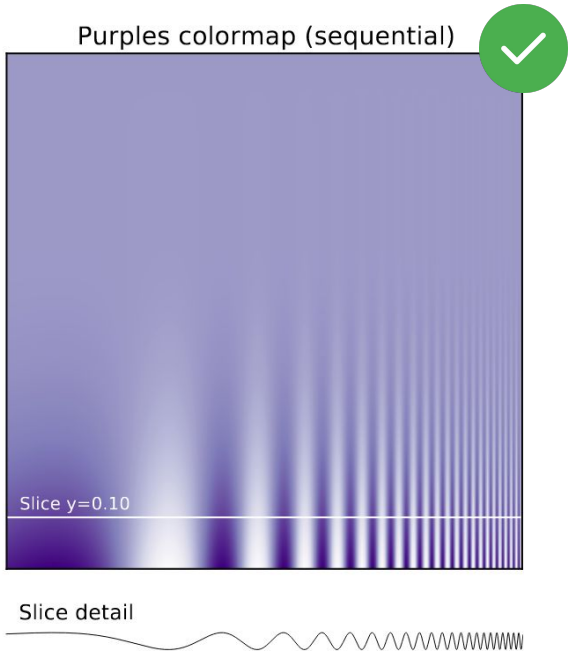
Common pitfall: using the wrong color scale



Qualitative: rapid variation of colors, used mainly for discrete/categorical data.



Diverging: variation between colors used to highlight deviation from a median value



Sequential: variation of a unique color, used for quantitative data varying low to high.

Time for hands-on exercises!

Exercise 2: which visualization should I use?

Have your cheatsheet at hand!:

https://matplotlib.org/cheatsheets/

Extra-Material (from ASPP-2021)

- **Scales & projections** (**notebook**). Tutorial on different type of scales (log scale, symlog scale, logit scale) and projections (polar, 3D, geographic).
- **Animation** (**notebook**). Animation with matplotlib can be created very easily using the animation framework. This notebook shows how to create an animation and save it as a movie.

Further Resources

At the implementation level (code, galleries and how-tos):

- **Seaborn library**, a library for statistical data visualization. Very recommended as a next step in your learning journey.
- **Matplotlib Cheatsheets**, Nicolas P. Rougier (2020)
- **Scientific Visualization – Python & Matplotlib**, open-source book from Nicolas P. Rougier (2021)
- **Python Graph Gallery**, Yan Holtz (2017)
- **Matplotlib Gallery**, Matplotlib team

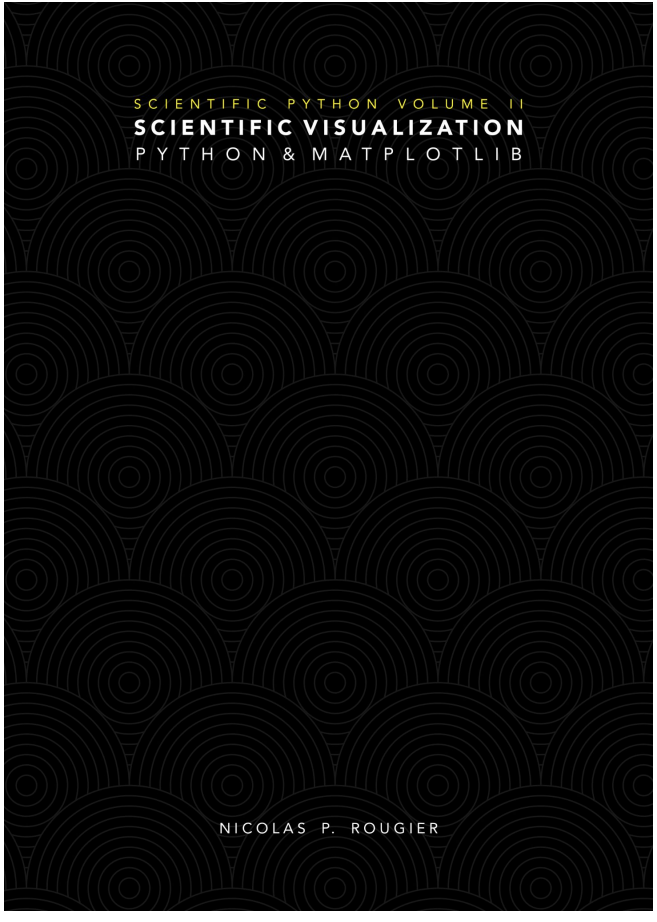
At the conceptual level :

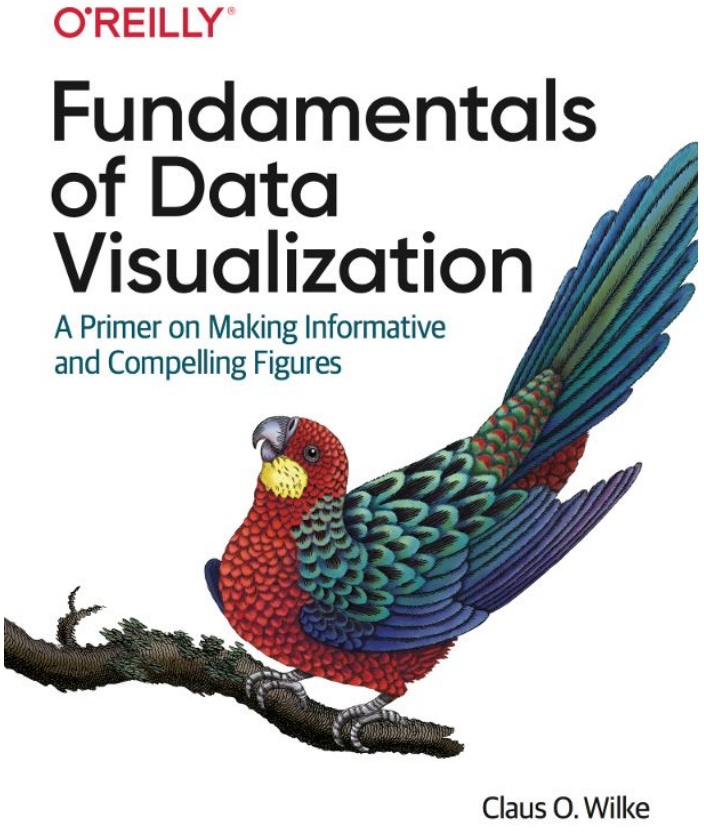
- **Ten simple rules for better figures**, Nicolas P. Rougier, Michael Droettboom, Philip E. Bourne (2014)
- **Fundamentals of Data Visualization**, book by Claus O. Wilke (2019)
- **Chart Suggestions - a though-starter** by A. Abelas.
- **Data Visualization Catalogue**
- **Edward Tufte**'s series of books: The Visual Display of Quantitative Information (1983), Envisioning Information (1990), Beautiful Evidence (2006), etc.

Interactive visualizations:

- **Widgets in Jupyter notebook**
- **Plotly**

Selected further resources

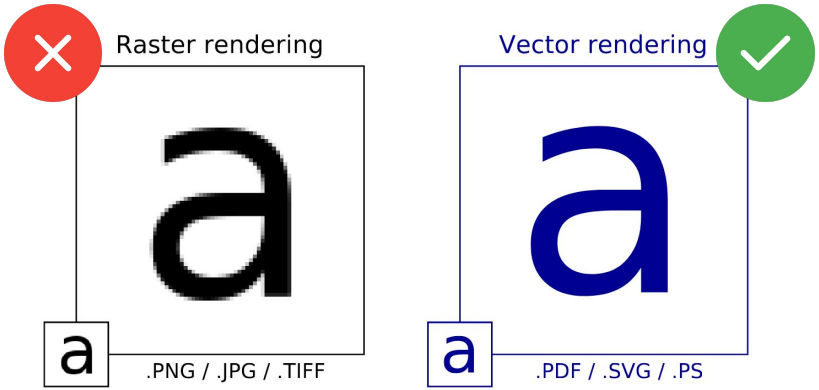


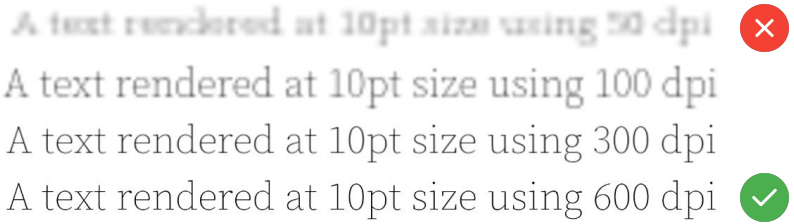


Some extra tips

Exporting a figure: vector format!

As a rule of thumb: Save in vector format and with enough DPI (dots per inch)





Bitmap formats

PNG: Portable Network Graphics (lossless)
JPG: Joint Photographic Experts Group (lossy)

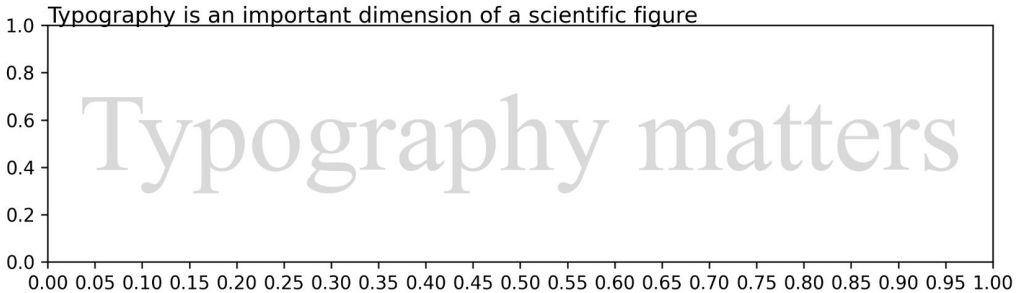
Vector formats

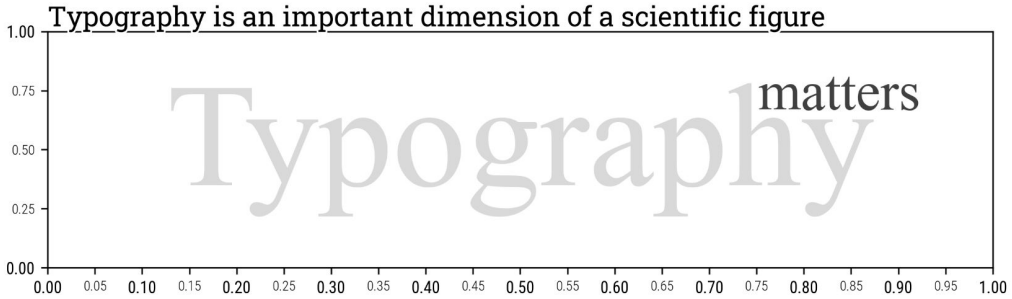
PDF: Portable Document Format
SVG: Scalable Vector Graphics

Text rendered in matplotlib and saved using different dpi

Font stack choice

Influence of typography on the perception of a figure. Choose the right font for you.





Serif
DejaVuSerif.ttf

Sans
DejaVuSans.ttf

Serif
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Sans
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Serif
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Monospace
DejaVuSansMono.ttf

Cursive
Apple Chancery.ttf

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Cursive
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ITC Zapf Chancery.ttf