UNIVERSITAT DE BARCELONA

DAS
DATA SCIENCE @ UNIVERSITAT DE BARCELONA

Data Visualization

Postgraduate Course on DataScience and BigData

Santi Seguí | 2017-2018

What is data Visualization?

A primary goal of data visualization is to **communicate information clearly**, **precisely** and **efficiently** to users via the selected information graphics, such as tables and charts.

The main goal of any graph or visualization is to be a tool for your eyes and brain to perceive what lies beyond the data.

The simplest Data Visualization

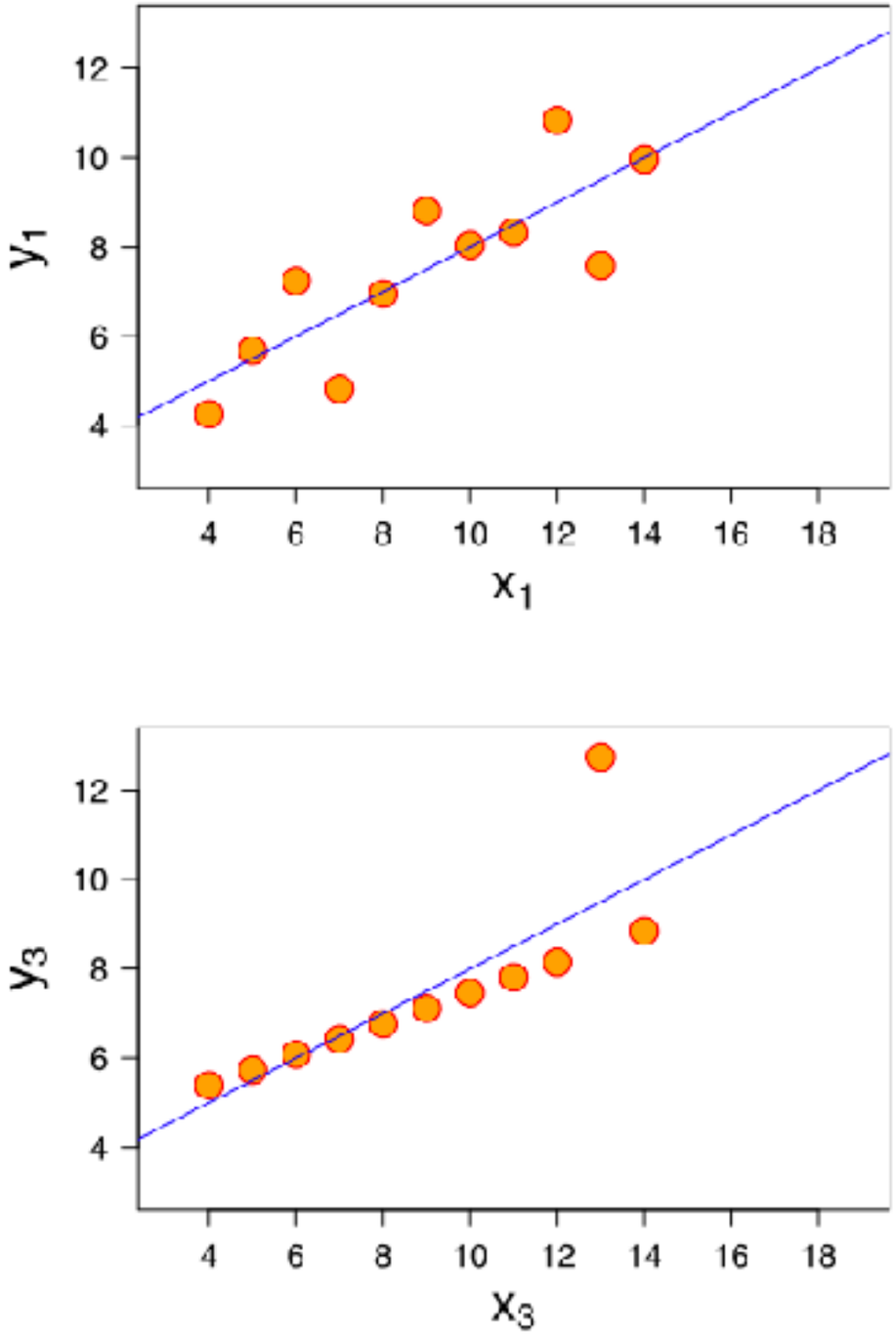
Anscombe's quartet

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

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

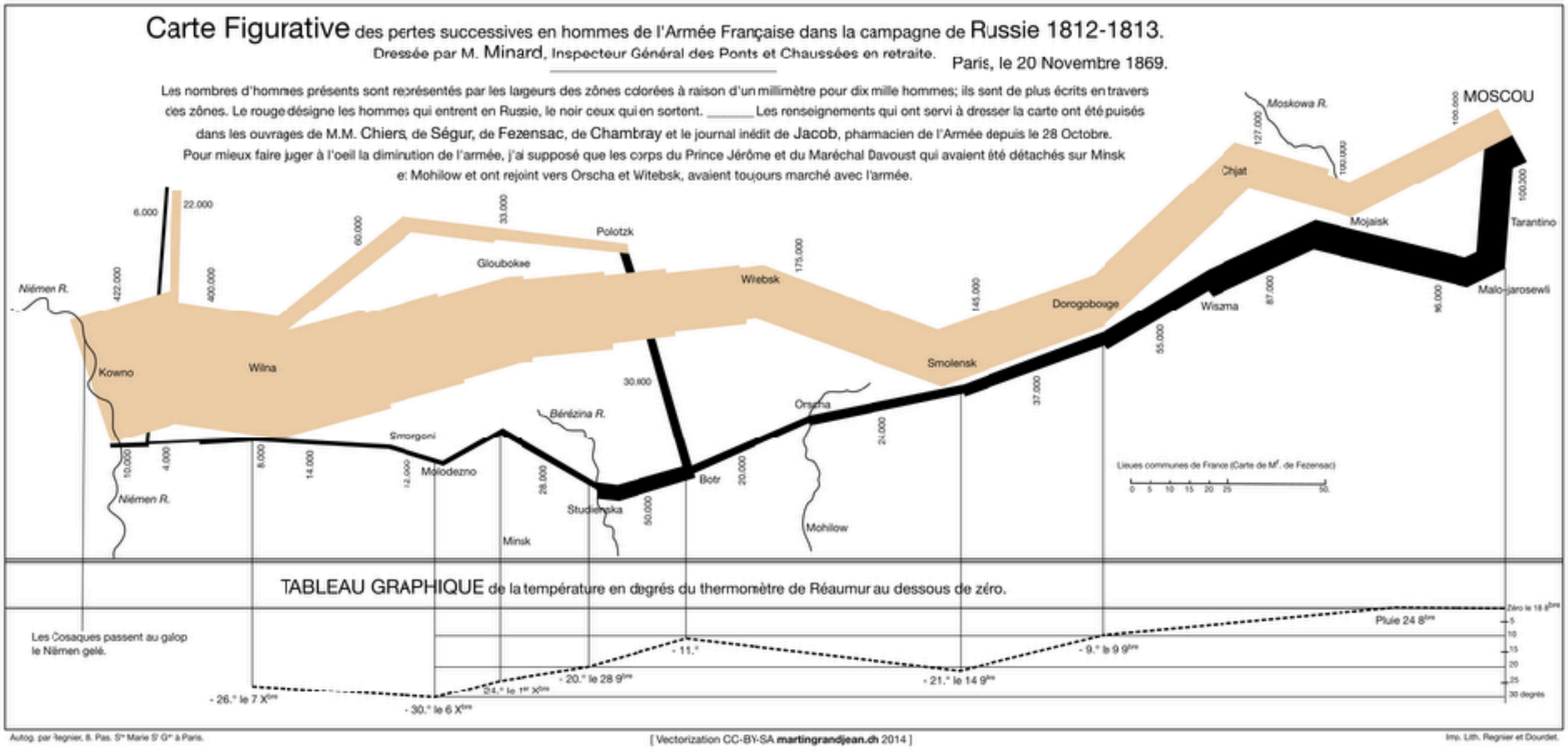
Property	Value	Accuracy
Mean of x	9	exact
Sample variance of x	11	exact
Mean of y	7.50	to 2 decimal places
Sample variance of y	4.125	plus/minus 0.003
Correlation between x and y	0.816	to 3 decimal places
Linear regression line	$y = 3.00 + 0.500x$	to 2 and 3 decimal places, respectively
Coefficient of determination of the linear regression	0.67	to 2 decimal places


y_1
x_1
y_2
x_2
y_3
x_3
y_4
x_4

What is a **good** (or excellent) Visualization?

Napoleon Invasion by Charles Joseph Minard

Edward Tufte said it "may well be the best statistical graphic ever drawn"



http://en.wikipedia.org/wiki/Charles_Joseph_Minard#mediaviewer/File:Minard.png

Variables displayed in the graph: 1) the number of Napoleon's troops; 2) the distance traveled; 3) temperature; 4) latitude and longitude; 5) direction of travel; and 6) location relative to specific dates

What is a **good** (or excellent) Visualization?

Accuracy — Story Telling — Knowledge Discovery

Accuracy?

The results have to be accurate!!

Let's see some examples of what you should not do!

The following graphs have been obtained from different websites and I use them here as illustrative samples of bad visualizations, however, I did not check the veracity of them.

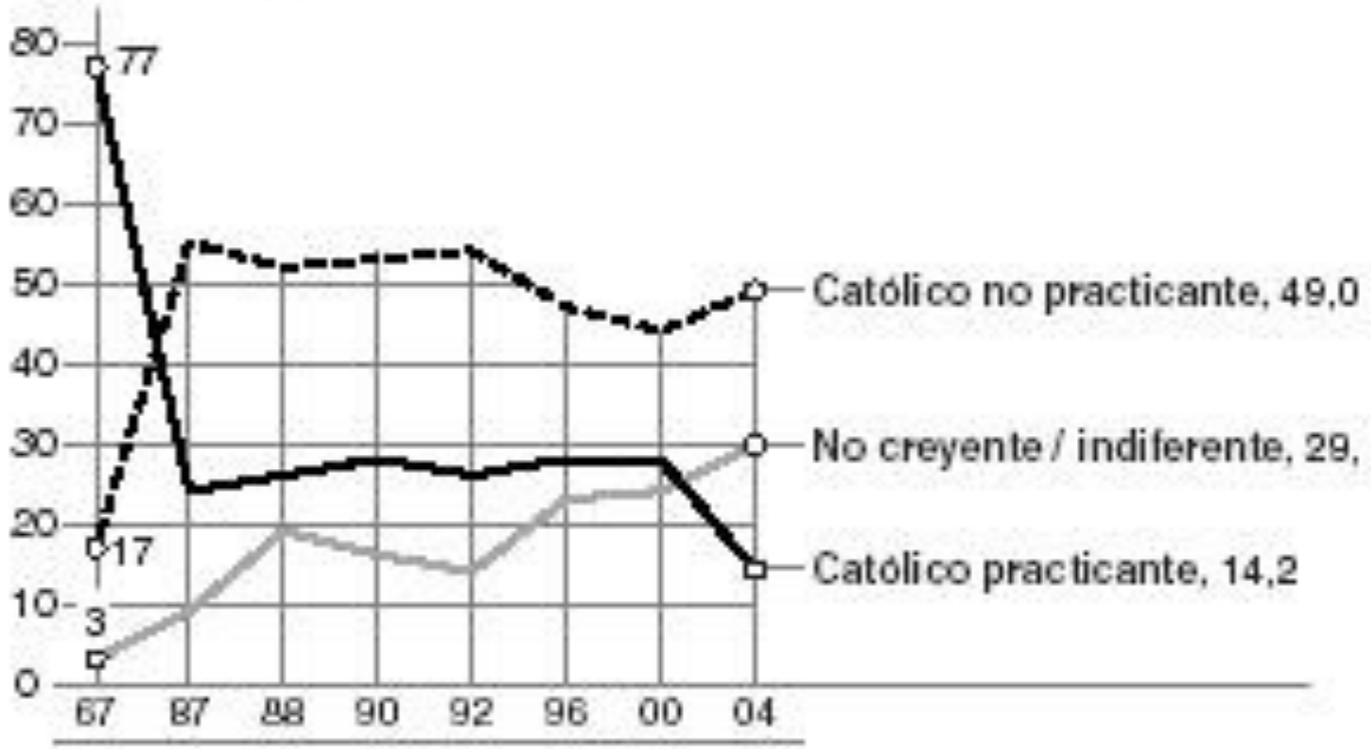
Case 1: What is wrong?

Encuesta a los jóvenes españoles

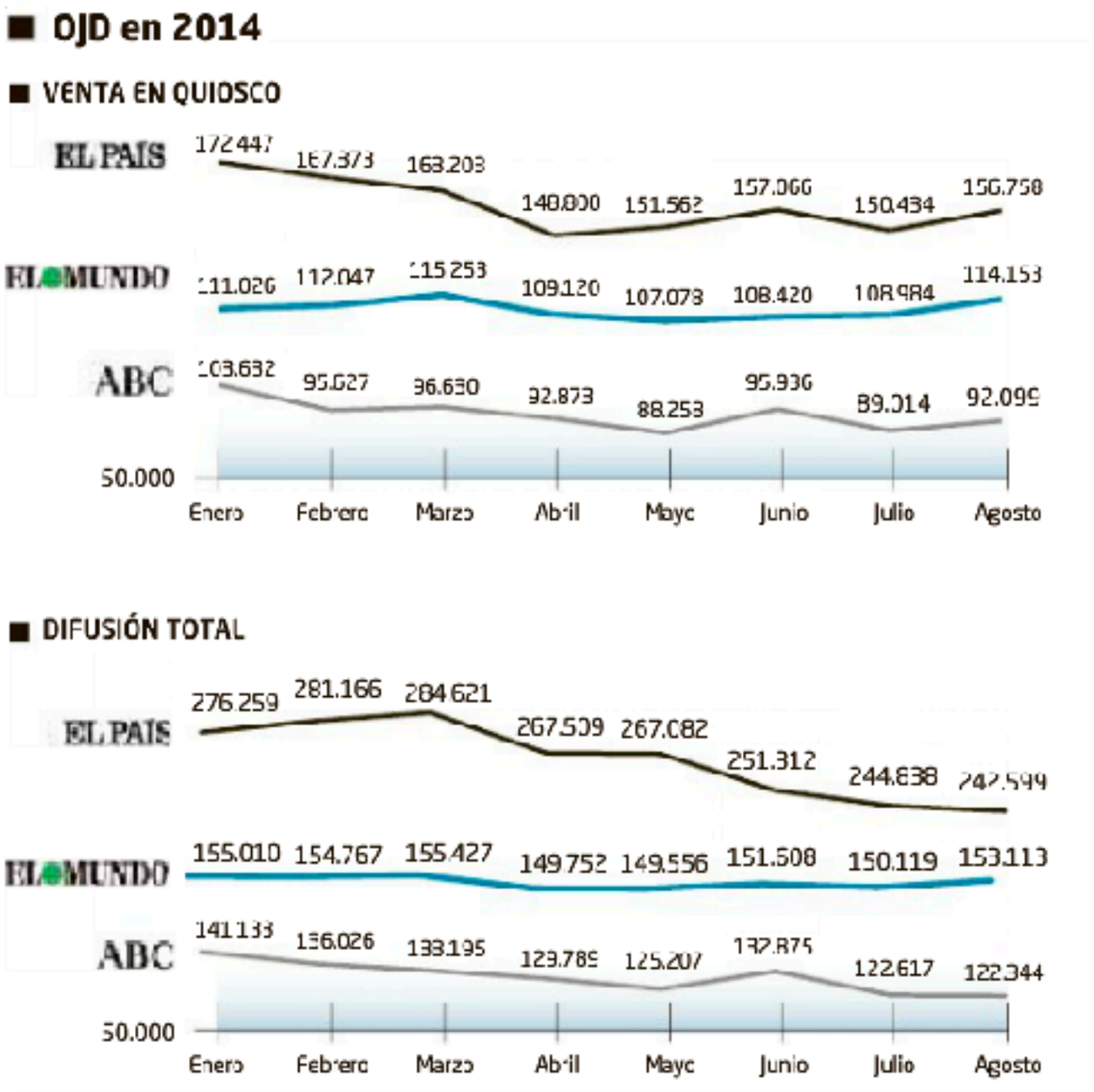
En porcentaje.

■ Evolución de la identificación religiosa de los jóvenes

Población entre 15 y 29 años.

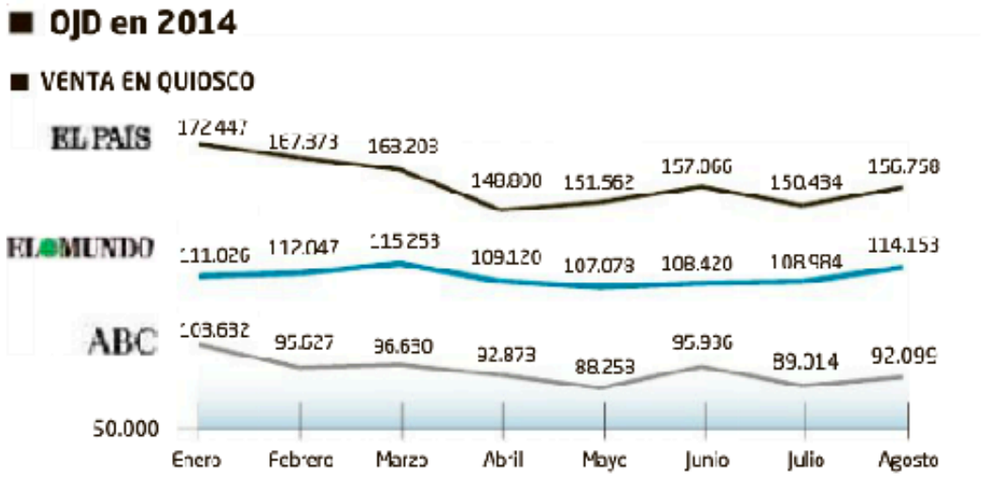


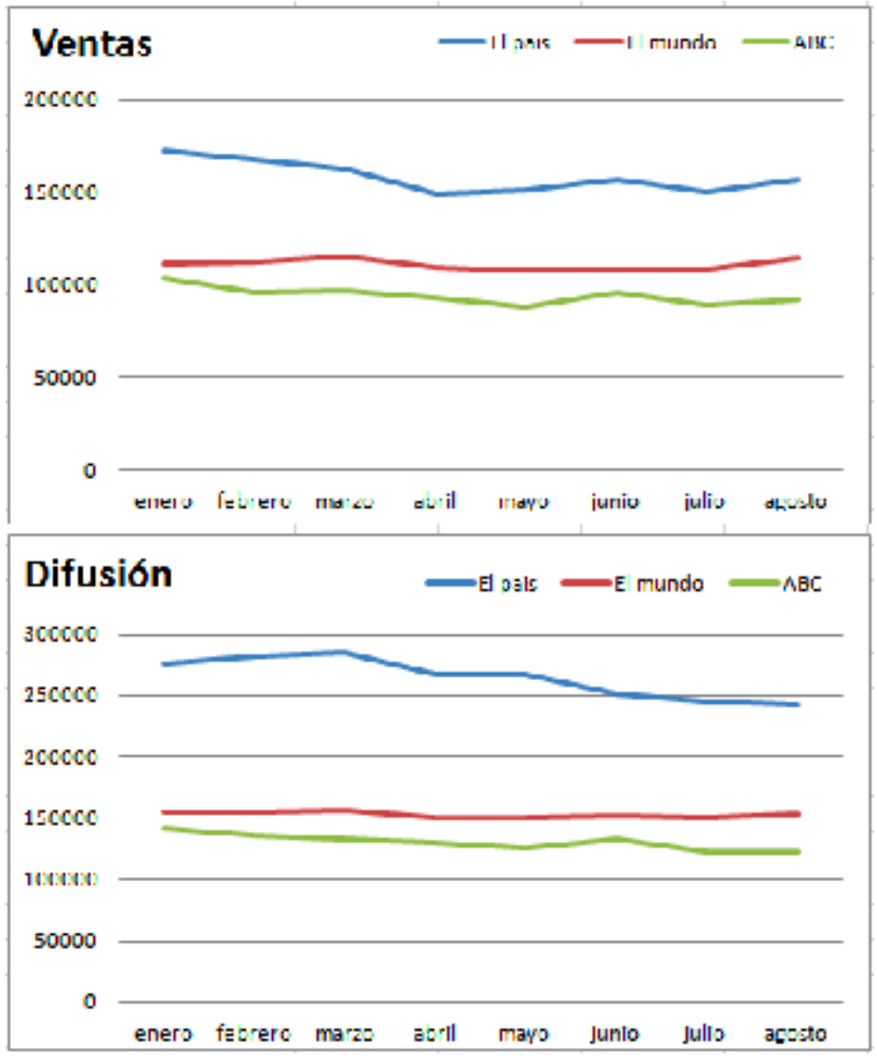
Case 2: Newspapers sells

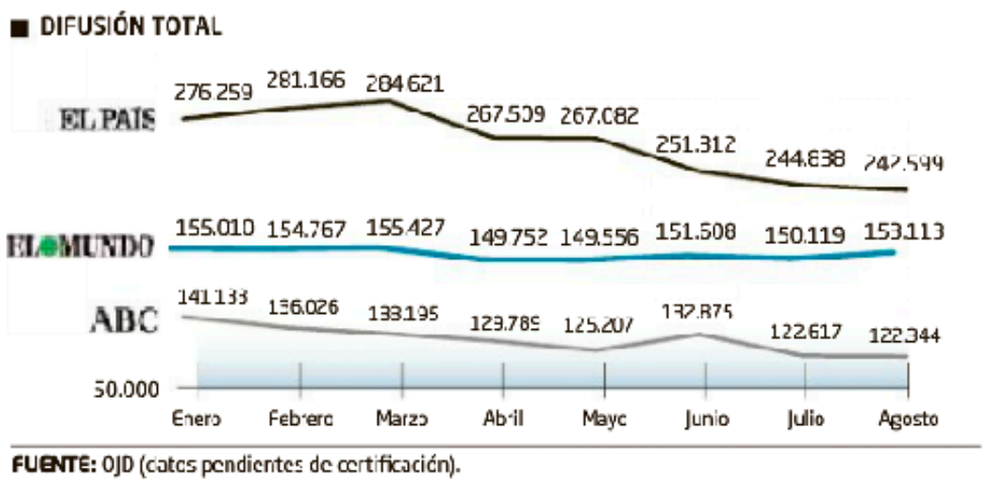


FUENTE: OJD (cotas pendientes de certificación).

Case 2: Newspapers sells

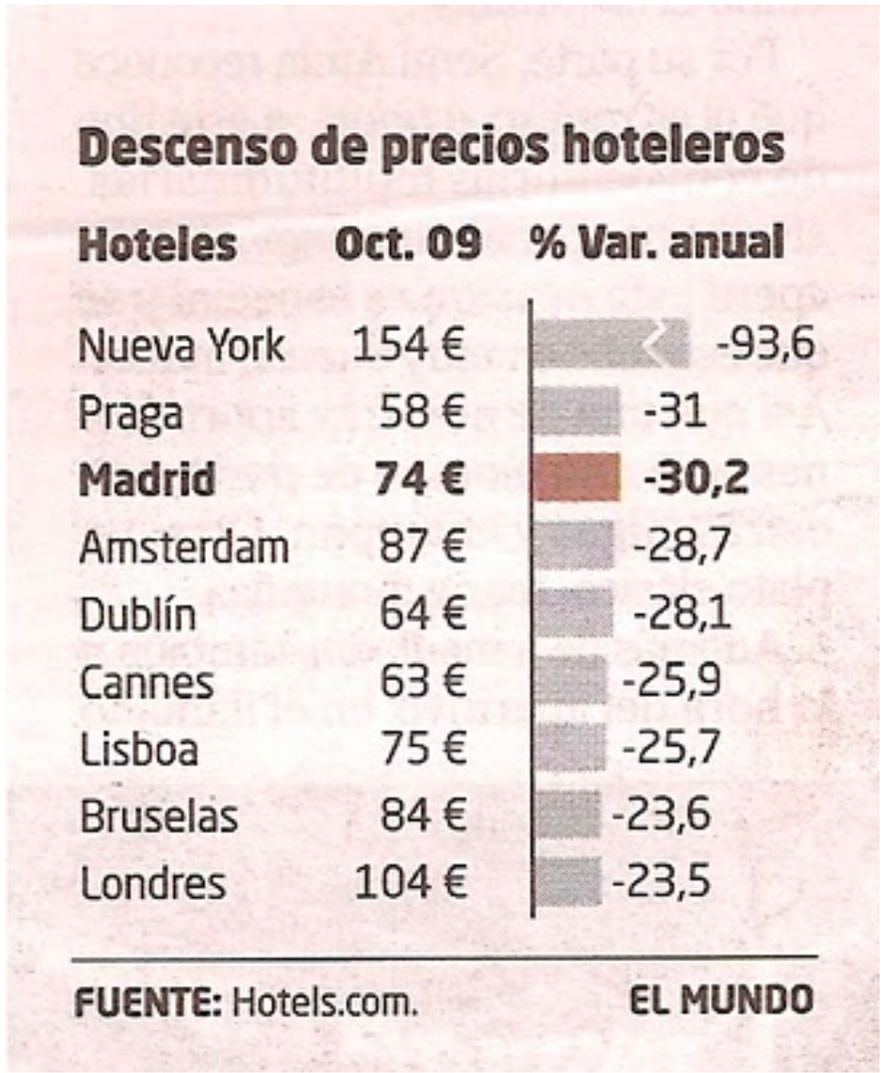






FUENTE: OJD (datos pendientes de certificación).

Case 3: Hotel Prices



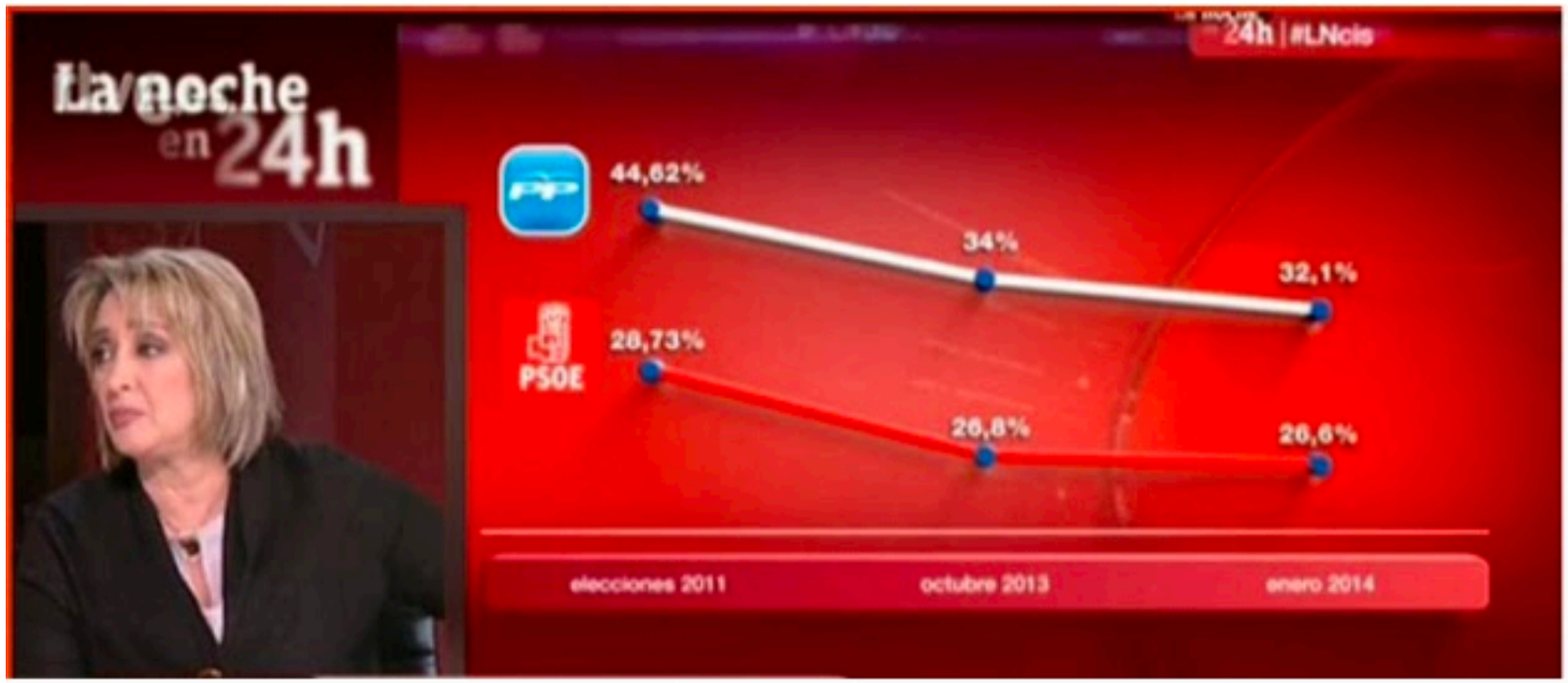
Descenso de precios hoteleros

Hoteles	Oct. 09	% Var. anual
Nueva York	154 €	-93,6
Praga	58 €	-31
Madrid	**74 €**	**-30,2**
Amsterdam	87 €	-28,7
Dublín	64 €	-28,1
Cannes	63 €	-25,9
Lisboa	75 €	-25,7
Bruselas	84 €	-23,6
Londres	104 €	-23,5

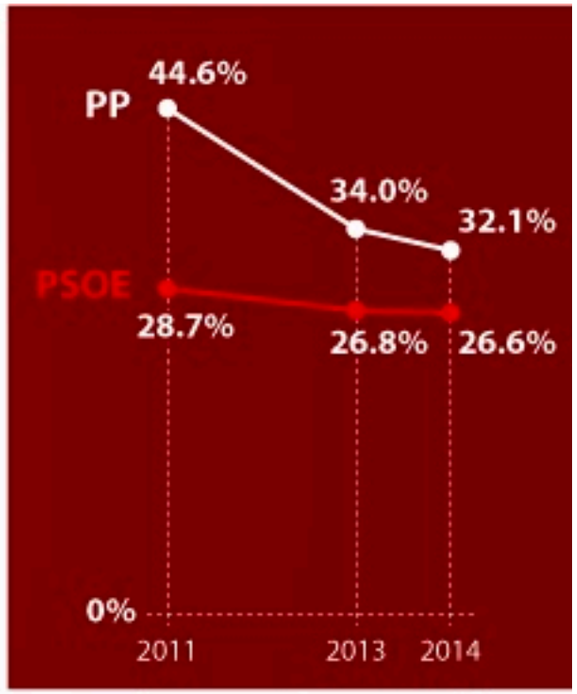
FUENTE: Hotels.com. **EL MUNDO**

"Los precios de los hoteles bajan el 94% en Nueva York. La caída más acusada en el sector hotelero de todo el mundo se registró en Nueva York, con un desplome del 93,57 por ciento en sus tarifas, hasta los 154 euros de media por noche, frente a los 218 euros del mismo mes de 2008."

Case 4: Y-Axis



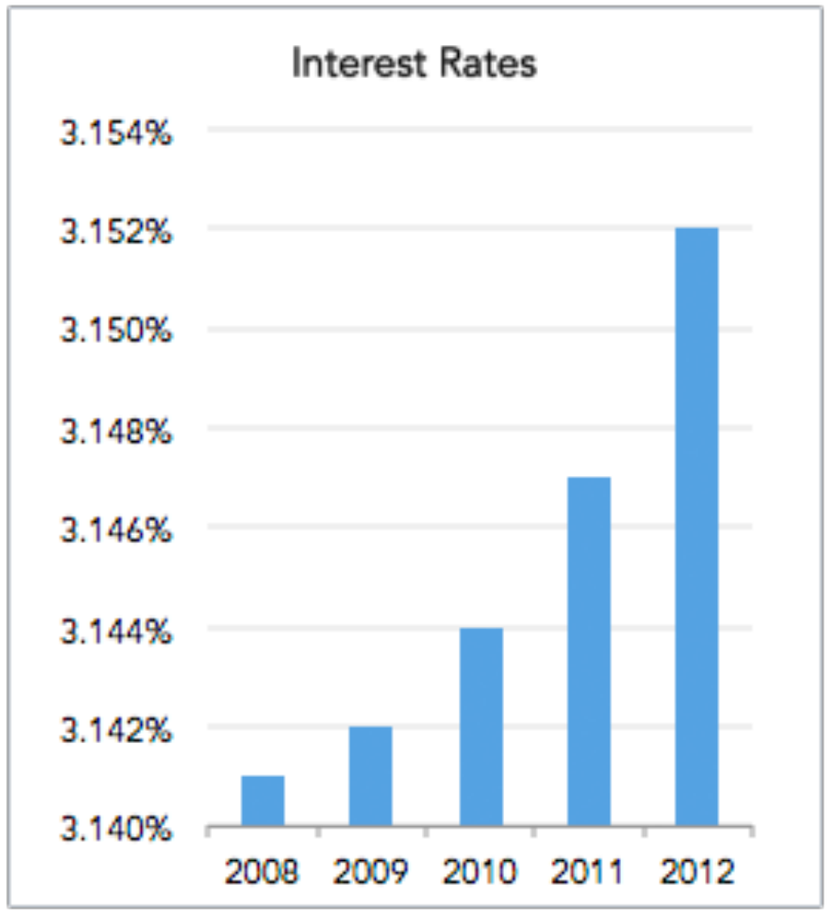
This is a lie

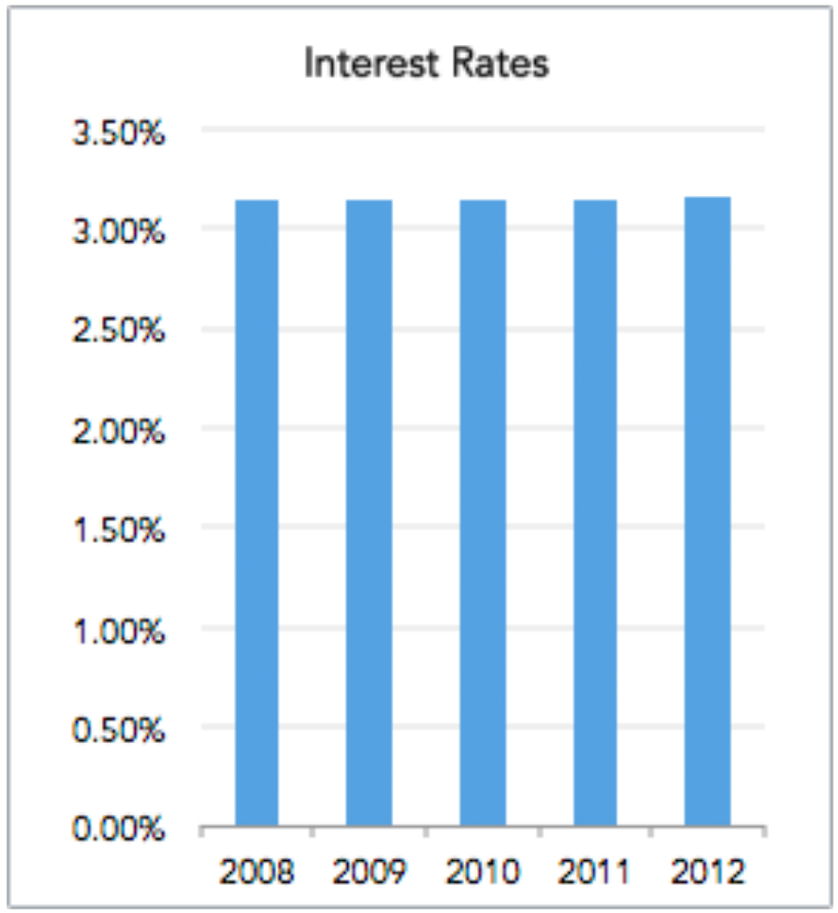


This is the truth

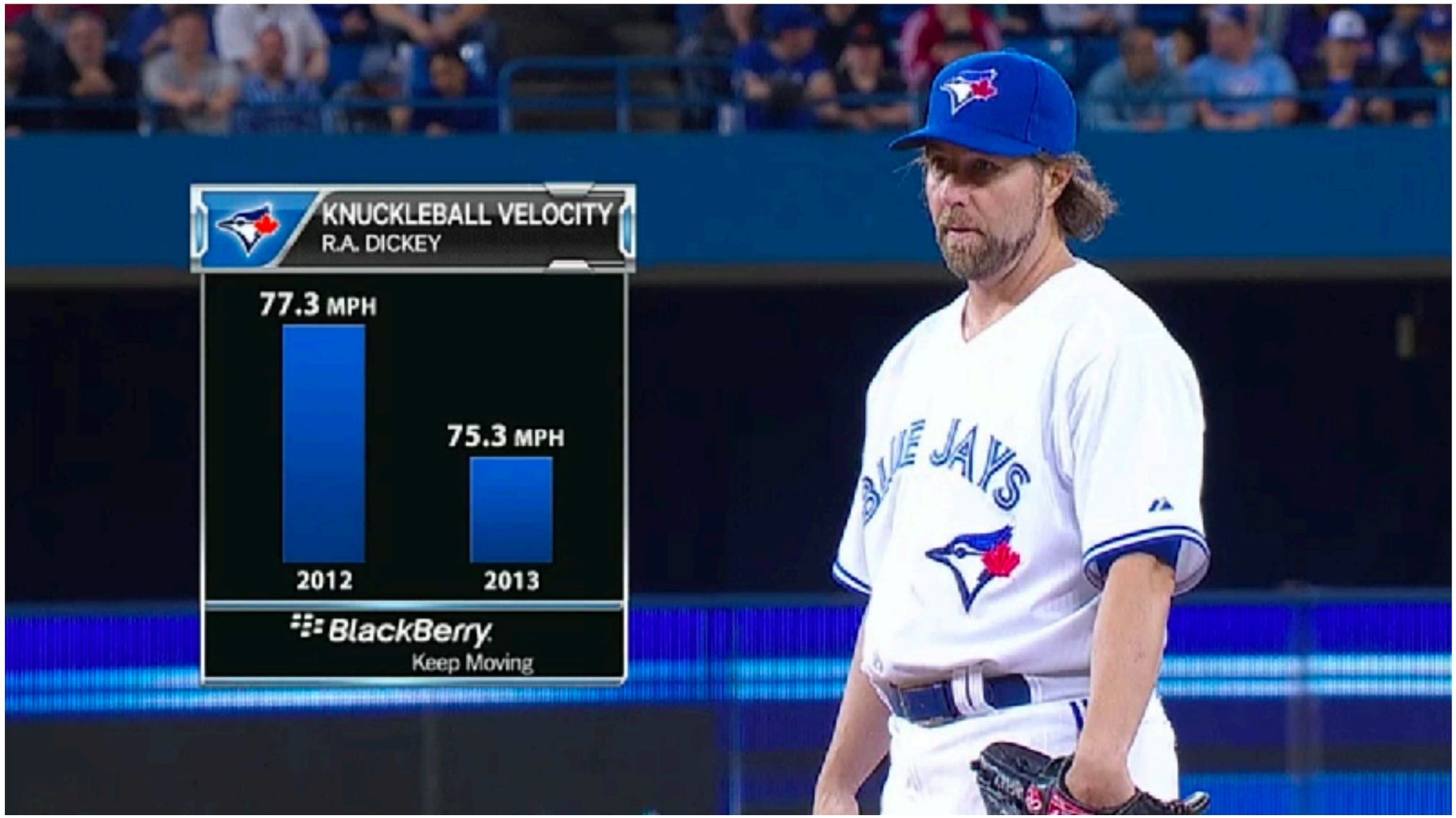
Case 5: Y-Axis

Same Data, Different Y-Axis

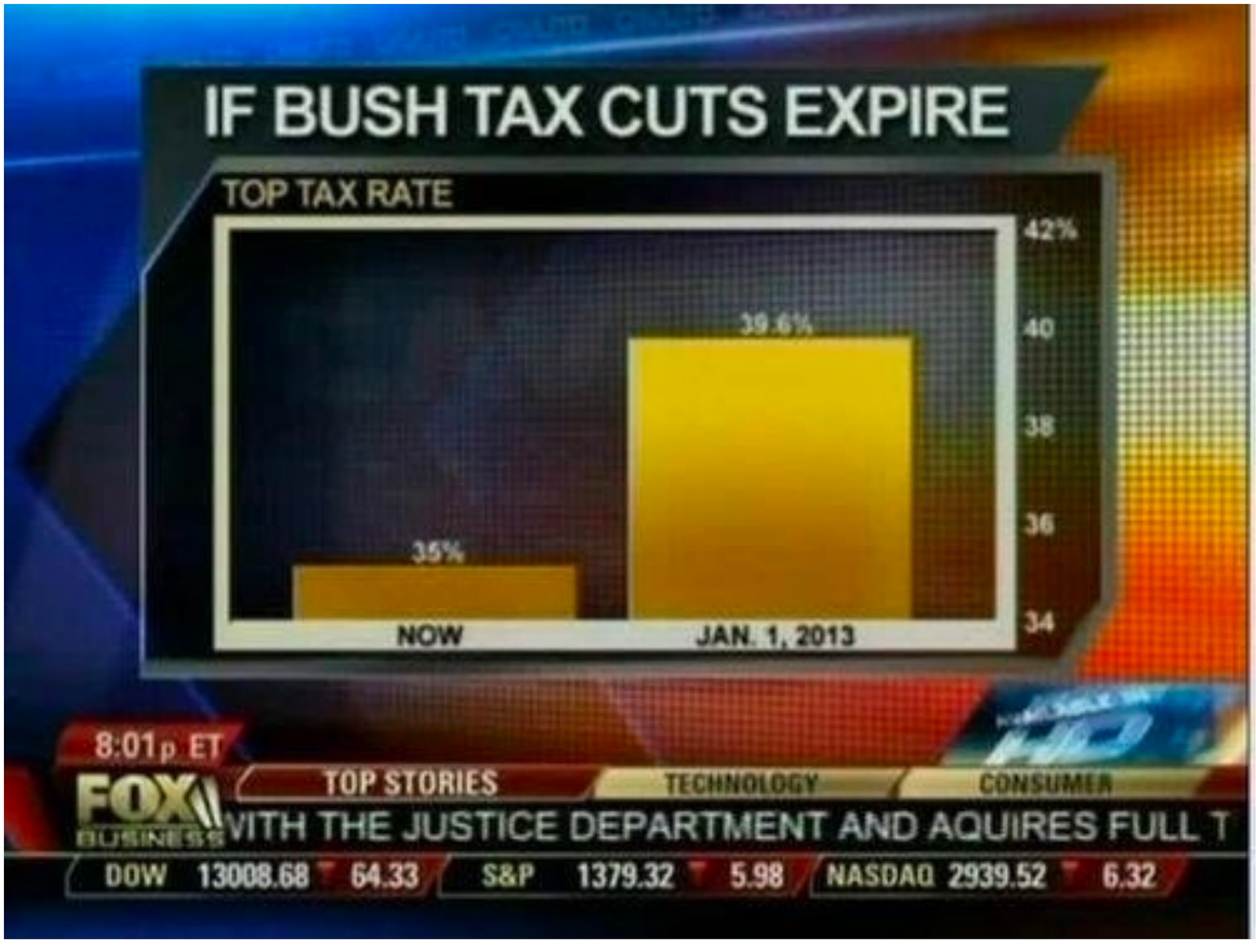




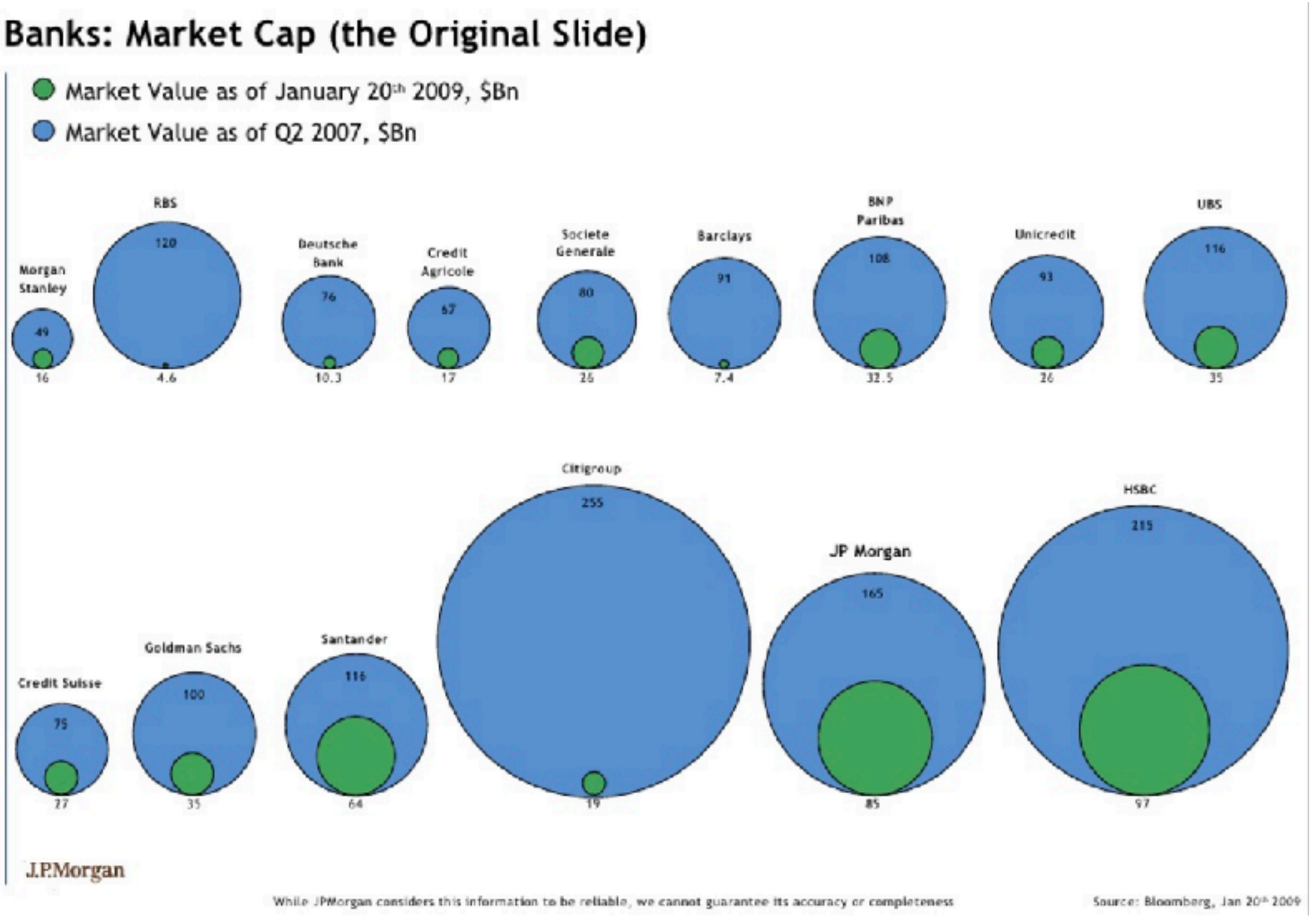
Case 5: Y-Axis


KNUCKLEBALL VELOCITY
R.A. DICKEY
77.3 MPH
75.3 MPH
2012
2013
BlackBerry
Keep Moving
BLUE JAYS

Case 5: Y-Axis


IF BUSH TAX CUTS EXPIRE
TOP TAX RATE
42%
39.6%
40
38
36
35%
34
NOW
JAN. 1, 2013
8:01p ET
FOX BUSINESS
TOP STORIES
TECHNOLOGY
CONSUMER
VITH THE JUSTICE DEPARTMENT AND AQUIRES FULL T
DOW 13008.68 64.33
S&P 1379.32 5.98
NASDAQ 2939.52 6.32

Case 6: The bubble Plague



This display compares the market capitalization (what it would cost to buy all of a company's stock at the current price) of 15 major banks as of January 20th, 2009 to their market capitalization in Q2 2007, before the banking crisis hit. People are supposed to compare the small green circles to the larger blue circles to see how much the market capitalization of each bank declined.

Case 6: The bubble Plague

Can you say the the percentage of capital loss observed from 2007 to 2009?

Can you say which was the value in 2009 if the value in 2007 was 116?

Case 6: The bubble Plague

Te creators of this graph encoded the values using the diameter of the circles, but when the diameter of the circle changes, the area changes even more quickly, which causes us to dramatically over-estimate the difference in values if we do what comes naturally—attempt to compare their areas.

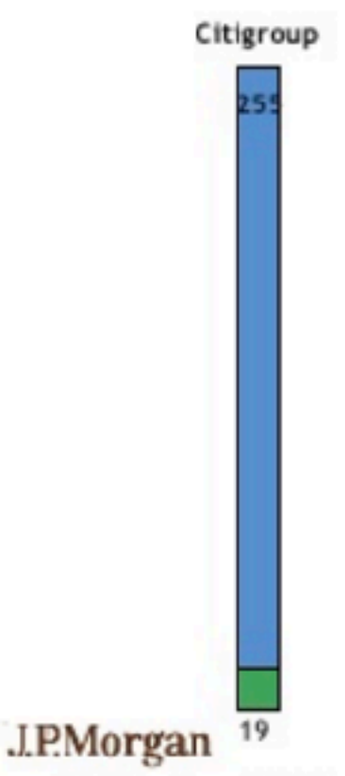


Fig. 1 - *13:1 ratio*

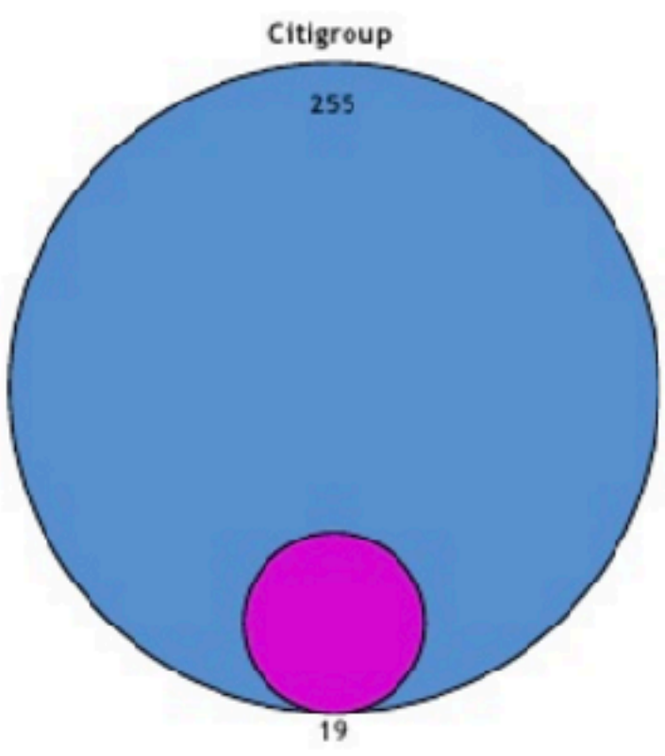


Fig. 2 - *13:1 ratio*

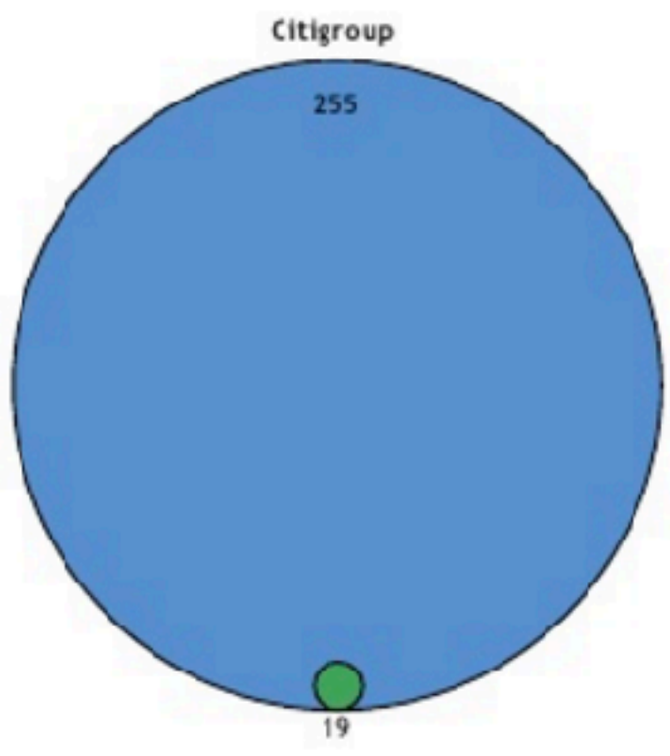
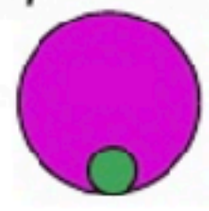
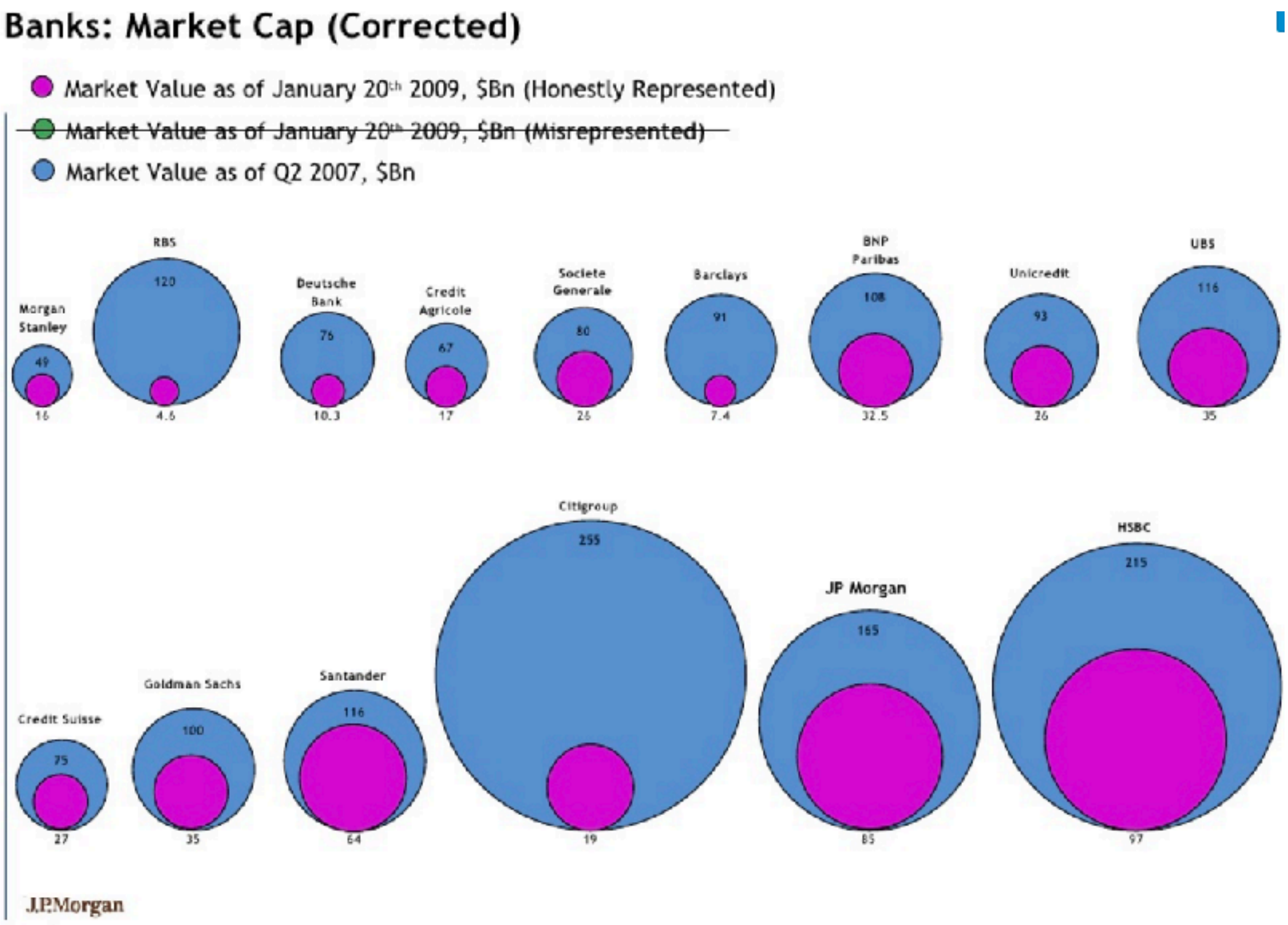


Fig. 3 - *JPMorgan illustration*

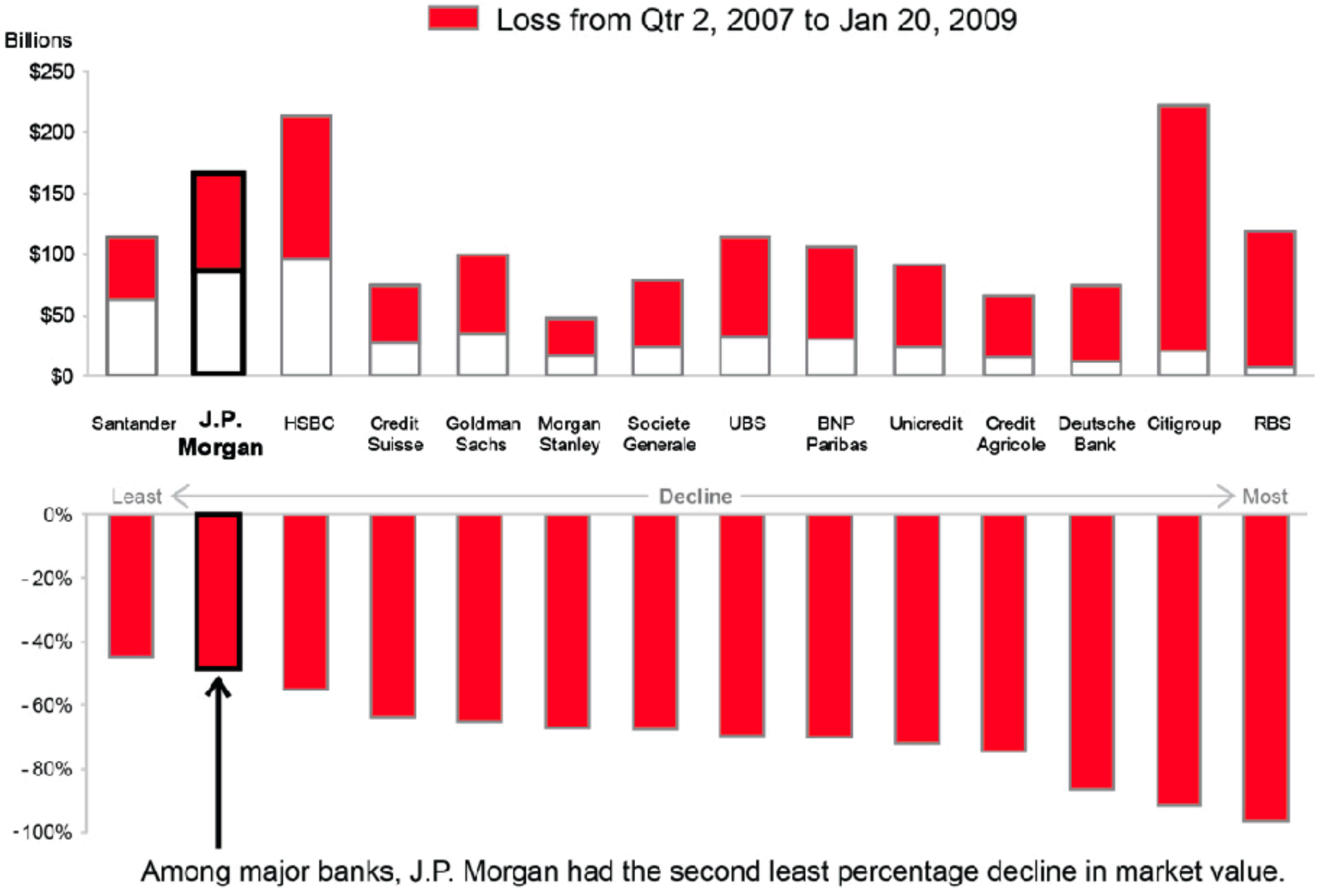
Fig. 4 - *27:1 misrepresentation*



Case 6: The bubble Plague



Declines in Bank Market Values Since the Financial Crisis Began



Among major banks, J.P. Morgan had the second least percentage decline in market value.

WHERE WE DONATE VS. DISEASES THAT KILL US

Heart Disease
Jump Rope for Heart (2013)

Suicide
Out of Darkness Overnight Walk (2014)

Diabetes
Step Out: Walk to Stop Diabetes (2013)

HIV / AIDS
Ride to End Aids (2013)

Breast Cancer
Komen Race for the Cure (2012)

Motor Neuron Disease (including ALS)
ALS Ice Bucket Challenge (2014)

Chronic Obstructive Pulmonary Disease
Fight for Air Climb (2013)

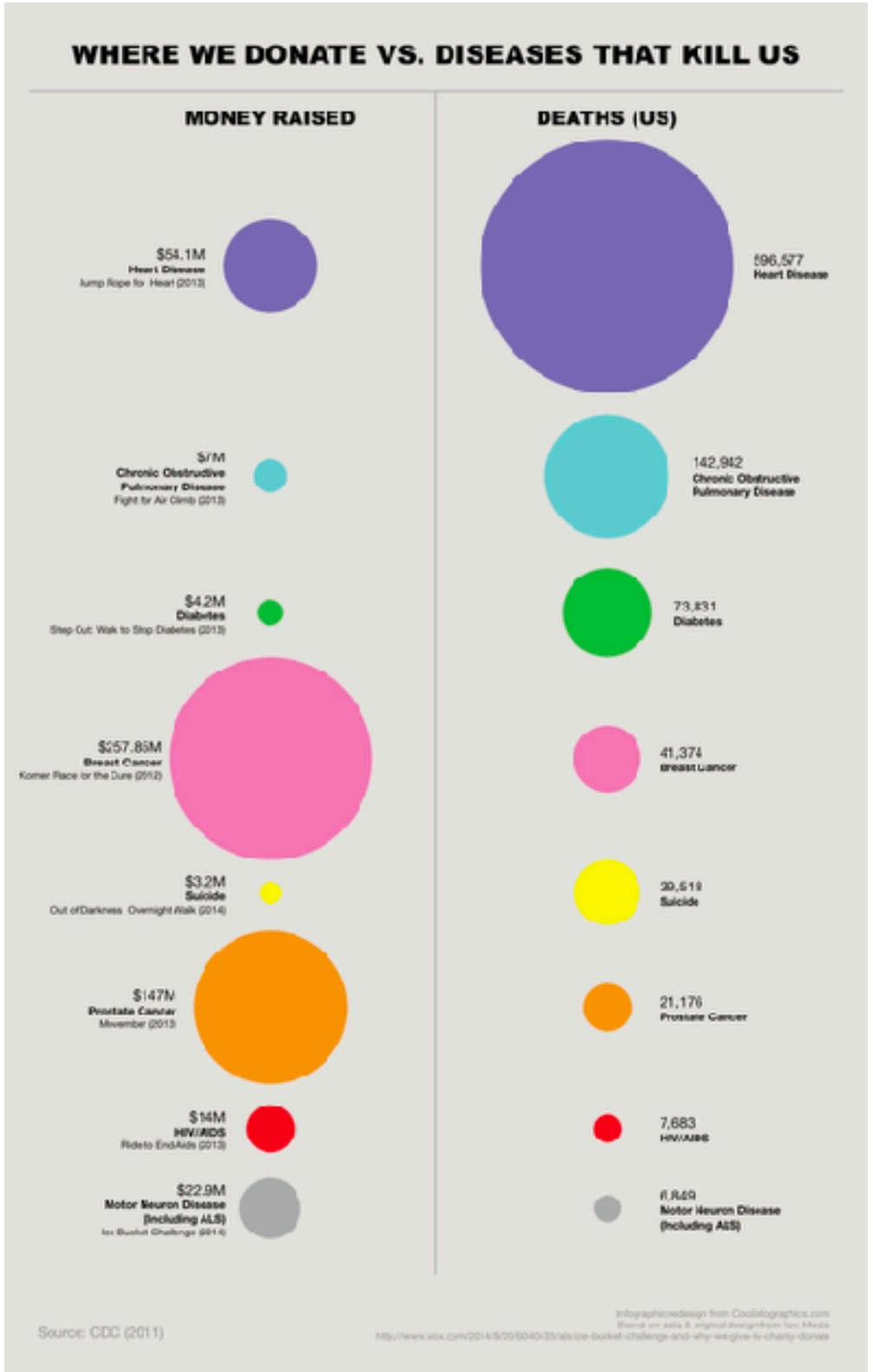
Prostate Cancer
November (2013)

MONEY RAISED

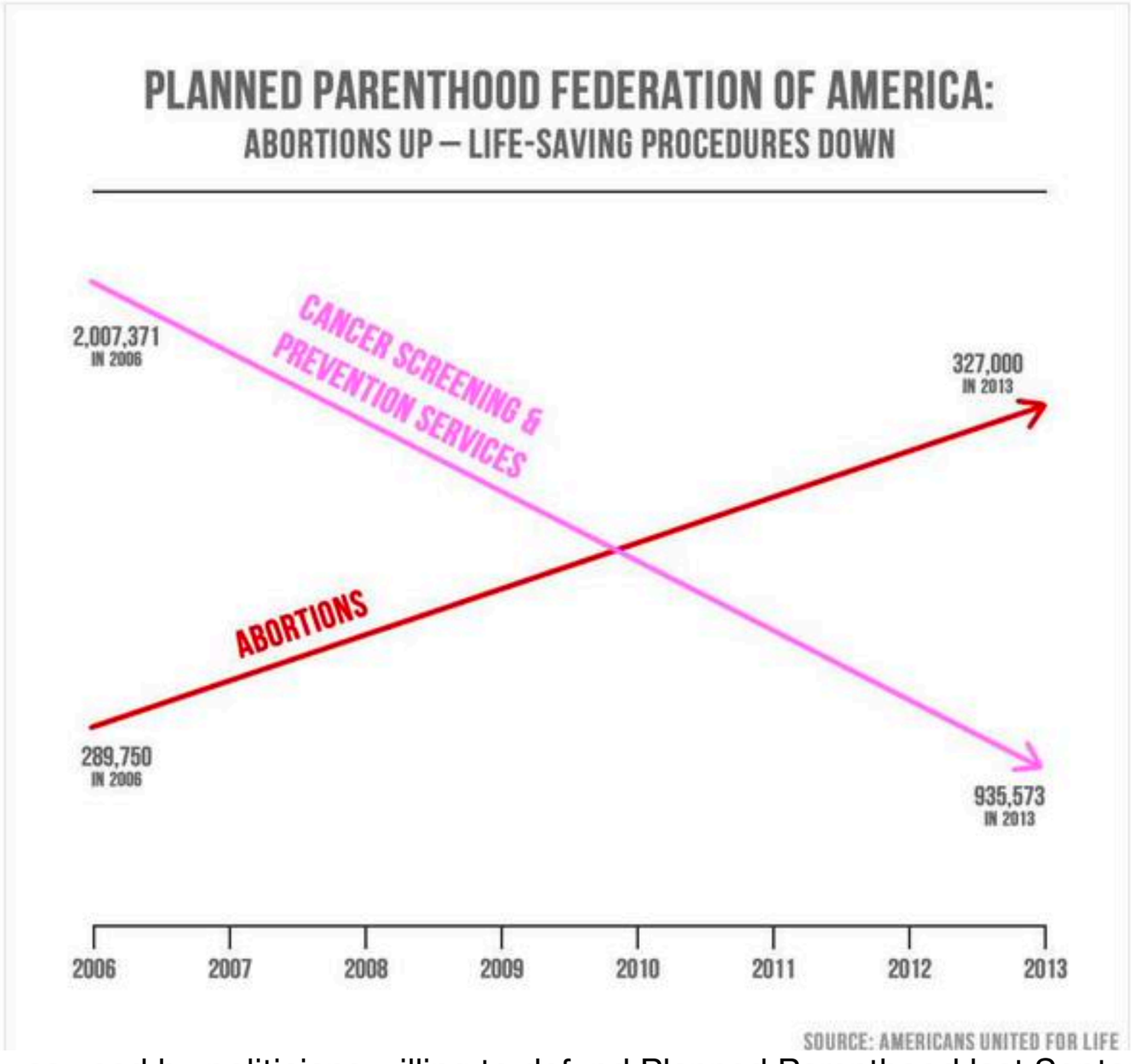
DEATHS (US)

Source: CDC (2011)

Much better but not perfect

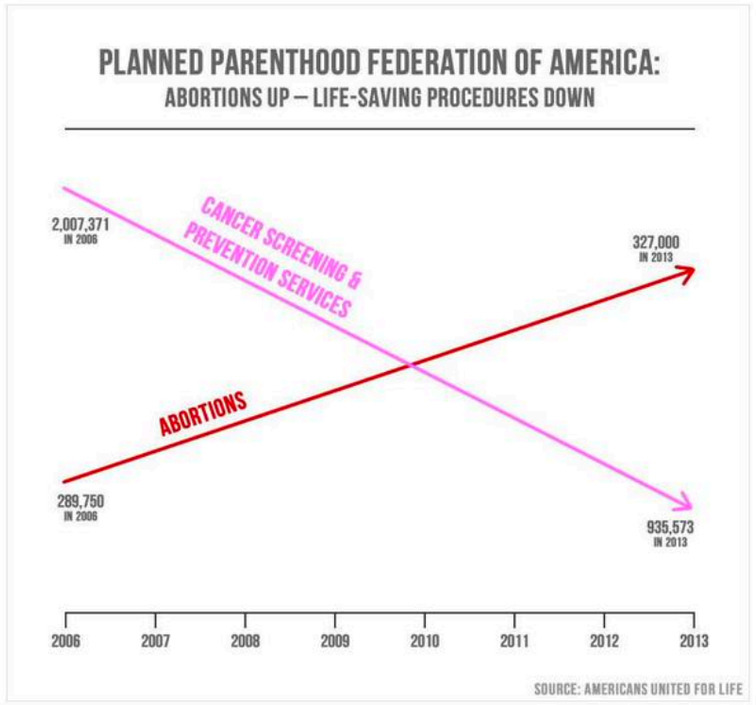


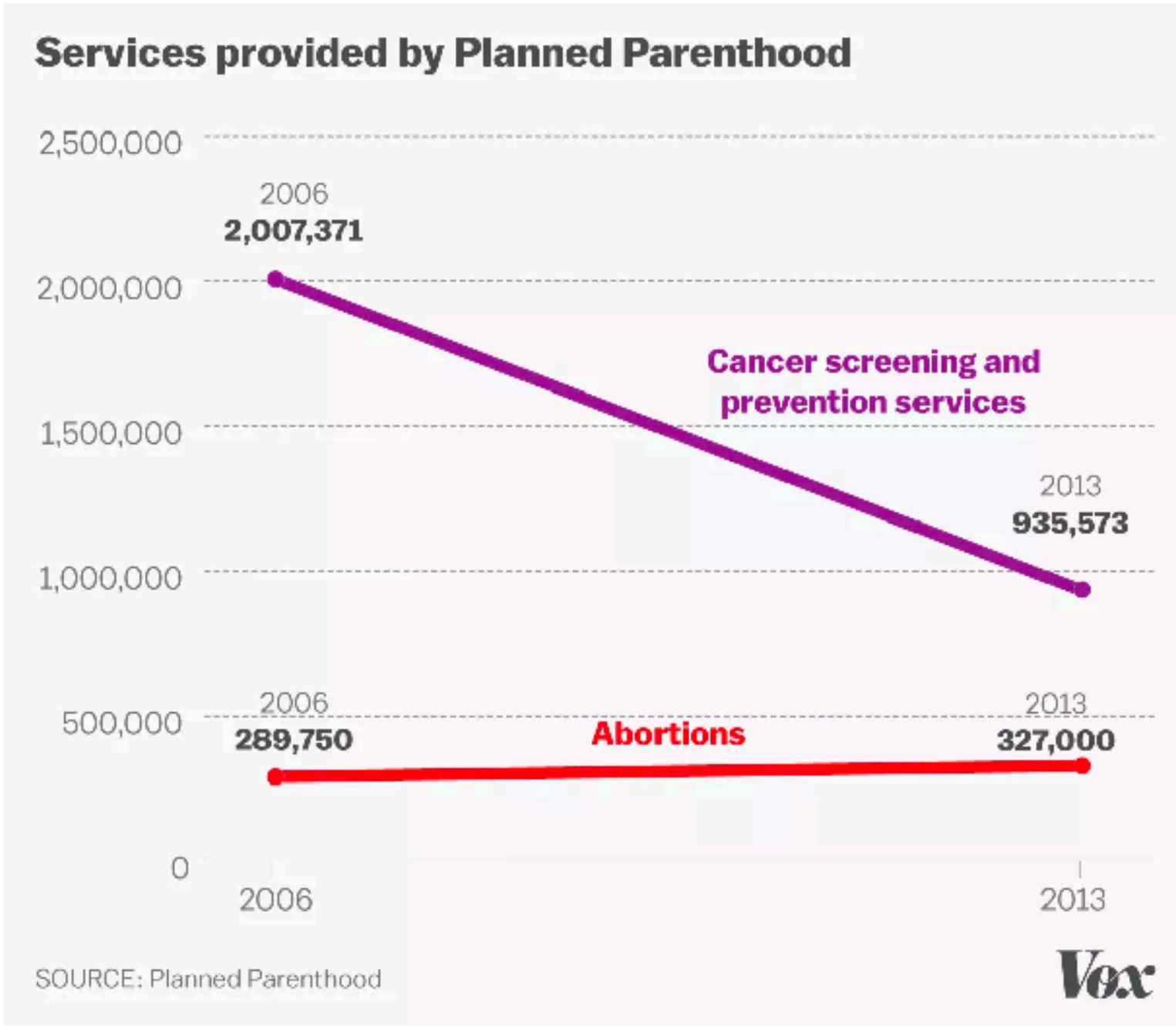
Correlations



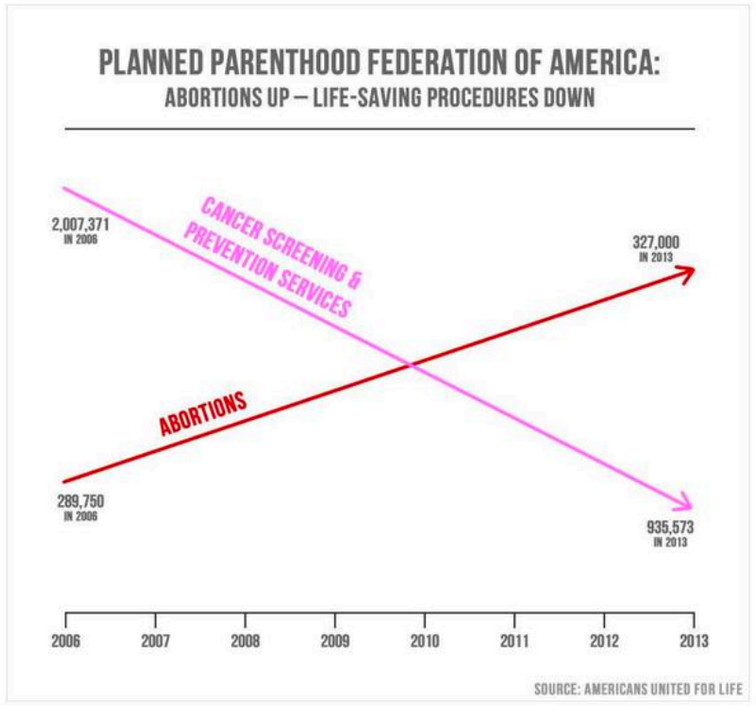
This chart was used by politicians willing to defund Planned Parenthood last September 2015 (http://www.vox.com/2015/9/29/9417845/planned-parenthood-terrible-chart)

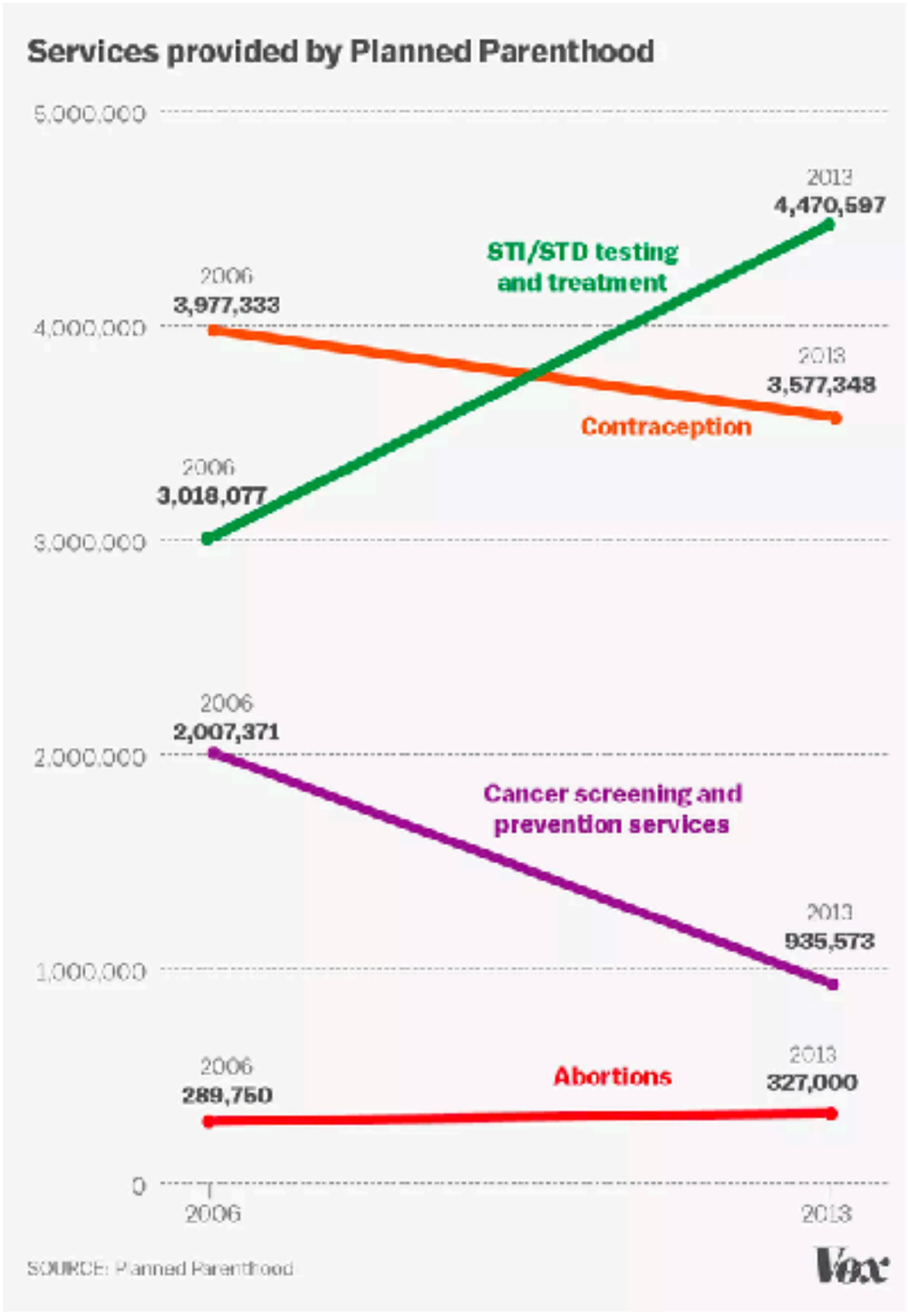
The real graph





The real graph

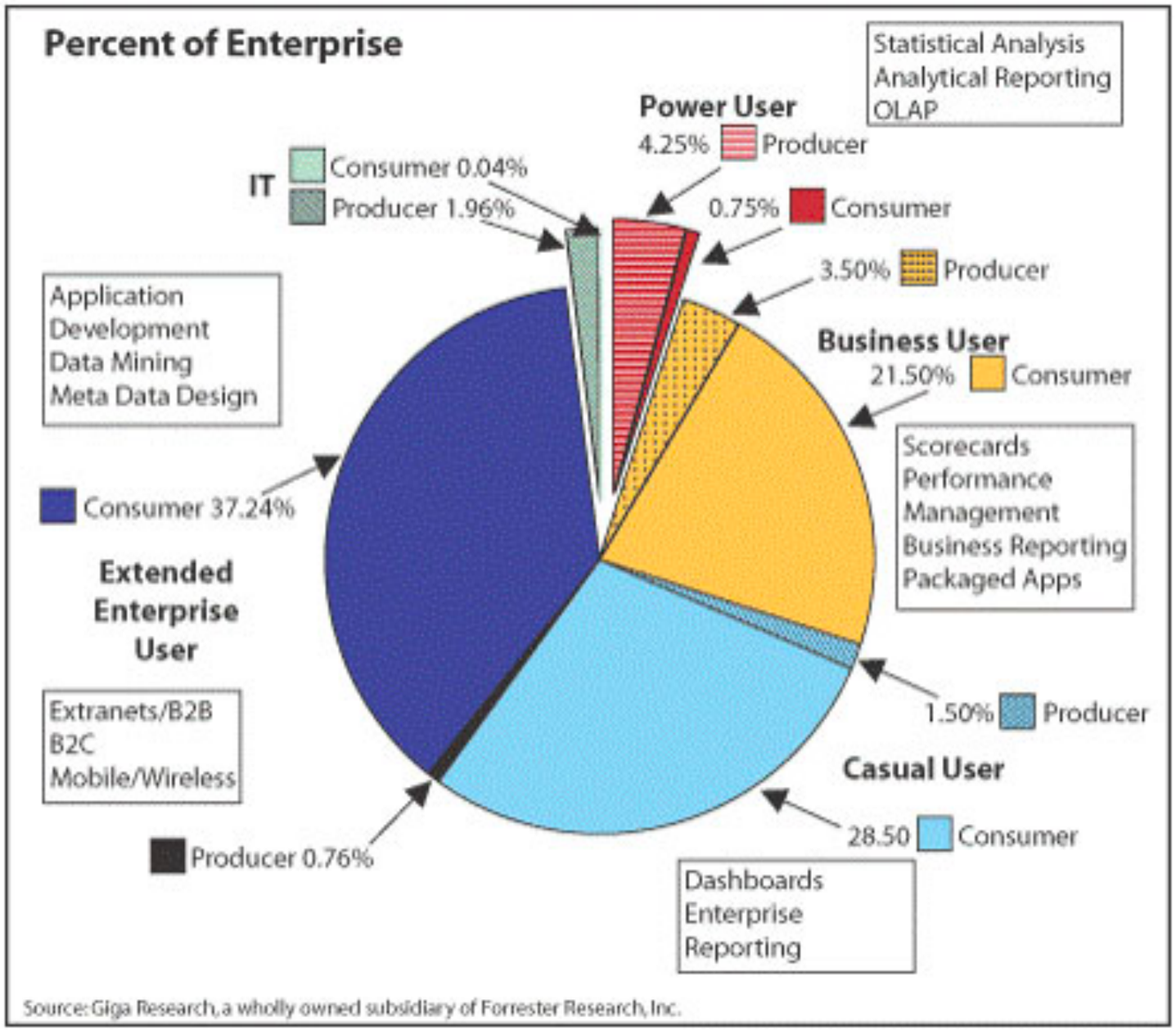




As a summary:

Typical error on Data Visualization

http://tcagency.es/errores-de-visualizacion-de-datos/



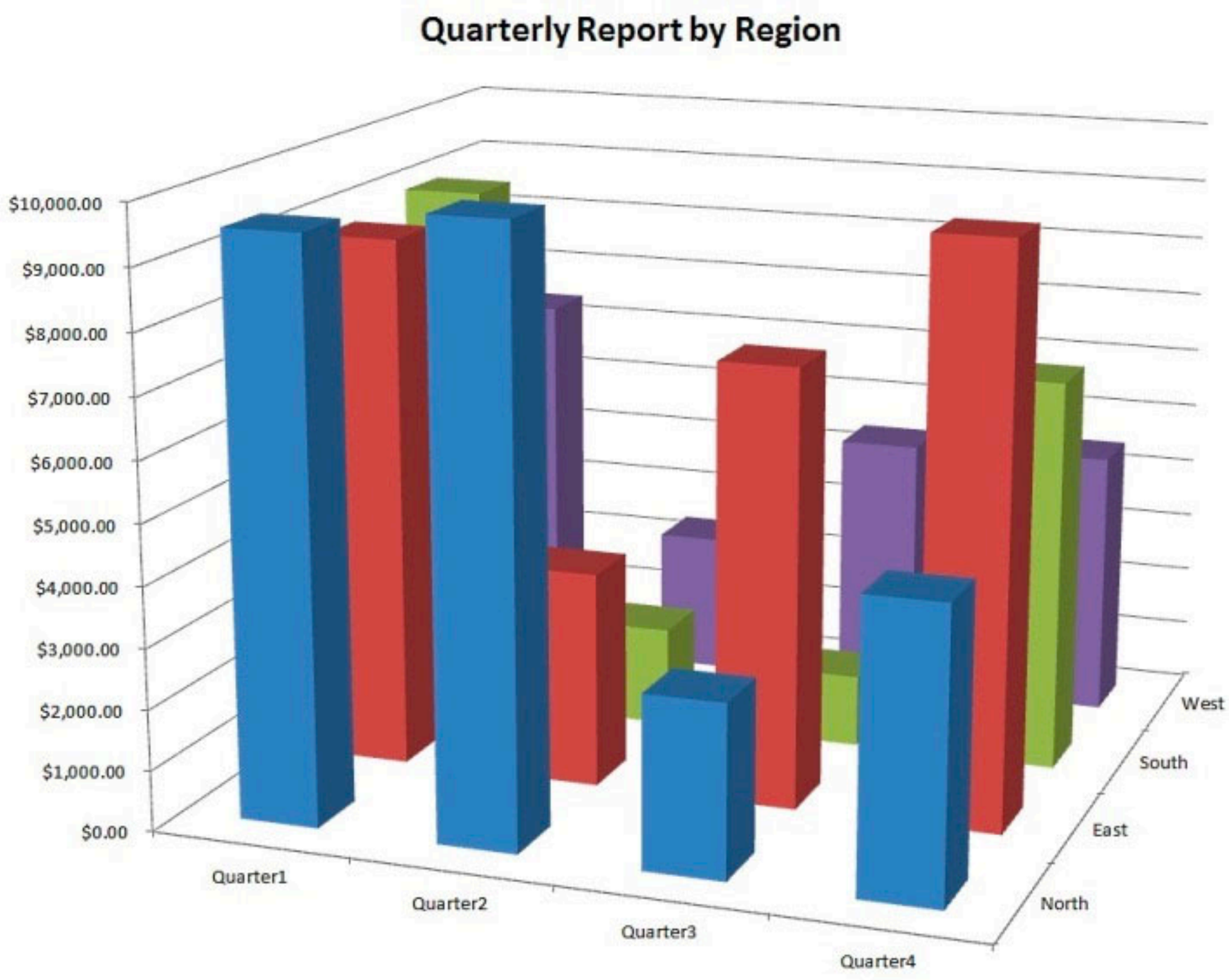
Too many information!

AVERAGE COST PER QUALIFIED LEAD

The wrong Scale!


THE SMALL BUSINESS ADMINISTRATION REPORTS:
NEW BUSINESS SURVIVAL RATES:
30%
new businesses
survive 10 years
70%
new businesses
survive 2 years
51%
new businesses
survive 5 years

Maths!

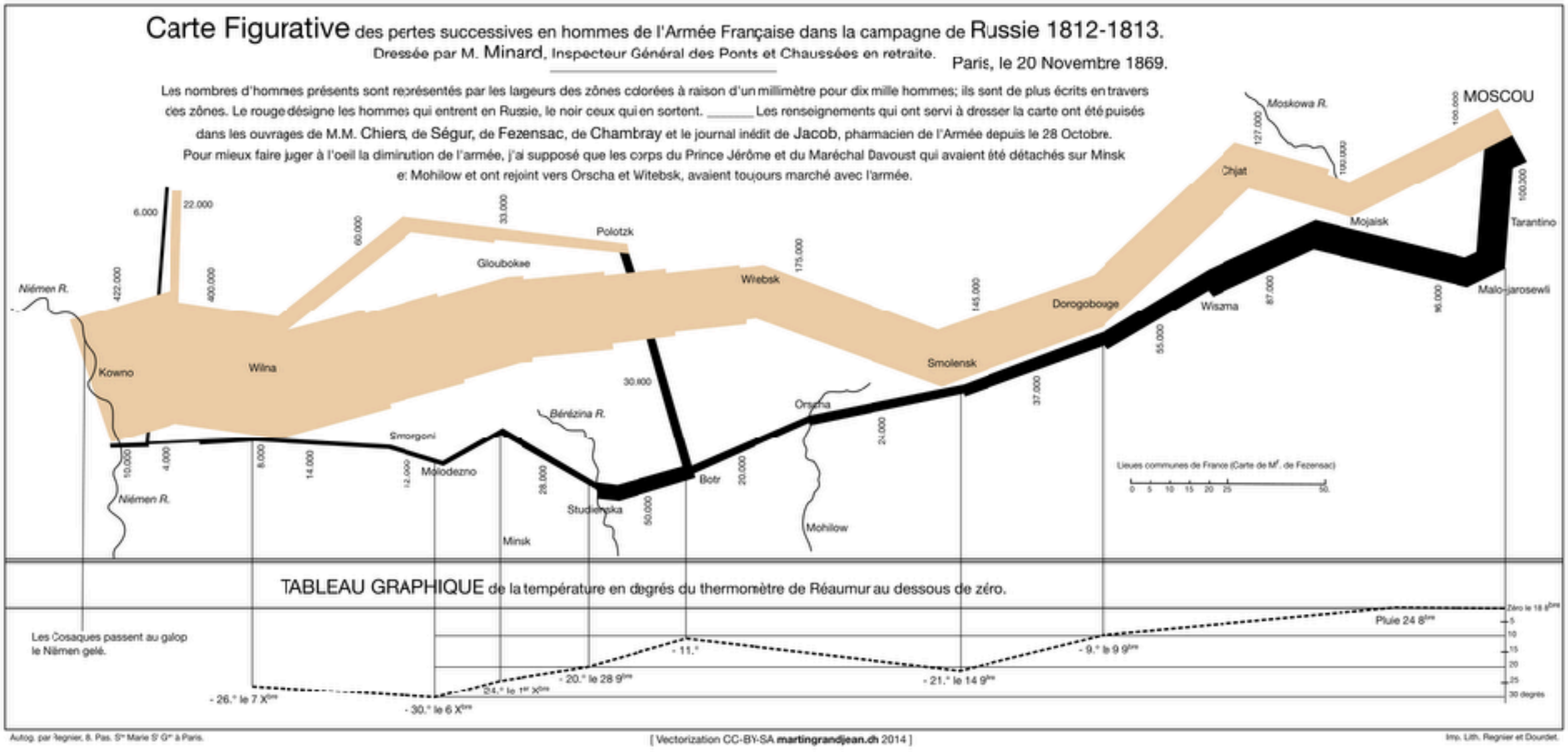


The choice of graph

Story Telling

Napoleon Invasion by Charles Joseph Minard

Edward Tufte said it "may well be the best statistical graphic ever drawn"



http://en.wikipedia.org/wiki/Charles_Joseph_Minard#mediaviewer/File:Minard.png

Variables displayed in the graph: 1) the number of Napoleon's troops; 2) the distance traveled; 3) temperature; 4) latitude and longitude; 5) direction of travel; and 6) location relative to specific dates

The story of the world in 200 countries over 200 years using 120,000 numbers by Hans Rosling

https://www.youtube.com/watch?time_continue=203&v=jbkSRLYSojo

Is the world overpopulated? Will the population increase?
by Hans Rosling

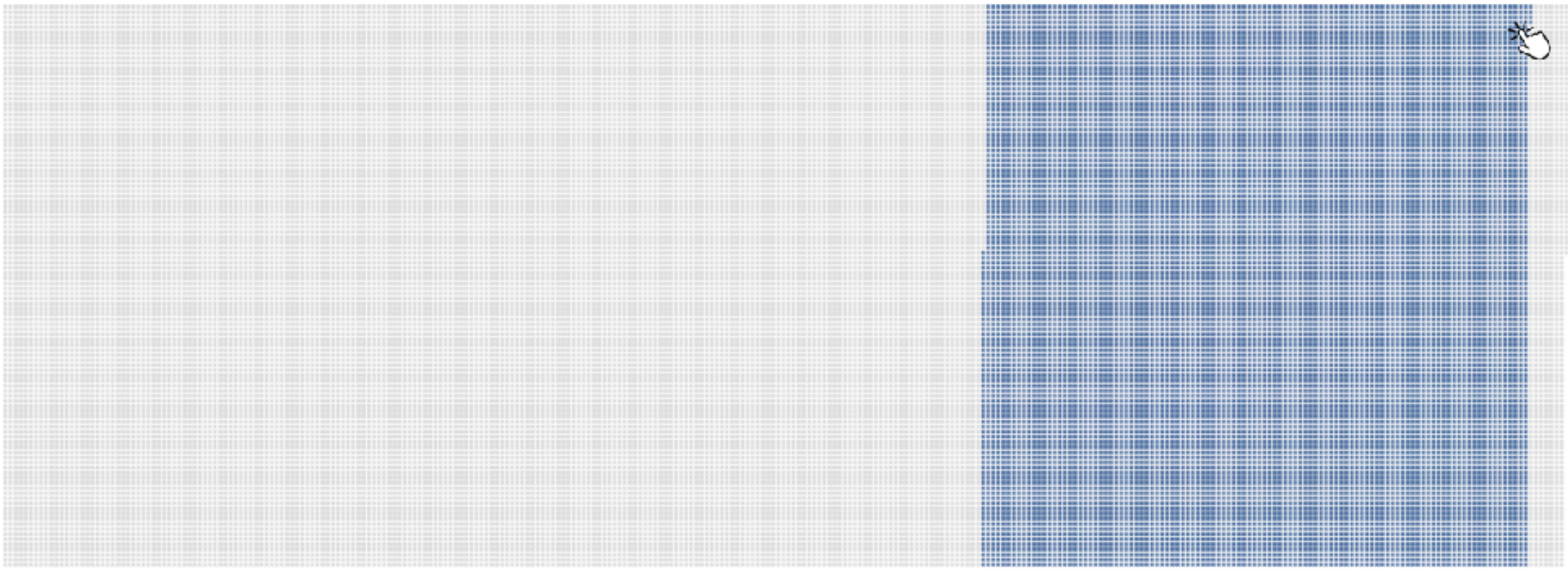
https://www.youtube.com/watch?v=-UbmG8gtBPM

Guns in America?

FiveThirtyEight

Share

Another third of all gun deaths — about 12,000 in total each year — are **homicides**.

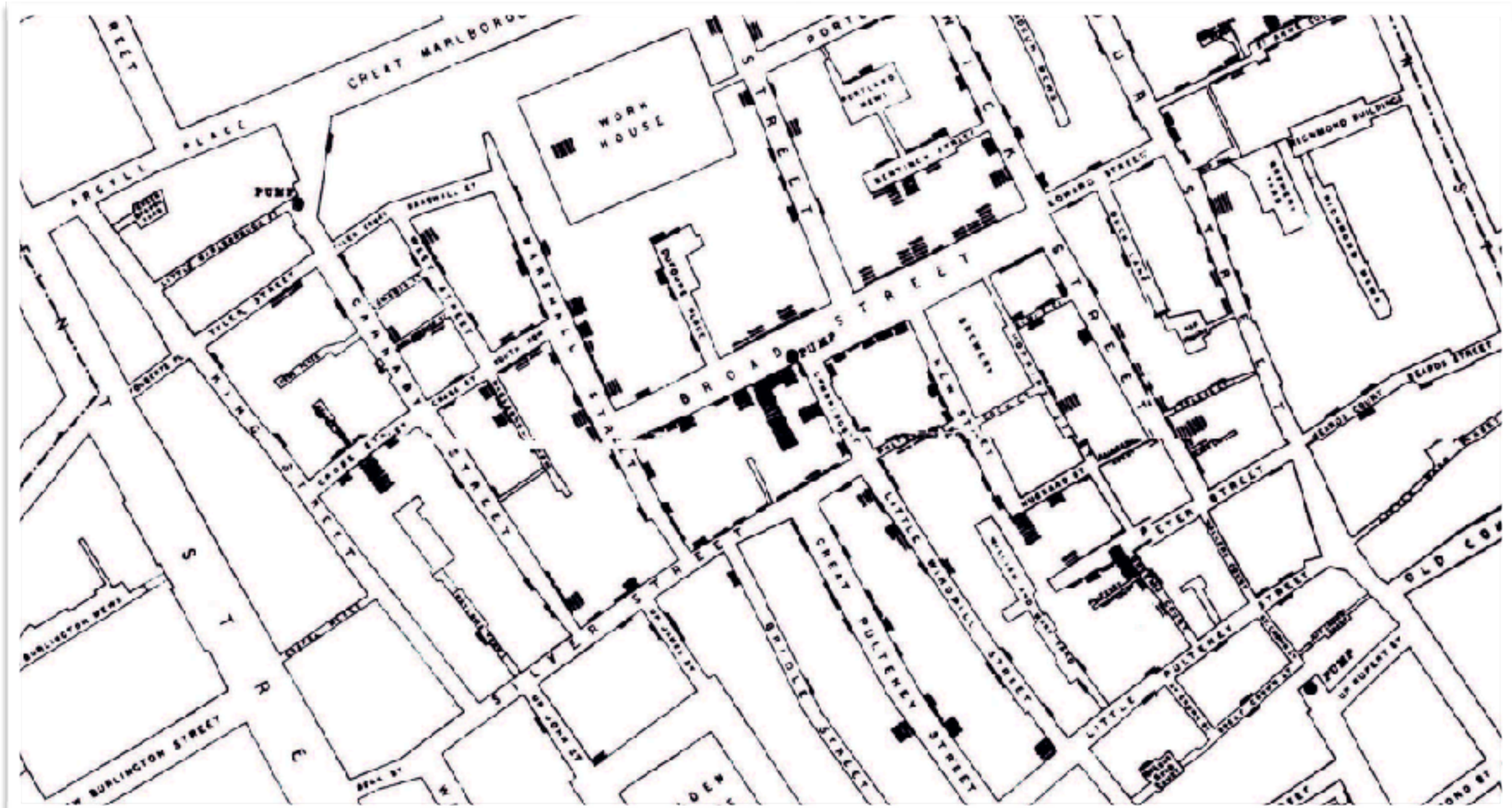


1 2 3 4 5 6 7 8 9 10 11 12 | Explore the data for yourself »

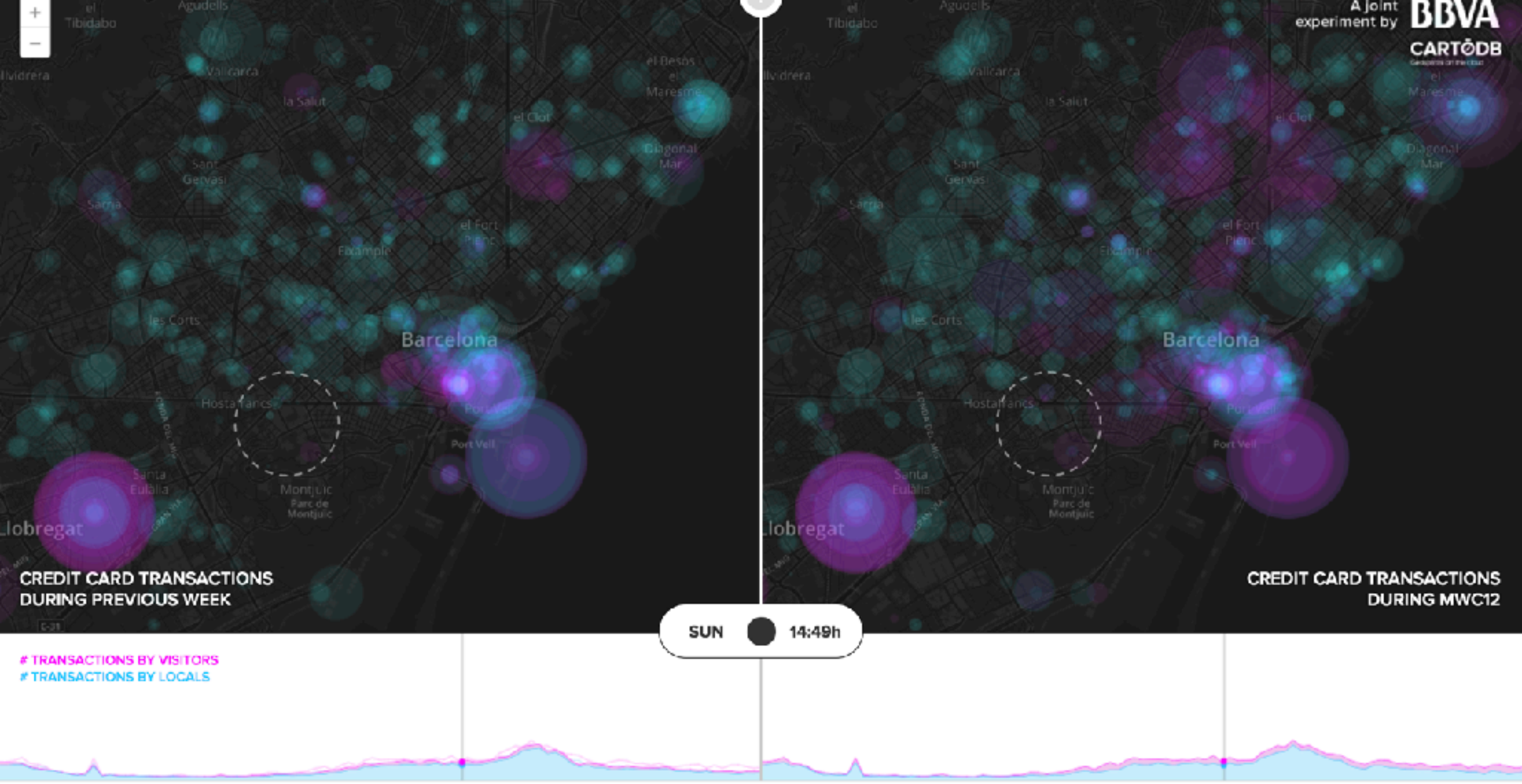
https://fivethirtyeight.com/features/gun-deaths/

Knowledge Discovery

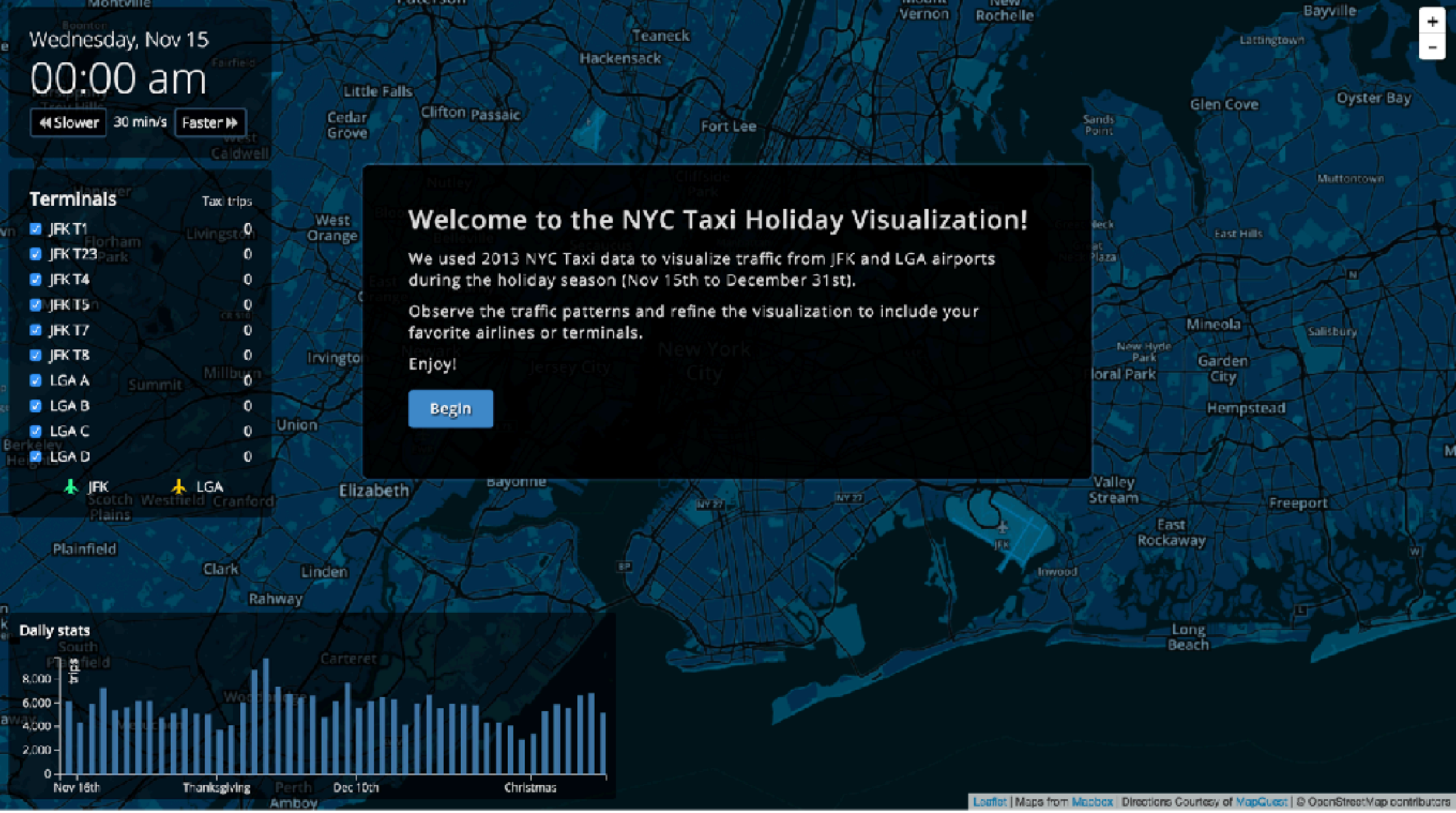
London 1854. Difficult times for London population, specially in Soho, when a cholera outbreak killed thousands. A map saved the city. How?



Map by John Snow. https://en.wikipedia.org/wiki/John_Snow



Economic Impact The economic impact of the MWC on Barcelona created with CartoDB and BBVA. The week before vs. the 2012 MWC week http://mwcimpact.com/



https://taxi.imagework.com/

UNIVERSITAT DE BARCELONA

DAS

One Dataset - Lots of interesting stuff to learn

Taxi GPS data helps researchers study Hurricane Sandy's effect on NYC traffic

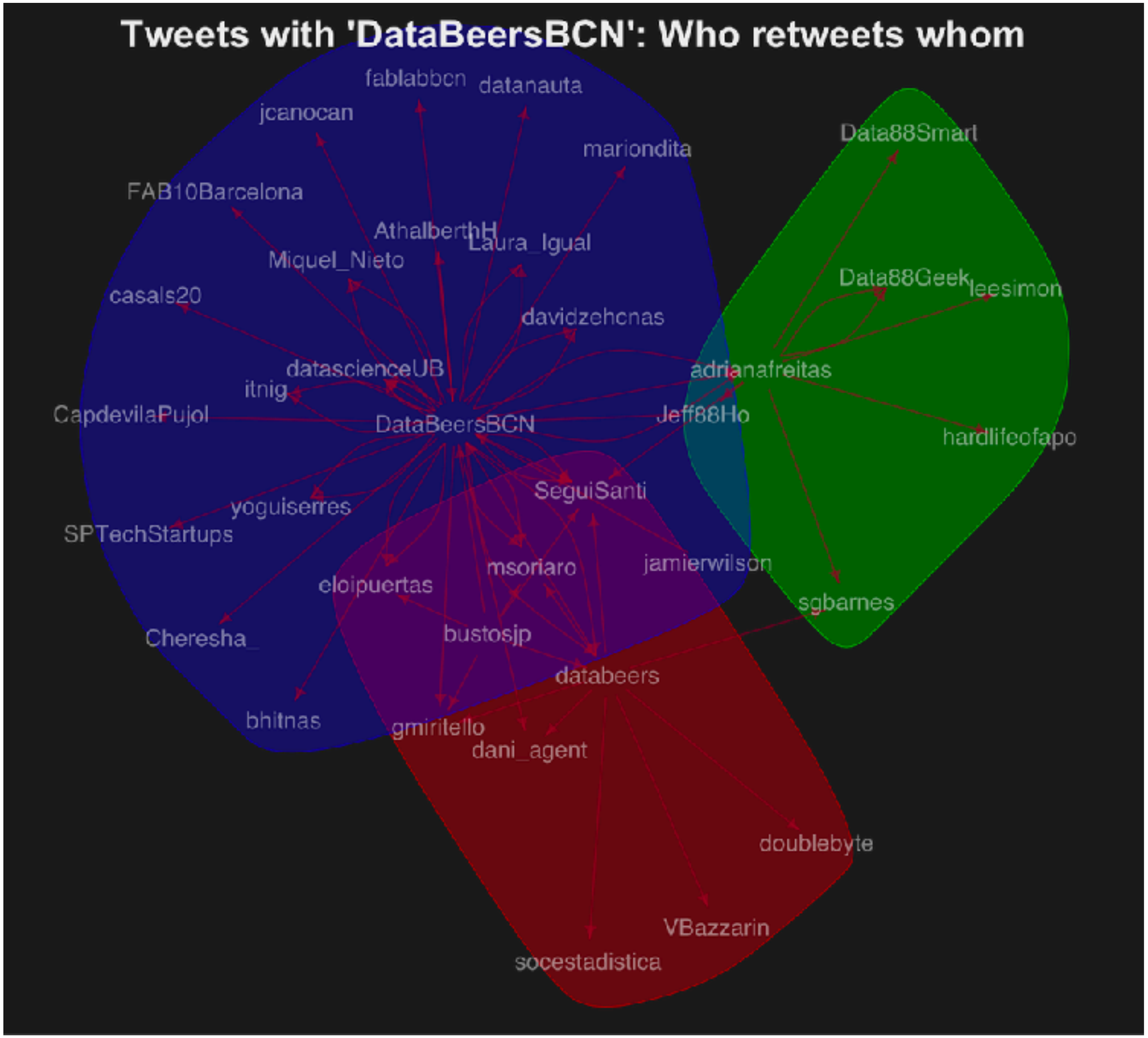
https://engineering.illinois.edu/news/article/9717

Exploring New York City taxi trails and sharing our way to a more sustainable urban future

http://hubcab.org/#13.00/40.7219/-73.9484

Public NYC Taxicab Database Lets You See How Celebrities Tip

http://gawker.com/the-public-nyc-taxicab-database-that-accidentally-track-1646724546


Tweets with 'DataBeersBCN': Who retweets whom
fablabbcn
datanauta
jcanocan
mariondita
Data88Smart
FAB10Barcelona
AthalberthH
Laura_Igual
Miquel_Nieto
Data88Geek
leesimon
casals20
davidzehcnas
datascienceUB
adrianafreitas
itnig
CapdevilaPujol
DataBeersBCN
Jeff88Ho
hardlifeofapo
SeguiSanti
yoguiserres
SPTechStartups
msoriaro
jamierwilson
eloipuertas
sgbarnes
Cheresha_
bustosjp
databeers
bhitnas
gmiritello
dani_agent
doublebyte
VBazzarin
socestadistica

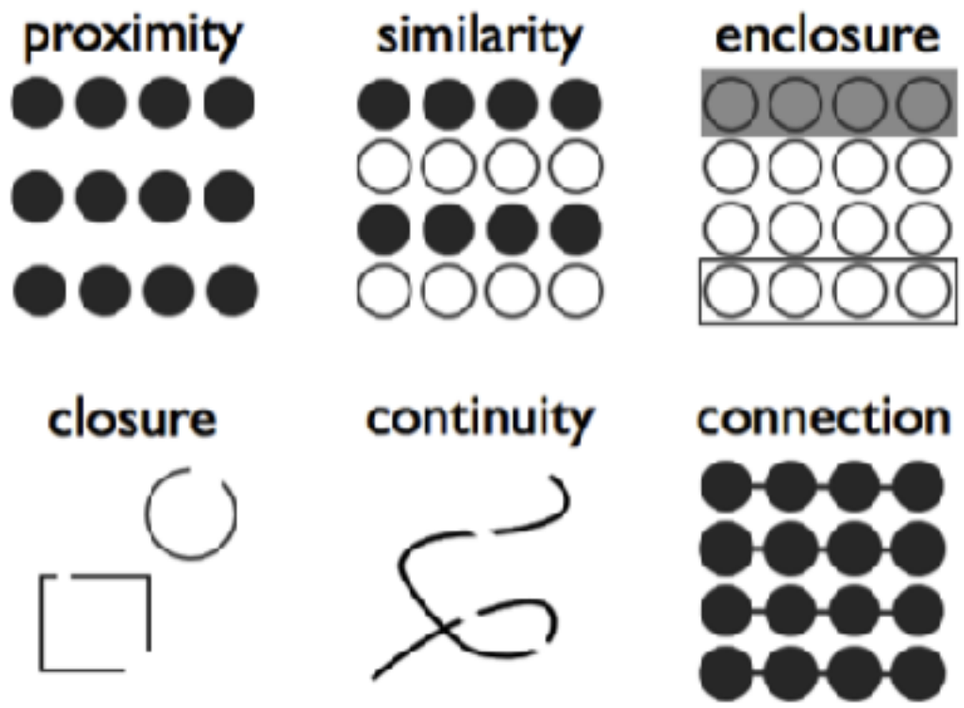
The Gestalt Principles

Similarity: When items look the same, people perceive them to be of the same type. We naturally assume that shapes that look the same are related. When you create a data viz and you keep items together that look the same, you make it easy for someone to understand that those items represent a group.

Closure: Our eyes tend to add any missing pieces of a familiar shape. If two sections are taken out of a circle, as shown in the following figure, people still perceive the whole circle.

Continuation: If people perceive objects as moving in a certain direction, they see them as continuing to move that way. The figure below shows an example.

Figure/ground: Depending on how people look at a picture, they see either the figure (foreground) or the ground (background) as standing out, as shown in the following figure.



More about perception

Great post about Perception: https://medium.com/@kennelliott/39-studies-about-human-perception-in-30-minutes-4728f9e31a73#.rwk4sut5h

One Example: **Reference point**:
In the previous link, they mentioned: "Three studies show that we have inherent biases related to the types of graphs we see and the objects we see in them. These biases may distort the information we retrieve from a graph. We know that from Steven's law, when an object is seen in context of other larger objects, it appears larger itself. When it is seen in context with smaller objects, it appears smaller. Jordan and Schiano (3) found that increasing spatial separation between lines produced the opposite effect. If lines were close enough, a line's length was more similar to the length of the line around it (this is also known as assimilation). If the lines were far apart, long lines appeared longer, and short lines appeared shorter (also known as contrast)."

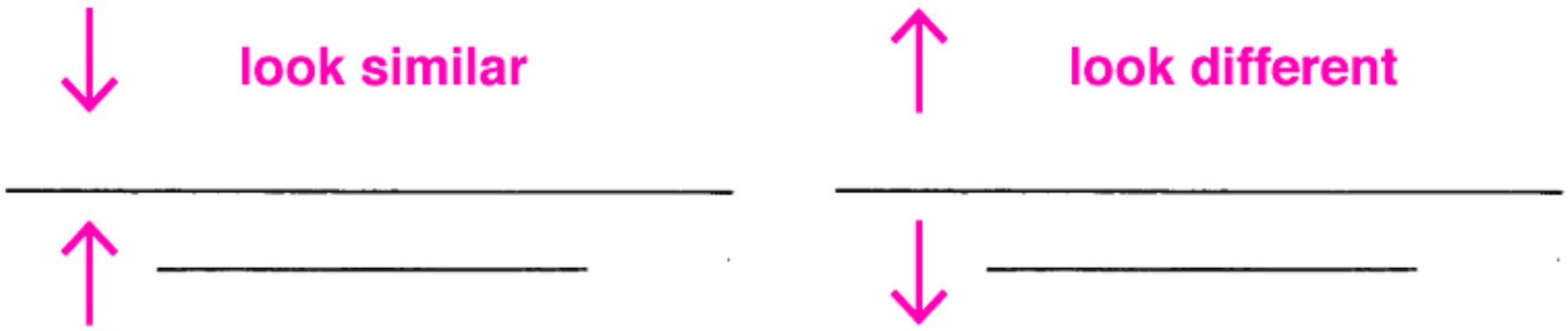


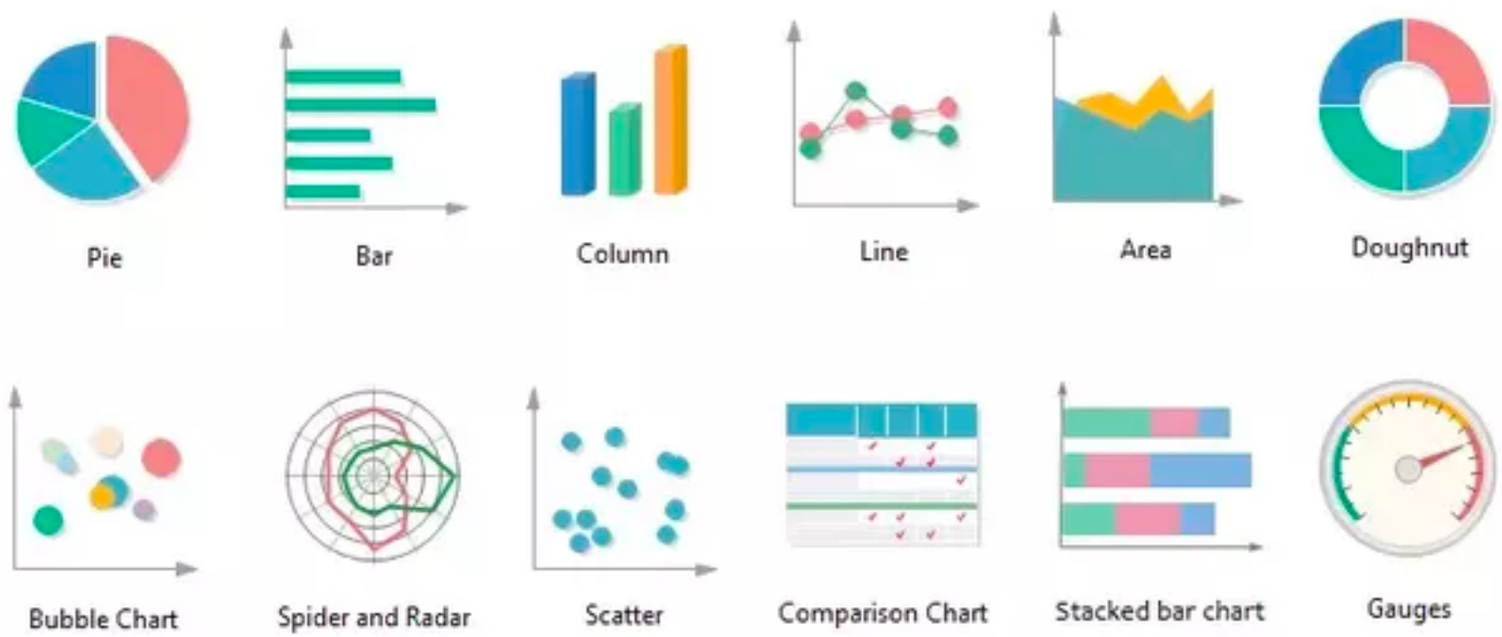
Figure 1. Example of the parallel-lines illusion configuration. Relative to a no-context control line, the test line is overestimated when presented with the longer contextual line.

Things to take into account when designing a visual data representation:

The Minimum Ink Principle

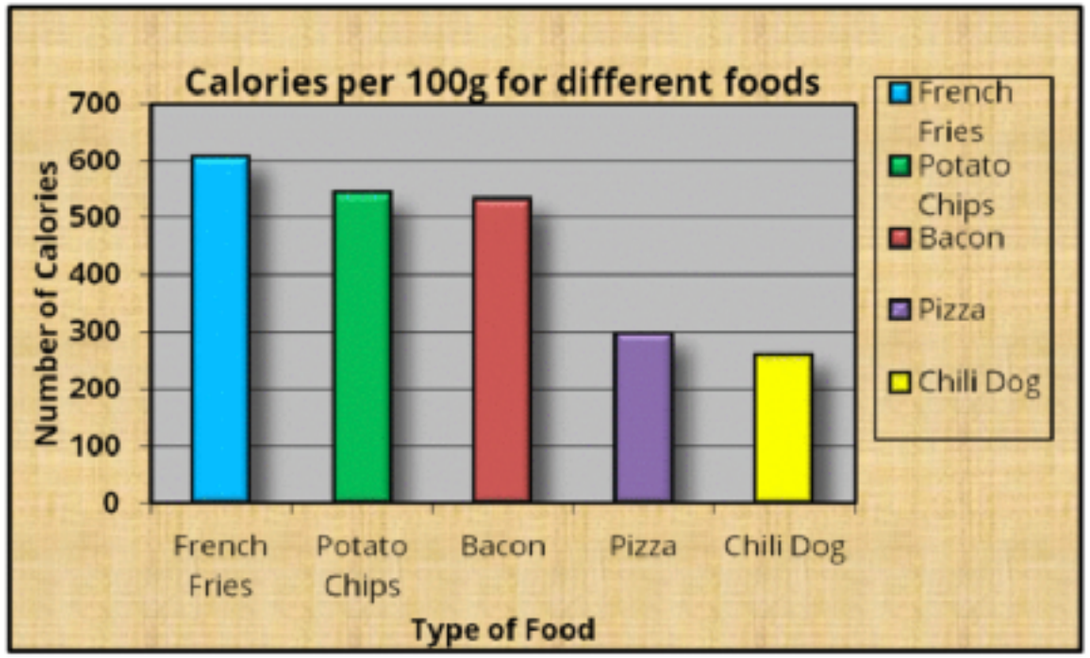
Colormap

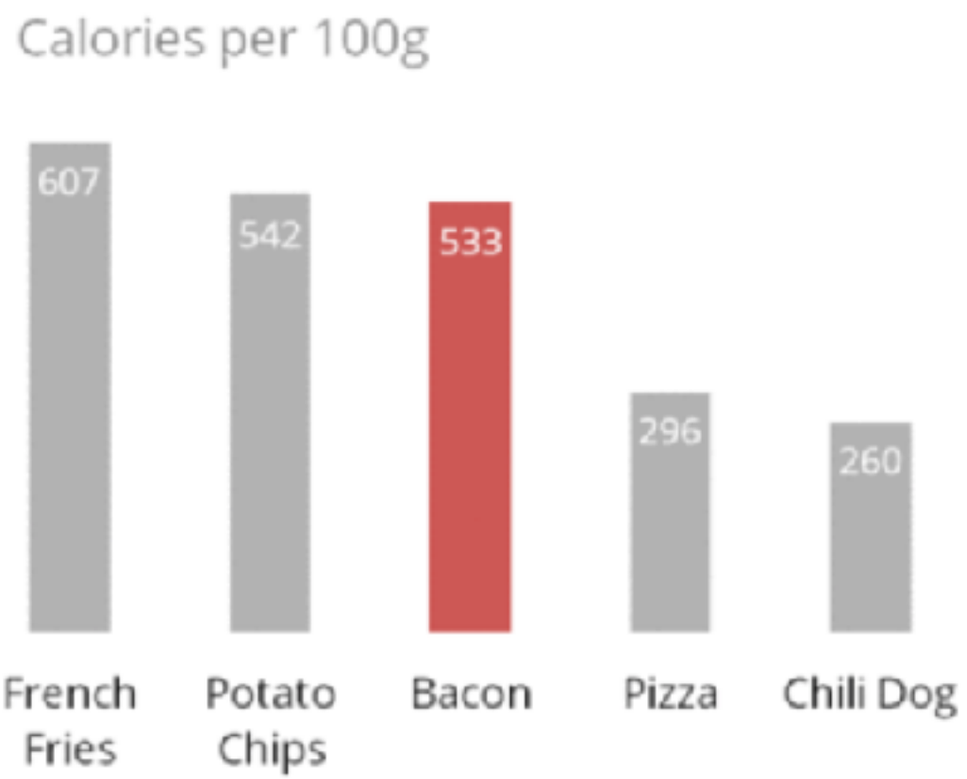
Type of chart or graph



The Minimum Ink Principle

The Minimum Ink Principle





How do I choose the proper colormap?

First Advise: Picking colors is really important task, you don’t have to reinvent the wheel. A number of great websites out there will help you choose the right palette for your infographic

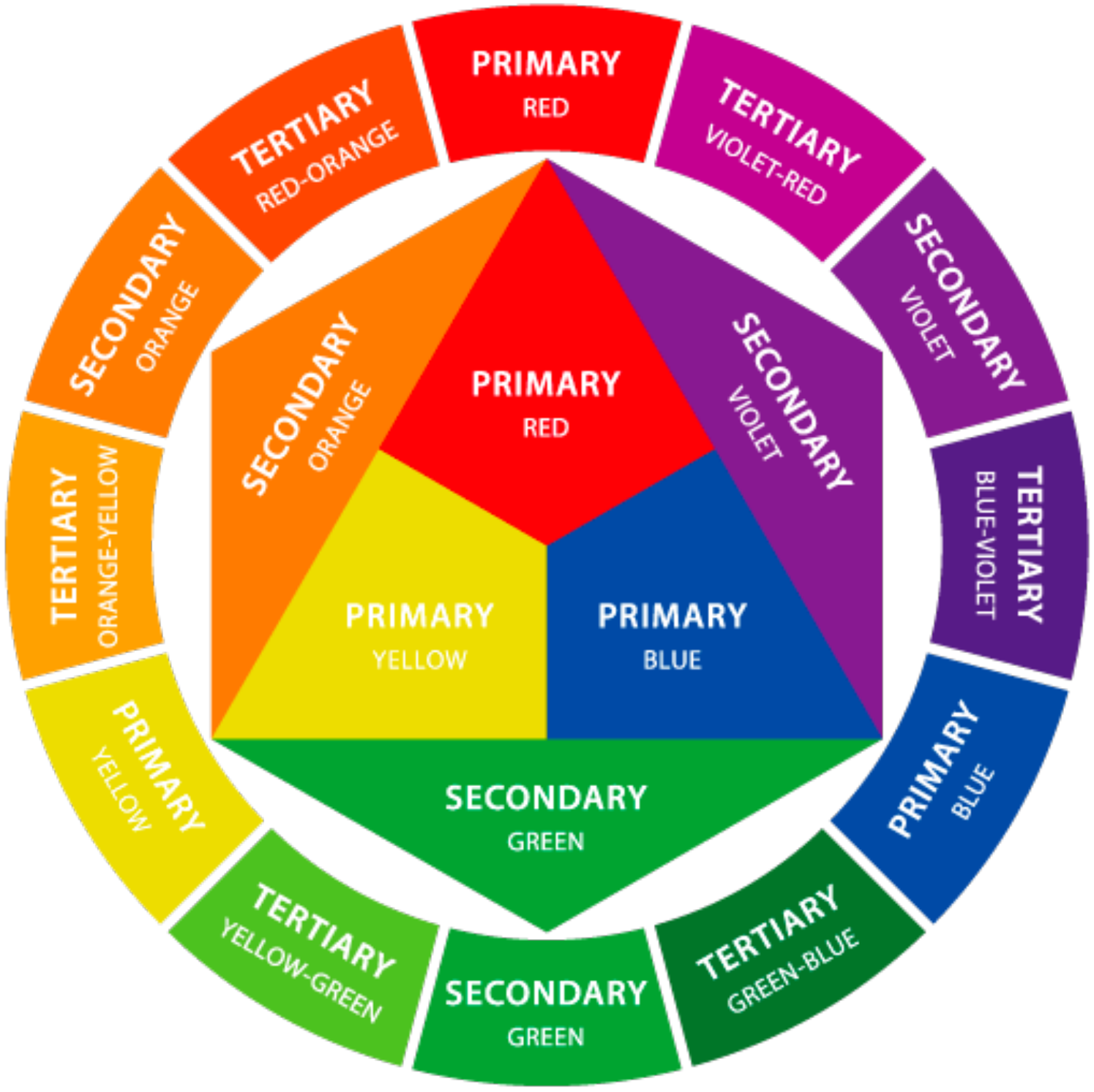
https://color.adobe.com/create/color-wheel/

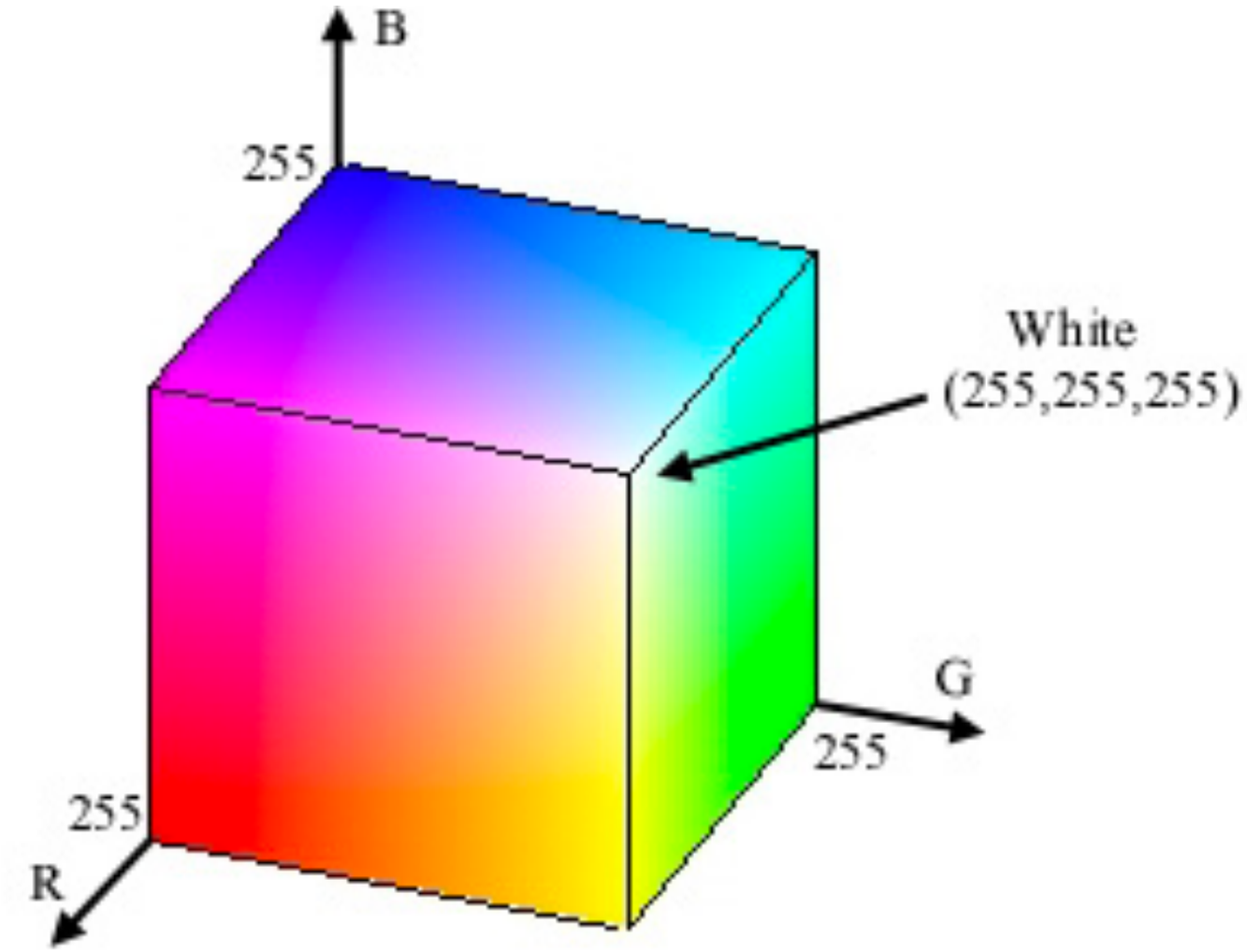
http://www.colourlovers.com/

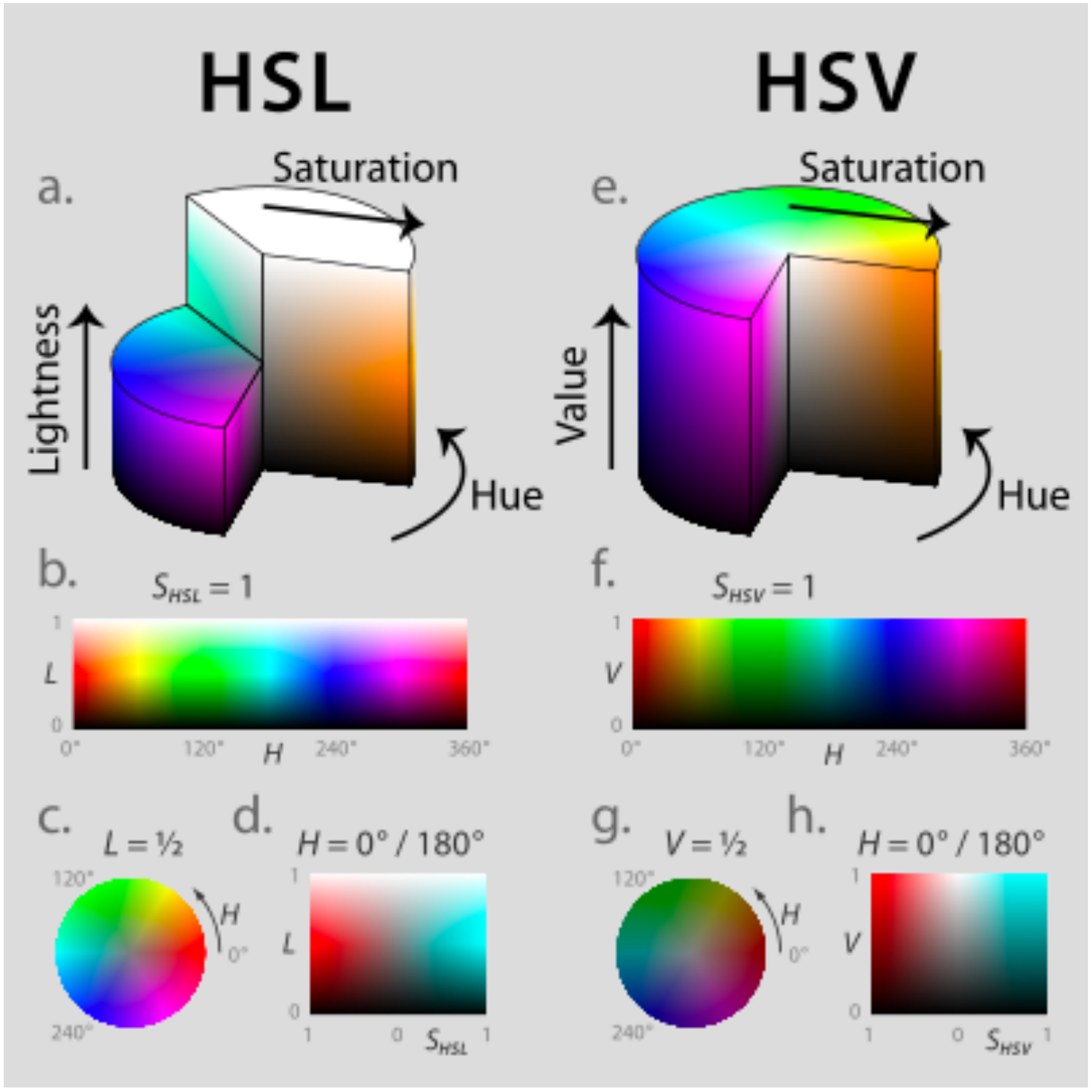

RED: Red is the color of fire and blood, so it is associated with energy, war, danger, strength, power, determination as well as passion, desire, and love.
ORANGE: Orange combines the energy of red and the happiness of yellow. It is associated with joy, sunshine, and tropics.
BLACK: Black is associated with power, elegance, formality, death, evil, and mystery.
THE BIG EIGHT
BRAND COLORS
PSYCHOLOGY BEHIND COLORS
YELLOW: Yellow is the color of sunshine. It's associated with joy, happiness, intellect, and energy.
WHITE: White is associated with light, goodness, innocence, and purity. It symbolizes safety, purity, and cleanliness. In heraldry, white depicts faith and purity.
GREEN: Green is the color of nature. It symbolizes growth, harmony, freshness, and fertility.
PURPLE: Purple combines the stability of blue and the energy of red. Purple is associated with royalty. It symbolizes power, nobility, luxury, and ambition.
BLUE: Blue is the color of the sky and sea. It is often associated with depth and stability. It symbolizes trust, loyalty, wisdom, confidence, intelligence, faith, truth, and heaven.

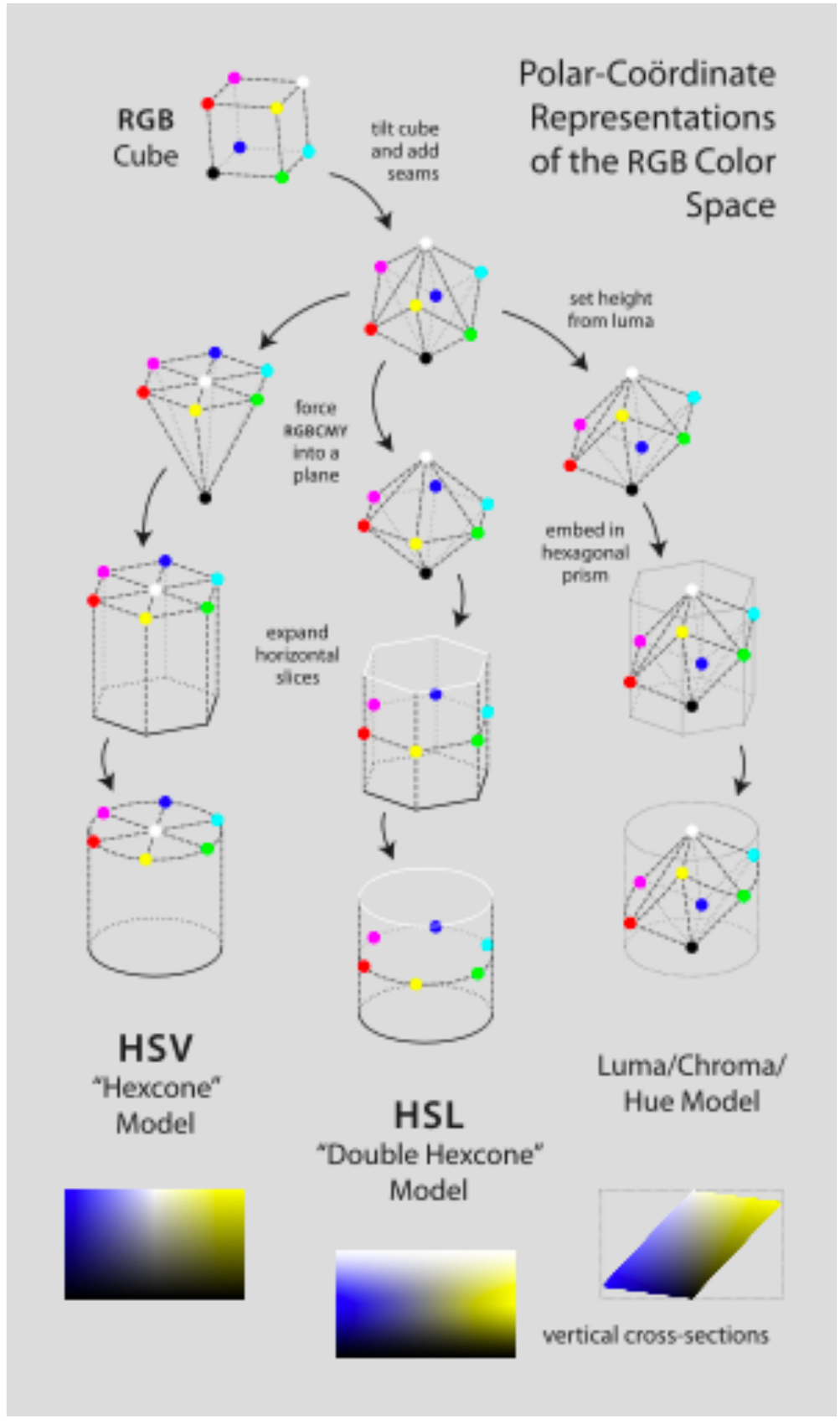
More tips

- For Categorical variables:
    - People have trouble differentiating between more than 5-7 hues (colors)
- For numerical variables:
    - People have trouble differentiating between more than 5-7 shades
    - Rainbow colors gradients are very problematic
- For highest contrast, only us color to highlight

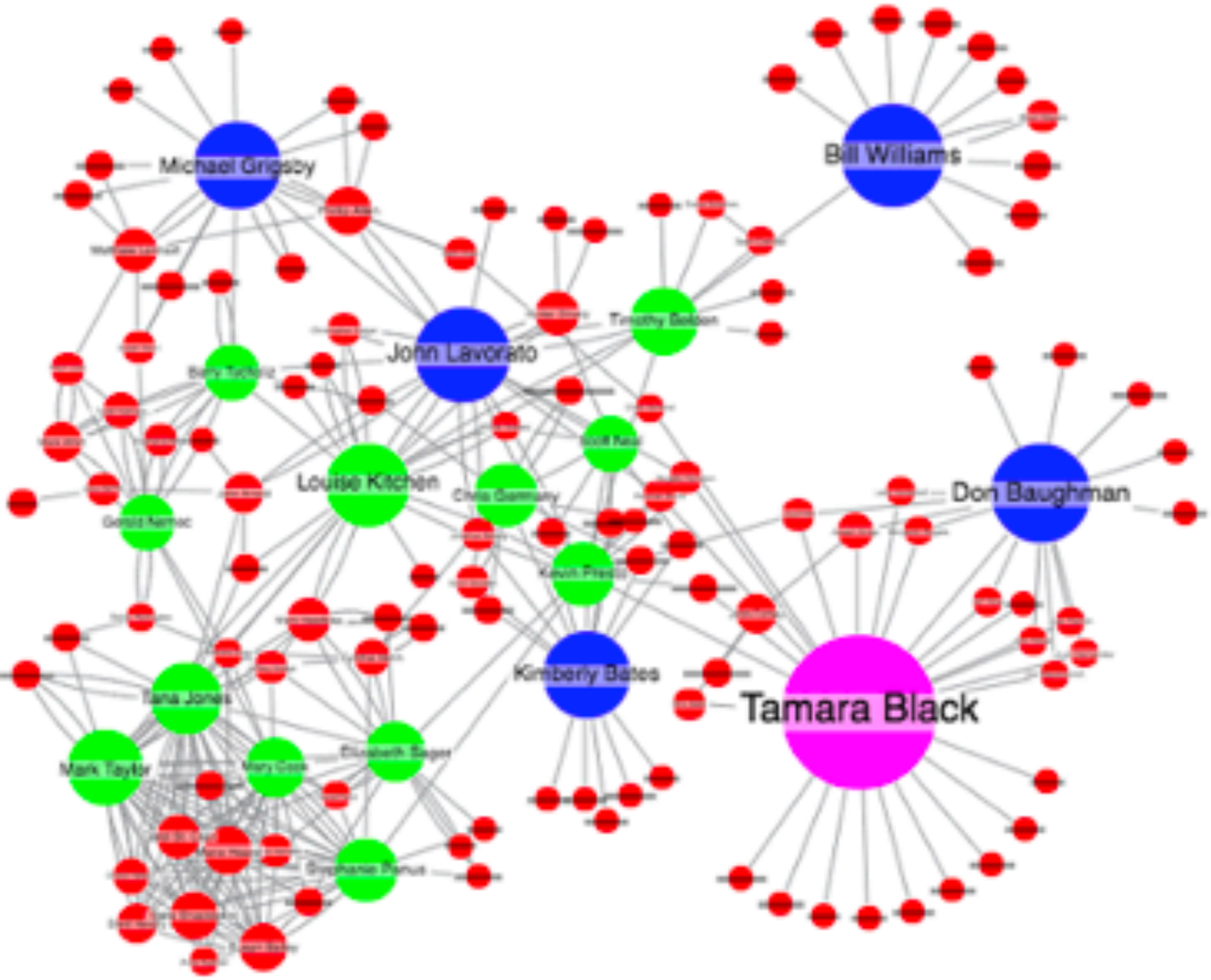

PRIMARY
RED
TERTIARY
VIOLET-RED
SECONDARY
VIOLET
TERTIARY
BLUE-VIOLET
PRIMARY
BLUE
TERTIARY
GREEN-BLUE
SECONDARY
GREEN
TERTIARY
YELLOW-GREEN
PRIMARY
YELLOW
TERTIARY
ORANGE-YELLOW
SECONDARY
ORANGE
TERTIARY
RED-ORANGE
PRIMARY
RED
SECONDARY
VIOLET
SECONDARY
ORANGE
PRIMARY
BLUE
PRIMARY
YELLOW
SECONDARY
GREEN


B
255
White
(255,255,255)
G
255
255
R


HSL
a.
Saturation
Lightness
Hue
b.
$S_{HSL} = 1$
L
H
0°
120°
240°
360°
c.
$L = ½$
H
d.
$H = 0° / 180°$
L
S_{HSL}
HSV
e.
Saturation
Value
Hue
f.
$S_{HSV} = 1$
V
H
g.
$V = ½$
h.
$H = 0° / 180°$
V
S_{HSV}


Polar-Coördinate Representations of the RGB Color Space
RGB Cube
tilt cube and add seams
set height from luma
force RGBCMY into a plane
embed in hexagonal prism
expand horizontal slices
HSV
"Hexcone" Model
HSL
"Double Hexcone" Model
Luma/Chroma/ Hue Model
vertical cross-sections

Which one do you prefer?



How to choose colors for your graphs?

- Step 1: Decide what the colors will represent
- Step 2: Understand your data scale
- Step 3: Decide how many hues you need
- Step 4: Look for obvious options
- Step 5: Create your palette

Colormap?

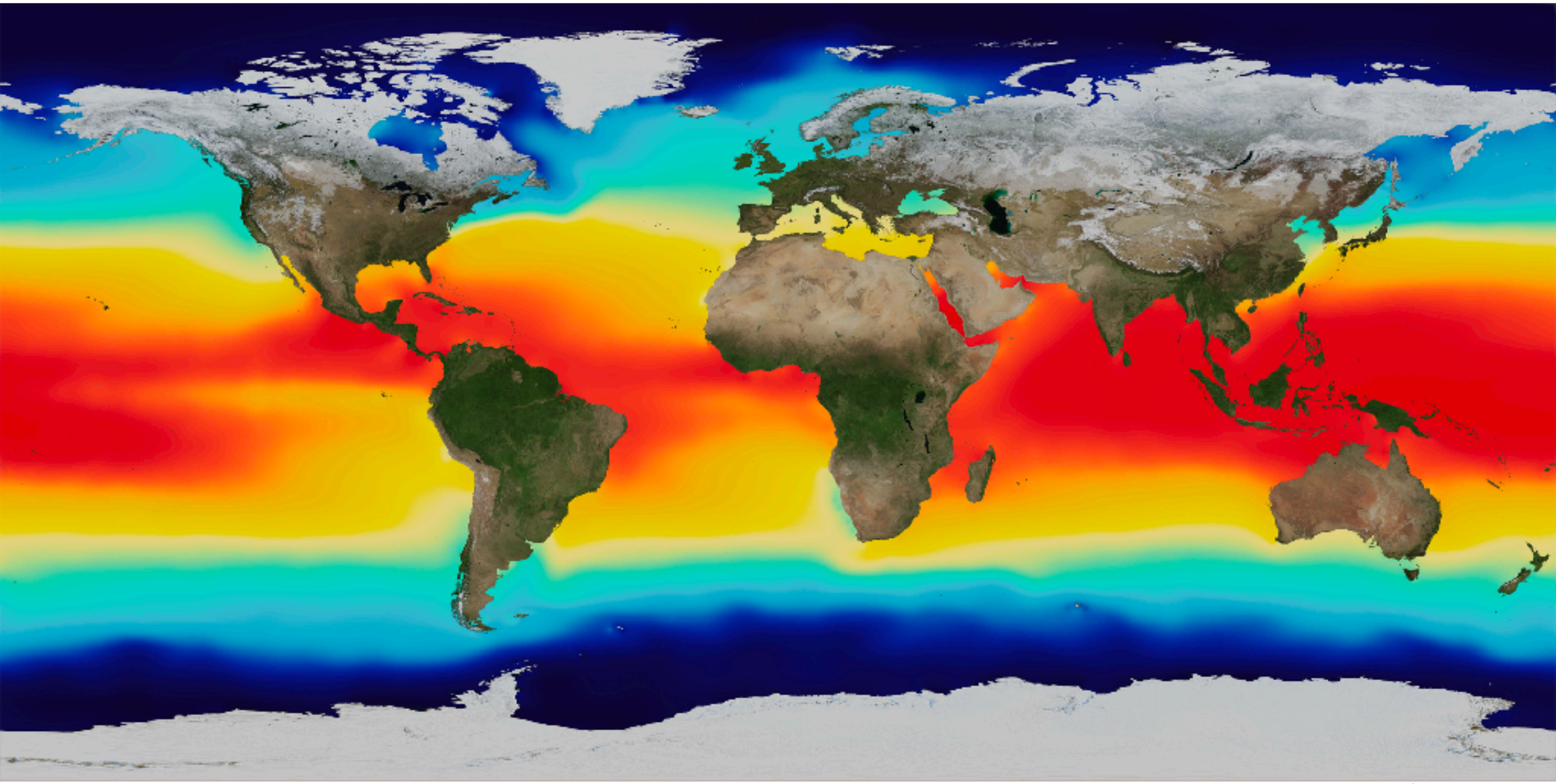
Colormaps are often split into several categories based on their function:

- Sequential;
- Diverging;
- Categorical

Usually only one color is used, changing light intensity or saturation. Should be used for representing information that has ordering.

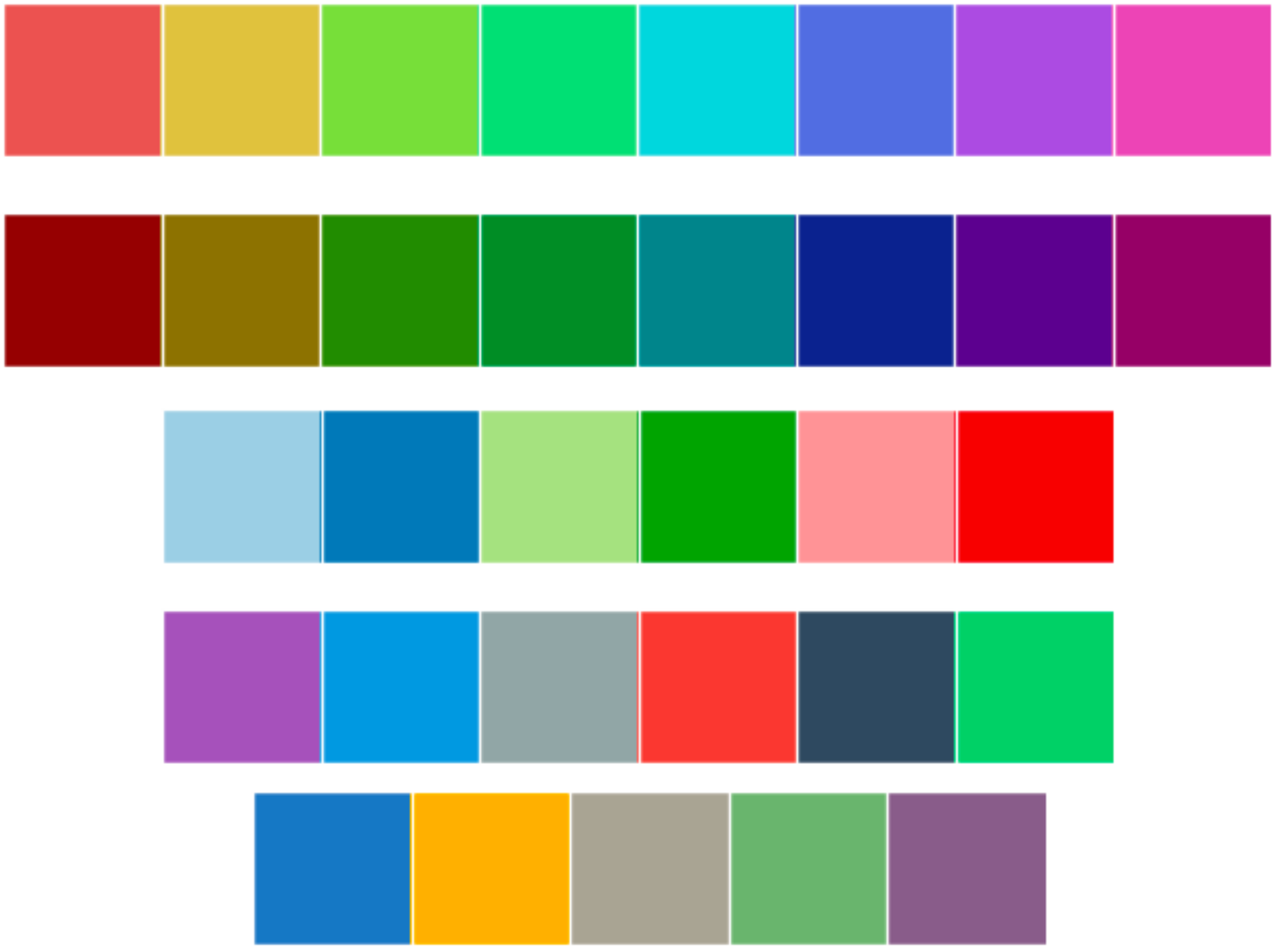
Colormap?

Diverging: Usually two colors and the trasition from on to the other are used. Should be used when the information being plotted has a critical middle value For instance, negative temperatures (blue) and positive temperatures (red).



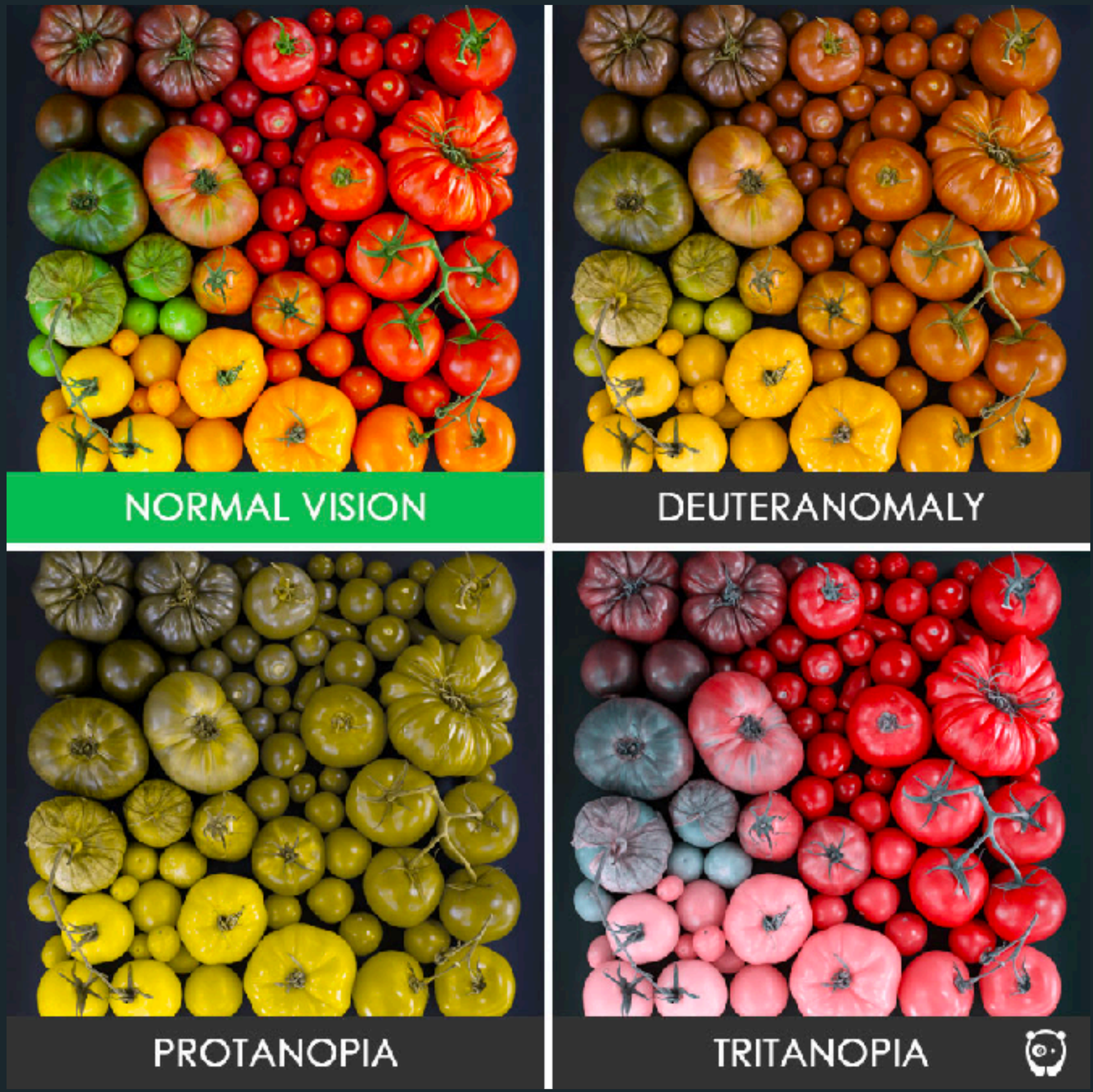
Colormap?

Categorical: often are miscellaneous colors; should be used to represent information which does not have ordering or relationships.

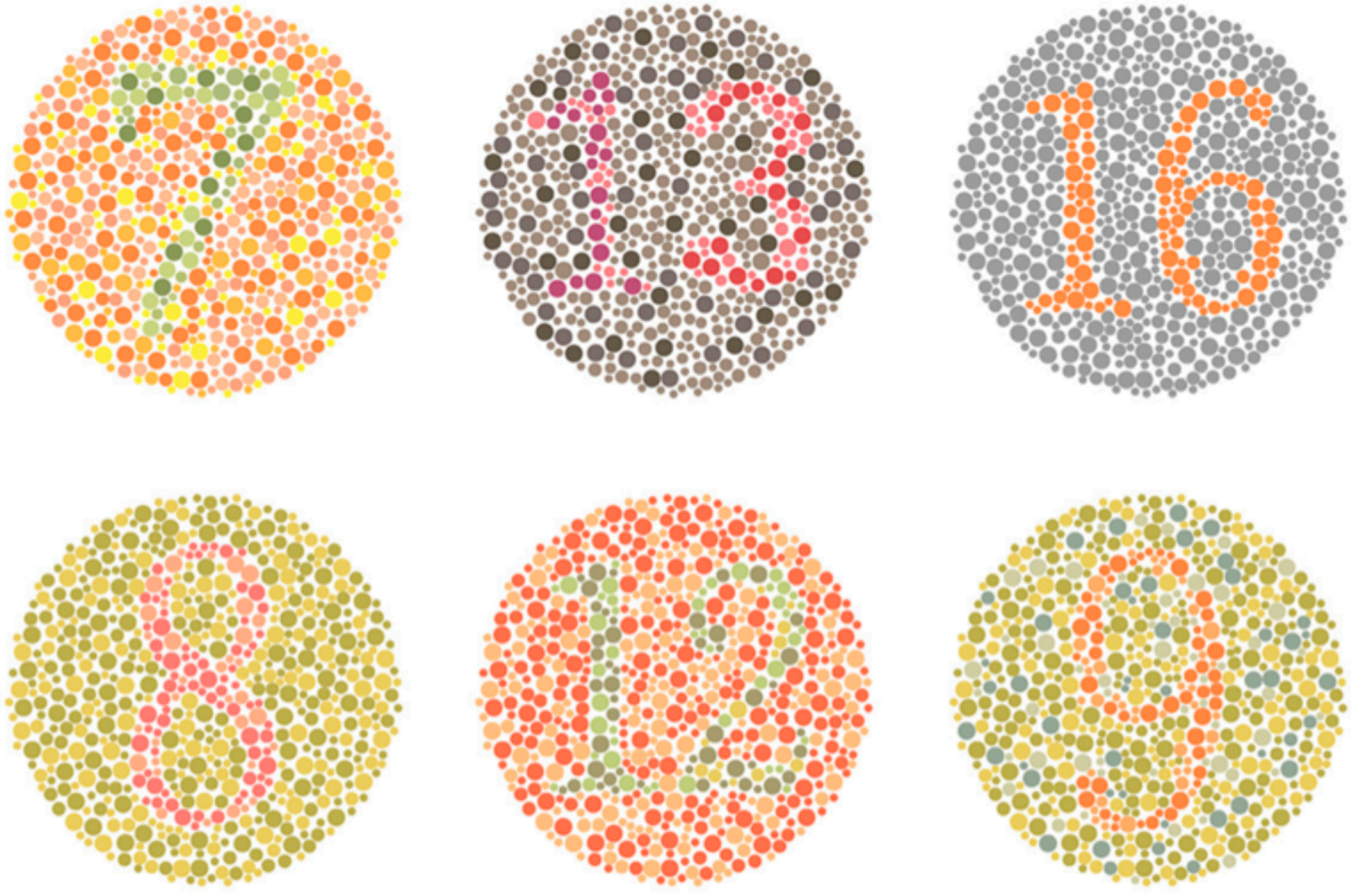


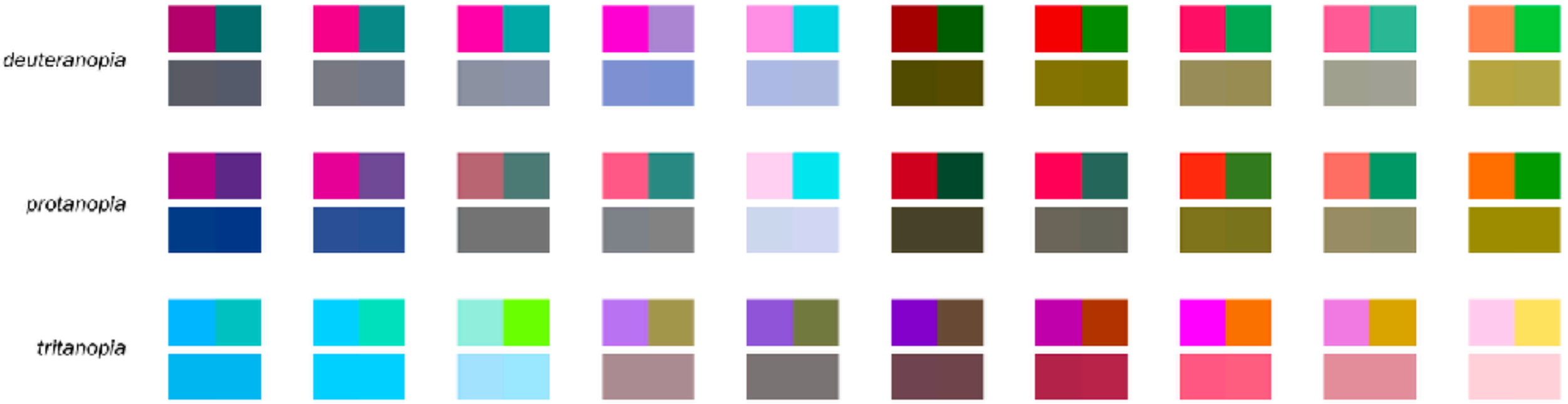
http://seaborn.pydata.org/tutorial/color_palettes.html

Color blindness



Color blind





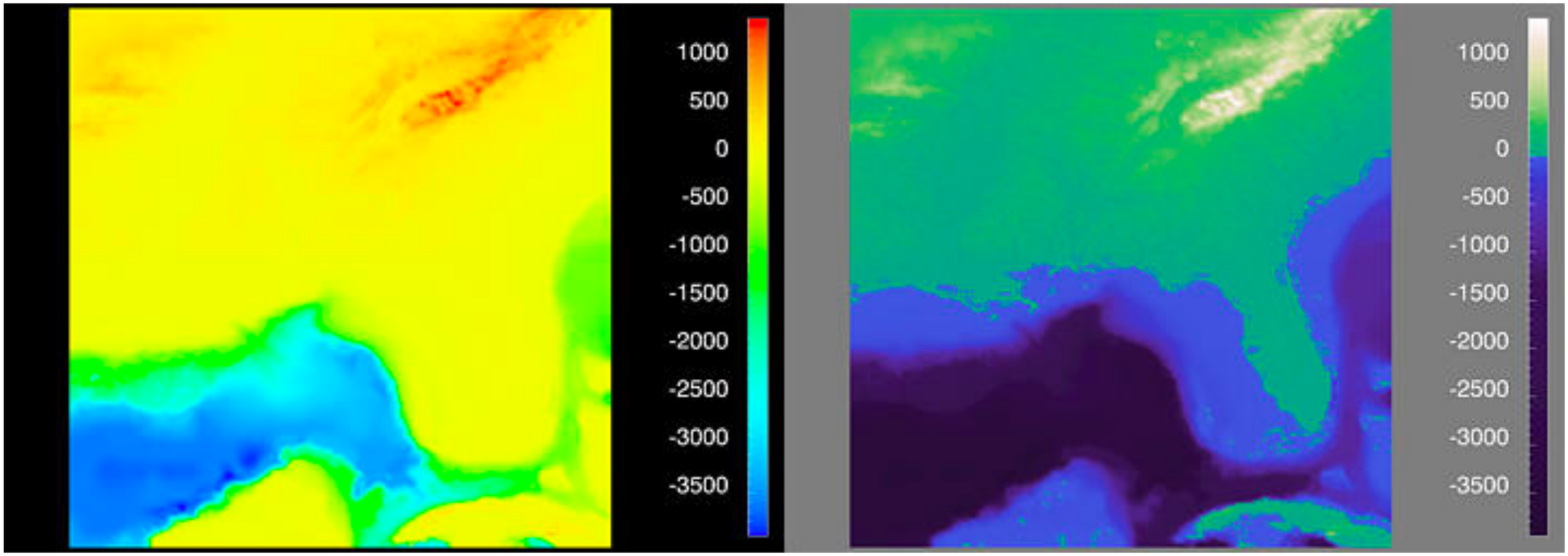
The issue:

"Ten percent of men are colorblind and mostly red/green issues."

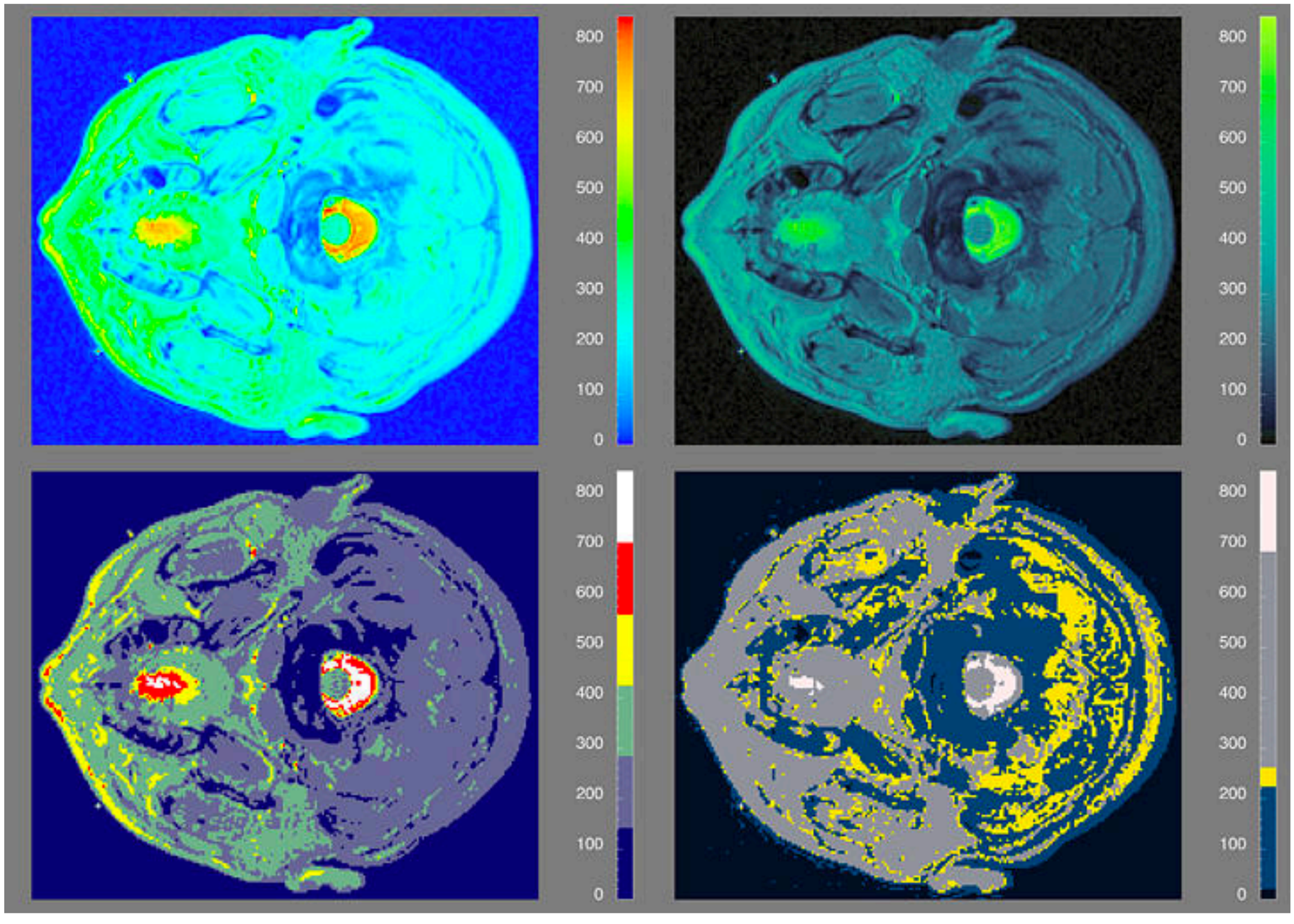
The reaction?

"Don't use red and green together."

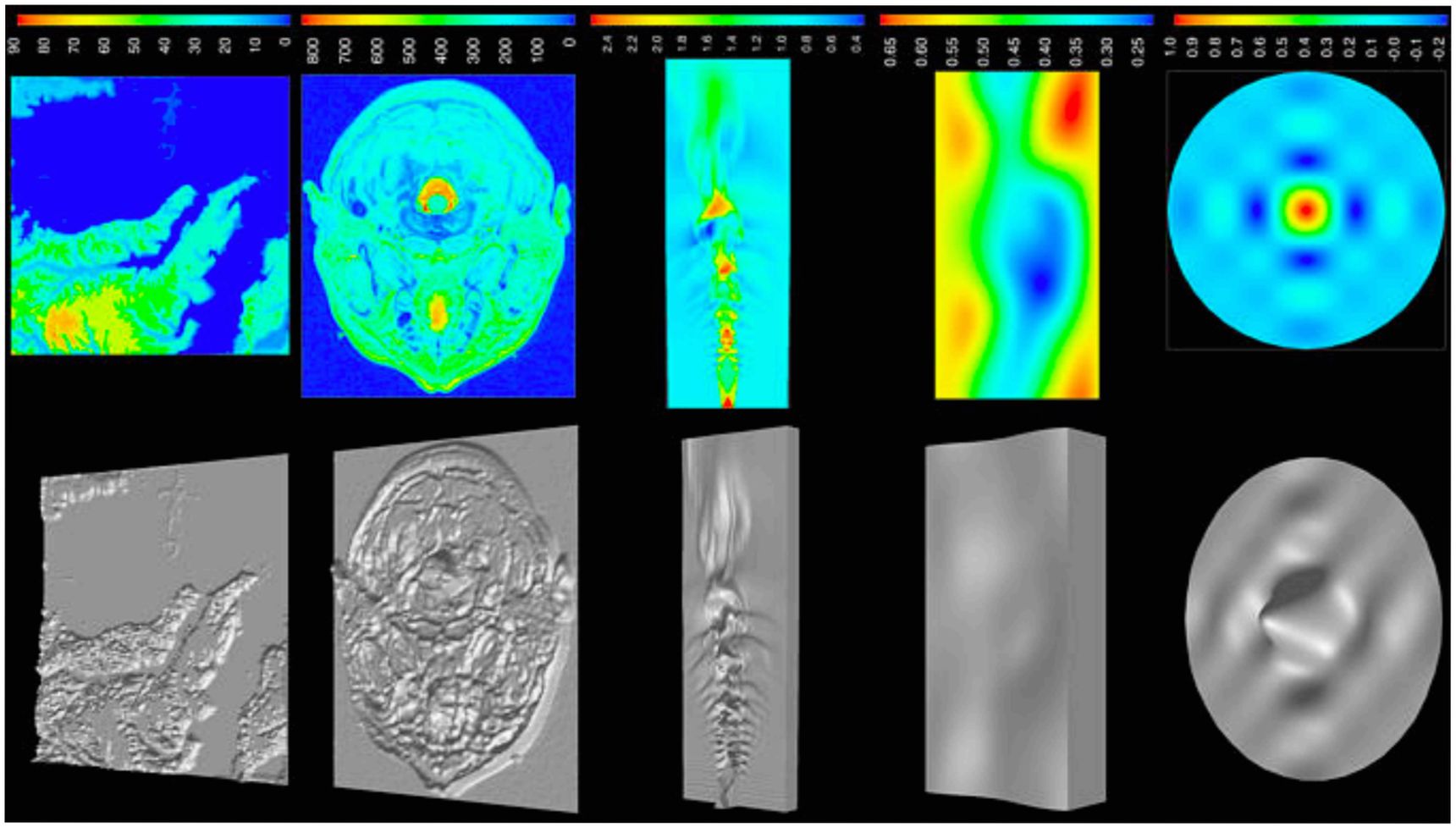
ColorMap


1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500

ColorMap



ColorMap


90 80 70 60 50 40 30 20 10 0
800 700 600 500 400 300 200 100 0
2.4 2.2 2.0 1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4
0.65 0.60 0.55 0.50 0.45 0.40 0.35 0.30 0.25
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 -0.0 -0.1 -0.2

The type of graphs

How do I choose which type of chart or graph to use?

First, we have to understand the message we want to present with the data!
When you're putting together a chart, you're trying to show one of four things with the data you have: a **relationship** between data points, a **comparison** of data points, a **composition** of data, or a **distribution** of data.

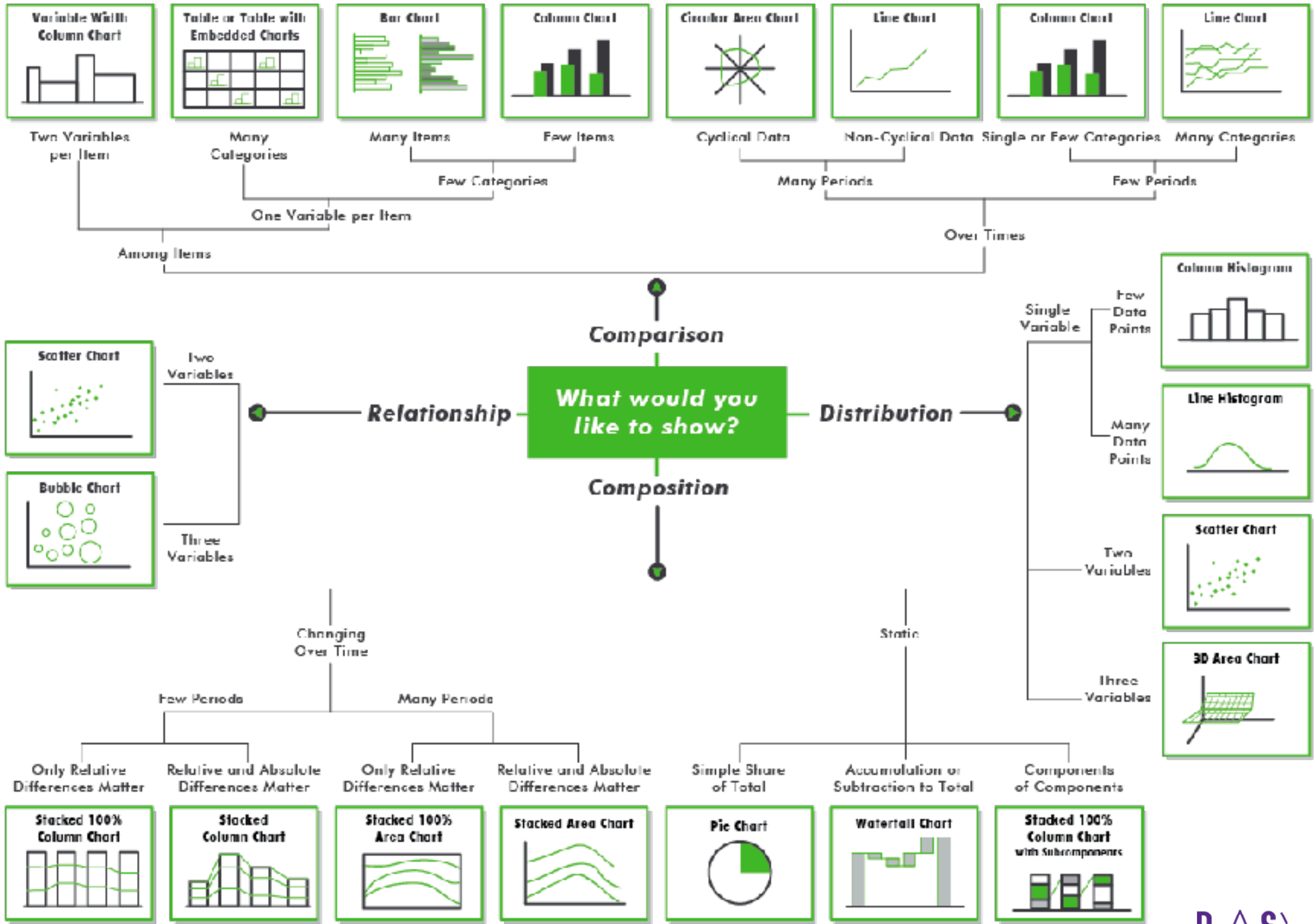
- A relationship tries to show a connection or correlation between two or more variables through the data presented, like the market cap of a given stock over time versus overall market trend.

- A comparison tries to set one set of variables apart from another, and display how those two variables interact, like the number of visitors to five competing web sites in a single month.

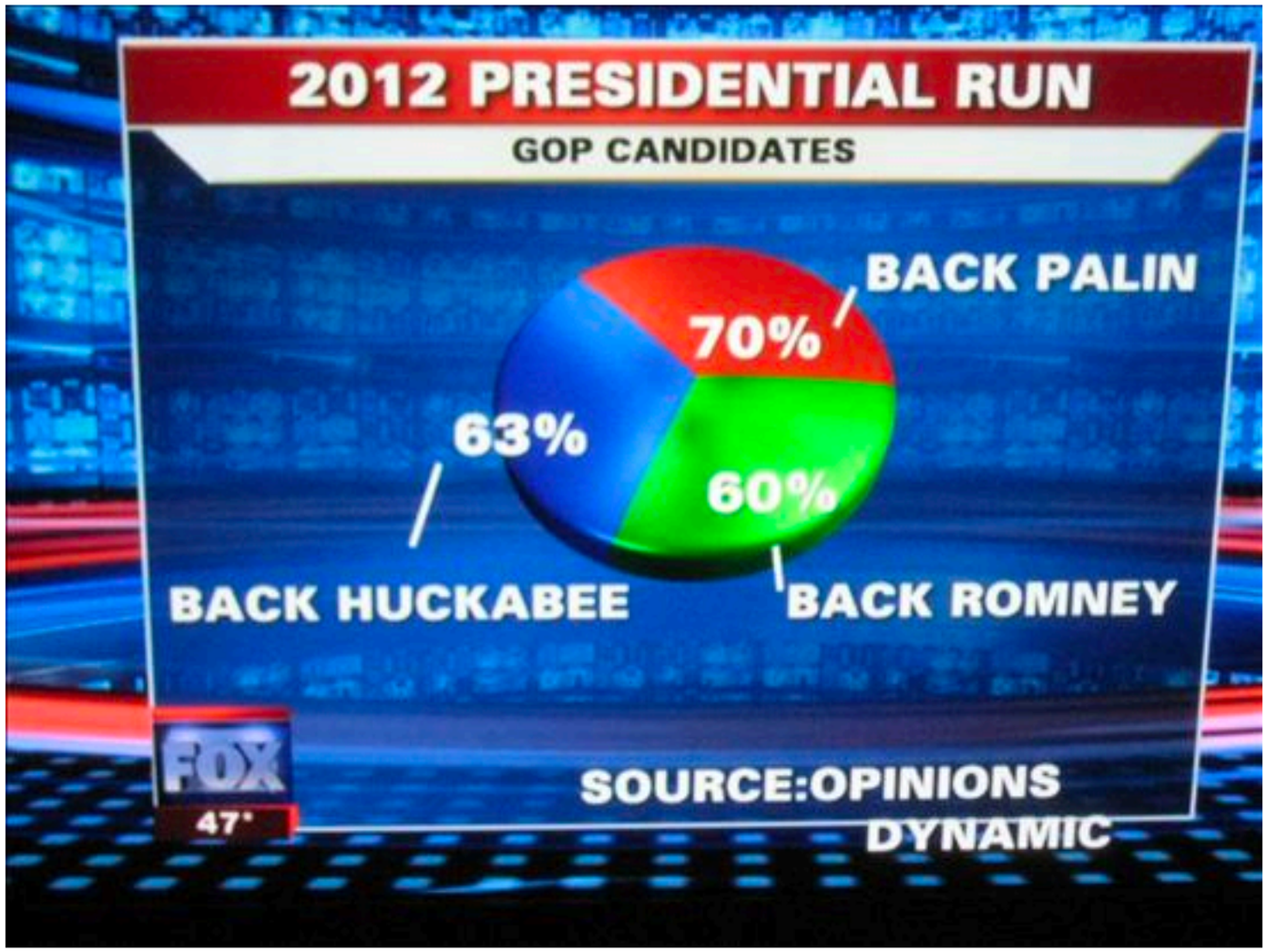
- A composition tries to collect different types of information that make up a whole and display them together, like the search terms that those visitors used to land on your site, or how many of them came from links, search engines, or direct traffic.

- A distribution tries to lay out a collection of related or unrelated information simple to see how it correlates, if at all, and to understand if there's any interaction between the variables, like the number of bugs reported during each month of a beta

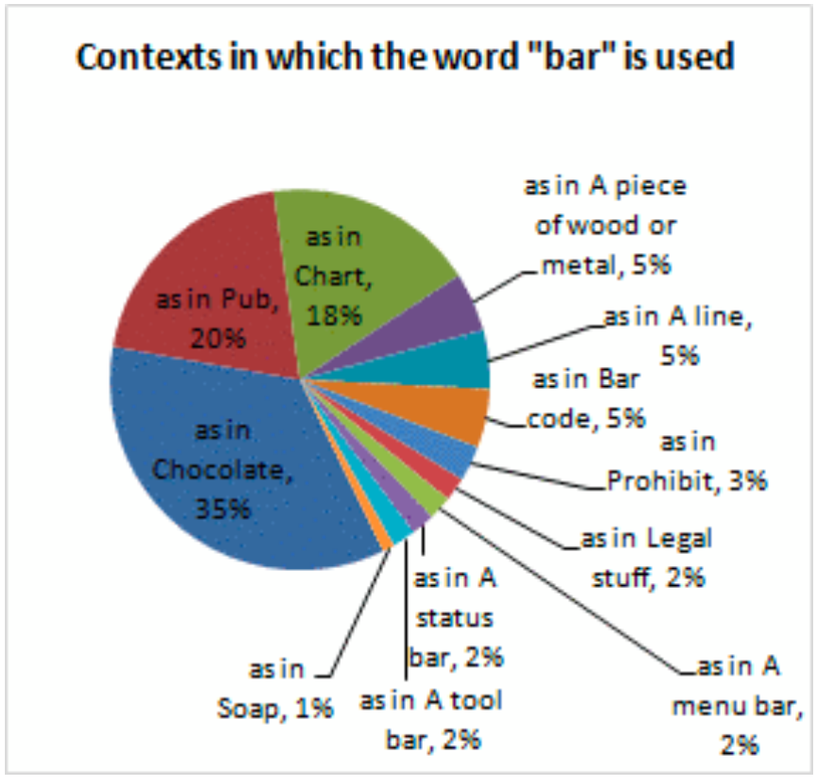
Data Visualization - Choosing the right Charts

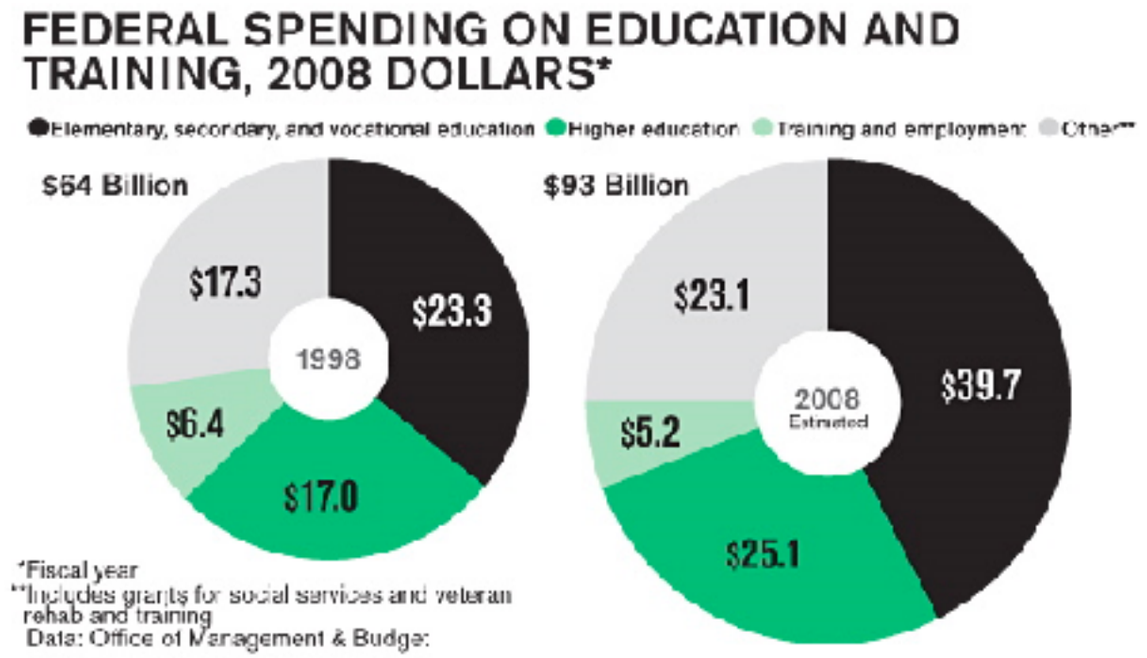


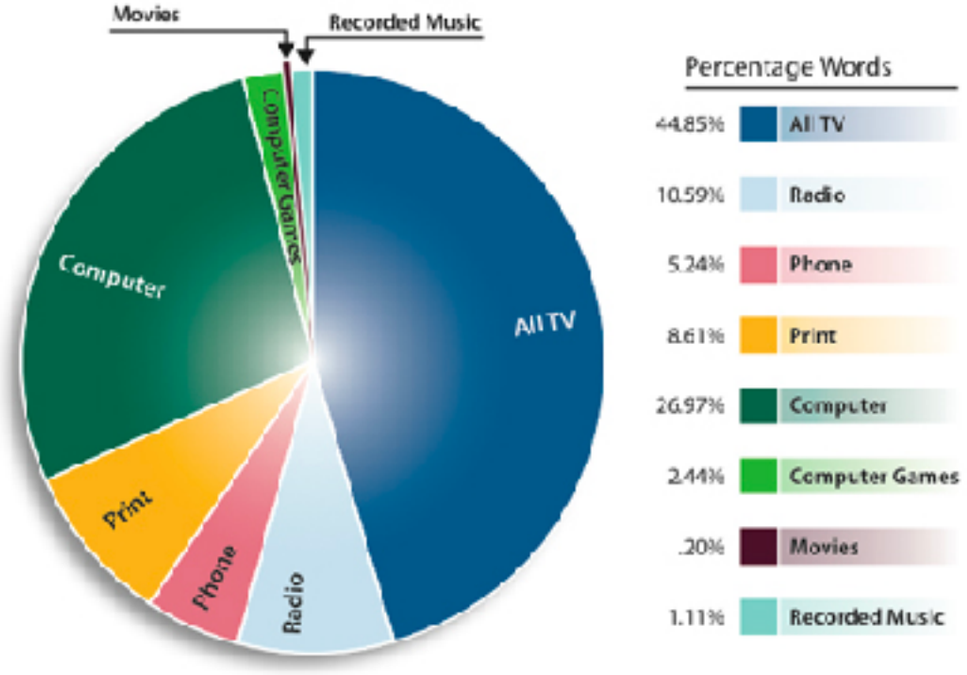
PieChart?


2012 PRESIDENTIAL RUN
GOP CANDIDATES
BACK PALIN
70%
63%
60%
BACK HUCKABEE
BACK ROMNEY
FOX
47'
SOURCE:OPINIONS
DYNAMIC

PieChart?


Contexts in which the word "bar" is used
as in Chart, 18%
as in A piece of wood or metal, 5%
as in Pub, 20%
as in A line, 5%
as in Bar code, 5%
as in Chocolate, 35%
as in Prohibit, 3%
as in Legal stuff, 2%
as in A status bar, 2%
as in Soap, 1%
as in A tool bar, 2%
as in A menu bar, 2%


FEDERAL SPENDING ON EDUCATION AND TRAINING, 2008 DOLLARS*
Elementary, secondary, and vocational education
Higher education
Training and employment
Other**
$54 Billion
$17.3
$23.3
1998
$6.4
$17.0
$93 Billion
$23.1
$39.7
2008 Estimated
$5.2
$25.1
*Fiscal year
**Includes grants for social services and veteran rehab and training
Data: Office of Management & Budge


Movies
Recorded Music
Computer Games
Computer
All TV
Print
Phone
Radio
Percentage Words
44.85% All TV
10.59% Radio
5.24% Phone
8.61% Print
26.97% Computer
2.44% Computer Games
.20% Movies
1.11% Recorded Music

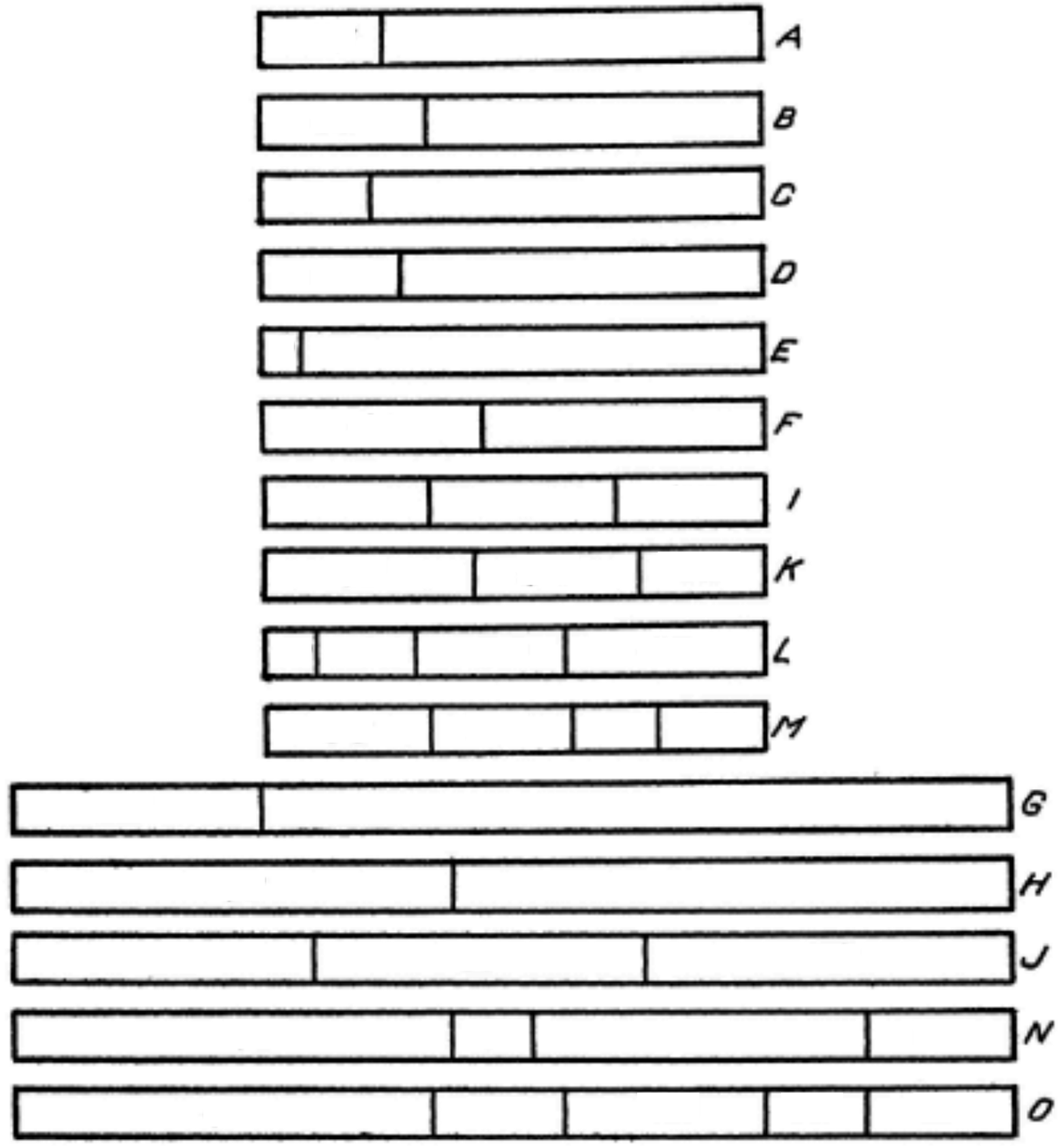


FIGURE II

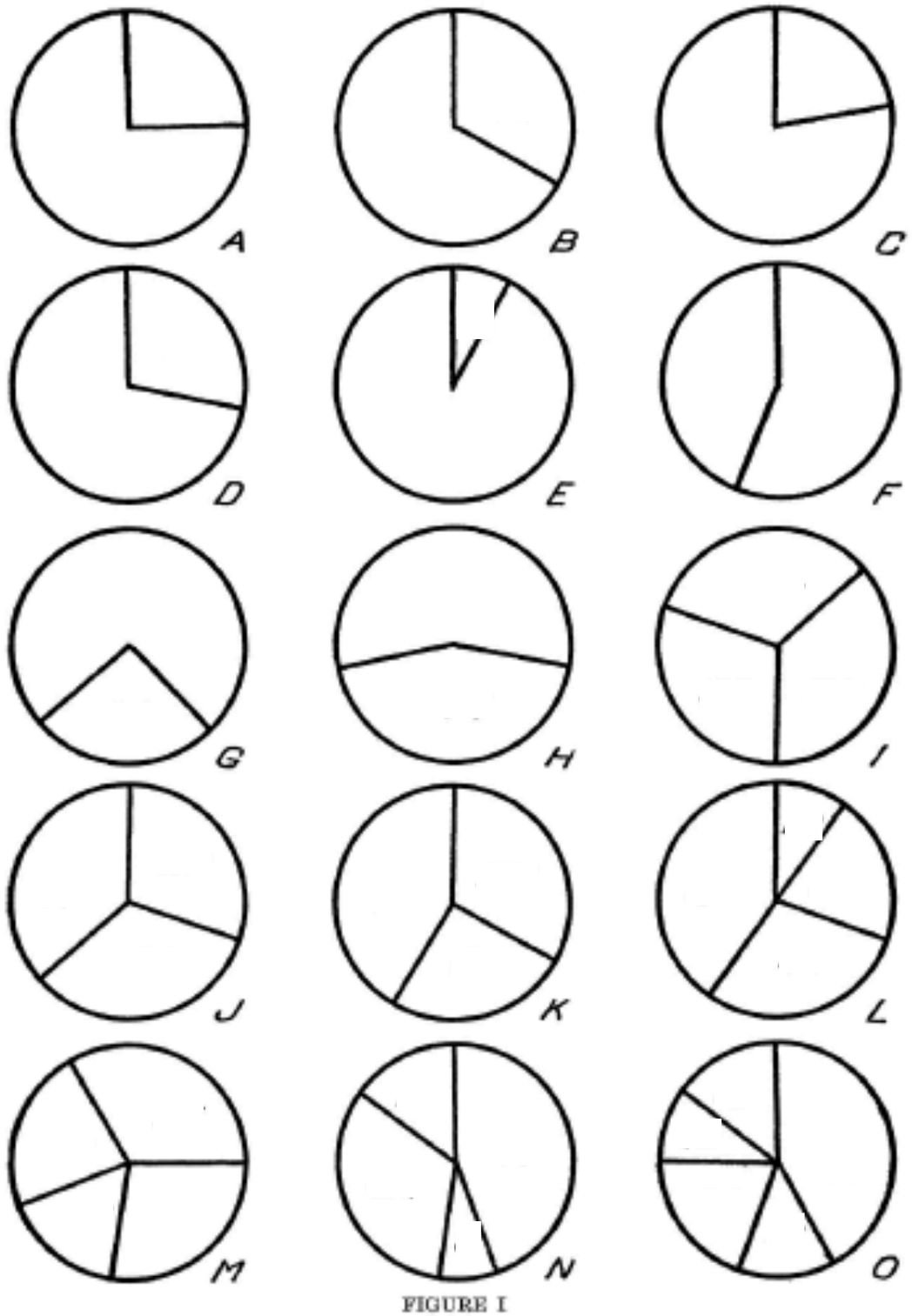


FIGURE I

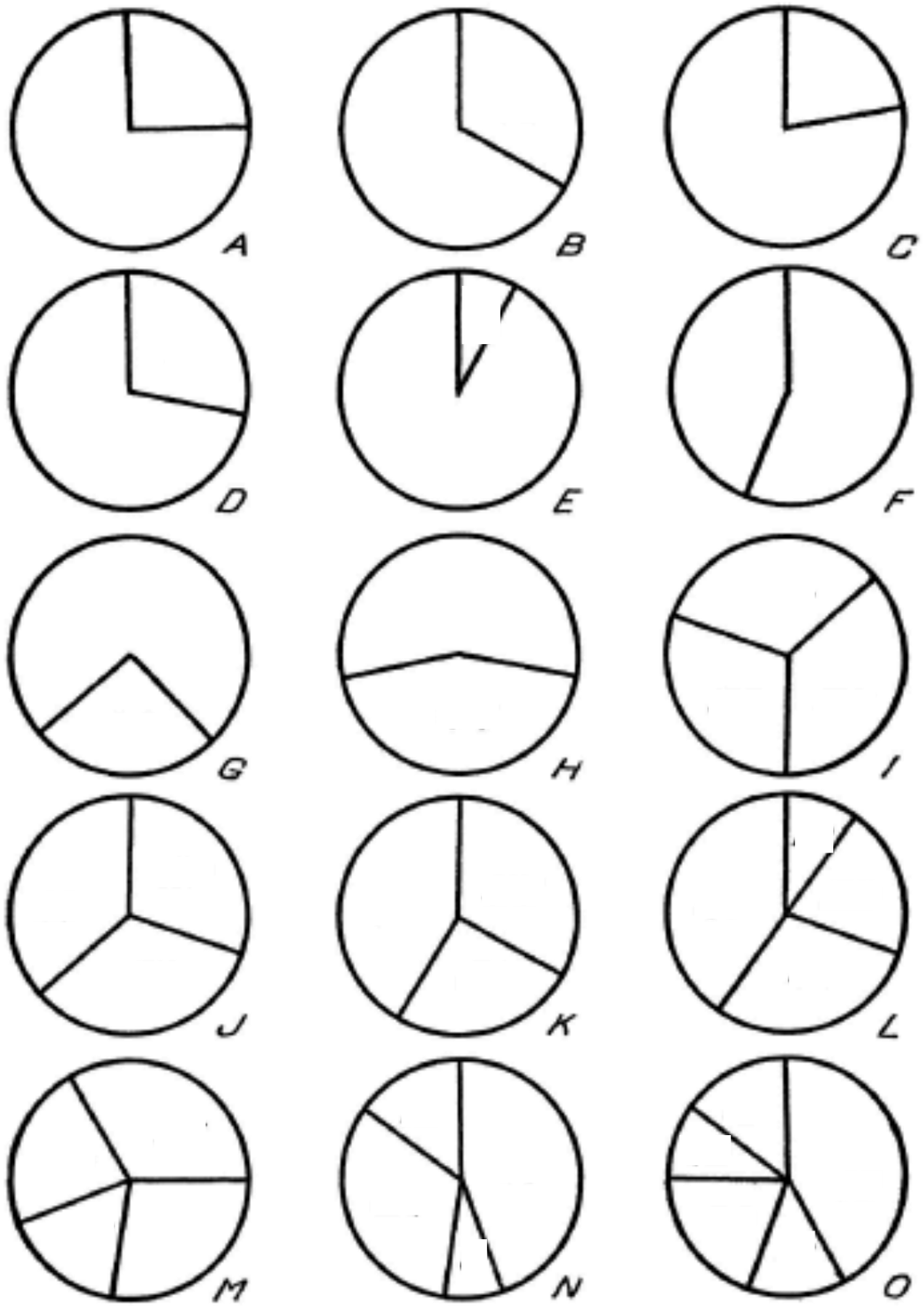


FIGURE I

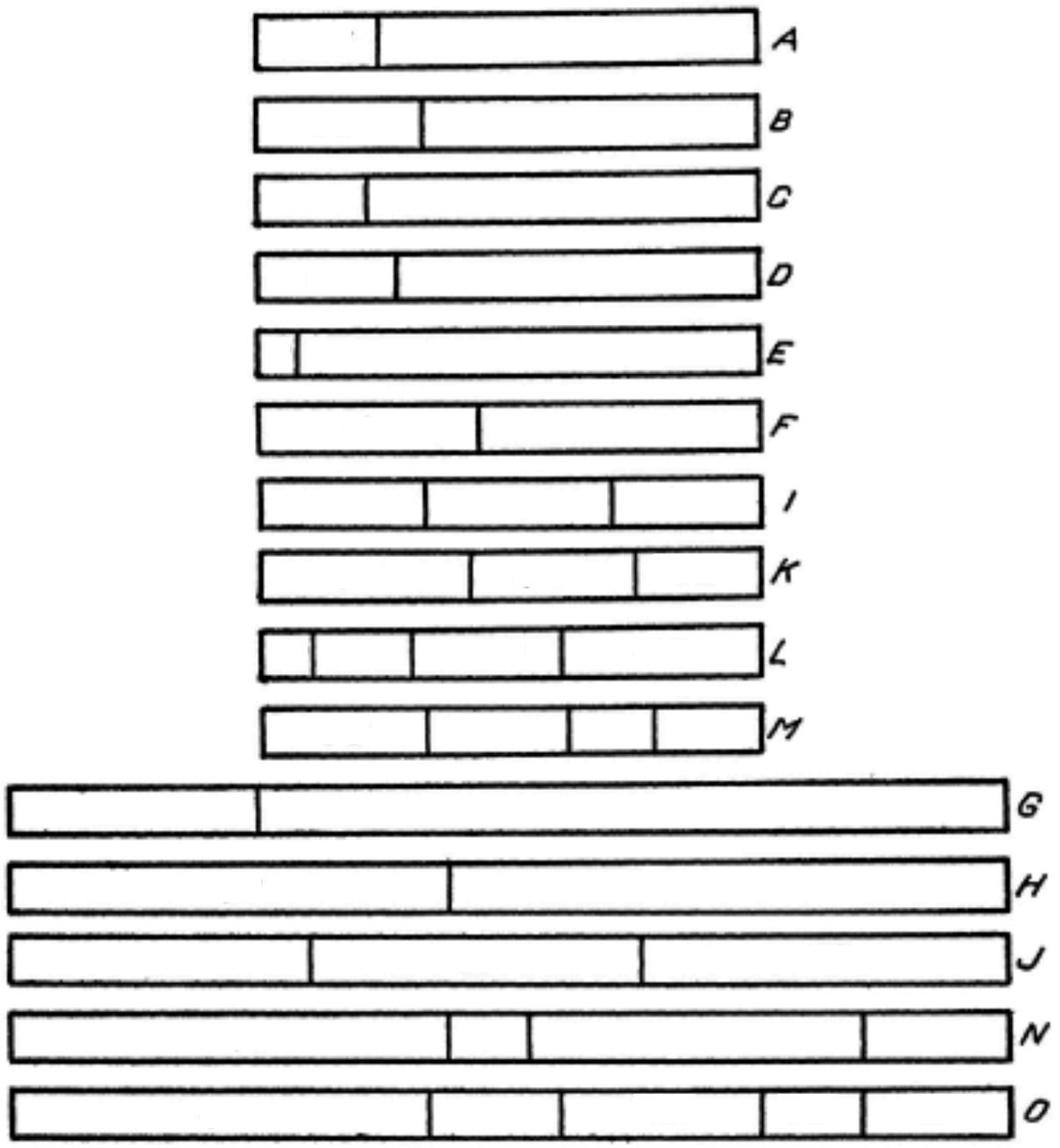


FIGURE II

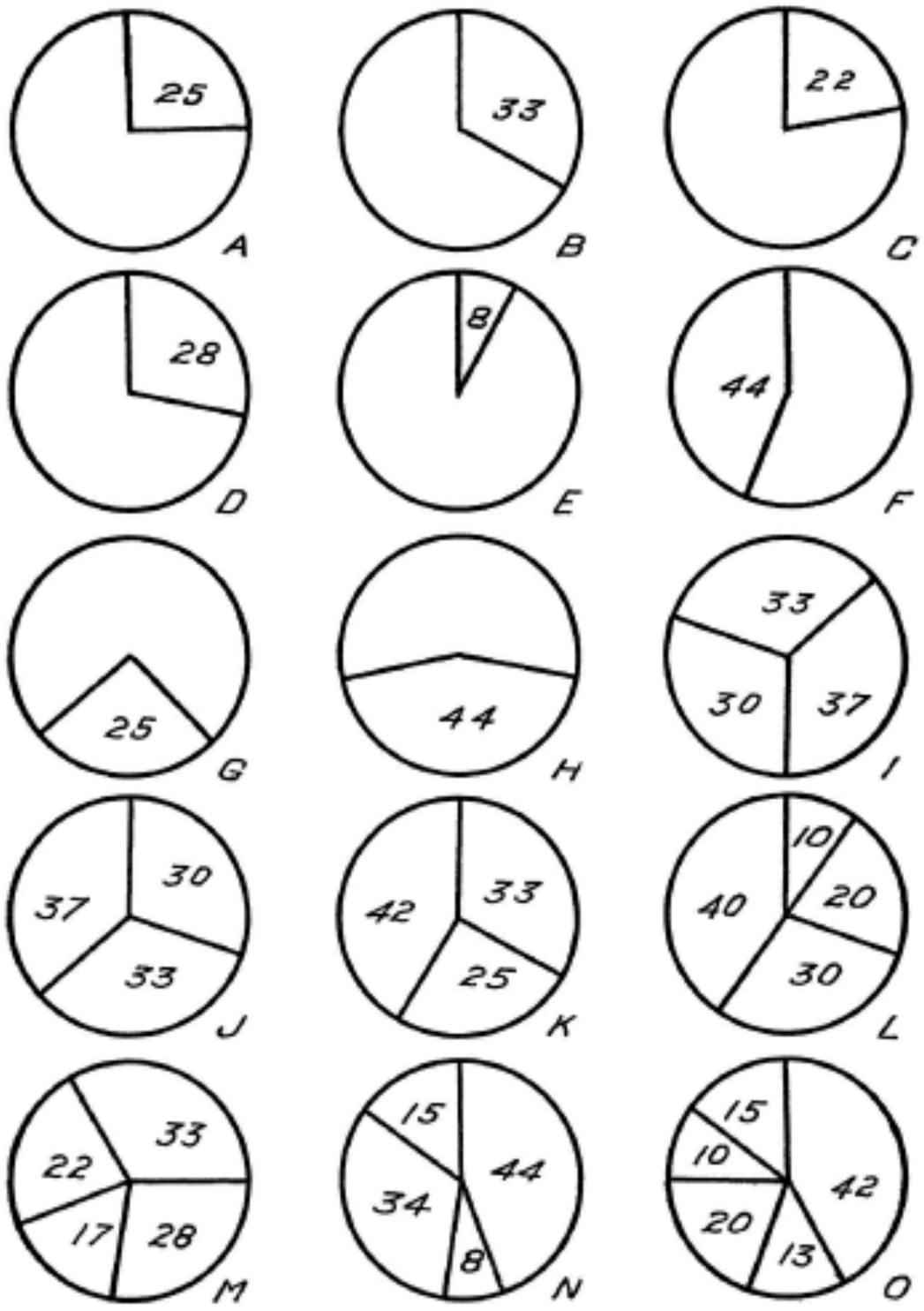


FIGURE I

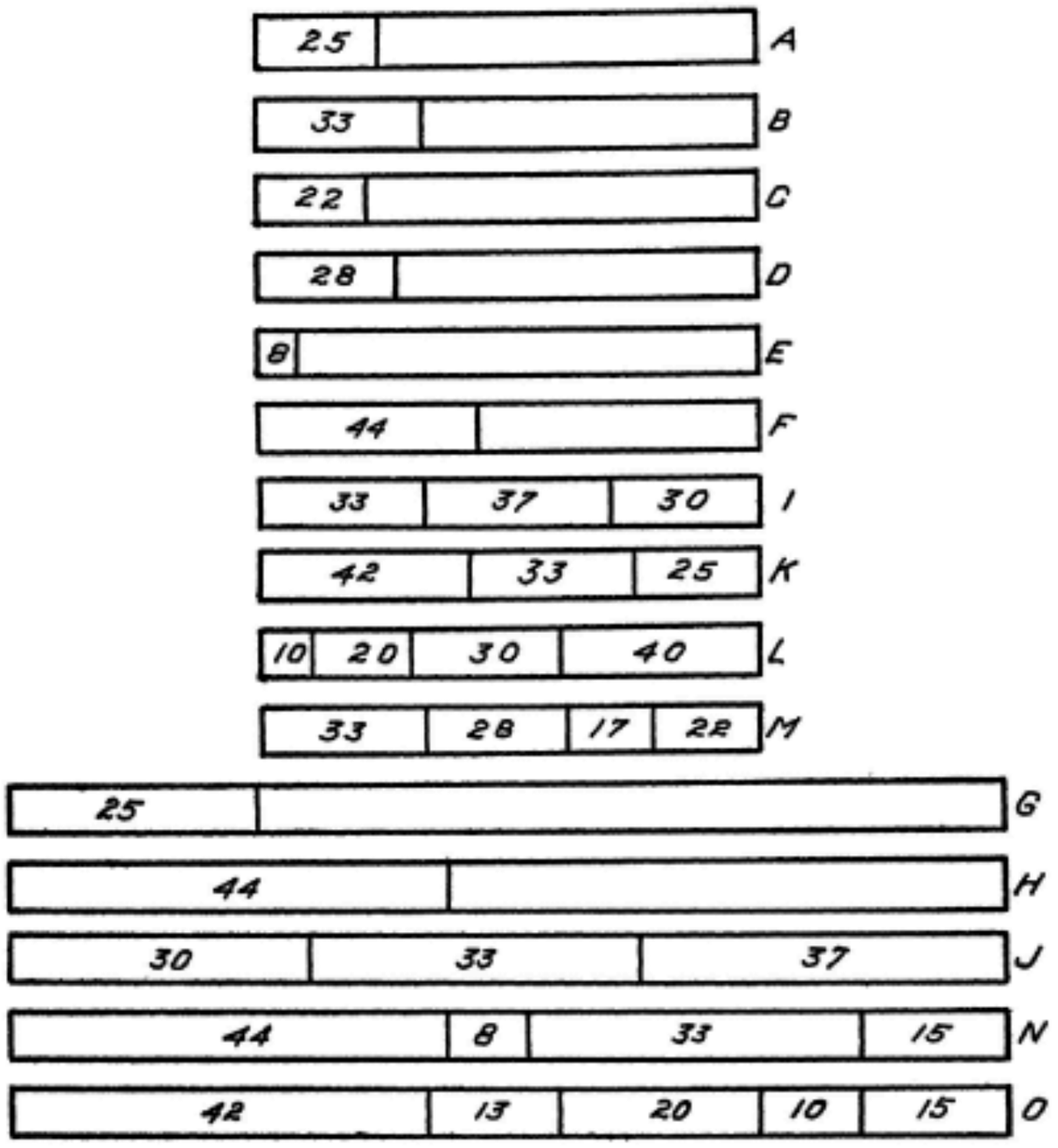
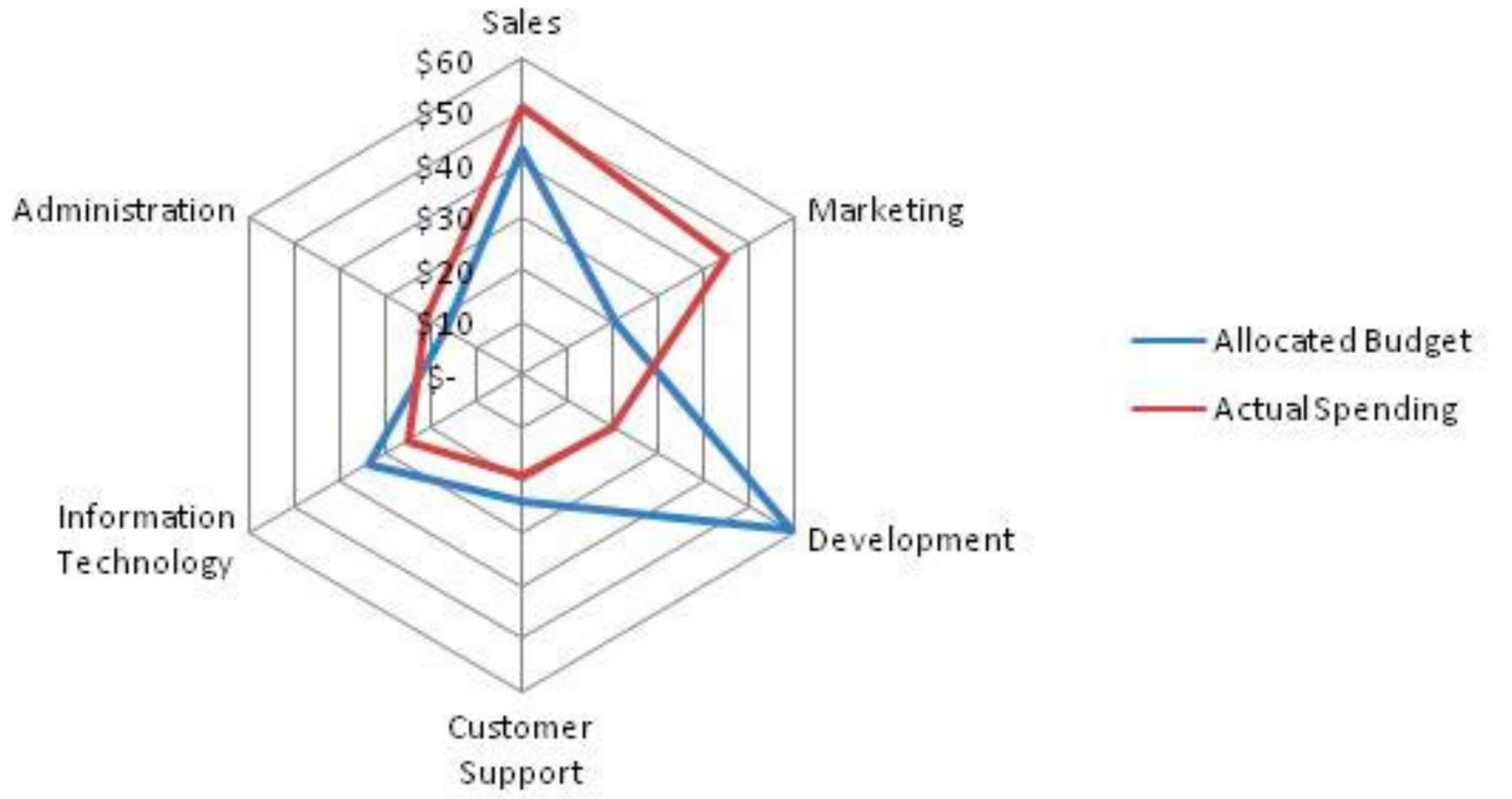


FIGURE II

Pie Charts

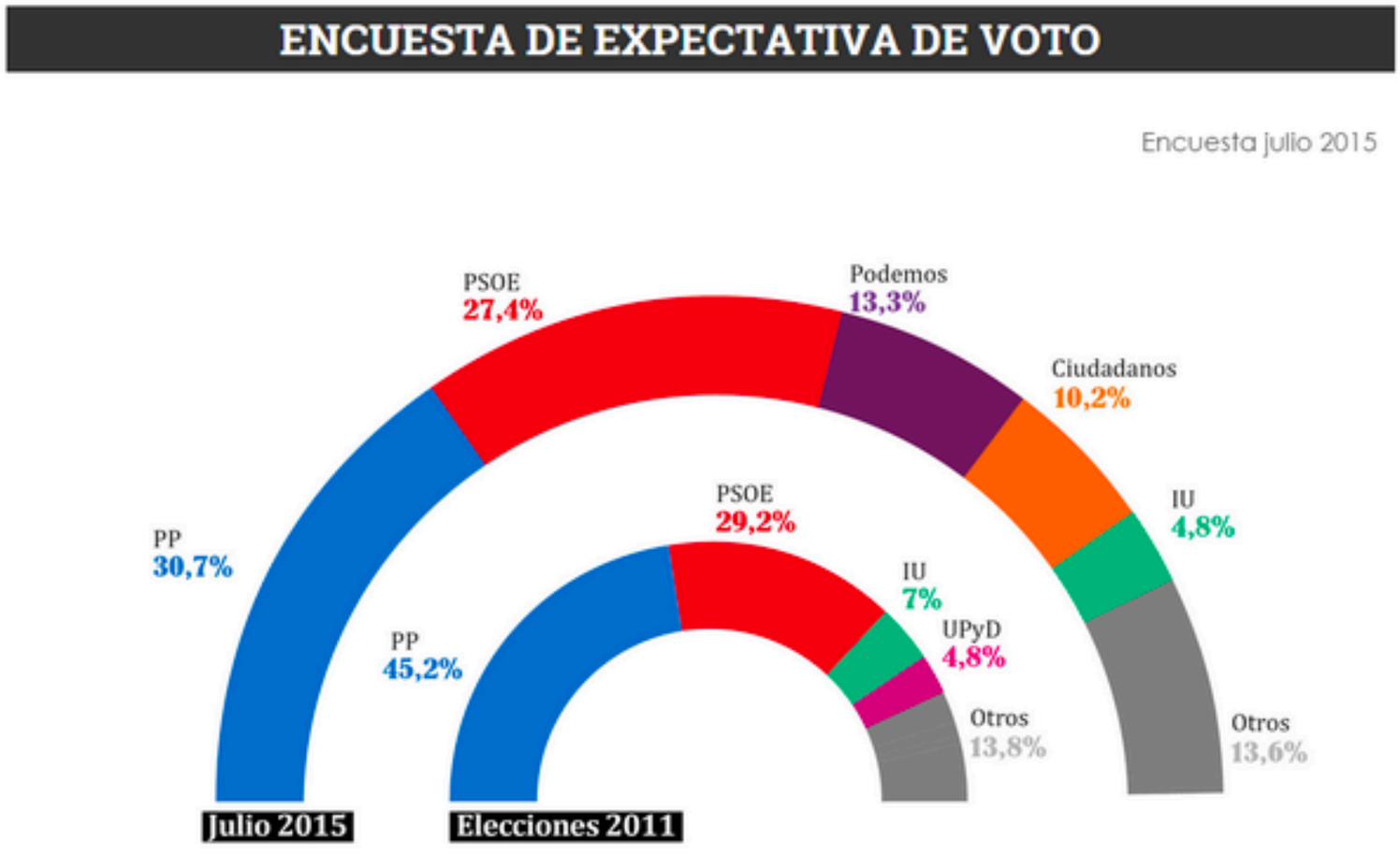
We are **not very good** at measuring **angles**,
but we recognize **90 and 180 degree angles** with very
high precision

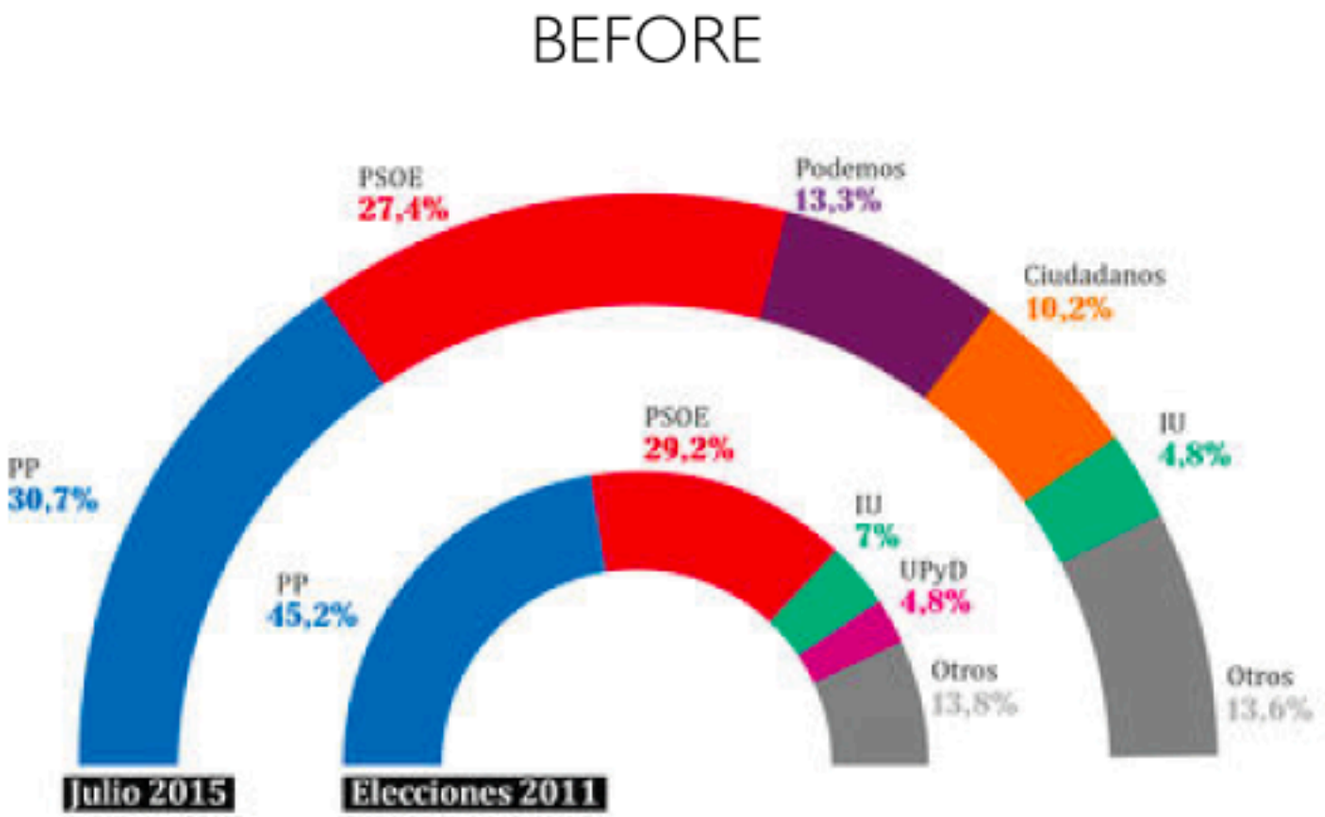
Radar Graph?

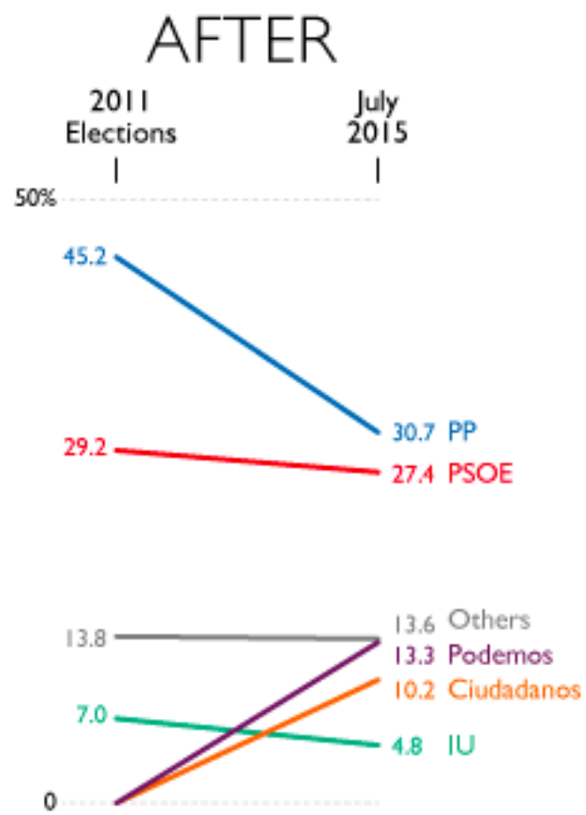


Do not use this graph!!!

Is this the proper chart?







Can we do it better? http://4.bp.blogspot.com/-ZsRWe33yhRY/VaO3ZVvoJ4I/AAAAAAAAFF8/qIh8n6oJmrs/s1600/BeforeAfterParlamento.png

Exercice

let’s try to find all possible ways to visualize a ludicrously small data set of two numbers: 37 and 75