Data Visualization

Exploring Data Through Visualization

Why Visualize Data?

Visualizing data can inspire you to ask new and more refined questions of your data and ultimately lead to better analysis.

“The greatest value of a picture is when it forces us to notice what we never expected to see.”

–John Tukey, 1977

The power of visualization comes from illustrating relationships, contrasts and comparisons between many different dimensions of data.

Show Comparisons, Contrasts and Differences

Show Multivariate Data

Integrate words, numbers, images and diagrams

Document your Evidence

Visualization Goals

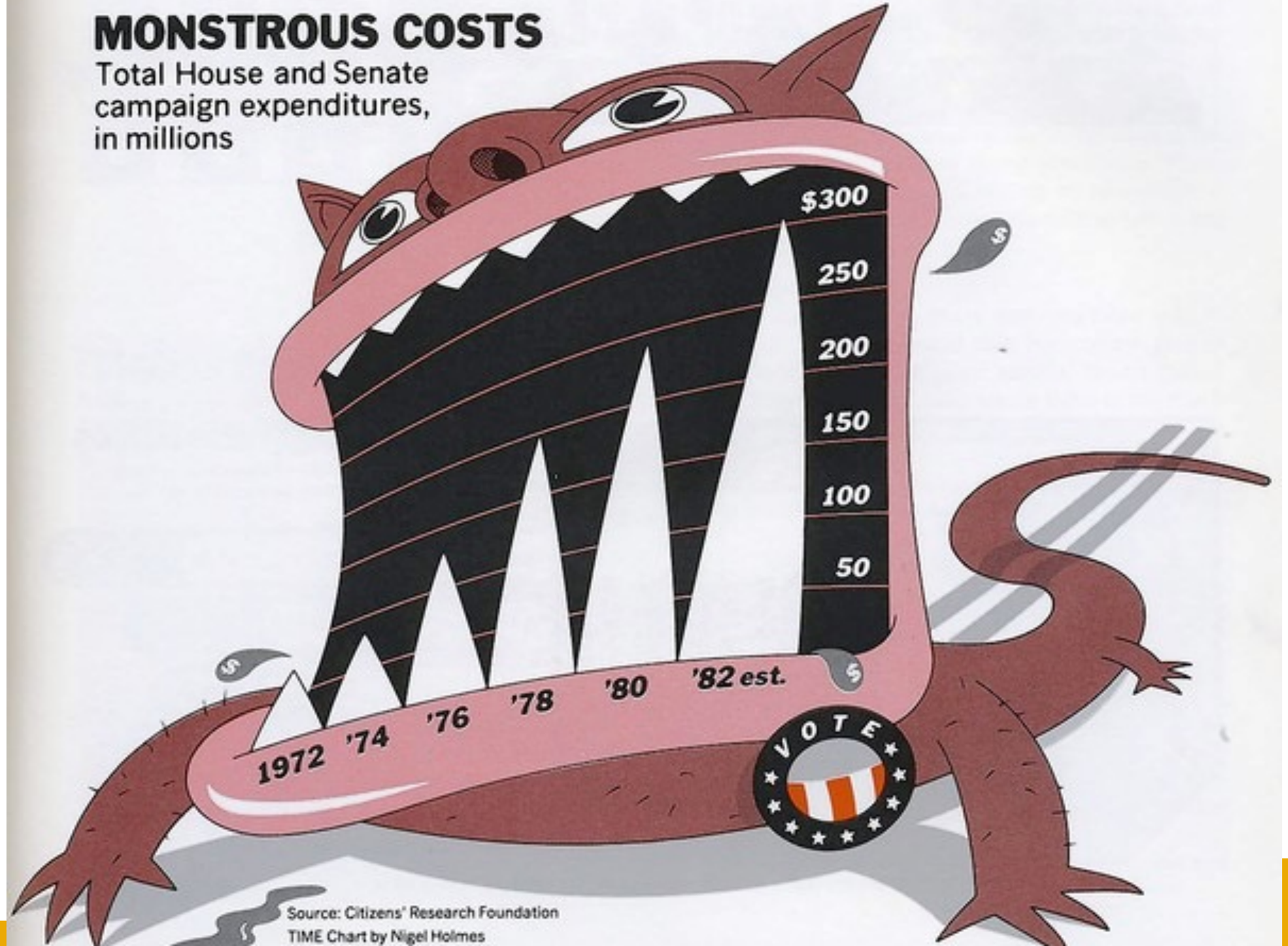
- Analyze
- Explore
- Assess
- Determine
- Decide

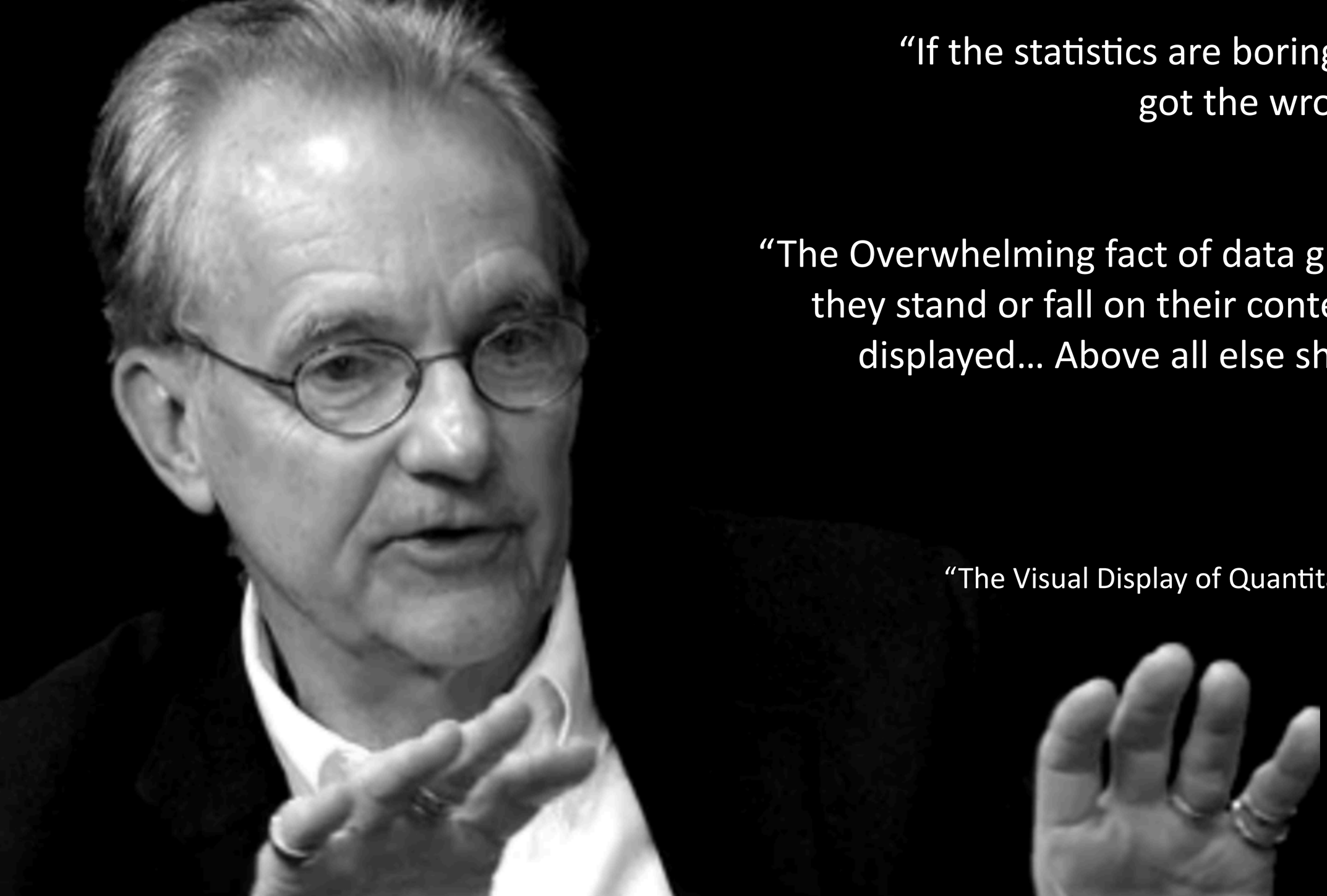
- Communicate
- Explain
- Present
- Prove
- Persuade

Elements of Good Visualizations

1. Graphical Integrity
2. Simple
3. Proper Display
4. Proper Color
5. Tells a story

Ultimately, the quality, relevance and integrity of the content is most important.


MONSTROUS COSTS
Total House and Senate campaign expenditures, in millions
$300
250
200
150
100
50
1972
'74
'76
'78
'80
'82 est.
VOTE
Source: Citizens' Research Foundation
TIME Chart by Nigel Holmes



“If the statistics are boring, then you’ve got the wrong numbers.”

“The Overwhelming fact of data graphics is that they stand or fall on their content, gracefully displayed… Above all else show the data.”

Edward R. Tufte
“The Visual Display of Quantitative Information"

Remove

to improve

(the **data-ink** ratio)

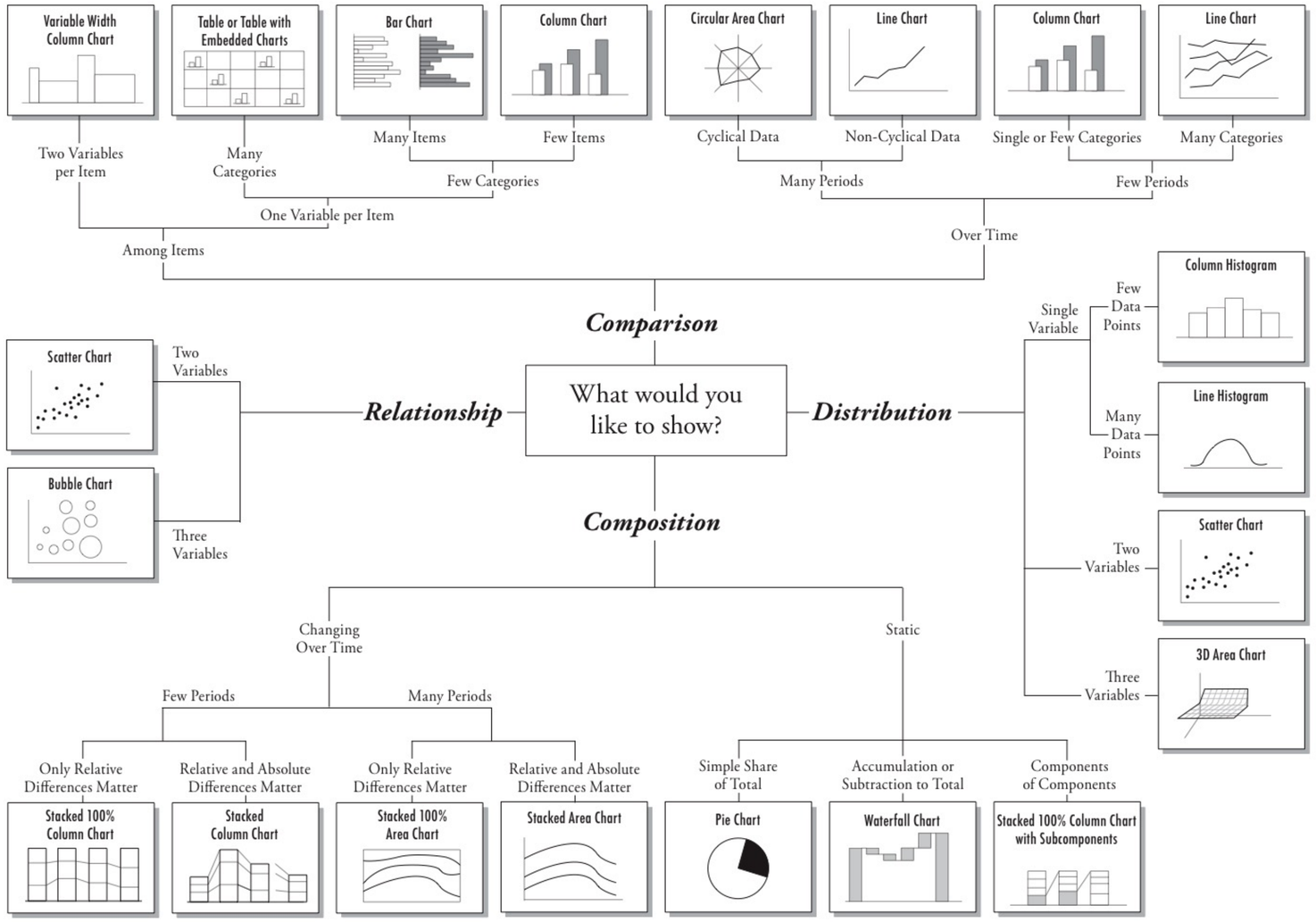
Visualization Types

Exploratory Visualizations

Vs.

Explanatory Visualizations

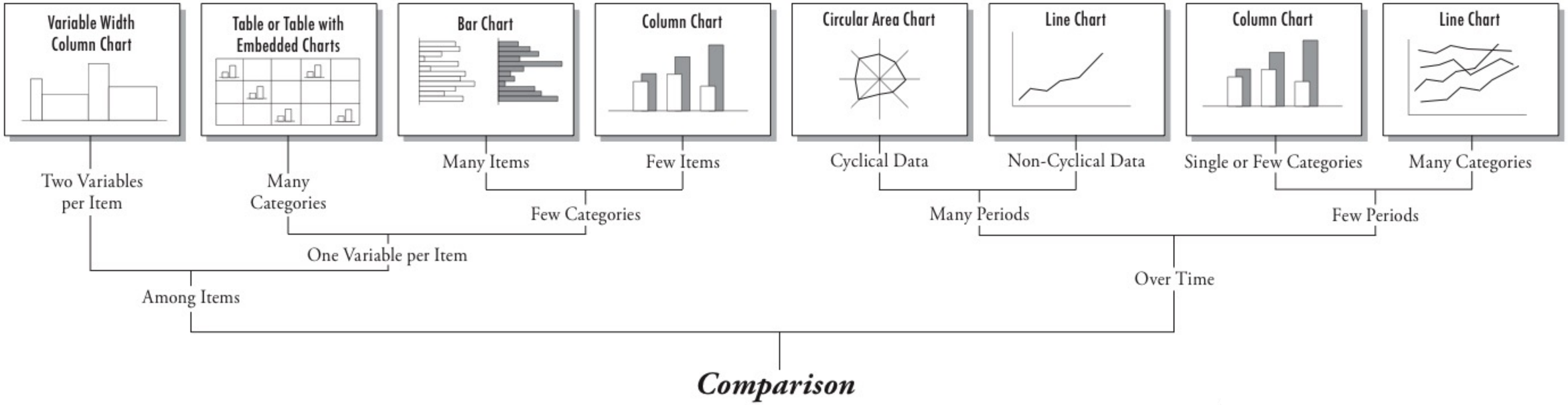
Chart Suggestions—A Thought-Starter



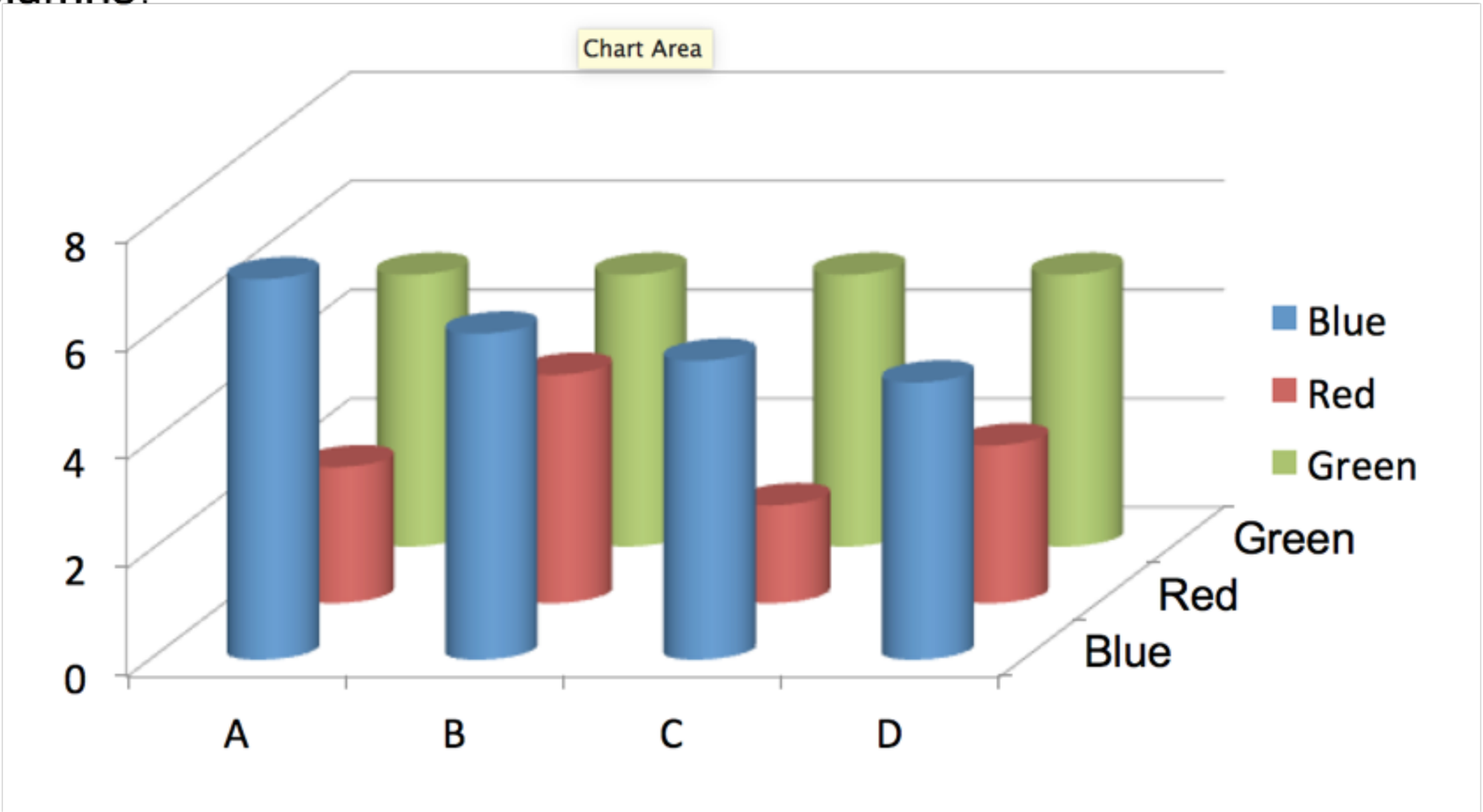
© 2006 A. Abela — a.v.abela@gmail.com

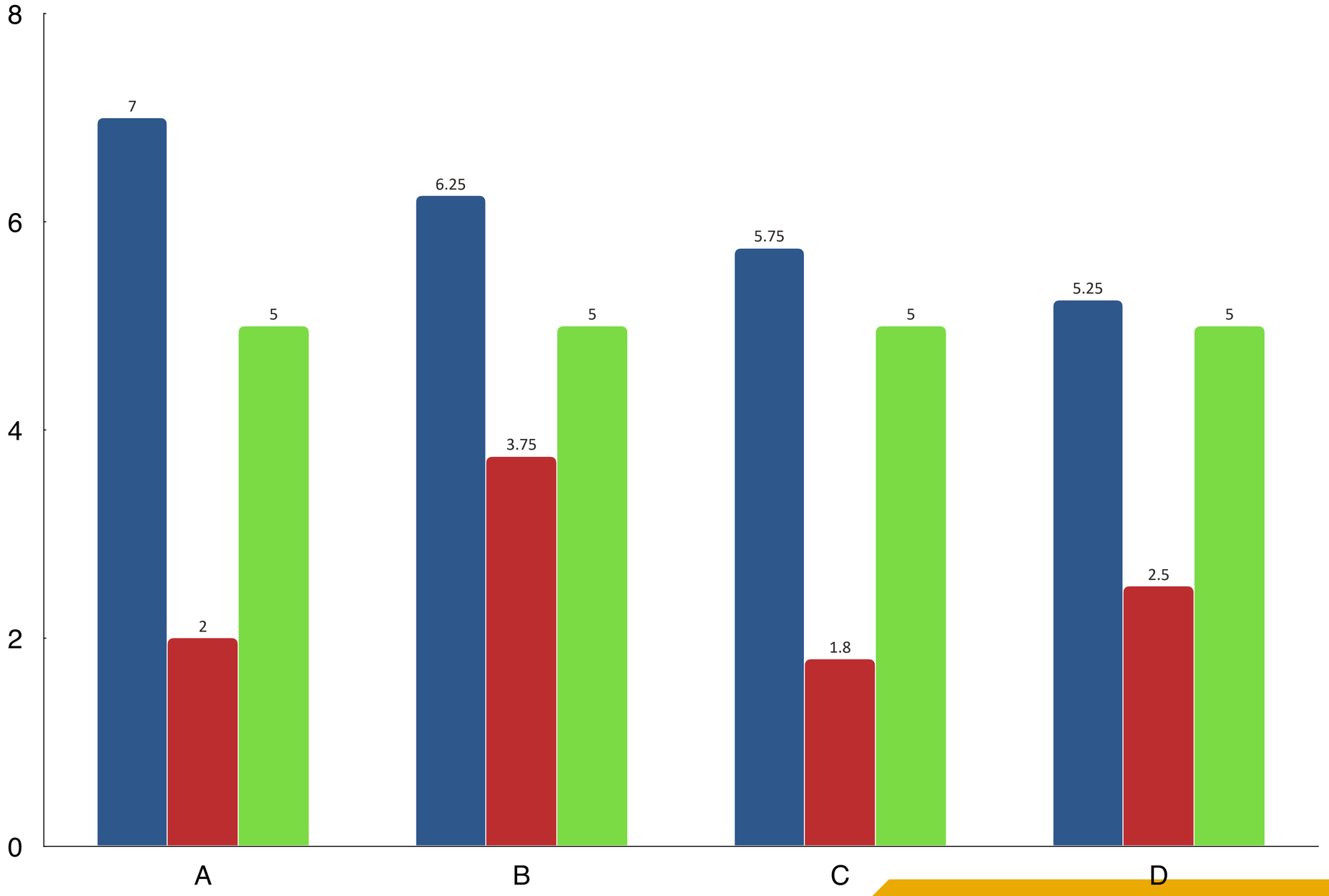
Stop

Comparison

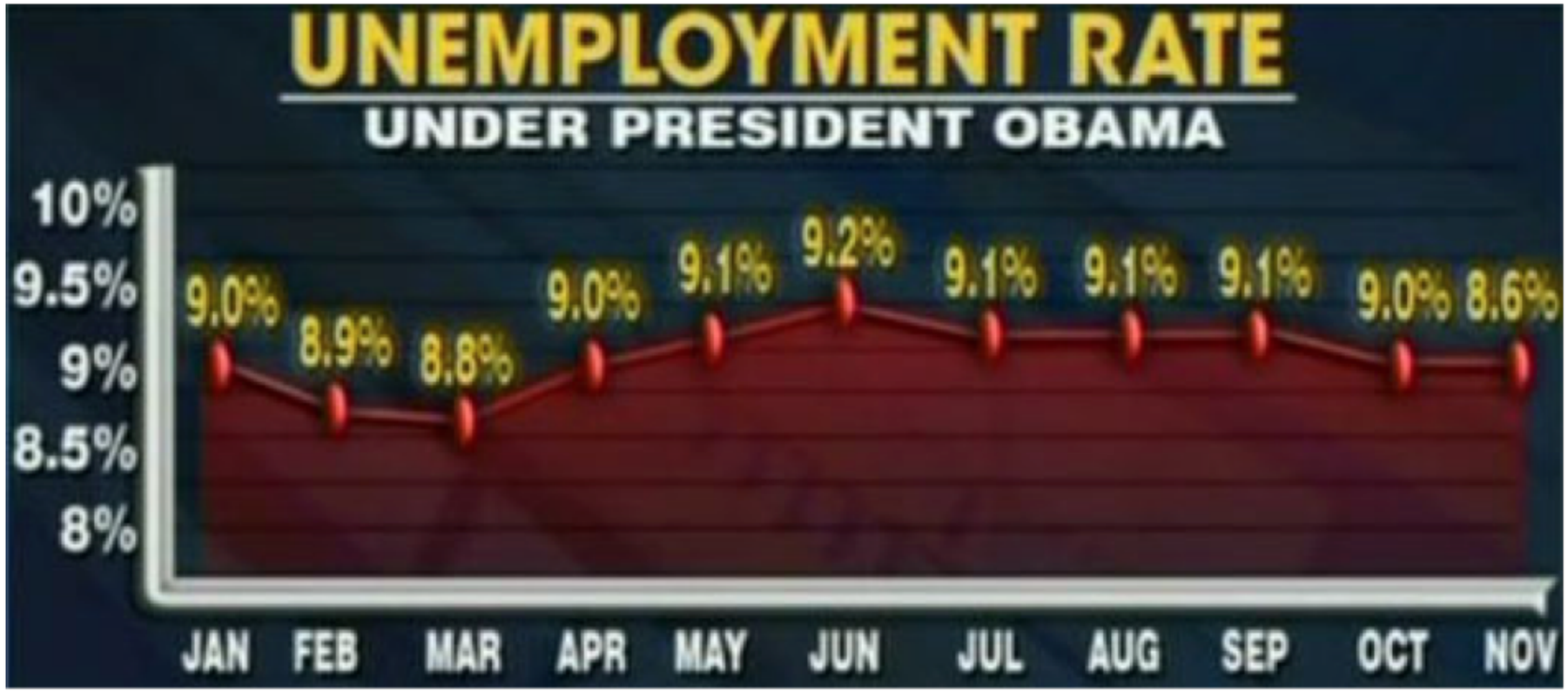

Variable Width Column Chart
Table or Table with Embedded Charts
Bar Chart
Column Chart
Circular Area Chart
Line Chart
Column Chart
Line Chart
Two Variables per Item
Many Categories
Many Items
Few Items
Cyclical Data
Non-Cyclical Data
Single or Few Categories
Many Categories
Few Categories
Many Periods
Few Periods
One Variable per Item
Over Time
Among Items
Comparison

Questions: What is the height of the green columns? For which categories (A,B,C,D) are the blue columns taller than the green columns?

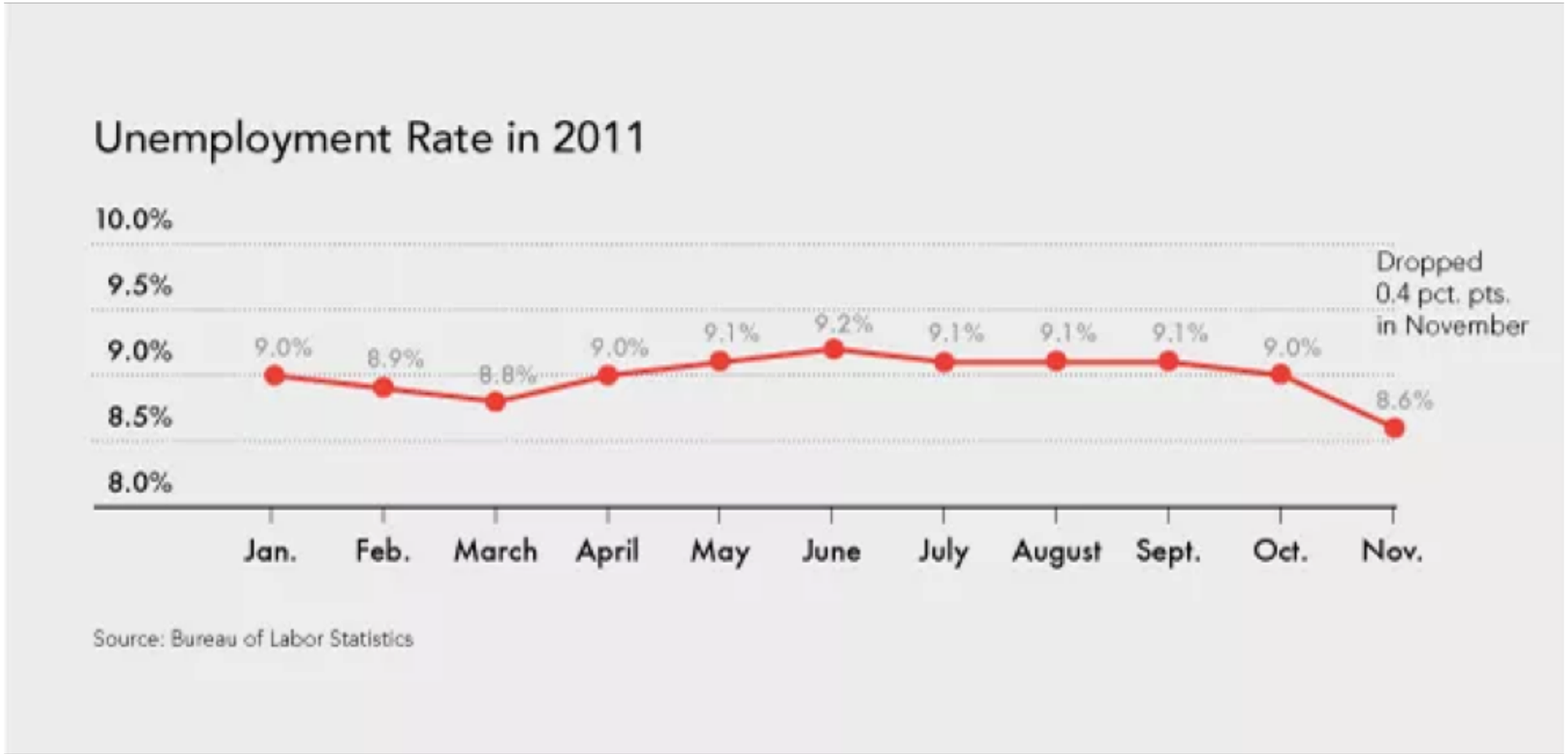



8
6
4
2
0
7
2
5
6.25
3.75
5
5.75
1.8
5
5.25
2.5
5
A
B
C
D

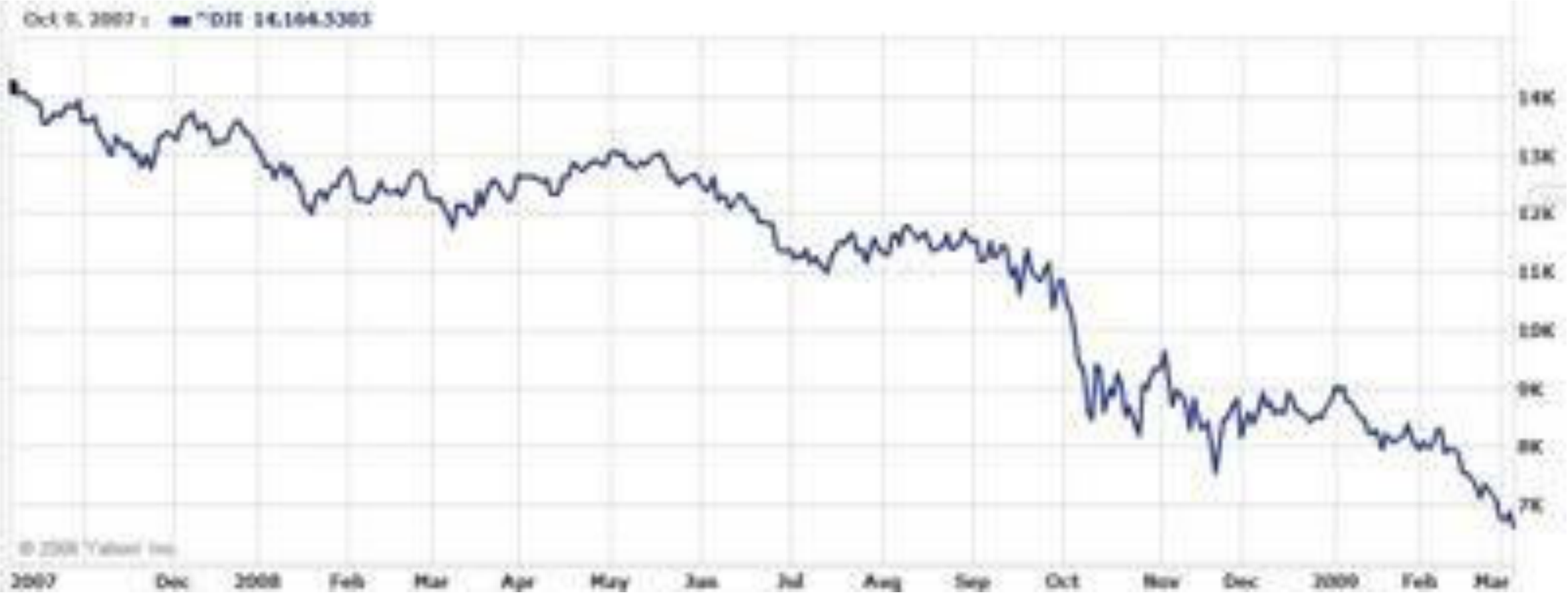
Graphical Integrity



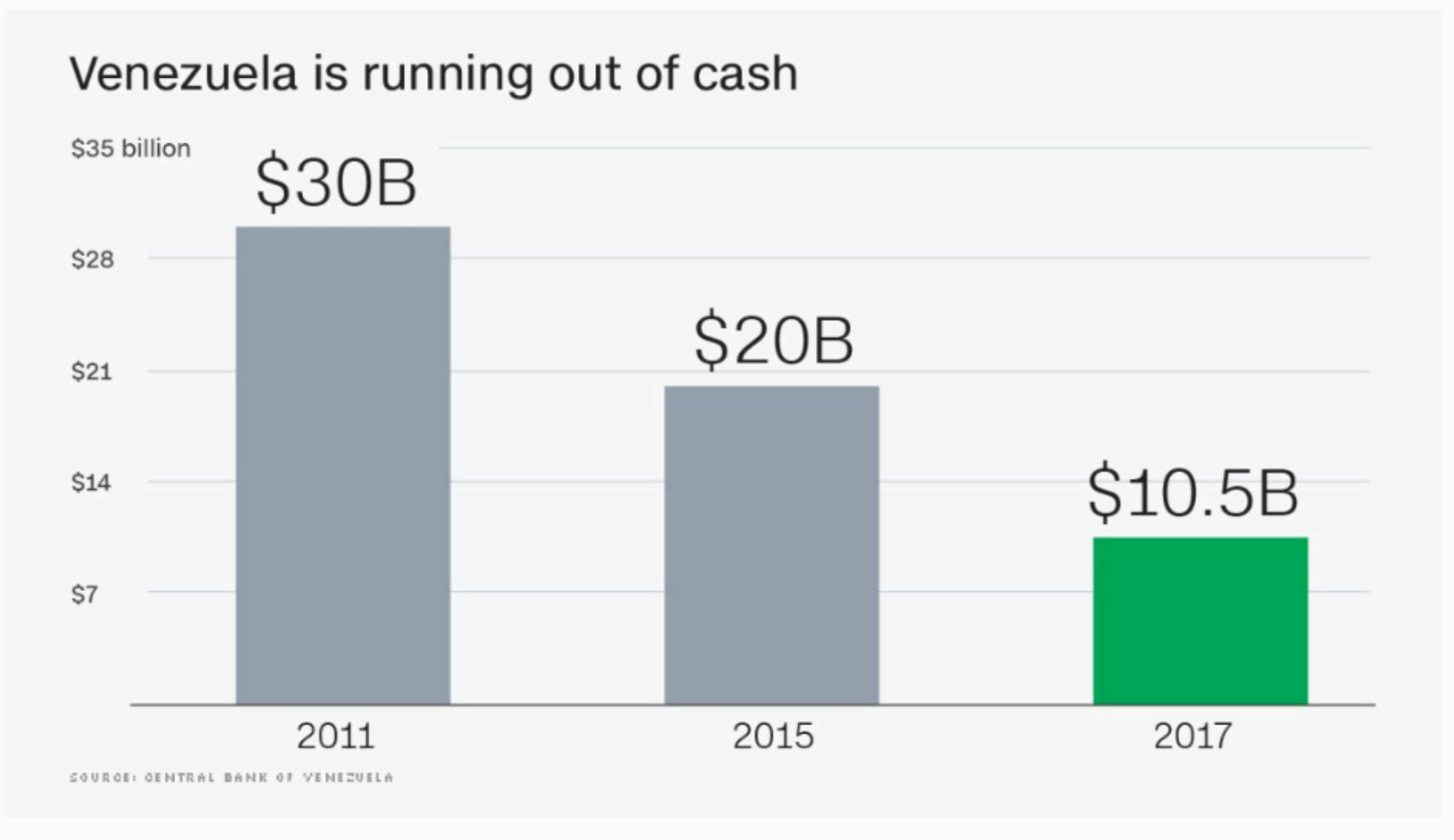
Graphical Integrity



STOCK MARKET SLIDE
NOV. 4, 2008
ELECTION DAY
9625.30
FRIDAY
MAR. 5, 2009
6626.94
JAN. 20, 2009
INAUGURATION DAY
7949.10
SOURCE: BUSINESSWEEK
6:31 CT
MSNBC

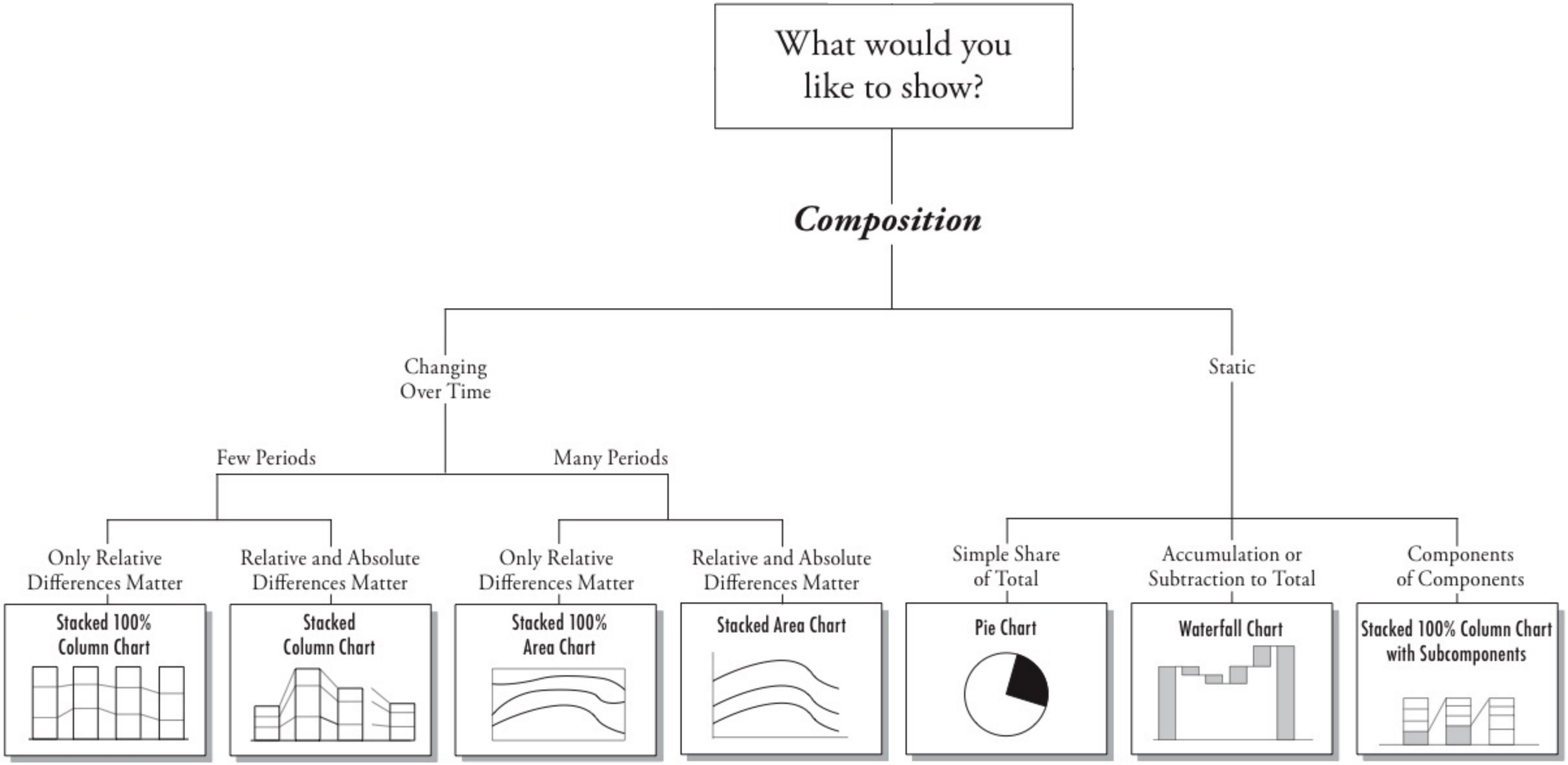

Oct 9, 2007 : ^DJI 14,164.5303
14K
13K
12K
11K
10K
9K
8K
7K
2007
Dec
2008
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2009
Feb
Mar

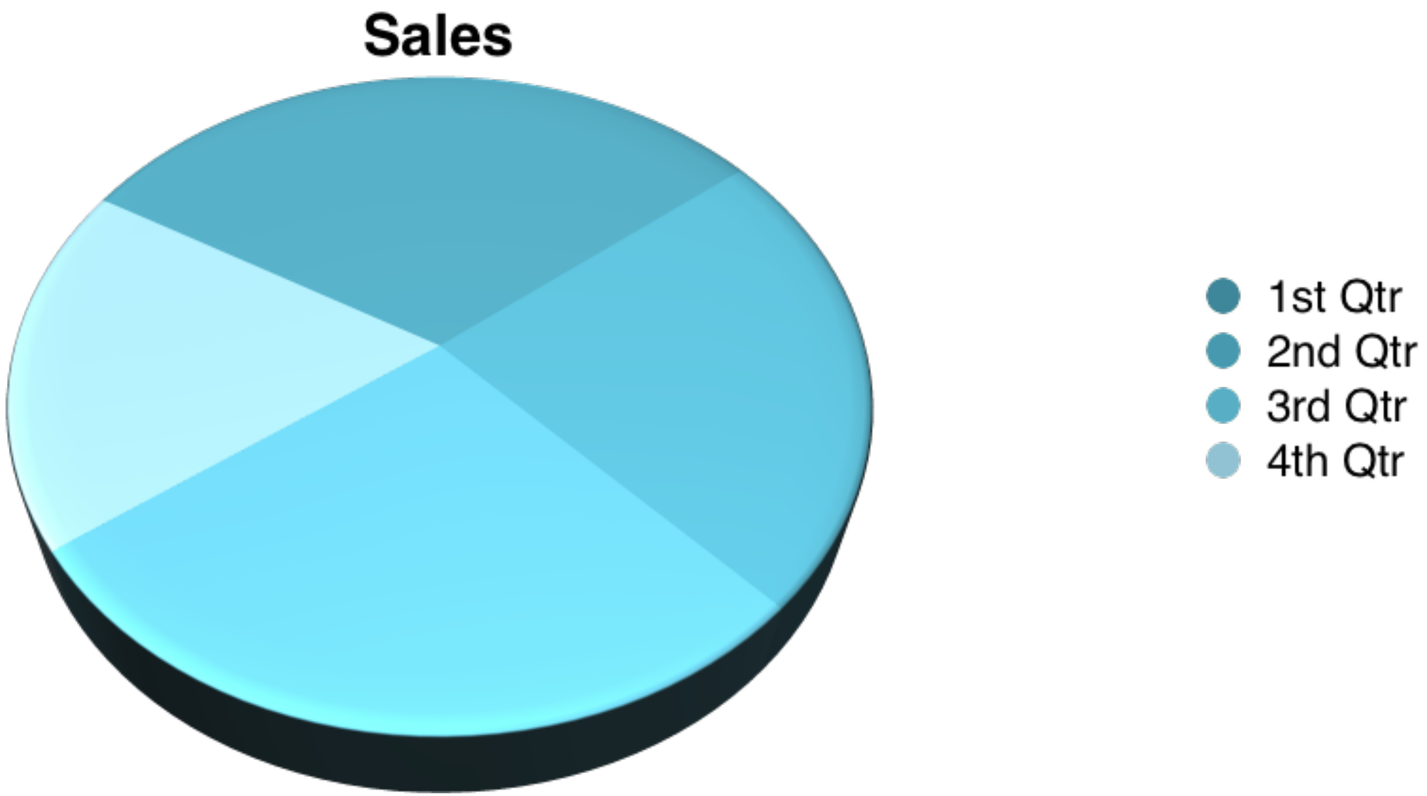
Graphical Integrity



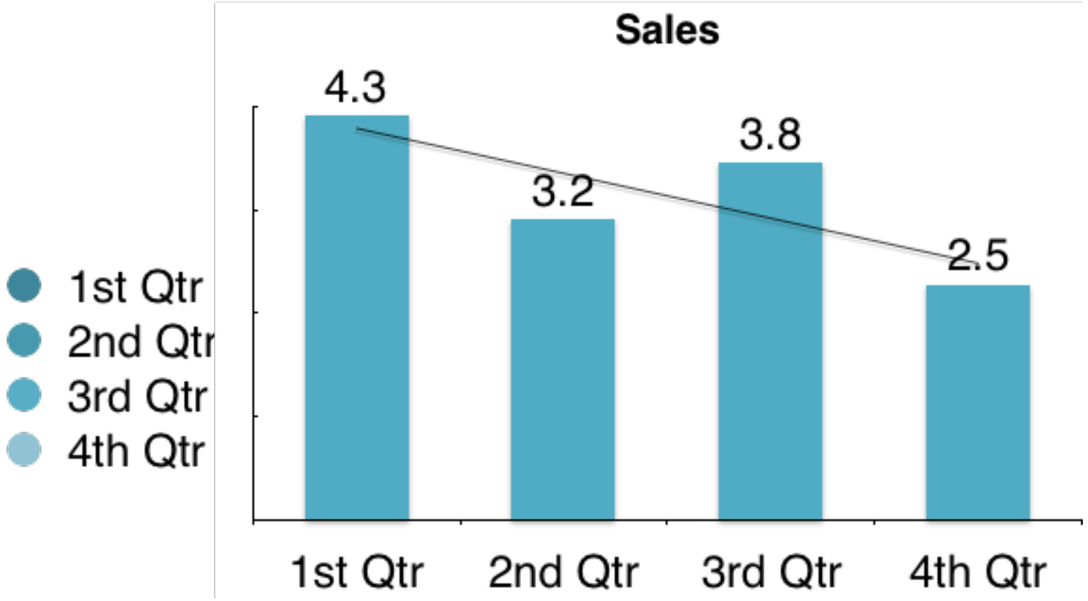
Stop

Composition

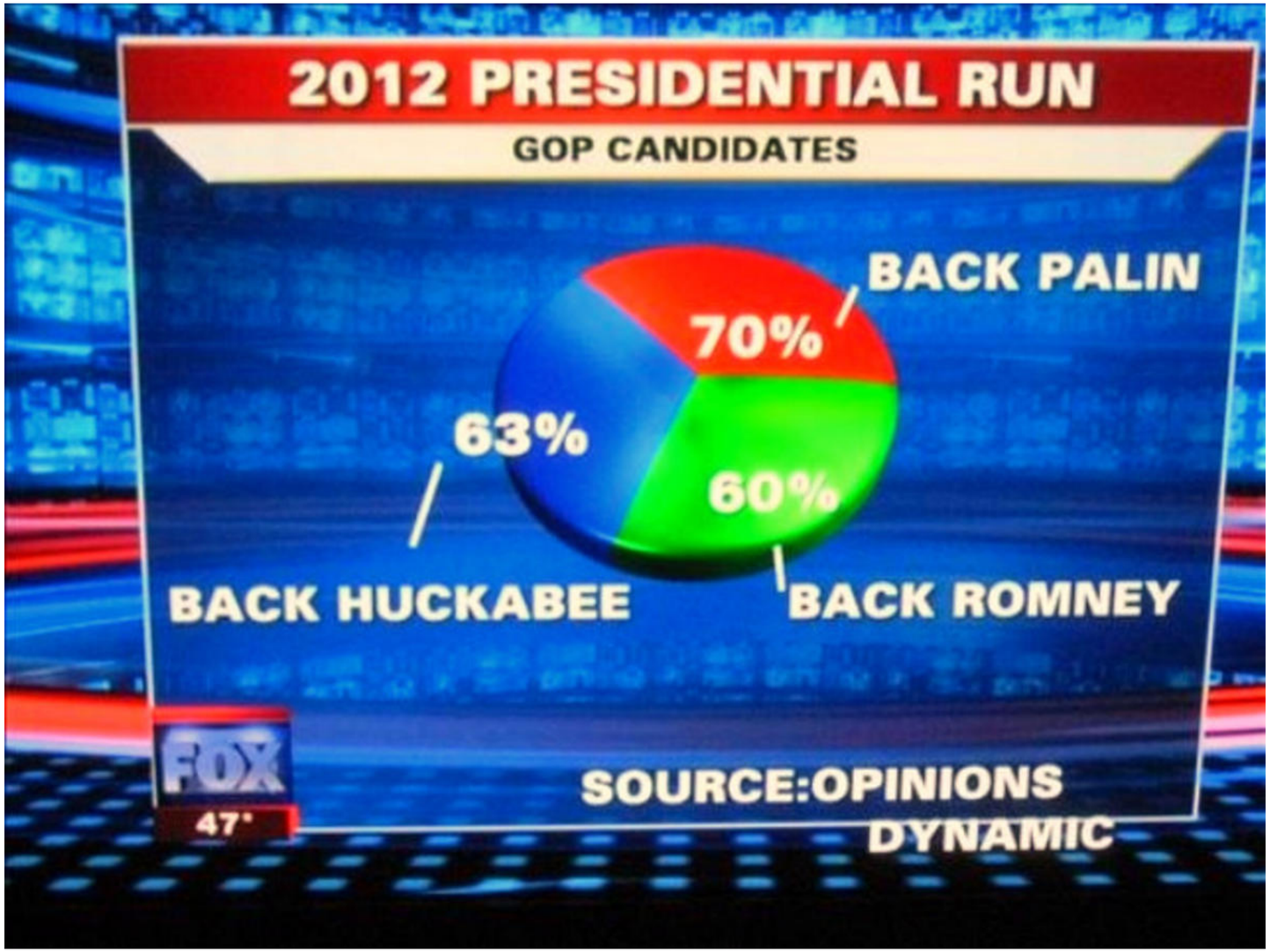


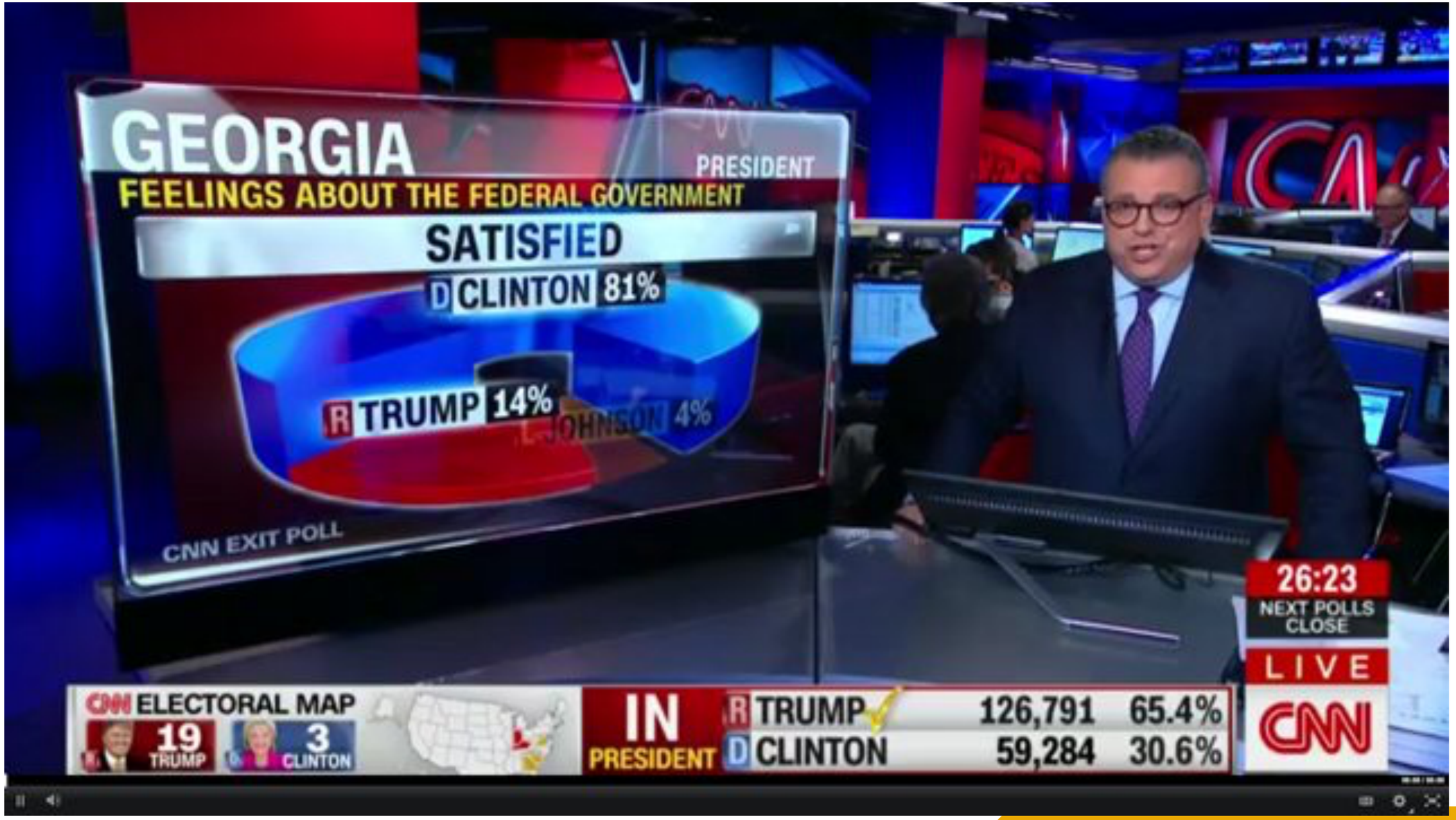

Sales
1st Qtr
2nd Qtr
3rd Qtr
4th Qtr

Proper Display



Graphical Integrity?

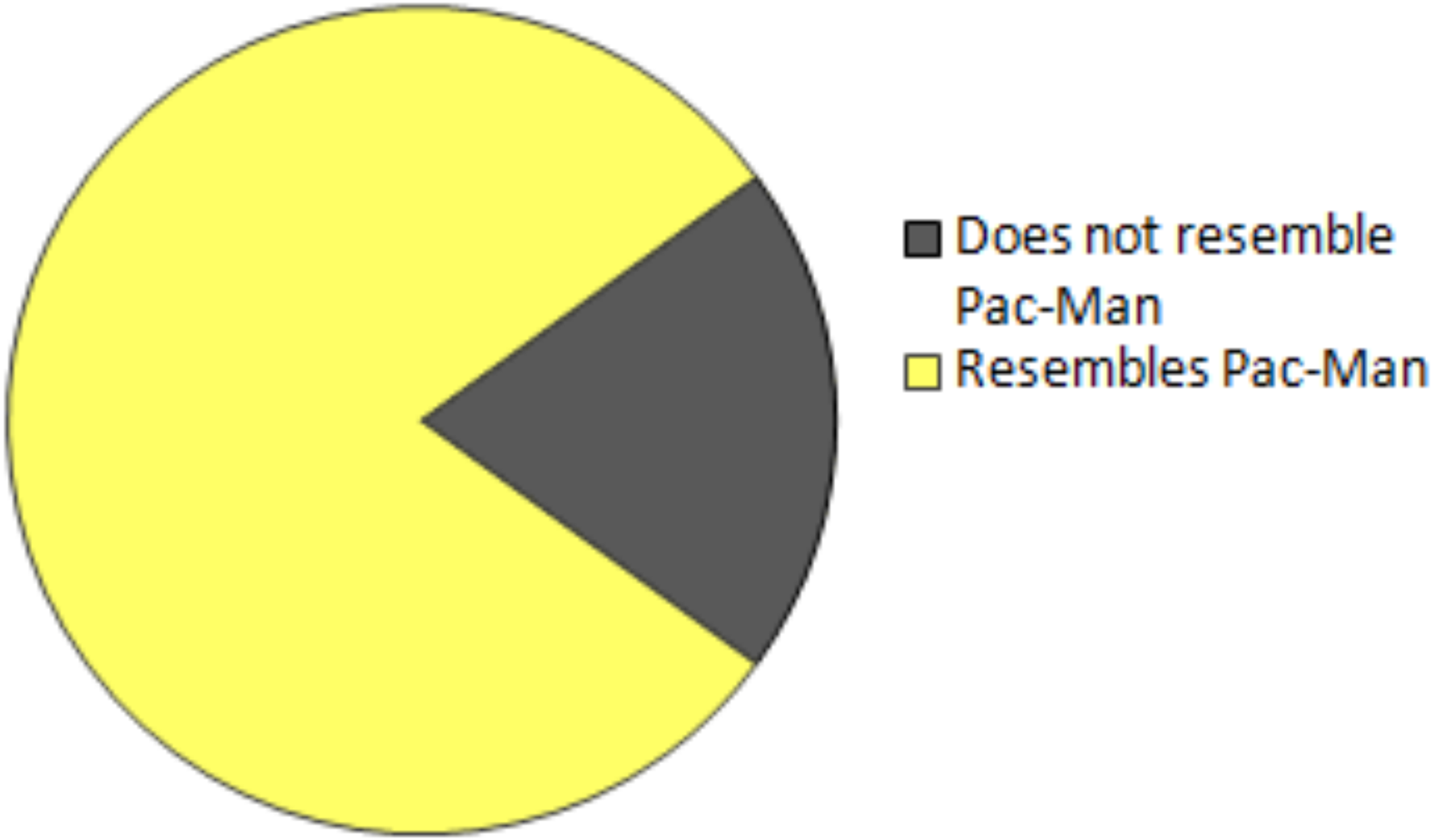


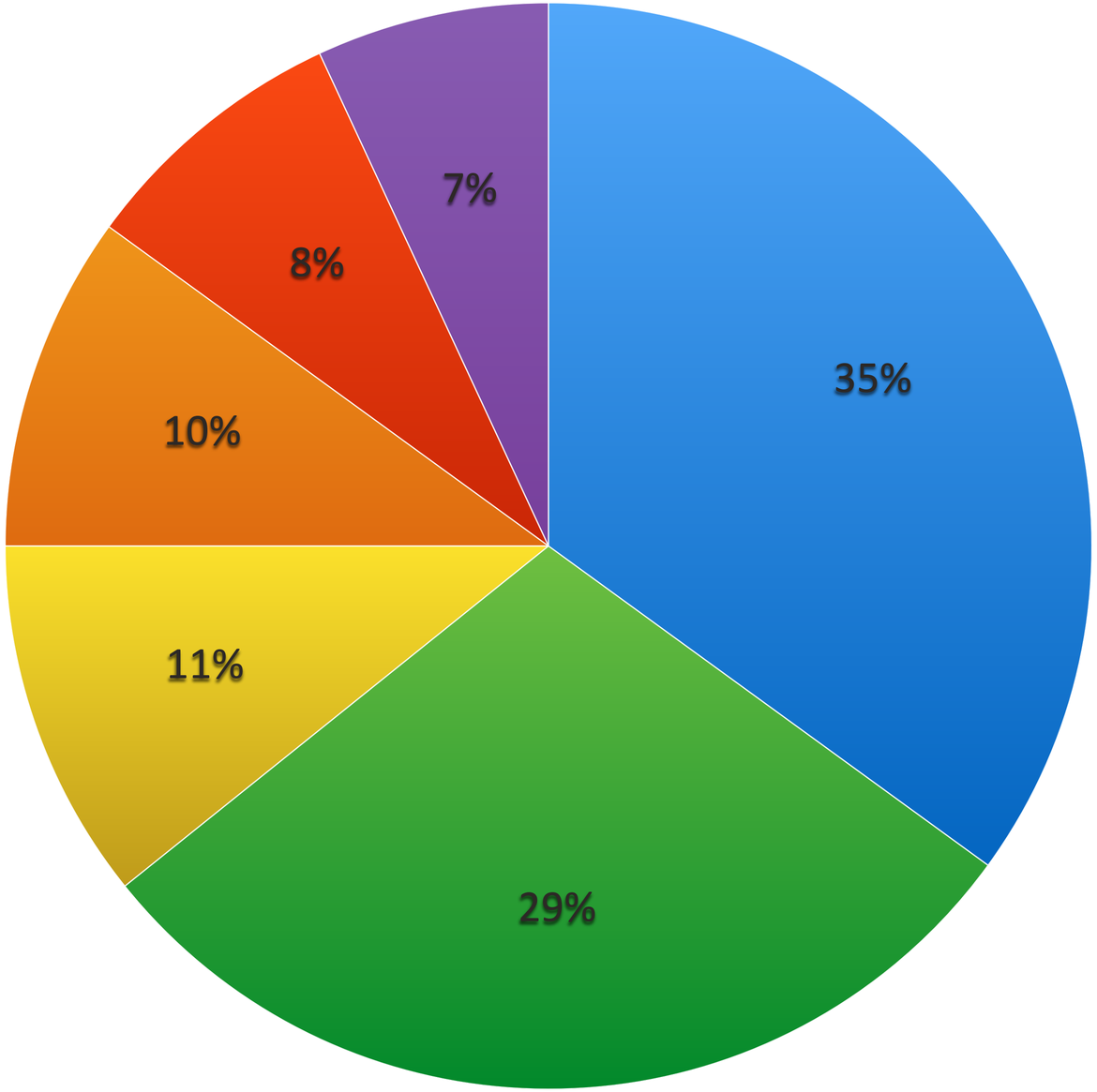

GEORGIA
PRESIDENT
FEELINGS ABOUT THE FEDERAL GOVERNMENT
SATISFIED
D CLINTON 81%
R TRUMP 14%
L JOHNSON 4%
CNN EXIT POLL
26:23
NEXT POLLS CLOSE
LIVE
CNN
CNN ELECTORAL MAP
19 TRUMP
3 CLINTON
IN PRESIDENT
R TRUMP 126,791 65.4%
D CLINTON 59,284 30.6%

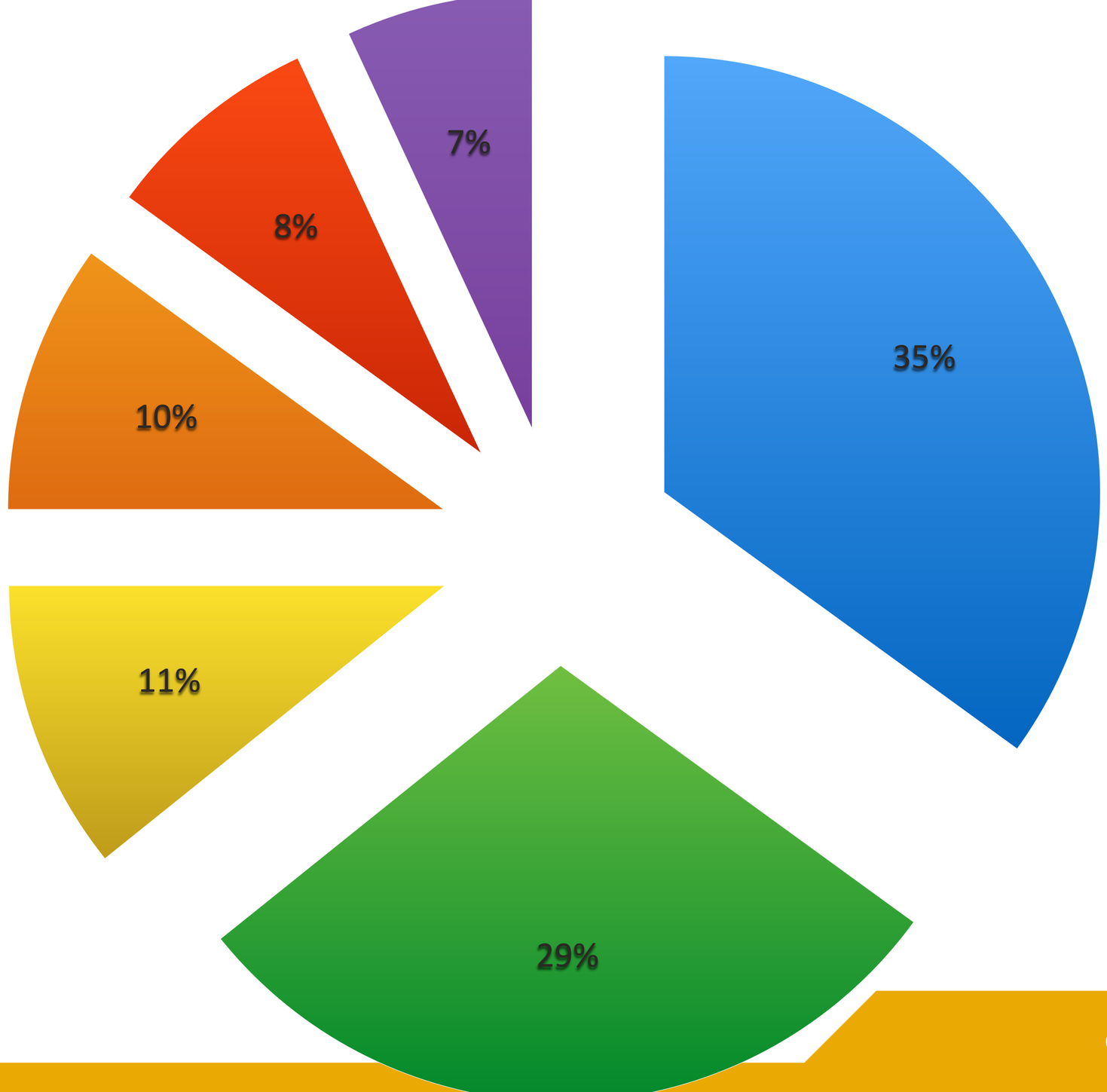
A Brief Interlude: Why Never to Use a Pie Chart

Pie I have eaten
Pie I have not yet eaten

Percentage of Chart Which Resembles Pac-Man




7%
8%
35%
10%
11%
29%


7%
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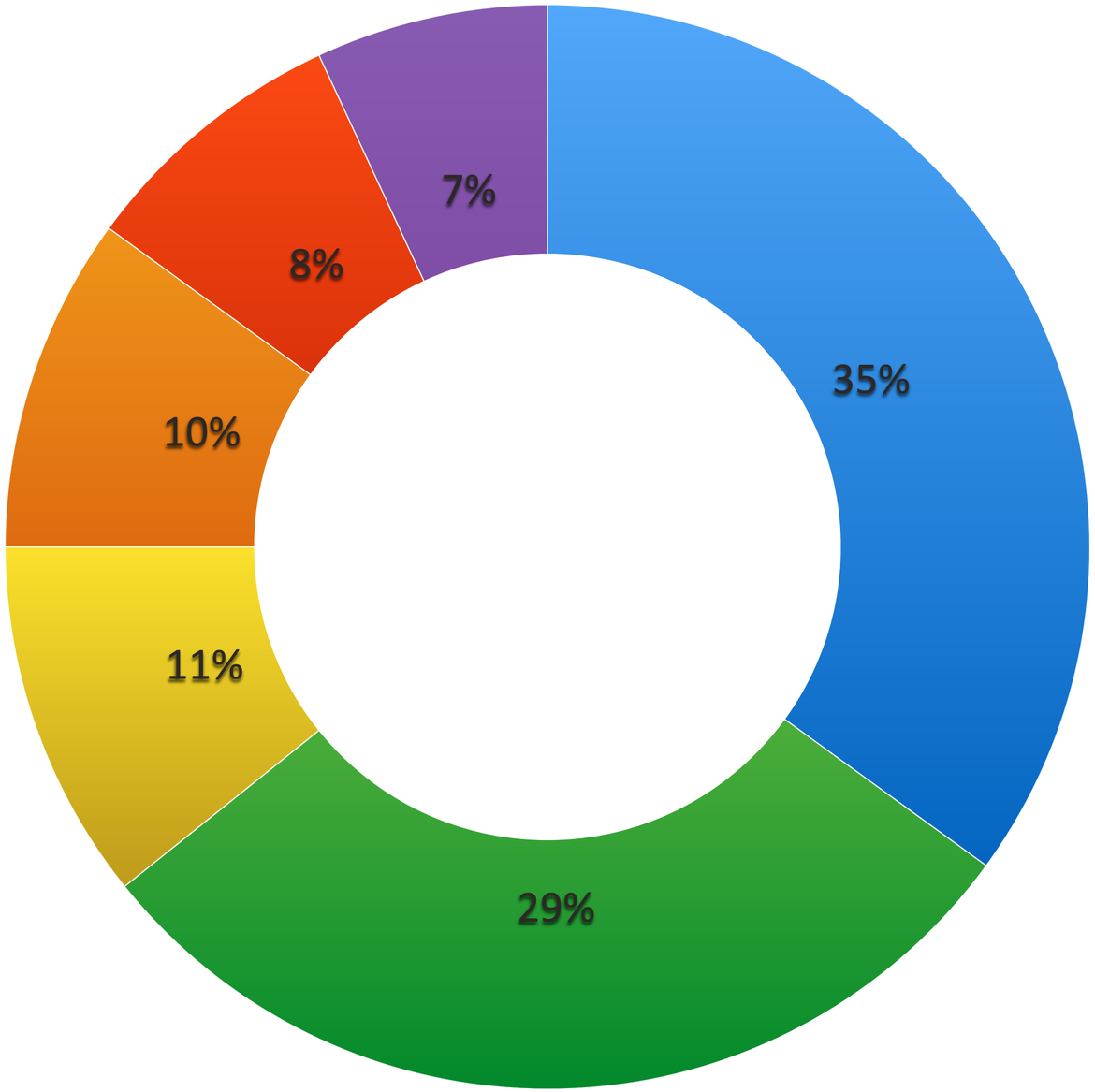
29%
35%


7%
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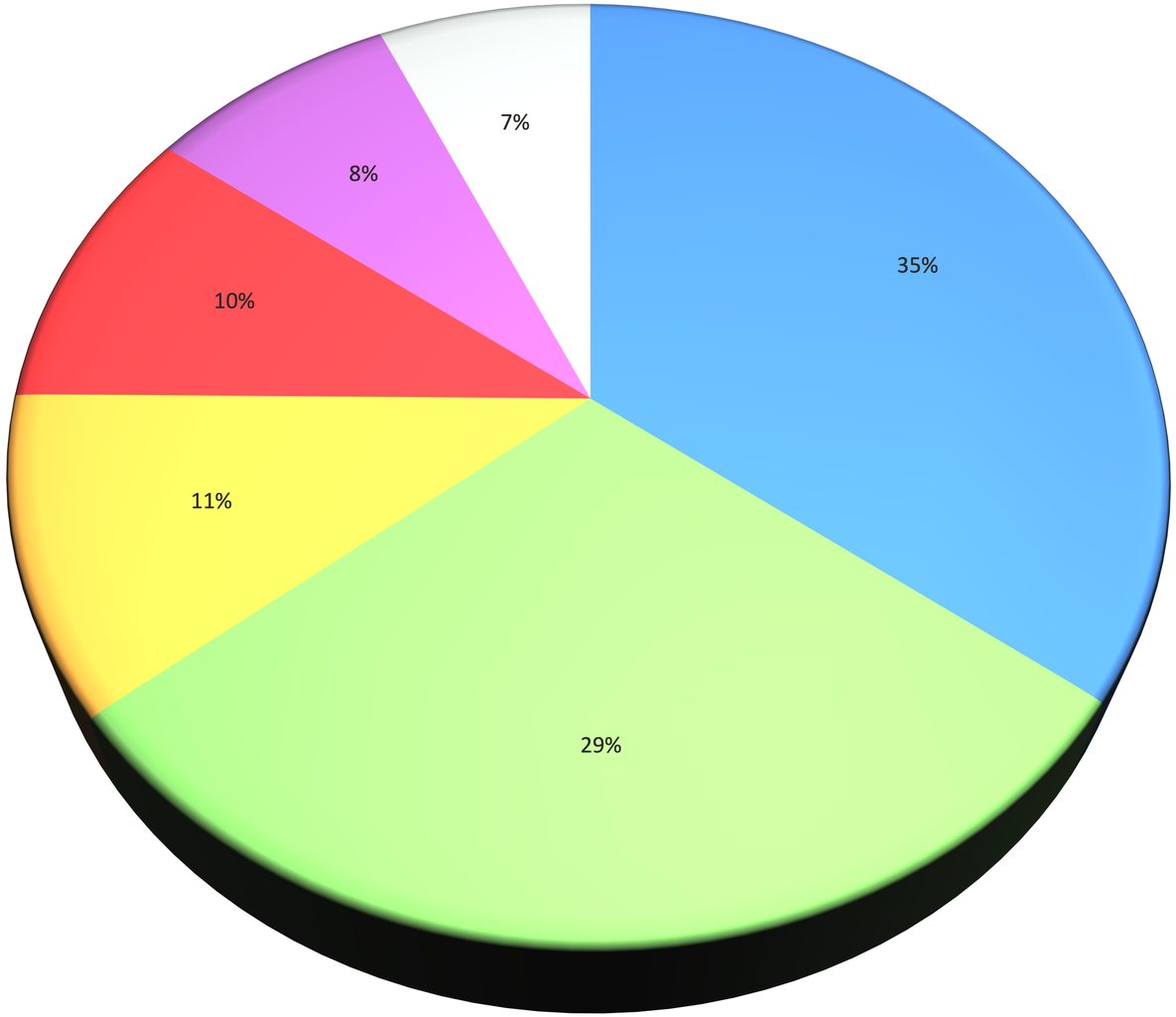
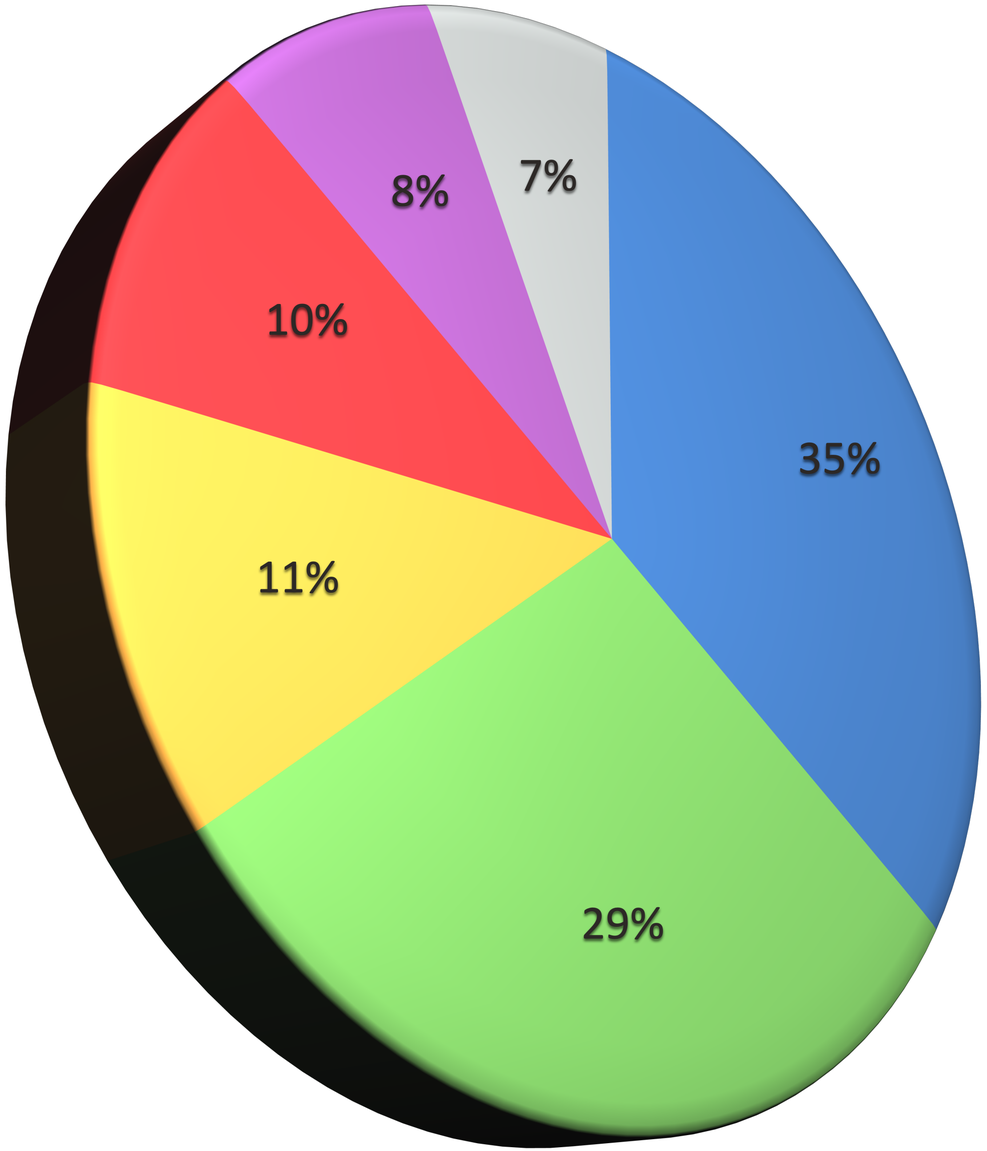
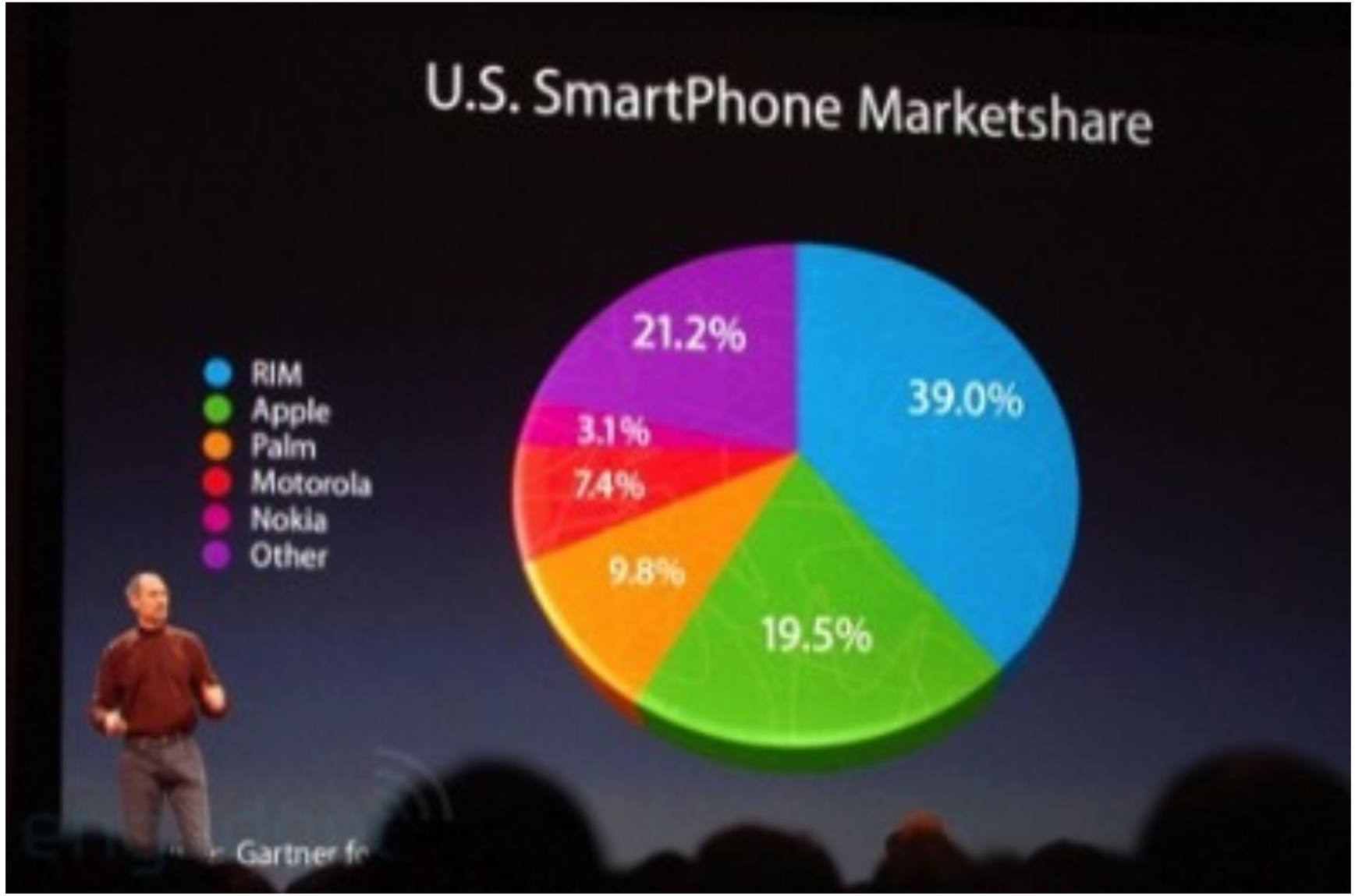
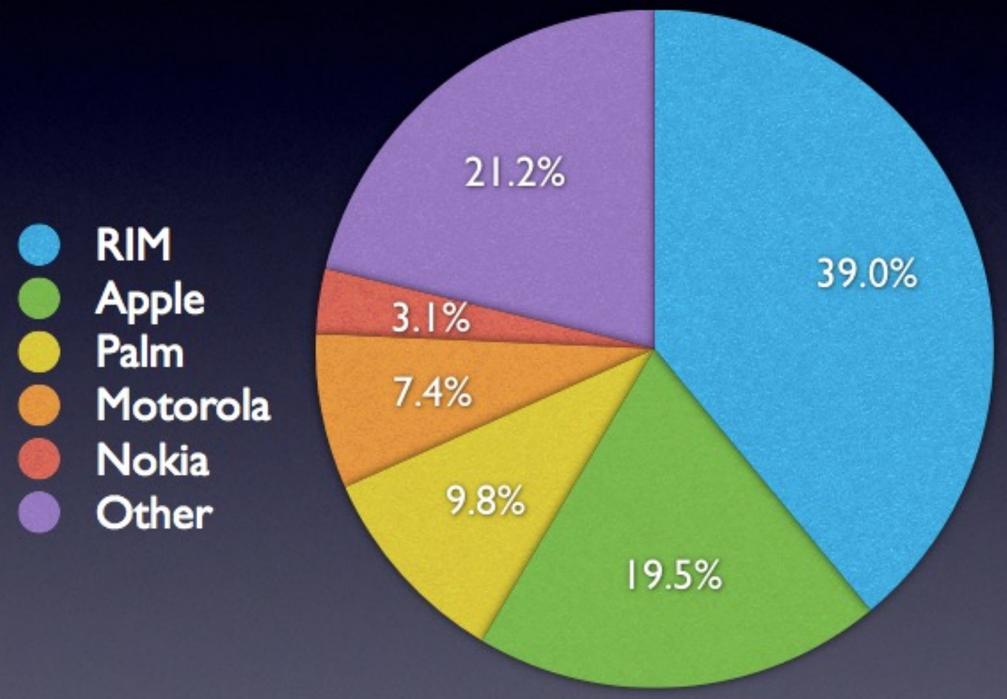
10%
11%
29%


7%
8%
35%
10%
11%
29%

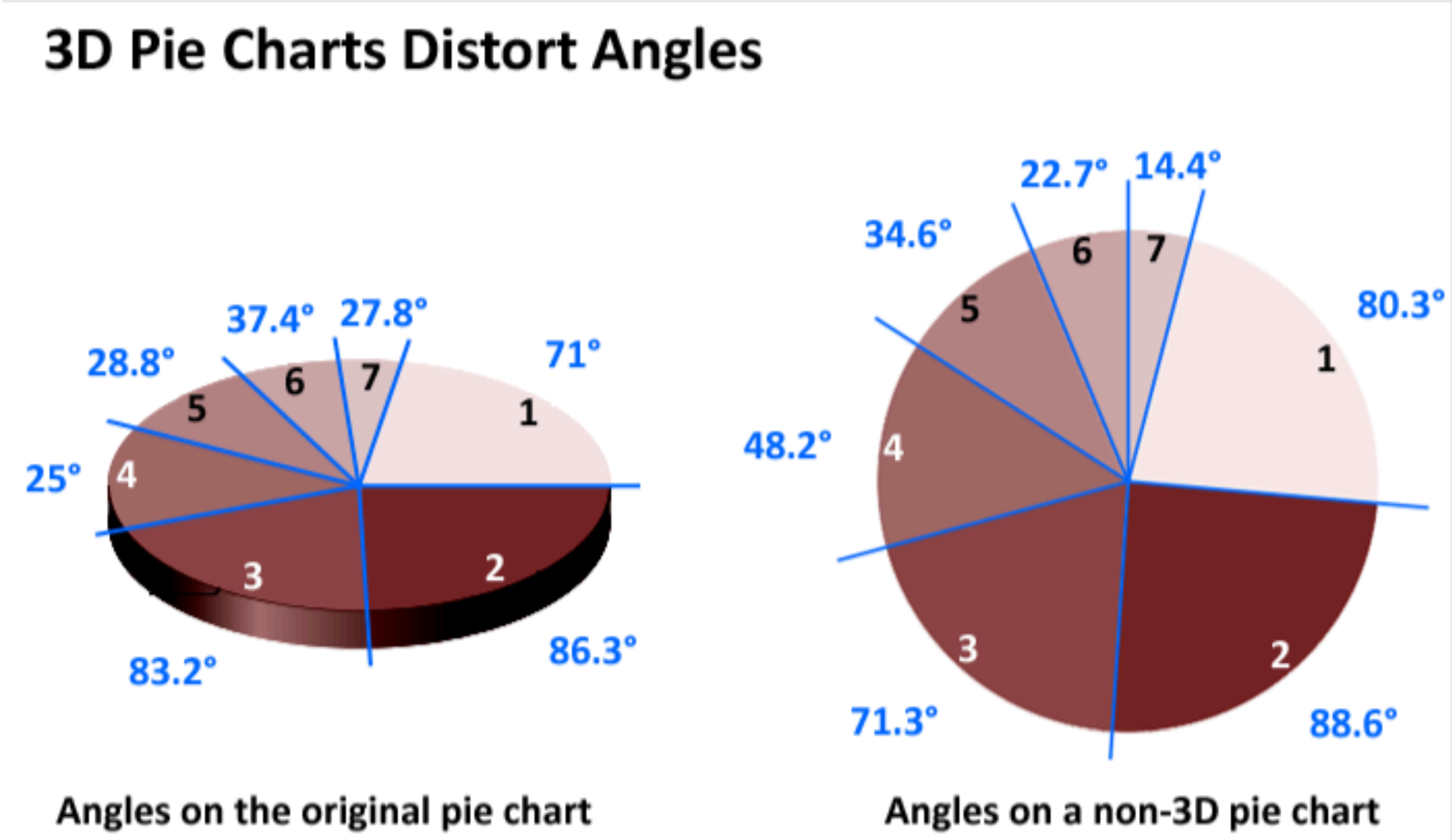

35%
29%
11%
10%
8%
7%


U.S. SmartPhone Marketshare
RIM
Apple
Palm
Motorola
Nokia
Other
39.0%
19.5%
9.8%
7.4%
3.1%
21.2%
Gartner fe

U.S. SmartPhone Marketshare

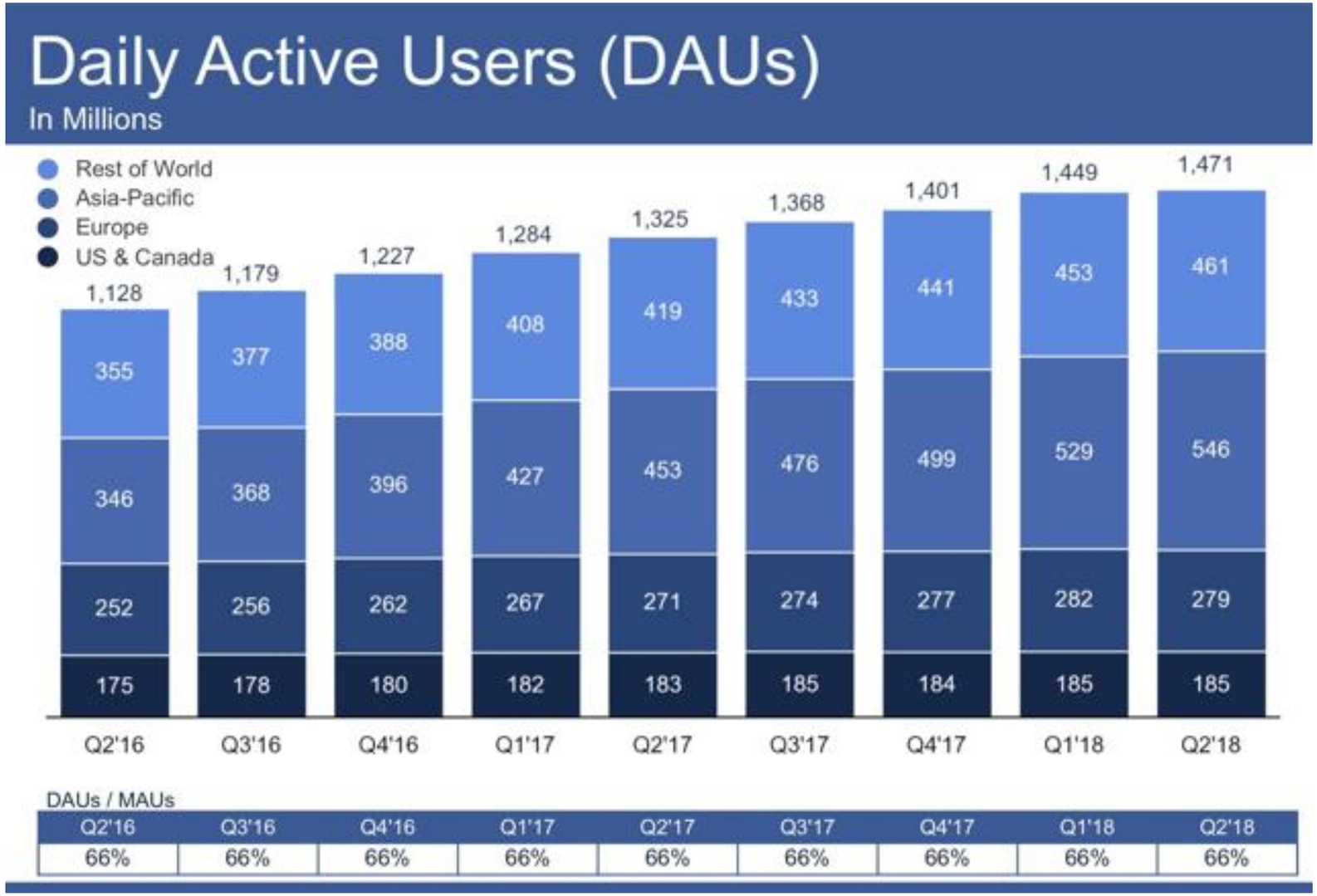


3D Pie Charts are BAD!



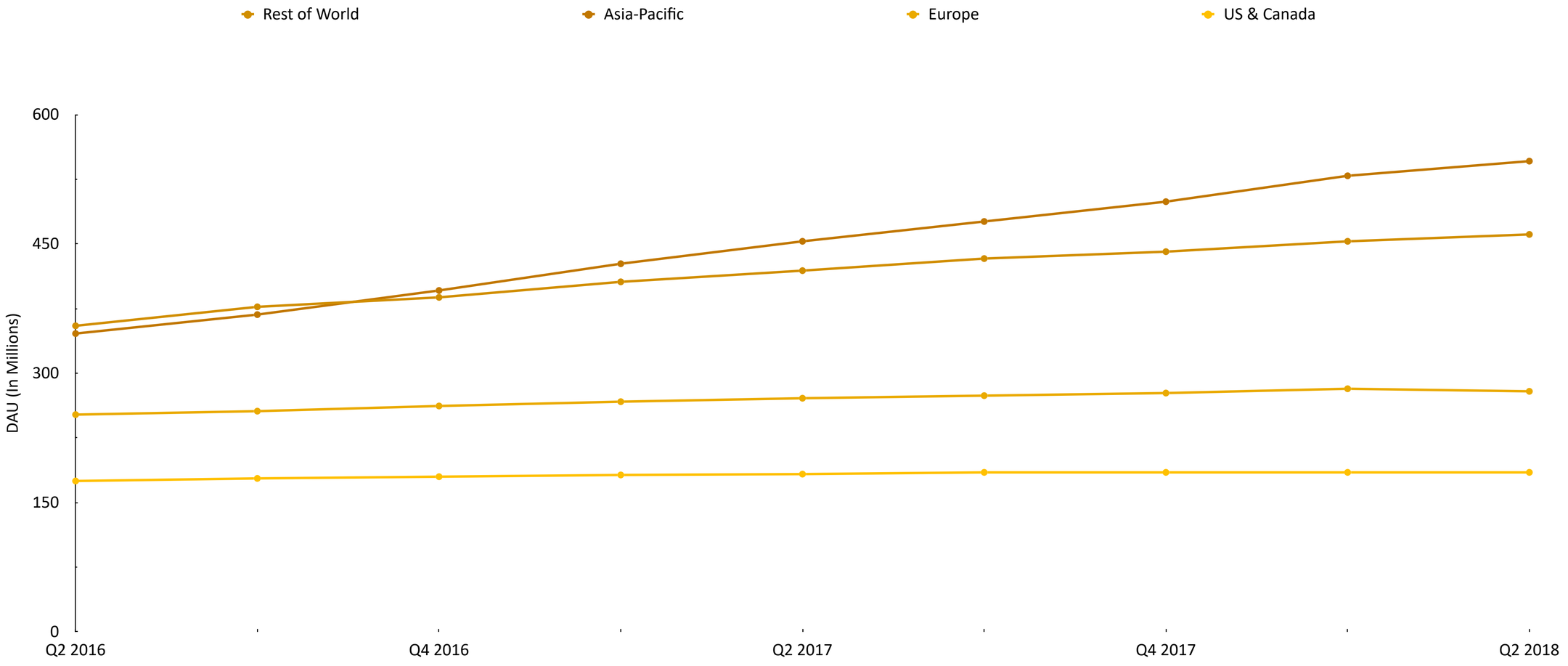
h8p://themendozaline.org/post/113828947026/3d-pie-charts-are-lie-charts

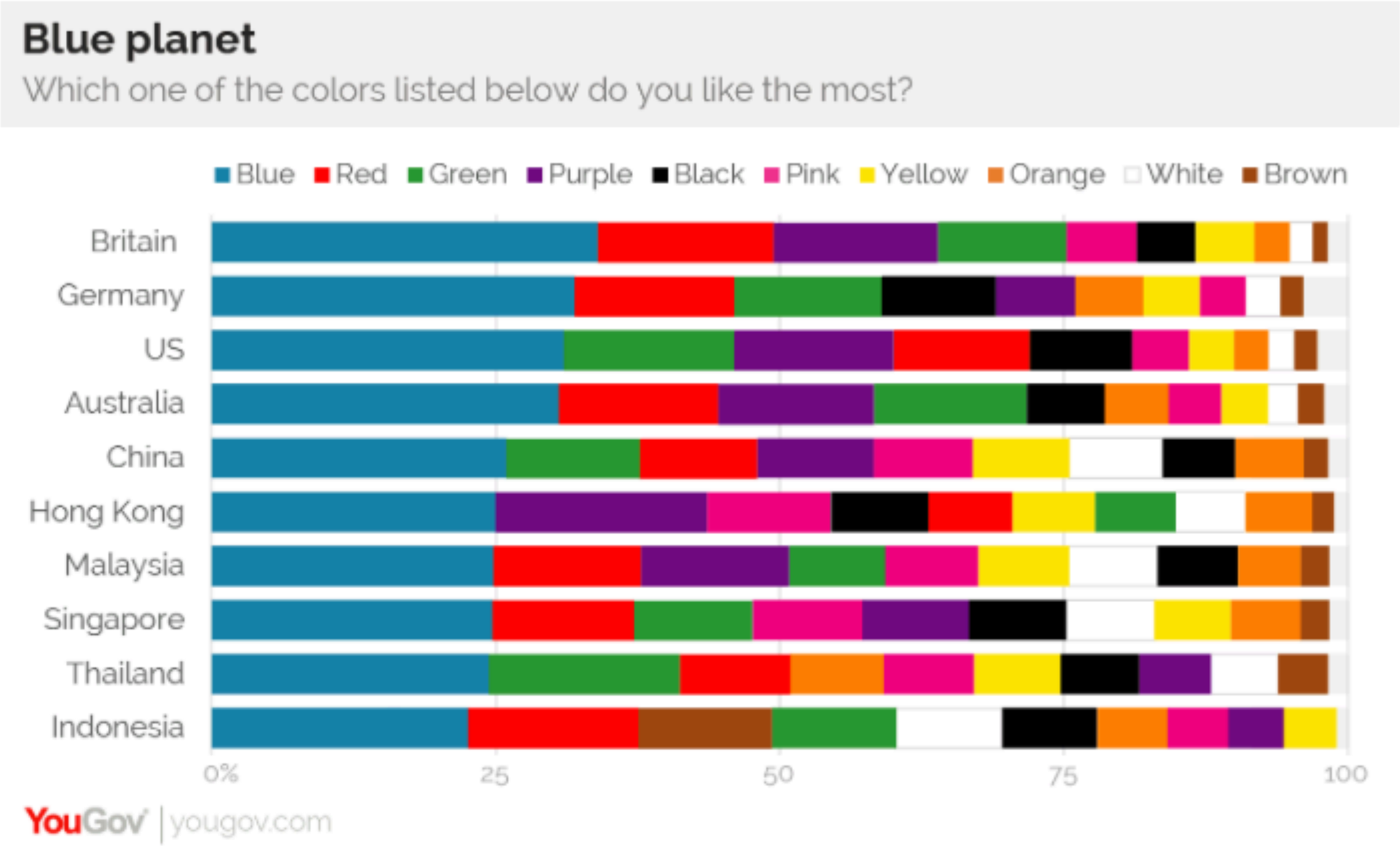
Proper Display?



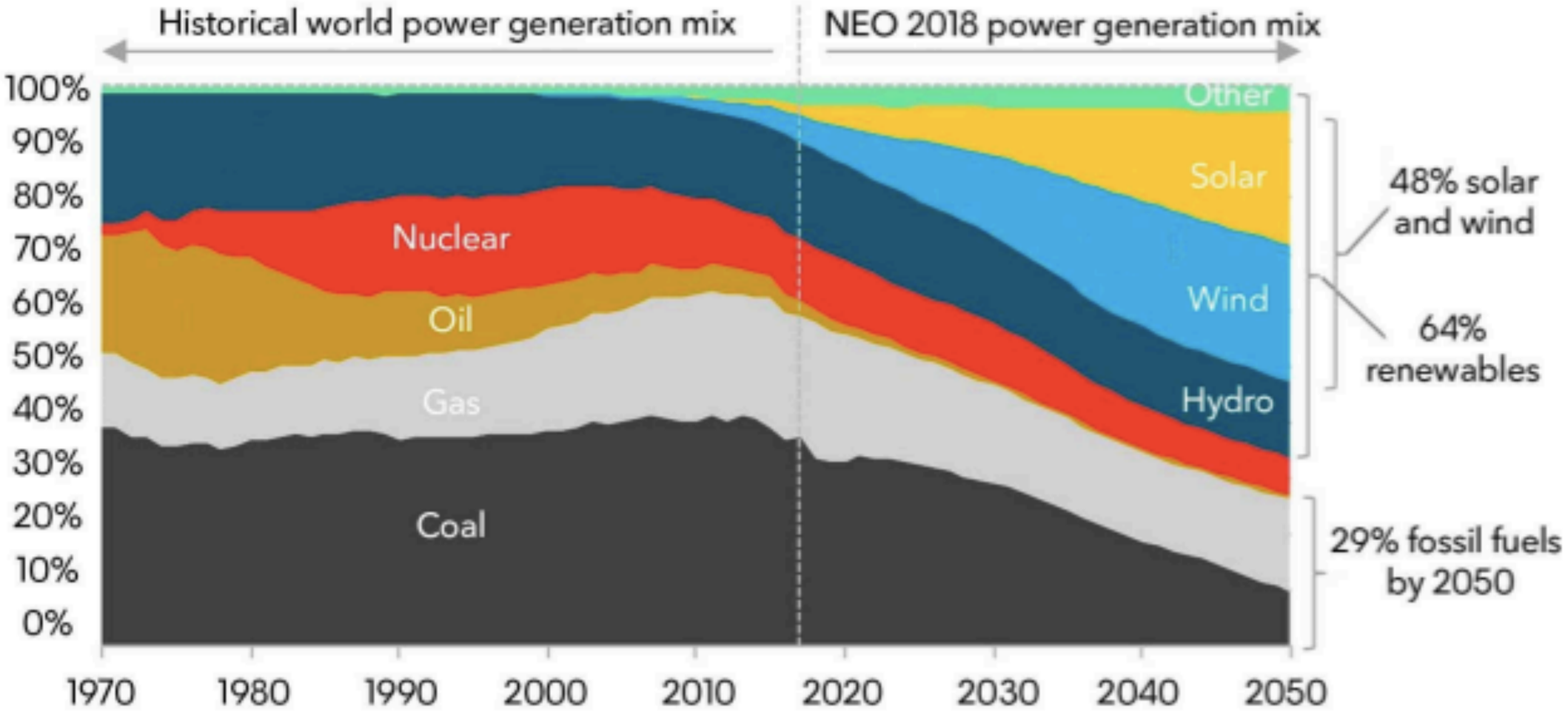
https://s21.q4cdn.com/399680738/files/doc_financials/2018/Q2/Q2-2018-Earnings-Presentation.pdf

Proper Display?




Blue planet
Which one of the colors listed below do you like the most?
Blue
Red
Green
Purple
Black
Pink
Yellow
Orange
White
Brown
Britain
Germany
US
Australia
China
Hong Kong
Malaysia
Singapore
Thailand
Indonesia
0%
25
50
75
100
YouGov | yougov.com

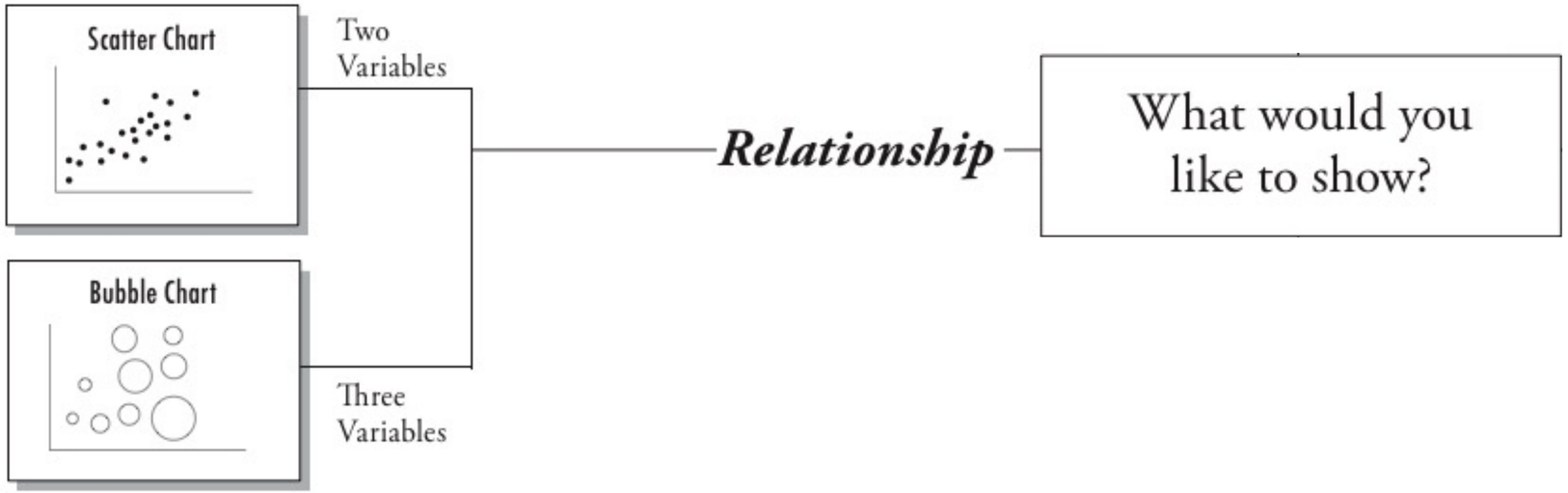
Power generation mix

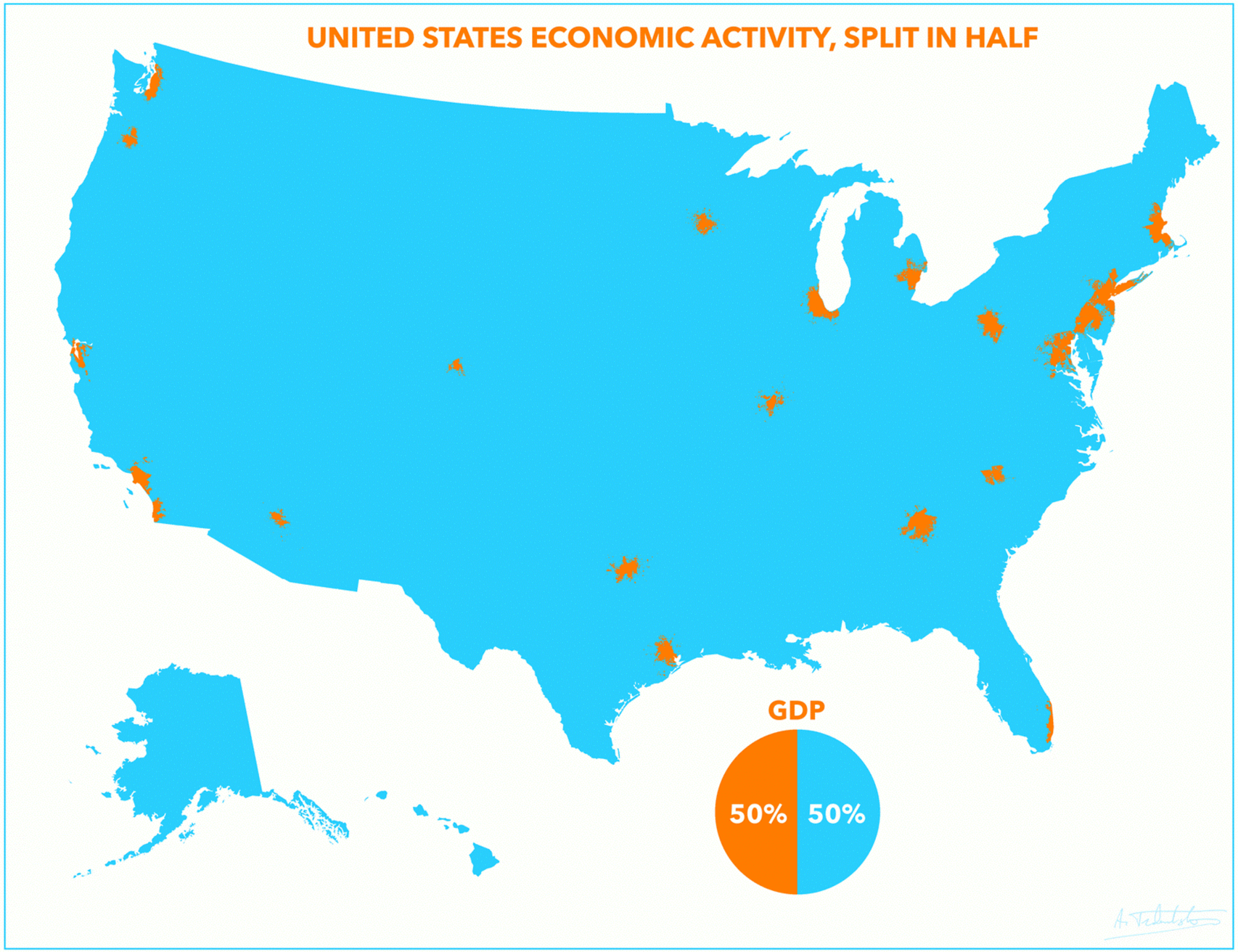


Source: Bloomberg NEF

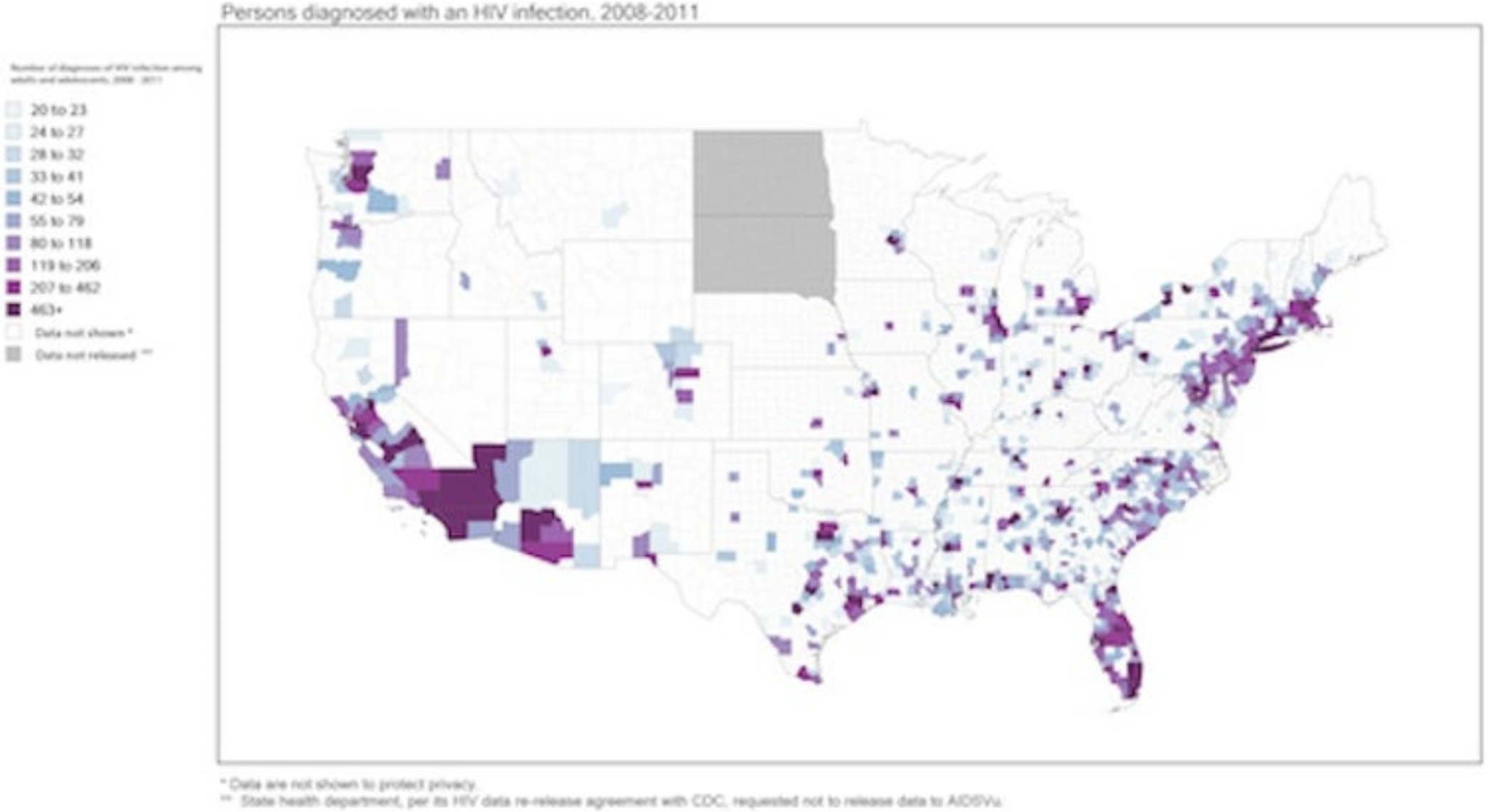
Stop

Relationship

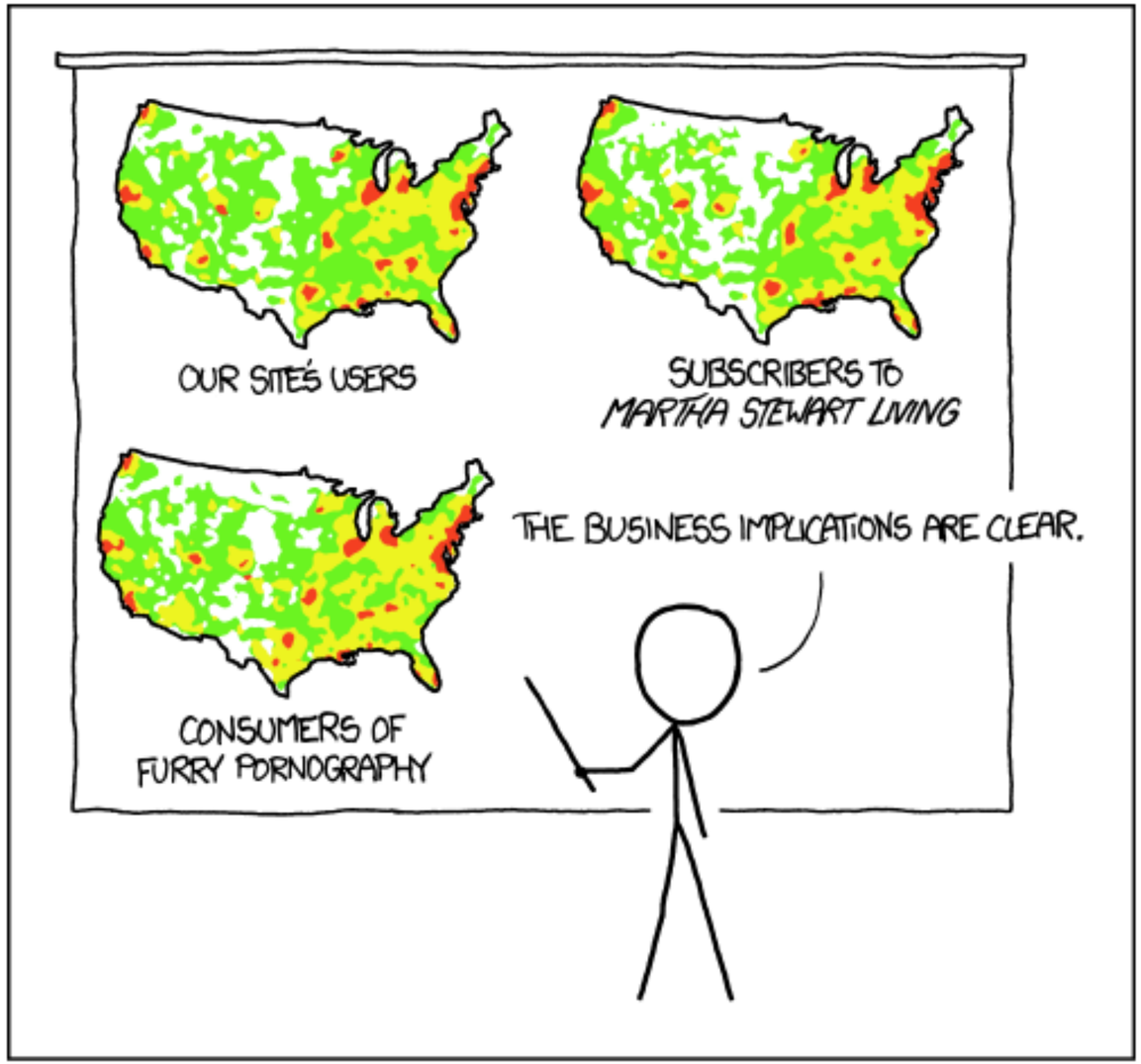



UNITED STATES ECONOMIC ACTIVITY, SPLIT IN HALF
GDP
50%
50%

Startling New Map: 92 Percent of New HIV Cases are in 25 Percent of Counties



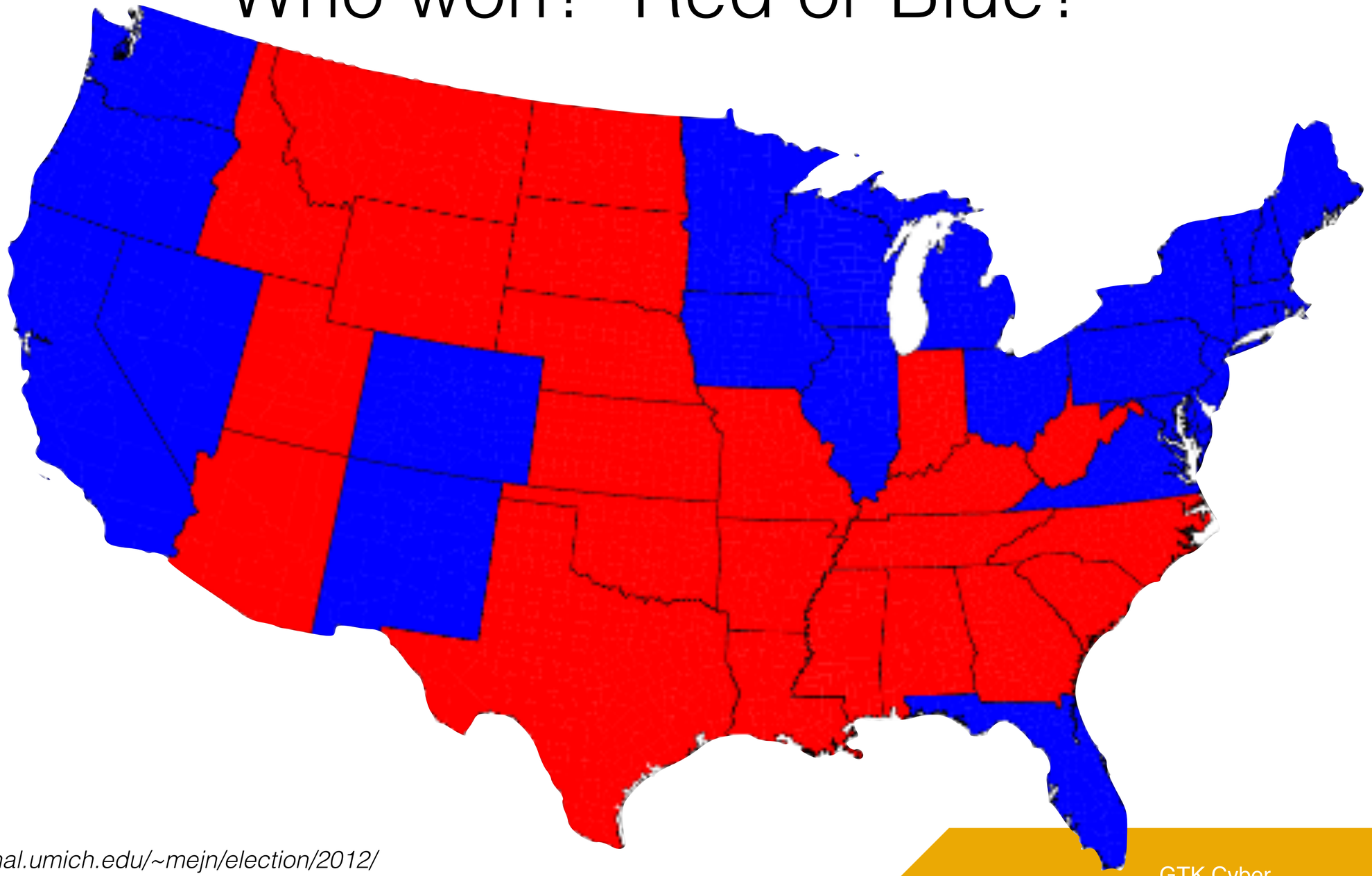
https://newrepublic.com/article/114822/maps-92-percent-new-hiv-cases-are-25-percent-counties



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

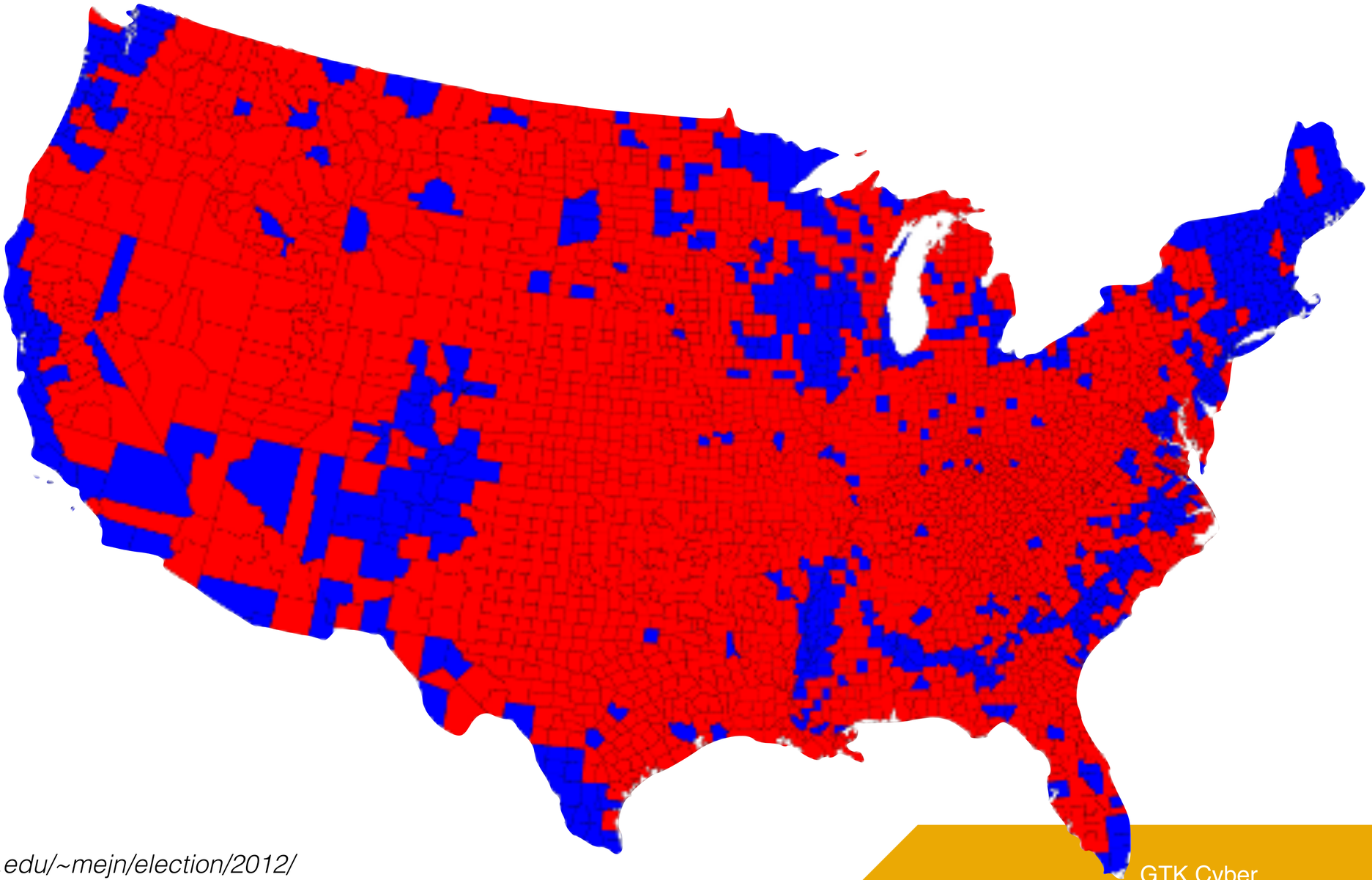
https://xkcd.com/1138/

Who won? Red or Blue?



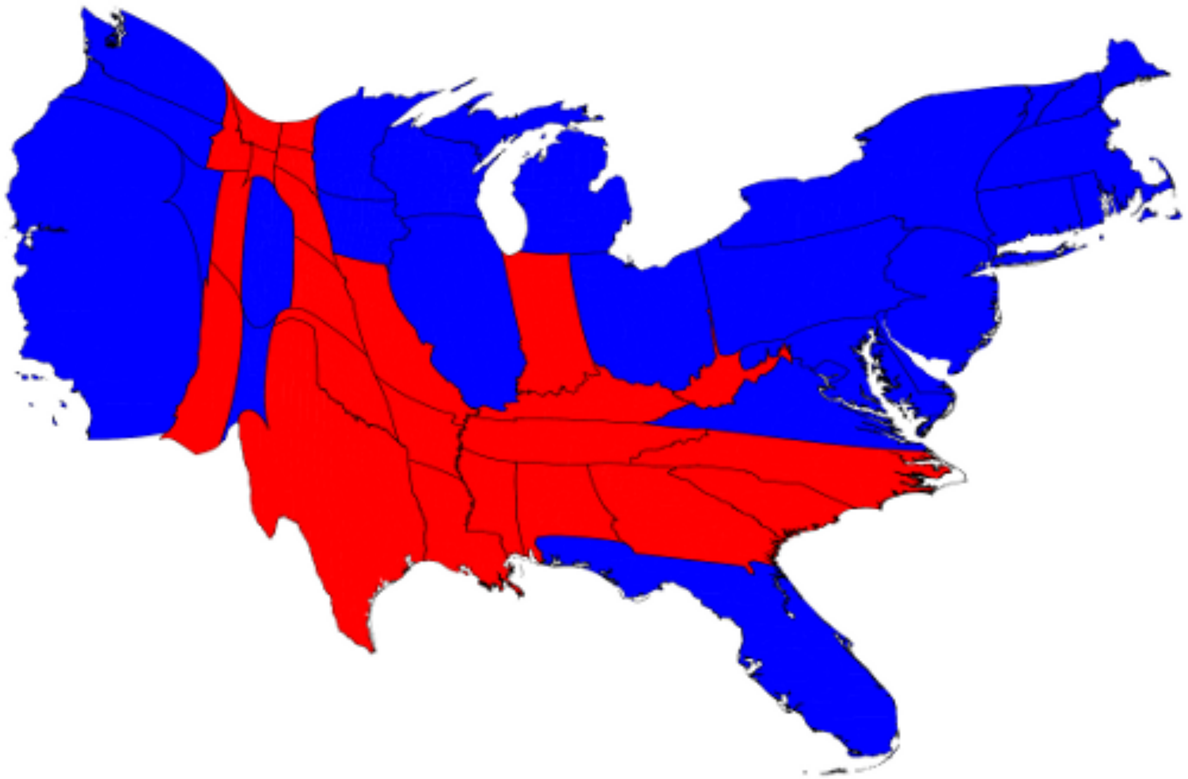
http://www-personal.umich.edu/~mejn/election/2012/

Who won? Red or Blue?

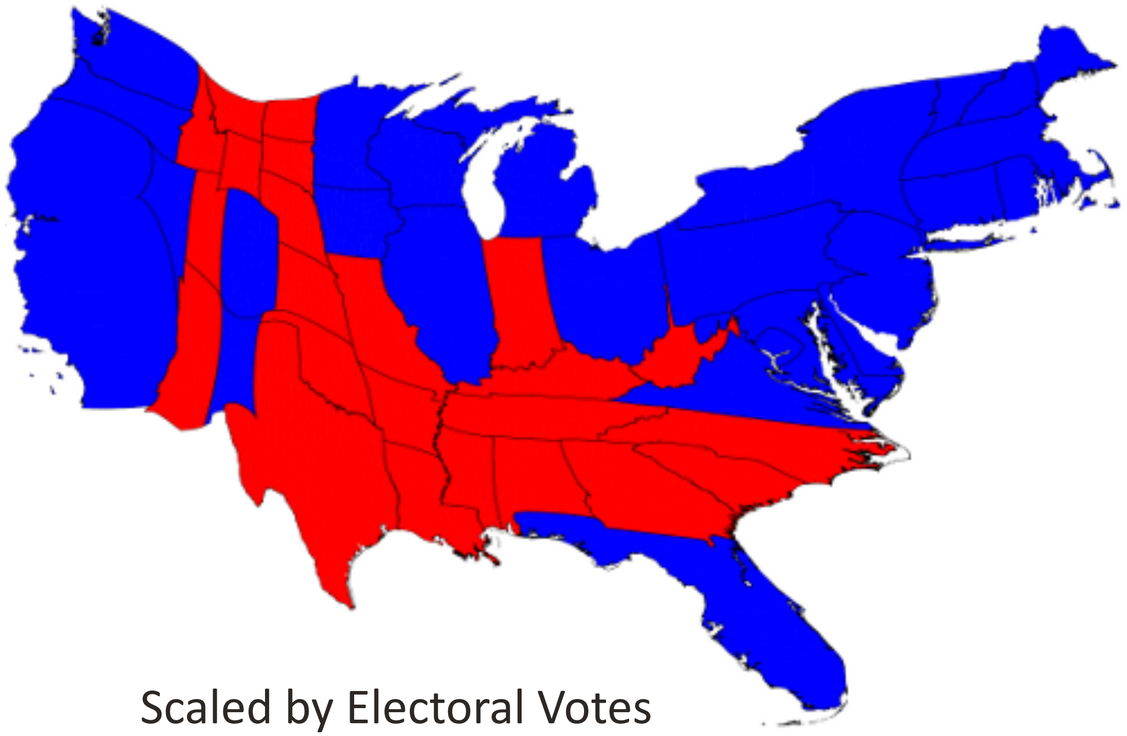


http://www-personal.umich.edu/~mejn/election/2012/

Who won? Red or Blue?

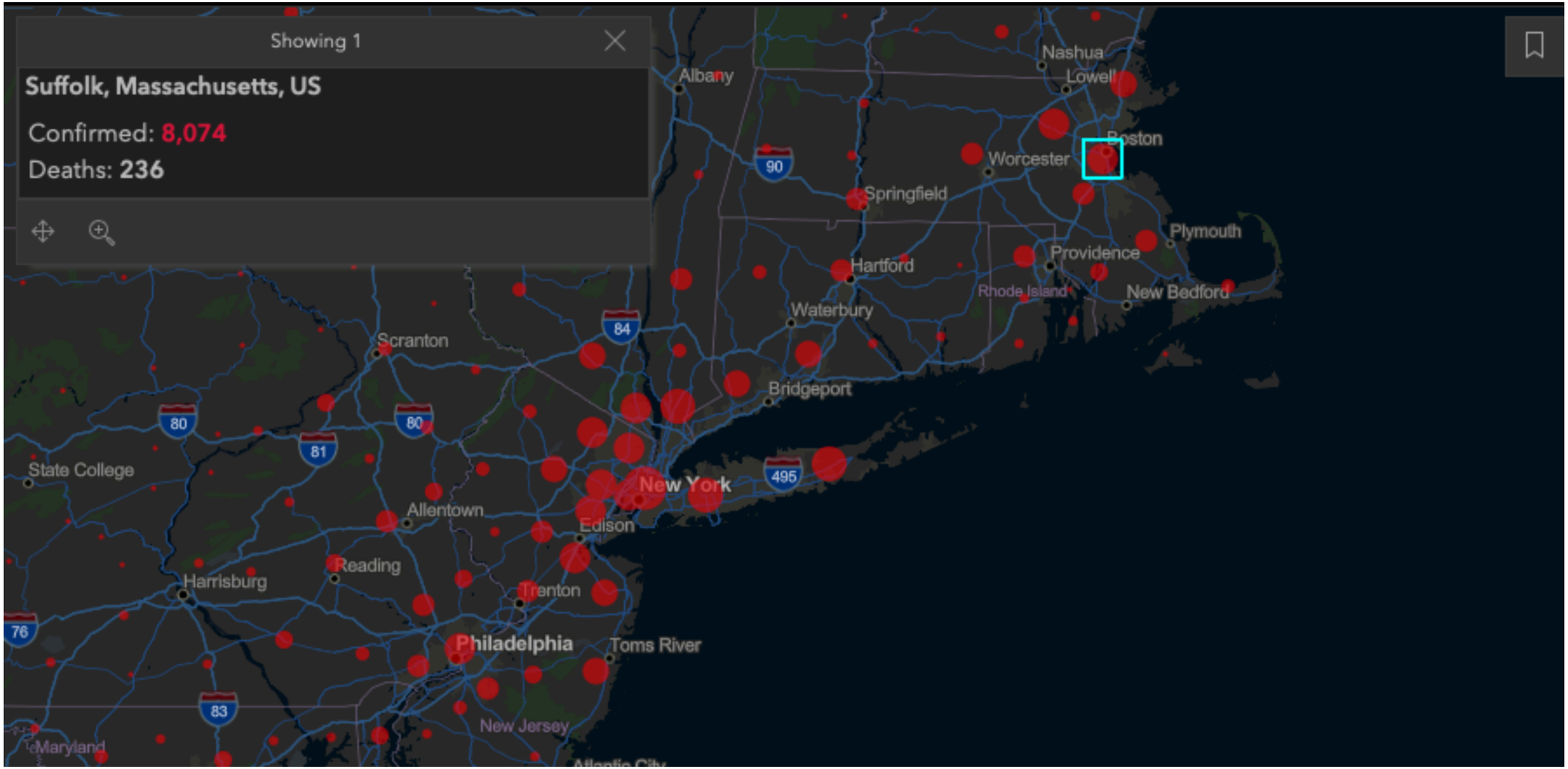


Scaled by Population

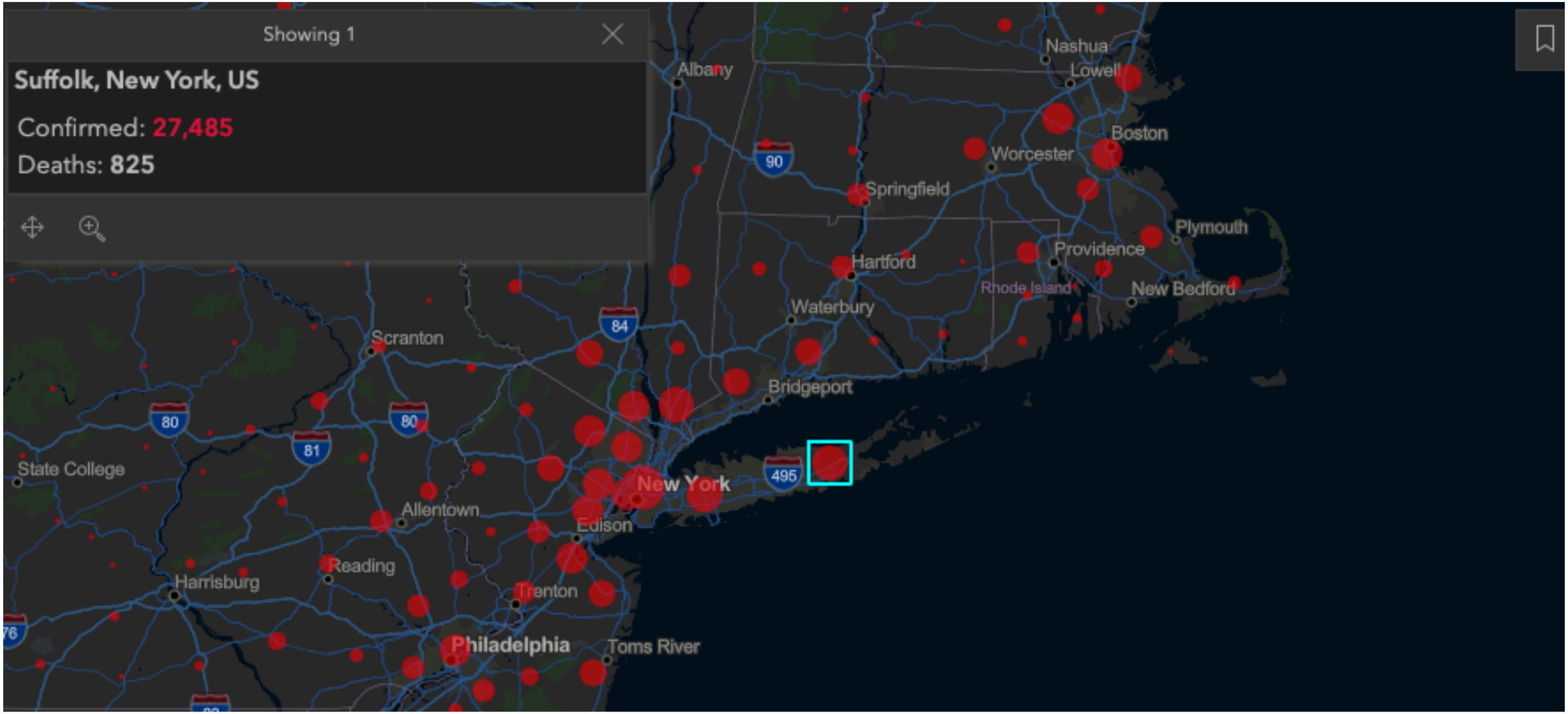


Scaled by Electoral Votes

http://www-personal.umich.edu/~mejn/election/2012/

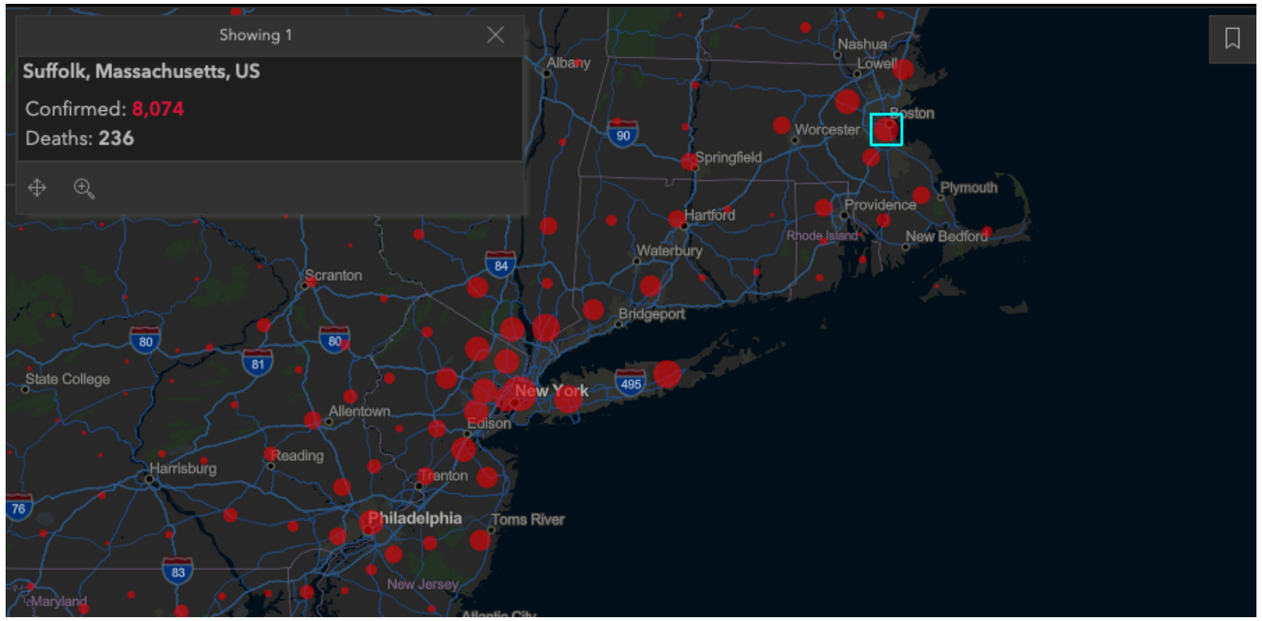


https://coronavirus.jhu.edu/map.html

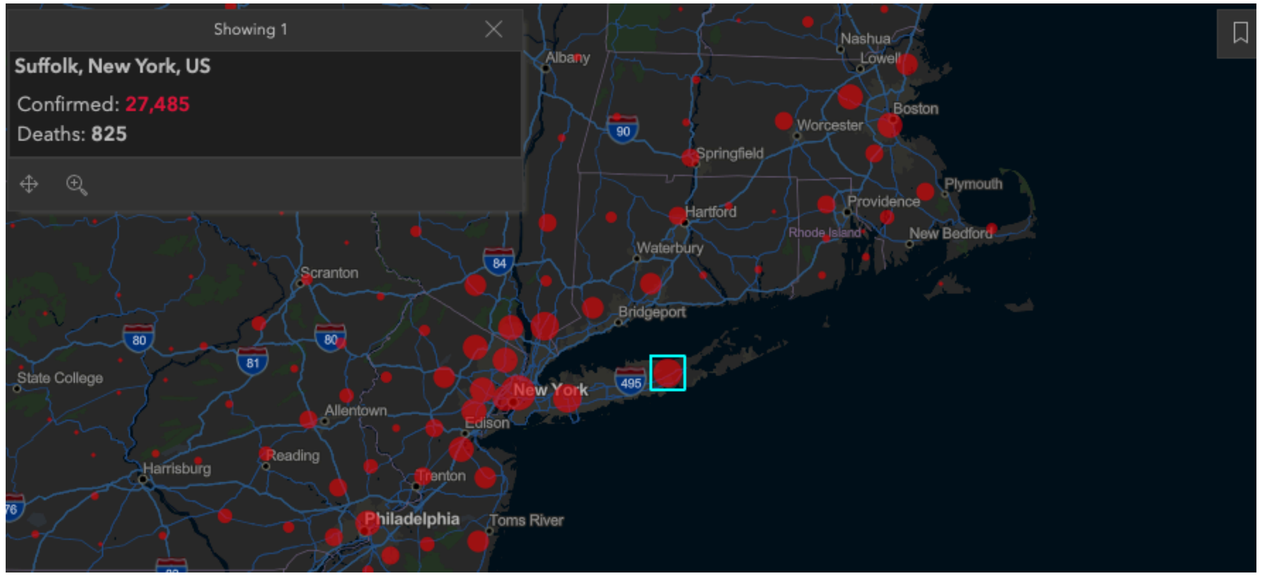


https://coronavirus.jhu.edu/map.html

Suffolk vs Suffolk



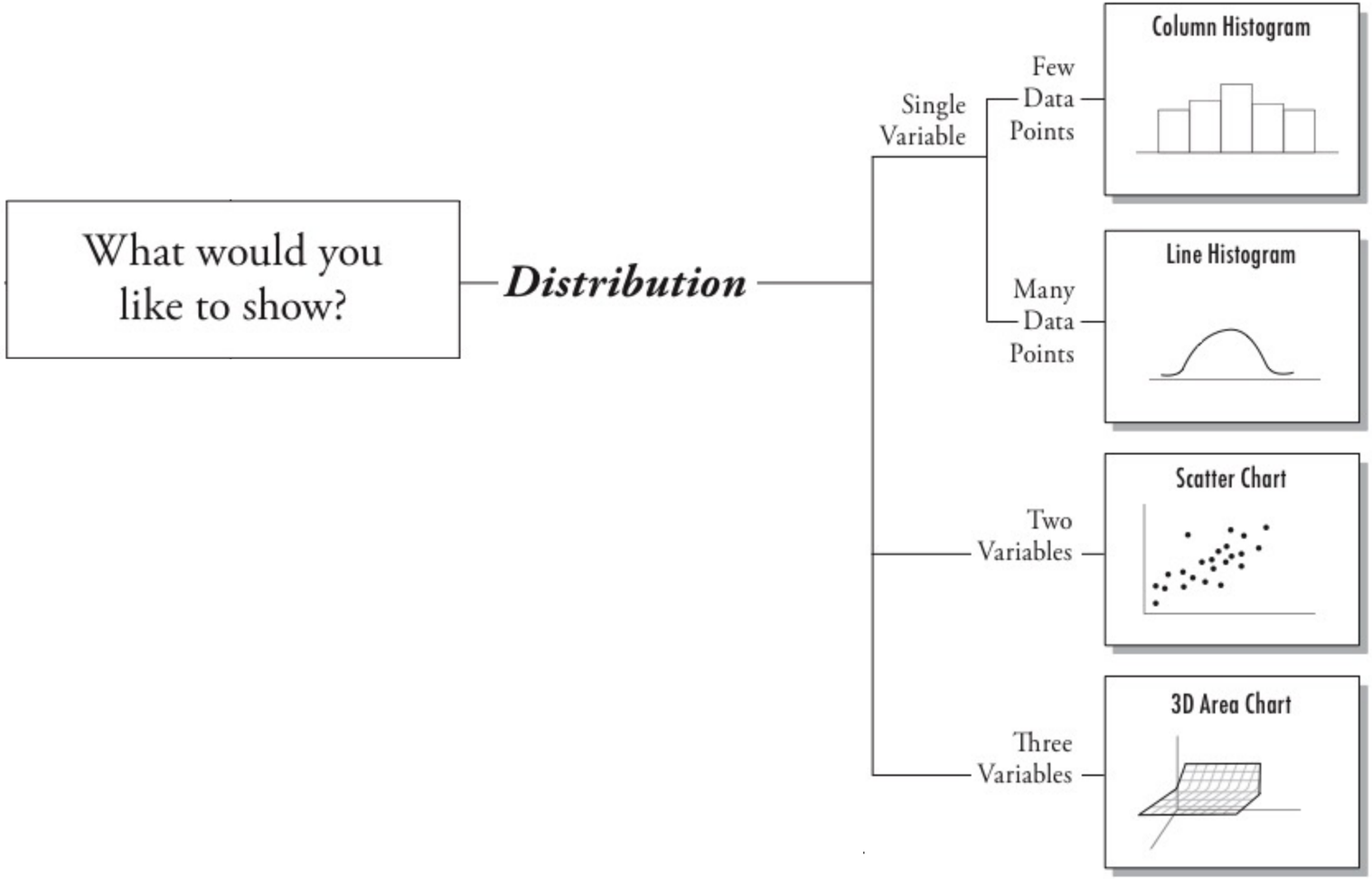
Suffolk, Massachusetts
8,074 confirmed cases

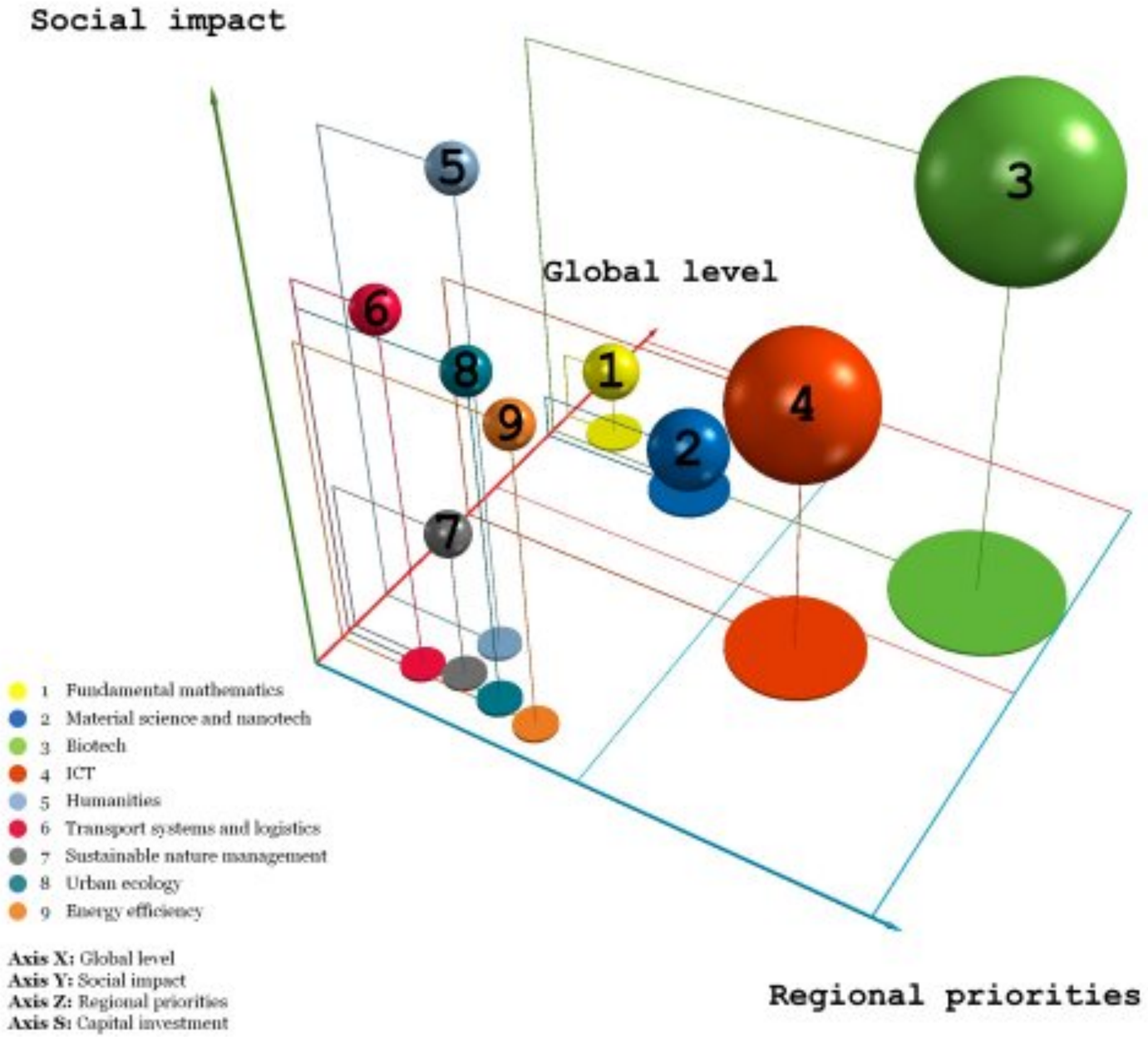


Suffolk New York
27,485 confirmed cases

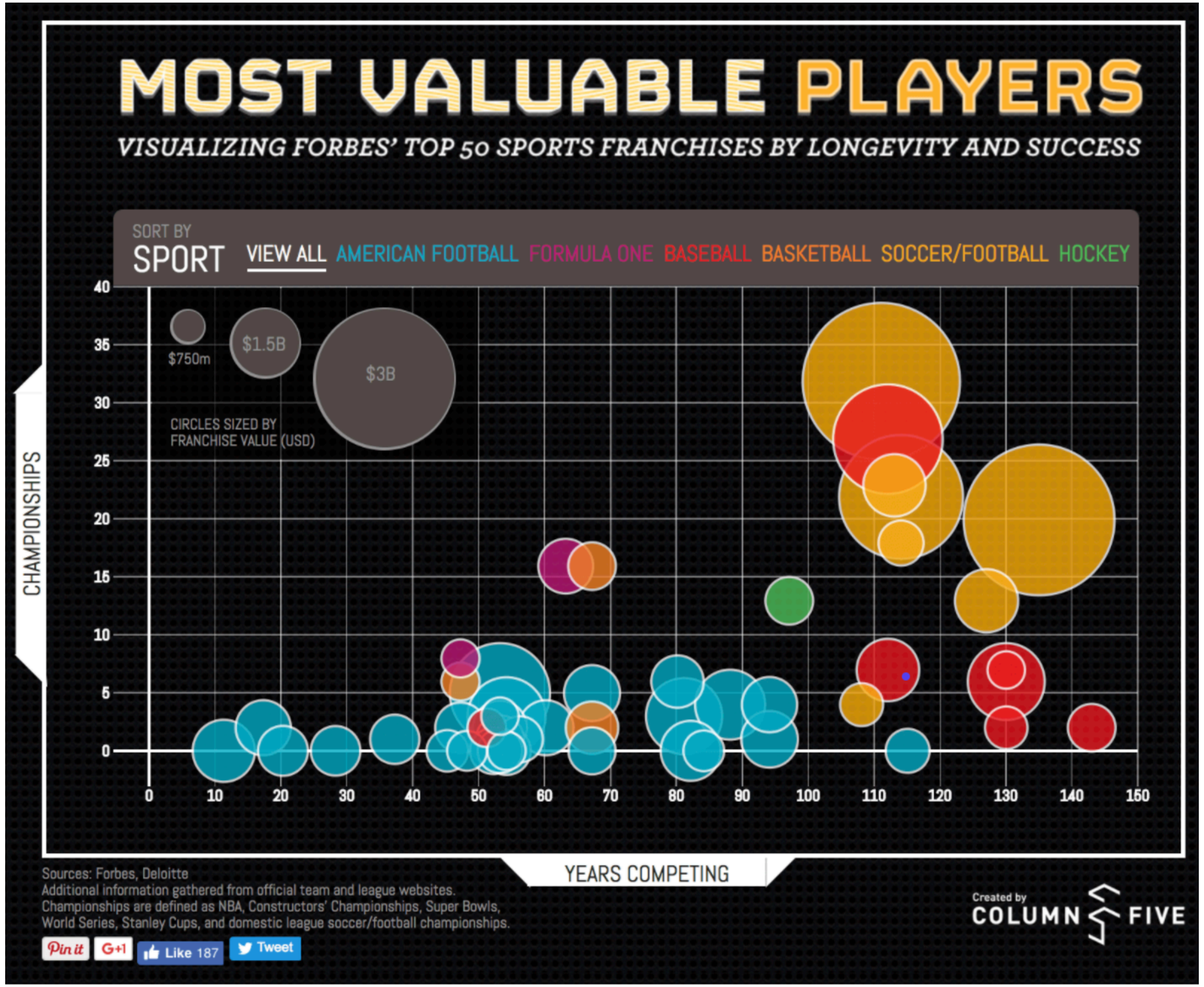
https://coronavirus.jhu.edu/map.html

Distribution





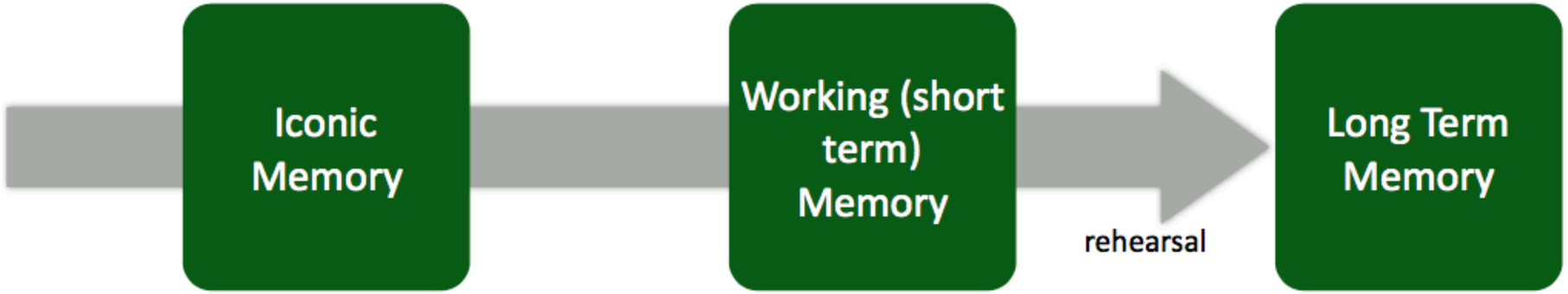
http://livingqlikview.com/the-9-worst-data-visualizations-ever-created/



https://www.columnfivemedia.com/work/interactive-most-valuable-sports-franchises/

Stop

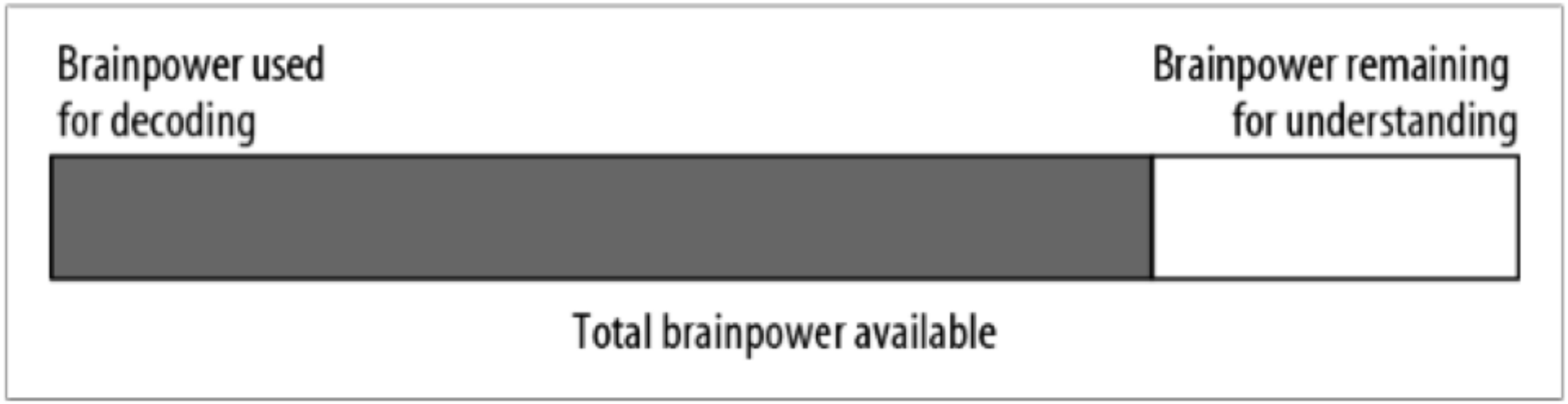
Visual Processing System



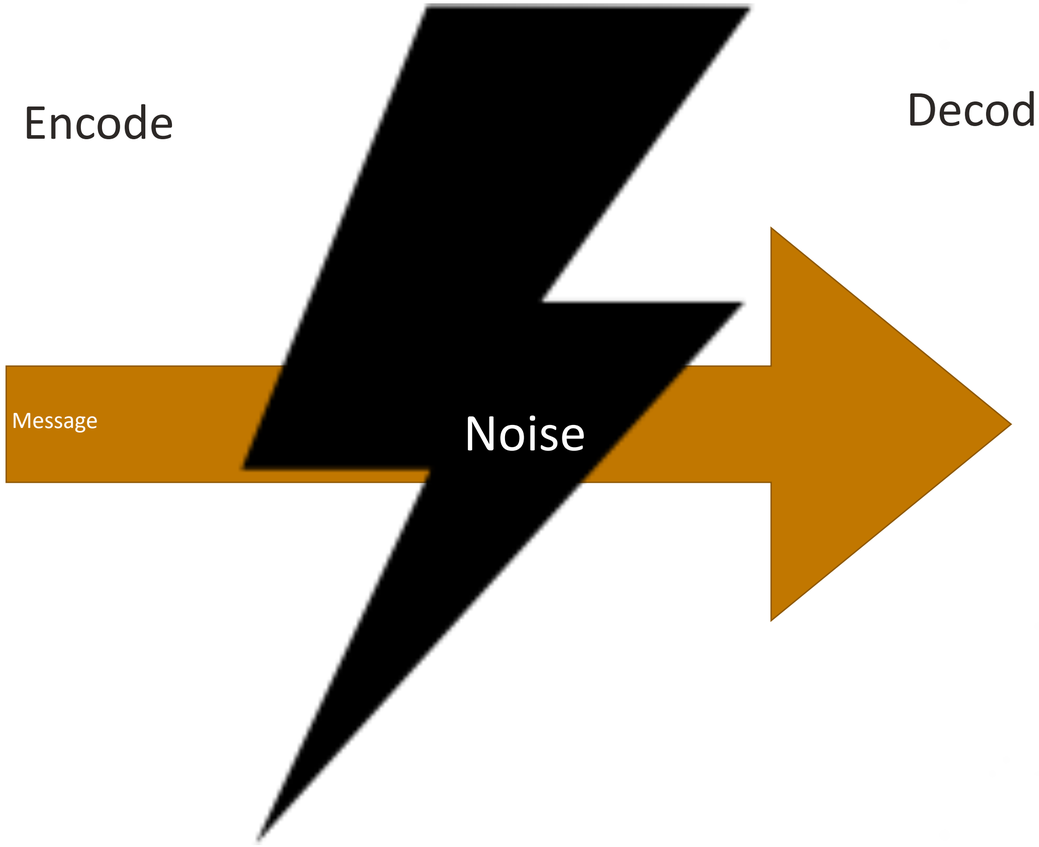
- < 1 second (or until replaced)
- Preattentive processing
- Saccadic movement
- ~20 objects

- Visual groupings
- Flexible, conscious
- 3-5 objects

- Affects dataviz through expectations


Brainpower used
for decoding
Brainpower remaining
for understanding
Total brainpower available

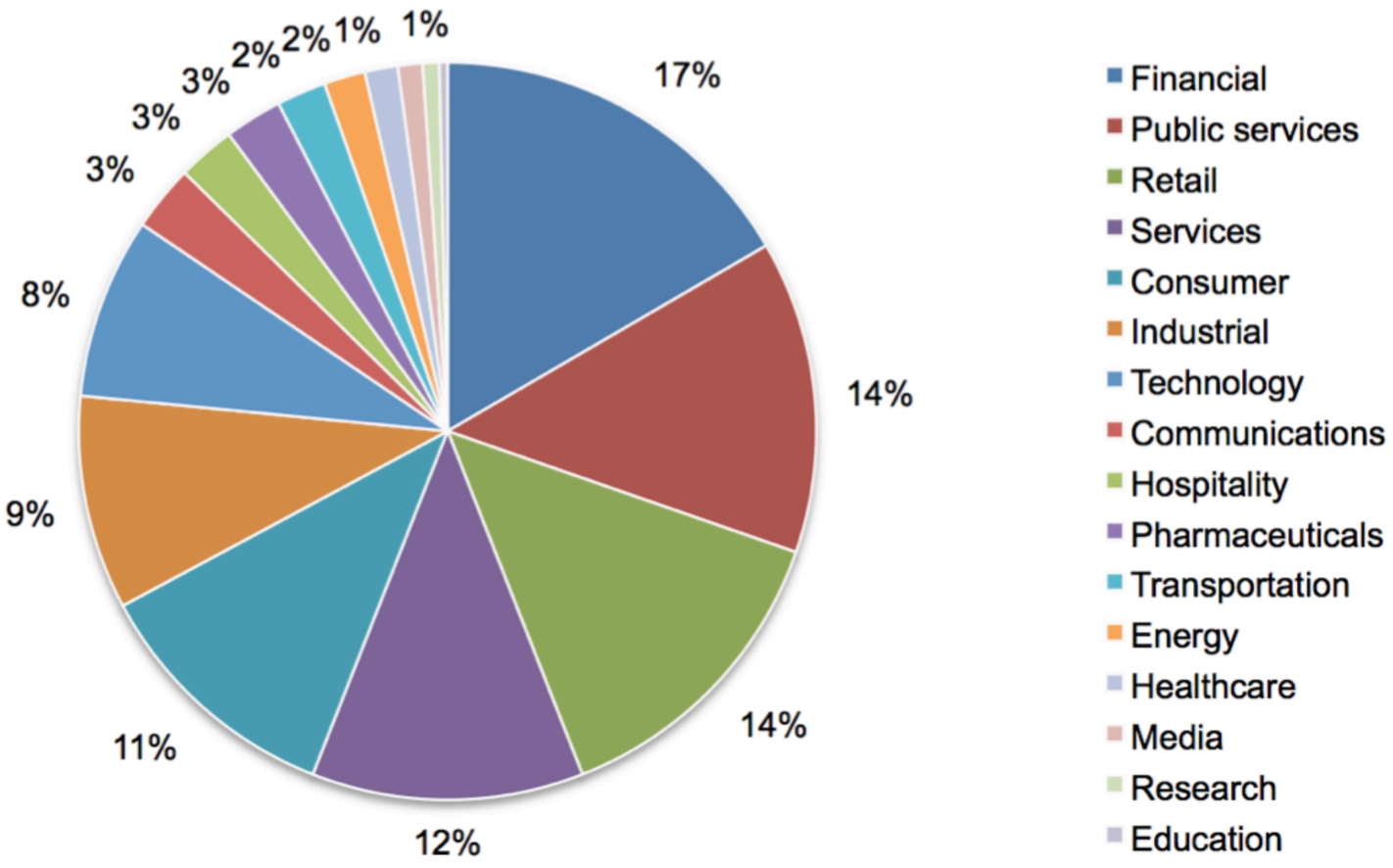
Encode



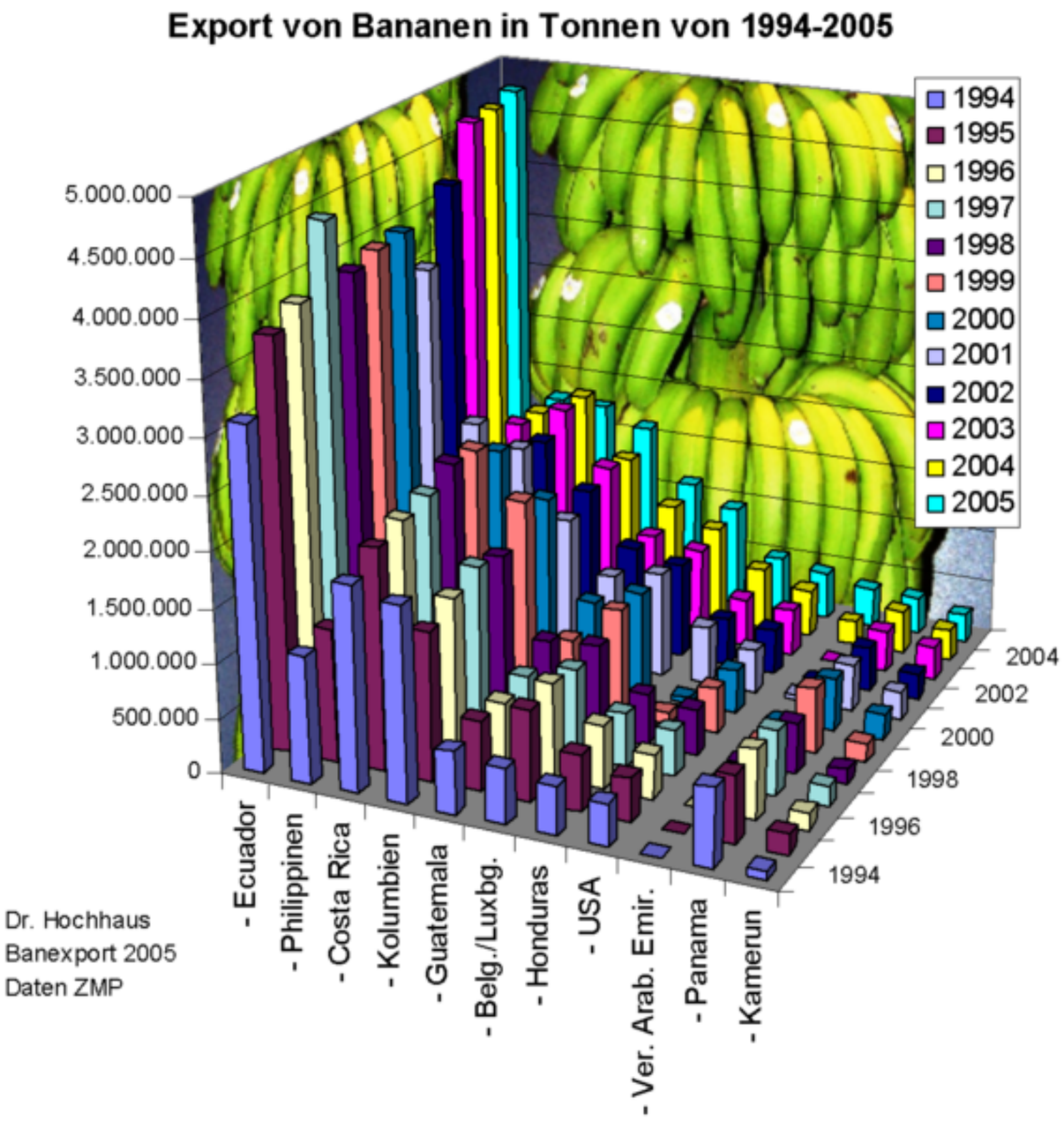
Decode

Overworking Visual Memory

Figure 20. Distribution of the benchmark sample by industry segment
Consolidated (n = 277 organizations)

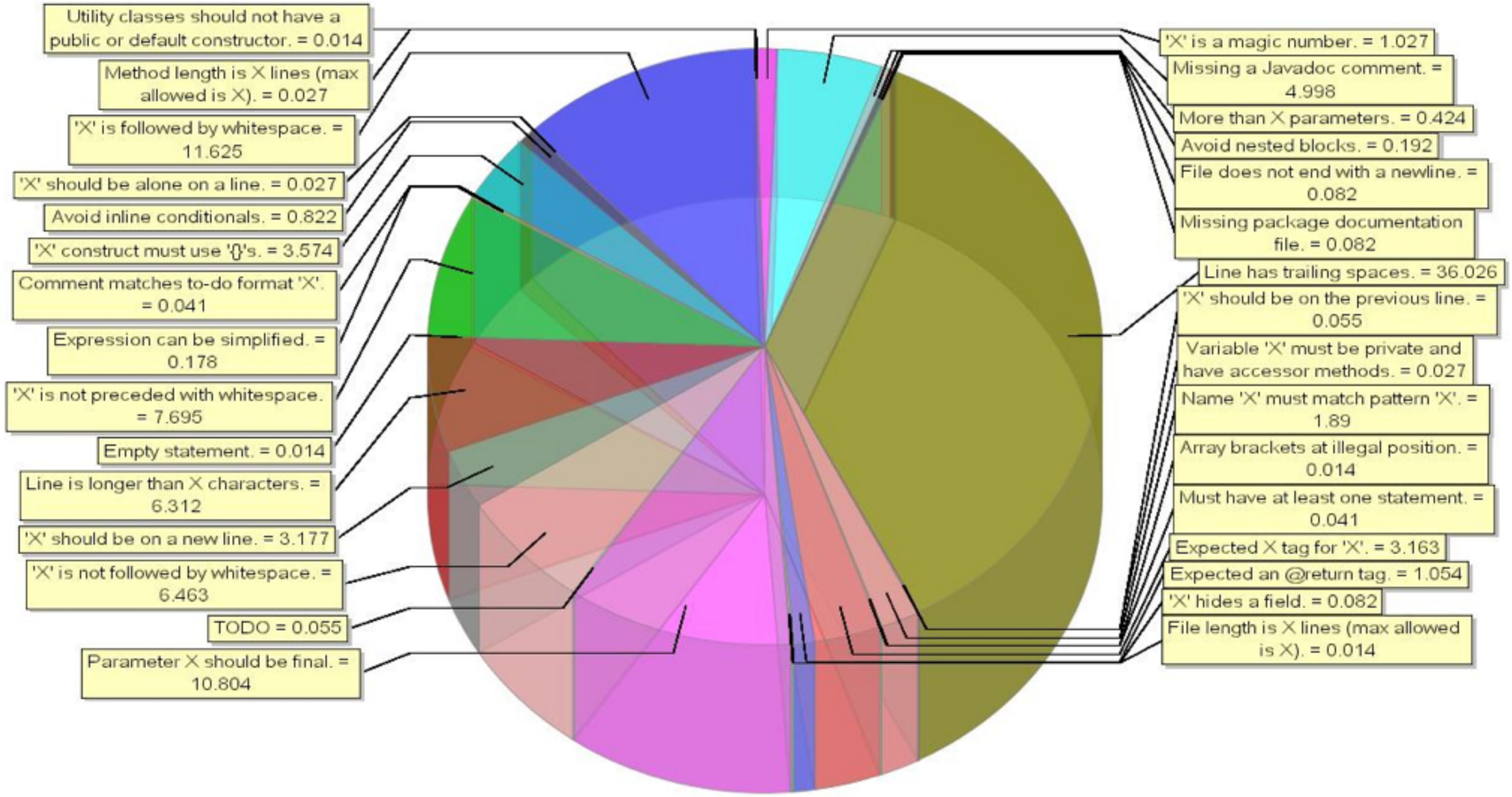


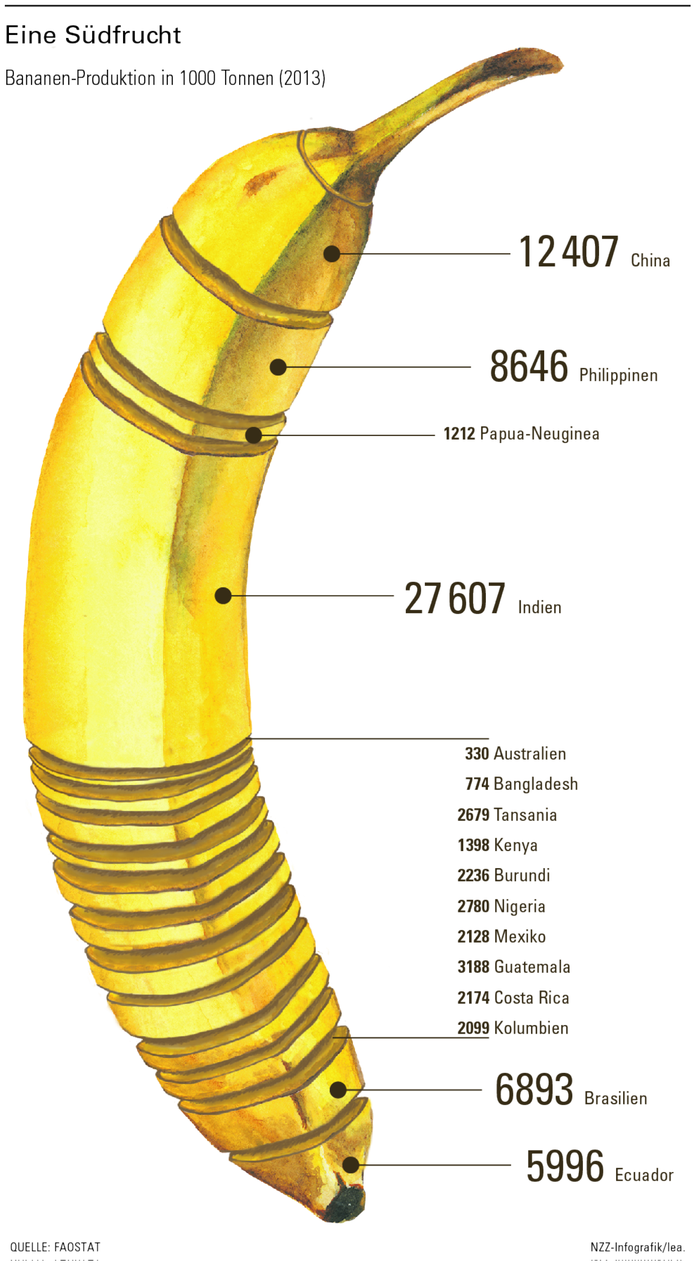
https://www4.symantec.com/mktginfo/whitepaper/053013_GL_NA_WP_Ponemon-2013-Cost-of-a-Data-Breach-Report_daiNA_cta72382.pdf



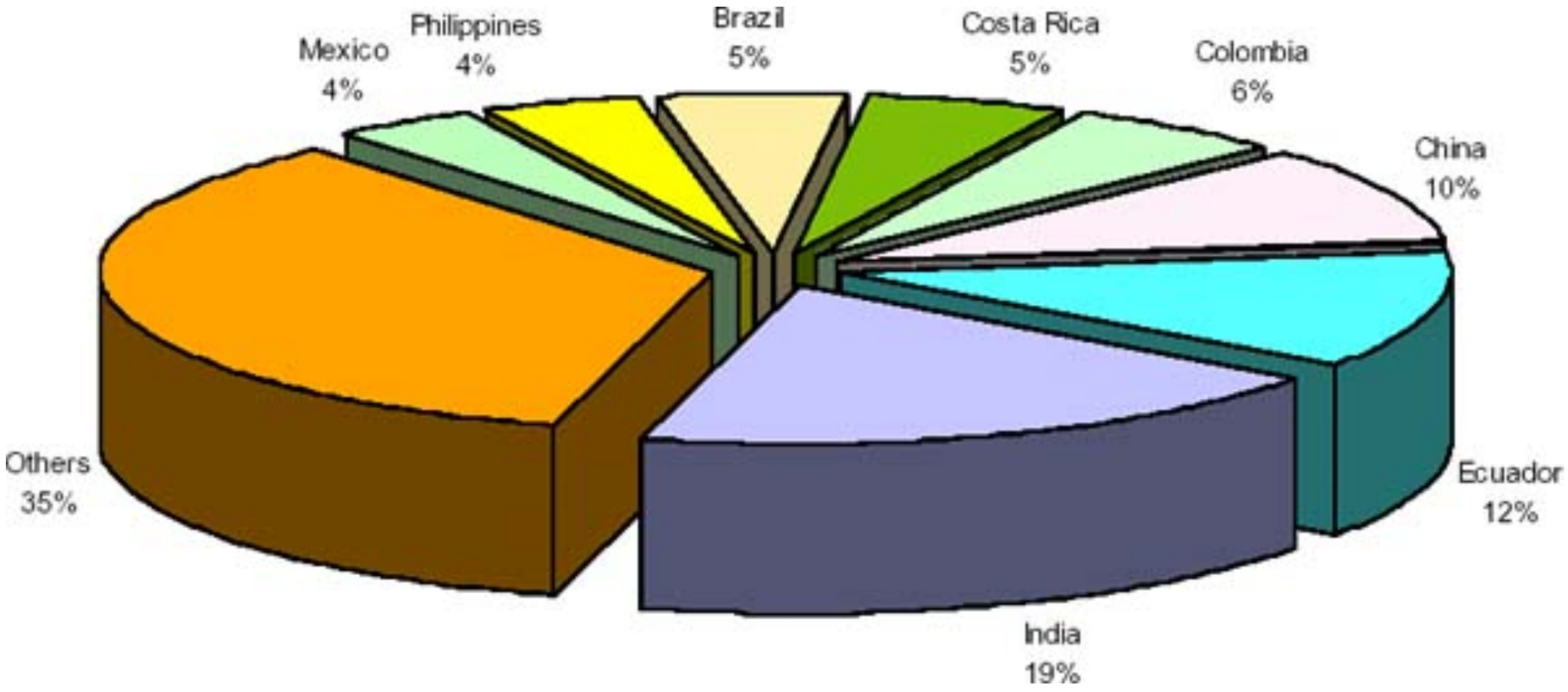
http://www.fao.org/faostat/en/#data/QC
https://hochhaus-schiffsbetrieb.jimdo.com/200-jahre-internationale-bananenschifffahrt-273/
https://excelcharts.com/change-bad-charts-in-the-wikipedia/

Simple


Utility classes should not have a public or default constructor. = 0.014
Method length is X lines (max allowed is X). = 0.027
'X' is followed by whitespace. = 11.625
'X' should be alone on a line. = 0.027
Avoid inline conditionals. = 0.822
'X' construct must use '{}'s. = 3.574
Comment matches to-do format 'X'. = 0.041
Expression can be simplified. = 0.178
'X' is not preceded with whitespace. = 7.695
Empty statement. = 0.014
Line is longer than X characters. = 6.312
'X' should be on a new line. = 3.177
'X' is not followed by whitespace. = 6.463
TODO = 0.055
Parameter X should be final. = 10.804
'X' is a magic number. = 1.027
Missing a Javadoc comment. = 4.998
More than X parameters. = 0.424
Avoid nested blocks. = 0.192
File does not end with a newline. = 0.082
Missing package documentation file. = 0.082
Line has trailing spaces. = 36.026
'X' should be on the previous line. = 0.055
Variable 'X' must be private and have accessor methods. = 0.027
Name 'X' must match pattern 'X'. = 1.89
Array brackets at illegal position. = 0.014
Must have at least one statement. = 0.041
Expected X tag for 'X'. = 3.163
Expected an @return tag. = 1.054
'X' hides a field. = 0.082
File length is X lines (max allowed is X). = 0.014

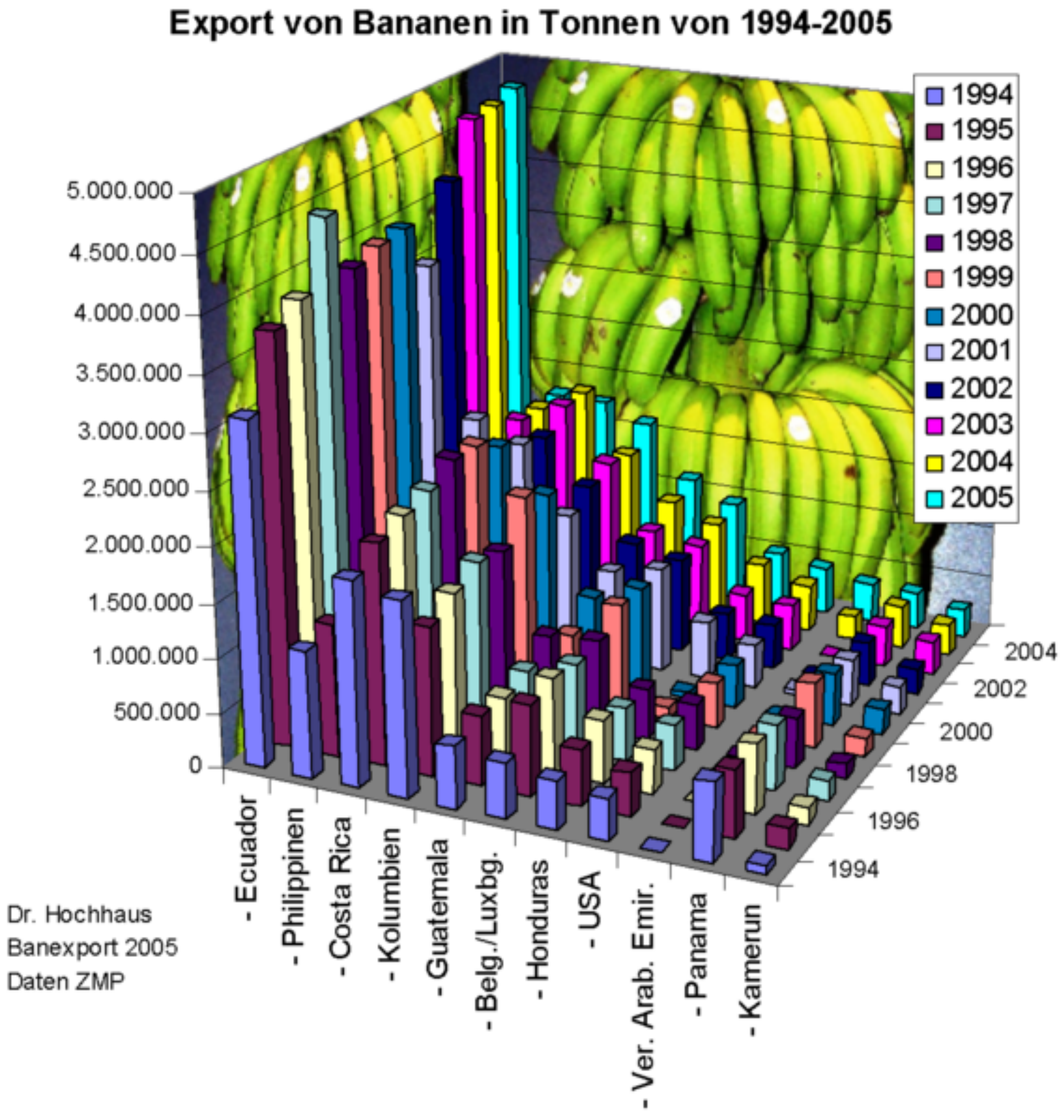


https://www.reddit.com/r/dataisbeautiful/comments/46jnrc/worldwide_banana_production_oc/



http://www.fao.org/3/y5102e/y5102e04.htm

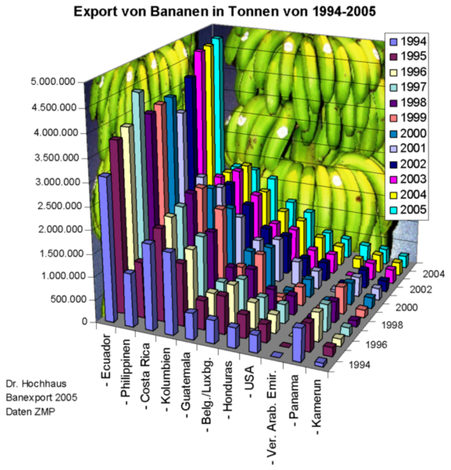
How could we fix this?



https://hochhaus-schiffsbetrieb.jimdo.com/200-jahre-internationale-bananenschifffahrt-273/

https://excelcharts.com/change-bad-charts-in-the-wikipedia/

How could we fix this?



Production of bananas in the world

data of 2013

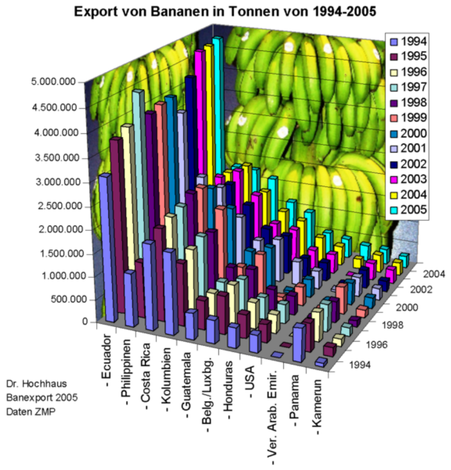
World rank	Countries	Production of bananas in thousand of ton
1	India	27575
2	China	12075
3	Philippines	8646
4	Brazil	6893
5	Ecuador	5996
6	Indonesia	5359
7	Guatemala	3188
8	Angola	3095
9	Tanzania	2679
10	Burundi	2236
11	Costa Rica	2175
12	Mexico	2128
13	Colombia	2099
14	Viêt Nam	1893
15	Thaïlande	1585

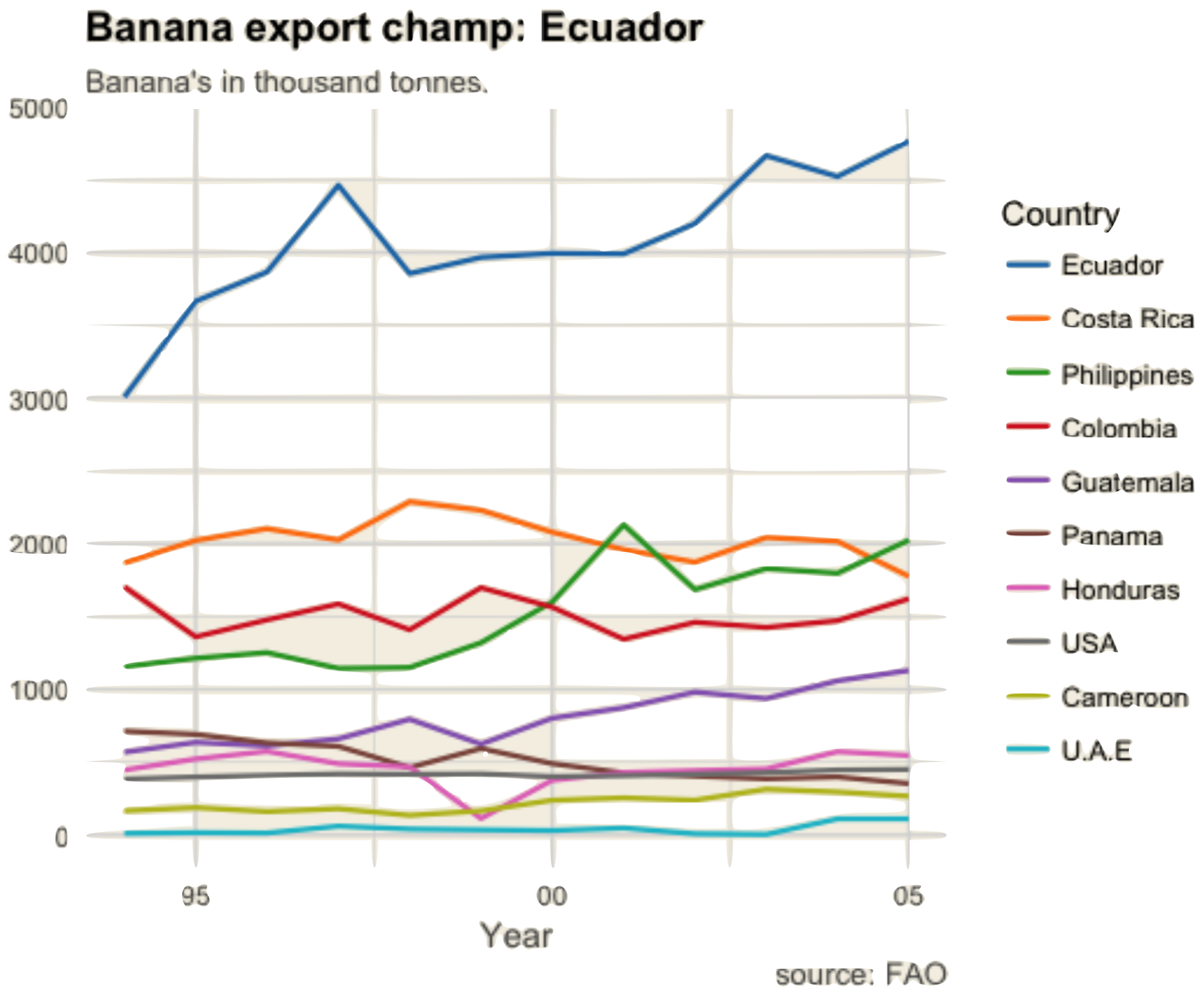
Post by PacoJoke

https://www.reddit.com/r/dataisbeautiful/comments/6dv56j/production_of_bananas_in_the_world_oc/

https://hochhaus-schiffsbetrieb.jimdo.com/200-jahre-internationale-bananenschifffahrt-273/

How could we fix this?

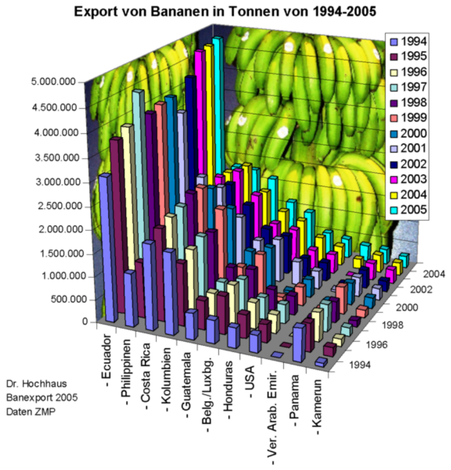


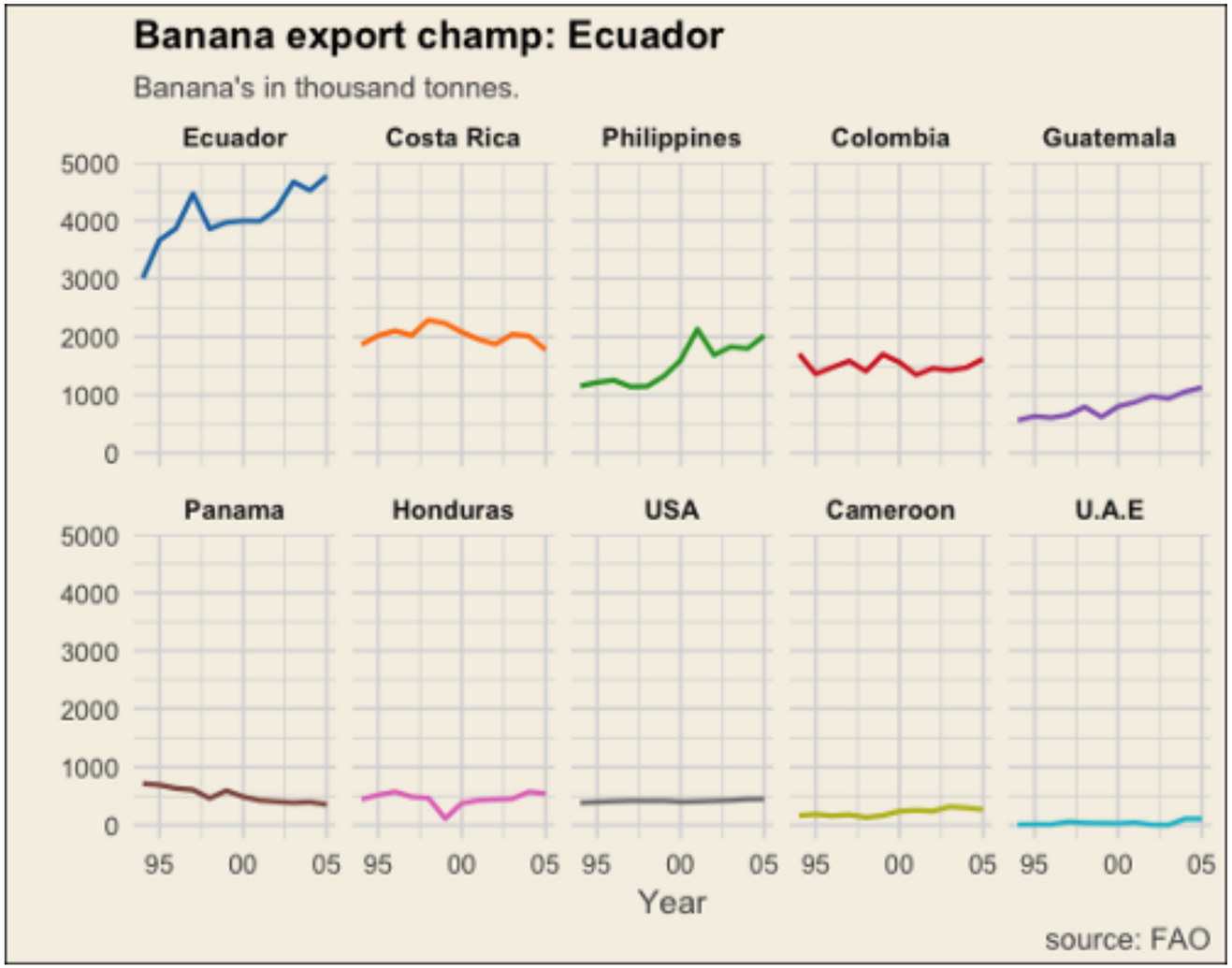


https://medium.com/tdebeus/redesign-of-a-truly-bananas-chart-1617f930808d

https://hochhaus-schiffsbetrieb.jimdo.com/200-jahre-internationale-bananenschifffahrt-273/

How could we fix this? Small Multiples

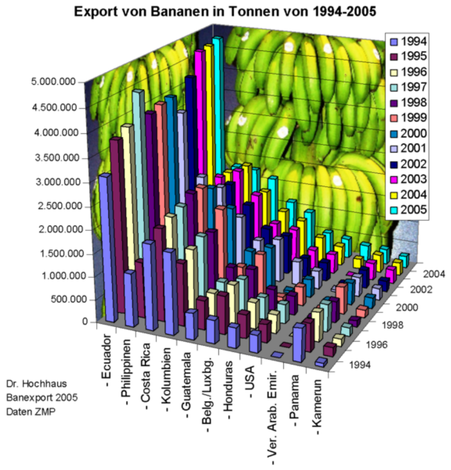


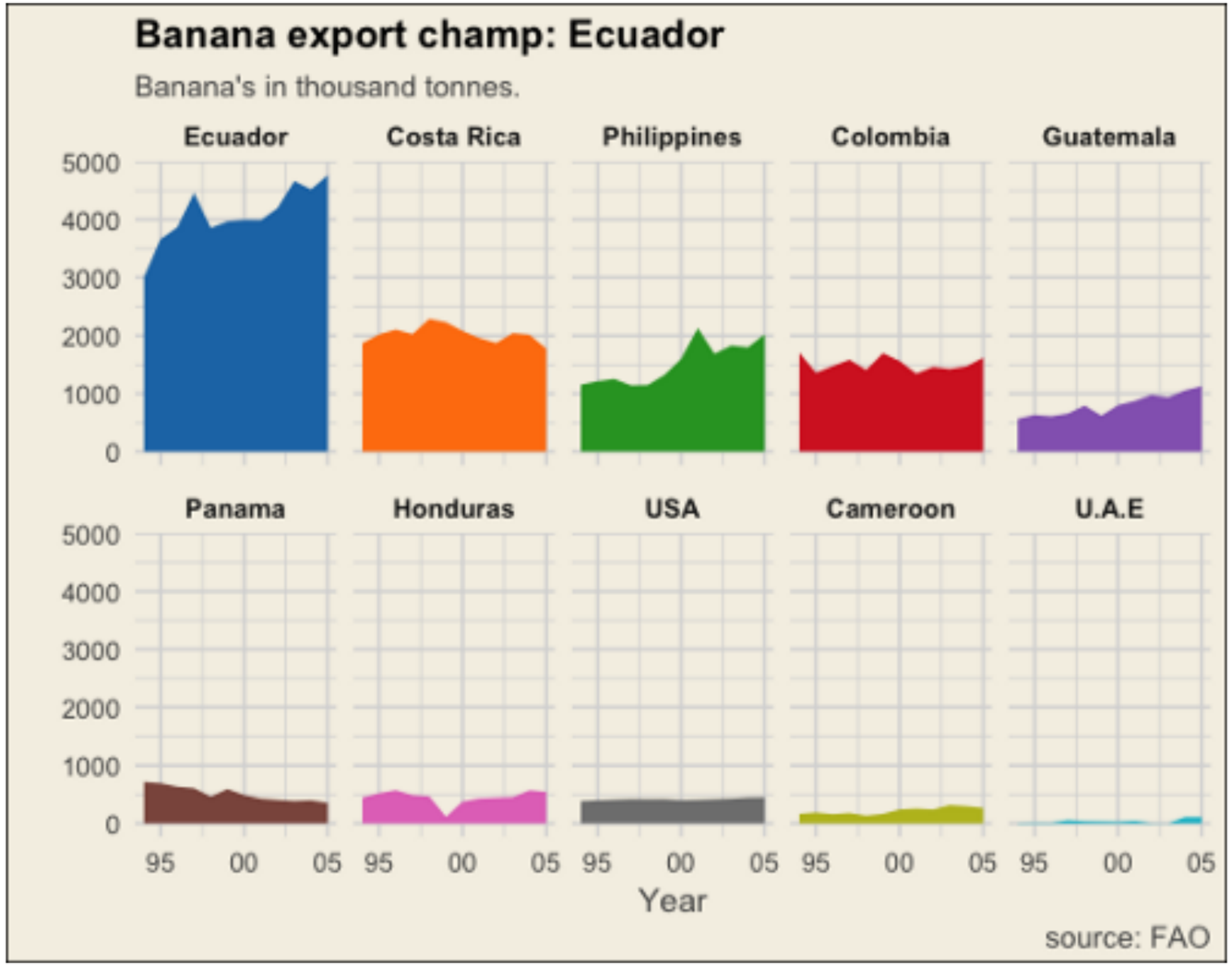


https://medium.com/tdebeus/redesign-of-a-truly-bananas-chart-1617f930808d

https://hochhaus-schiffsbetrieb.jimdo.com/200-jahre-internationale-bananenschifffahrt-273/

How could we fix this? Small Multiples





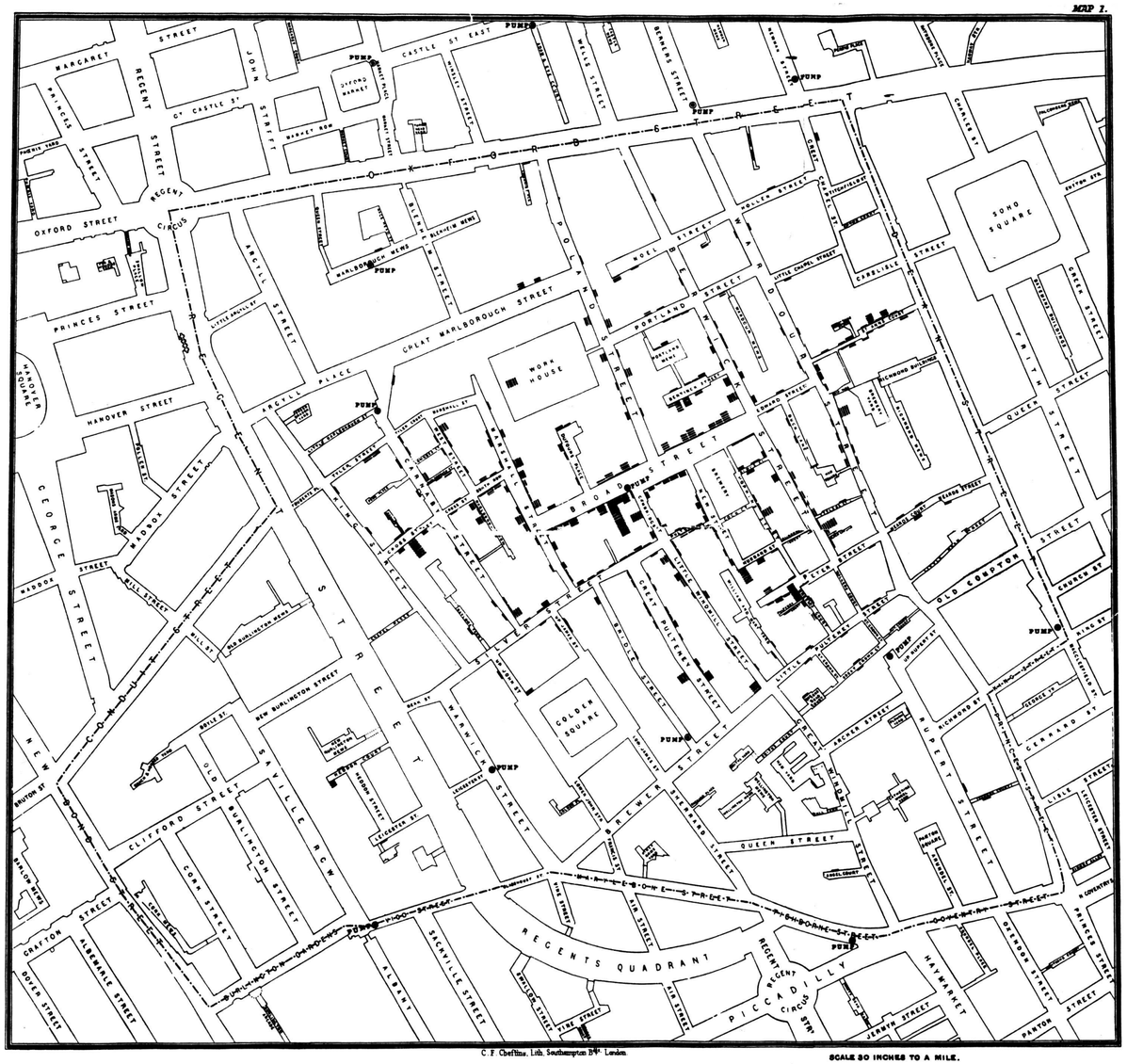
https://medium.com/tdebeus/redesign-of-a-truly-bananas-chart-1617f930808d

https://hochhaus-schiffsbetrieb.jimdo.com/200-jahre-internationale-bananenschifffahrt-273/

Stop

Proper Display

Google Finance



- Created by John Snow in 1854
- This visualization proved that cholera was water-borne
- Snow identified the source of the outbreak as a water pump on Broad Street
- Spurred city to create a true sewage system

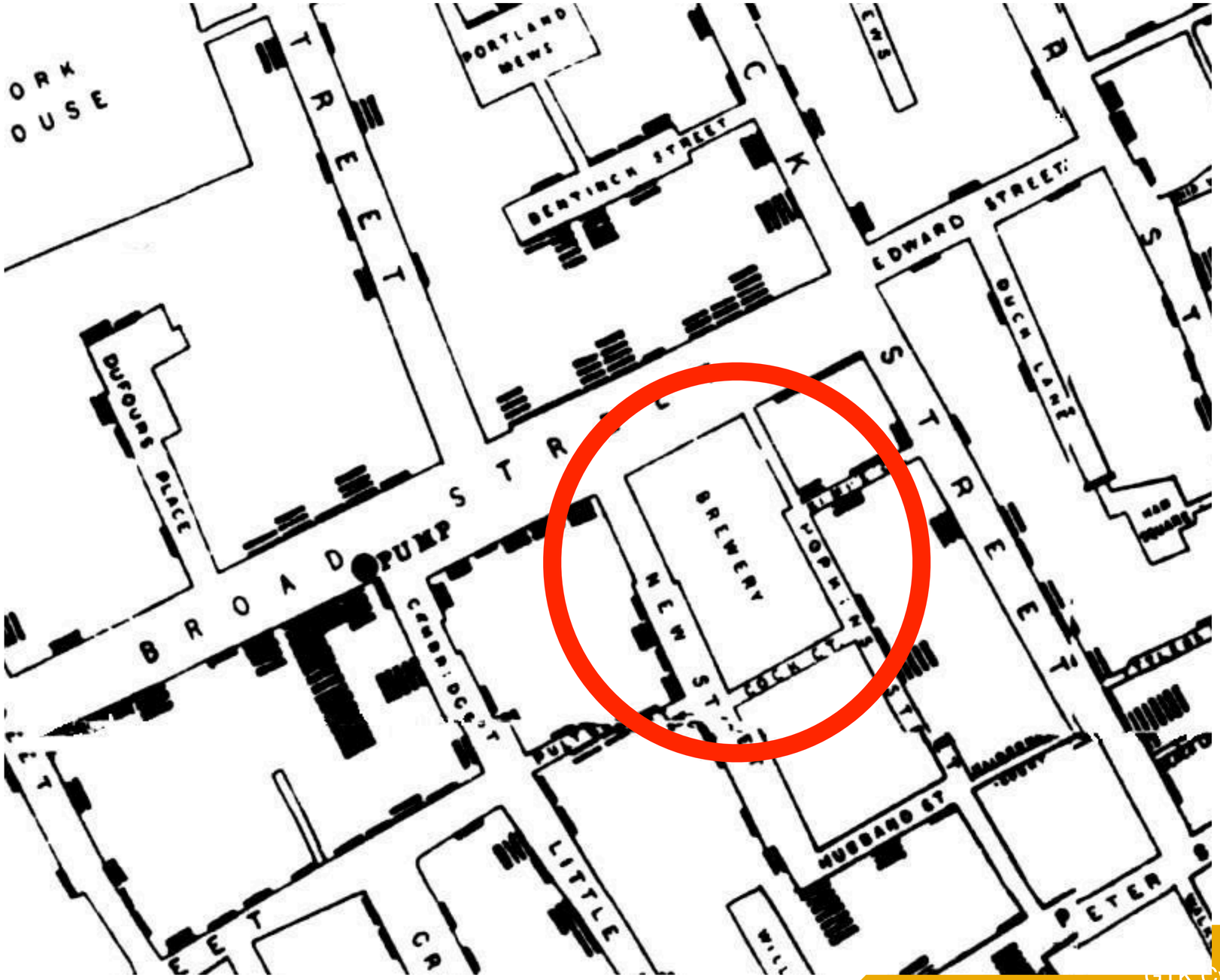
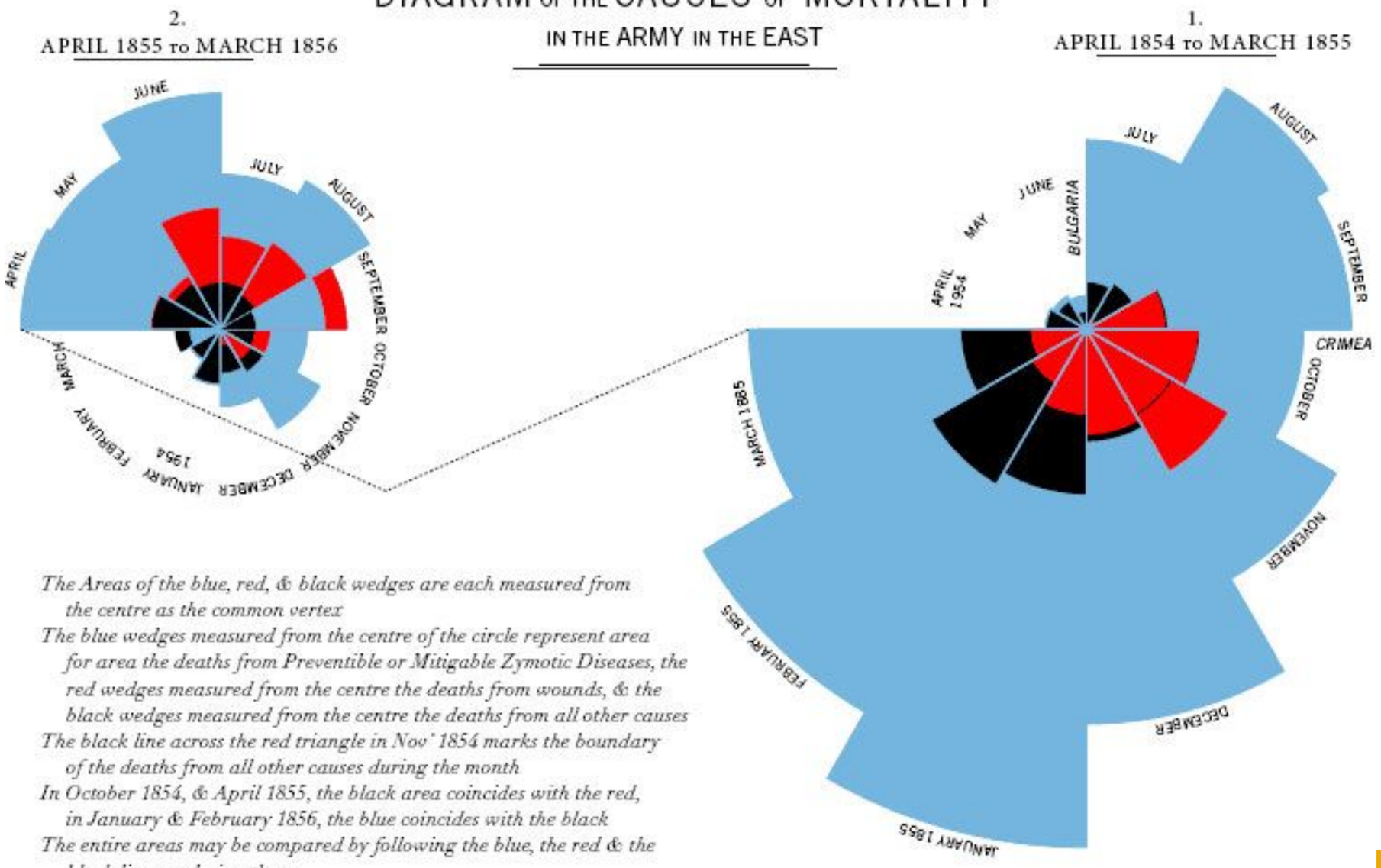

PORTLAND MEWS
BENTINCK STREET
EDWARD STREET
DUCK LANE
DUFOURS PLACE
BROAD STREET
PUMP
BREWERY
NEW STREET
HOPKINS
HUBBARD ST
LITTLE
PETER

DIAGRAM OF THE CAUSES OF MORTALITY

IN THE ARMY IN THE EAST



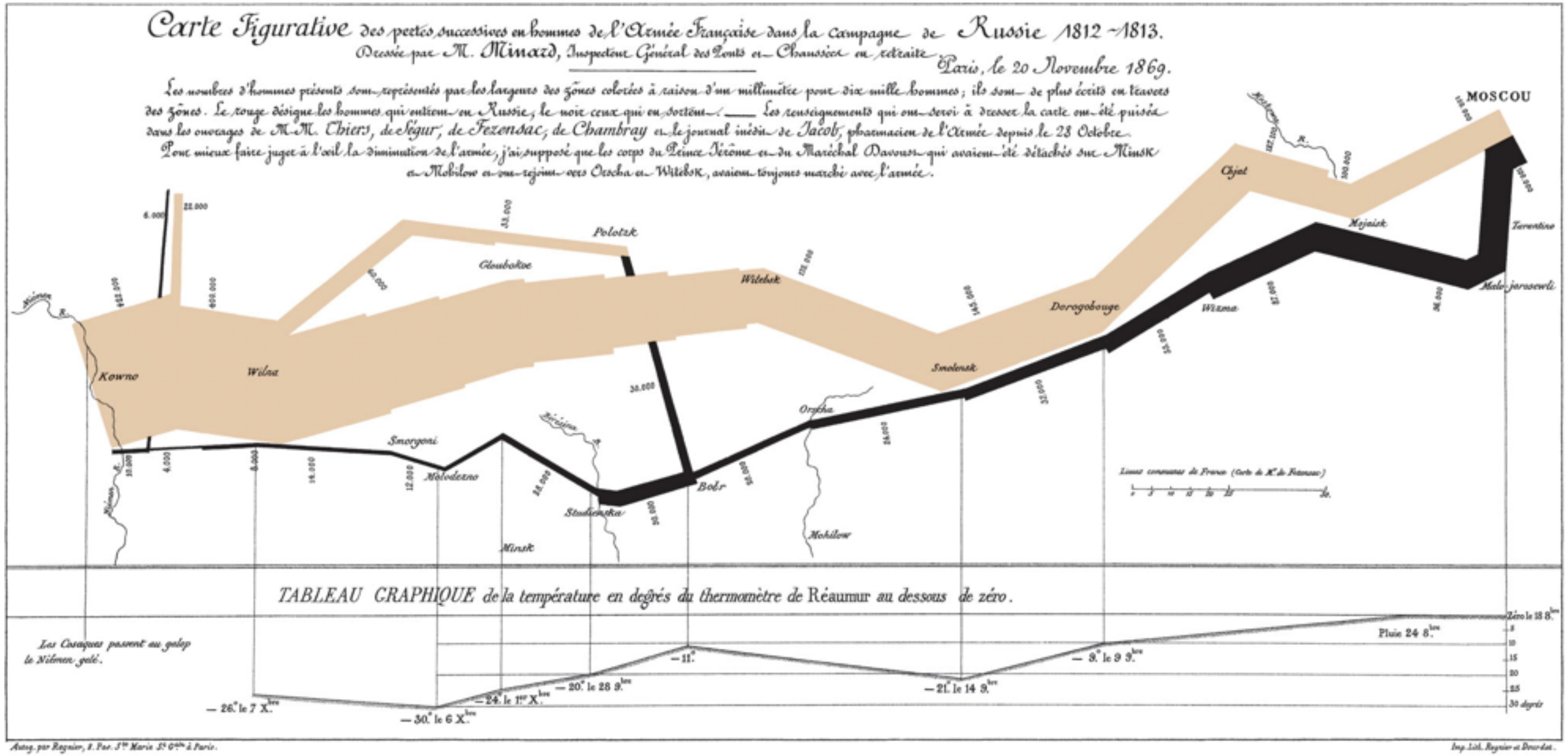
The Areas of the blue, red, & black wedges are each measured from the centre as the common vertex

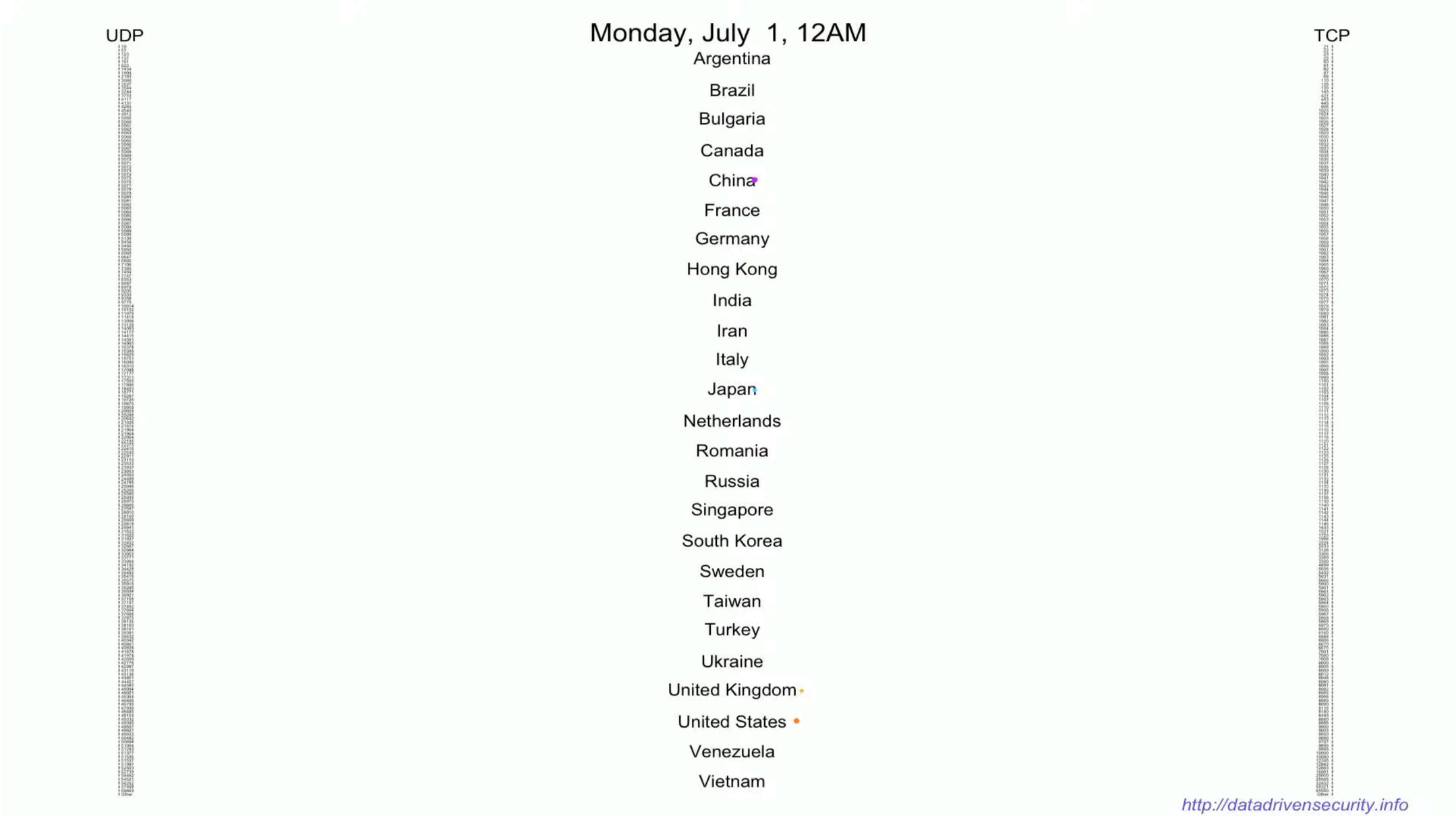
The blue wedges measured from the centre of the circle represent area for area the deaths from Preventible or Mitigable Zymotic Diseases, the red wedges measured from the centre the deaths from wounds, & the black wedges measured from the centre the deaths from all other causes

The black line across the red triangle in Nov' 1854 marks the boundary of the deaths from all other causes during the month

In October 1854, & April 1855, the black area coincides with the red, in January & February 1856, the blue coincides with the black

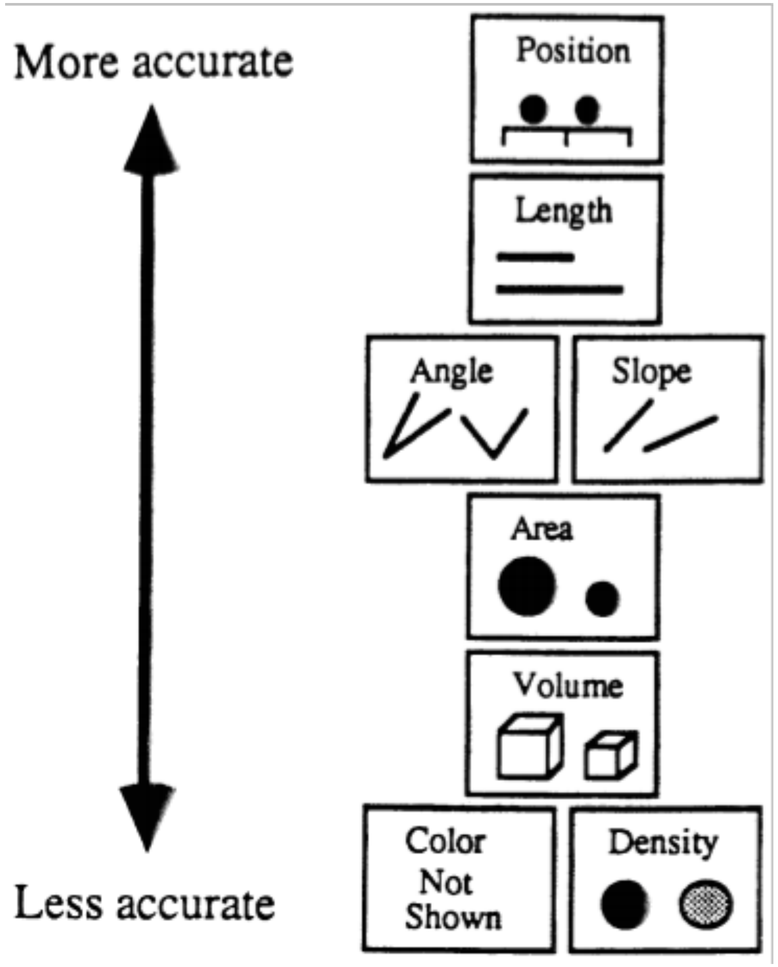
The entire areas may be compared by following the blue, the red & the black lines enclosing them.

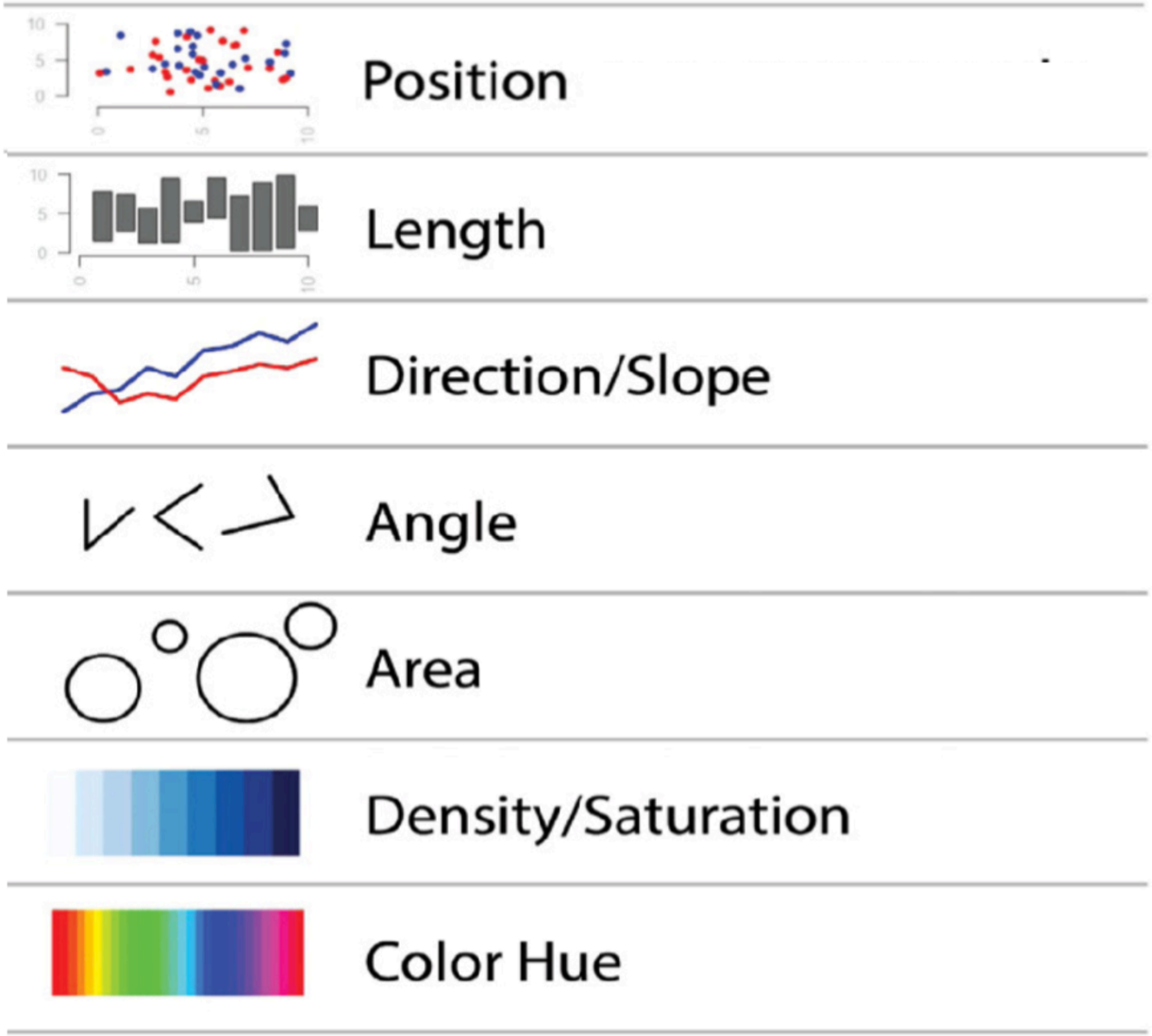

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.
Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite.
Paris, le 20 Novembre 1869.
Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.
Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mobilow et non rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.
MOSCOU
Kowno
Wilna
Gloubokoe
Polotzk
Witebsk
Smolensk
Dorogobouge
Wizma
Chjat
Mojaisk
Tarentino
Malo-jarosewli
Smoryoni
Molodezno
Studienska
Minsk
Bobr
Orscha
Mohilow
Niémen R.
Wilia R.
Moskowa R.
Lieues communes de France (Carte de M. de Fezensac)
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.
Les Cosaques passent au galop le Niémen gelé.
— 26.° le 7 X.bre
— 30.° le 6 X.bre
— 24.° le 1er X.bre
— 20.° le 28 9.bre
— 11.°
— 21.° le 14 9.bre
— 9.° le 9 9.bre
Pluie 24 8.bre
Zéro le 18 8.bre
30 degrés
Autog. par Regnier, 8. Pas. St Marie St Gdin à Paris.
Imp. Lith. Regnier et Dourdet.



https://datadrivensecurity.info/blog/posts/2014/Jun/marx-ports/

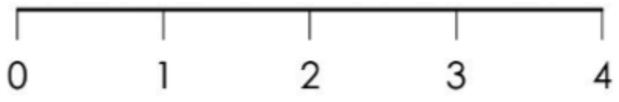
Visual Encoding


More accurate
Position
Length
Angle
Slope
Area
Volume
Color Not Shown
Density
Less accurate


Position
Length
Direction/Slope
Angle
Area
Density/Saturation
Color Hue

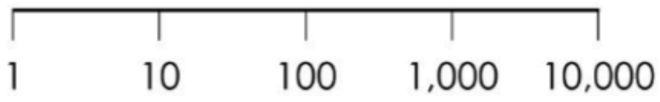
Linear

Values are evenly spaced



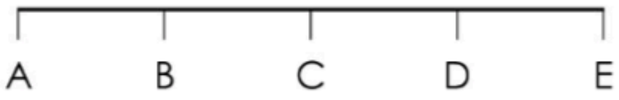
Logarithmic

Focus on percent change



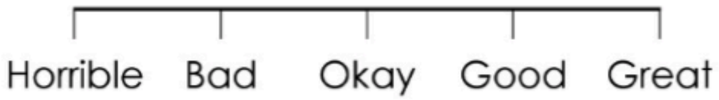
Categorical

Discrete placement in bins



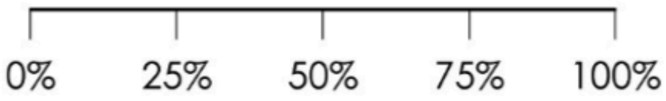
Ordinal

Categories where order matters



Percent

Representing parts of a whole

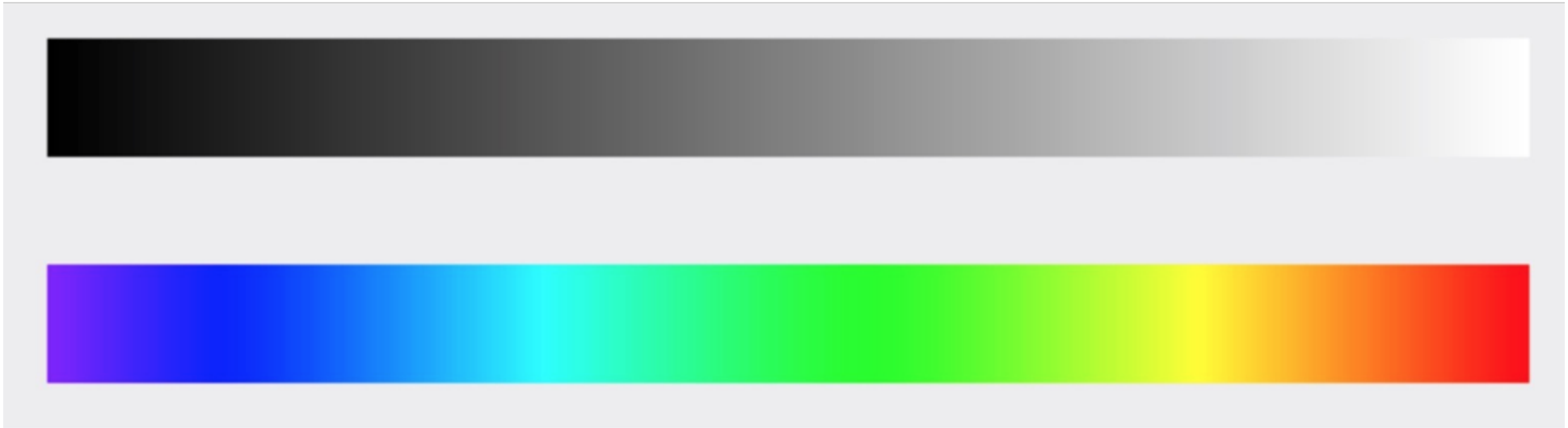


Time

Units of months, days, or hours

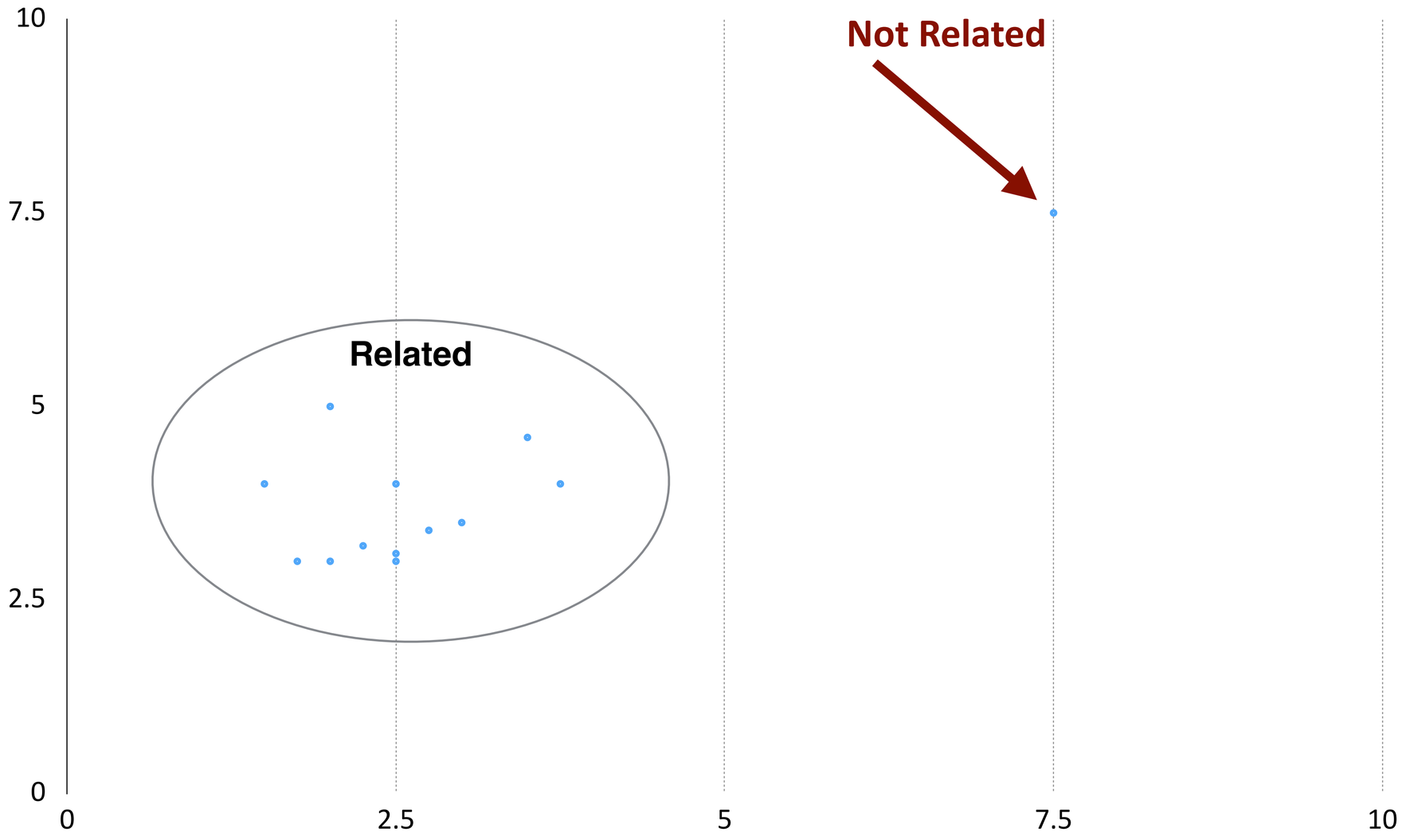
Source: Nathan Yau, Data Points

Color

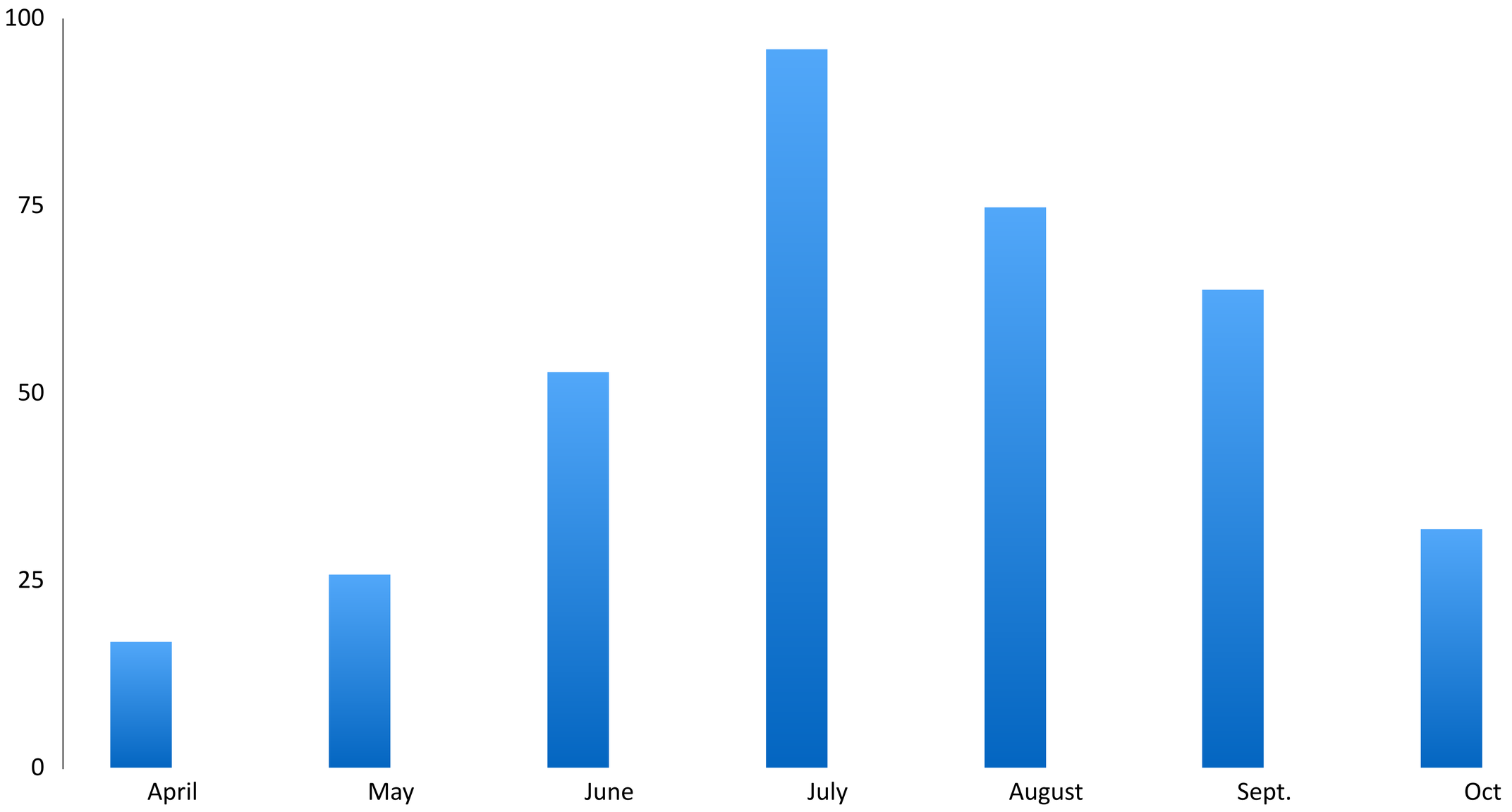


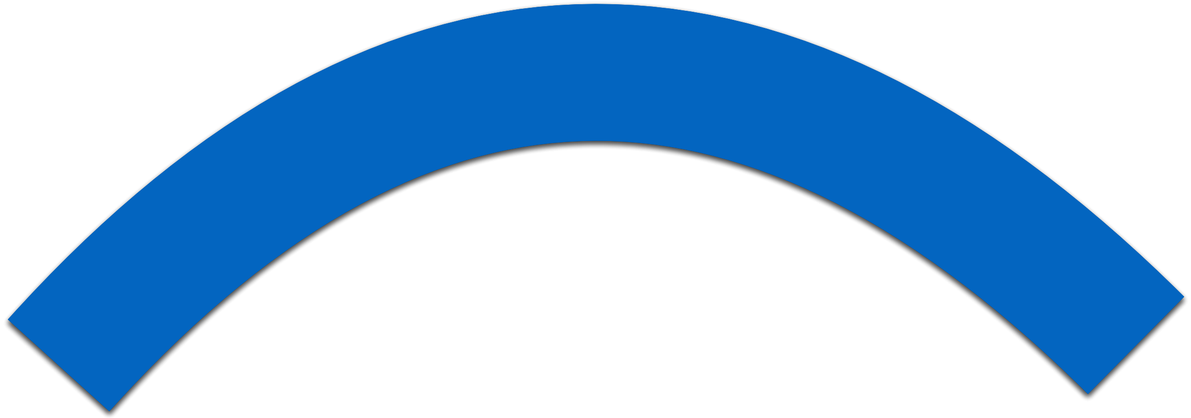
Stop

Encoding by Position

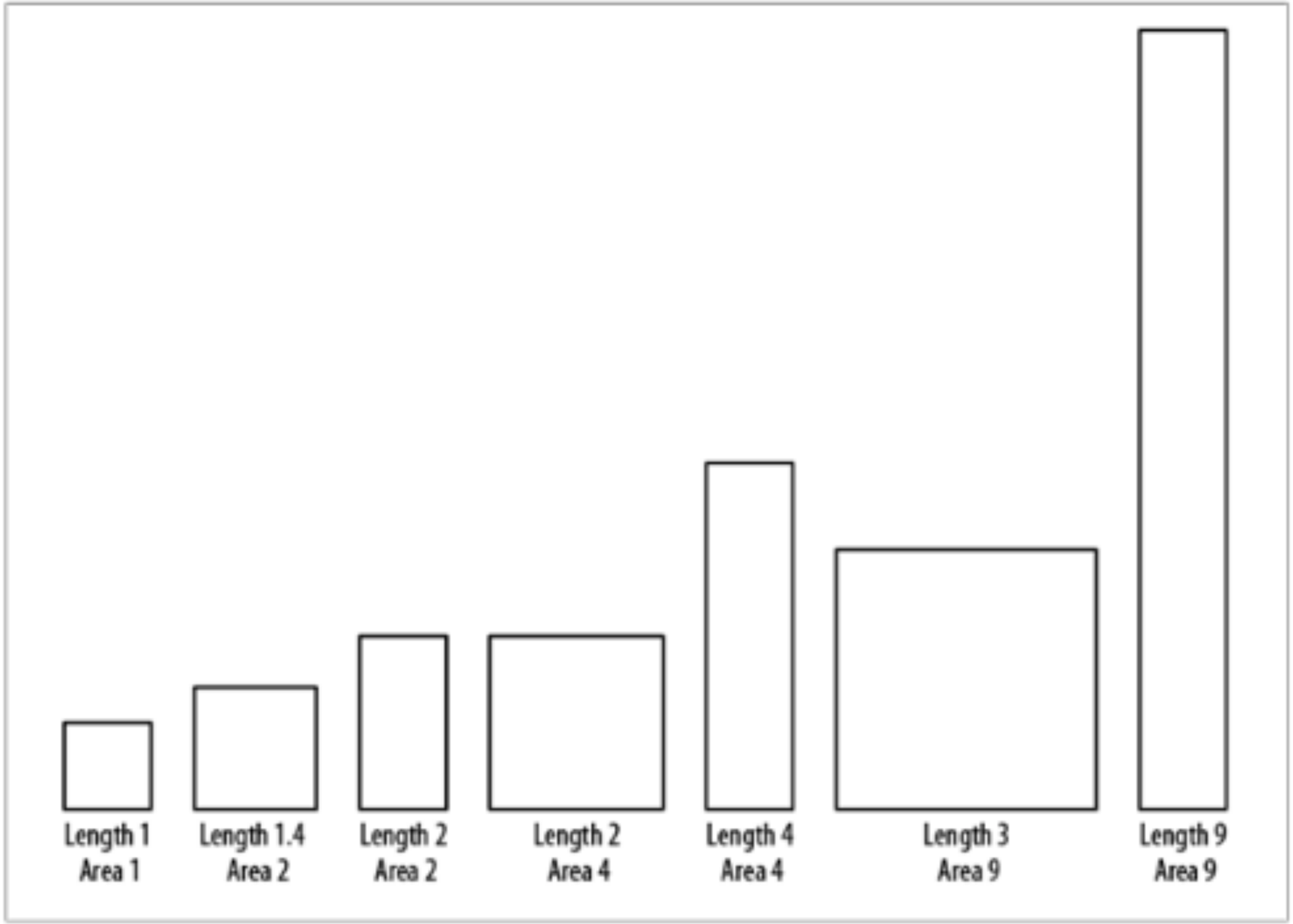

10
7.5
5
2.5
0
0
2.5
5
7.5
10
Not Related
Related

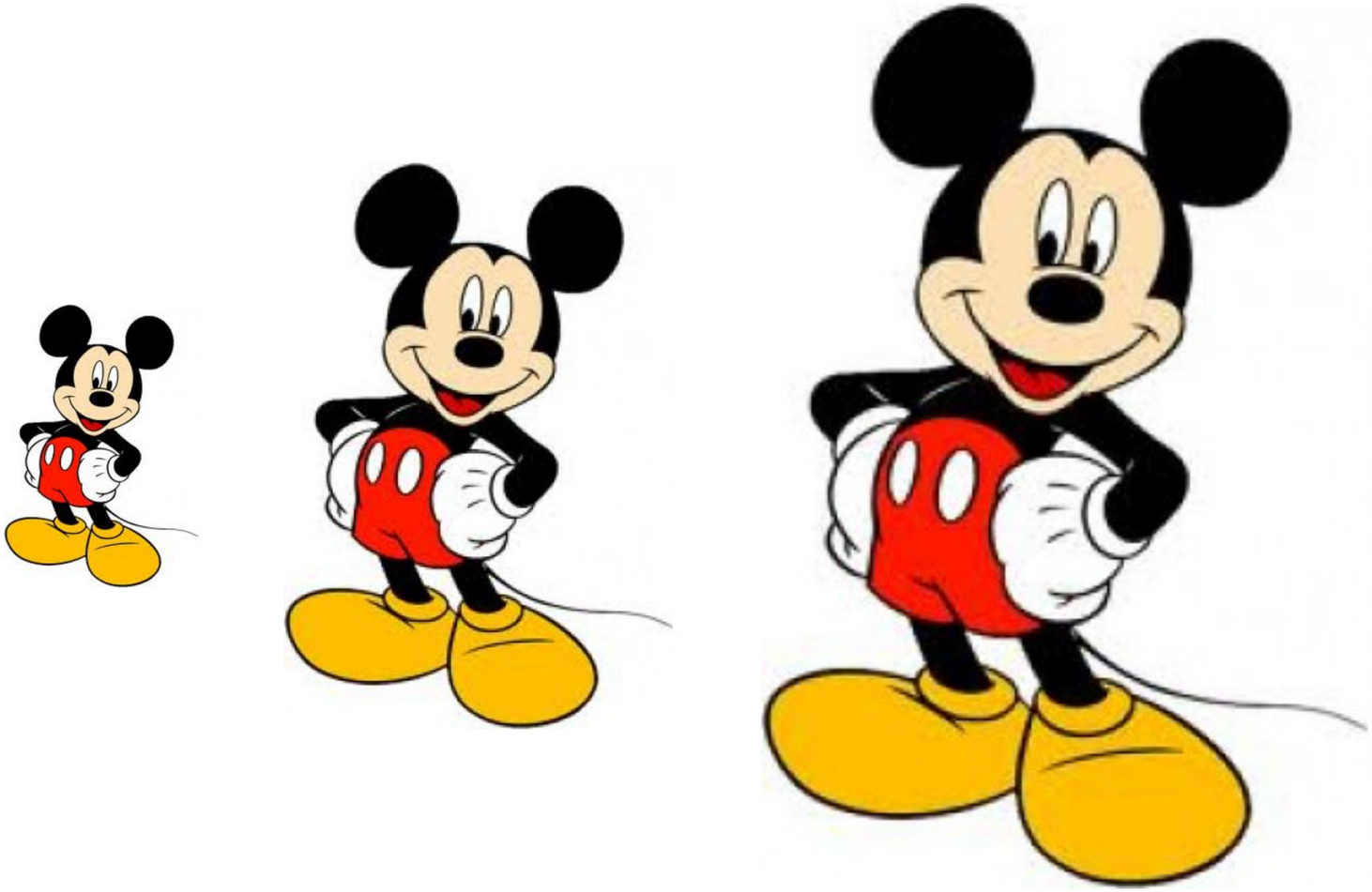
Encoding by Length


100
75
50
25
0
April
May
June
July
August
Sept.
Oct



Visual Encodings: Size


Length 1
Area 1
Length 1.4
Area 2
Length 2
Area 2
Length 2
Area 4
Length 4
Area 4
Length 3
Area 9
Length 9
Area 9



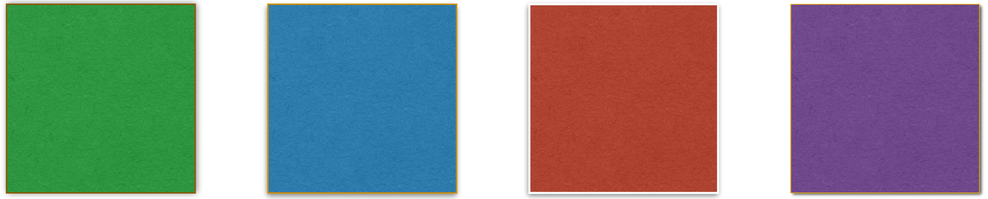
Stop

Visual Encodings: Color

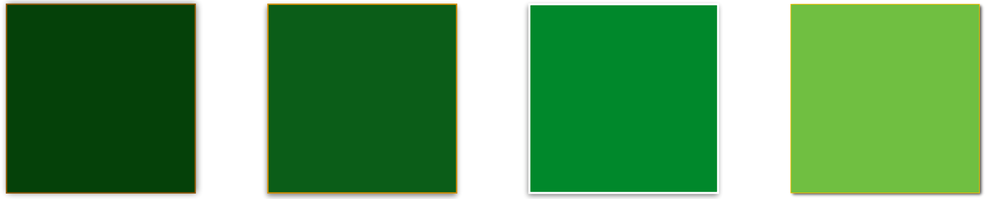
Encoding by Color

- **Hue** should be used to encode categorical data
- **Saturation** should be used to encode intensity or a continuous value

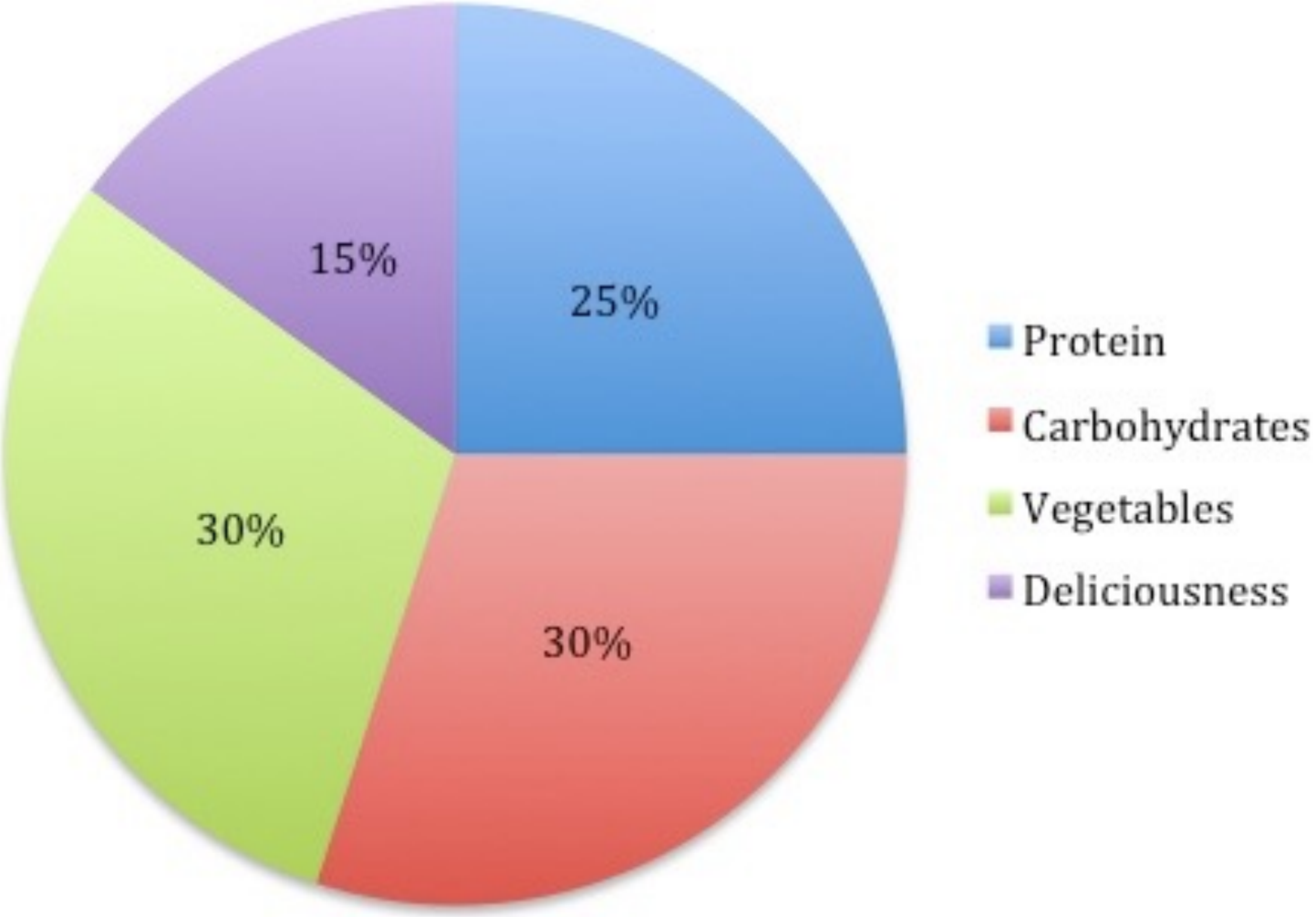
Hue



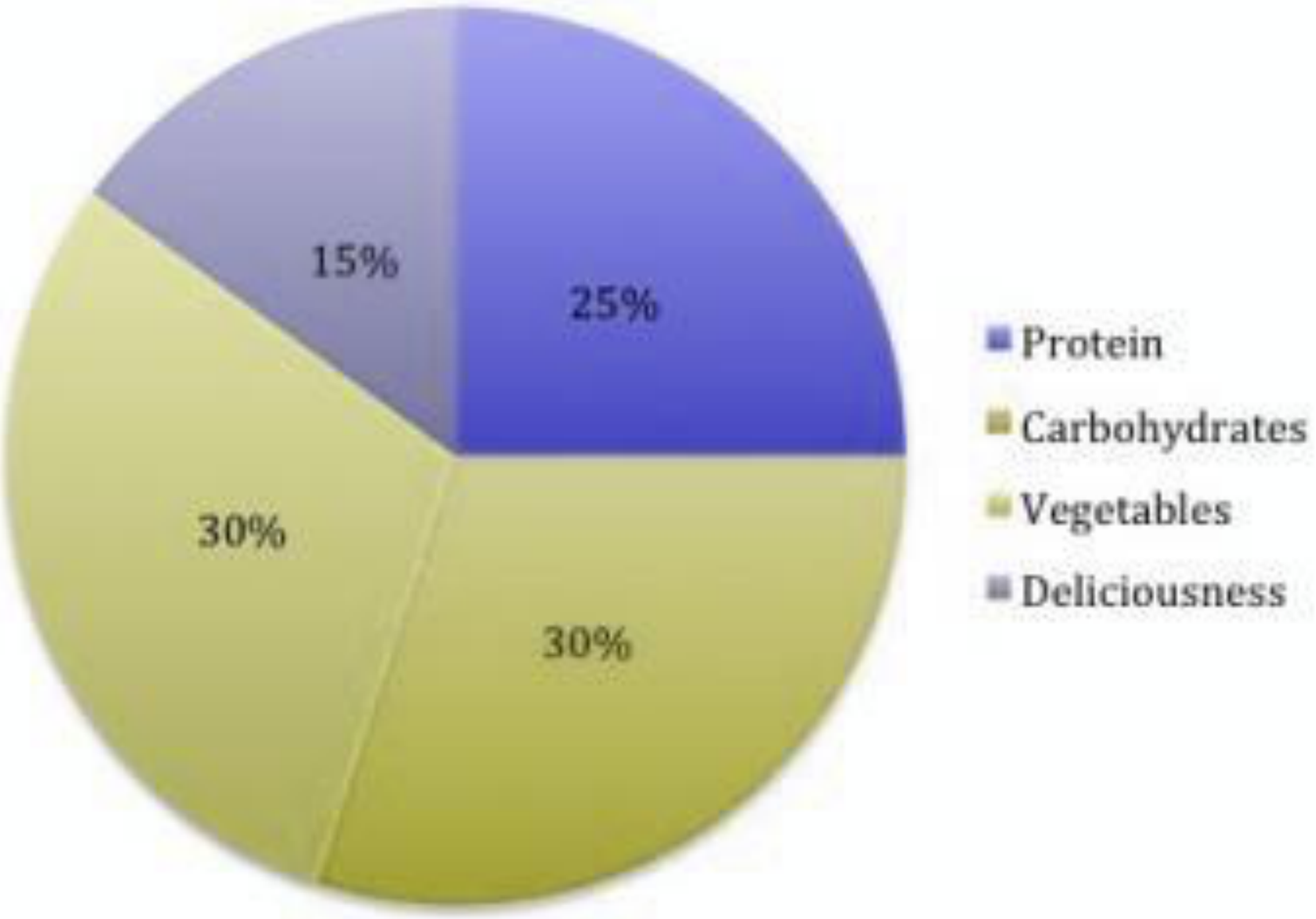
Saturation



A Healthy Meal



A Healthy Meal



elastica
Dashboard
Users
Total (192)
28
High Risk
0
Med Risk
4
Blocked
Policies
Total (231)
3
Blocking
142
Alerting
Policy Alerts
Alerting
443
Blocked
13
Rest
0
Threat Alerts
High Risk
2
Med Risk
2
Low Risk
17
Audited Services
by Users
High Risk (736)
Medium Risk (3k)
Low Risk (3k)
3k
494.3 GB
963k
243

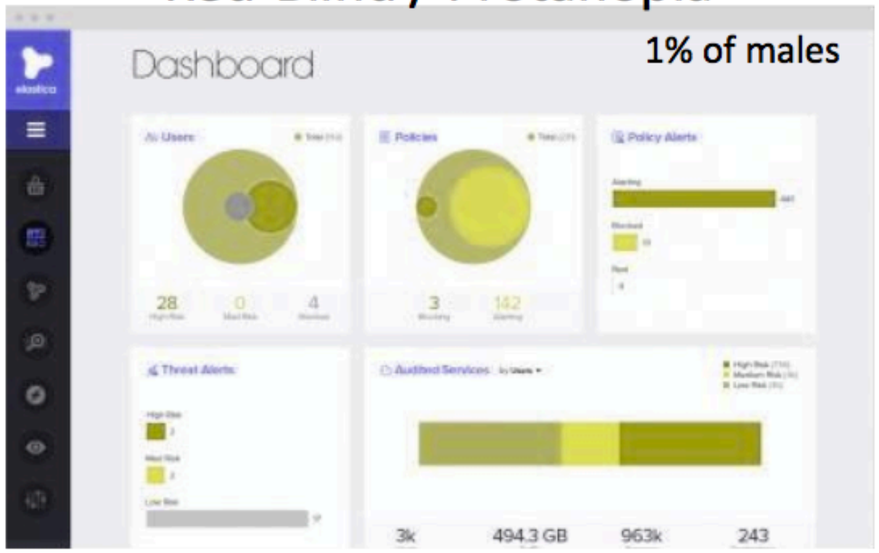
Original

Green-Blind / Deuteranopia

8% of male
0.5% female

Red-Blind / Protanopia

1% of males

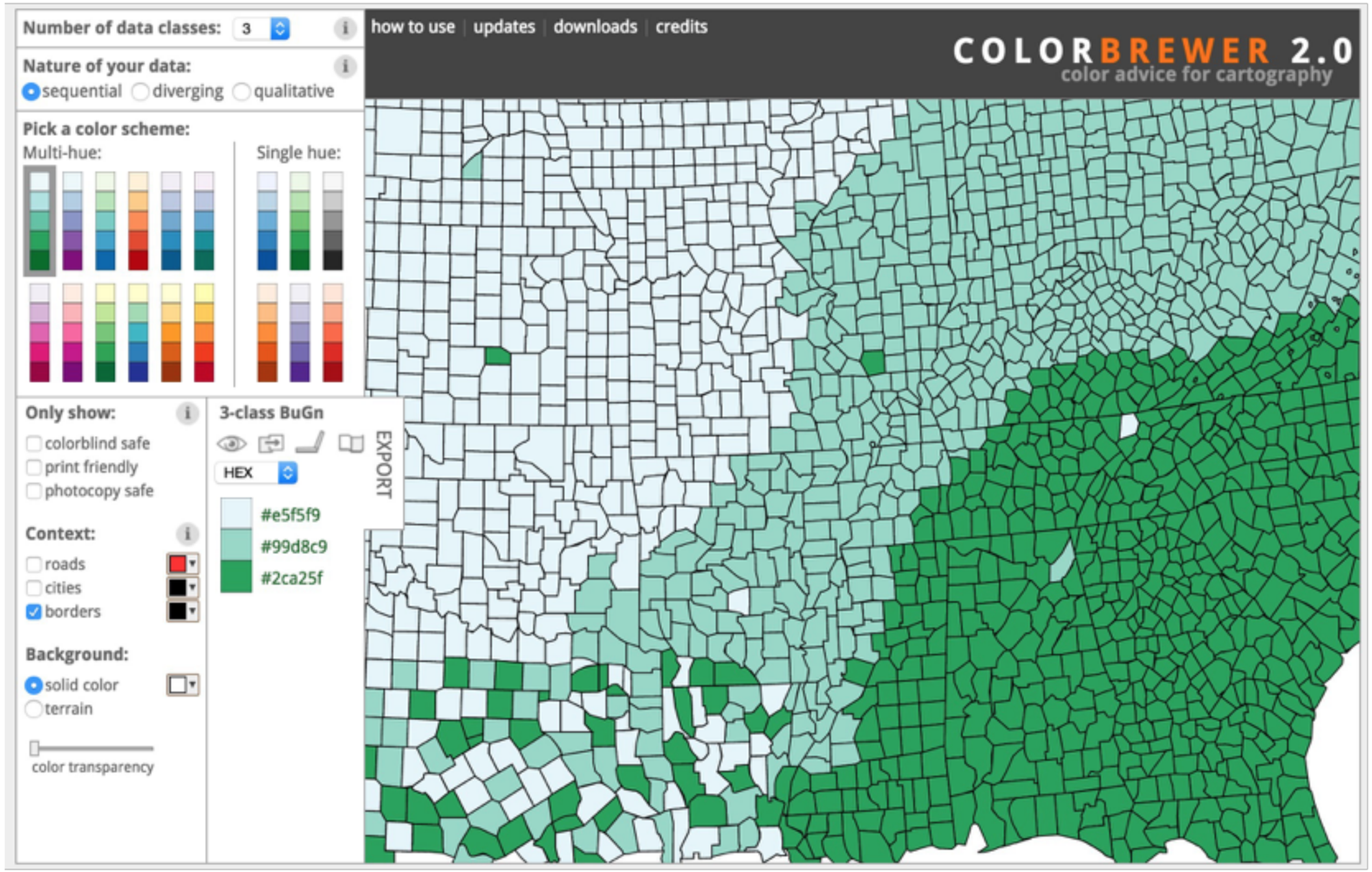


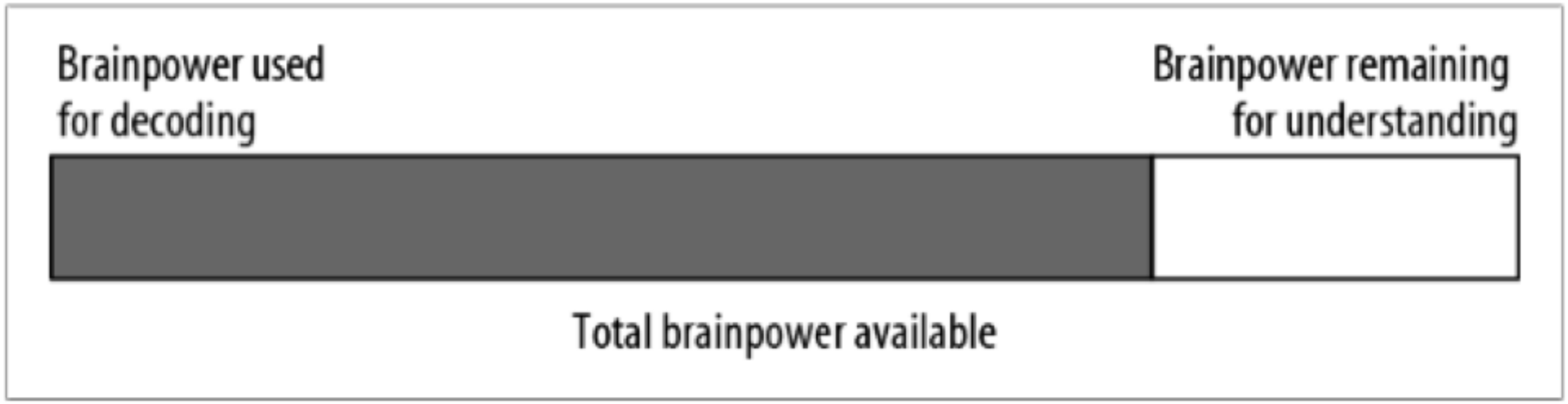
Blue-Blind / Tritanopia

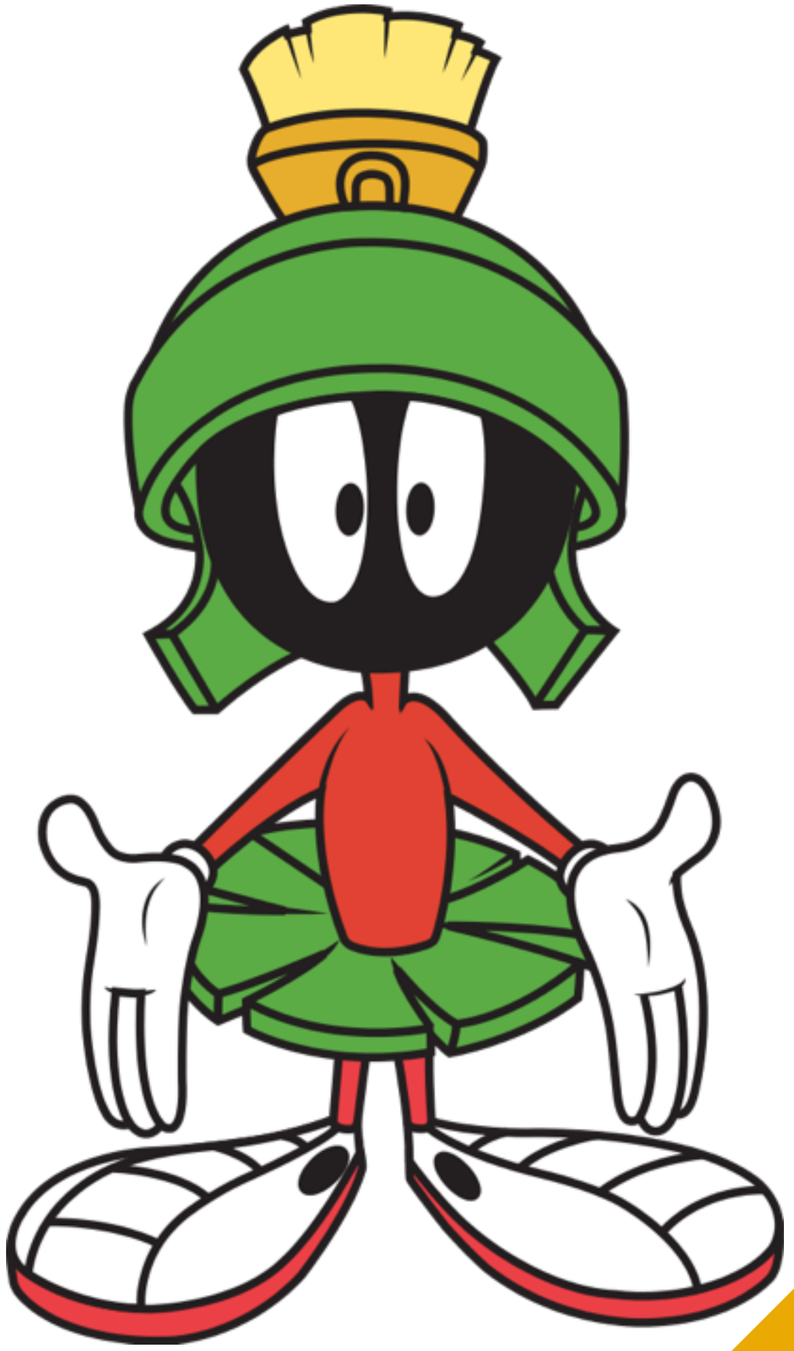
rare

http://www.color-blindness.com/coblis-color-blindness-simulator/

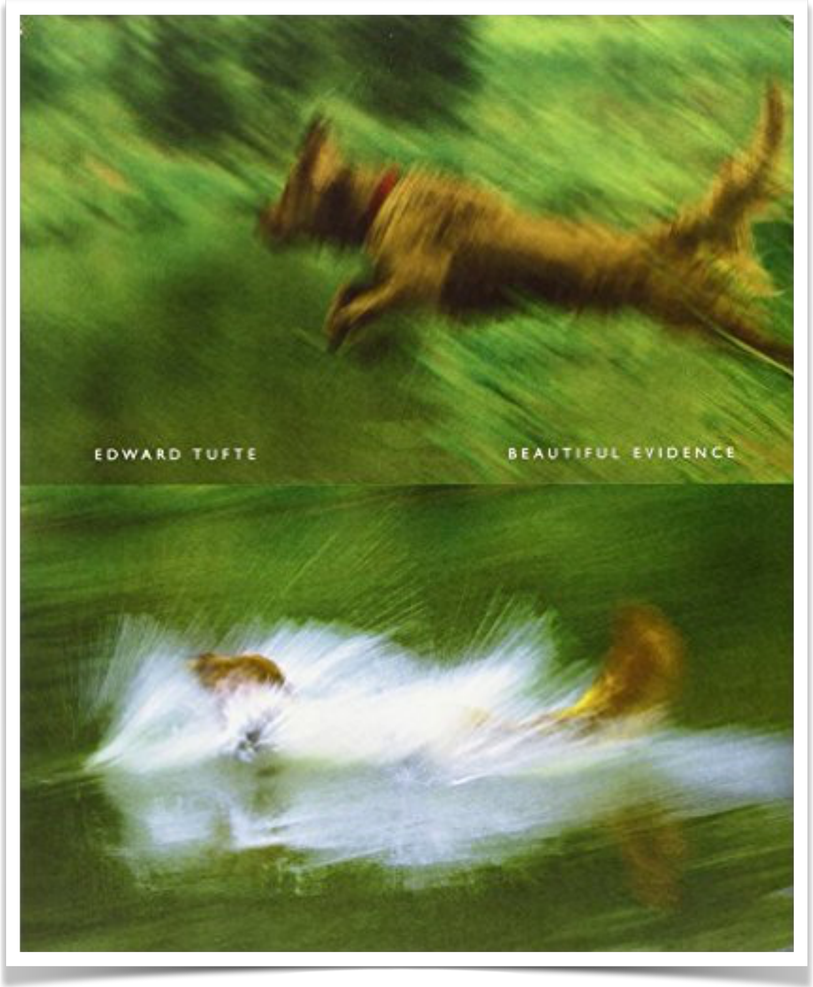
Color


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
print friendly
photocopy safe
3-class BuGn
HEX
EXPORT
#e5f5f9
#99d8c9
#2ca25f
Context:
roads
cities
borders
Background:
solid color
terrain
color transparency

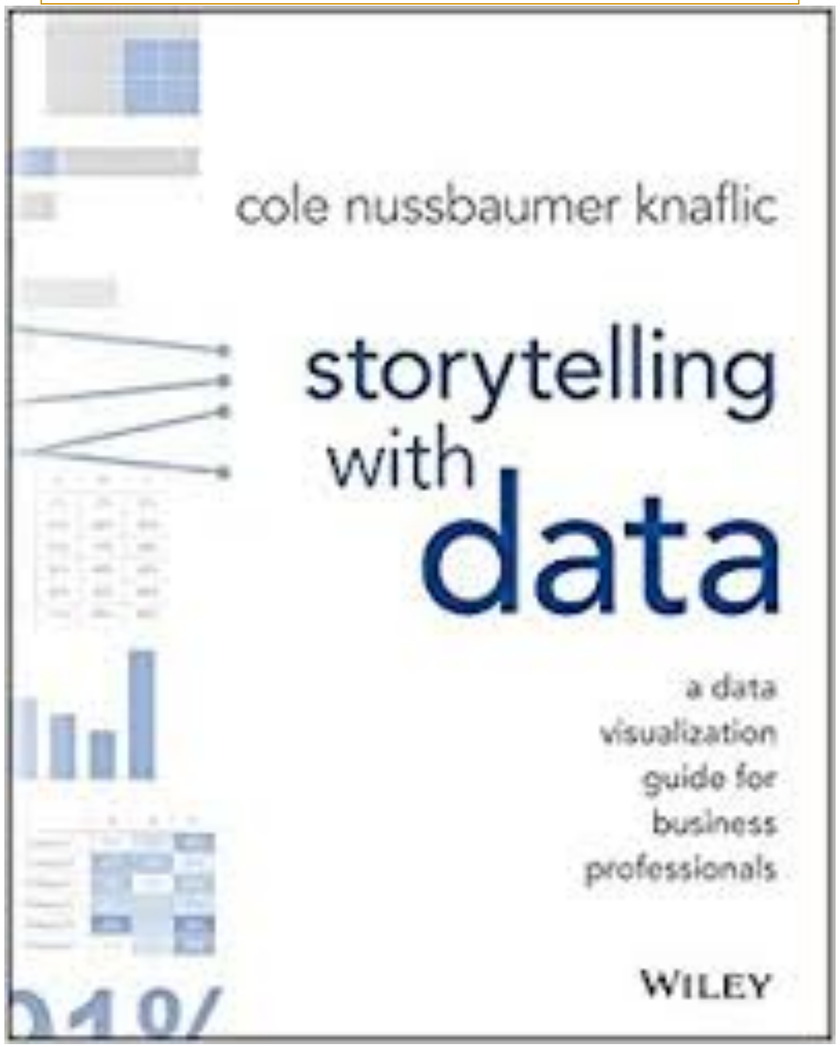

Brainpower used
for decoding
Brainpower remaining
for understanding
Total brainpower available



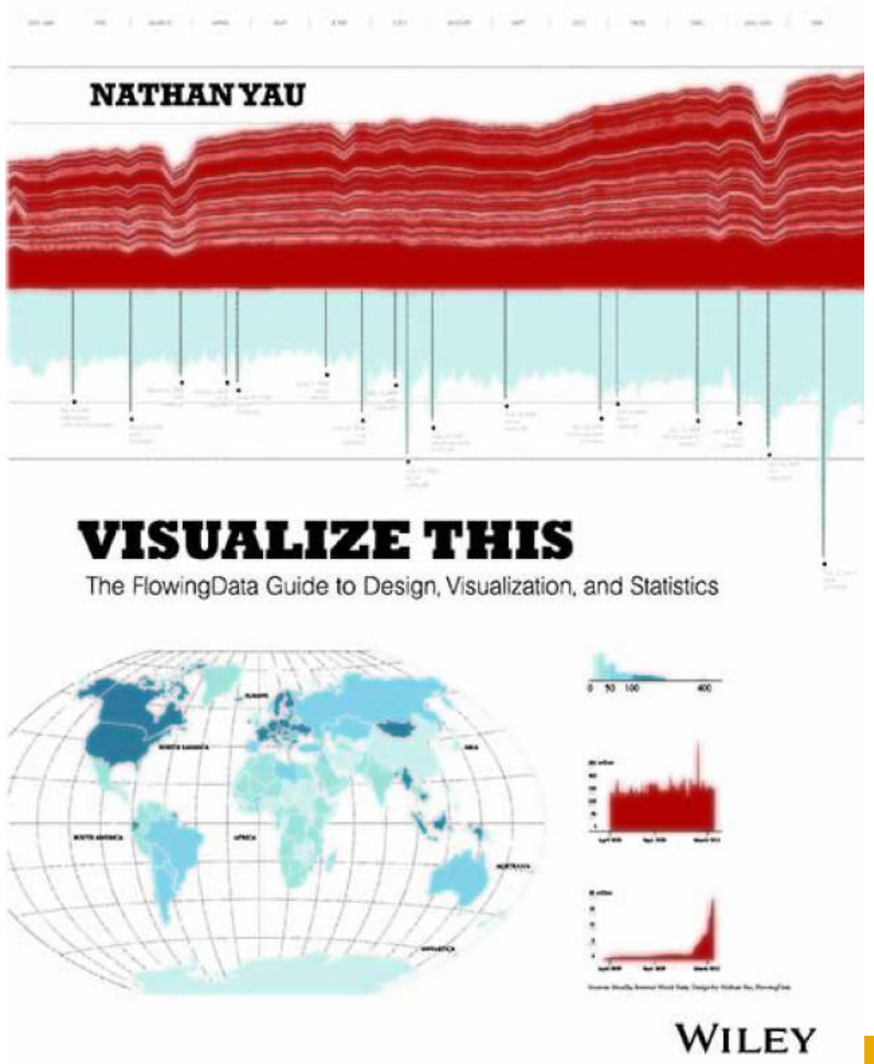
Recommended Reading



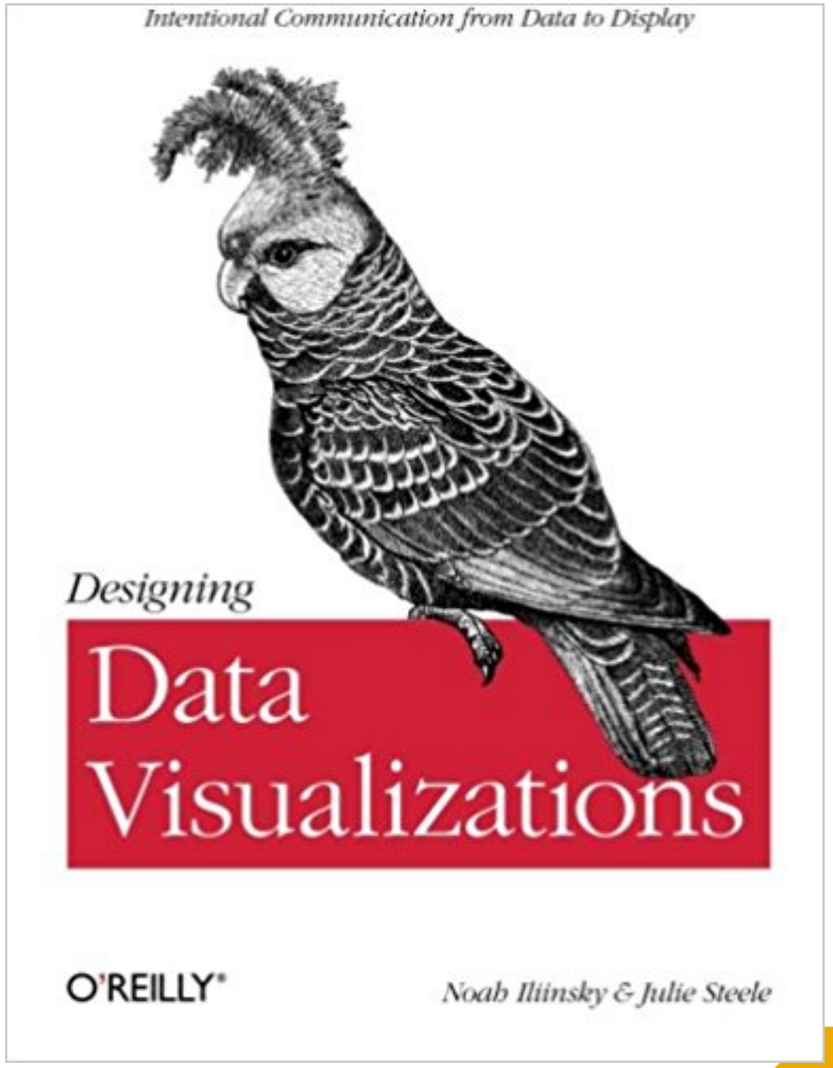
Recommended Reading



Recommended Reading



Recommended Reading



Stop

Data Visualization in Python

Python Visualization Libraries

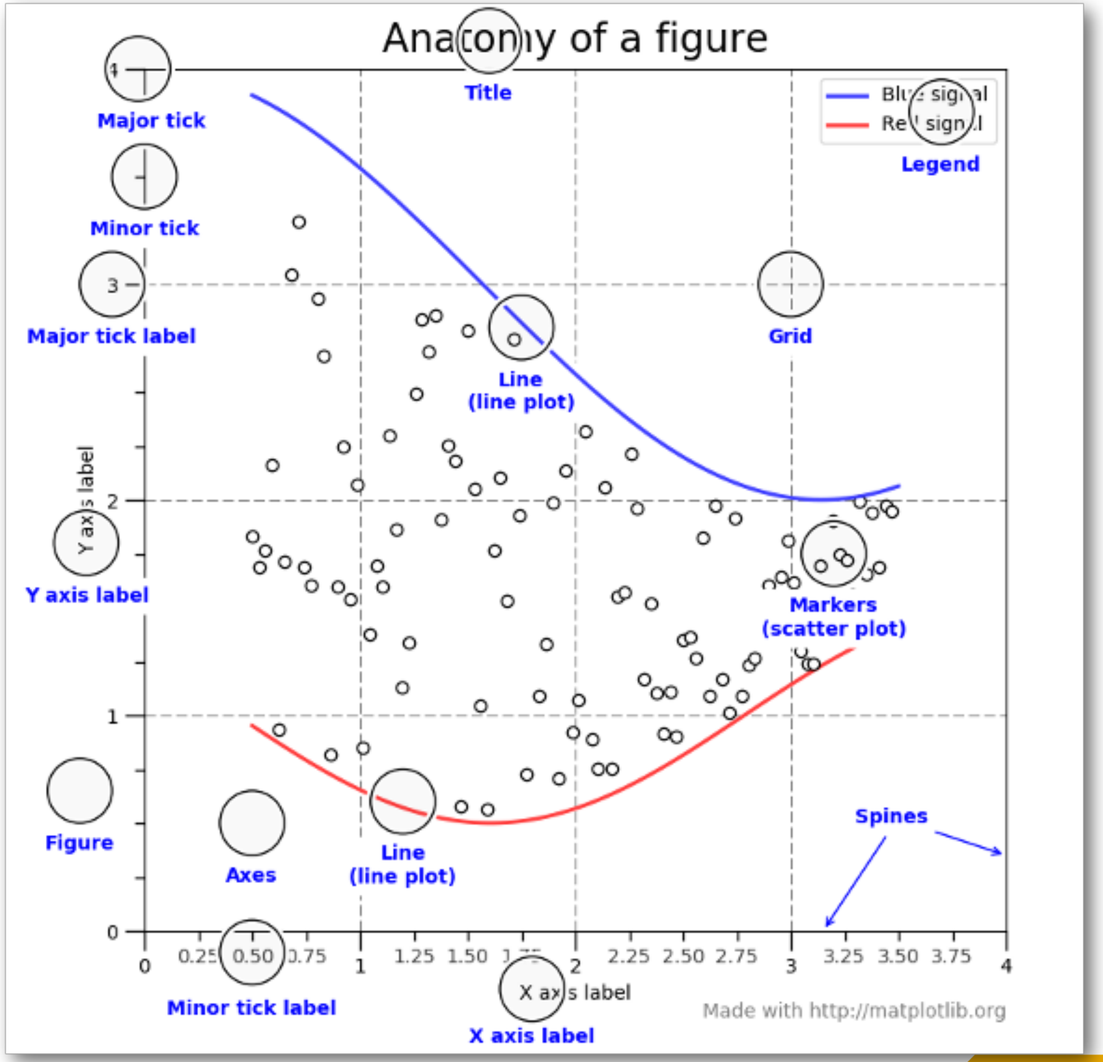
- **Matplotlib**: “Lowest” level visualization library. Very powerful, but little abstraction
- **Pandas/Pyplot**: Easier, but requires transformation for complex visualizations
- **Seaborn:** Good for advanced statistical visualizations
- **Altair:** New library: declarative statistical visualization library
- **Plotly / Cufflinks:** Make it interactive!

Other Visualization Libraries

- **Panel**: Powerful library for creating apps and dashboards
- **hvPlot**: Quickly generate interactive plots from data
- **HoloViews:** Helps you make all data instantly visualizable
- **GeoViews:** HoloViews for geo-spatial data
- **ggplot2/PlotNine:** This is Python's implementation of R's ggplot2
- For more useful info about Python visualization, check out pyviz.org

https://pyviz.org/tools.html

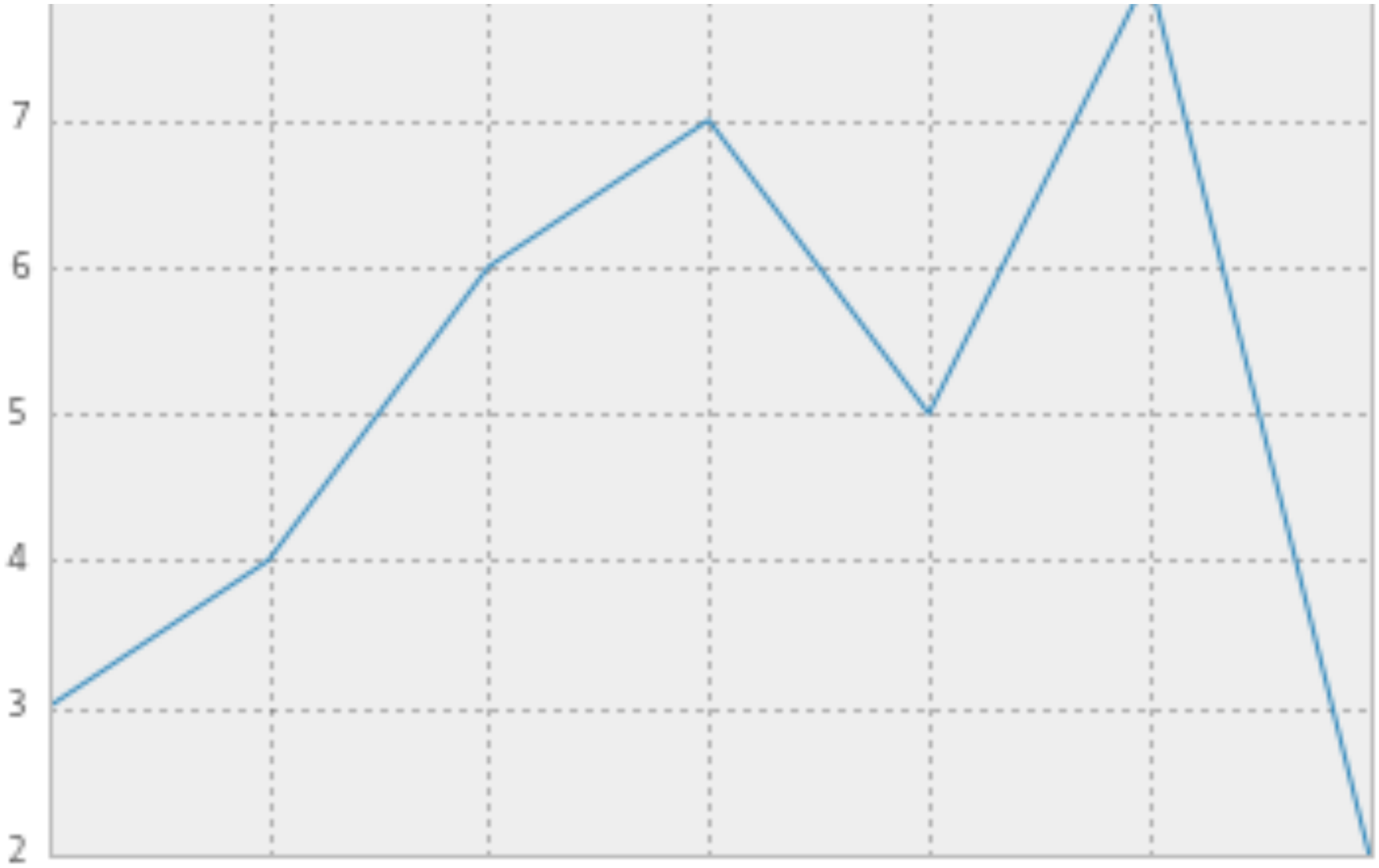
Customizing your Charts



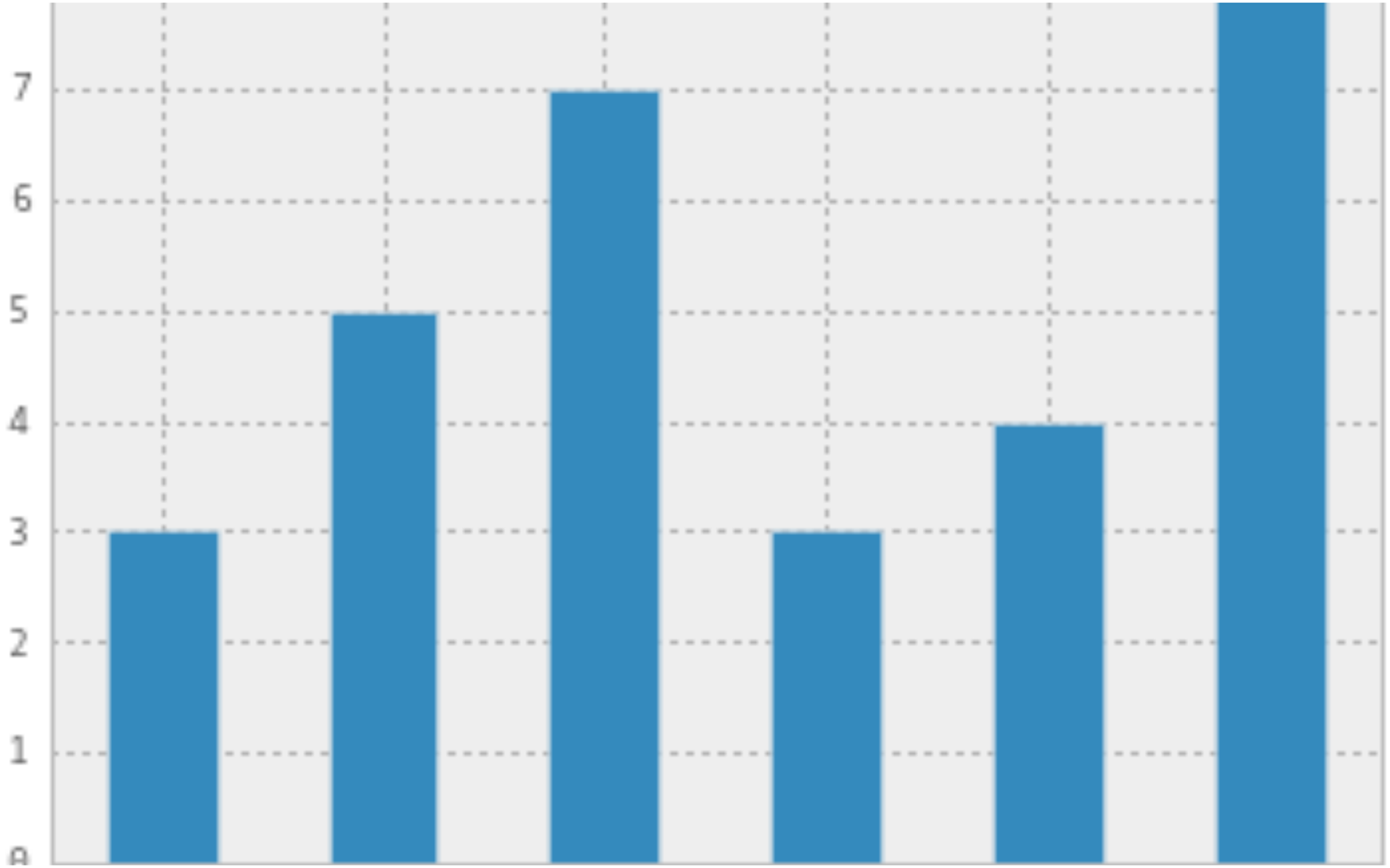
https://pbpython.com/effective-matplotlib.html

```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
%matplotlib inline
```

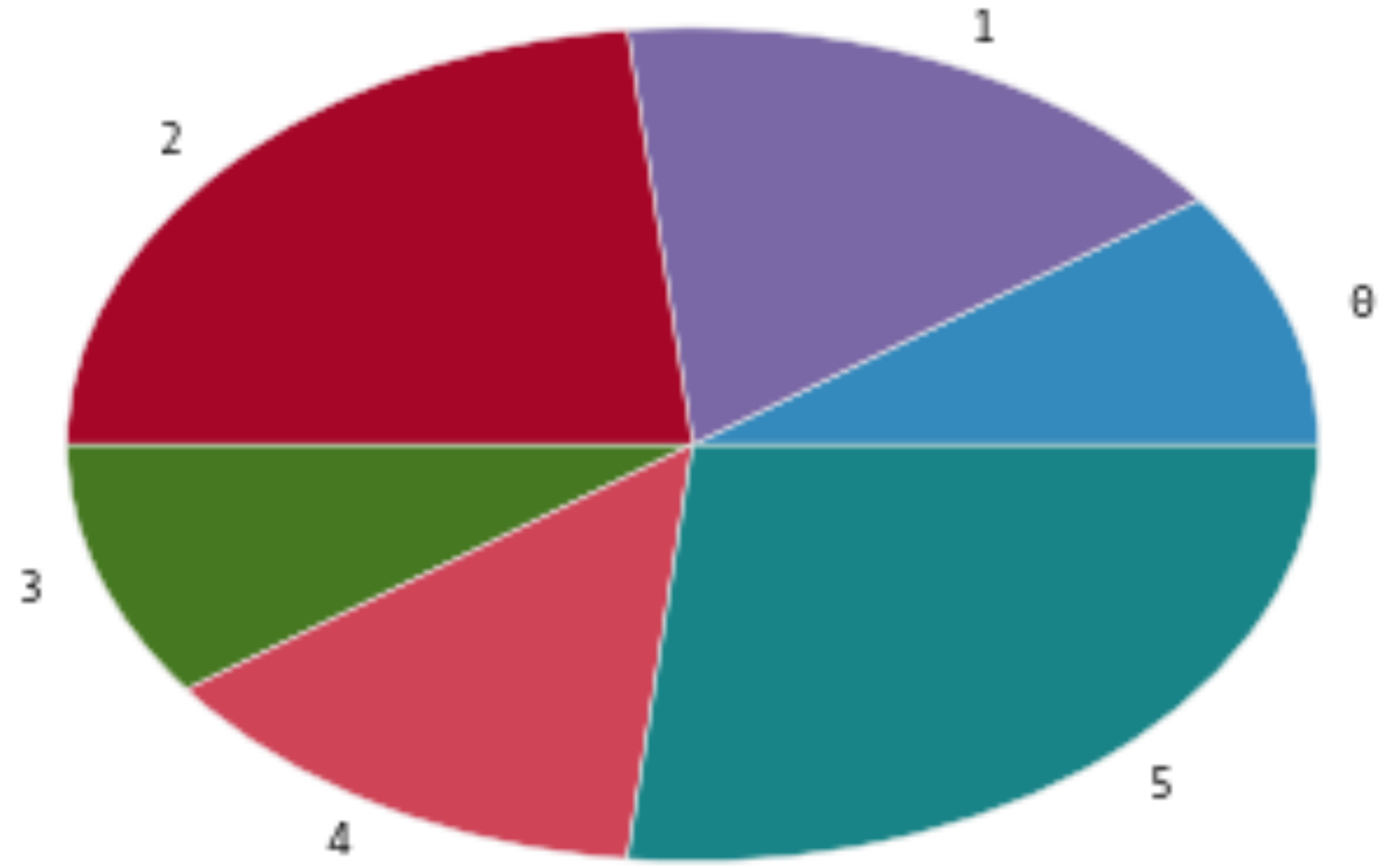
```
data = pd.Series( [3,4,6,7,5,8,2 ])
graph = data.plot()
```

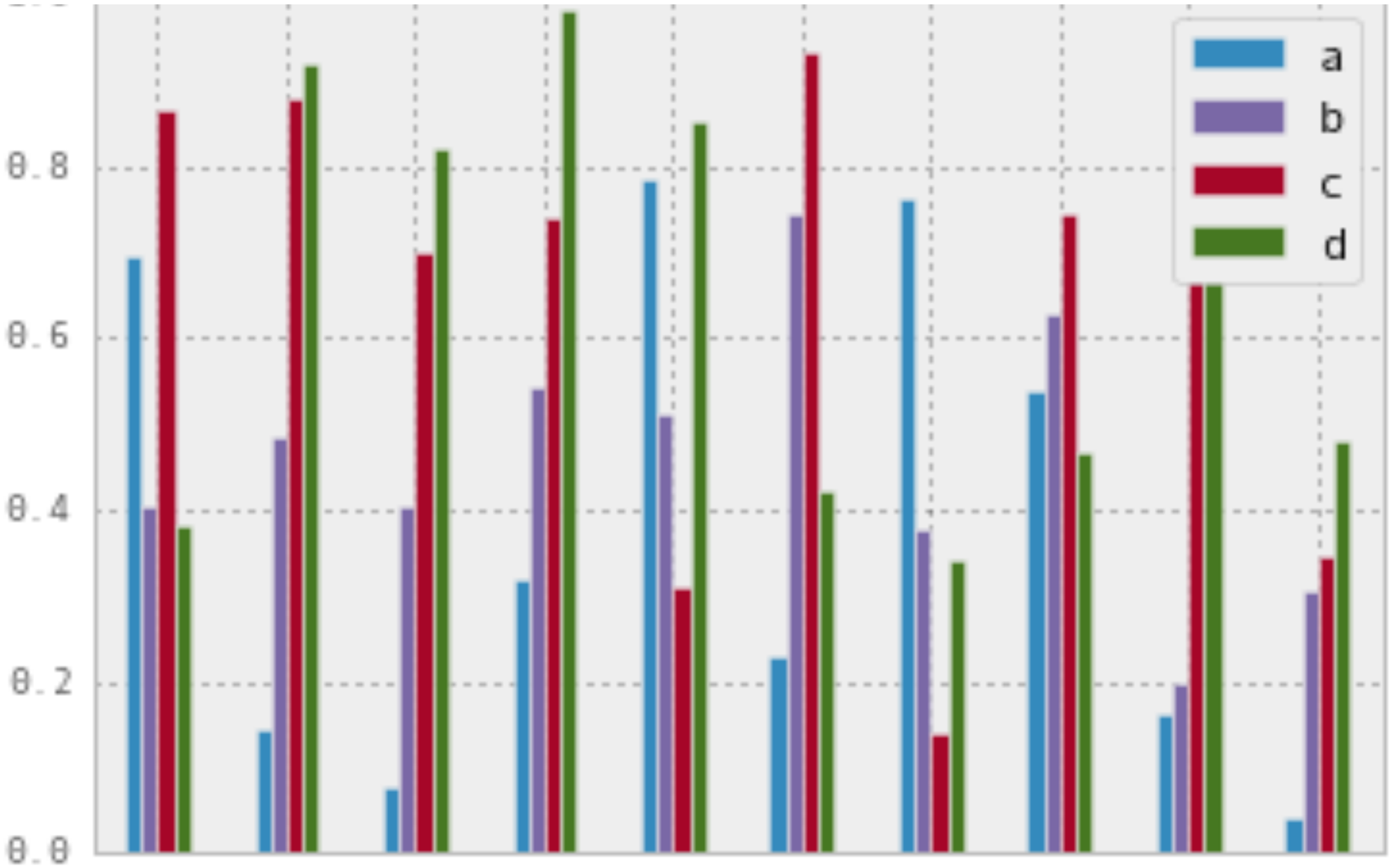


```
barchart = data.plot( kind="bar" )
```

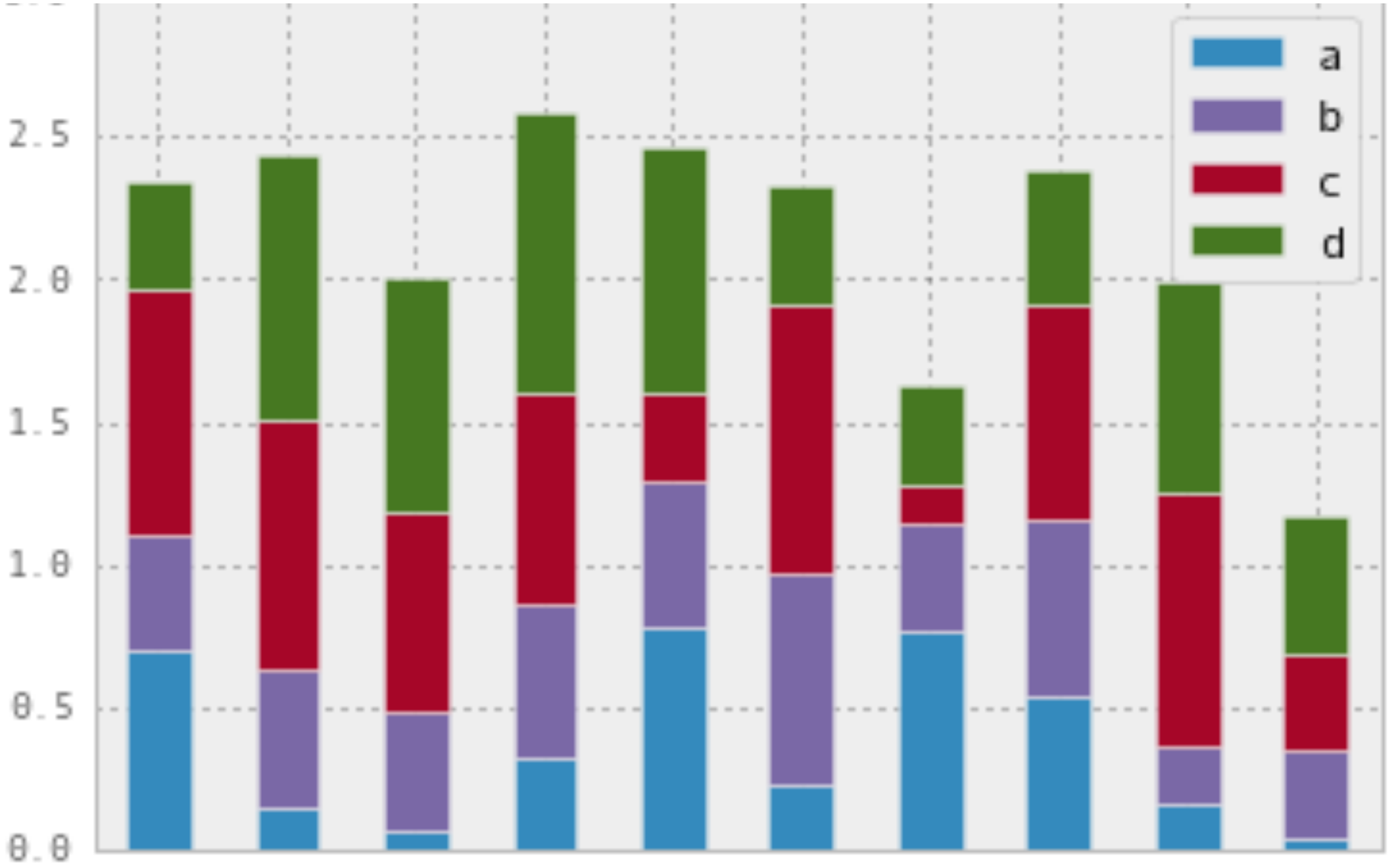


```
piechart = data.plot( kind="pie" )
```

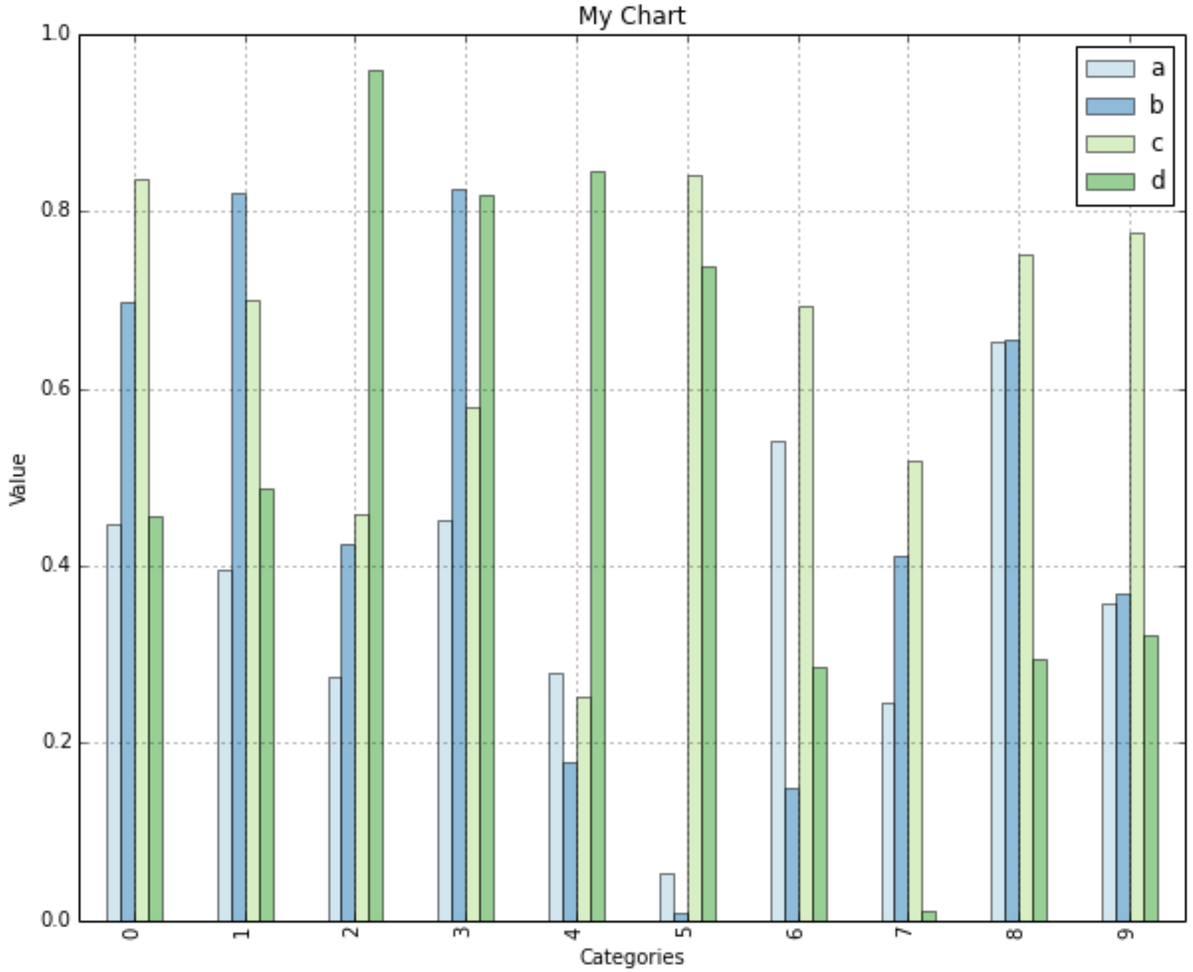




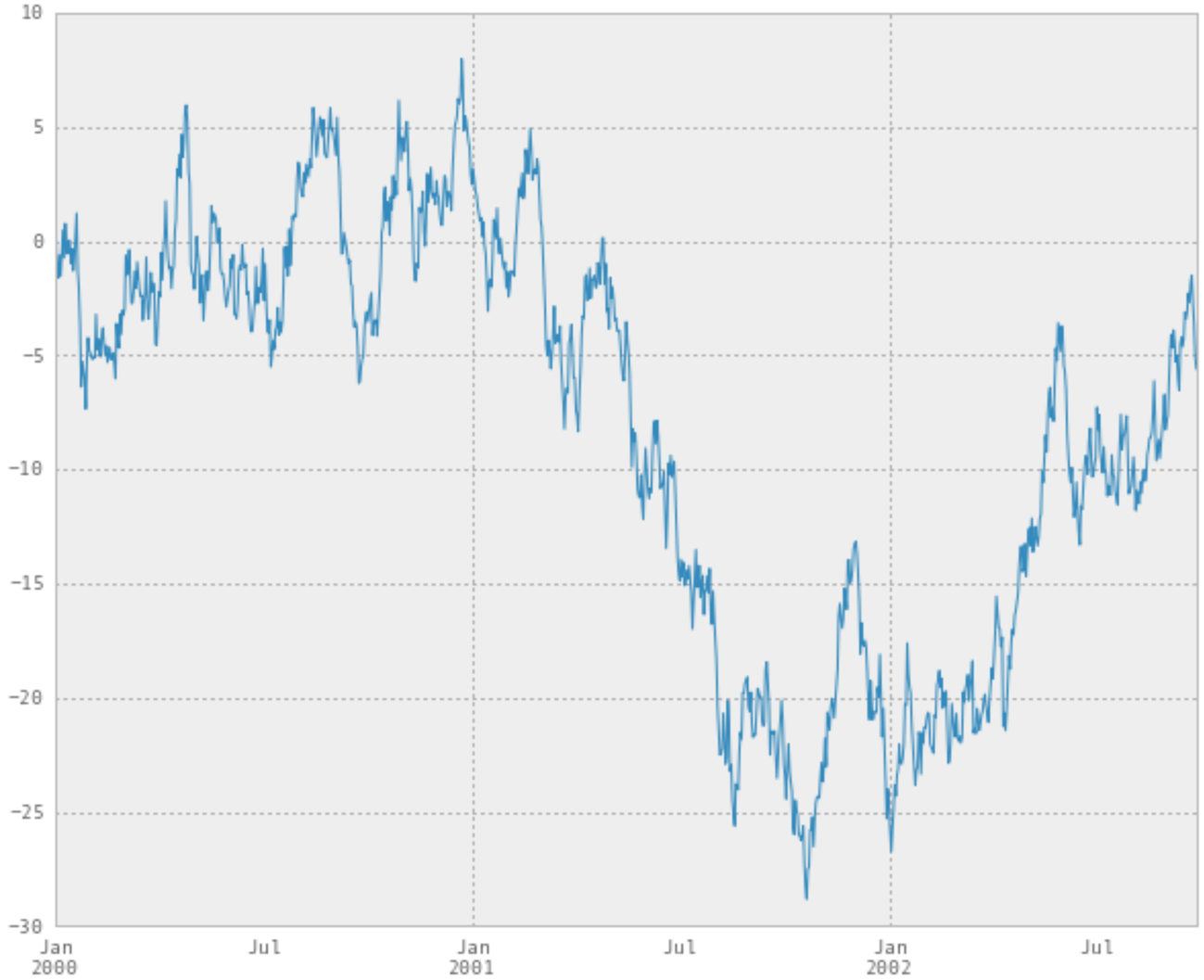

```
df2 = pd.DataFrame(np.random.rand(10, 4), \
    columns=['a','b','c','d'])

df2.plot( kind='bar' )
```



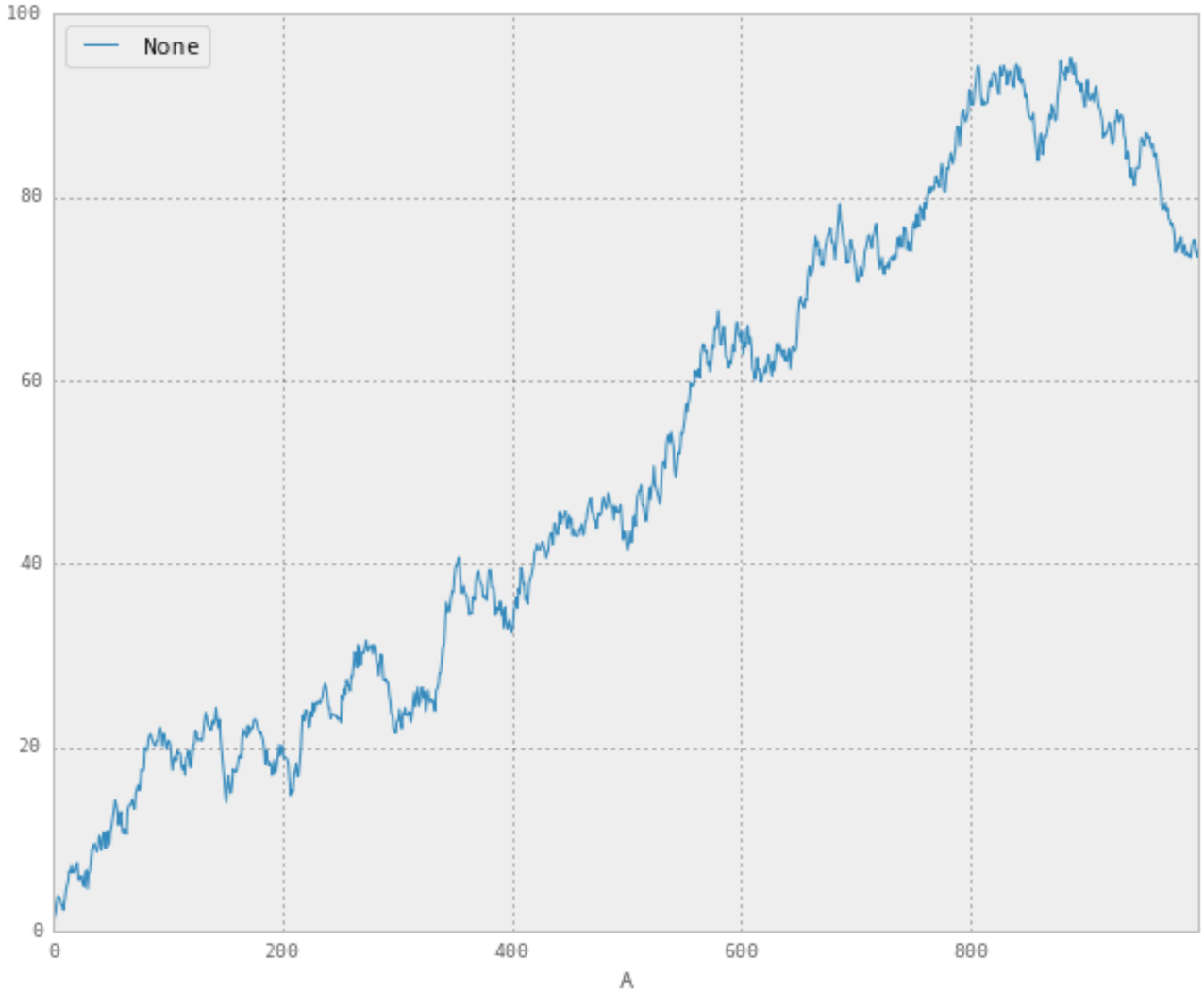

```
df2.plot( kind='bar', stacked=True )
```



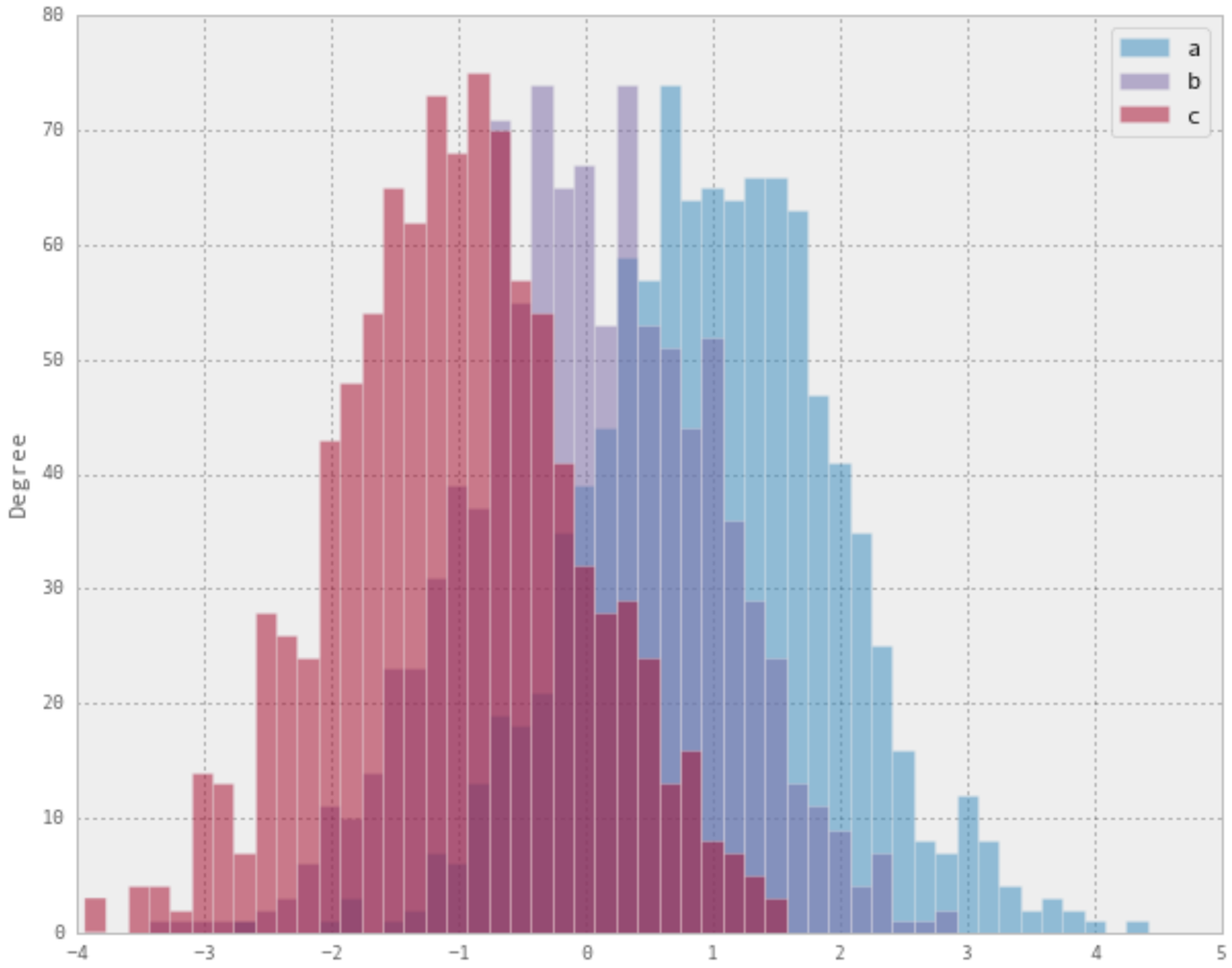

```
df2.plot( kind='bar',
          color=('#a6cee3','#1f78b4','#b2df8a','#33a02c'),
          alpha=0.5,
          width=0.5,
          figsize=(10,8))
plt.title( "My Chart" )
plt.xlabel( "Categories" )
plt.ylabel( "Value" )
```




```
ts = pd.Series(np.random.randn( 1000),
index=pd.date_range('1/1/2000', periods=1000))
ts = ts.cumsum()
timeseriesChart = ts.plot( figsize=(10, 8) )
```



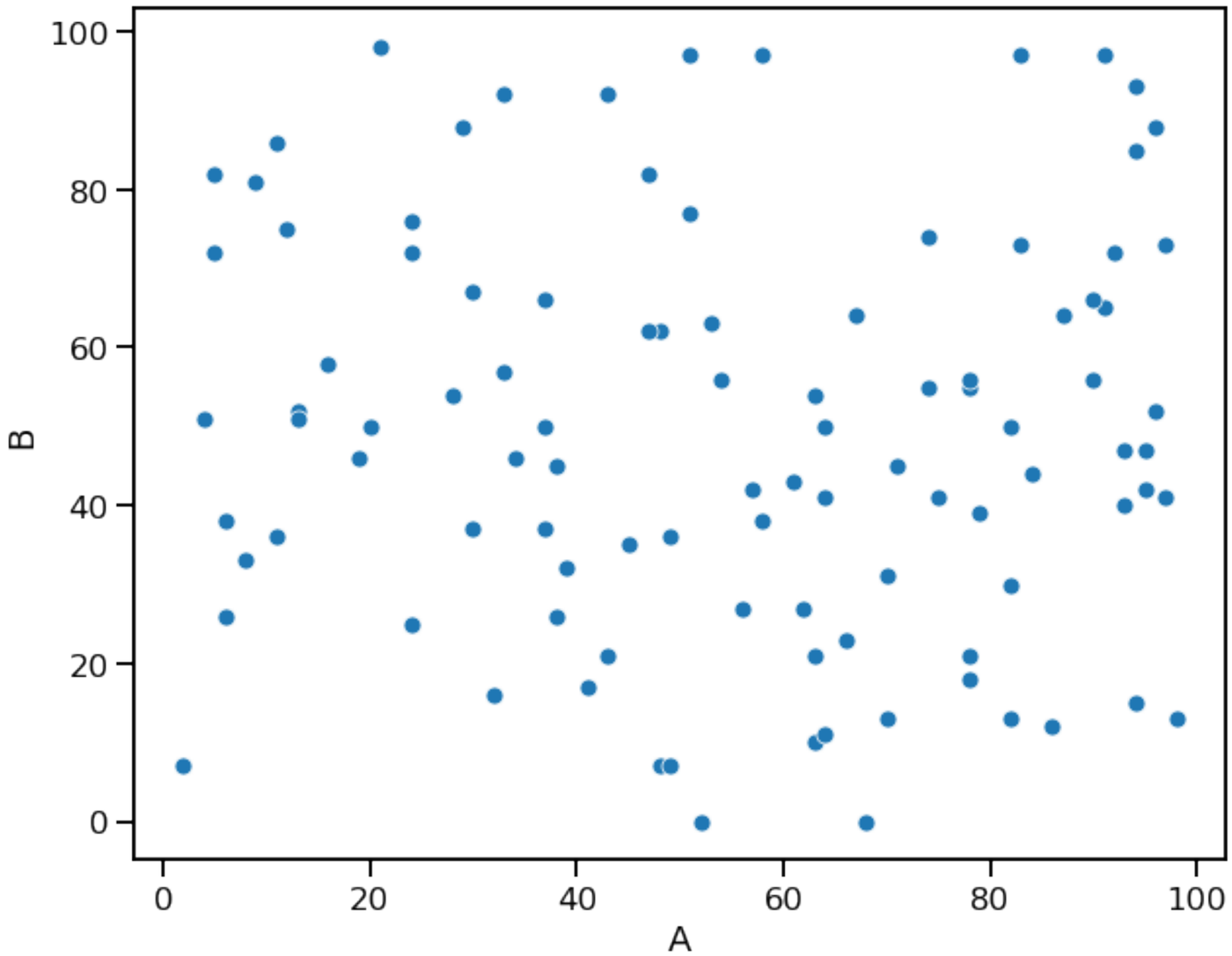

```
df3 = pd.DataFrame(np.random.randn(1000, 2),
     columns=['B', 'C']).cumsum()
df3['A'] = pd.Series(list(range(len(df3))))

df3.plot( x='A', y='B' )
```



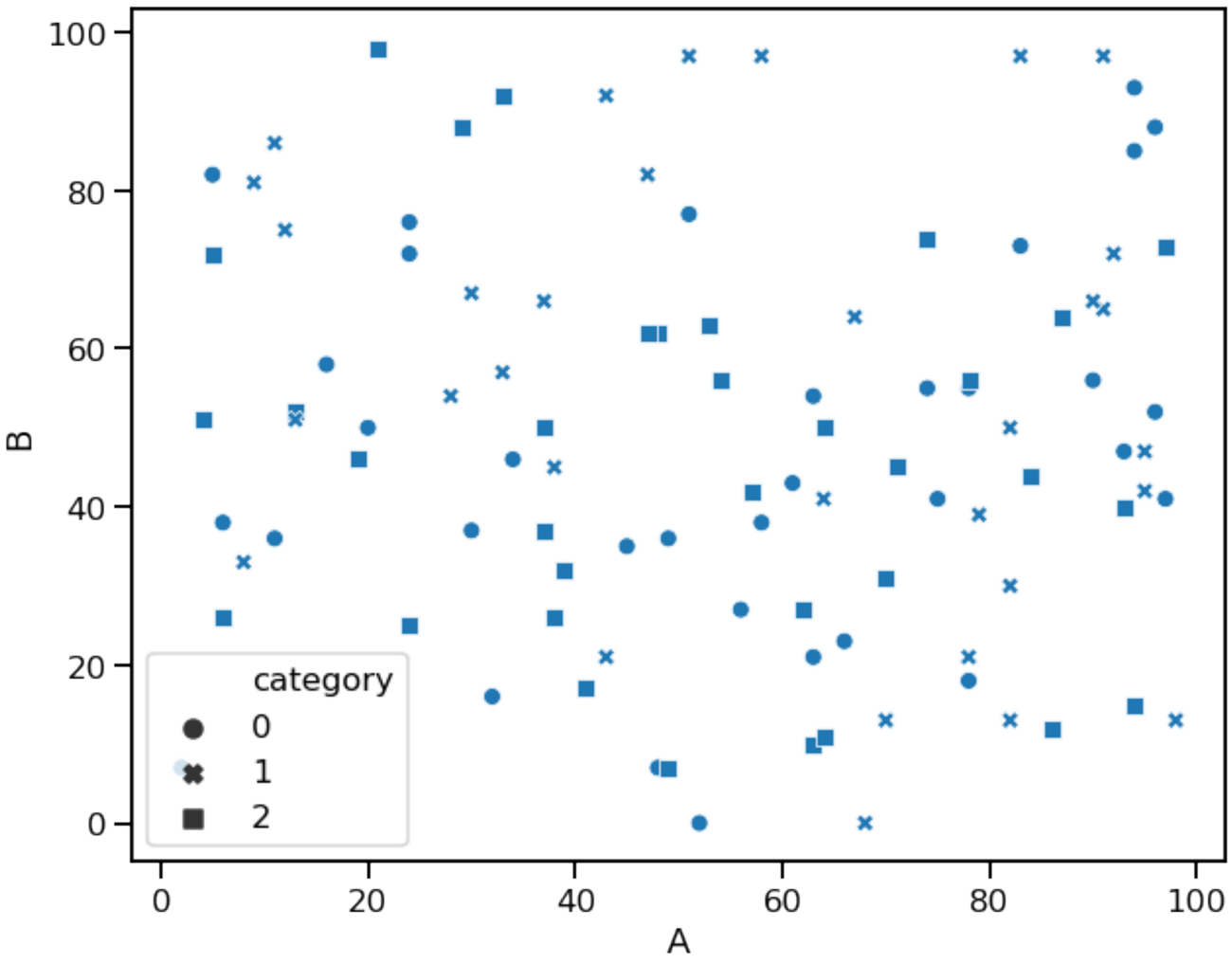

```
df4.plot(kind='hist',
         alpha=0.5,
         bins=50 )
```

Stop

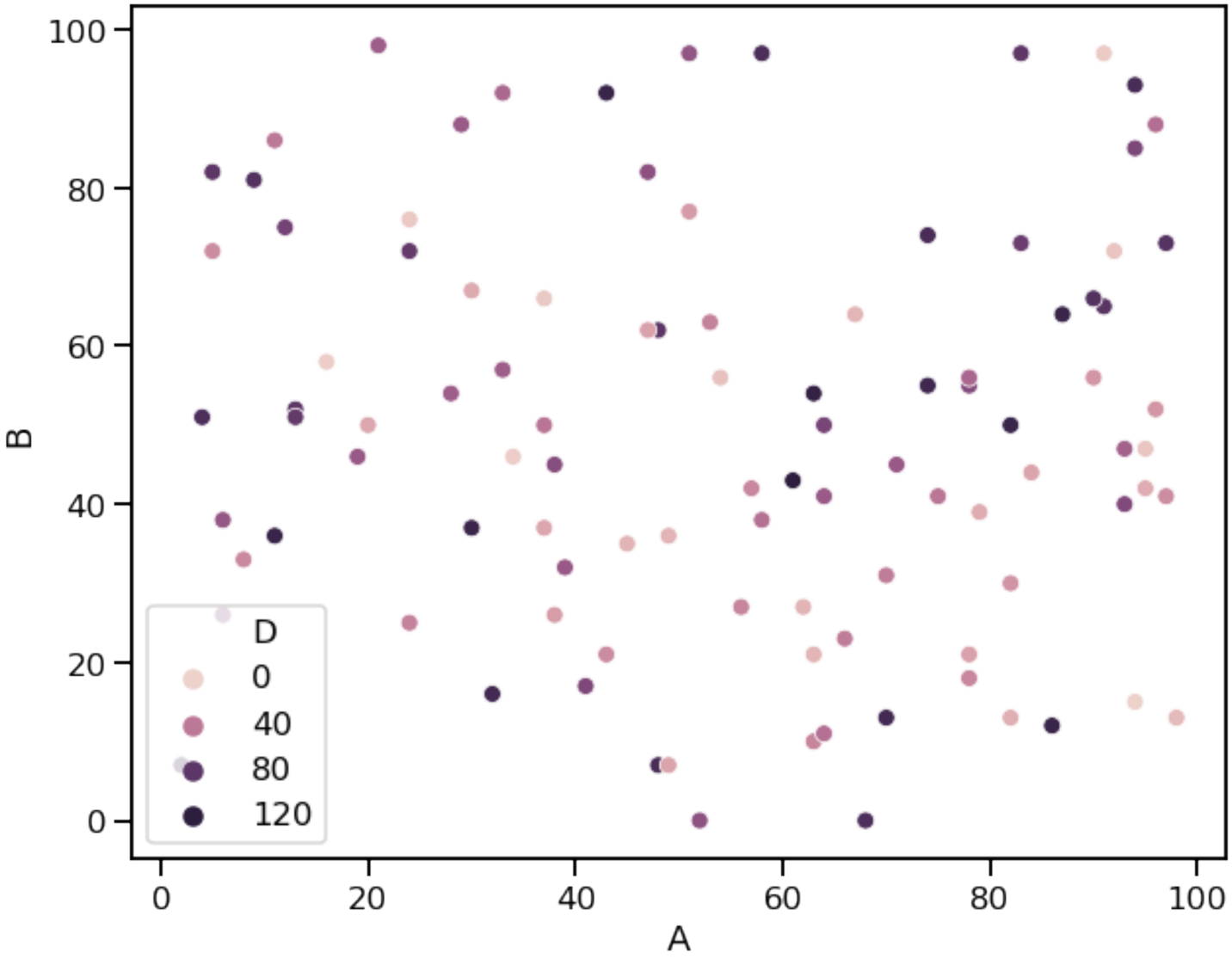
```
import seaborn as sns
```



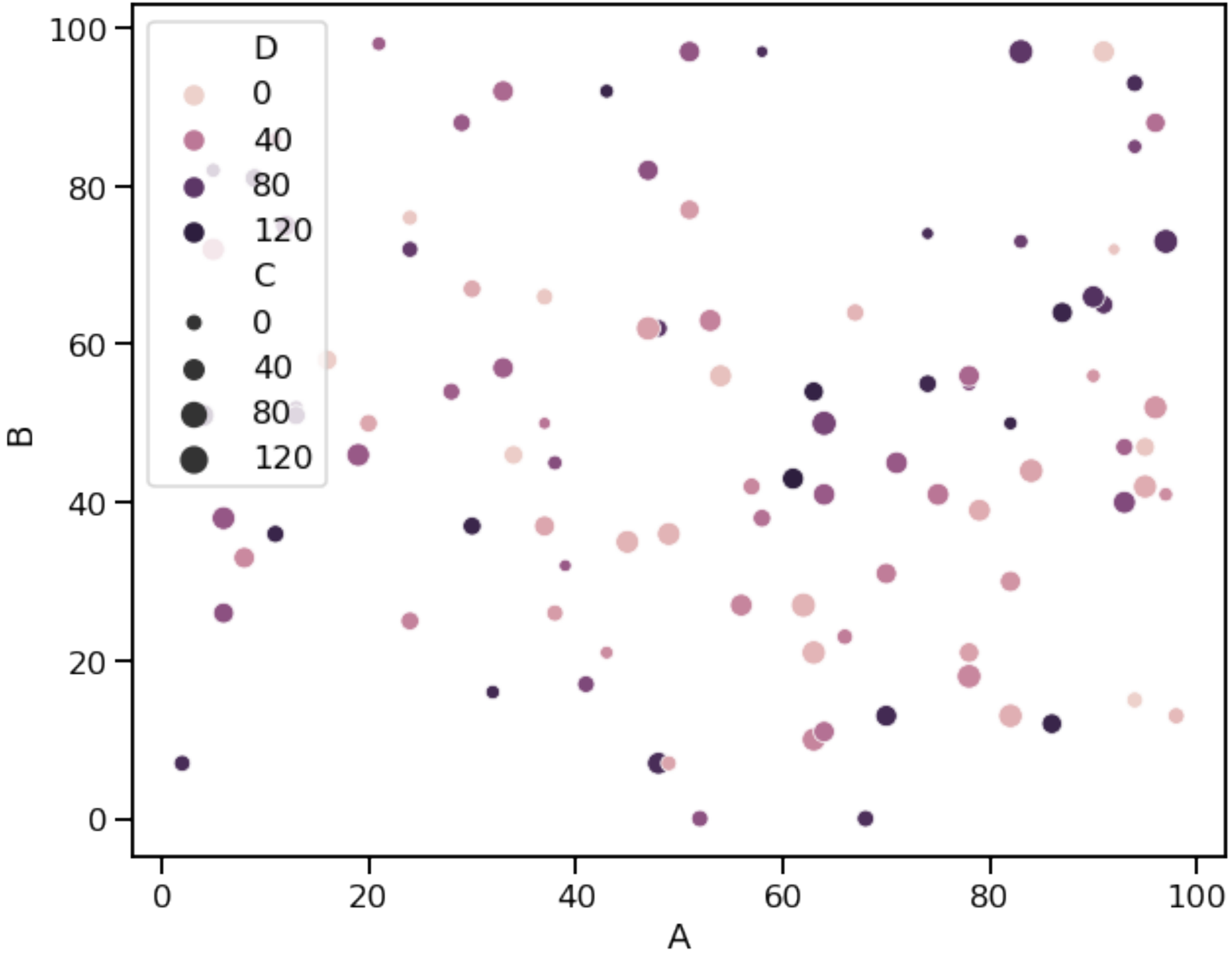

```
df = pd.DataFrame(np.random.randint(
    0,100,size=(100, 4)),
    columns=list('ABCD'))
df['category'] = df['C'] % 3

sns.scatterplot(x=df['A'], y=df['B'], data=df)
```



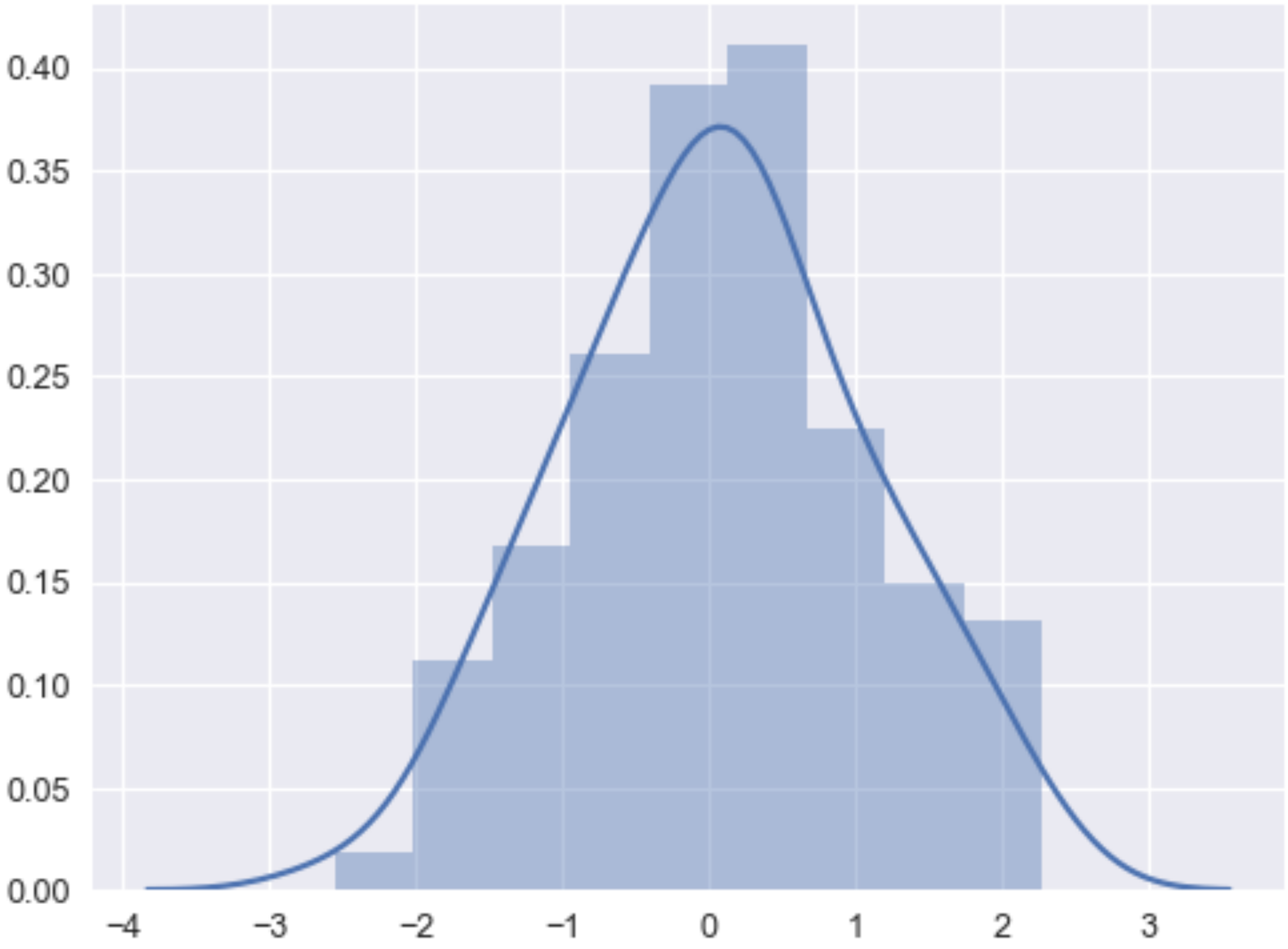

```
sns.scatterplot(x=df['A'], y=df['B'],
style=df['category'])
```



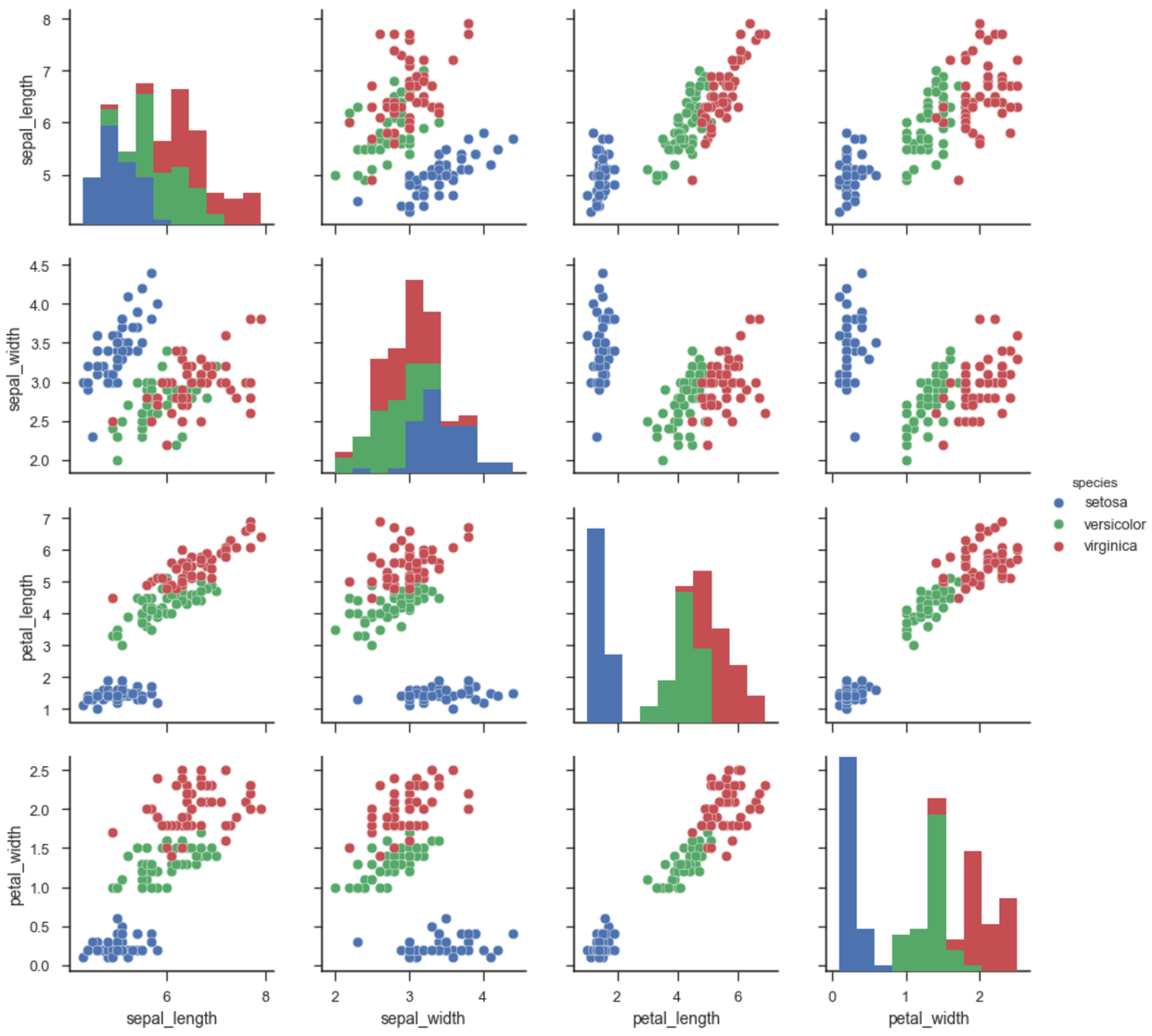

```
sns.scatterplot(x=df['A'], y=df['B'], hue=df['D'])
```




```
sns.scatterplot(x=df['A'], y=df['B'], size=df['C'],
                hue=df['D'])
```

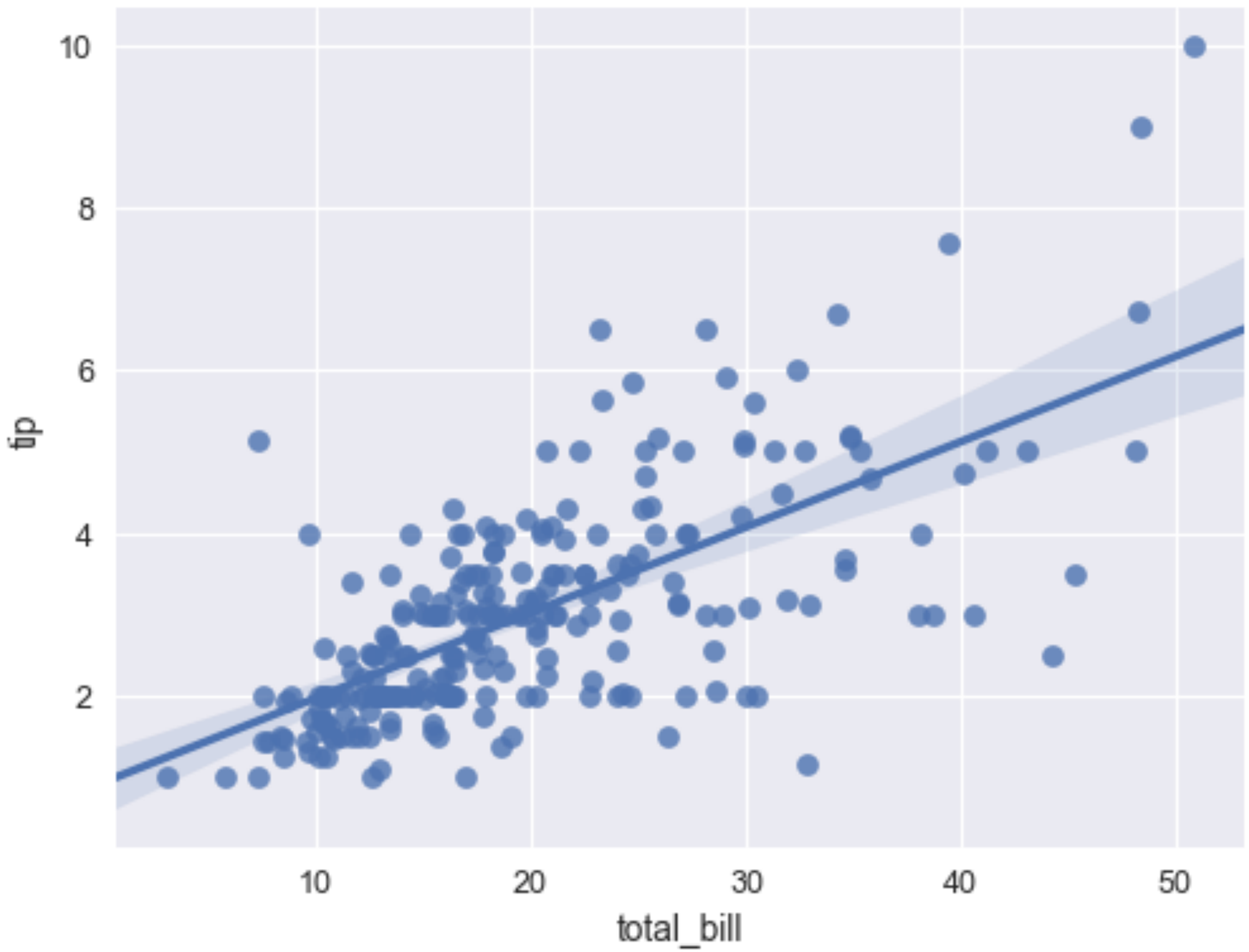


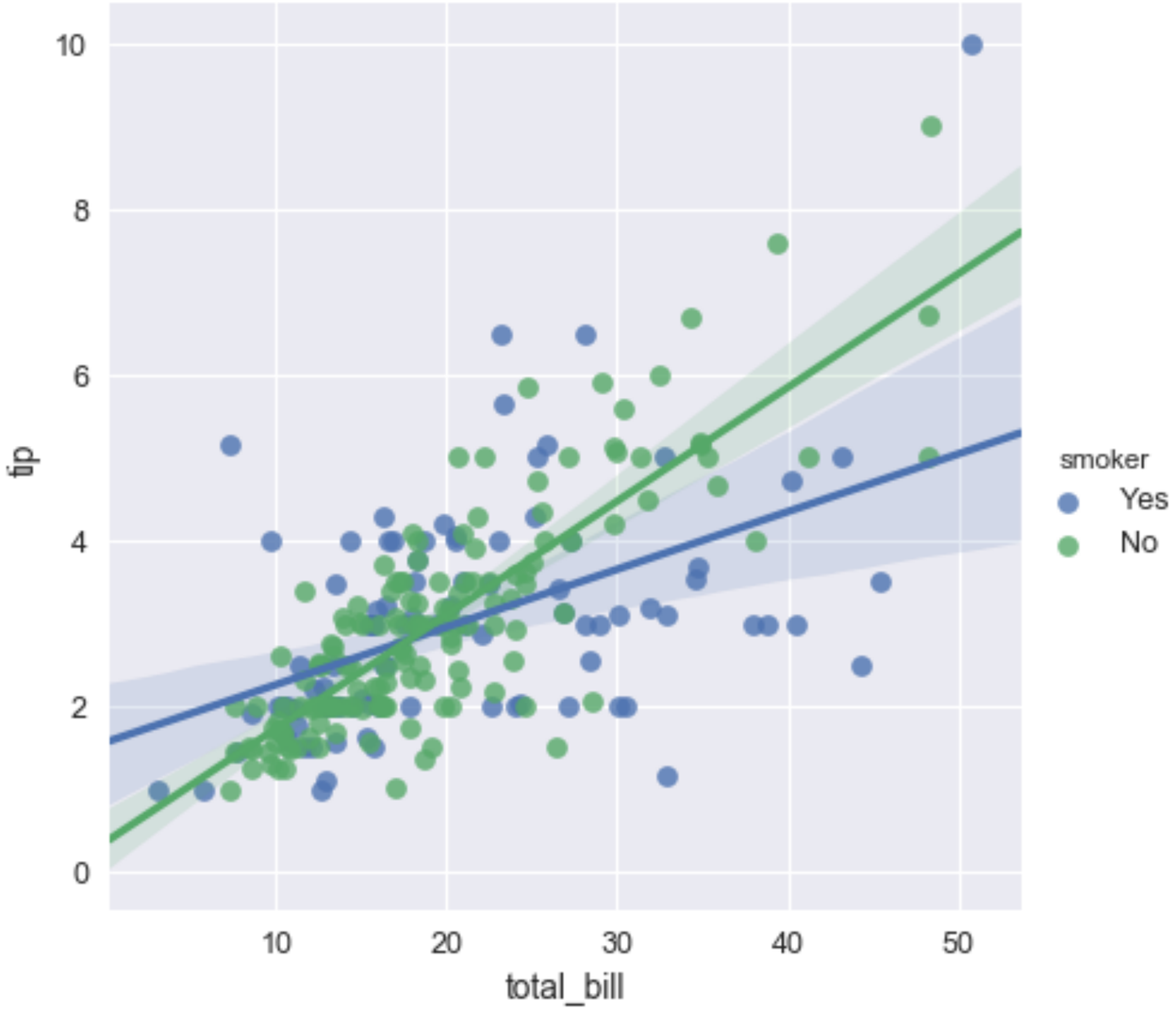

```
ax = sns.distplot(<data>)
```




```
g = sns.pairplot(<data>, hue="<target>")
```

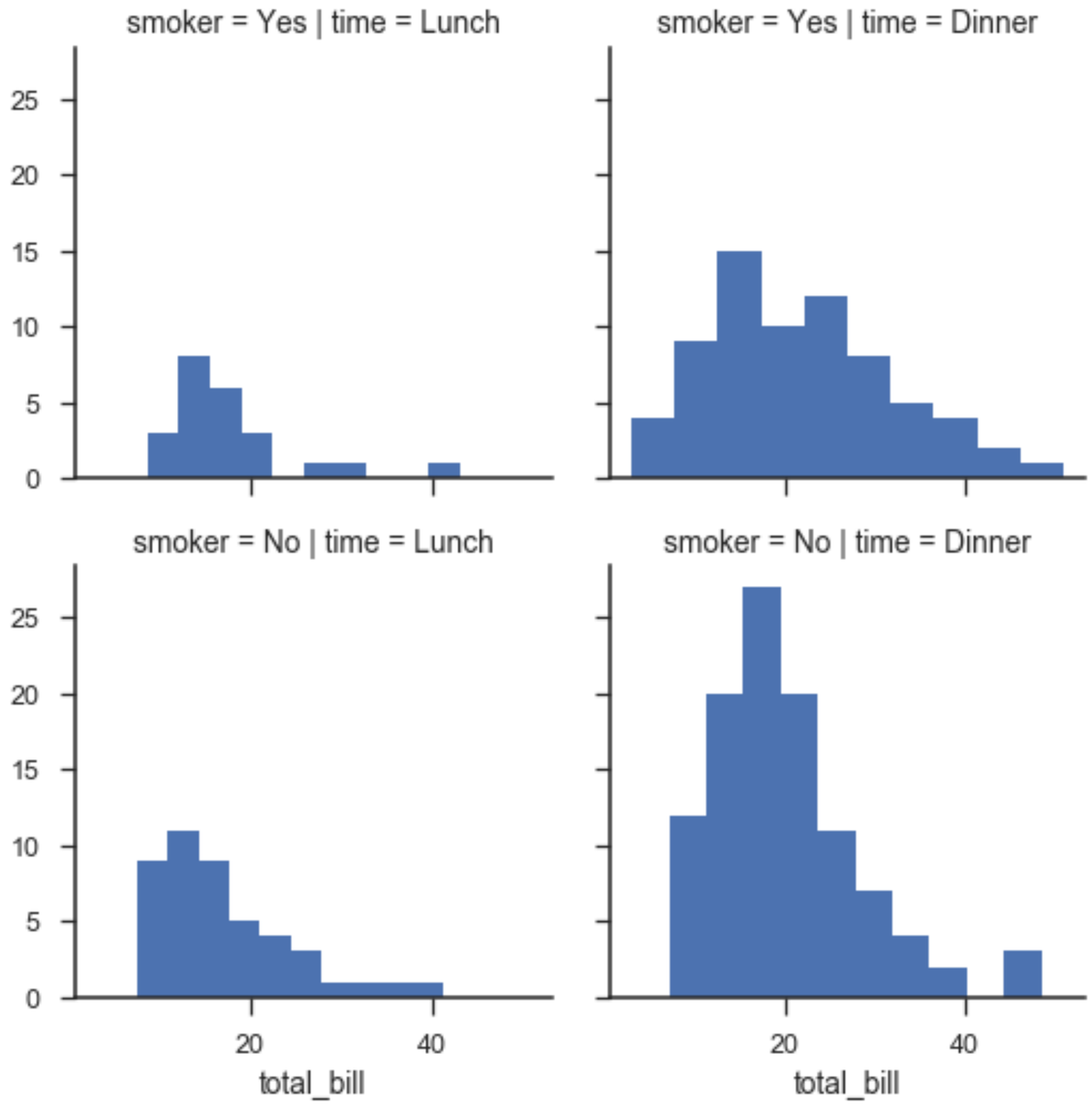
```
ax = sns.regplot(x="total_bill", y="tip",
data=tips)
```






```
g = sns.lmplot(x="total_bill", y="tip",
hue="smoker", data=tips)
```

```
g = sns.FacetGrid(tips, col="time",  row="smoker")
>>> g = g.map(plt.hist, "total_bill")
```



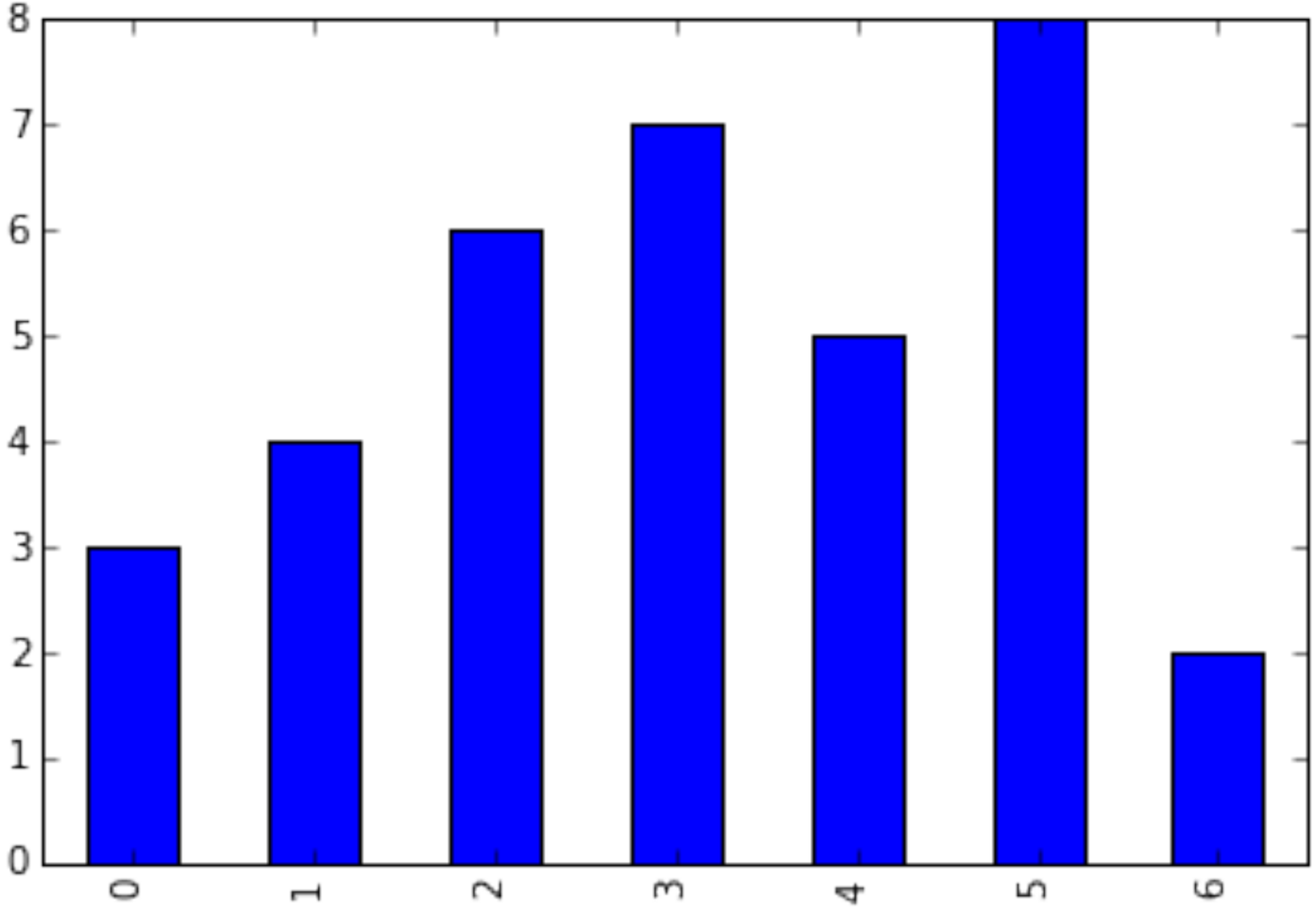
```
scatterPlot.get_figure().savefig( "scatterPlot.png" )
```

```
print(plt.style.available)
```

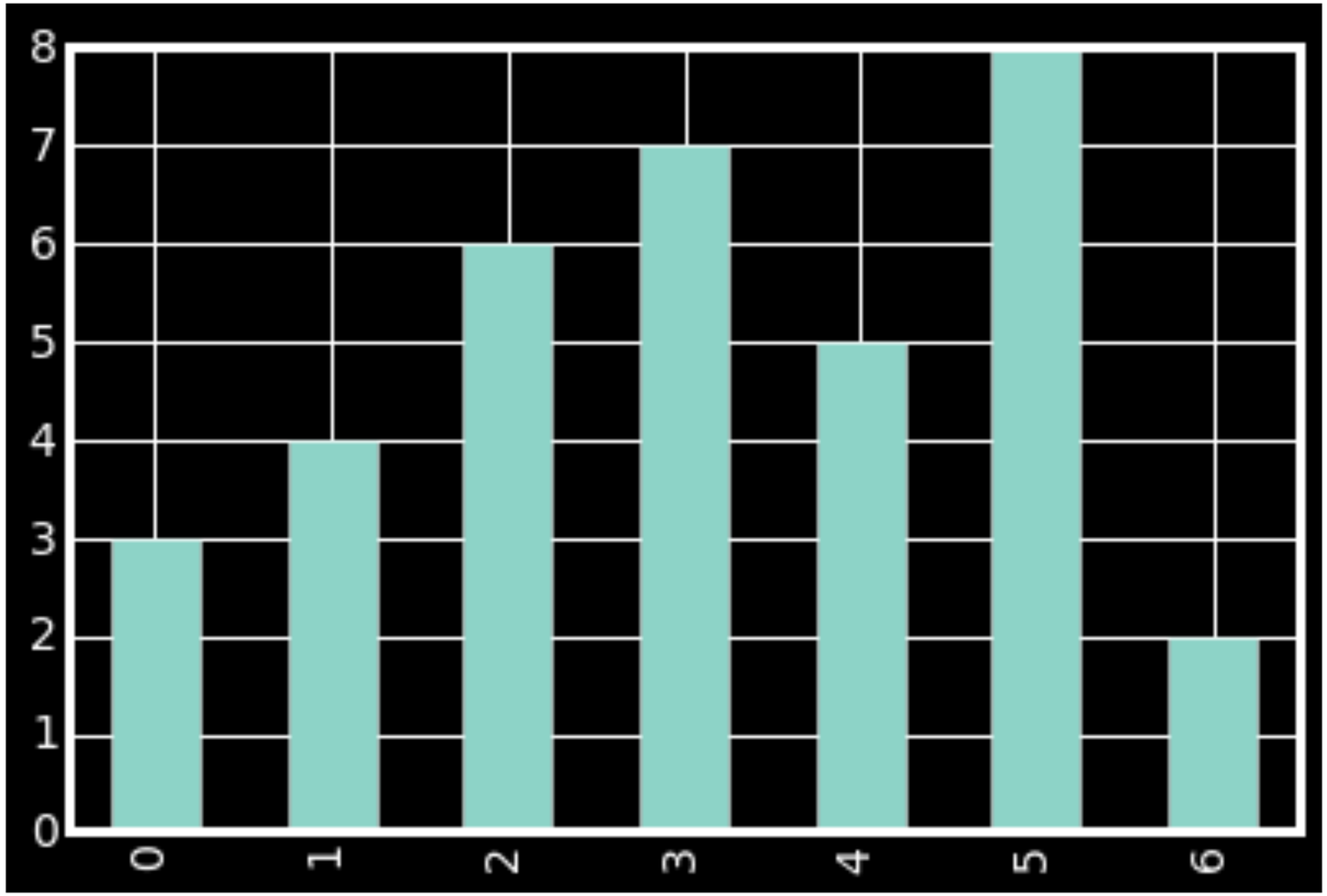
```
['dark_background', 'grayscale', 'ggplot', 'bmh', 'fivethirtyeight']
```

UGLY

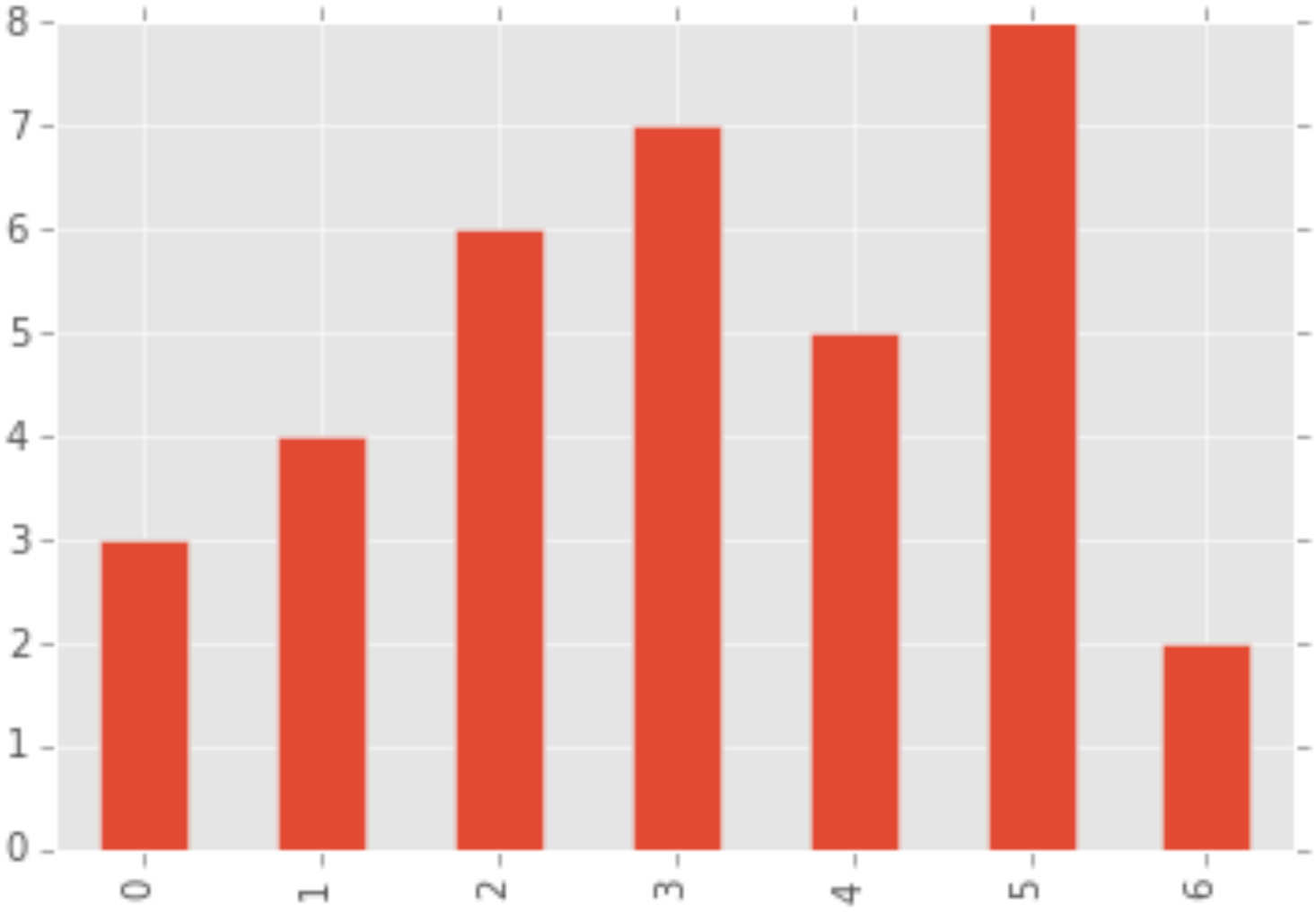
```
data = pd.Series( [3,4,6,7,5,8,2 ])
barchart = data.plot( kind="bar" )
```



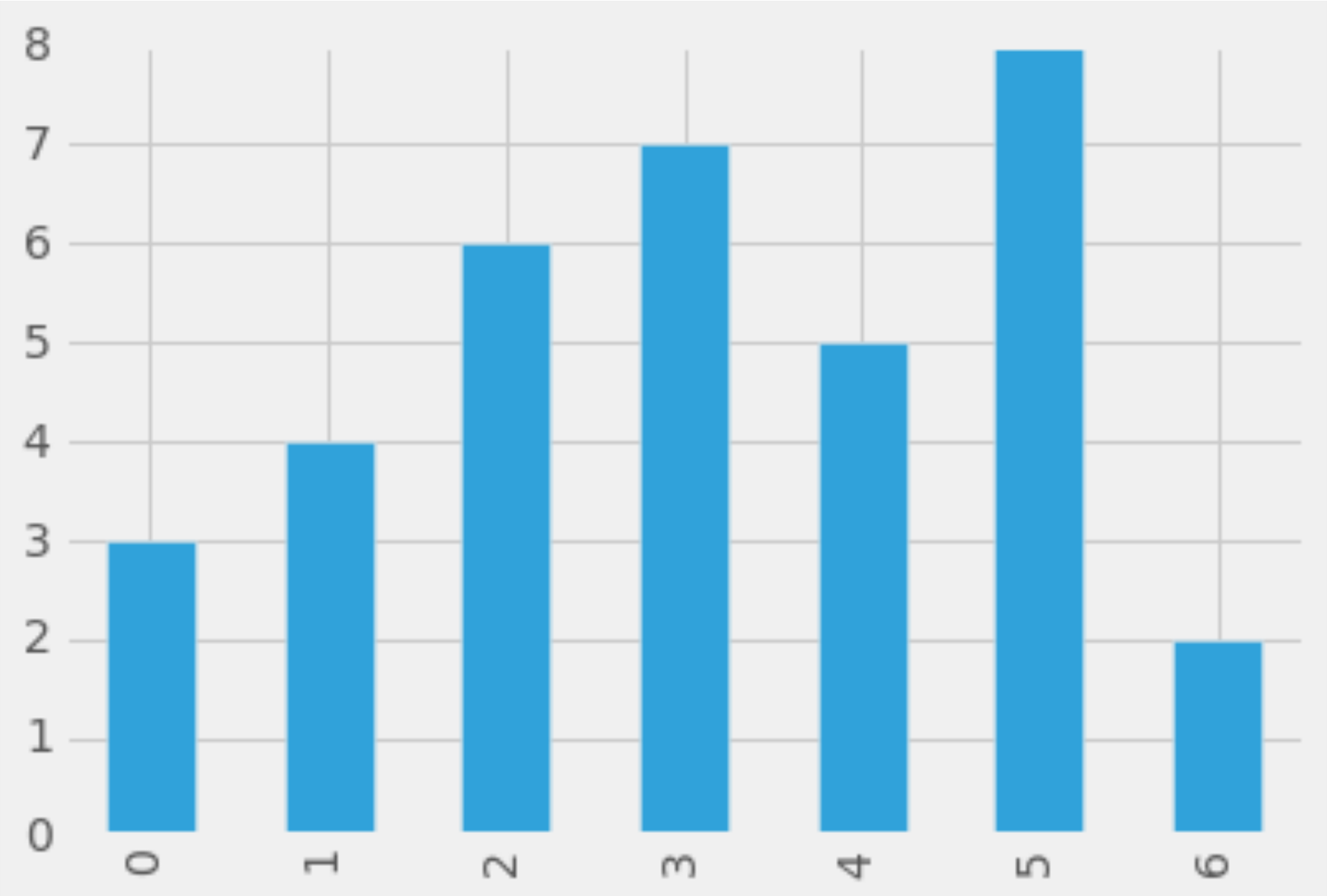
```
plt.style.use('dark_background')
barchart = data.plot( kind="bar" )
```



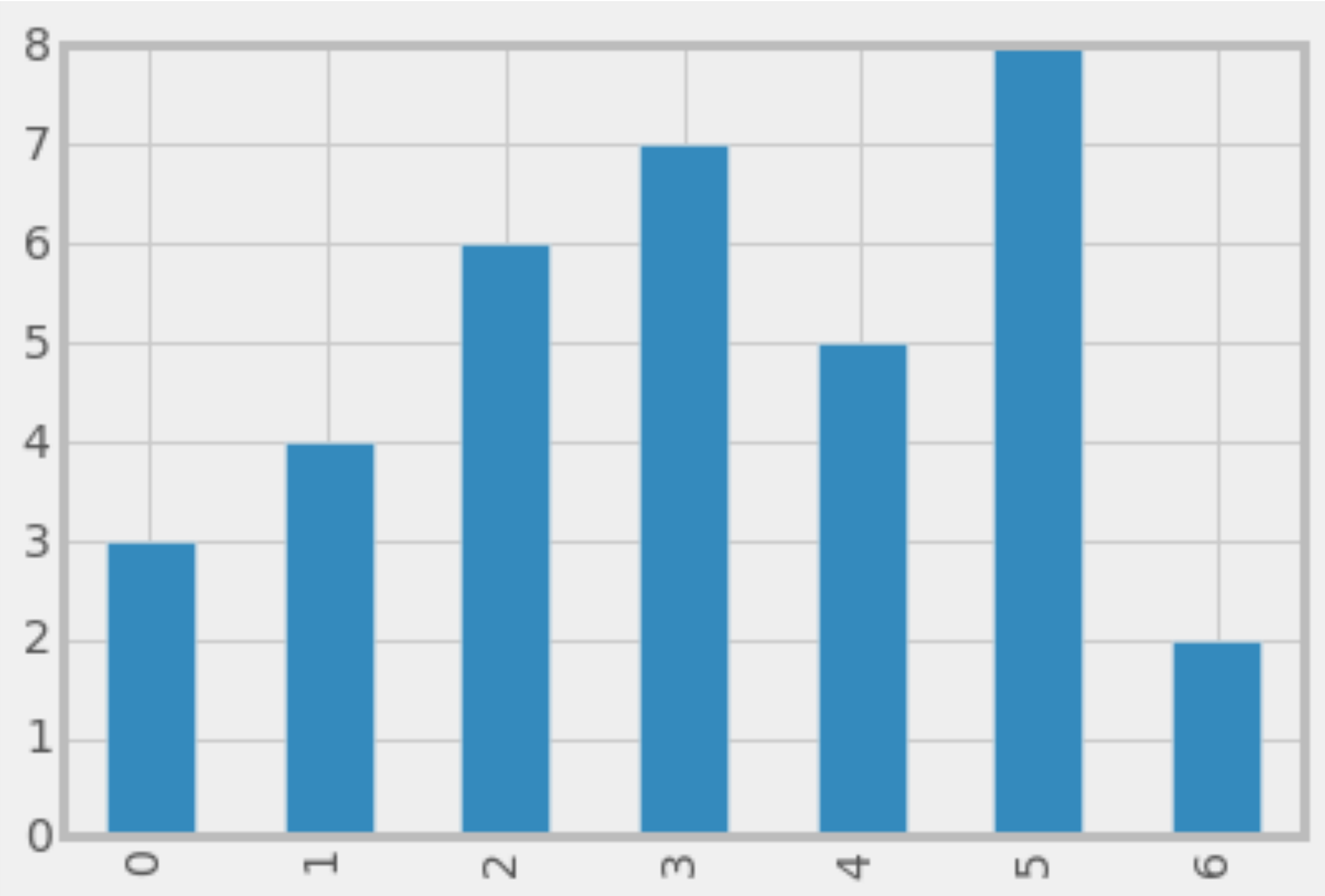
```
plt.style.use('ggplot')
barchart = data.plot( kind="bar" )
```



```
plt.style.use('fivethirtyeight')
barchart = data.plot( kind="bar" )
```



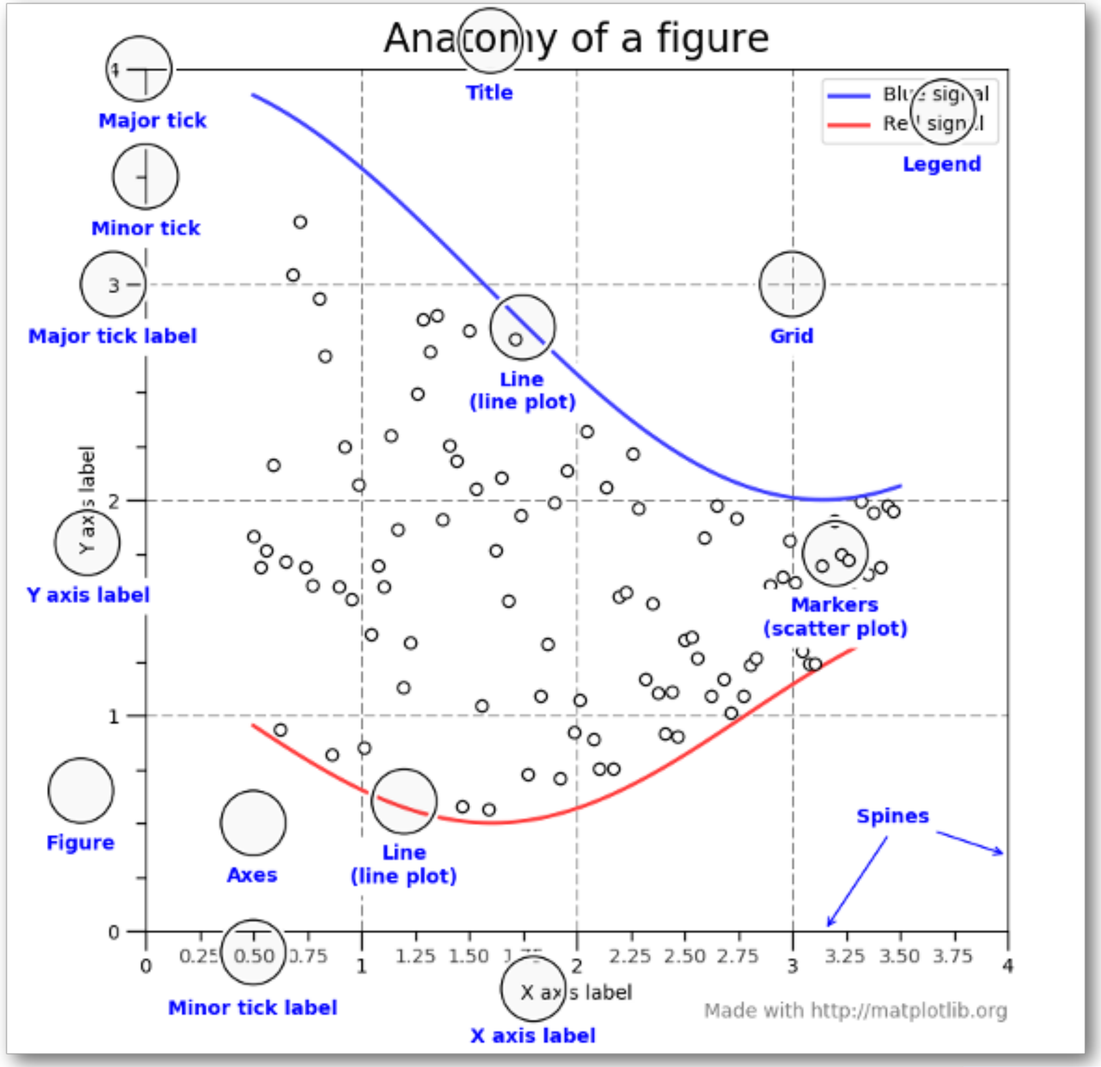
```
plt.style.use('bmh')
barchart = data.plot( kind="bar" )
```



Stop

Customizing your Charts

Customizing your Charts



https://pbpython.com/effective-matplotlib.html

Customizing your Charts

- **Axes:** Axes represent an individual plot or chart.
- **Figure:** This is the final complete image and may contain 1 or more axes.

Customizing your Charts

- Matplotlib has both an object-oriented and state-based interface. This can be confusing when you look up answers on Stack Overflow.
- Use basic pandas plotting for simple plots
- Seaborn, YellowBrick and others for more complex visualizations
- Use the OO interface in MatPlotLib to customize simple visualizations.

Customizing your Charts

```
fig, ax = plt.subplots()
df.plot(..., ax=ax)
```

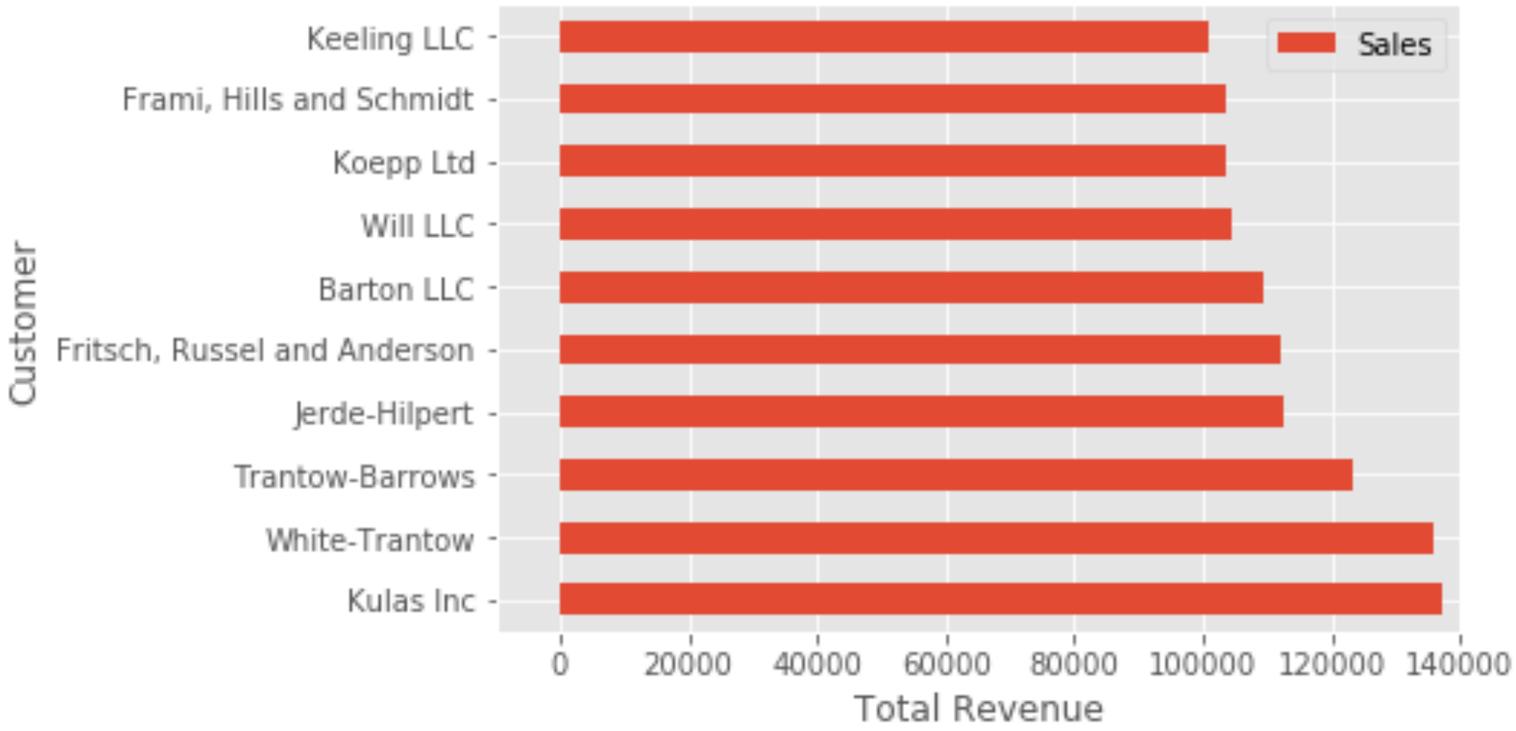
This method gets you access to the **figure** and **axes**.

Customizing your Charts

- **Axes:** Long list of possible options to configure your chart: https://matplotlib.org/3.1.0/api/axes_api.html#the-axes-class

Add Axis Labels

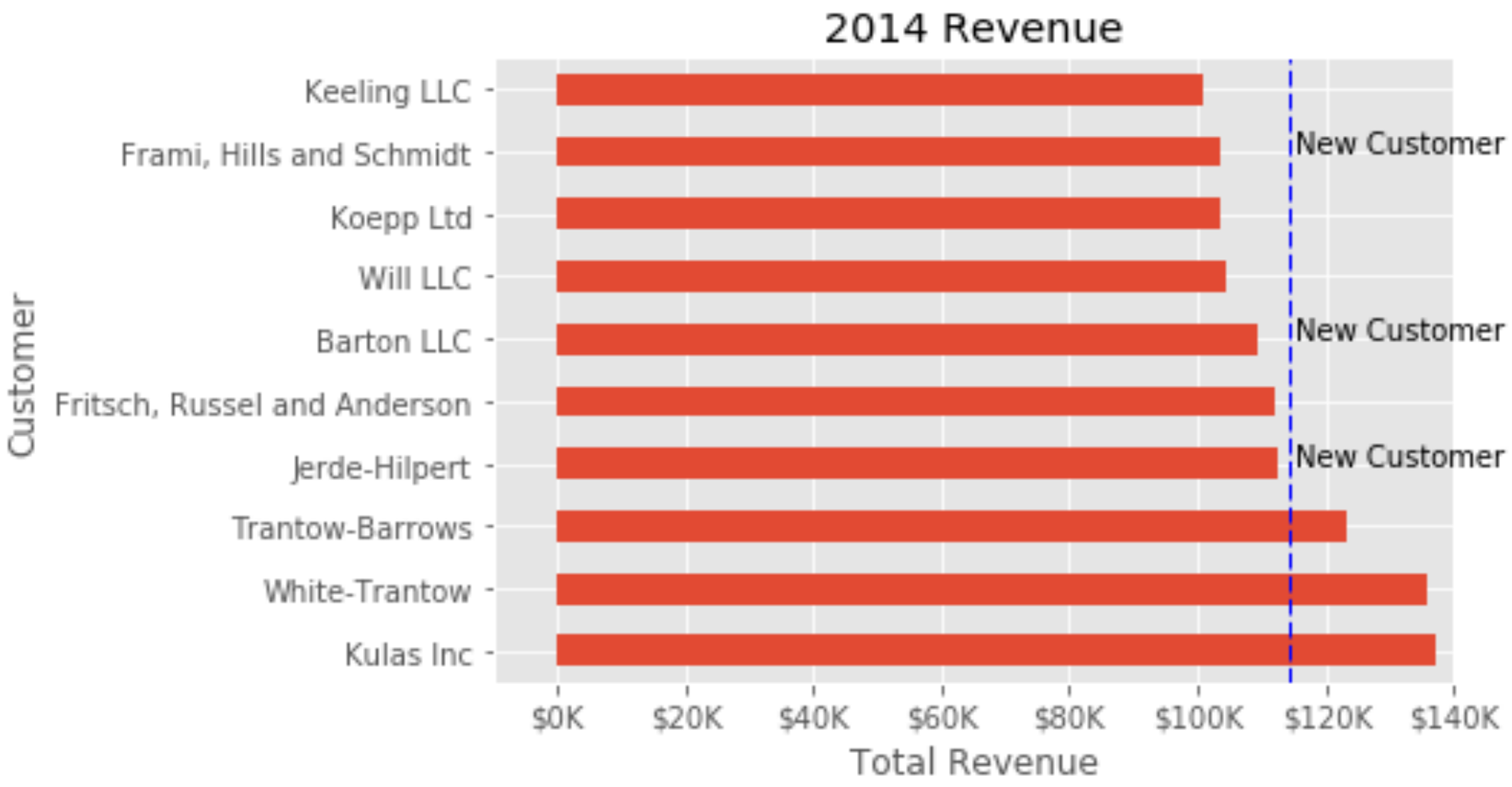
```
fig, ax = plt.subplots()
df.plot(kind='barh', ax=ax)
ax.set_xlim([-10000, 140000])
ax.set_xlabel('Total Revenue')
ax.set_ylabel('Customer');
```



https://pbpython.com/effective-matplotlib.html

Add Annotations

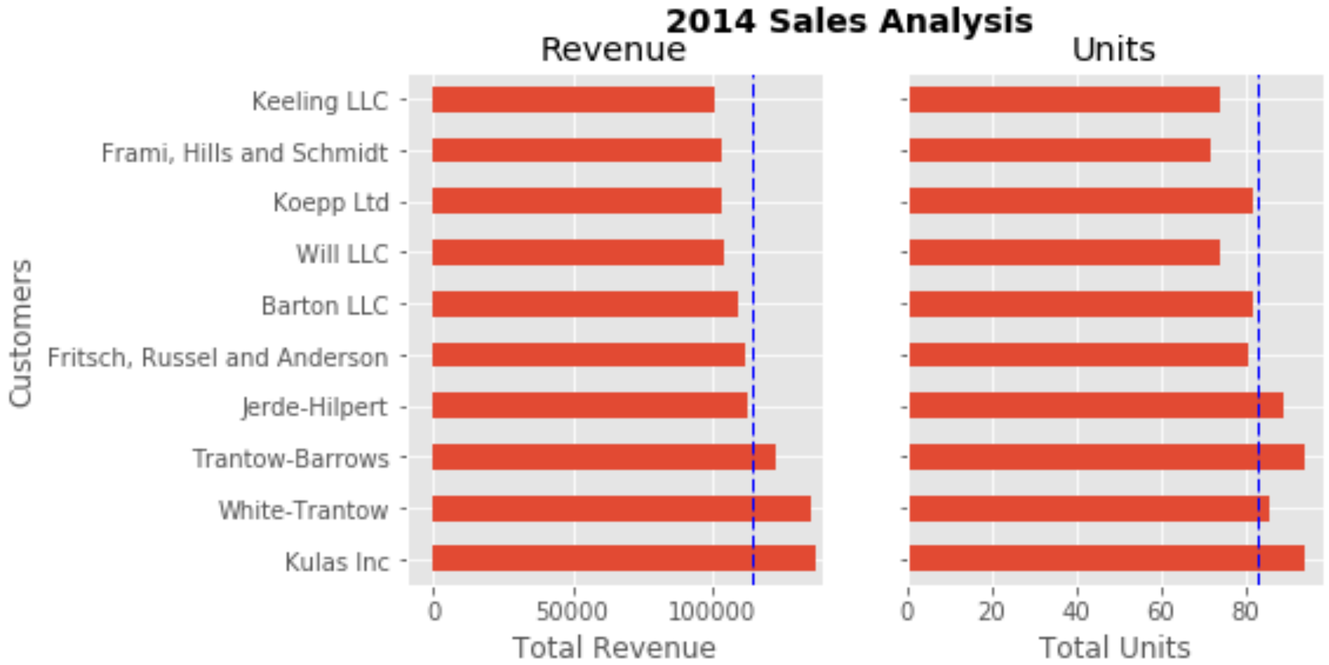
```
fig, ax = plt.subplots()
df.plot(kind='barh', ax=ax)
avg = df['Sales'].mean()

ax.axvline(x=avg,
     color='b',
     label='Average',
     linestyle='--',
     linewidth=1)

for cust in [3, 5, 8]:
    ax.text(115000, cust,
            "New Customer")
```



https://pbpython.com/effective-matplotlib.html

Subplots

```
fig, (ax0, ax1) = plt.subplots(nrows=1,
     ncols=2,
     sharey=True,
     figsize=(7, 4))
df.plot(kind='barh', ax=ax0)
ax0.set_xlim([-10000, 140000])
...
df.plot(kind='barh', ax=ax1)
avg = df['Purchases'].mean()
ax1.set(title='Units',
    xlabel='Total Units',
    ylabel='')
ax1.axvline(x=avg, color='b',
      label='Average',
      linestyle='--',
      linewidth=1)
```

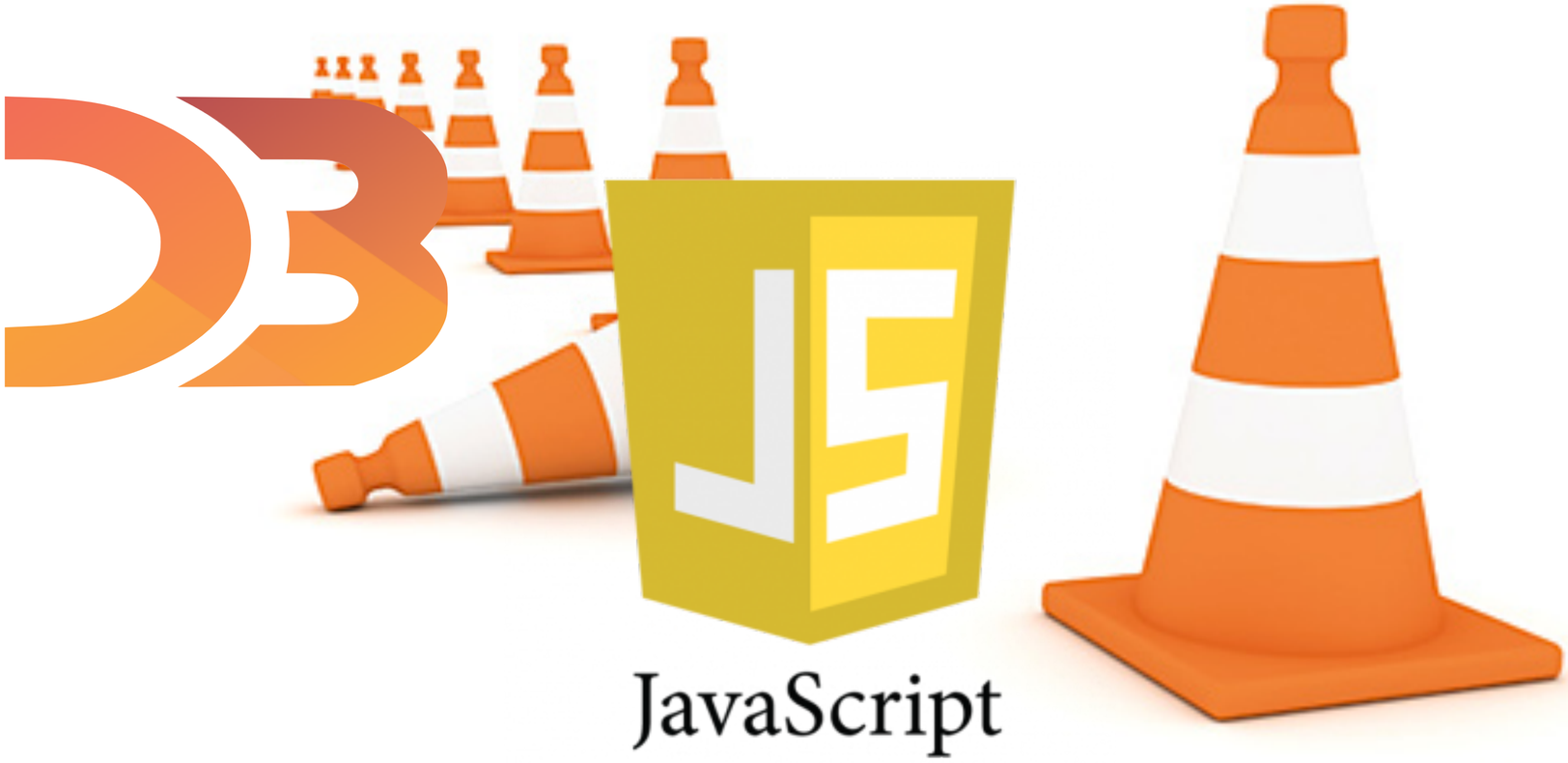


https://pbpython.com/effective-matplotlib.html

Interactive Visualizations

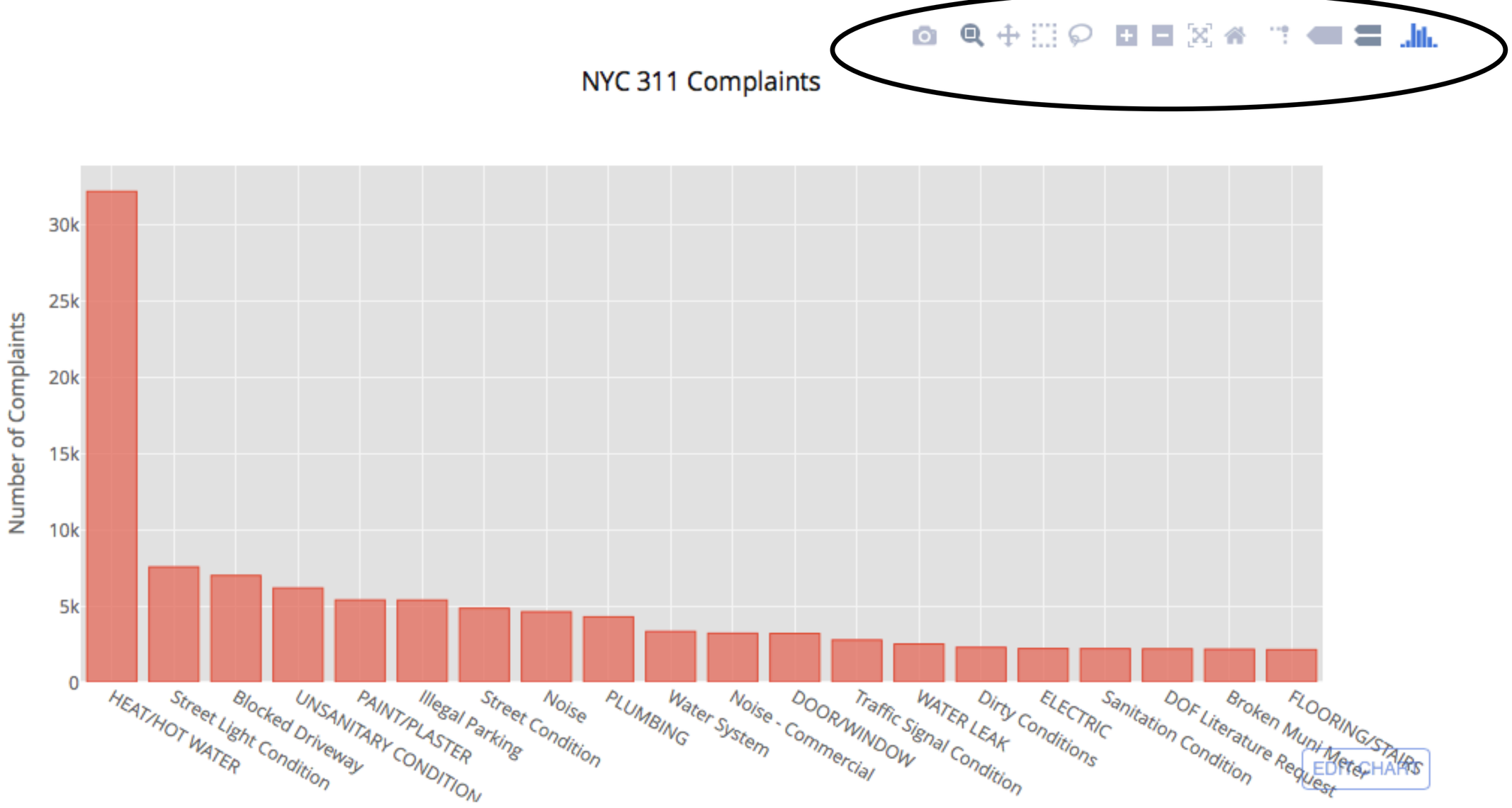
QlikView

FEDERAL RESERVE NOTE
THE UNITED STATES OF AMERICA
AE 63456225 C
ONE HUNDRED DOLLARS


JavaScript

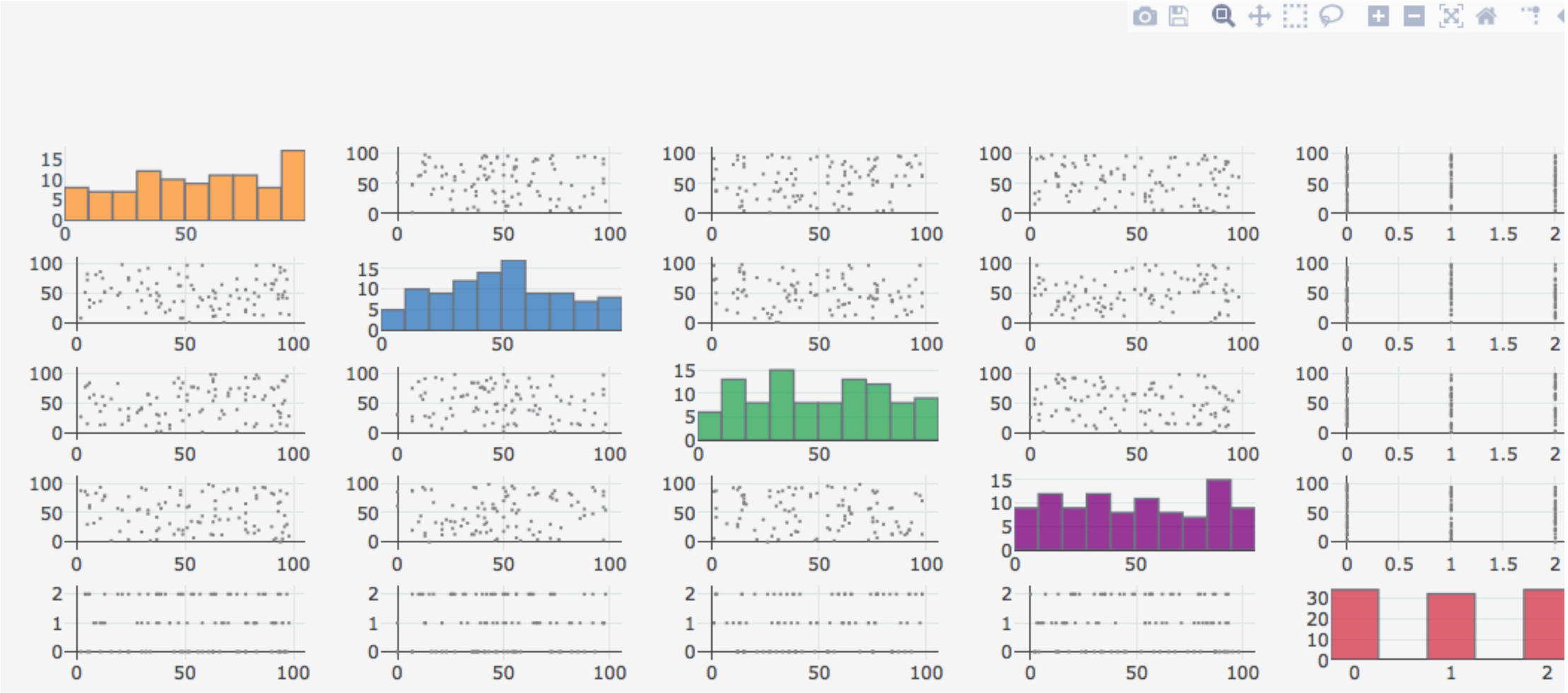
Easy to use… if you know R

ntroducing Cufflinks




```
series.iplot(kind='bar', yTitle='Number of Complaints', title='NYC 311
Complaints')
```

https://plot.ly/ipython-notebooks/cufflinks/



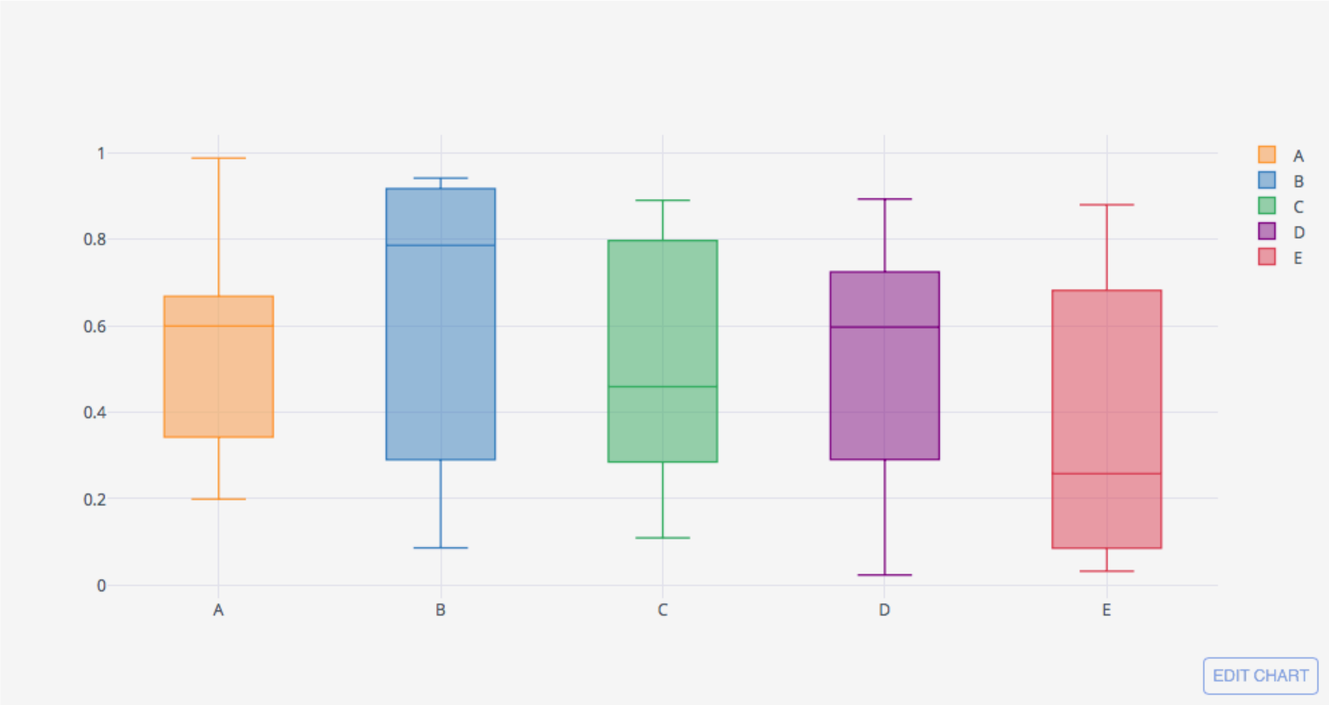
```
df.scatter_matrix()
```

https://plot.ly/ipython-notebooks/cufflinks/

Supported Chart Types

- line
- bar
- histogram
- box (boxplot)
- area
- scatter
- bubble
- heat map

```
df.iplot(kind='<type>')
```



https://plot.ly/ipython-notebooks/cufflinks/

In Class Exercise

Please take 30 min to complete Worksheet 3: Data Visualization

Questions?