



# Introduction to Data Visualization

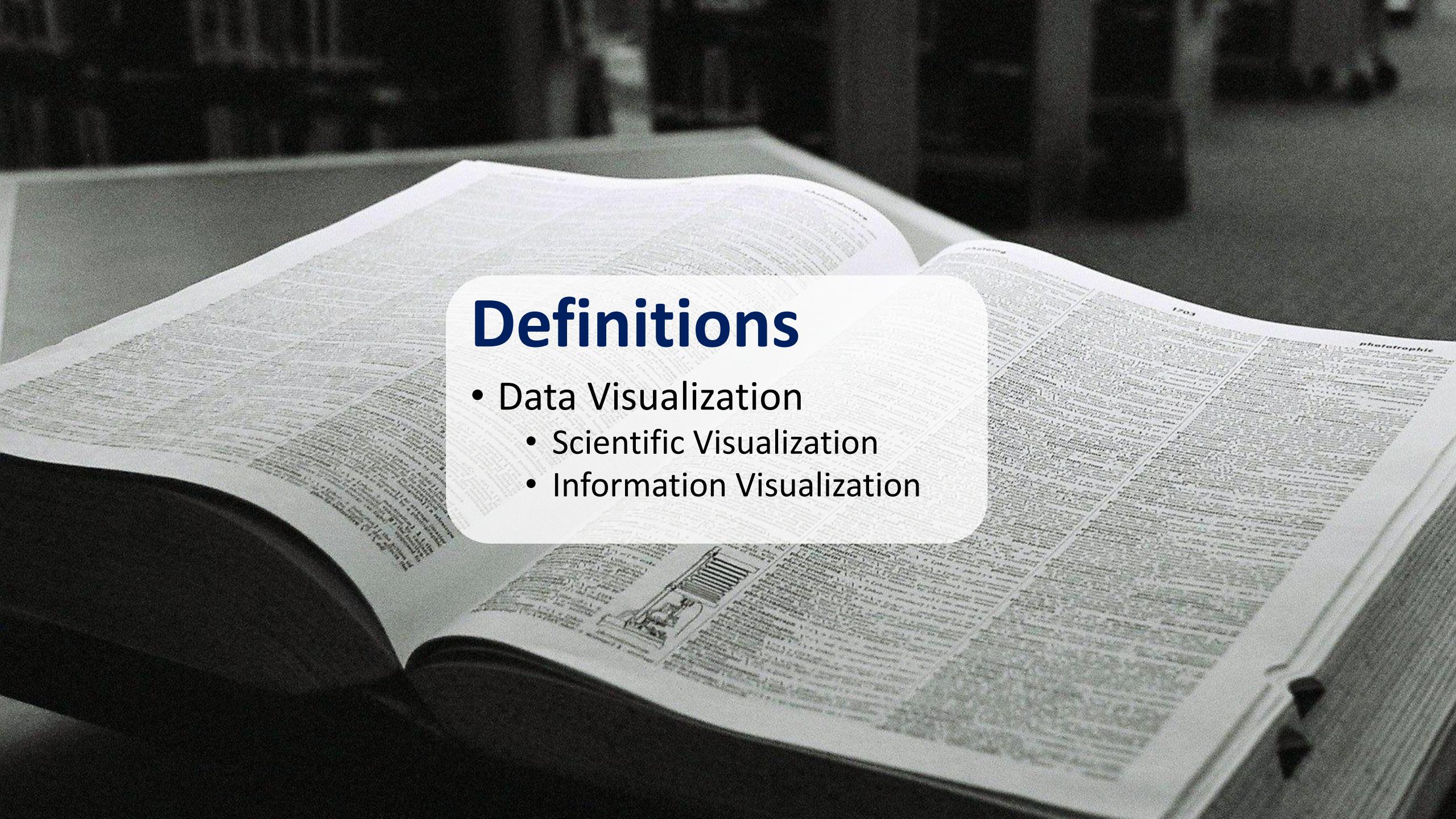
Kelly Schultz, Data Visualization Librarian

# Agenda

- Learning Objectives
- Definitions
- Why Visualize?
- Data Visualization Workflow
- Break
- *Activity: Critiques of Data Visualizations*
- *Activity: Hands-on Practice with Tableau Desktop*
- Wrap-Up: Map & Data Library Services

# Learning objectives

- Participants will be:
  - ✓ Able to identify and apply the Data Visualization Workflow steps to design effective data visualizations
  - ✓ Aware of various data visualization forms and know when to use them
  - ✓ Able to critique data visualizations by identifying data viz best practices and pitfalls
  - ✓ Able to use Tableau Desktop to create simple visualizations
  - ✓ Aware of Map & Data Library services and know where to go for more help



# Definitions

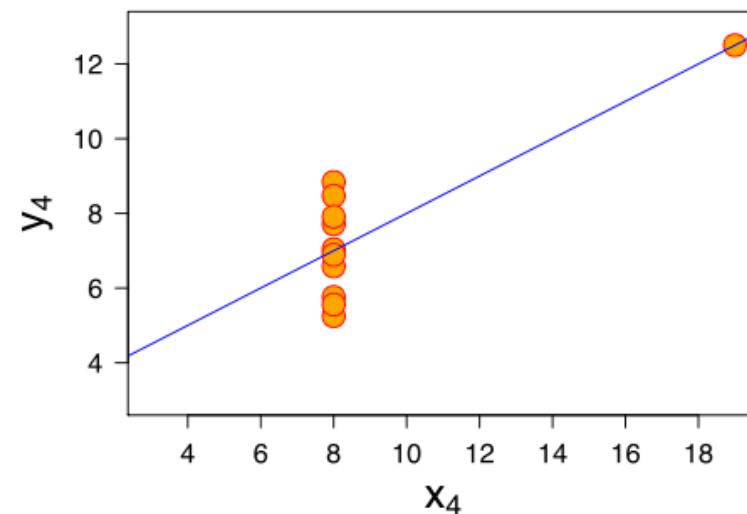
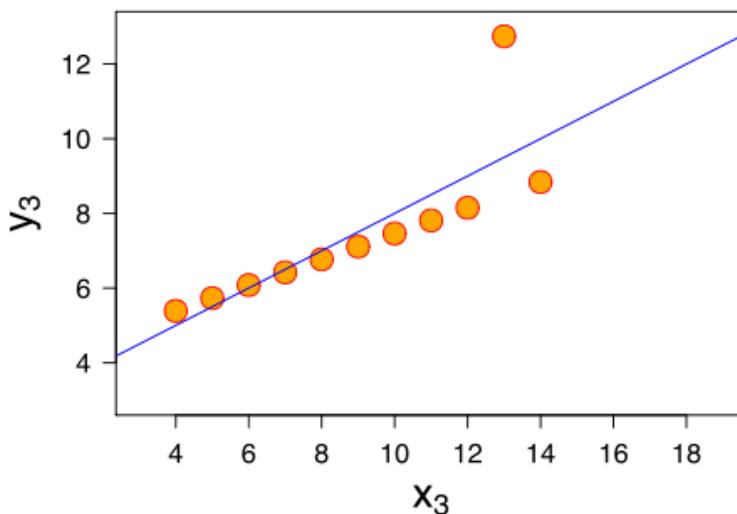
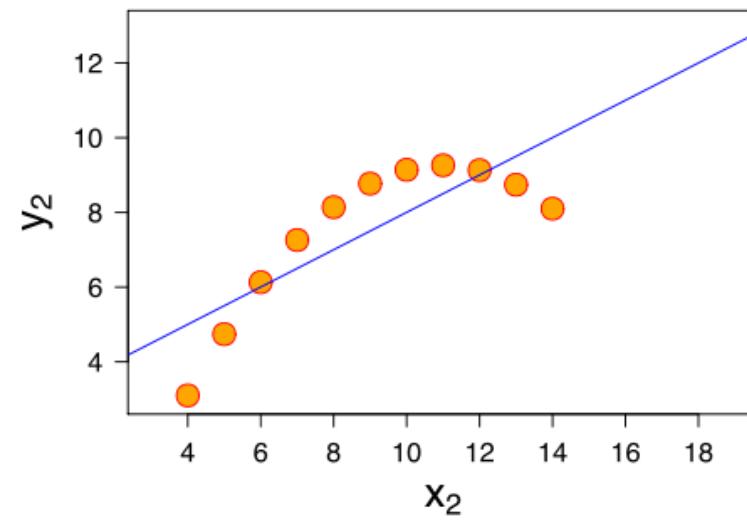
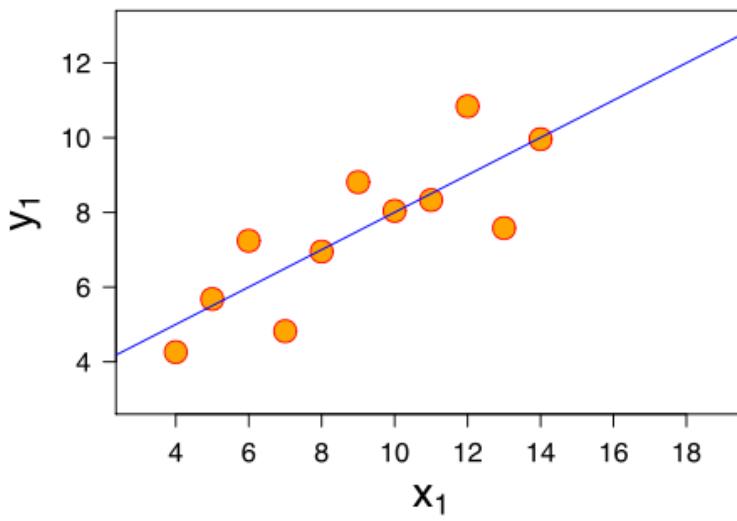
- Data Visualization
  - Scientific Visualization
  - Information Visualization

# Why Visualize?

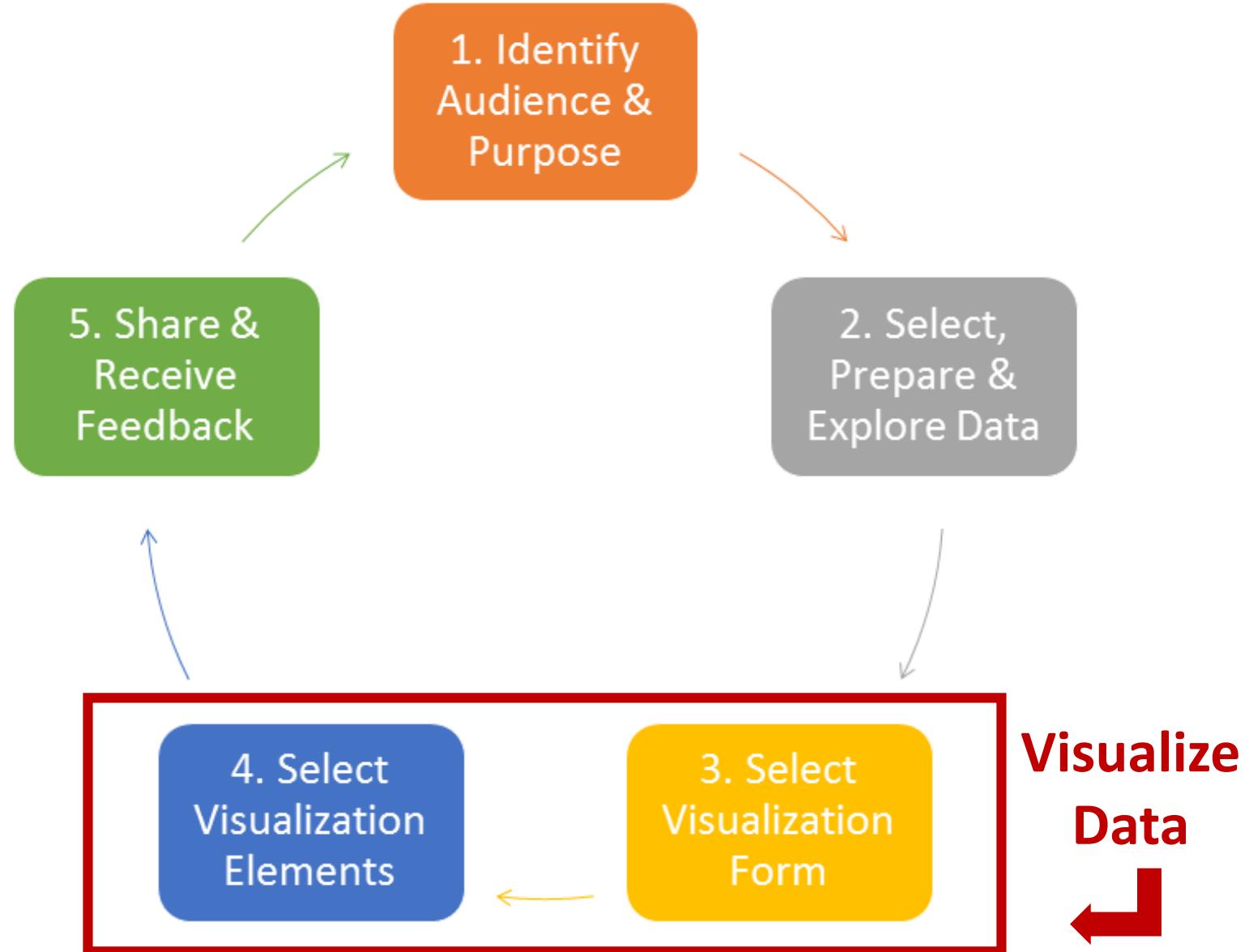
Anscombe's quartet

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

# Why Visualize?



# Visualization Workflow





1. Identify  
Audience &  
Purpose

## 2. Select, Prepare & Explore Data



# Select Your Data



A photograph showing a person's hands wearing yellow rubber gloves. One hand holds a red spray bottle with a trigger mechanism, while the other hand holds a blue microfiber cloth. They appear to be in the middle of cleaning a light-colored wooden or laminate floor. In the background, a white bucket with a green lid is visible.

# Prepare/Clean Your Data

A	B	C	D	E	F	G
1	Table 1: Spending on services					
2	Prepared March 14, 2016					
3						
4	OECD Countries					
5			Spending (\$ Millions)			
6	Country	Identifier	2012-01	2013-01	2014-01	2015-01
7	Canada	124	7.5	7.7	9	8.4
8	Germany	276	4.2	4.1	4.4	4.7
9						
10	Non-OECD Countries					
11			Spending (\$ Millions)			
12	Country	Identifier.Code	2012-01	2013-01	2014-01	2015-01
13	China	156	7.9	7.5	7.7	7.6
14	Costa Rica	188	9.5	9	9.2	8
15						



## Example

A	B	C	D	E
1	Country	OECD_Status	Identifier	Date
2	Canada	OECD	124	2012-01-01
3	Canada	OECD	124	2013-01-01
4	Canada	OECD	124	2014-01-01
5	Canada	OECD	124	2015-01-01
6	Germany	OECD	276	2012-01-01
7	Germany	OECD	276	2013-01-01
8	Germany	OECD	276	2014-01-01
9	Germany	OECD	276	2015-01-01
10	China	Non-OECD	156	2012-01-01
11	China	Non-OECD	156	2013-01-01
12	China	Non-OECD	156	2014-01-01
13	China	Non-OECD	156	2015-01-01
14	Costa Rica	Non-OECD	188	2012-01-01
15	Costa Rica	Non-OECD	188	2013-01-01
16	Costa Rica	Non-OECD	188	2014-01-01
17	Costa Rica	Non-OECD	188	2015-01-01
18				



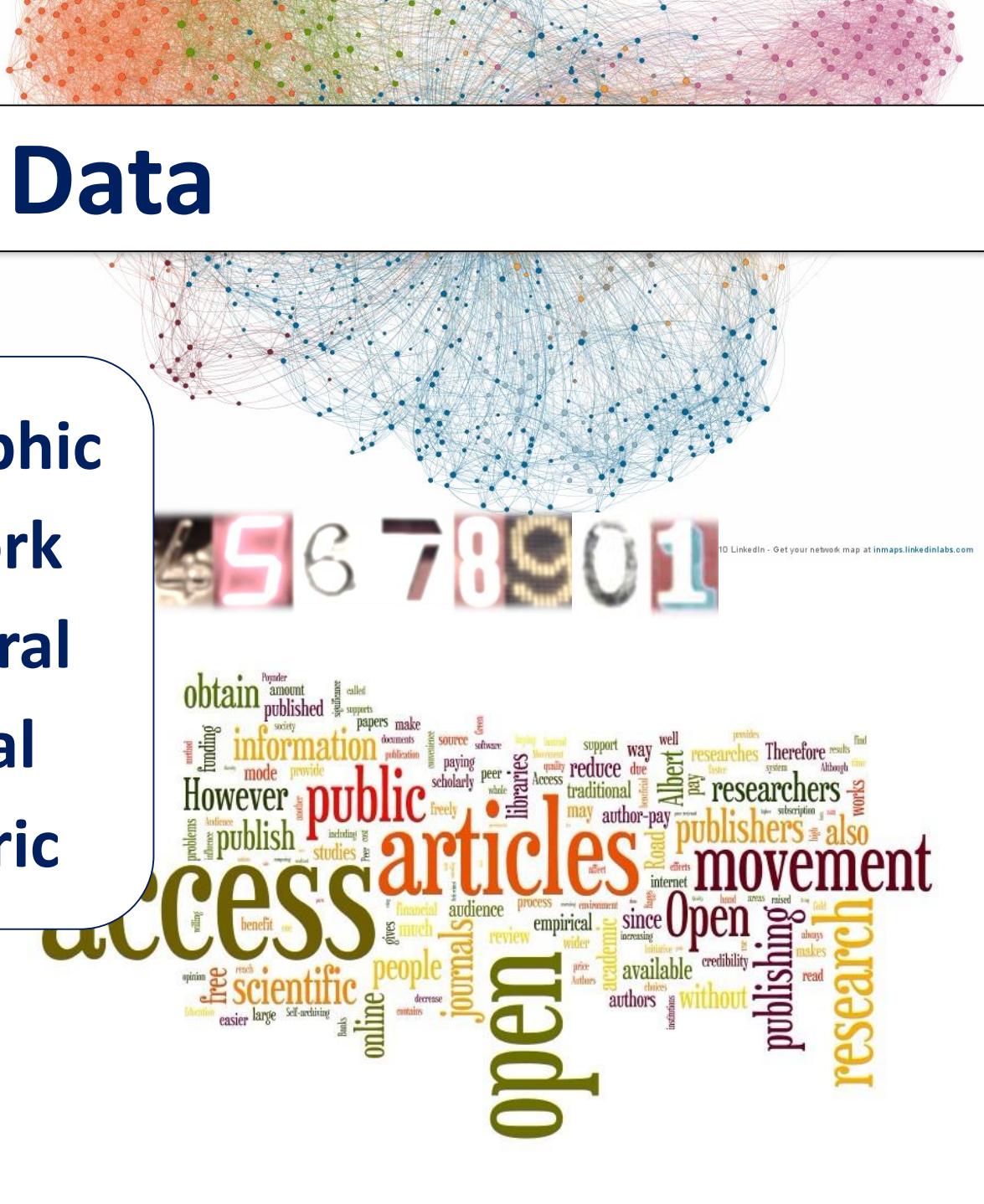
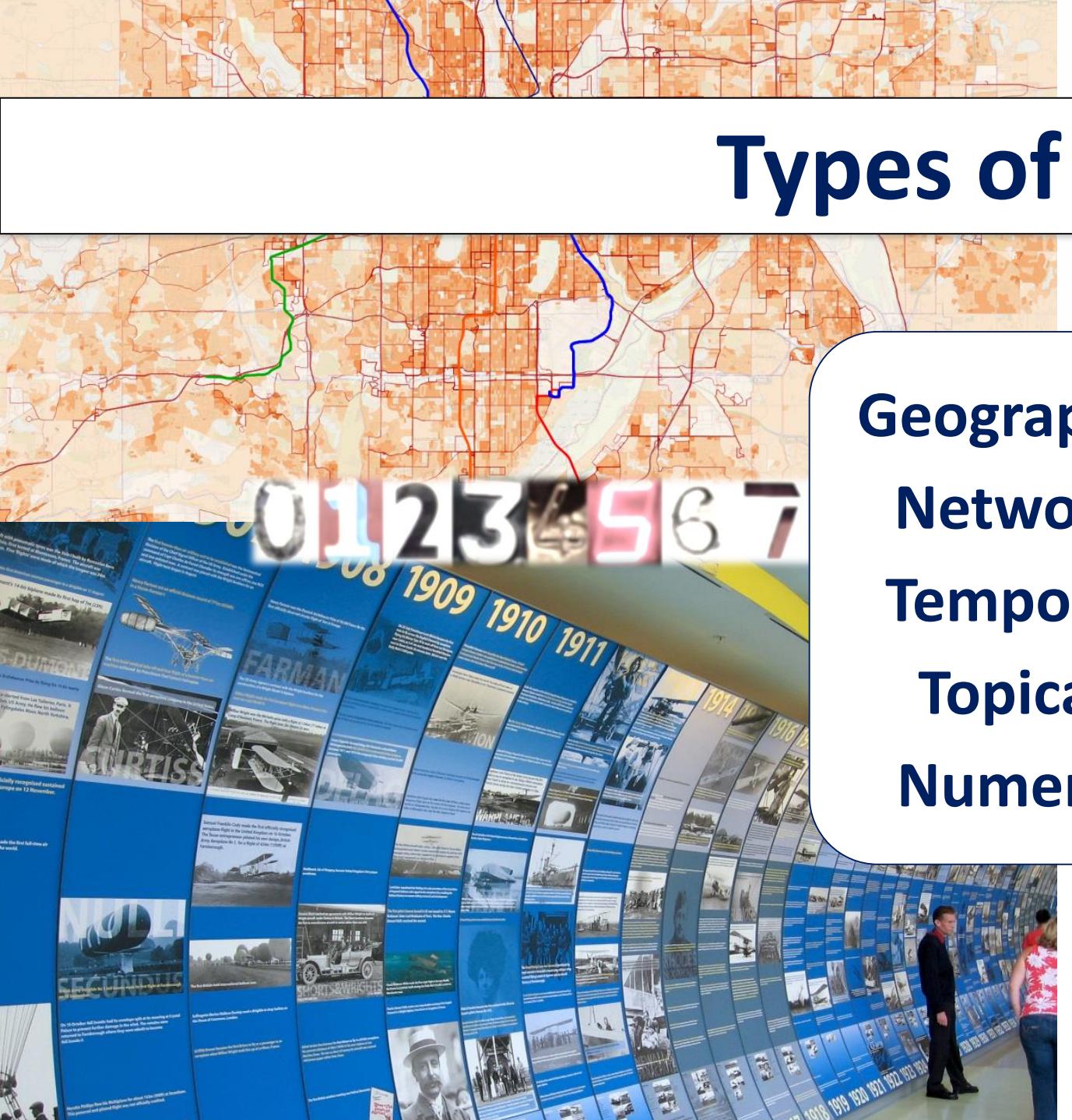
**Explore Your Data**

# Types of Data: Quantitative & Qualitative

1098.3	262.2	915.8	1179.6	0.4345	1.2095	1.164
1099.5	267.7	911.9	1181.0	0.4412	1.1909	1.1790
1100.6	272.8	908.3	1182.4	0.4475	1.1790	1.167
1101.6	277.6	904.8	1183.6	0.4534	1.167	
1102.6	282.2	901.4				
1103.5	286.6	898.2	1184.8	0.4591		
1104.3	290.8	895.1	1185.9	0.4644		
1105.0	294.8	892.1	1186.9	0.4695		
1105.8	298.6	889.2	1187.8	0.4747		
1107.1	305.9	883.7	1189.6	0.4798		
1108.3	312.7	878.5	1191.3			
1109.4	319.0	873.5	1192.5			
1110.3	325.1	868.7	1193.7			
1111.3	330.8	864.3	1194.8			
1112.0	336.3	859.8	1195.8			

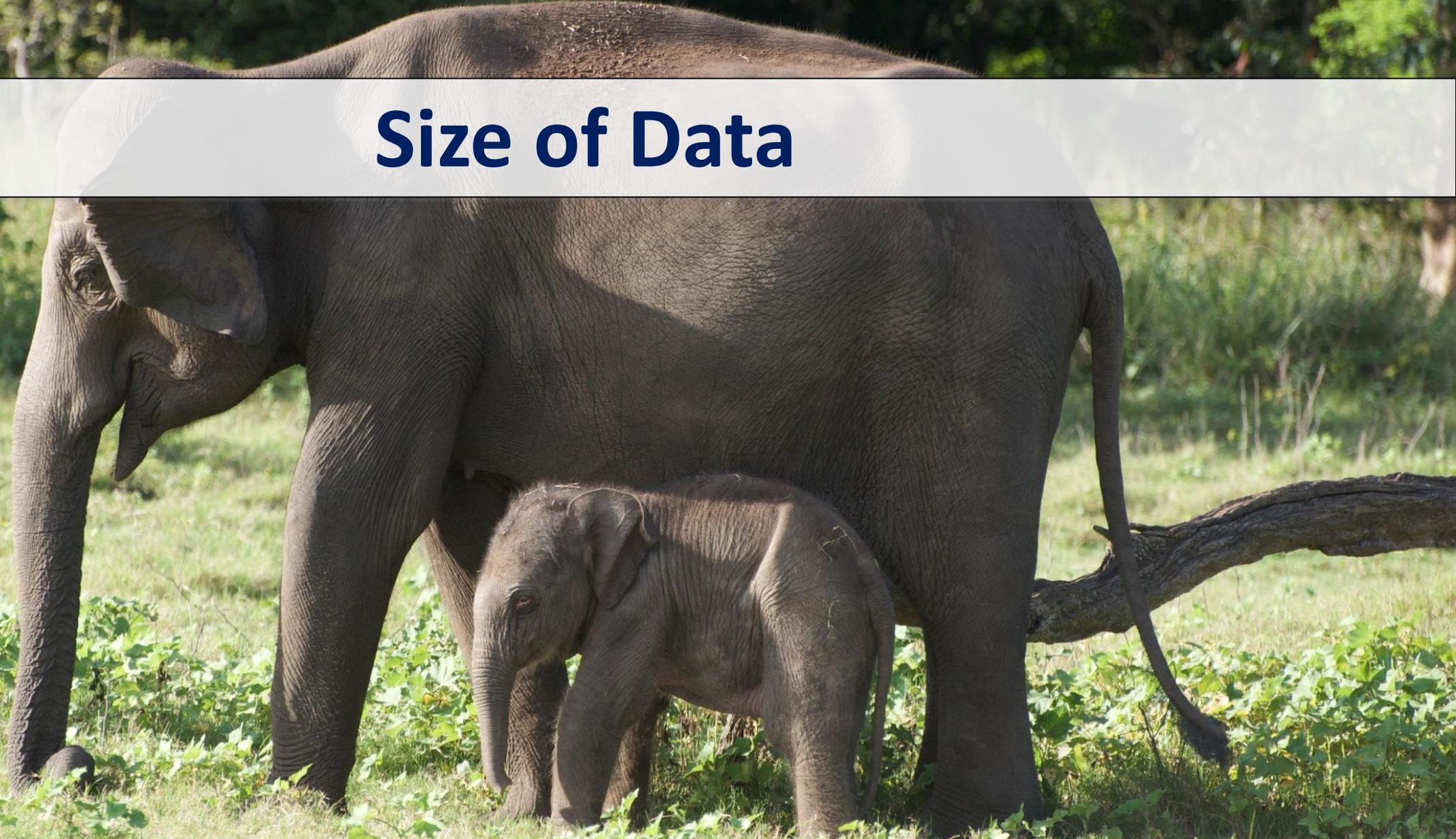
Being for  
Dro. E. What mean  
Ant. S. Upon my life,  
The villain is o'er-raught, by some device,  
As, nimble jugglers that deceive the  
Dark-working witches that deform  
Soul-killing cheaters, prating mon-  
Disguised such-like liberties  
And many I will be gone  
If it prove so, I will to the Centaur, to go se-  
I'll to the I greatly fear my money  
before th

# Types of Data



# Geographic Network Temporal Topical Numeric

# Size of Data



# The Story



# Exercise – Part 1



## Box Plots

# 3. Select Visualization Form

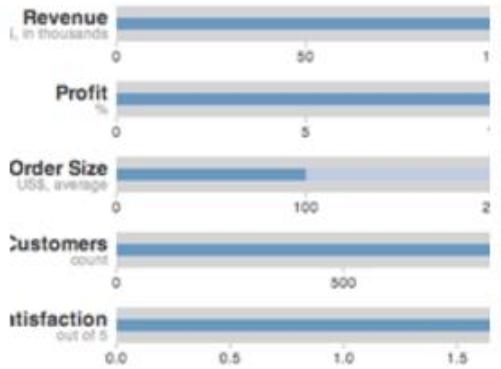
## Non-contiguous Cartogram



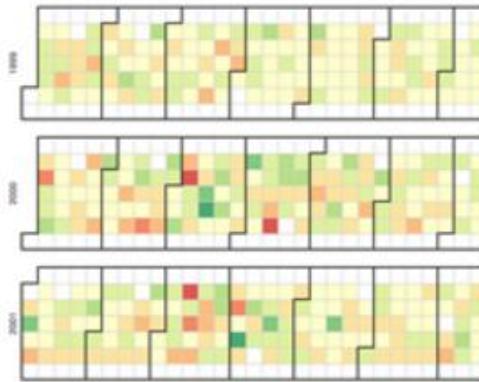
## Bubble Chart



## Bullet Charts



## Calendar View



## Circle Packing



## Population Pyramid 2000



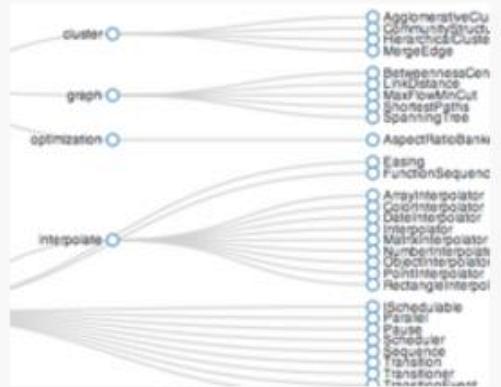
## Stacked Bars



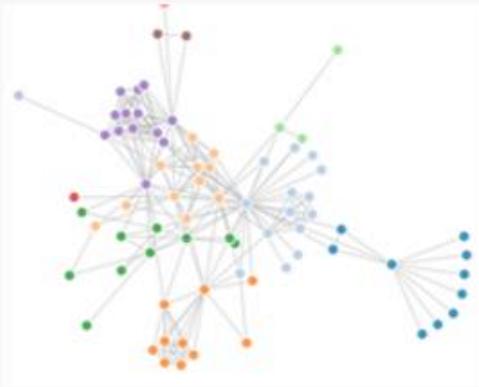
## Chord Diagram



## Dendrogram



## Force-Directed Graph

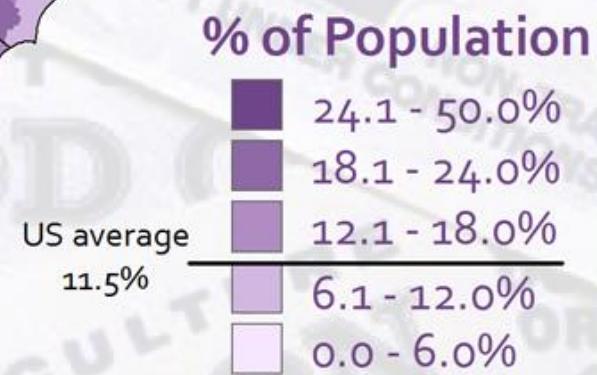


## Streamgraph





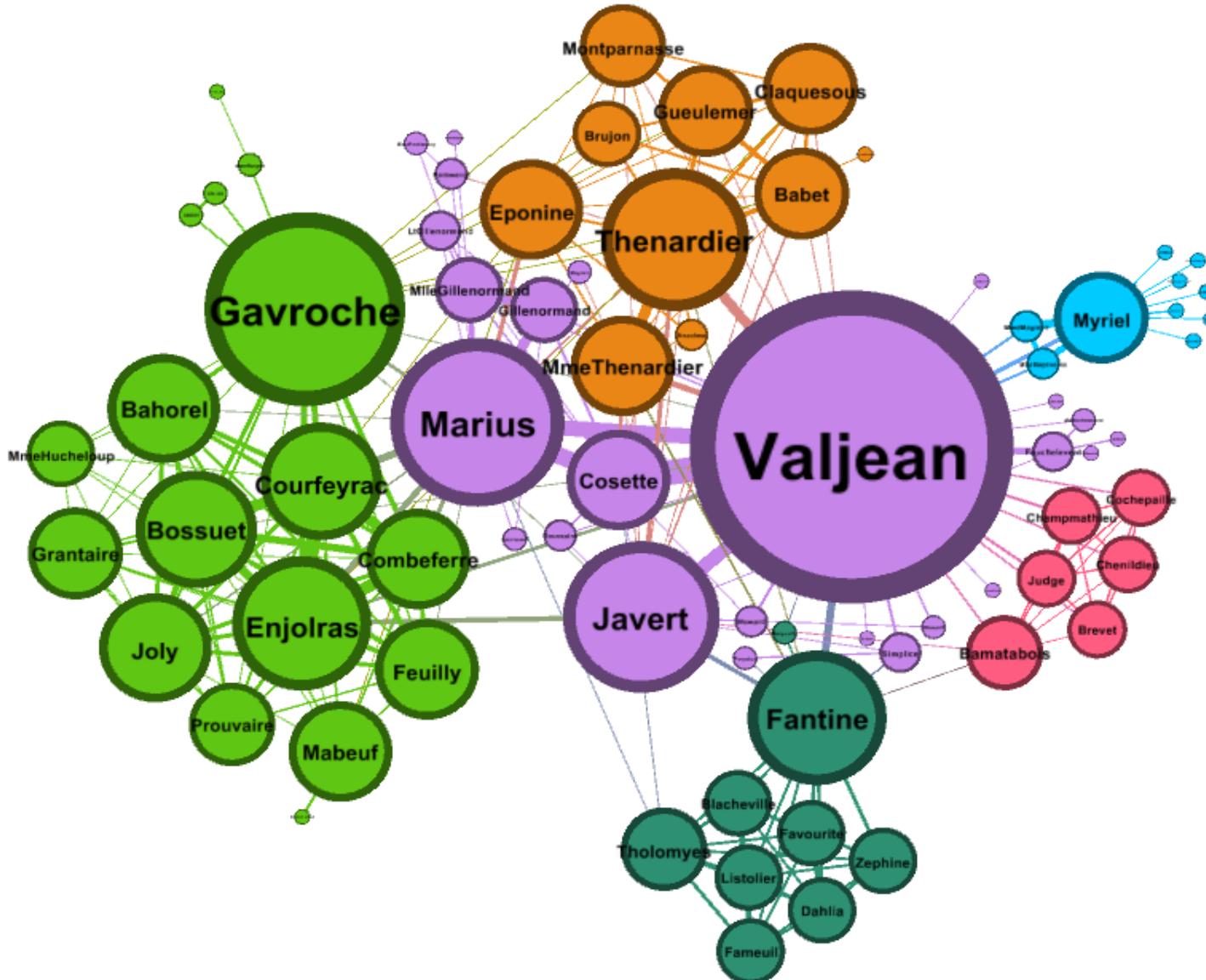
# Geographic



Cartography by Scott A. Drzyzga (November 2009)

Geospatial data:

US Census Bureau (2000) US State and US County and County Equivalent cartographic boundary files.



# Networks



*Easy to see.*



*Can still see.*

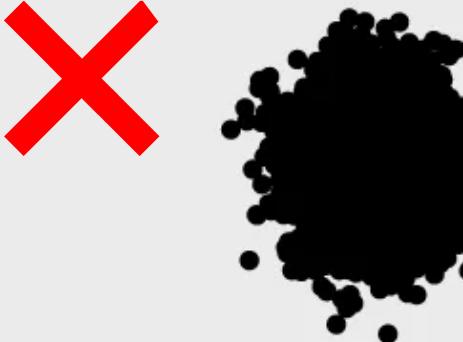


*Can't see middle.*

## Networks – Watch Out!



*Looking blobby.*

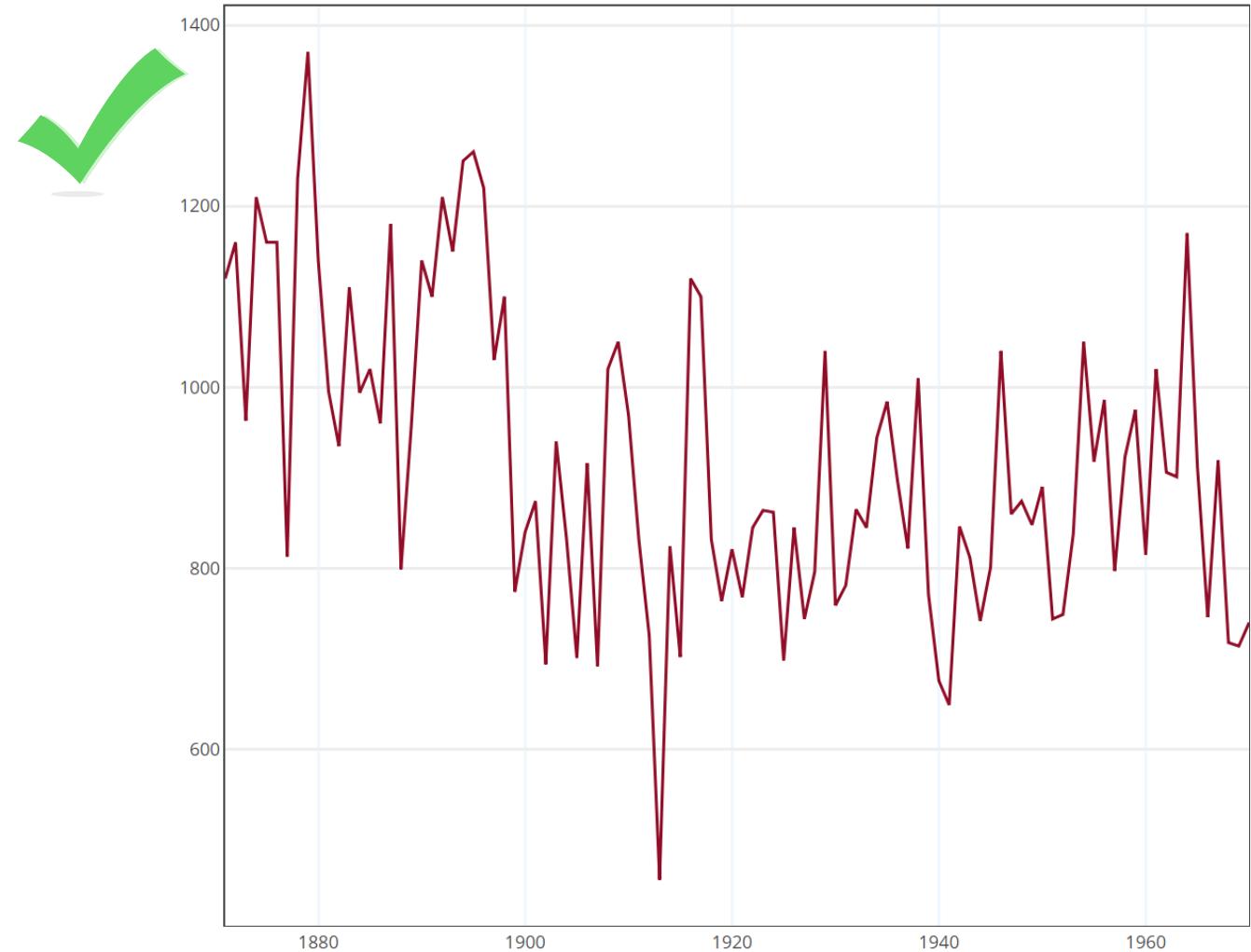
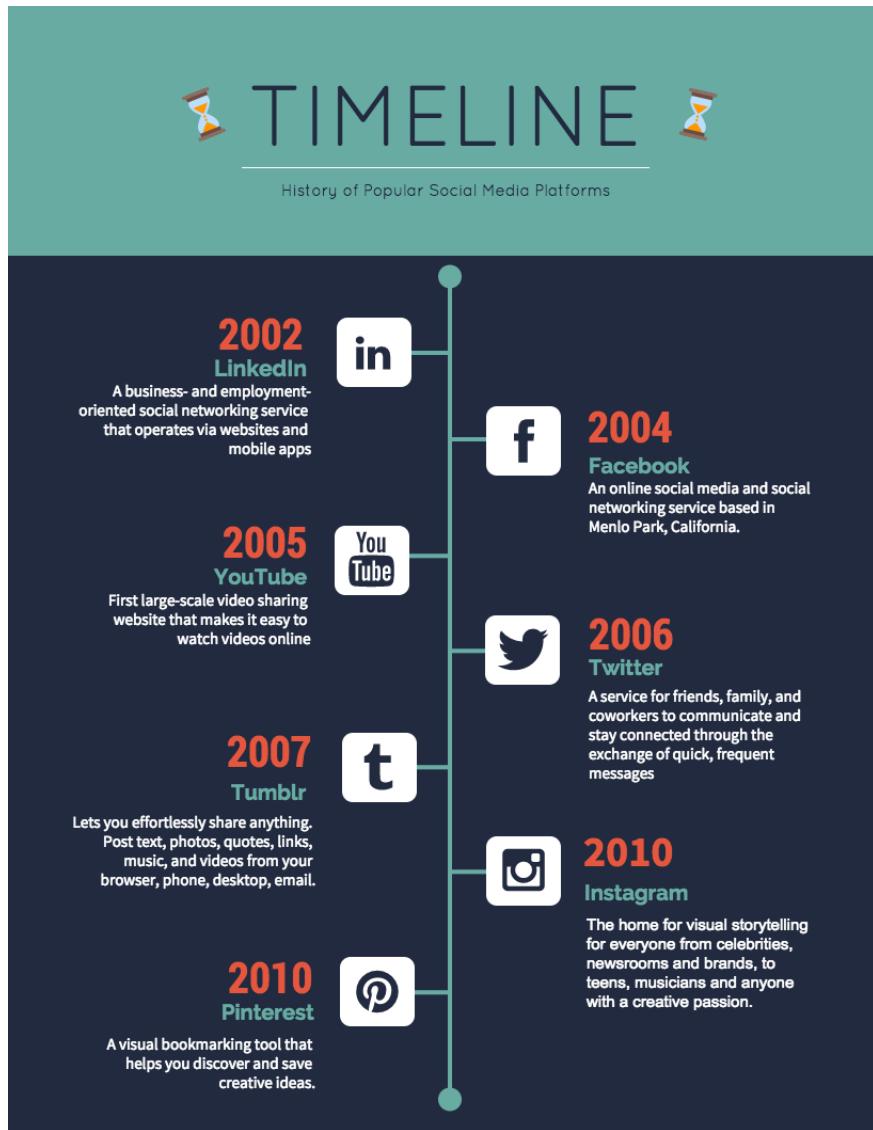


*Okay, it's a blob.*



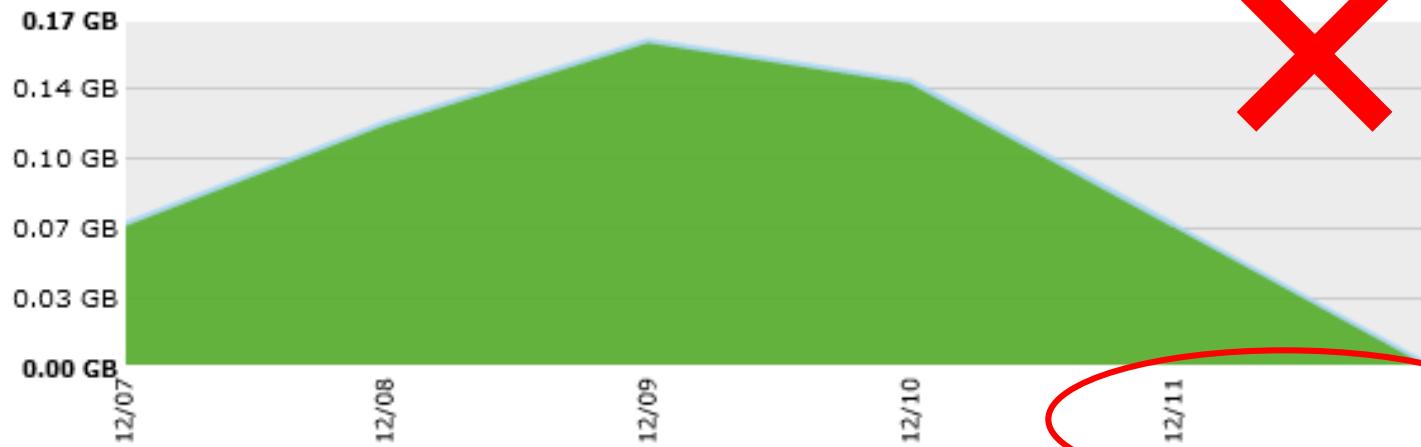
*I don't even.*

# Temporal



# Temporal – Watch Out!

December 07 - January 06

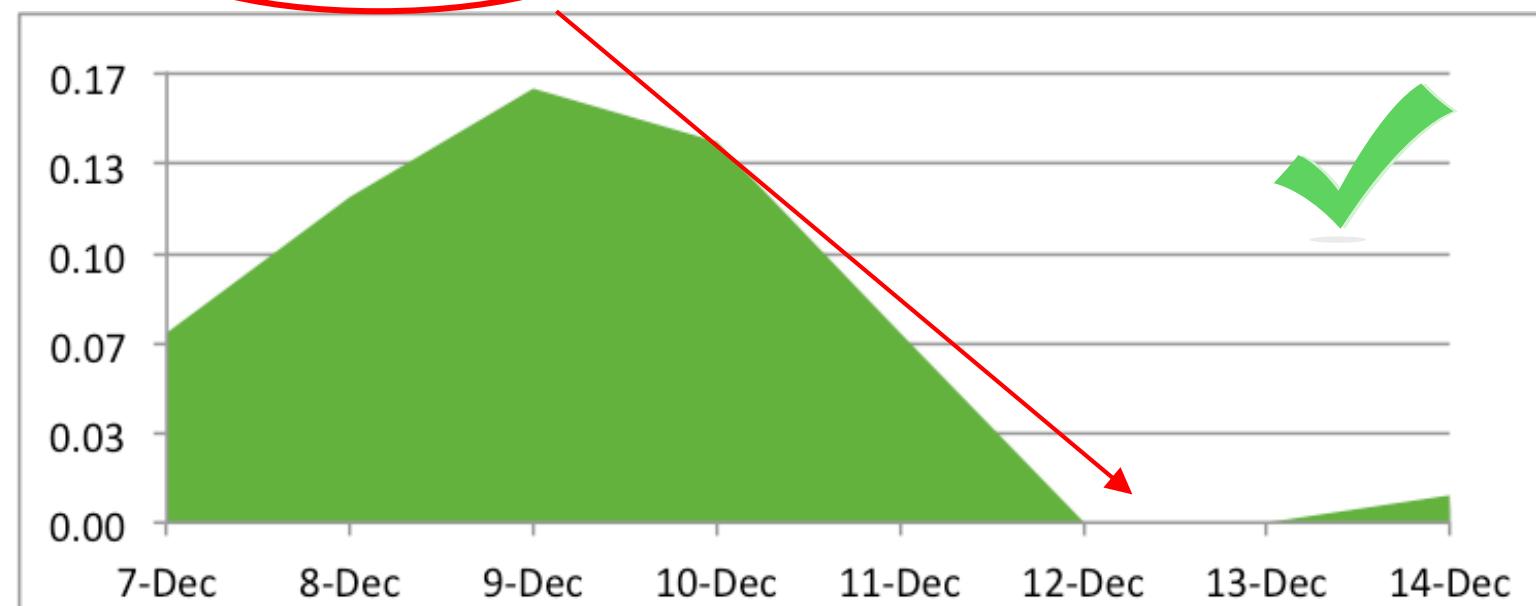


Included  
(0 - 2.00 GB)



12/11

12/14

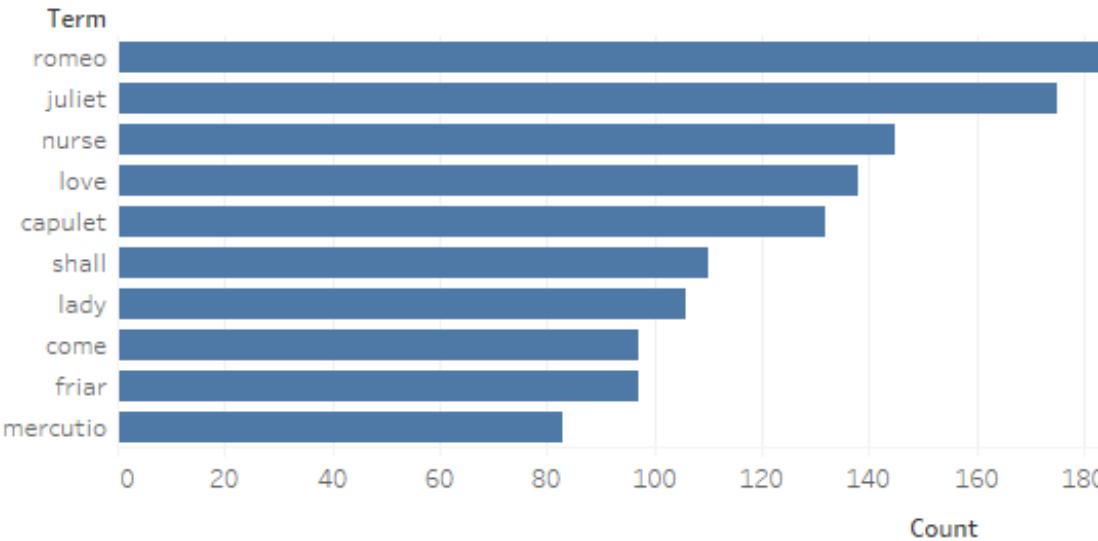


come  
juliet  
romeo  
lady  
tybalt  
sir  
man  
montague  
sweet  
eyes  
know lord  
ay  
death  
merurse  
love  
romeo  
lady  
night  
fair  
let  
ext  
day  
make  
tis  
god house  
look  
light  
benvolio  
friar  
mercuto  
enter  
dead  
paris  
laurence  
good  
like  
exeunt  
shall  
hath  
say  
all  
i'll  
shall  
gone  
prince  
Capulet  
Capulet  
tis  
god house  
look  
light  
bed  
bed  
benvolio  
friar  
mercuto  
enter  
dead

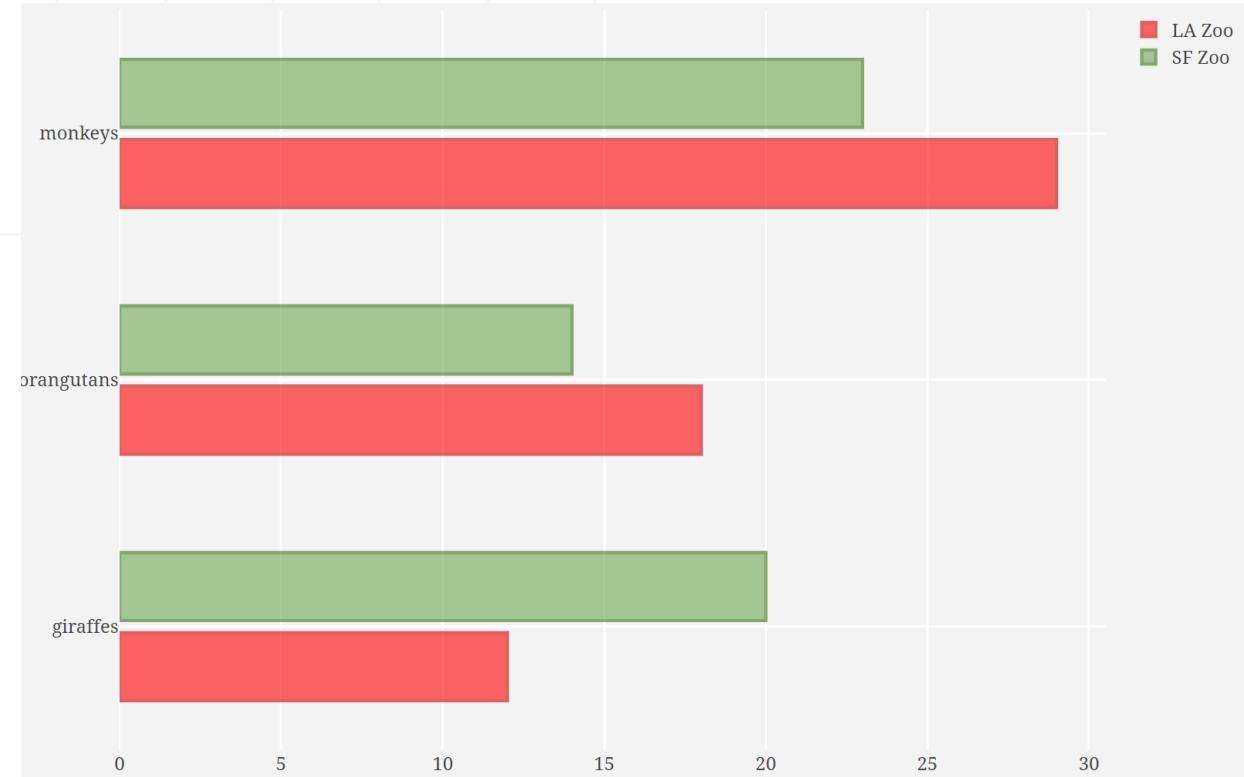
# Topical

# Numeric - Comparisons

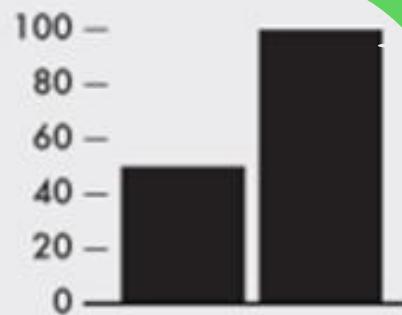
Top 10 Most Used Words in Romeo and Juliet



Sum of Count for each Term. The view is filtered on Term, which keeps 10 of 154 members.

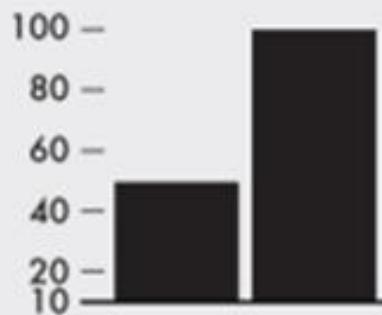


Baseline at 0



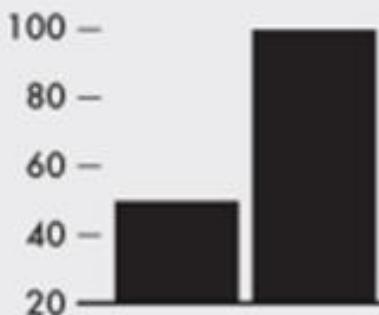
*This is correct.*

Baseline at 10



*Hm, first bar got shorter.*

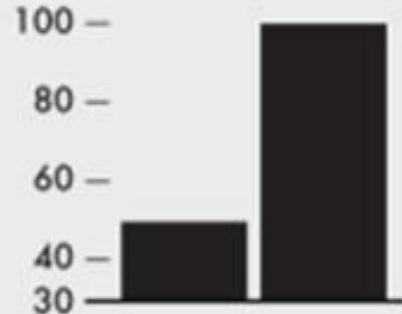
Baseline at 20



*It's going...*

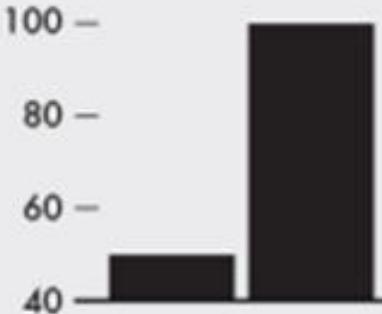
## Numeric – Comparisons – Watch Out!

Baseline at 30



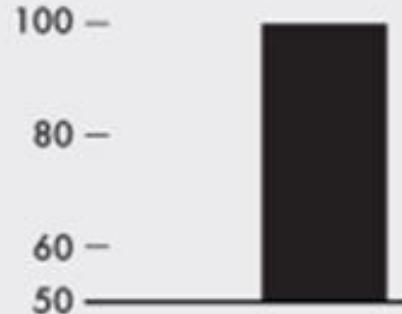
*...going...*

Baseline at 40



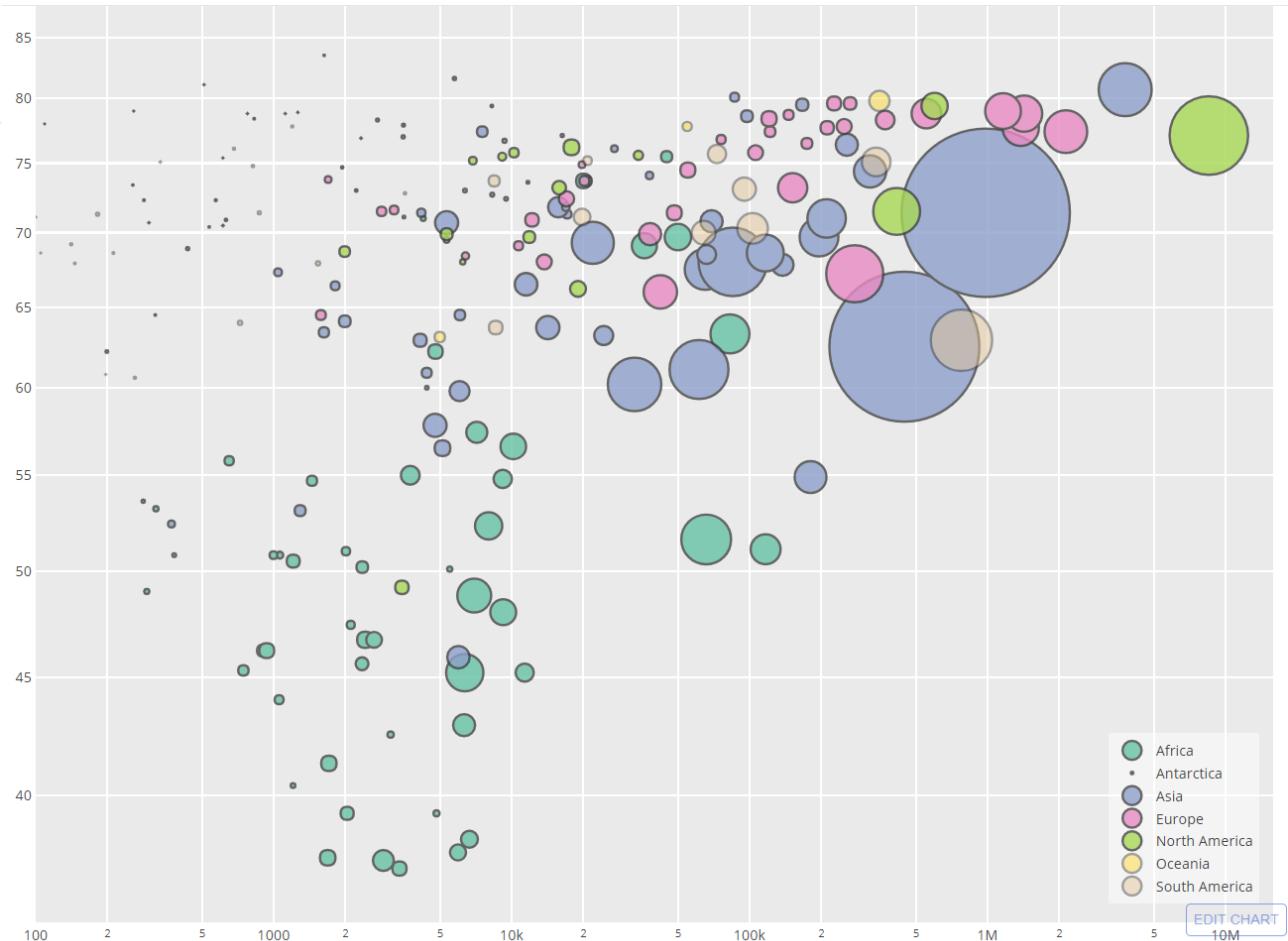
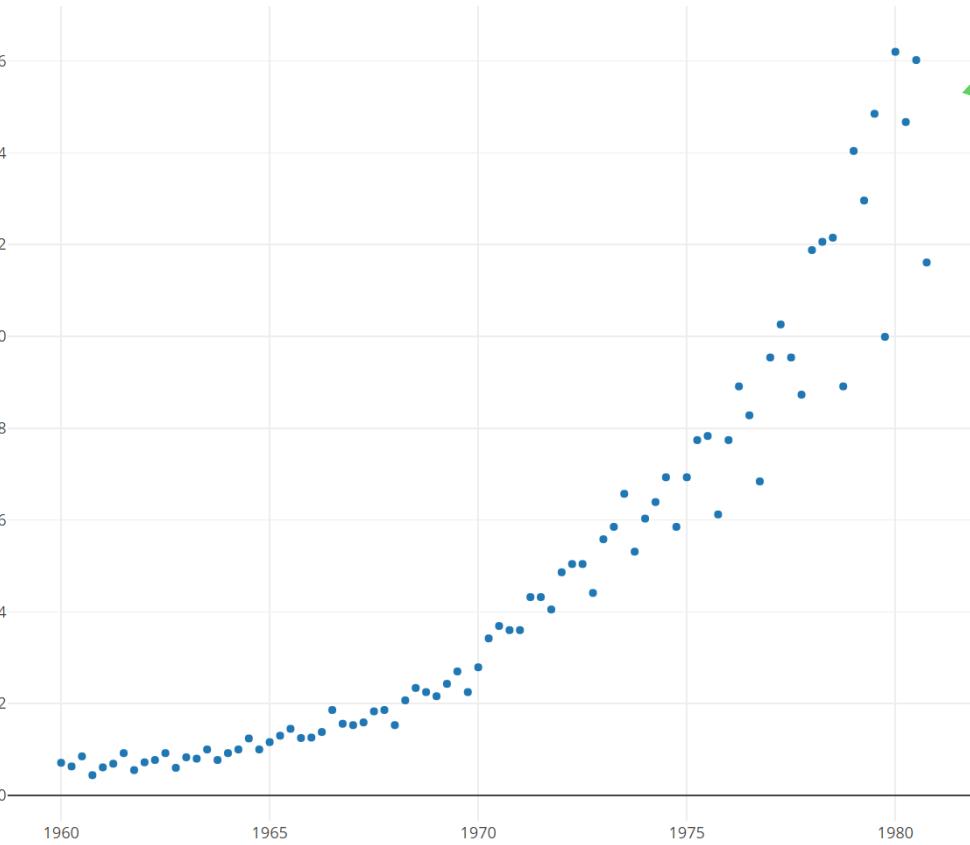
*...going.*

Baseline at 50



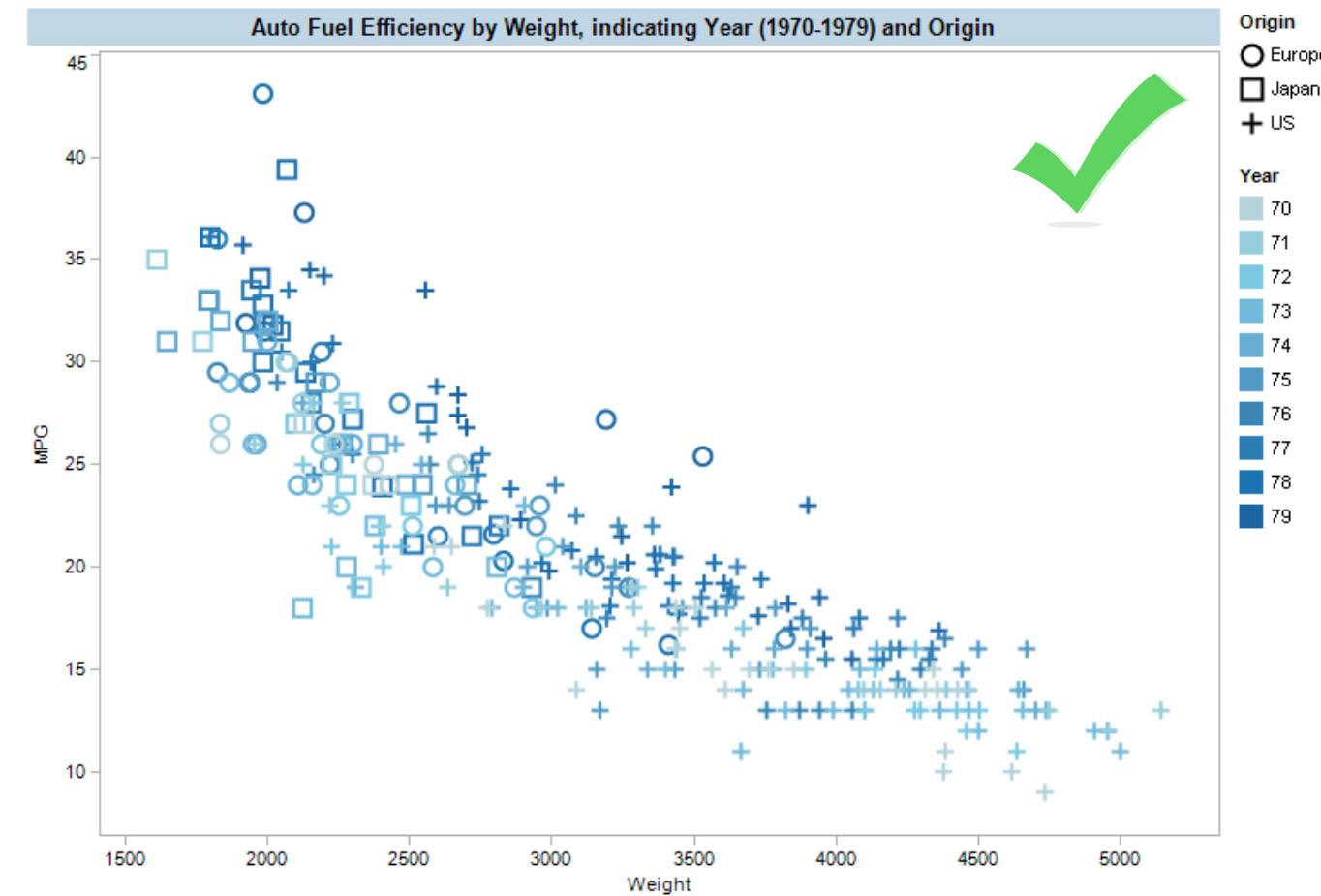
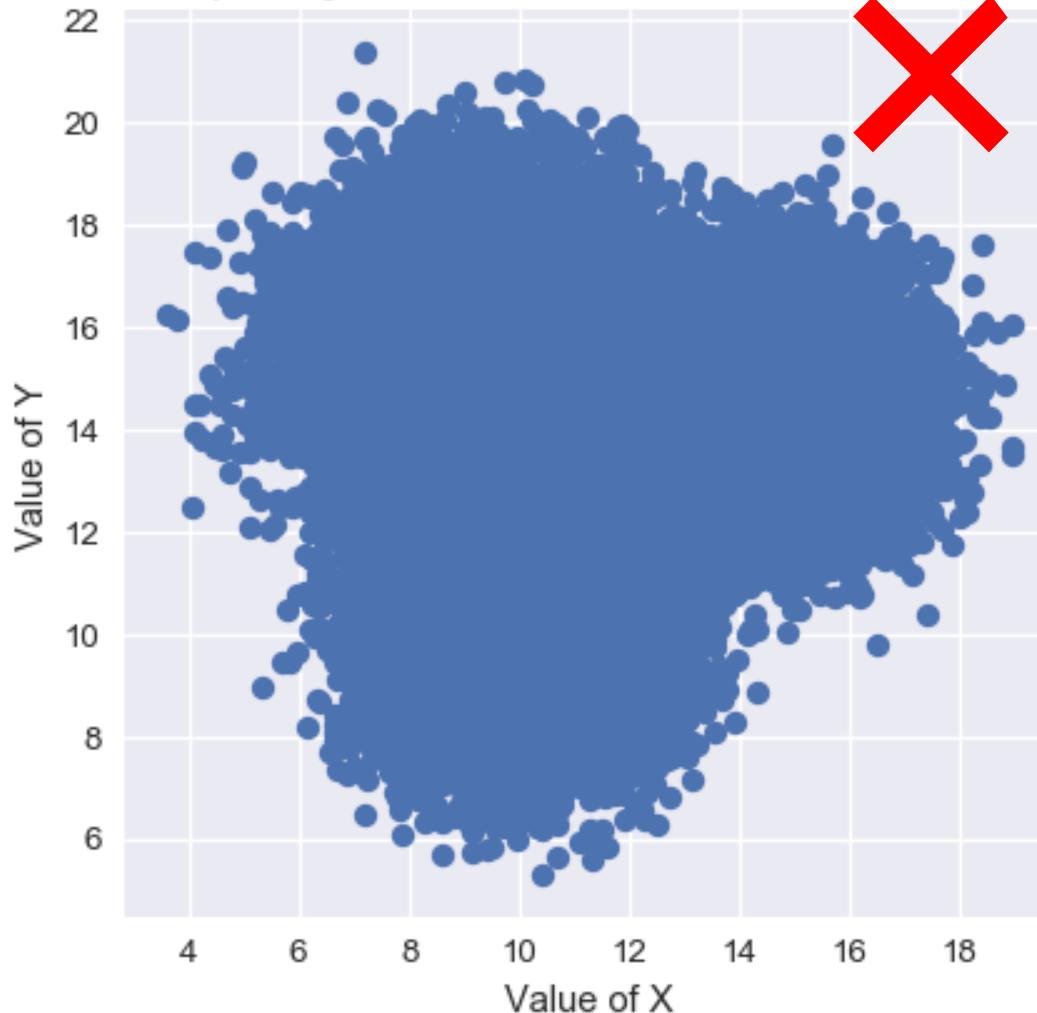
*First bar is gone.*

# Numeric – Relationships

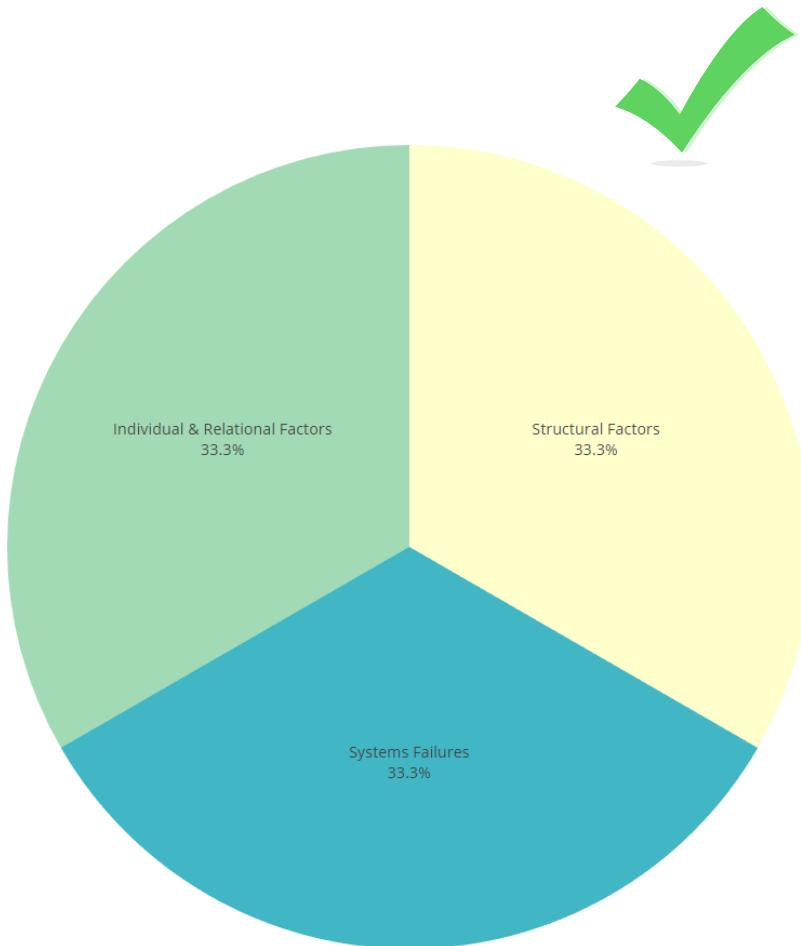


# Numeric – Relationships – Watch Out!

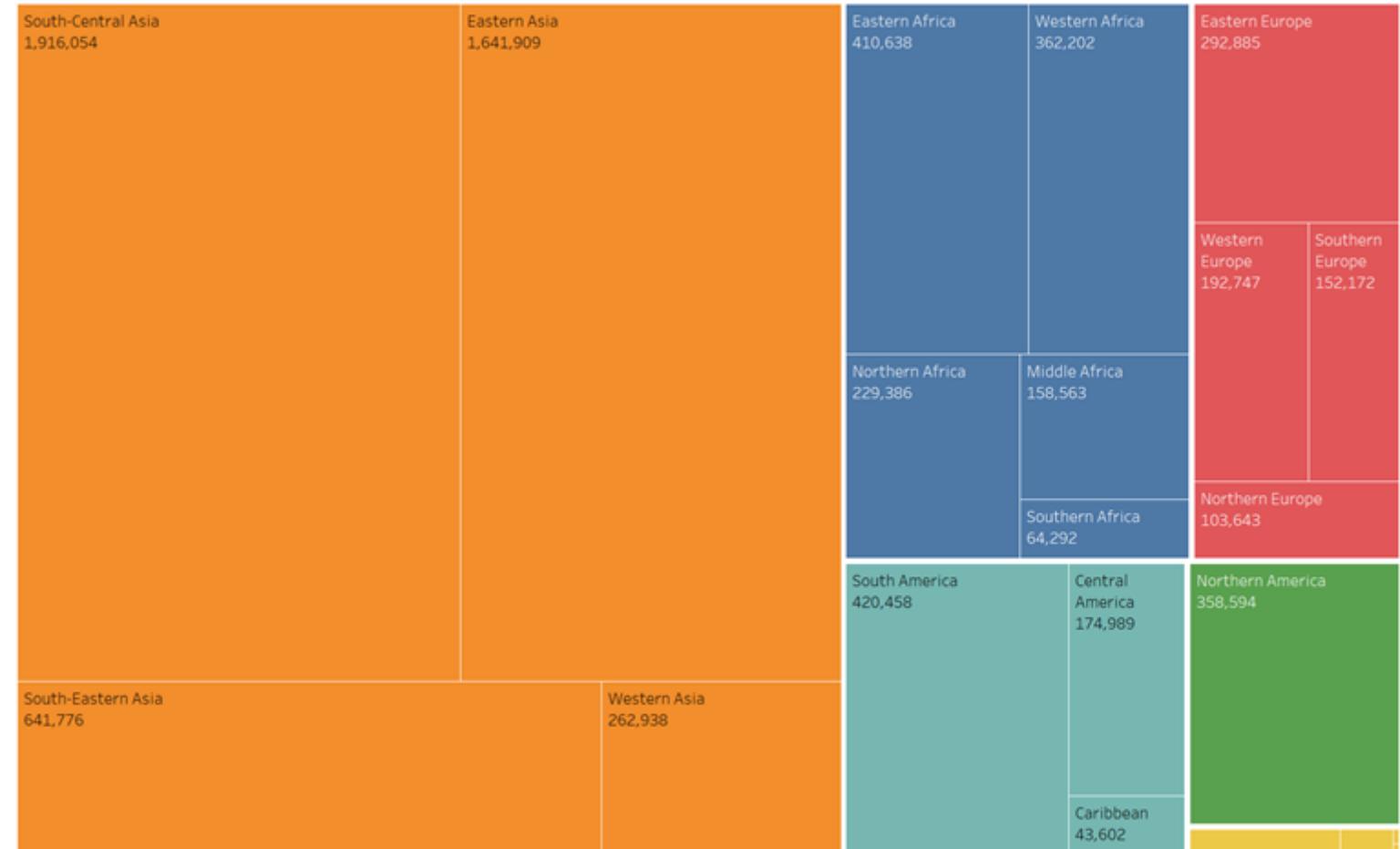
Overplotting looks like that:



# Numeric – Composition



Population (in thousands) of World Regions (2016)



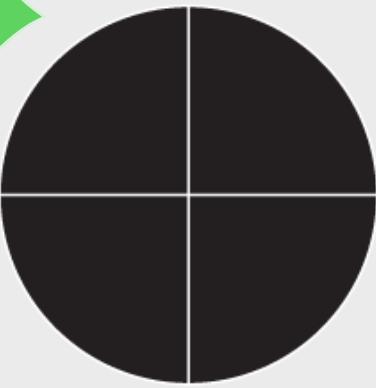
Region and sum of 2016 Population in thousands. Color shows details about Continent. Size shows sum of 2016 Population in thousands.. The marks are labeled by Region and sum of 2016 Population in thousands.

2 slices



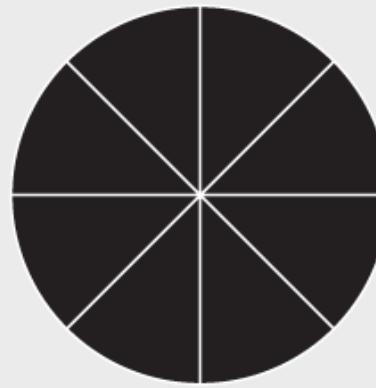
*Not bad.*

4 slices



*Still bearable.*

8 slices

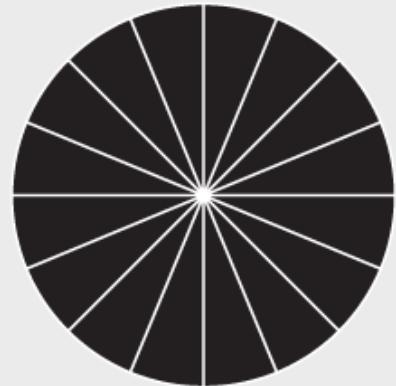


*Um.*



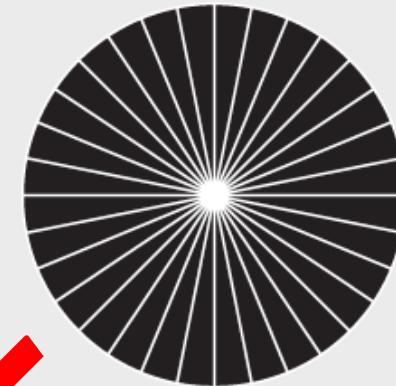
## Numeric – Composition – Watch Out!

16 slices



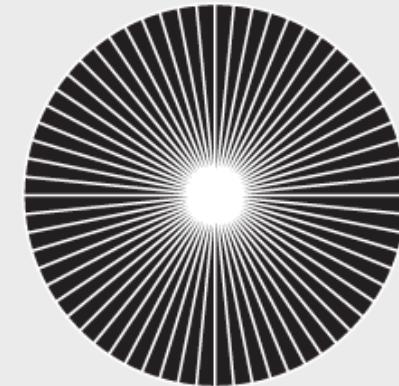
*Wait.*

32 slices



*Stop it.*

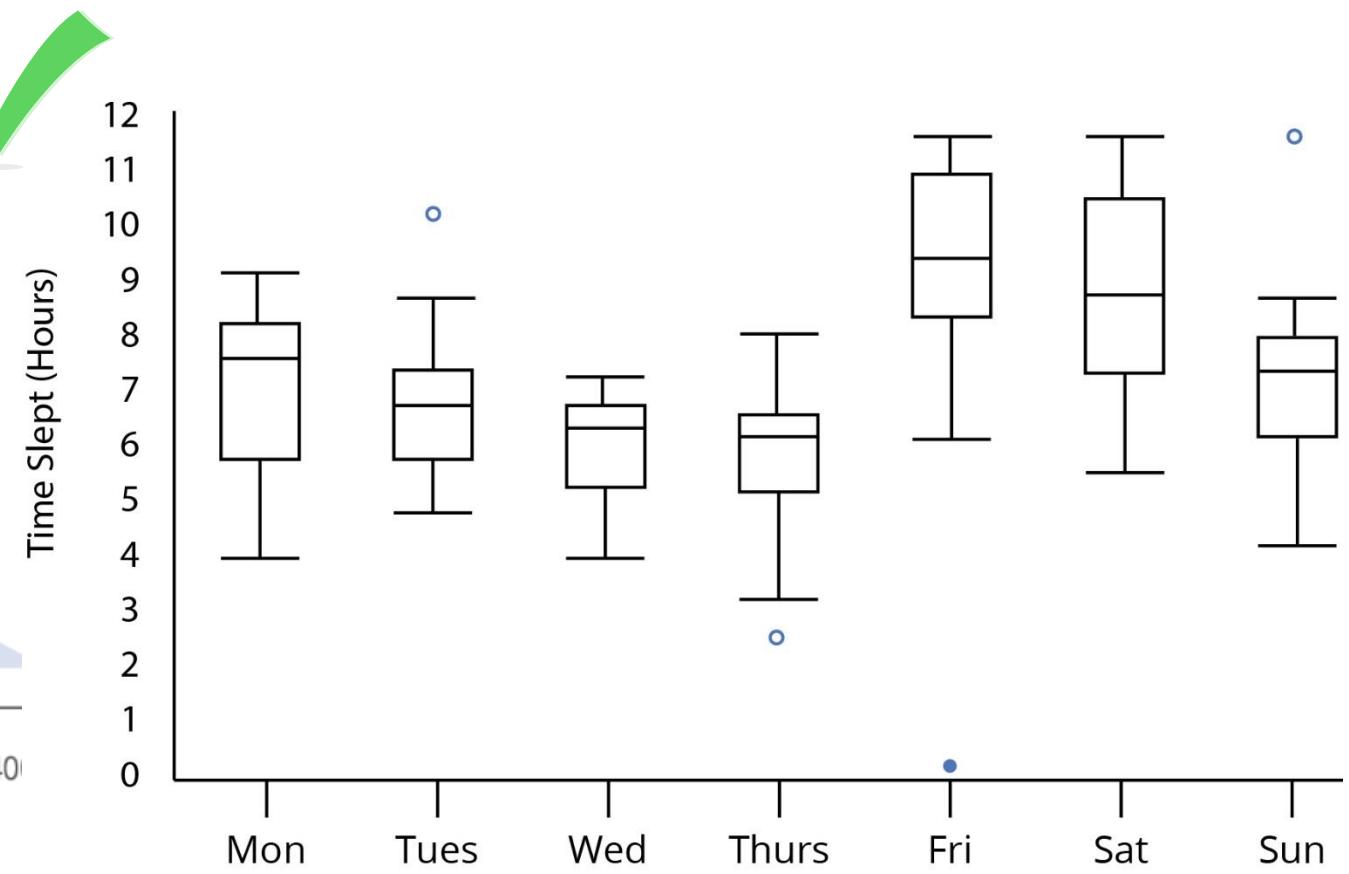
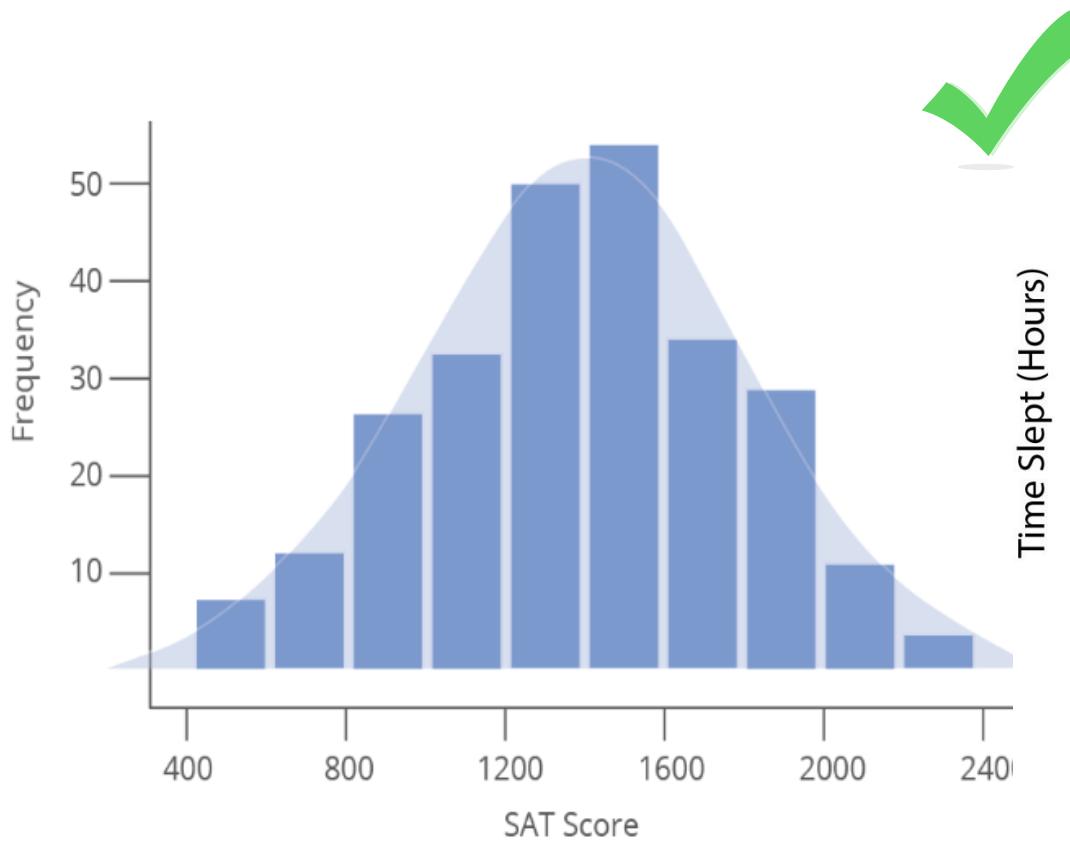
64 slices



*Now you've done it.*



# Numeric – Distributions



# Tables

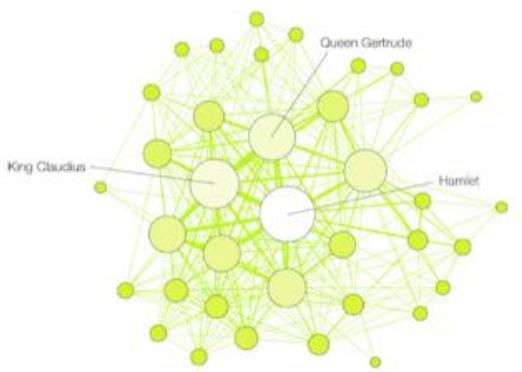
	St. George	Mississauga	Scarborough	Domestic	International	Total Enrolment
Graduate	17,072	668	298	15,053	2,985	18,038
Undergraduate	43,523	14,073	13,132	56,261	14,467	70,728
<b>Total</b>	<b>60,595</b>	<b>14,741</b>	<b>13,430</b>	<b>71,314</b>	<b>17,452</b>	<b>88,766</b>

A woman with dark hair, wearing a yellow tank top, white shorts, and blue running shoes, is jogging on a paved path. She is in mid-stride, with her right leg forward. The background shows a grassy field and a white fence under a clear blue sky.

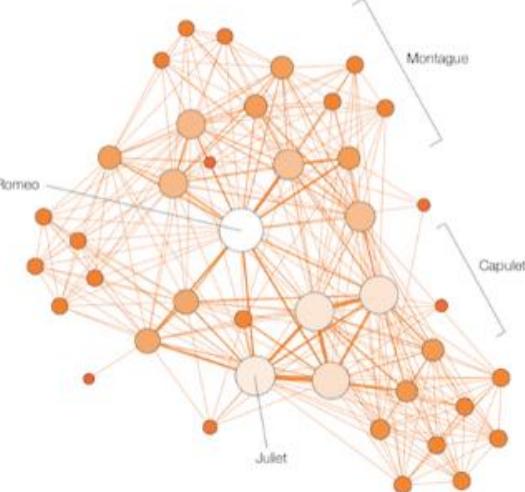
## Exercise – Part 2

# 4. Select Visualization Elements

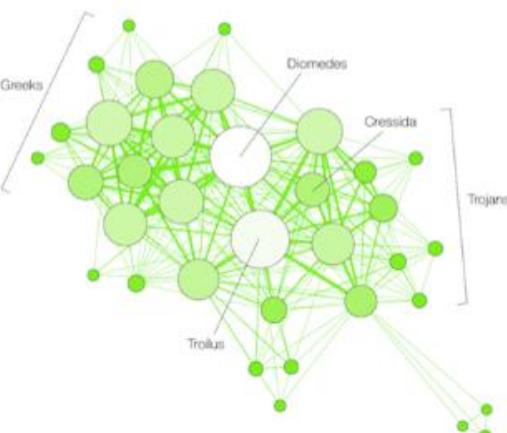
TITUS ANDRONICUS  
Number of characters **36** | 50% Network density



HAMLET  
Number of characters **37** | 39% Network density



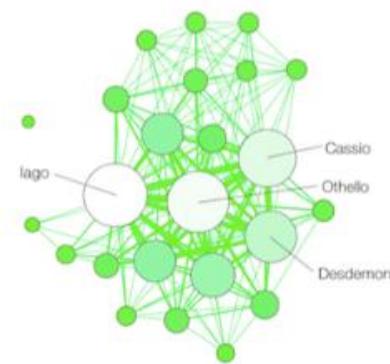
ROMEO AND JULIET  
Number of characters **41** | 37% Network density



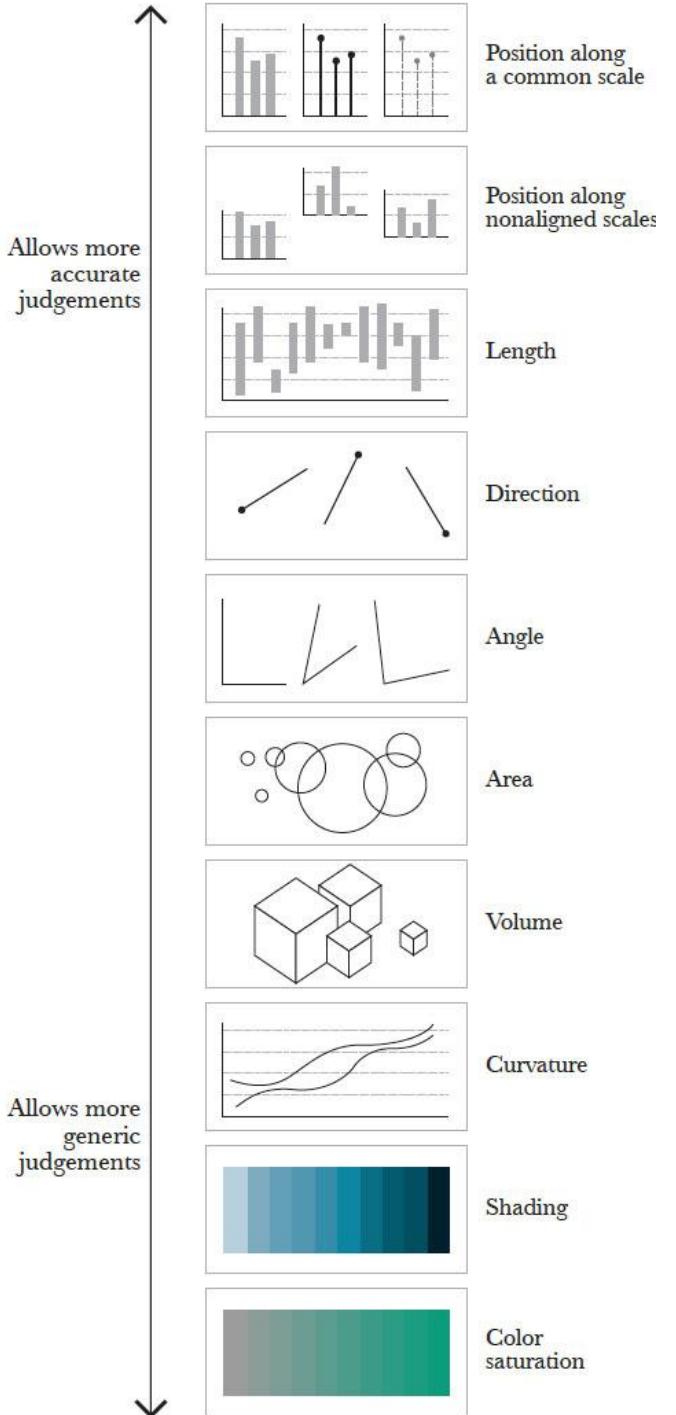
TROILUS AND CRESSIDA  
Number of characters **35** | 40% Network density



JULIUS CAESAR  
Number of characters **46** | 34% Network density

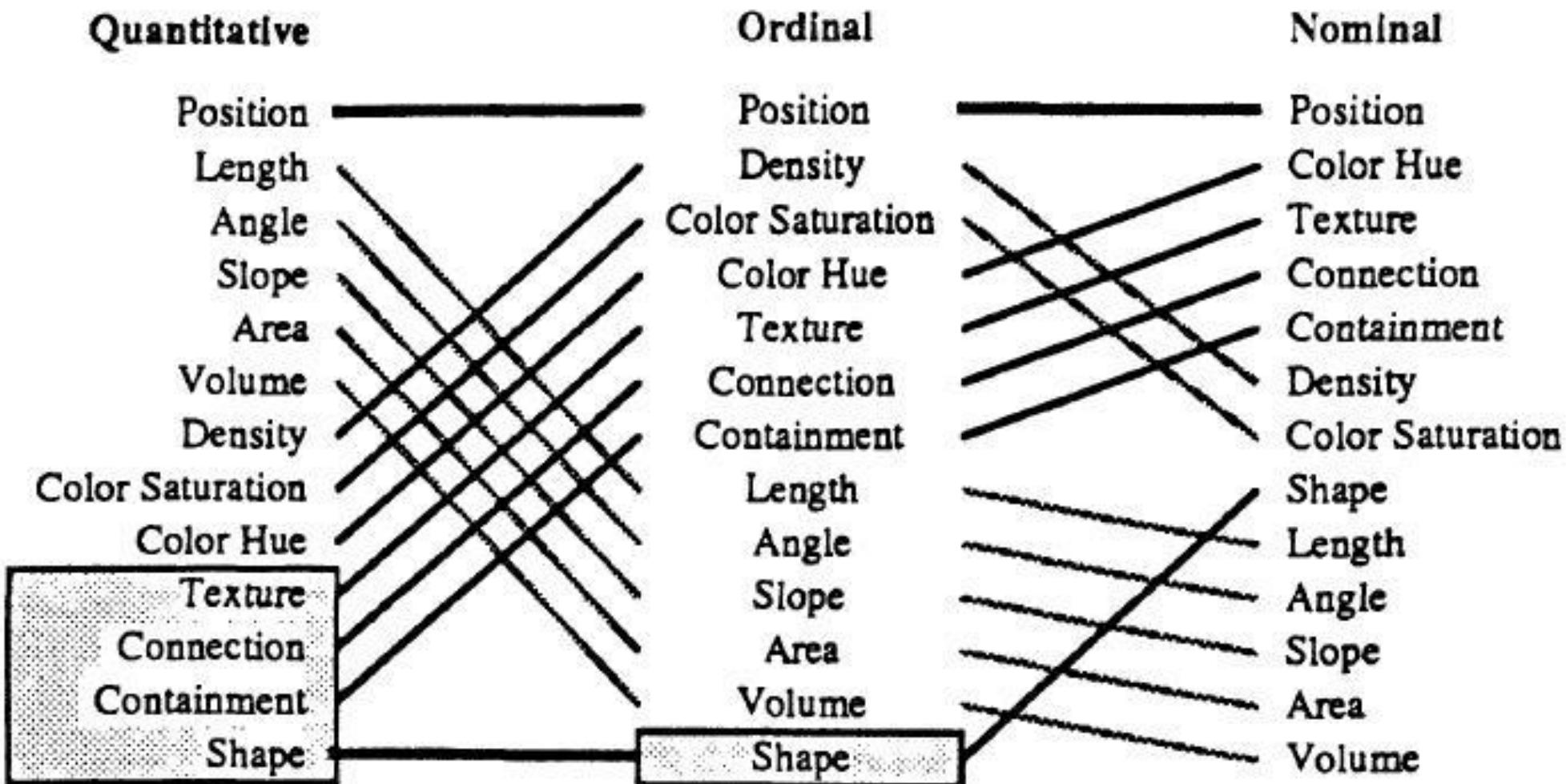


OTHELLO  
Number of characters **24** | 55% Network density



# Cleveland & McGill's Ranking System

# Mackinlay's Ranking System



# Bertin's Visual Variables

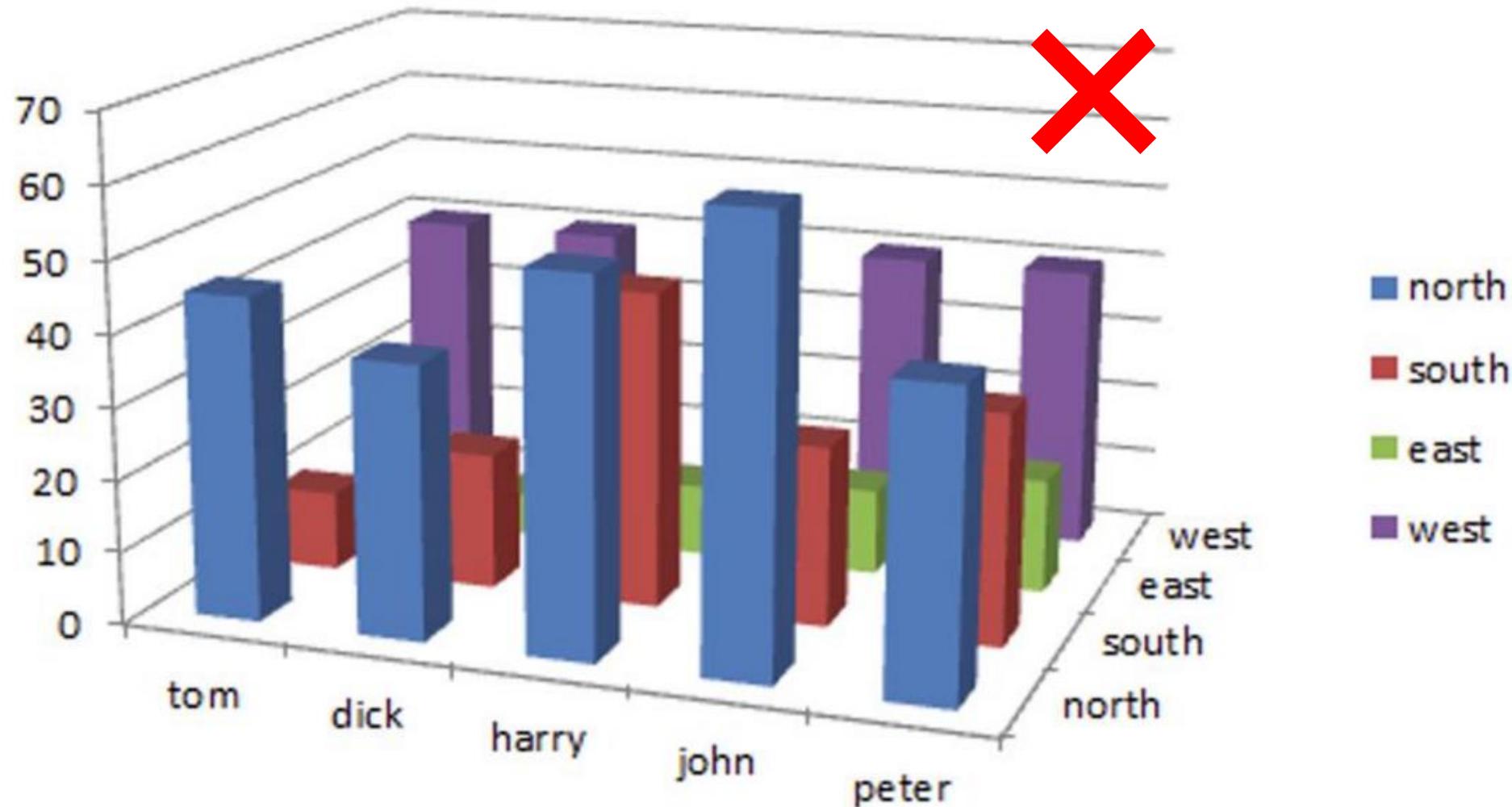
Bertin's Original Visual Variables	
<b>Position</b> changes in the x, y location	
<b>Size</b> change in length, area or repetition	
<b>Shape</b> infinite number of shapes	
<b>Value</b> changes from light to dark	
<b>Colour</b> changes in hue at a given value	
<b>Orientation</b> changes in alignment	
<b>Texture</b> variation in 'grain'	

# Position

Bertin's Visual Variables

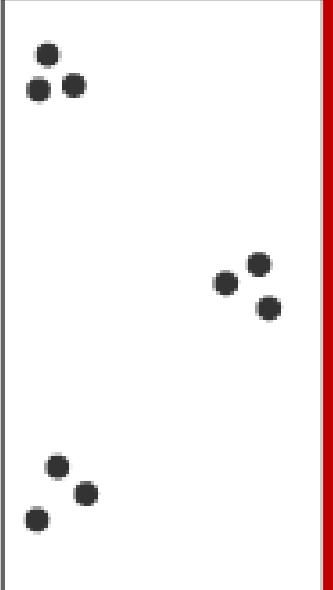
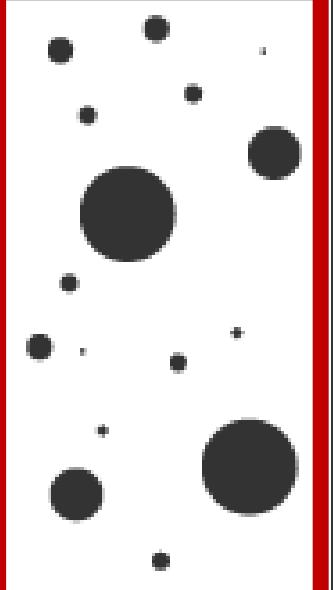
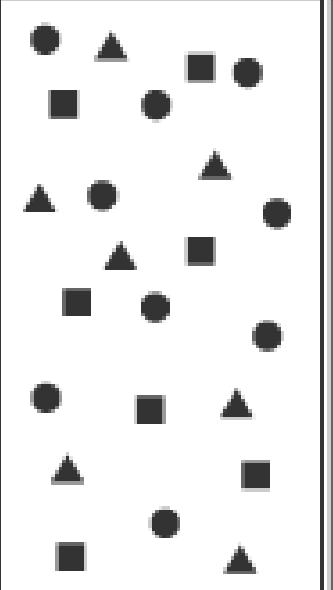
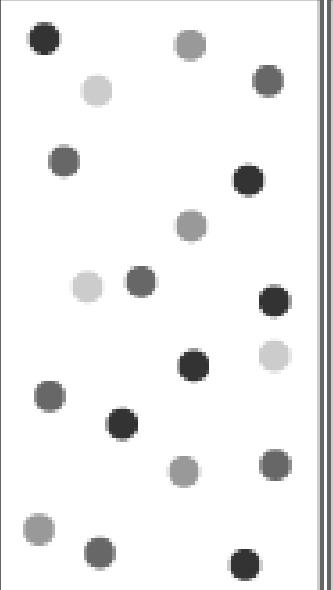
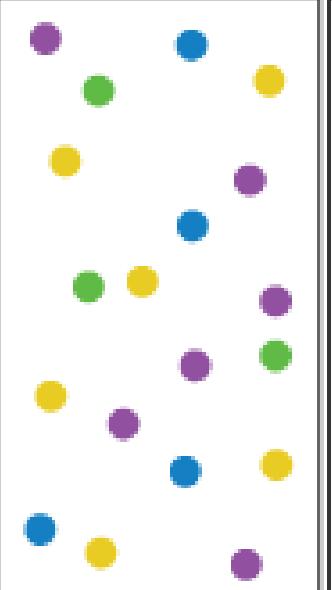
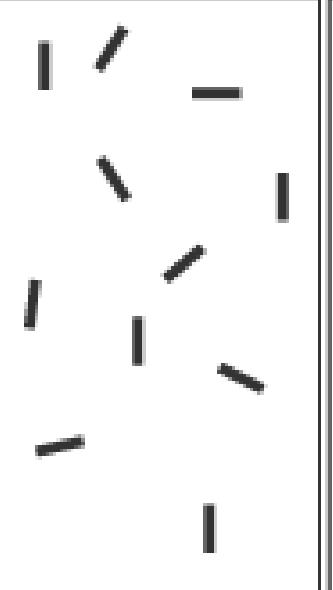
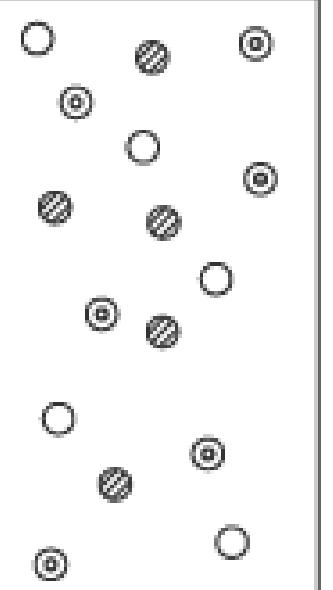
POSITION	SIZE	SHAPE	VALUE	HUE	ORIENTATION	TEXTURE
Selective Associative Ordered Quantitative	Selective Ordered Quantitative	Associative	Selective Ordered Quantitative	Selective Associative	Selective Associative (sometimes)	Selective Associative Ordered (sometimes)

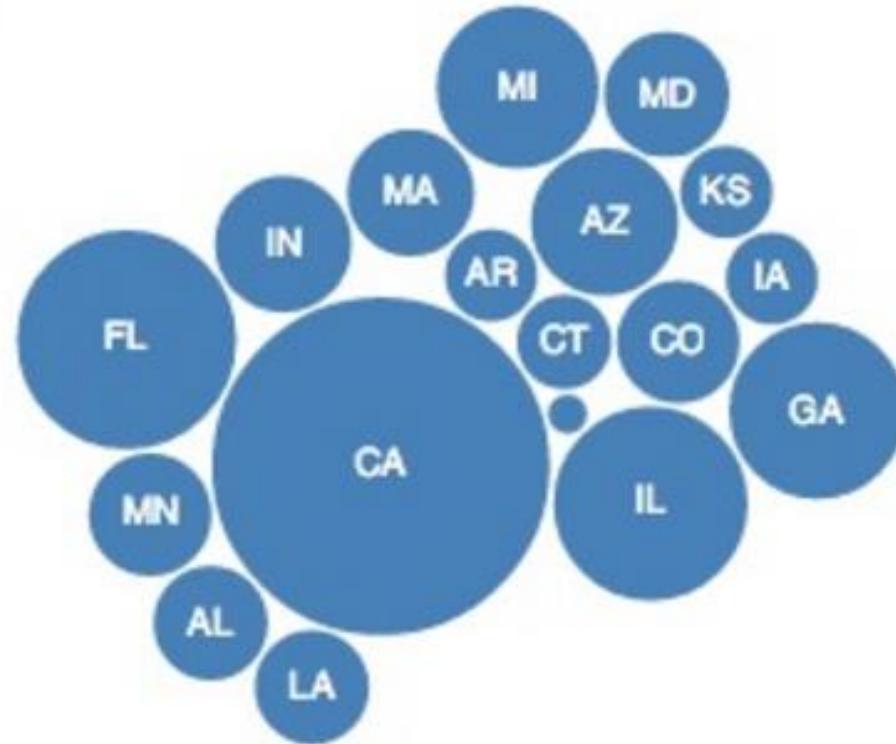
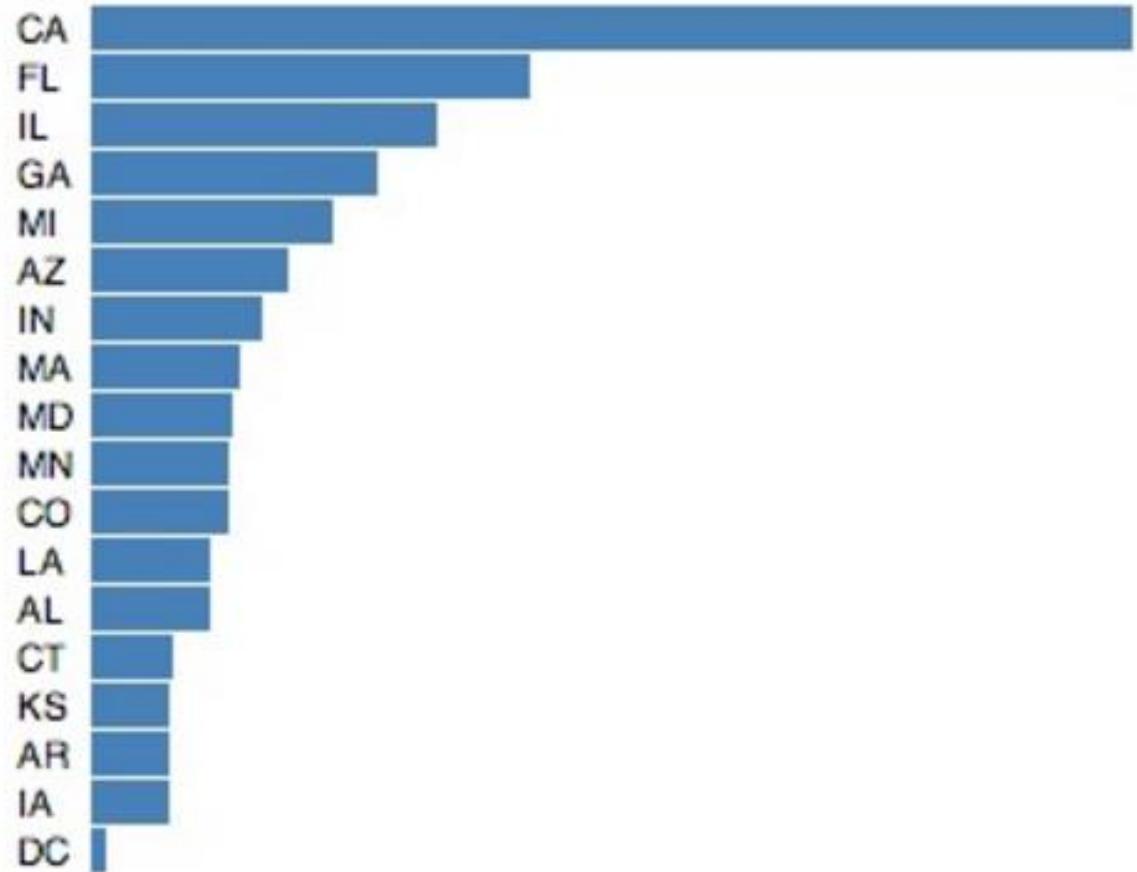
# Position – Watch Out!



# Area/Size

Bertin's Visual Variables

POSITION	SIZE	SHAPE	VALUE	HUE	ORIENTATION	TEXTURE
						
Selective Associative Ordered Quantitative	Selective Ordered Quantitative	Associative	Selective Ordered Quantitative	Selective Associative	Selective Associative (sometimes)	Selective Associative Ordered (sometimes)



**Area/Size – Watch Out!**

# Shape

## Bertin's Visual Variables

POSITION	SIZE	SHAPE	VALUE	HUE	ORIENTATION	TEXTURE
Selective Associative Ordered Quantitative	Selective Ordered Quantitative	Associative	Selective Ordered Quantitative	Selective Associative	Selective Associative (sometimes)	Selective Associative Ordered (sometimes)

Number of data classes: 3 ▾

[how to use](#) | [updates](#) | [downloads](#) | [credits](#)

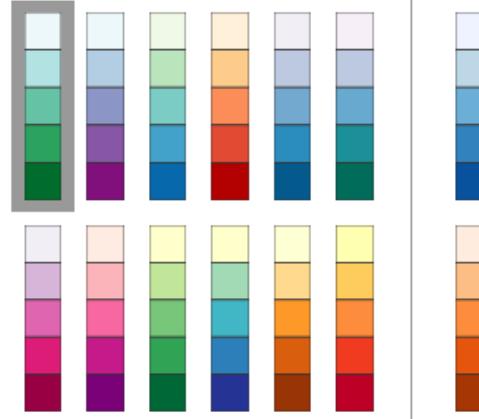
**COLORBREWER 2.0**  
color advice for cartography

Nature of your data:

sequential  diverging  qualitative

Pick a color scheme:

Multi-hue:



Single hue:



Only show:

- colorblind safe
- print friendly
- photocopy safe

Context:

- roads
- cities
- borders

Background:

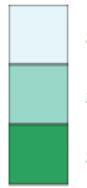
- solid color
- terrain

i

3-class BuGn



HEX ▾

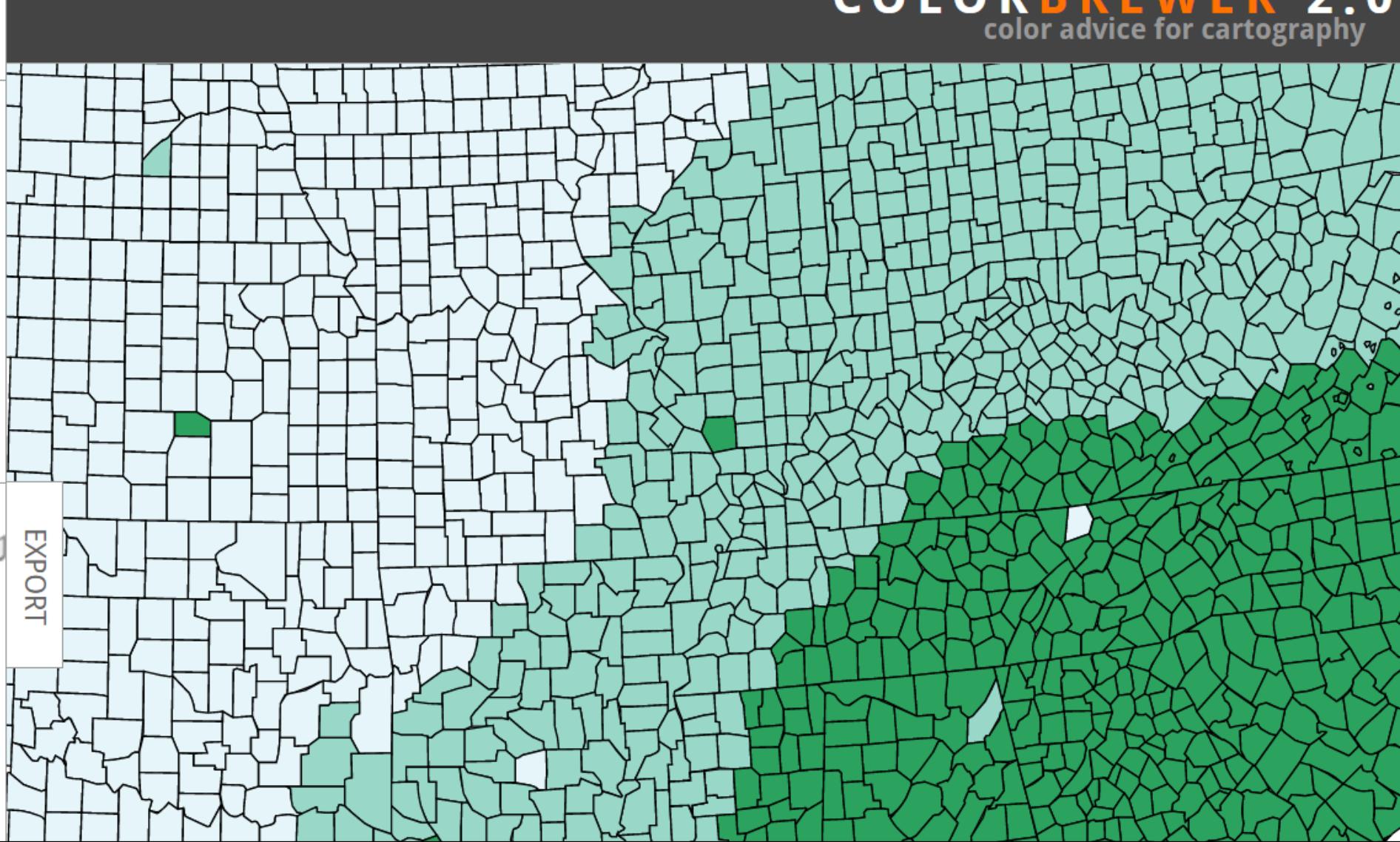


#e5f5f9

#99d8c9

#2ca25f

EXPORT



Colour

Number of data classes: 3 ▾

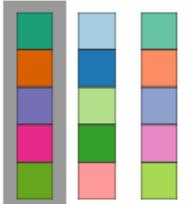
[how to use](#) | [updates](#) | [downloads](#) | [credits](#)

Nature of your data:

i

sequential  diverging  qualitative

Pick a color scheme:



Only show:

i

3-class Dark2



HEX ▾

#1b9e77  
#d95f02  
#7570b3

EXPORT

Context:

i

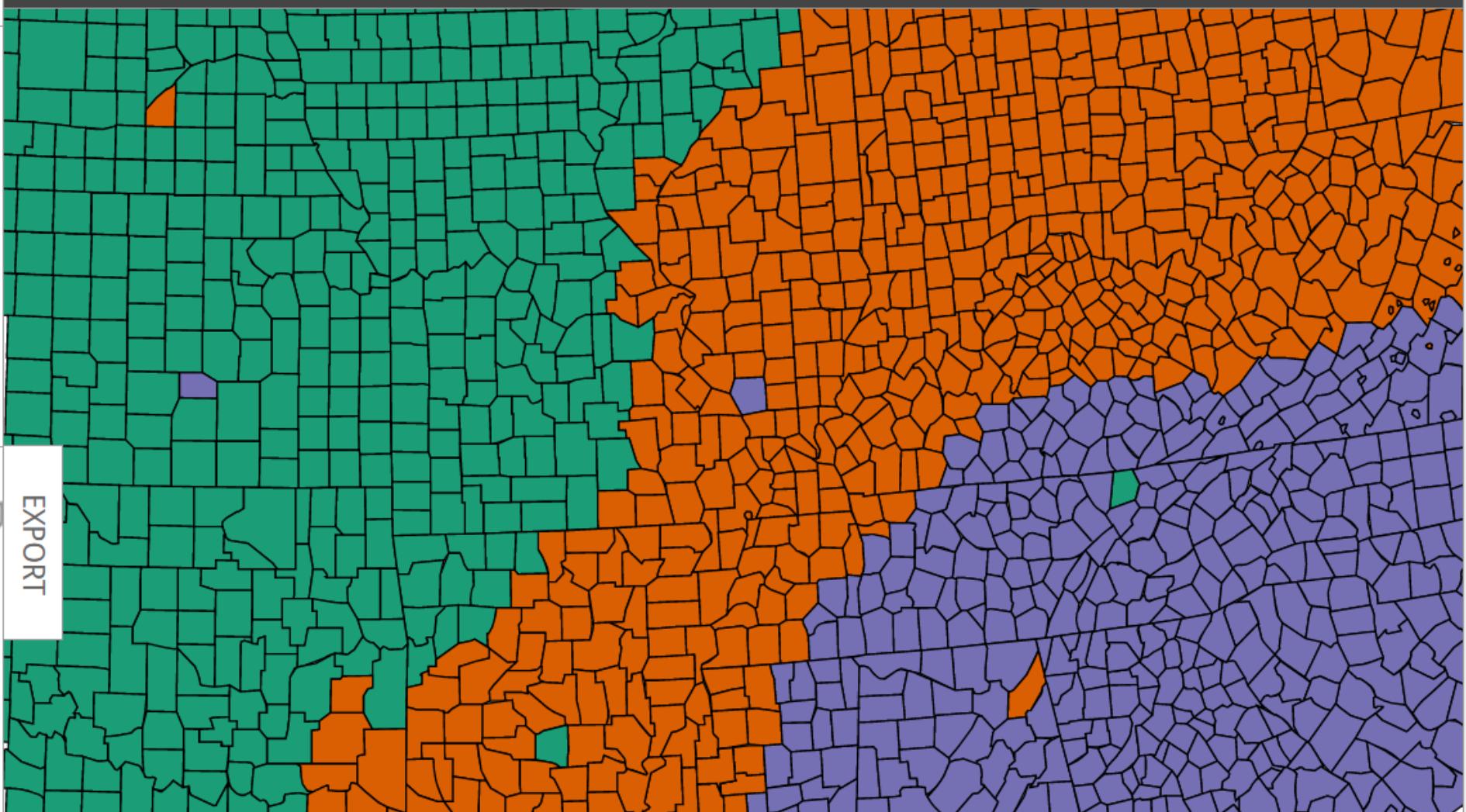
roads  
 cities  
 borders



Background:

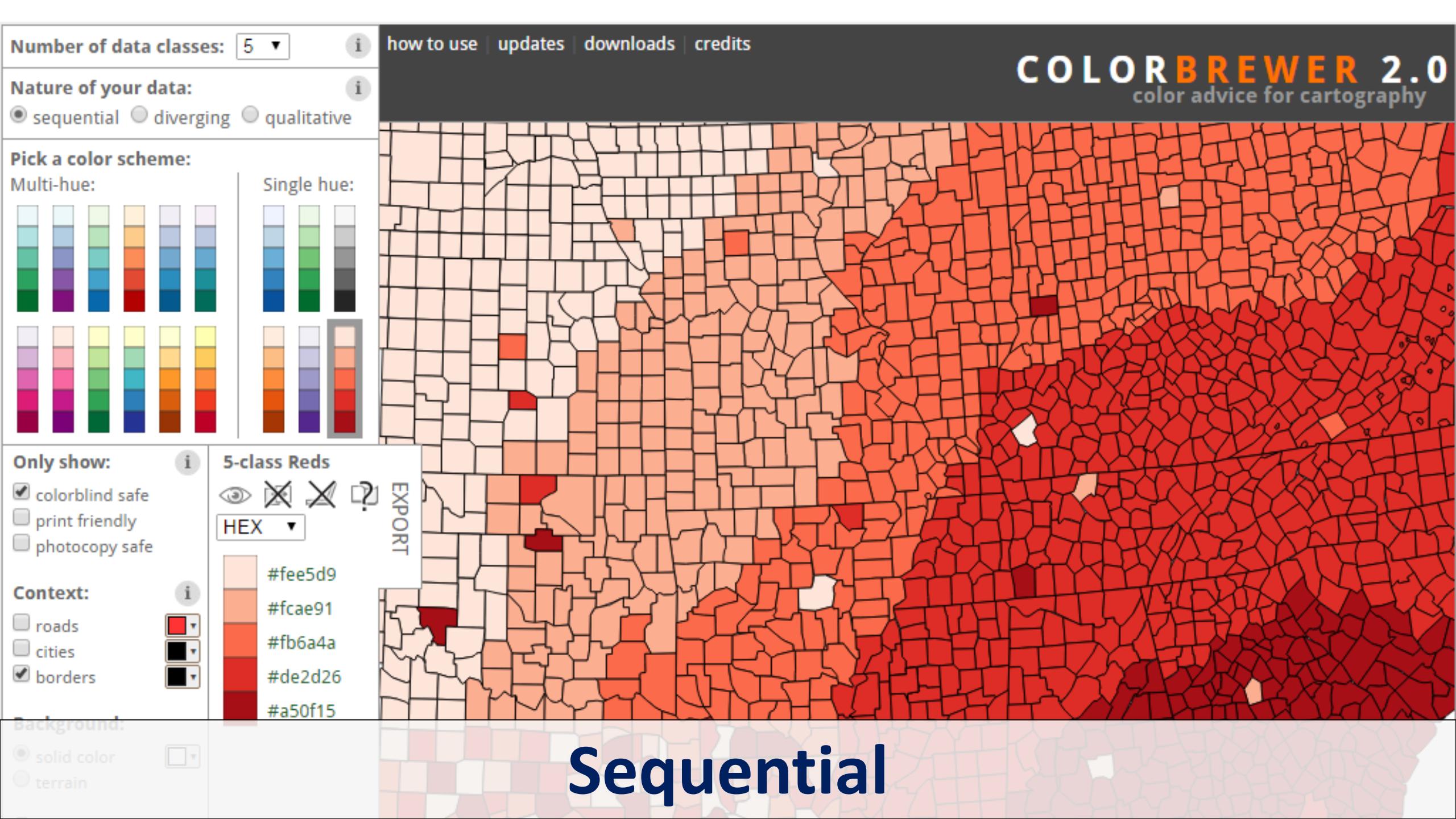
i

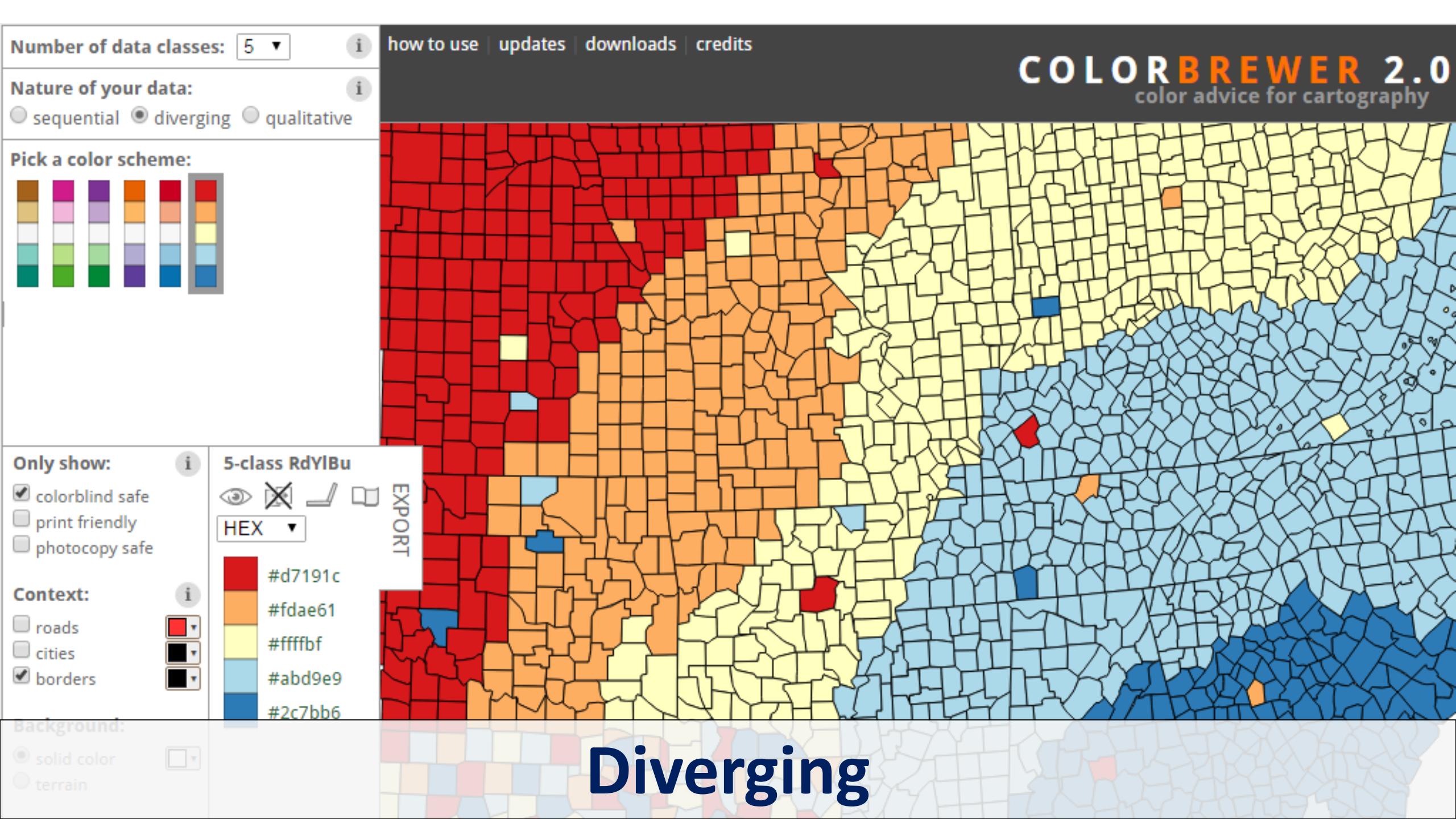
solid color  
 terrain



# Qualitative

**COLORBREWER 2.0**  
color advice for cartography





Drag and drop or paste your file in the area below or:  COLOURlove...n\_Five.png

*Trichromatic view: Anomalous Trichromacy:*

Normal

Red-Weak/Protanomaly

Green-Weak/Deuteranomaly

Blue-Weak/Tritanomaly

*Dichromatic view:*

Red-Blind/Protanopia

Green-Blind/Deuteranopia

Blue-Blind/Tritanopia

*Monochromatic view:*

Monochromacy/Achromatopsia

Blue Cone Monochromacy

Use lens to compare with normal view:  No Lens  Normal Lens  Inverse Lens

[Reset View](#)

## Colour Blindness - Coblis



Drag and drop or paste your file in the area below or:  COLOURlove...n\_Five.png

*Trichromatic view: Anomalous Trichromacy:*

Normal

Red-Weak/Protanomaly

Green-Weak/Deuteranomaly

Blue-Weak/Tritanomaly

*Dichromatic view:*

Red-Blind/Protanopia

Green-Blind/Deuteranopia

Blue-Blind/Tritanopia

*Monochromatic view:*

Monochromacy/Achromatopsia

Blue Cone Monochromacy

Use lens to compare with normal view:  No Lens  Normal Lens  Inverse Lens

[Reset View](#) [Open simulated image in new window](#)

# Colour Considerations

# Text

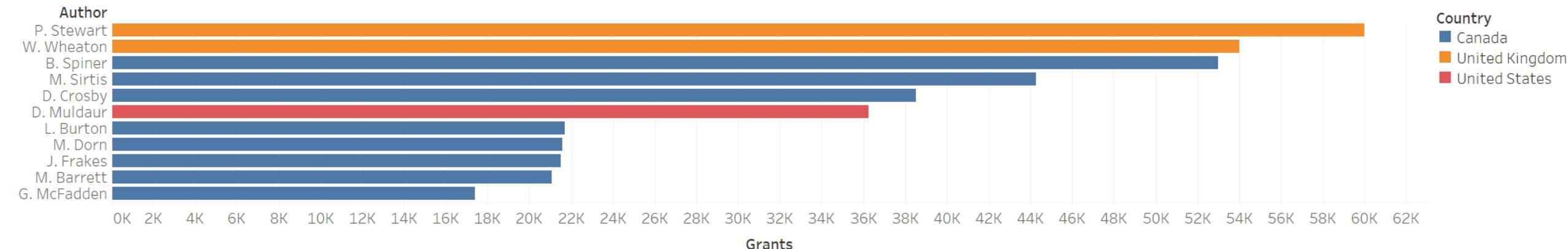
# Design Principles



A photograph capturing a dynamic scene of a track and field race, likely a sprint or relay, at sunset. The sun is low on the horizon, casting a warm, golden glow over the scene. In the foreground, several runners are in motion on a red track. One runner in a blue tank top and black shorts is prominent on the left, wearing a race bib with the number 67. To his right, a runner in a white tank top and dark shorts is also in mid-stride. In the background, a two-story stadium building with a balcony is visible, featuring the "College of DuPage" logo. The stands are partially filled with spectators, some of whom are holding colorful balloons. The overall atmosphere is energetic and captures the intensity of competitive sports.

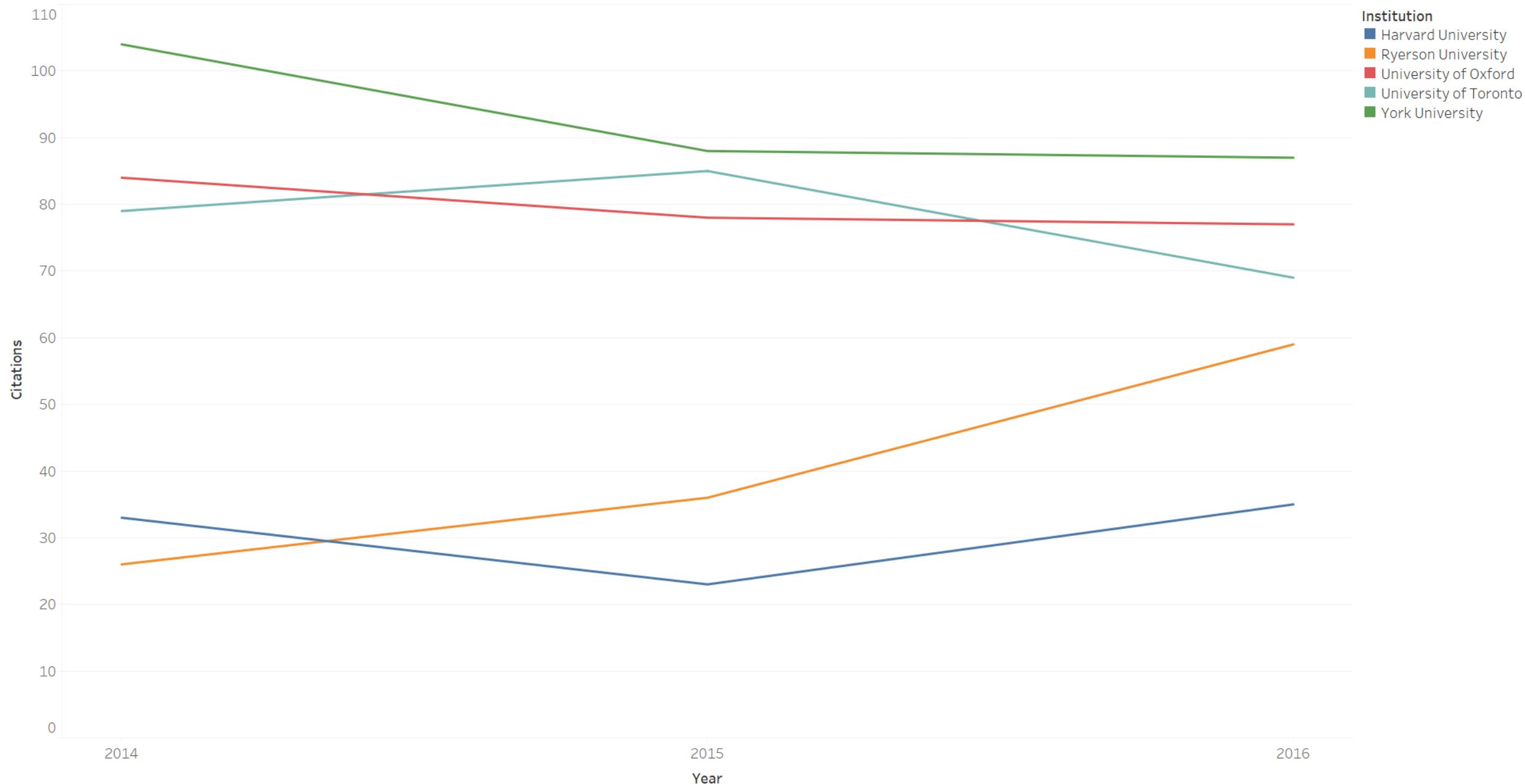
# Exercise – Part 3

## Sum of Grants by Author

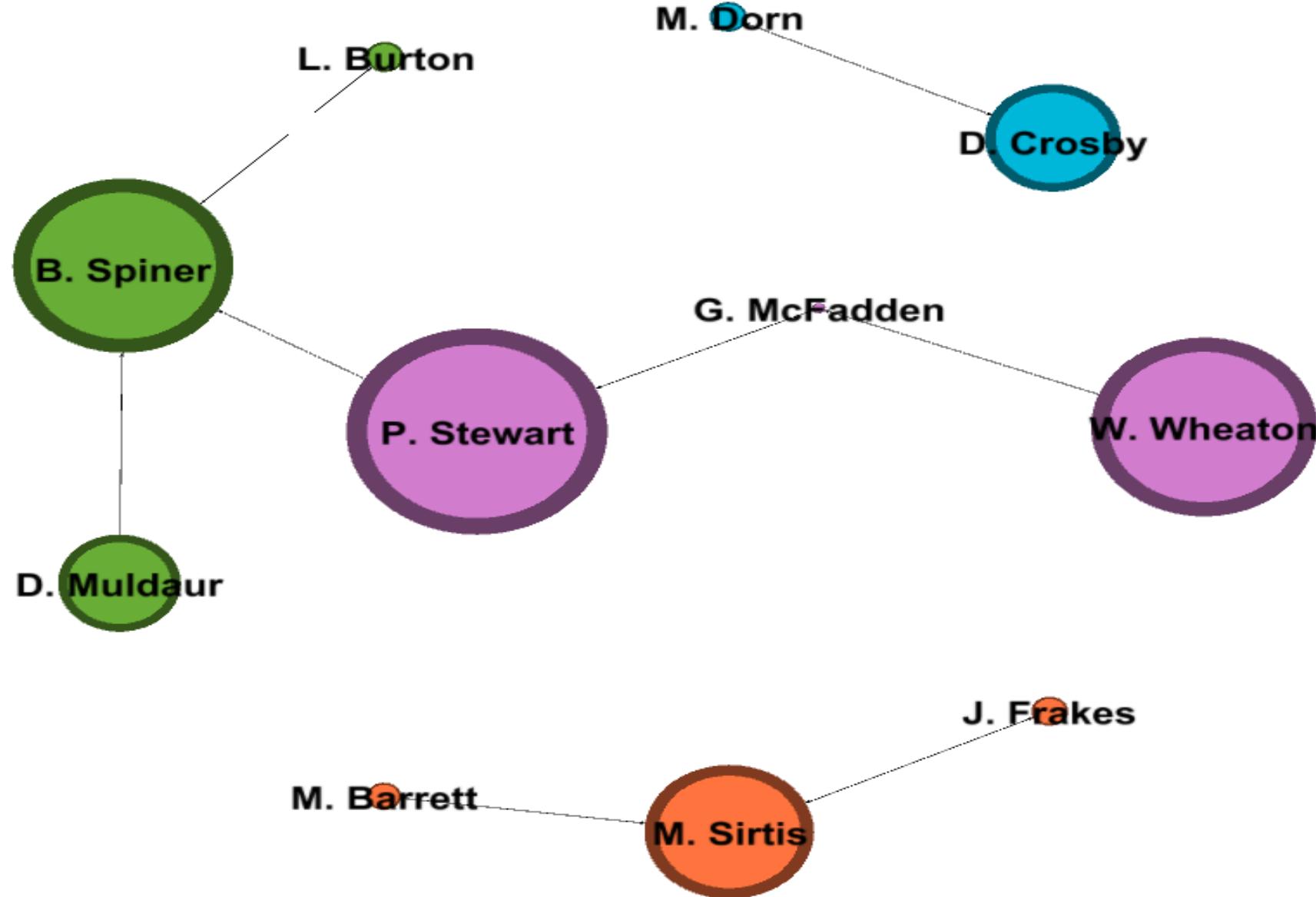


Sum of Grants for each Author. Color shows details about Country.

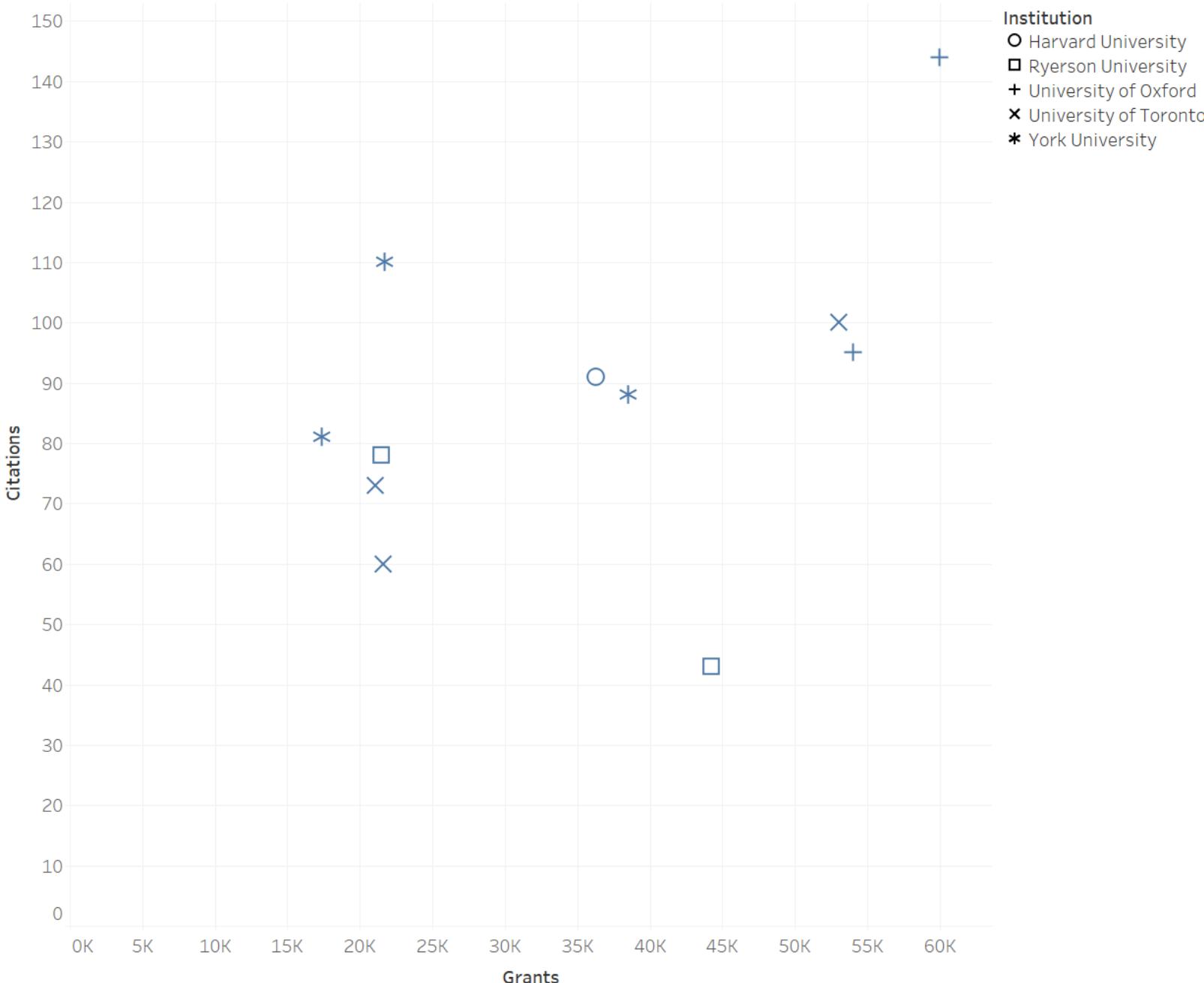
# Number of Citations Per Year by Institution



The trend of sum of Citations for Year Year. Color shows details about Institution.

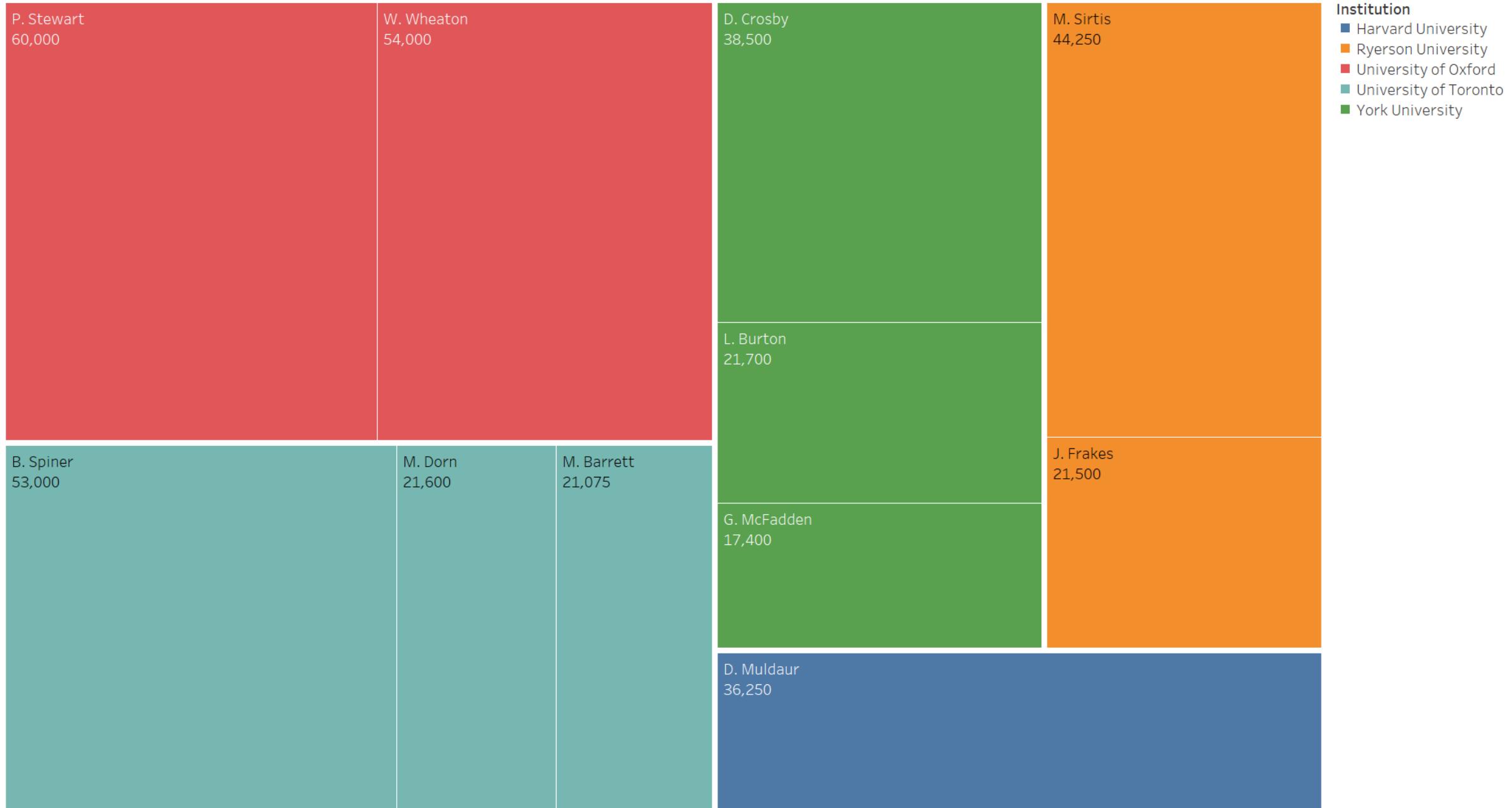


## Citations vs Grants by Authors

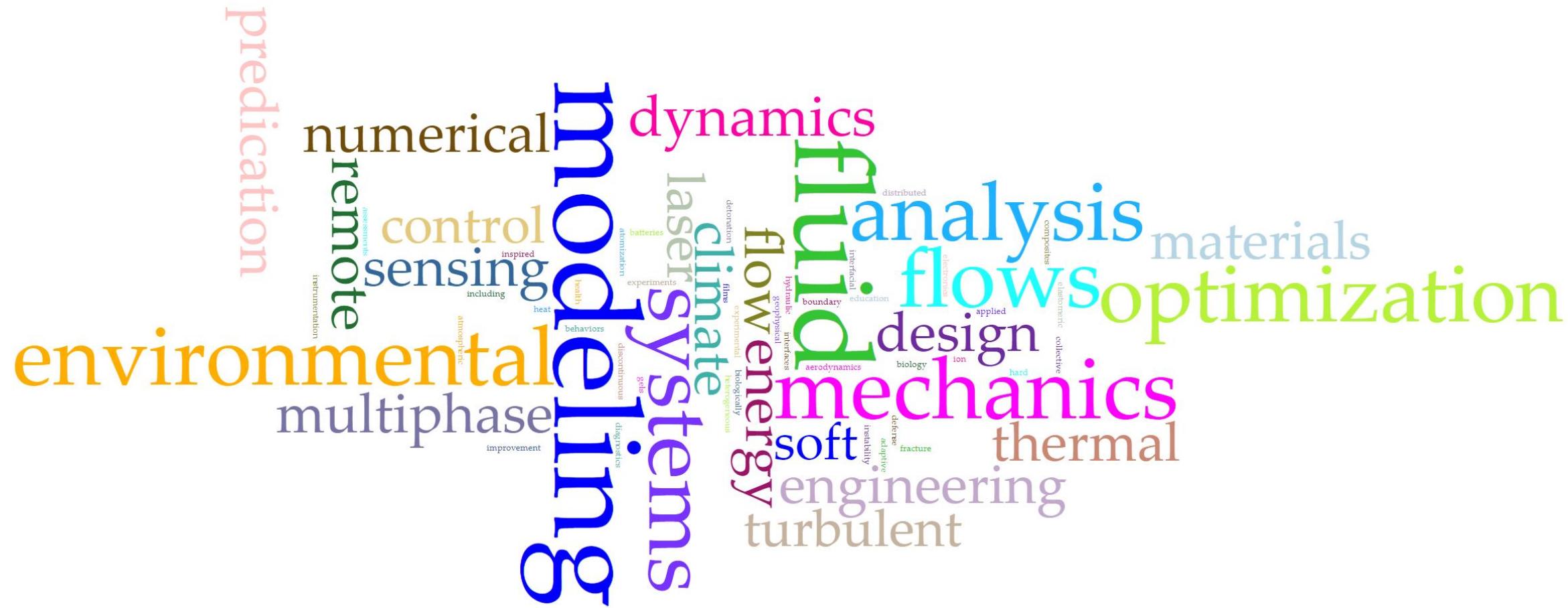


Sum of Grants vs. sum of Citations. Shape shows details about Institution. Details are shown for Author.

# Proportion of Grants by Institution, Sub-Divided by Researcher



Author and sum of Grants. Color shows details about Institution. Size shows sum of Grants. The marks are labeled by Author and sum of Grants.

Terms:

## 5. Share & Receive Feedback



A photograph of two white ceramic cups filled with coffee, each featuring intricate latte art on the surface. The cups are placed on a dark brown wooden table with visible planks. In the foreground, the bottom half of another cup and saucer is partially visible, along with a spoon resting on the saucer. The lighting is warm, highlighting the rich brown color of the coffee and the cream patterns.

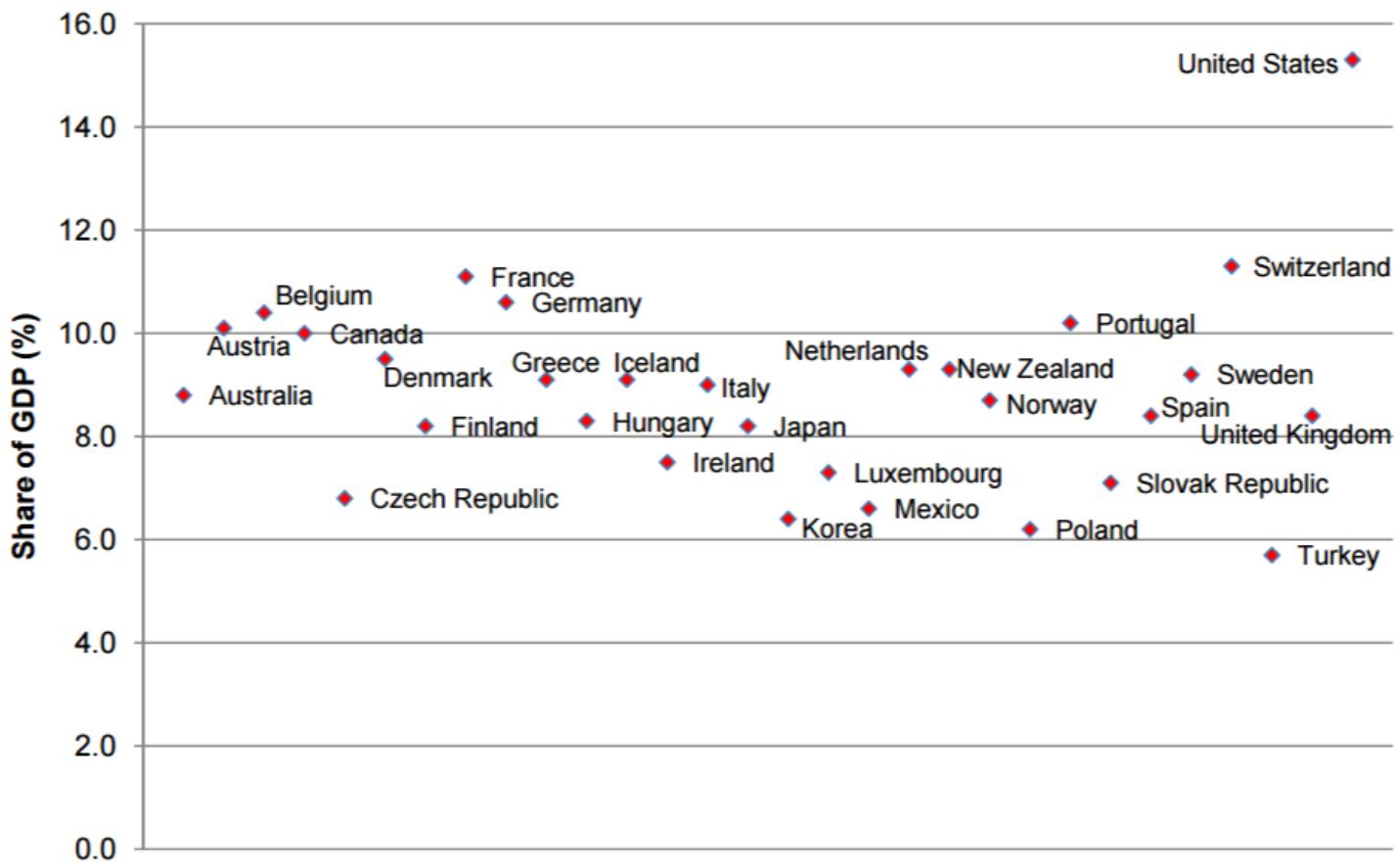
**Break**



## Improving Visualizations

Let's work together – groups of 2 or 3

**Chart 2 - Total Expenditures on Health as a Percentage Share of GDP,  
OECD Countries, 2006**

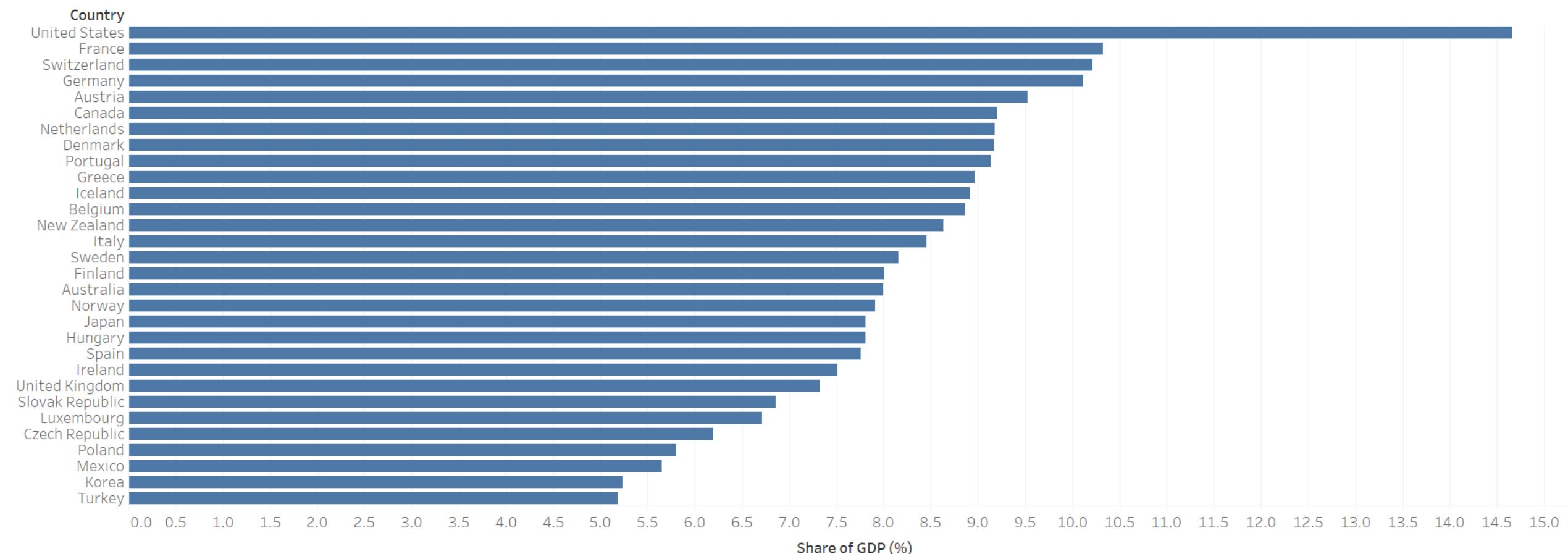


Source: OECD Health Data 2008.

Note: For the United States the 2006 data reported here do not match the 2006 data point for the United States in Chart 1 since the OECD uses a slightly different definition of "total expenditures on health" than that used in the National Health Expenditure Accounts.

## Example 1

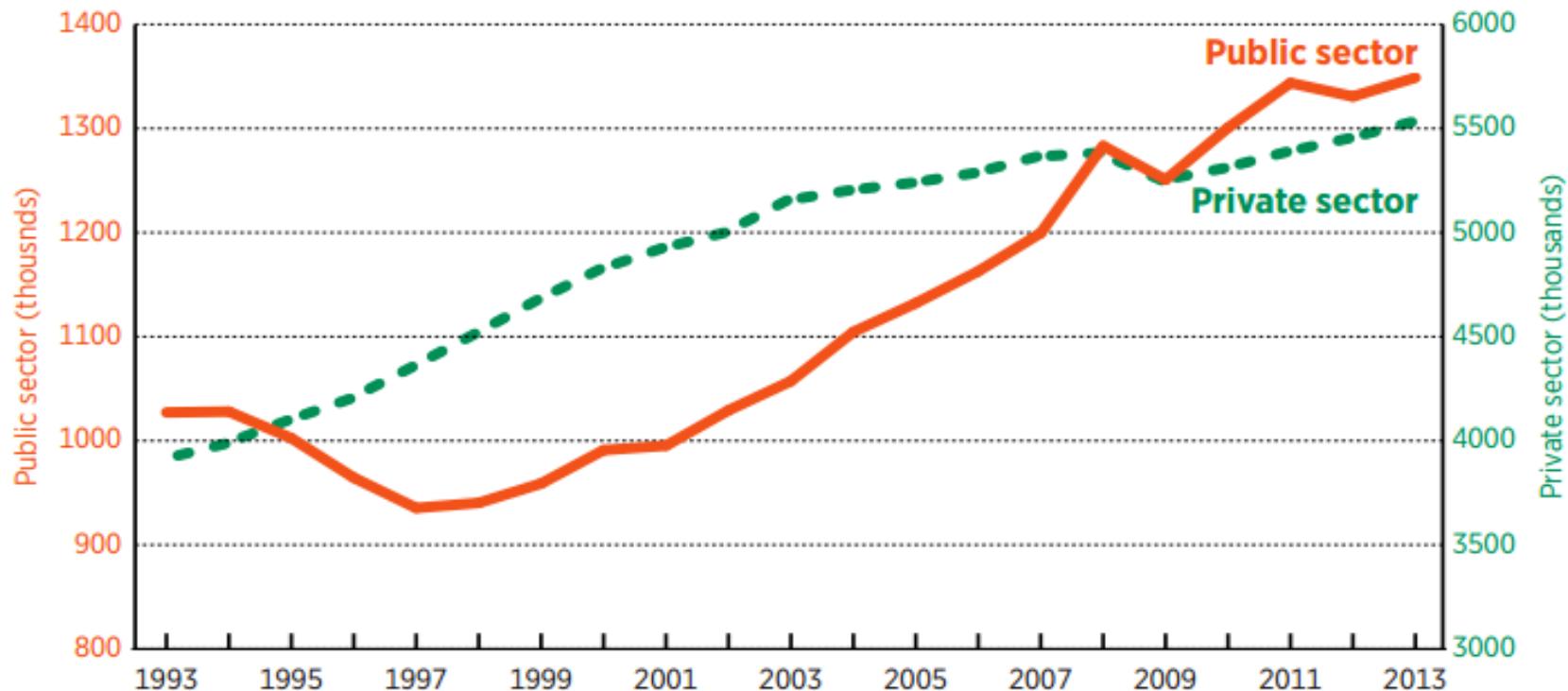
Total Expenditures on Health as a Percentage Share of GDP, OECD Countries, 2006



Sum of Share of GDP for each Country. The view is filtered on Country, which keeps 30 of 36 members.

# Example 1 – Suggestion for Improvement

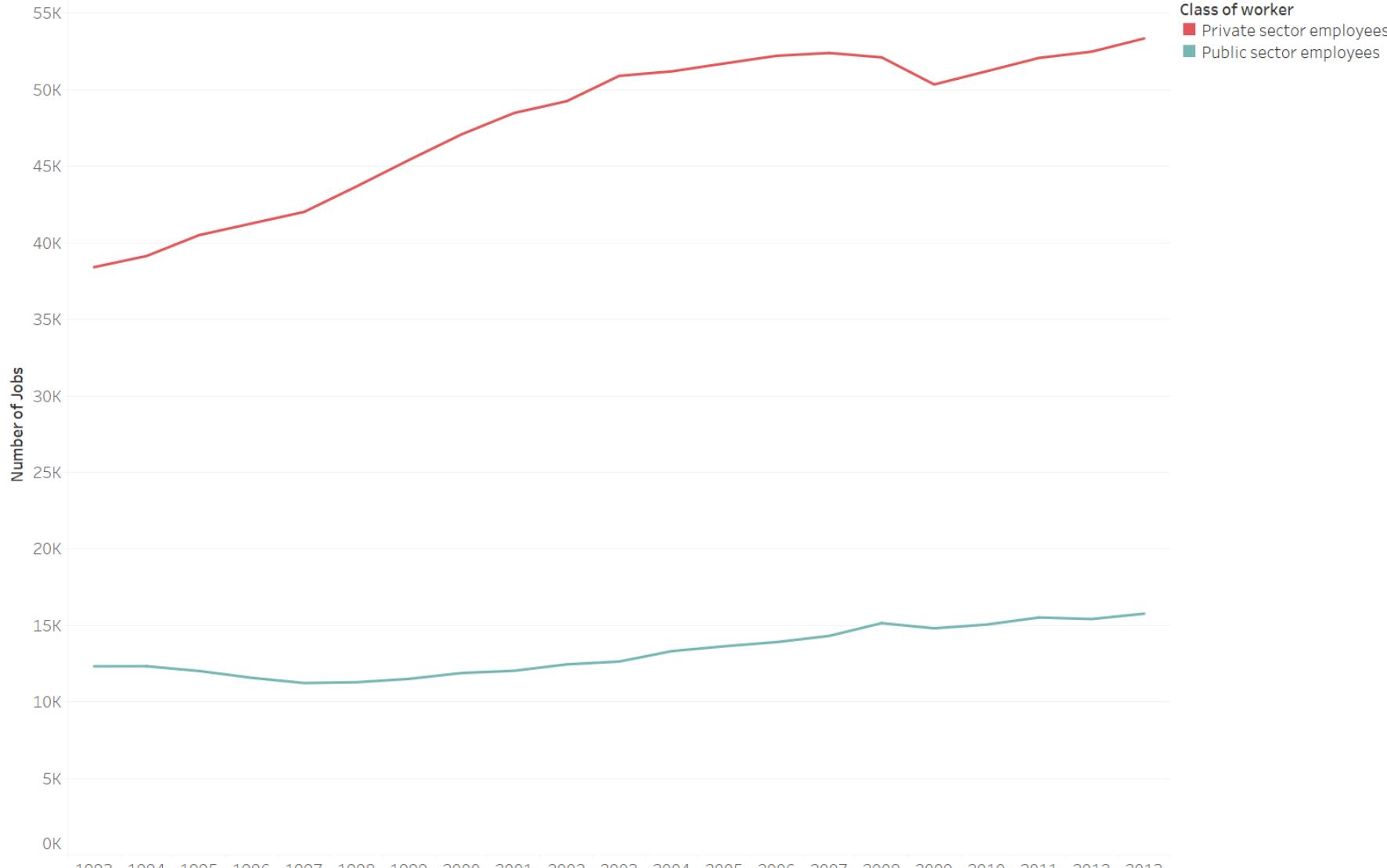
**Figure 10: Public- and private-sector jobs (000s) in Ontario, 1993–2013**



Source: Statistics Canada, CANSIM Table 282-0089: *employment by class of worker and sex, seasonally adjusted and unadjusted; Ontario; Public sector and private sector employees; Both sexes; Seasonally adjusted (x 1,000)*.

## Example 2

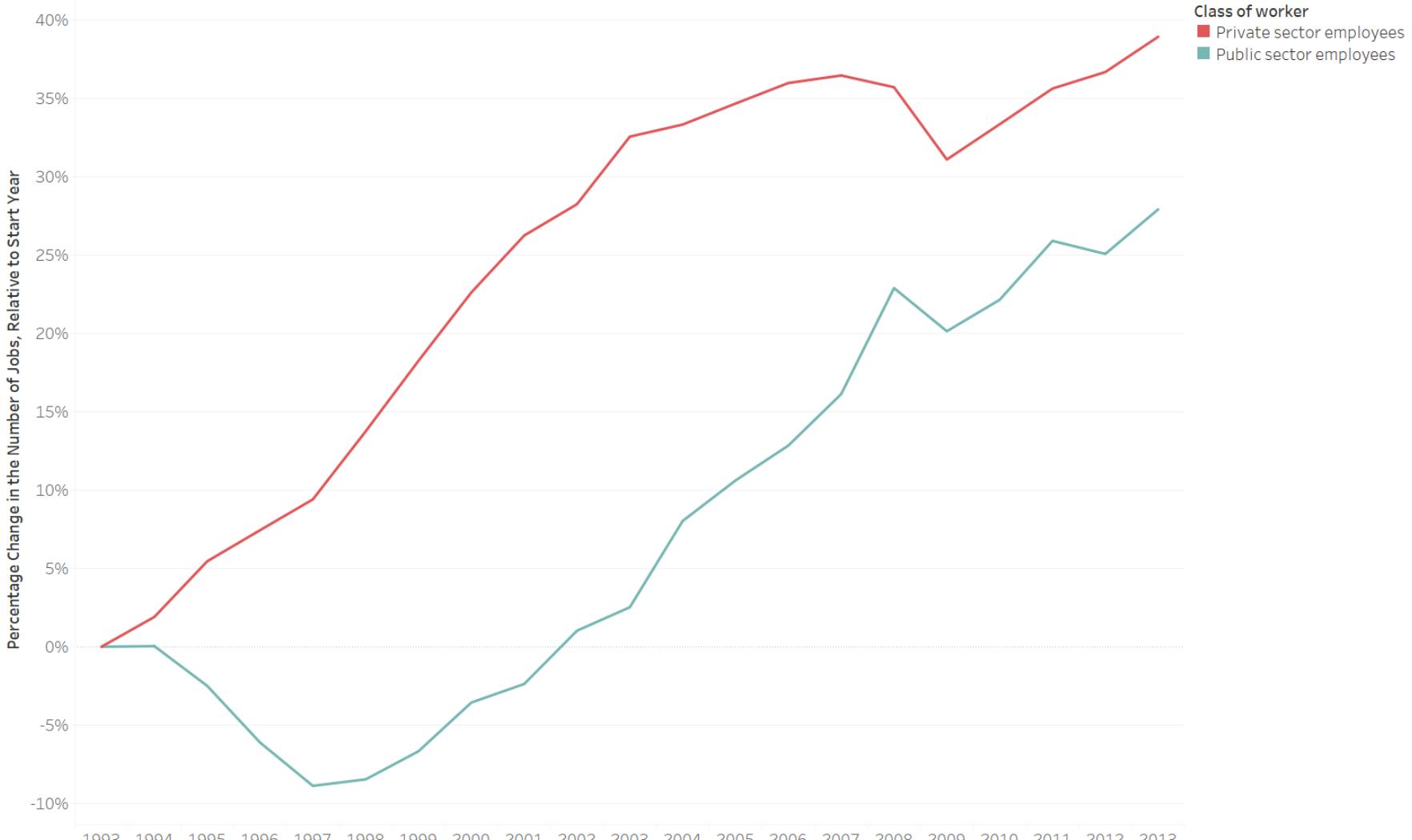
## Number of Public- and Private-Sector Jobs in Ontario, 1993 to 2013



The trend of sum of Value for Ref Date Year. Color shows details about Class of worker. The data is filtered on Data type, which keeps Seasonally adjusted.  
The view is filtered on Class of worker, which keeps Private sector employees and Public sector employees.

## Example 2 – Suggestion for Improvement #1

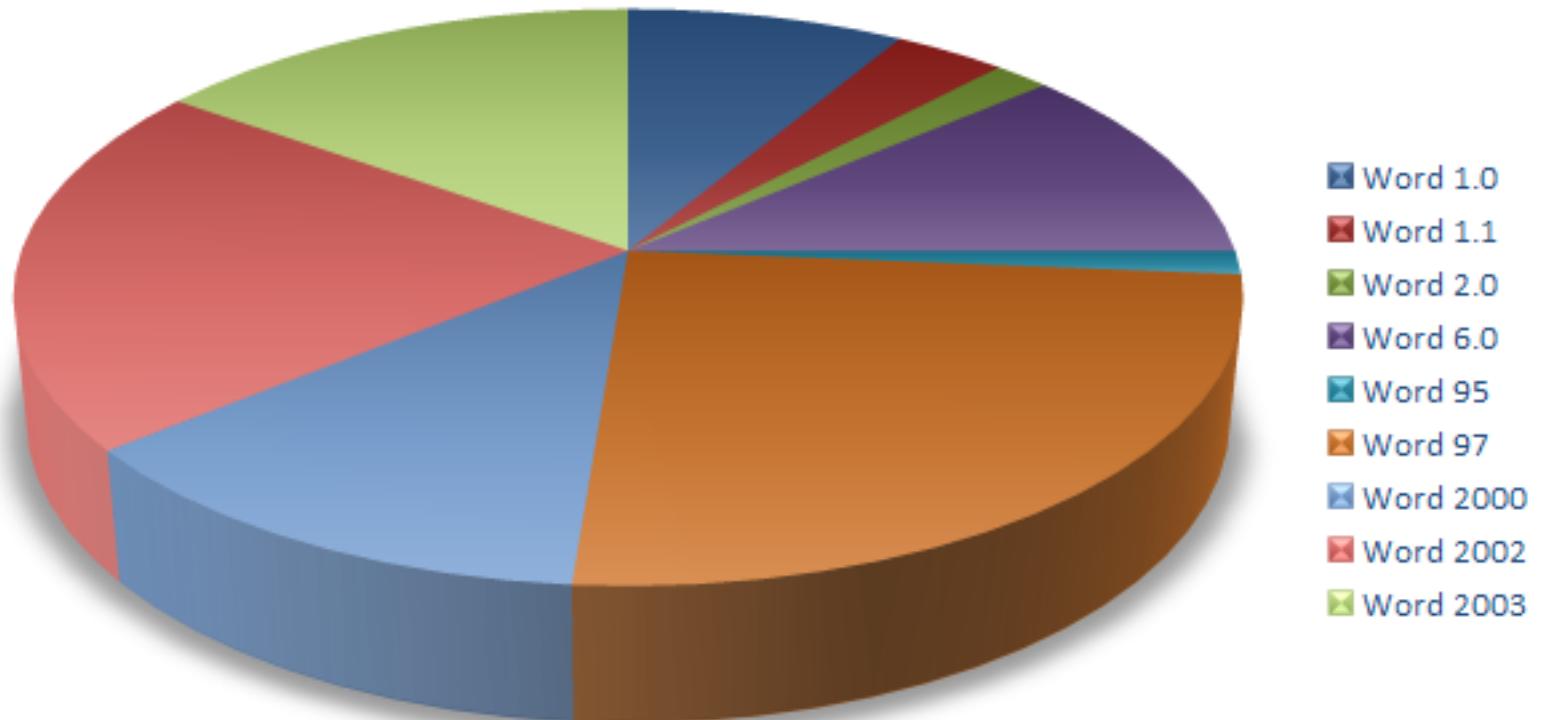
Percentage Change in the Number of Public- and Private-Sector Jobs in Ontario, Relative to the Start Year, 1993 to 2013



The trend of % Difference in Value for Ref Date Year. Color shows details about Class of worker. The data is filtered on Data type, which keeps Seasonally adjusted. The view is filtered on Class of worker, which keeps Private sector employees and Public sector employees.

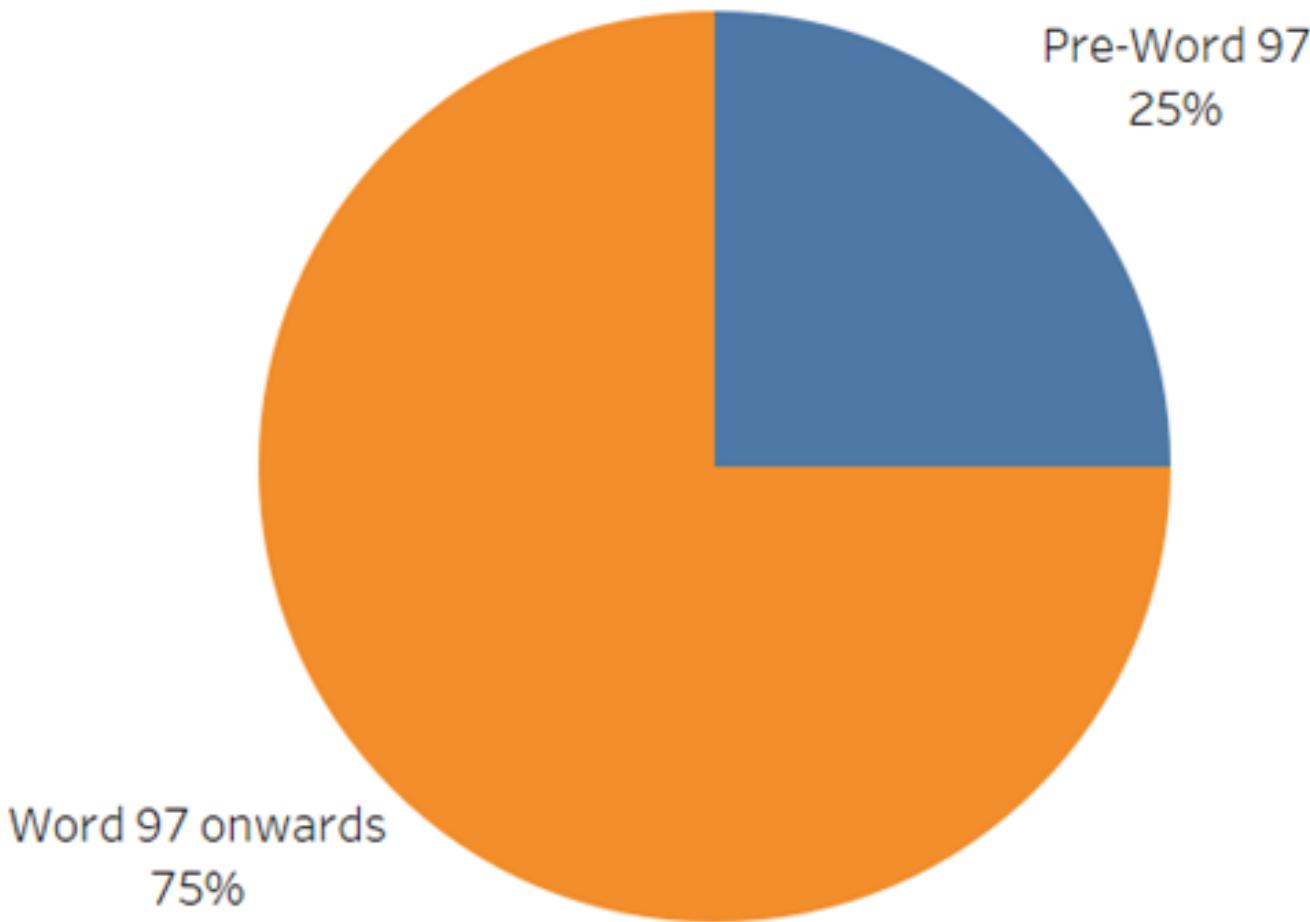
## Example 2 – Suggestion for Improvement #2

### Microsoft Word Features By Version Added



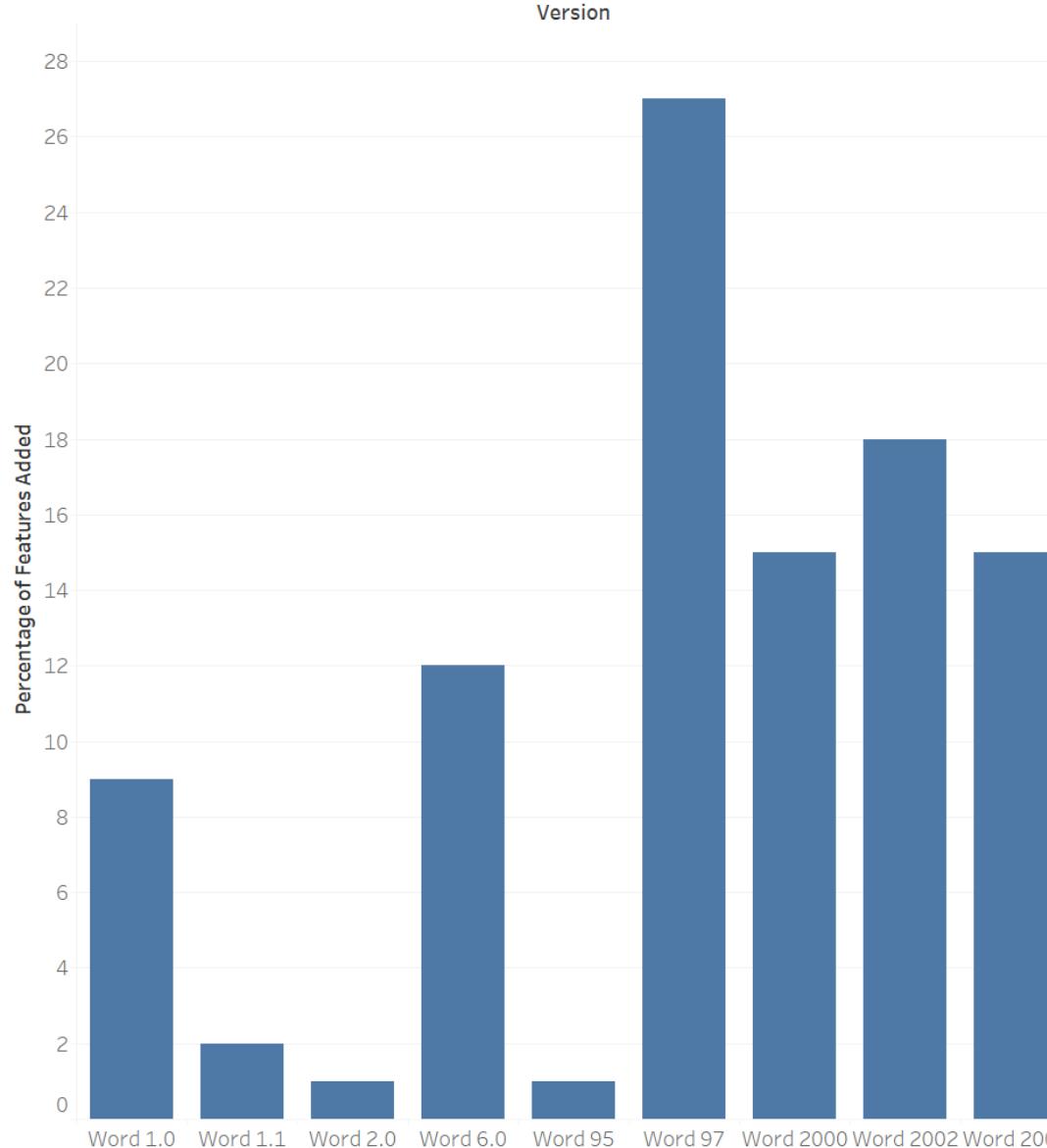
Example 3

## Percentage of Features Added to Microsoft Word



**Example 3 – Suggestion for Improvement #1**

Percentage of Features Added to Microsoft Word by Version



**Example 3 – Suggestion for Improvement #2**

# Data Visualization Tools:

## Tableau Desktop Demo



Products Solutions Learning Community Support About

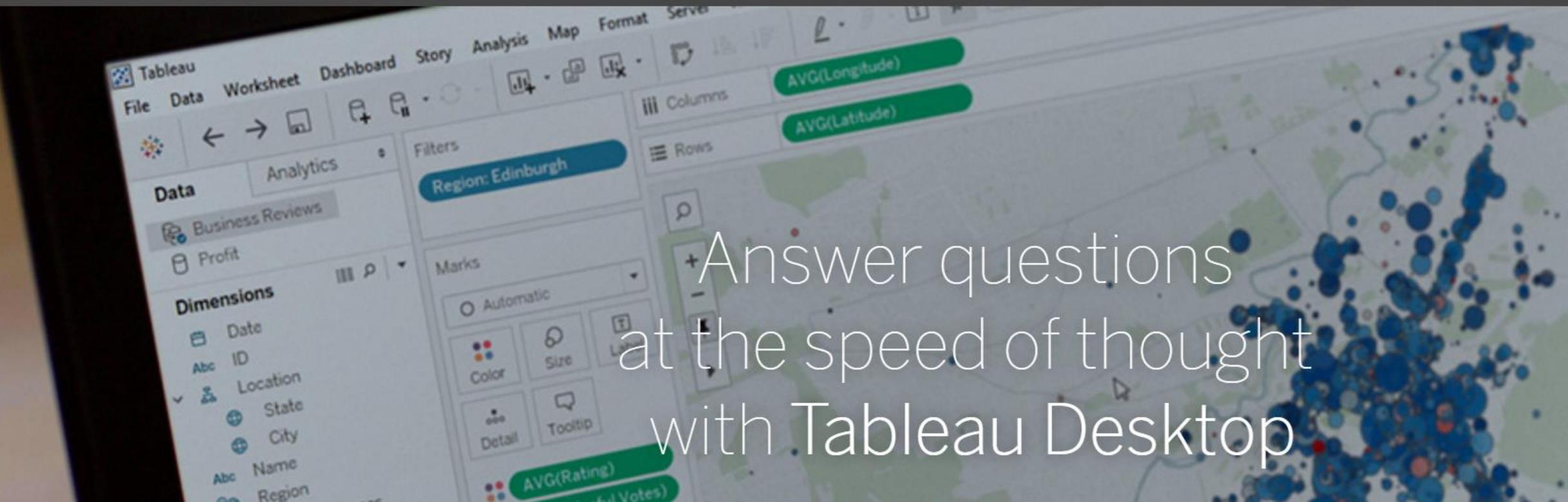
Tableau Desktop

Overview

Features

Stories

Pricing & Specs



A screenshot of the Tableau Desktop interface. The top navigation bar includes 'File', 'Data', 'Worksheet', 'Dashboard', 'Story', 'Analysis', 'Map', 'Format', 'Server', and various icons. Below the navigation is a toolbar with 'Data', 'Analytics', and 'Business Reviews' buttons. A sidebar on the left lists dimensions: Date, ID, Location, State, City, Name, and Region. The main workspace shows a map with numerous blue and red circular markers of varying sizes. Overlaid on the map are several green rounded rectangles containing text: 'Region: Edinburgh', 'AVG(Longitude)', 'AVG(Latitude)', and 'AVG(Rating)'. The bottom right corner contains the text 'Answer questions at the speed of thought with Tableau Desktop'.

Answer questions  
at the speed of thought  
with Tableau Desktop

# **Activity (Can be used for GPS Credit)**

**Email me ([kelly.schultz@utoronto.ca](mailto:kelly.schultz@utoronto.ca)) within 1 week**

## **Visualization – One Image**

1. Choose one of the provided data sets
2. Select 2-3 variables and create a data visualization
3. Be sure to select a visualization form appropriate to your data selection
4. Select appropriate visualization elements for the data

## **Reflection – One Paragraph**

1. What you thought were the most important things you learned today
2. Why are they important
3. How you will apply this knowledge in the future

# Resources

- Data Visualization Guide (under the Learn section of the MDL website):  
<https://mdl.library.utoronto.ca/dataviz/getting-started>
- Design Workflow Overview: <https://mdl.library.utoronto.ca/dataviz/workflow>
  - Chart Chooser Lists/Guides: <https://mdl.library.utoronto.ca/dataviz/workflow#form>
  - Visual Ranking Systems and Visual Variables & Colour:  
<https://mdl.library.utoronto.ca/dataviz/workflow#elements>
- Design Principles: <https://mdl.library.utoronto.ca/dataviz/design-principles>
- Specialty Visualization Areas Tips (including Cartography/Mapping Tips):  
<https://mdl.library.utoronto.ca/dataviz/specialty-visualization-areas>
  - Database Joins: <https://www.codeproject.com/Articles/33052/Visual-Representation-of-SQL-Joins>
- Tools & Tutorials: <https://mdl.library.utoronto.ca/dataviz/tools-tutorials>
  - Data Cleaning Tools List: <https://mdl.library.utoronto.ca/dataviz/tools-tutorials#cleaningpreparationtools>
  - Tableau: <https://mdl.library.utoronto.ca/dataviz/tools-tutorials#generalvisualizationtools>

# Resources continued

- Books, Blogs, and More: <https://mdl.library.utoronto.ca/dataviz/books-blogs-and-more>
- A few recommended books to get you started...
  - *Visual Insights: A Practical Guide to Making Sense of Data* by Katy Börner and David E. Polley: <http://go.utlib.ca/cat/9161339>
  - *Now You See It: Simple Visualization Techniques for Quantitative Analysis* by Stephen Few: <http://go.utlib.ca/cat/6930152>
  - *The Functional Art: An Introduction to Information Graphics and Visualization* by Alberto Cairo: <http://go.utlib.ca/cat/8699226>
- Get Tableau Desktop
  - Students: <https://www.tableau.com/academic/students>
  - Academic Teachers/Researchers: <https://www.tableau.com/academic/teaching>



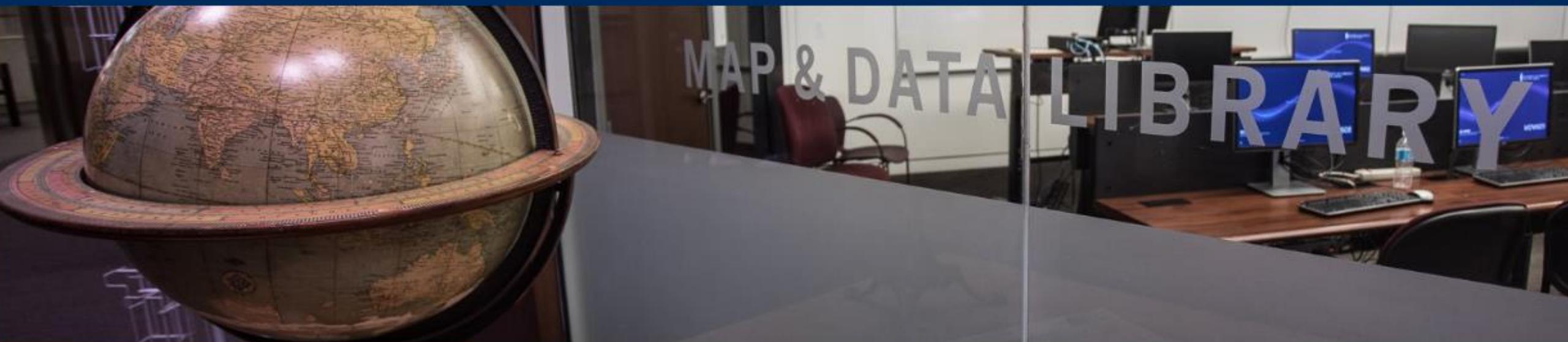
Research



Learn



Technolo



## About MDL

Our collection includes hundreds of geospatial and numeric datasets, over hundreds of thousands of maps, photographs, and more! We provide assistance finding maps and data and using GIS and statistical soft

Start your search **-> [mdl.library.utoronto.ca](http://mdl.library.utoronto.ca)**

Find maps, data, books, and library info



search by title  Map and Data only

### Geospatial data

Scholars GeoPortal | Geospatial data | Remote sensing | Air photo

### Numeric data

Microdata | Statistics | Census of Canada

### Maps and atlases

Scanned maps | Fire insurance plans | Rare maps

Contact me: [kelly.schultz@utoronto.ca](mailto:kelly.schultz@utoronto.ca)



# Wrap-Up

- 1) Key lesson?**
  - 2) Anything unclear?**
  - 3) Useful workshop?**
- Why/Why not?**

# Data sources

- 2015RainfallByMonthByCountry.xls & 2015TemperaturesByMonthByCountry.xls files:  
[http://sdwebx.worldbank.org/climateportal/index.cfm?page=downscaled\\_data\\_download&menu=historical](http://sdwebx.worldbank.org/climateportal/index.cfm?page=downscaled_data_download&menu=historical) (average monthly rainfall or temperature from 1901-2015)
- 2016PopulationbyRegion.xls file: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, custom data acquired via website: <https://esa.un.org/unpd/wpp/DataQuery/>
- RomeoAndJulietWordFrequenciesByAct.xls file from the play *Romeo and Juliet* by William Shakespeare full text (acquired via [http://shakespeare.mit.edu/romeo\\_juliet/full.html](http://shakespeare.mit.edu/romeo_juliet/full.html)) and then split into a document per act and run through Voyant tools: <https://voyant-tools.org/>

# Image Credits

- **Slide 1:** *Woman Using a Samsung VR Headset at SXSW*, flickr.com/Nan Palmero, <https://flic.kr/p/qJPZEL>
- **Slide 2:** *Manos*, morguefile.com/xololounge, <http://mrg.bz/Yda9Is>
- **Slide 3:** *Drawing and coloring*, Freelmages.com/ Ove Tøpfer, <http://www.freeimages.com/photo/drawing-1313453>
- **Slide 4:** *Dictionary*, flickr.com/greeblie, <https://flic.kr/p/662Len>
- **Slides 5 & 6:** *Anscombe's quartet*. (n.d.). Retrieved July 11, 2017 from Wikipedia: [https://en.wikipedia.org/wiki/Anscombe%27s\\_quartet](https://en.wikipedia.org/wiki/Anscombe%27s_quartet)
- **Slide 7:** Adapted and simplified visualization workflow from Borner, K., & Polley, D. (2014) *Visual Insights*. Cambridge, MA: The MIT Press.
- **Slide 8:** *audience wave*, flickr.com/Gavin Tapp, <https://flic.kr/p/aqvnet>
- **Slide 9:** *data.path Ryoji.Ikeda – 4*, flickr.com/r2hox, <https://flic.kr/p/gdMuhT>
- **Slide 10:** *IMG\_3223-21 [Pick Your Own]*, flickr.com/Travis Modisette, <https://flic.kr/p/g51mtL>

# Image Credits

- **Slide 11:** *Bond cleaning*, flickr.com/Thomas Morris, <https://flic.kr/p/W3E7Ko>
- **Slide 13:** *Binoculars portrait (dscn4659\_mod\_vign\_sm)*, flickr.com/gerlos, <https://flic.kr/p/5KGg5B>
- **Slide 14:** *Immersed in numbers*, flickr.com/Chris Khamken, <https://flic.kr/p/HUqtq>
- **Slide 14:** *The Comedy of Errors*, 1885, flickr.com/Ed Suominen, <https://flic.kr/p/hK4JRJ>
- **Slide 15:** *density-with-proposed-routes*, flickr.com/Michael Hicks, <https://flic.kr/p/gVB6X9>
- **Slide 15:** *My LinkedIn network, visualized*, flickr.com/Kars Alfrink, <https://flic.kr/p/9di83Y>
- **Slide 15:** *Timeline*, flickr.com/Marcin Wichary, <https://flic.kr/p/4t5RuE>
- **Slide 15:** *Open access in Wordle*, flickr.com/fyzhou1, <https://flic.kr/p/bLsykz>
- **Slide 15:** *Numbers in transport*, flickr.com/James Cridland, <https://flic.kr/p/4sQbS7>
- **Slide 16:** *Mother and baby elephant*, flickr.com/Jon Connell, <https://flic.kr/p/6hLGrU>
- **Slide 17:** *Not Fade Away.....*, flickr.com/Daniel Go, <https://flic.kr/p/ayqr9r>

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- **Slide 18:** *Starting line*, flickr.com/Jon Marshall, <https://flic.kr/p/p4zWb>
- **Slide 19:** *D3 Gallery's Visual Index*, D3 Wiki, <https://github.com/d3/d3/wiki/Gallery>
- **Slide 20:** *Prevalence of food stamp use*, flickr.com/Scott Drzyzga, <https://flic.kr/p/7k5N8i>
- **Slide 21:** Screenshot of network built on example data that comes with the networking visualization tool, Gephi: <https://gephi.org/>
- **Slide 22:** “Real Chart Rules to Follow”, Nathan Yau, <http://flowingdata.com/2015/08/11/real-chart-rules-to-follow/>
- **Slide 23:** “How to Create a Timeline Infographic in 6 Easy Steps”, Midori Nediger, <https://venngage.com/blog/how-to-create-a-timeline-infographic-in-6-steps/>; “Line Graphs in Chart Studio”, Plot.ly, <https://help.plot.ly/make-a-line-graph/>
- **Slide 24:** “Chart Dos and Don’ts”, Angela Zoss, <https://guides.library.duke.edu/datavis/topten>
- **Slide 26:** “Make a Bar Chart Online with Plotly and Excel”, Plot.ly, <https://help.plot.ly/excel/bar-chart/>

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- **Slide 27:** “Real Chart Rules to Follow”, Nathan Yau, <http://flowingdata.com/2015/08/11/real-chart-rules-to-follow/>
- **Slide 28:** “Scatter Plots in Chart Studio”, Plot.ly, <https://help.plot.ly/how-to-make-a-scatter-plot/>; “Make a Bubble Chart Online with Plotly and Excel”, Plot.ly, <https://help.plot.ly/excel/bubble-chart/>
- **Slide 29:** “How to avoid overplotting with python”, The Python Graph Gallery, <https://python-graph-gallery.com/134-how-to-avoid-overplotting-with-python/>; “Auto Fuel Efficiency by Weight, indicating Year (1970-1979) and Origin,” in *Search User Interfaces* by Marti Hearst (2009) <http://searchuserinterfaces.com/book/images/auto-scatterplot-years.png>
- **Slide 30:** “Pie Charts in Chart Studio”, Plot.ly, <https://help.plot.ly/make-a-pie-chart/>;
- **Slide 31:** “Real Chart Rules to Follow”, Nathan Yau, <http://flowingdata.com/2015/08/11/real-chart-rules-to-follow/>
- **Slide 32:** “Intro to Histograms”, Plot.ly, <http://help.plot.ly/histogram/>; “What is a Box Plot?”, Plot.ly, <http://help.plot.ly/what-is-a-box-plot/>

# Image Credits

- **Slide 33:** *Quick Facts*, from the University of Toronto website, <https://www.utoronto.ca/about-u-of-t/quick-facts>
- **Slide 34:** *run*, flickr.com/brett lohmeyer, <https://flic.kr/p/68oeCp>
- **Slide 35:** “Network visualization: mapping Shakespeare’s tragedies”, Martin Grandjean, <http://www.martingrandjean.ch/network-visualization-shakespeare/>
- **Slide 36:** Cleveland & McGill’s Ranking System in *The Functional Art* by Alberto Cairo (2013)
- **Slide 37:** “Automating the Design of Graphical Presentations of Relational Information” [Figure 15] by J.D. Mackinlay, published in ACM Transactions on Graphics (TOG), Vol. 5, Issue 2, April 1986, DOI: 10.1145/22949.22950
- **Slide 38:** “Considering Visual Variables as a Basis for Information Visualisation” [Table 1] by M.S.T. Carpendale, Research report 2001-693-16, Department of Computer science, University of Calgary, Calgary, AB, Canada, 2003: <http://innovis.cpsc.ucalgary.ca/Publications/ 34>
- **Slide 39:** “Cartography Guide: Visual Variables” by Axis Maps, <http://www.axismaps.com/guide/general/visual-variables/>

# Image Credits

- **Slide 40:** “Trellis Plot Alternative to Three-Dimensional Bar Charts” by Naomi Robbins from *Forbes.com*, <https://www.forbes.com/sites/naomirobbins/2012/06/07/trellis-plot-alternative-to-three-dimensional-bar-charts/#1f7b276c7dab>
- **Slide 41:** “Cartography Guide: Visual Variables” by Axis Maps, <http://www.axismaps.com/guide/general/visual-variables/>
- **Slide 42:** “Seven dirty secrets of data visualisation” by huyenlt from Joomla Vision, <http://www.joomlavision.com/dirty-secrets-data-visualisation/>
- **Slide 43:** “Cartography Guide: Visual Variables” by Axis Maps, <http://www.axismaps.com/guide/general/visual-variables/>
- **Slides 44-47:** ColorBrewer website: <http://colorbrewer2.org>
- **Slides 48 & 49:** Coblis — Color Blindness Simulator: <http://www.color-blindness.com/coblis-color-blindness-simulator/>
- **Slide 50:** *Typography*, flickr.com/Taryn, <https://flic.kr/p/5q1Qj1>
- **Slide 51:** *Photo Editing*, bestreviewsbase.com & flickr.com/James Baker, <https://flic.kr/p/WjBc3z>

# Image Credits

- **Slide 52:** *Fifth Annual Laps with the Chaps 5K Attracts Record Crowd 172*, flickr.com/COD Newsroom, <https://flic.kr/p/zcGYvk>
- **Slide 59:** *DesignLab consultation*, flickr.com/college.library, <https://flic.kr/p/hxzJFX>
- **Slide 60:** *Coffee break*, flickr.com/Berit Watkin, <https://flic.kr/p/dzBrCi>
- **Slide 61:** *WisCEL\_classroom12\_7871*, flickr.com/college.library, <https://flic.kr/p/e8RE6D>
- **Slide 62:** “Chart 2 - Total Expenditures on Health as a Percentage Share of GDP, OECD Countries, 2006” from *The Long-Term Projection Assumptions for Medicare and Aggregate National Health Expenditures* report, <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/ReportsTrustFunds/downloads/projectionmethodology.pdf>
- **Slide 64:** “Figure 10: Public- and private-sector jobs (000s) in Ontario, 1993–2013” from *Ontario – No Longer a Place to Prosper* report, <https://www.fraserinstitute.org/sites/default/files/ontario-no-longer-a-place-to-prosper.pdf>
- **Slide 67:** *Evil Pies* by Michael Friendly from DataVis.ca, <http://www.datavis.ca/gallery/evil-pies.php> (larger image size from: [https://ndevisual.files.wordpress.com/2010/09/pie\\_microsoft.png](https://ndevisual.files.wordpress.com/2010/09/pie_microsoft.png))

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