

Data Visualization: Introduction and Overview

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$ echo "Data Science Institute"
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Acknowledgement

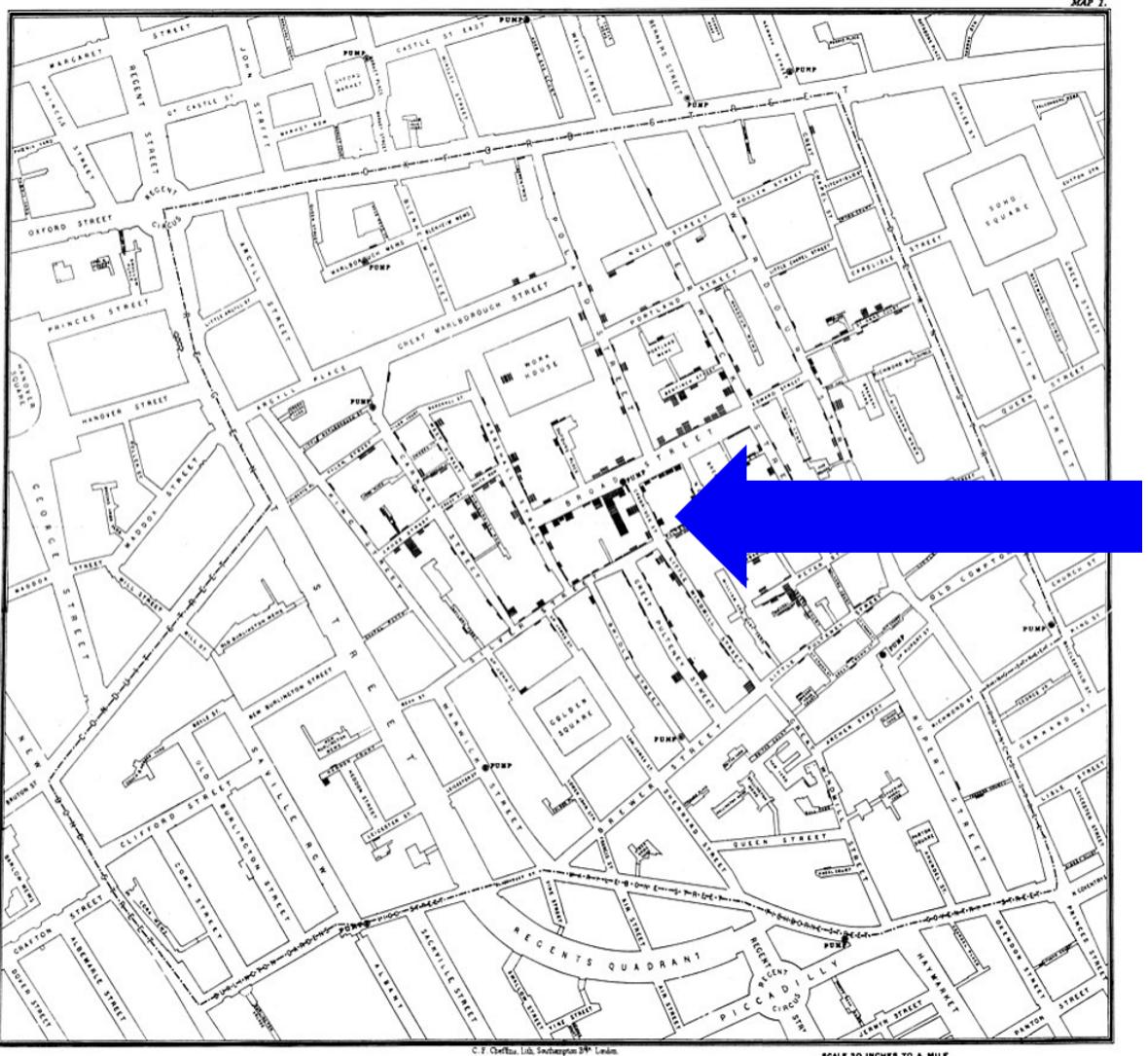
I wish to acknowledge this land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and the Mississaugas of the Credit. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

Today, we will...

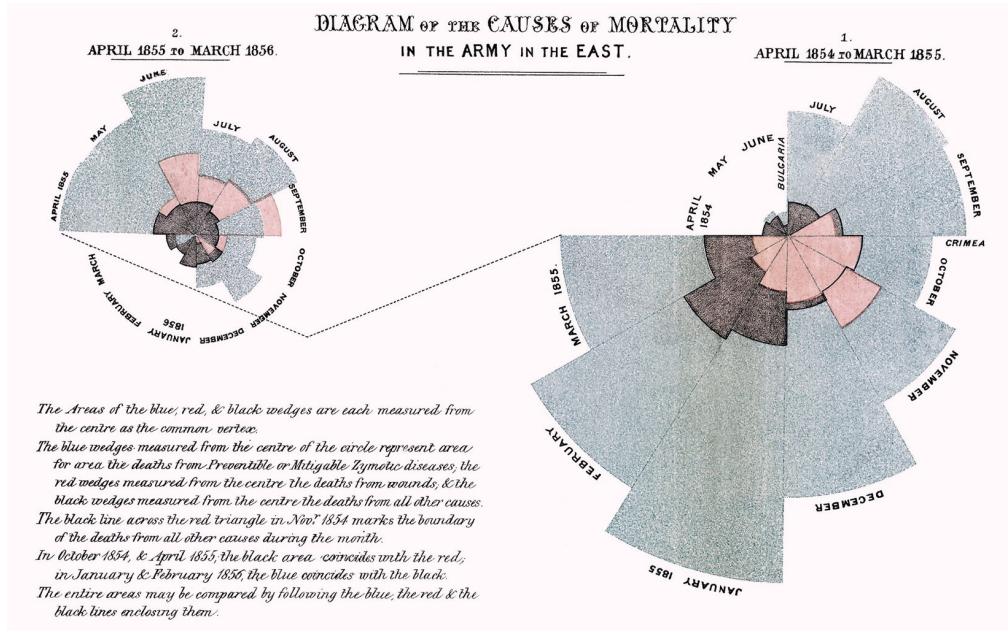
- Explore why we should care about data visualization
- Question what makes 'good' data visualization
- Introduce a range of software and tools that are used for data visualization
- Go through an overview of what to expect in the rest of this course

Case Study: Why should we care about data visualization?

- No matter how good or groundbreaking our data science work is, if we can't communicate it, its impact will be severely limited.
- Often, the best way to communicate insights from data is in visual format.
- We can see examples of this idea throughout history.



- By plotting black bars at the locations of each cholera death, Dr. John Snow was able to provide evidence **tracing** an 1854 **outbreak** to a specific water pump.
- This visualization is **often cited** as one of the early origins of the field of epidemiology.



- This 1858 visualization by Florence Nightingale shows soldiers' deaths due to wounds in battle (pink), other causes (black), and disease (blue) and was used to advocate for prioritizing nutrition, ventilation, and shelter, revolutionizing army medicine.

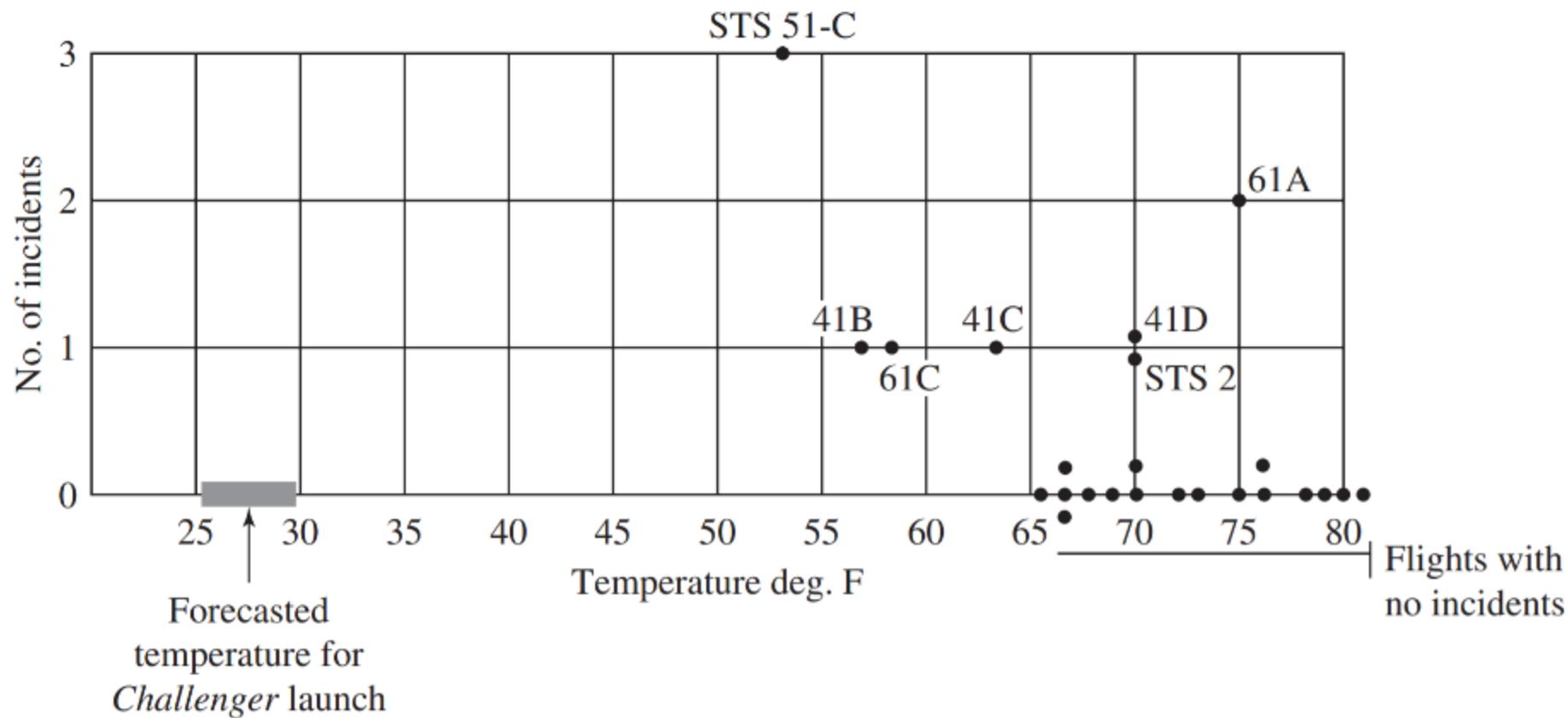
But data visualization is not always so straightforward...

The Challenger Disaster

- In 1986, the space shuttle *Challenger* exploded 73 seconds after launch, killing everyone aboard.
- The explosion occurred because hot propellant gases burned through rubber seals ("O-rings") on the shuttle's right solid rocket booster.
- For months, up until the night before the launch, concerns about the O-rings and the safety of the launch had been raised, but launch proceeded anyway

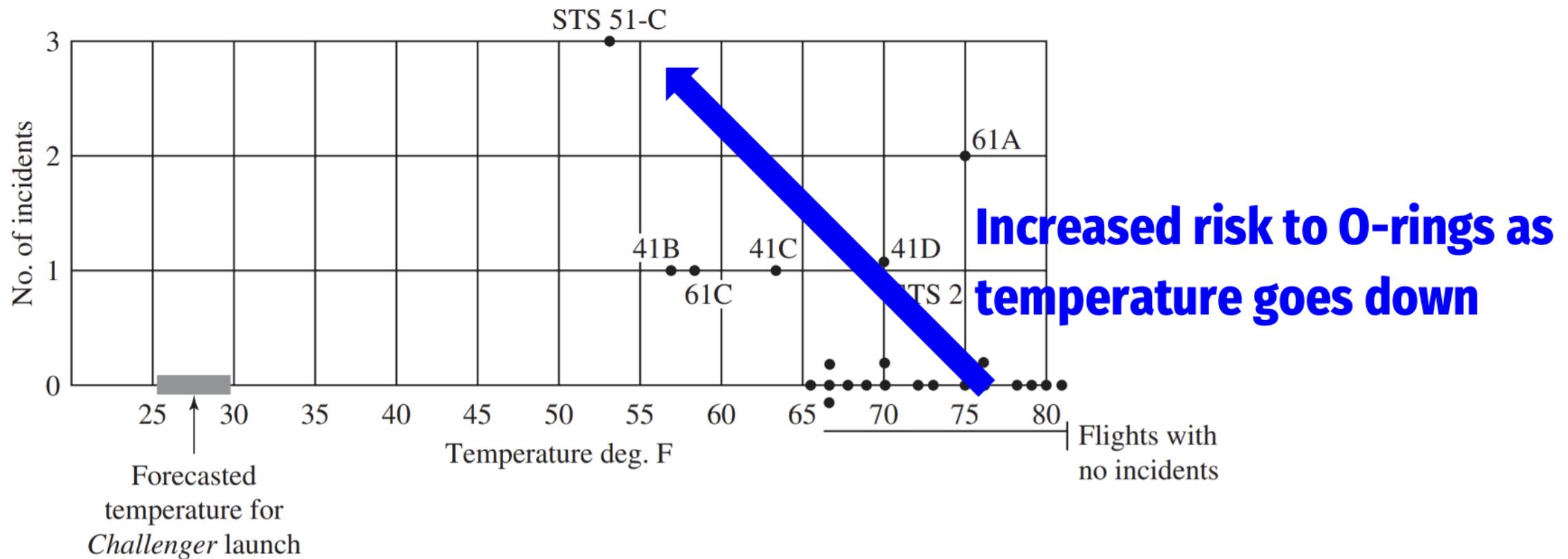
The Challenger Disaster - Tufte's Graph

- In 1997, Edward Tufte famously published a visualization showing the relationship between temperature during launches of test shuttle flights (pre-Challenger) and incidents of damage to O-rings (image: Tufte, 1997 



The Challenger Disaster - Tufte's Graph

- Tufte's graph seems to show that as launch temperatures decreased, O-ring incident rate increased; thus, by launching at temperatures lower than those tested, NASA unnecessarily endangered *Challenger* (image: Tufte, 1997 ↗)

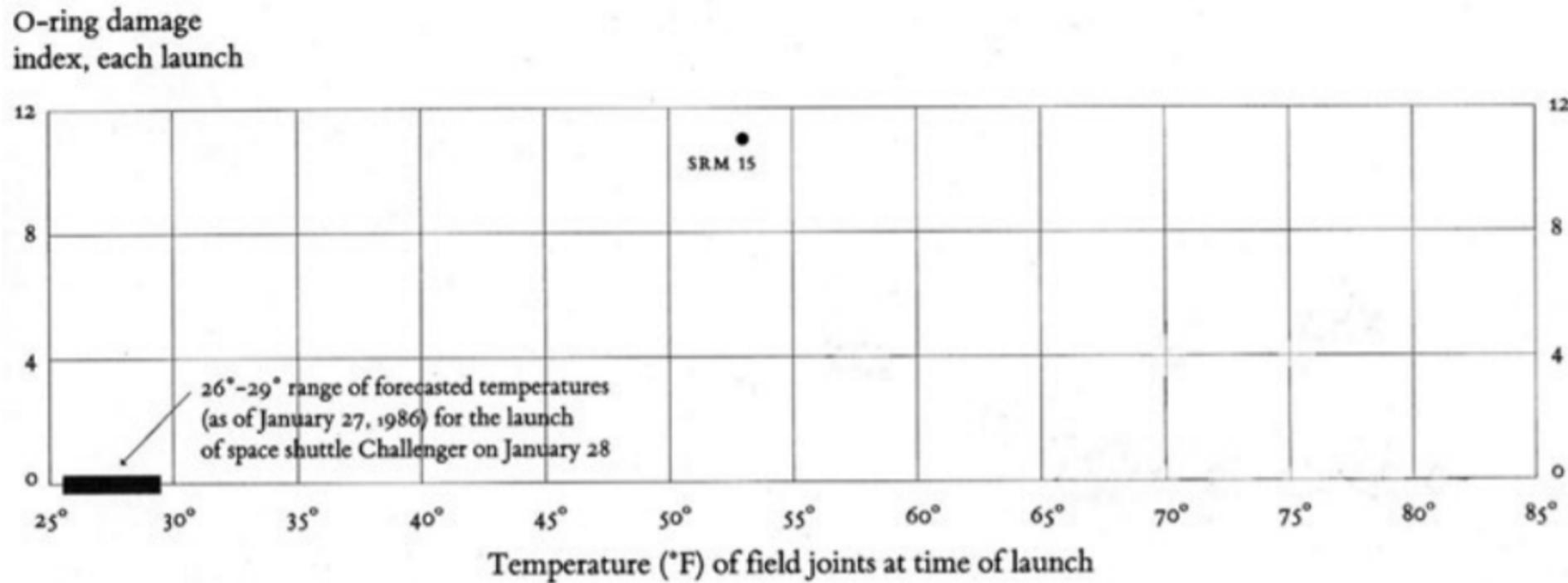


The Challenger Disaster - Tufte's Graph

- Tufte argued that the engineers responsible for communicating the results of the O-ring tests had failed to represent the data that might have saved the crew of *Challenger*.
- Tufte's graph is used as a classic case study demonstrating the importance of data visualization as a way to communicate complex information.
- Another case of data visualization saving lives?

The Challenger Disaster - But...

- The accuracy of Tufte's visualization has [been debated](#), with Robison identifying several errors in Tufte's use of data.
- Robison suggests that only one test launch had actually produced relevant O-ring temperature data, producing this visual instead: (image: Robison, 1997, 2002 



The Challenger Disaster - But...

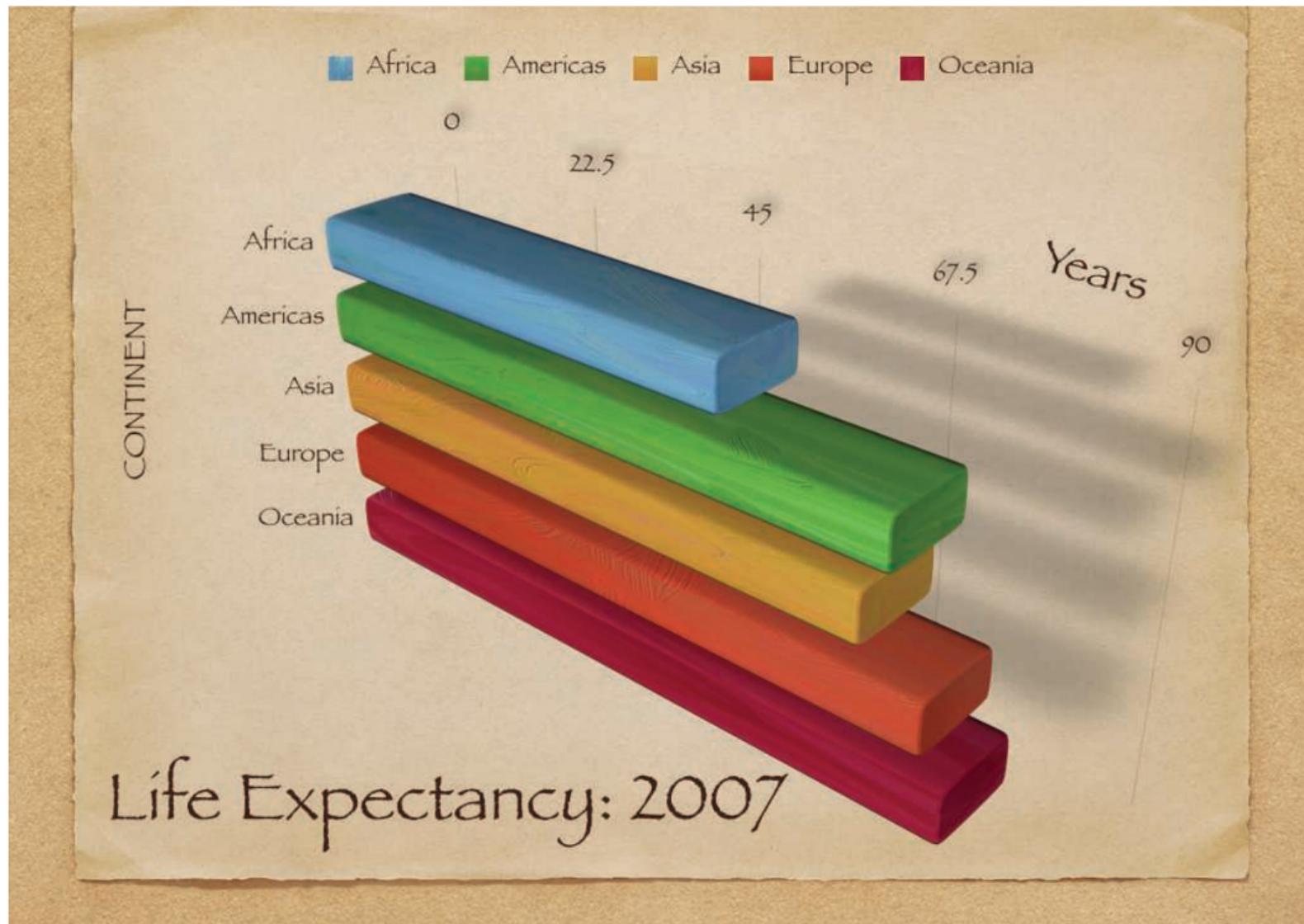
- Per Tufte, the *Challenger* disaster is a case where good data visualization could have facilitated understanding of complex data and saved lives.
- Per Robison, Tufte's work is a case of bad data visualization unfairly placing blame and leading the audience to a faulty conclusion.

The choices we make about visualizing our data have consequences - so how do we make better ones?

Activity: What is 'good' data visualization?

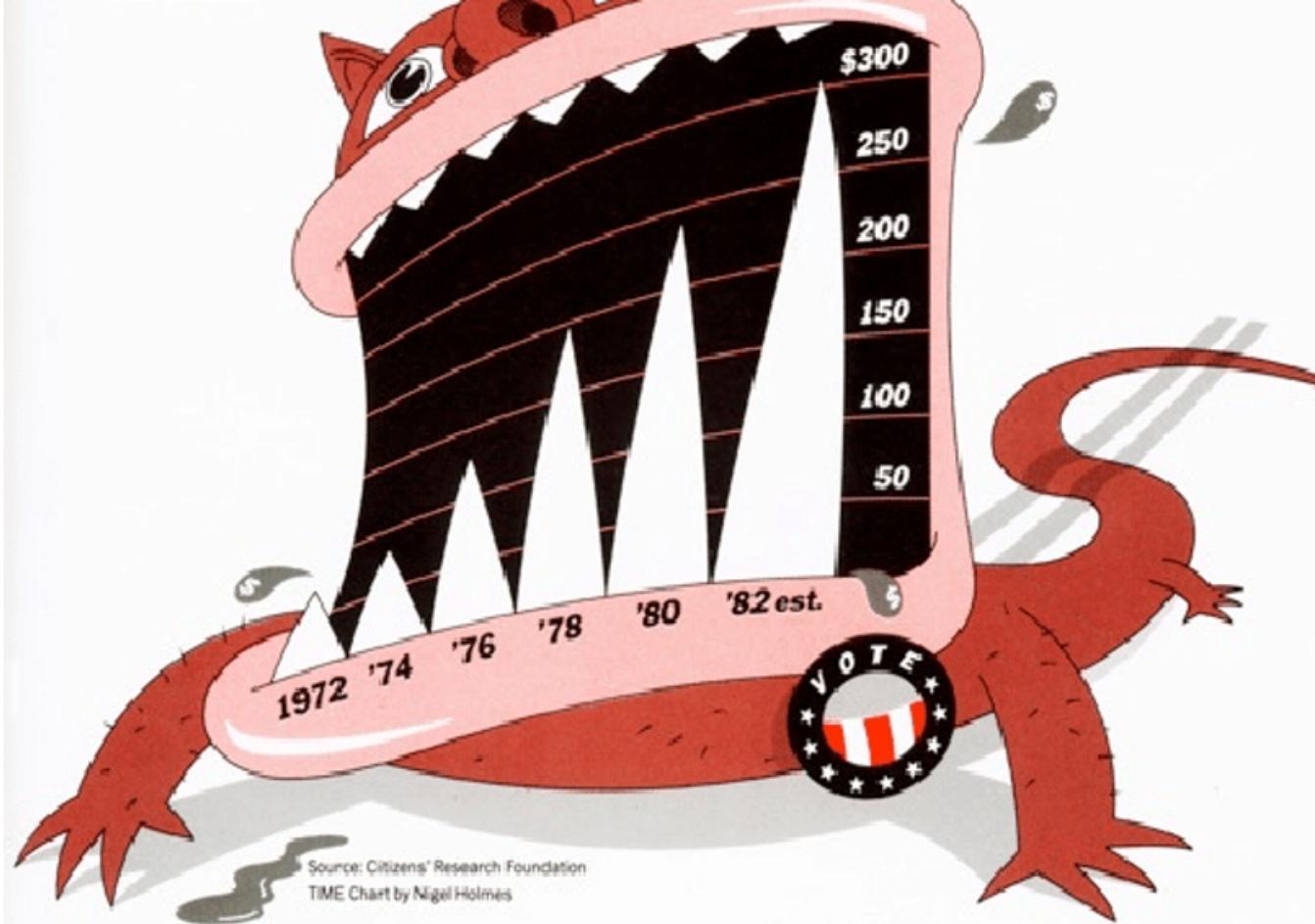
Activity

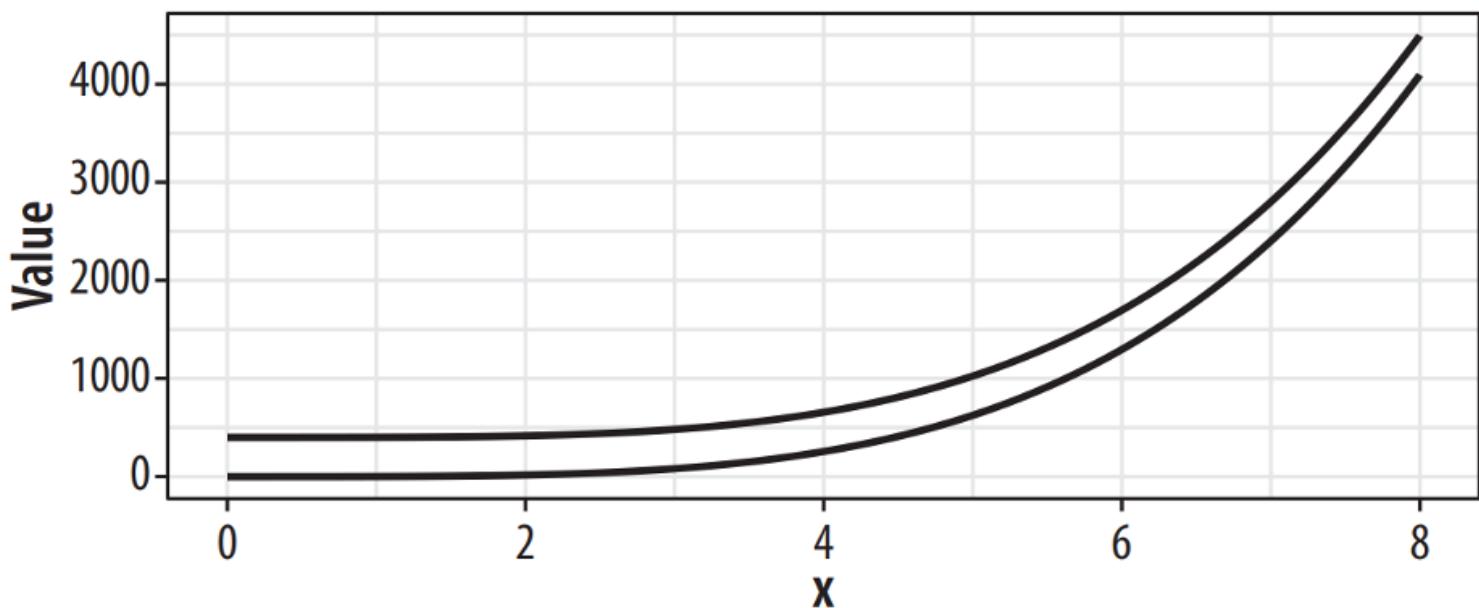
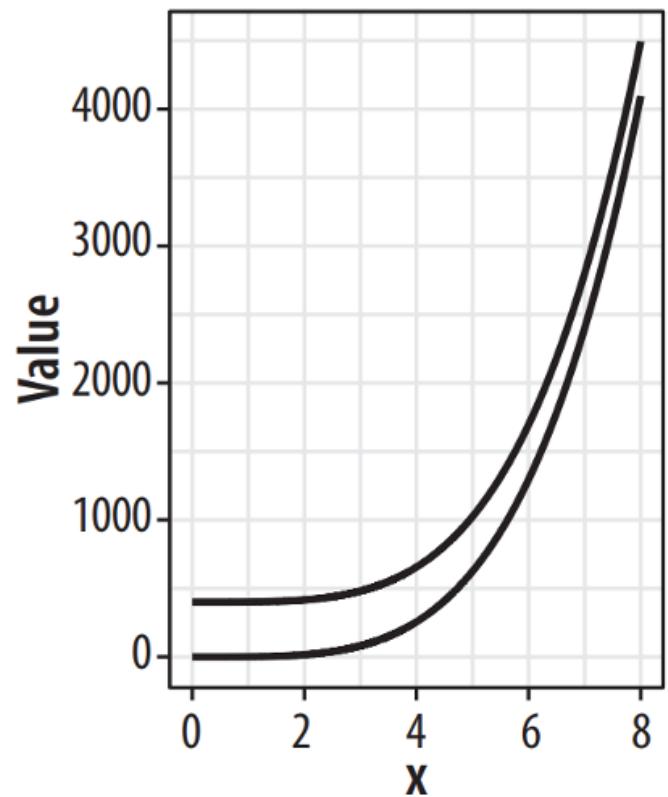
- Look at the following examples of data visualizations. For each, consider:
 - Is the visualization pleasing to look at?
 - Does the visualization accurately represent data?
 - Can we understand what message the maker of the visualization is attempting to convey?
 - Consider factors such as colour, size, use of images. Is this a 'good' data visualization? Why or why not?



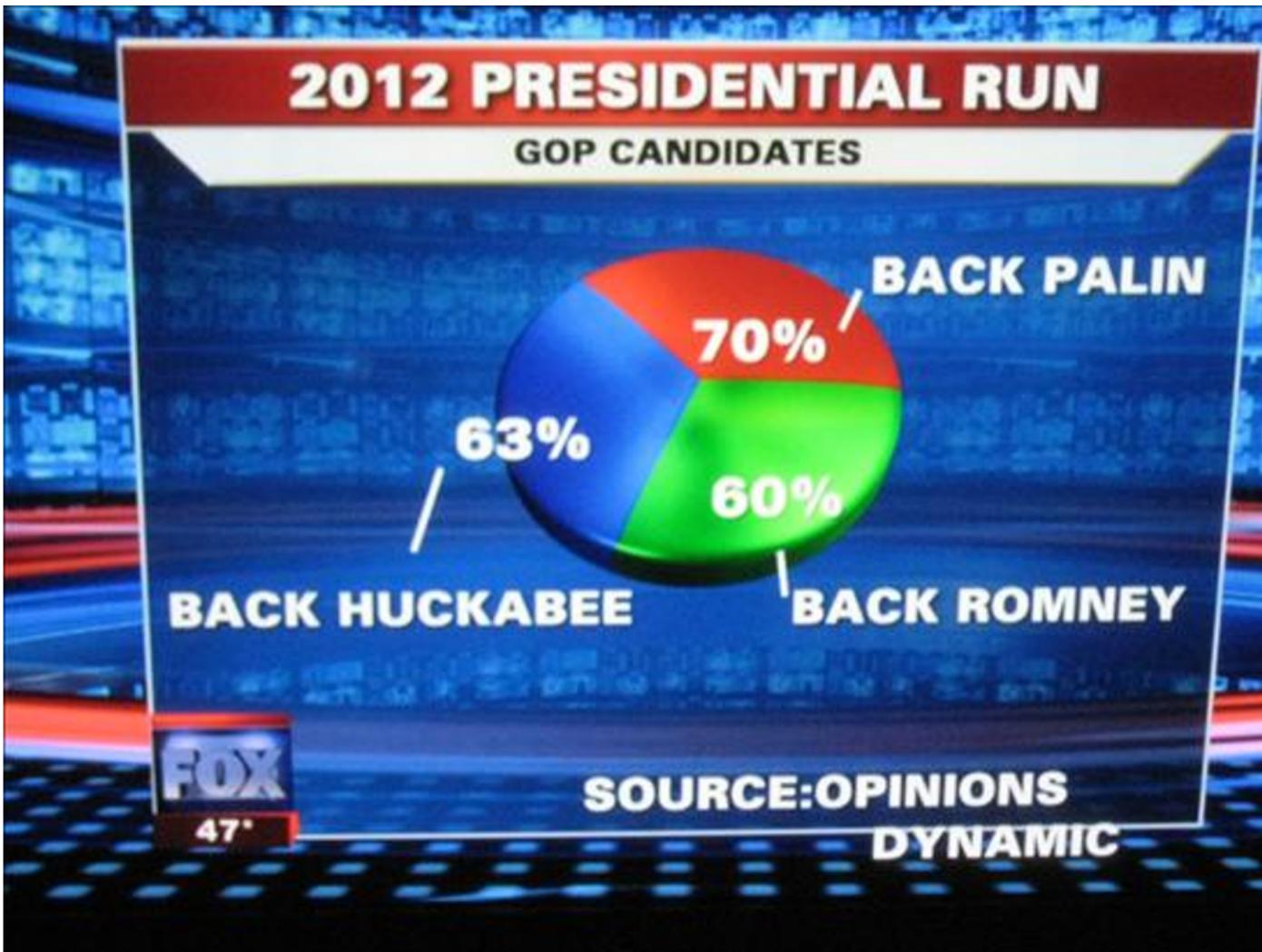
MONSTROUS COSTS

Total House and Senate campaign expenditures,
in millions





(The same data presented with two different aspect ratios)



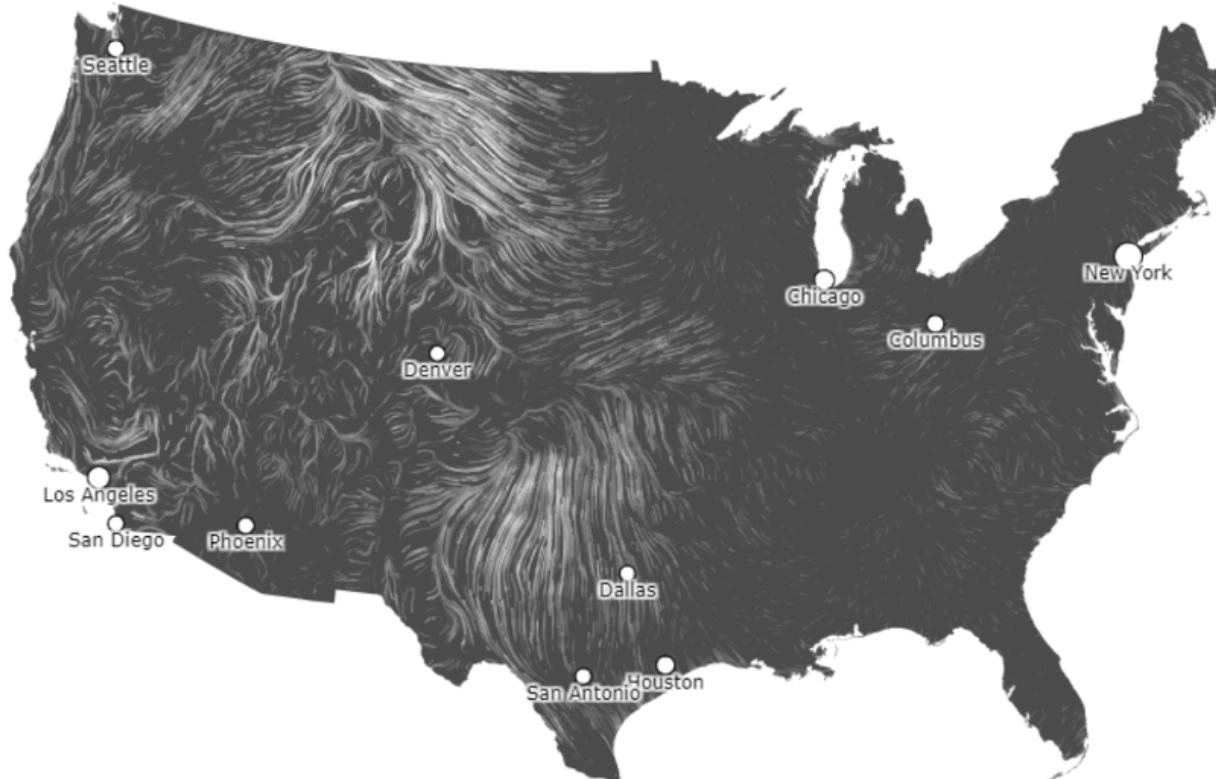
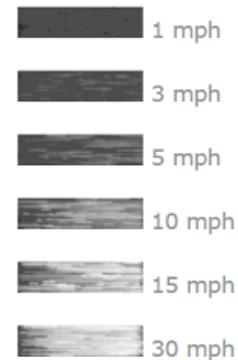
wind map

October 23, 2021

3:07 am EST

(time of forecast download)

top speed: 27.0 mph
average: 7.1 mph



(Click image to view interactive visualization)

Activity

- Each of the questions corresponds to an important quality of data visualizations:
 - Is the visualization pleasing to look at? → **Aesthetic**
 - Does the visualization accurately and honestly present data? → **Substantive**
 - Can we understand what message the maker of the visualization is attempting to convey? → **Perceptual**
- We need to consider all of these qualities when evaluating and designing 'good' data visualizations

What data visualization IS

- Dependent on:
 - **Context** → *where and how* will our visualization be used? (eg. academic journal, poster, infographic)
 - **Audience** → *who* is intended to use our visualization? (eg. subject experts, general public)
 - **Data structure** → *what* information do our data capture? (eg. quantities, relationships)

What data visualization is NOT

- Hard and fast rules for every situation → **visualizing data means making decisions**

What tools are used for data visualization?

Tools for Data Visualization

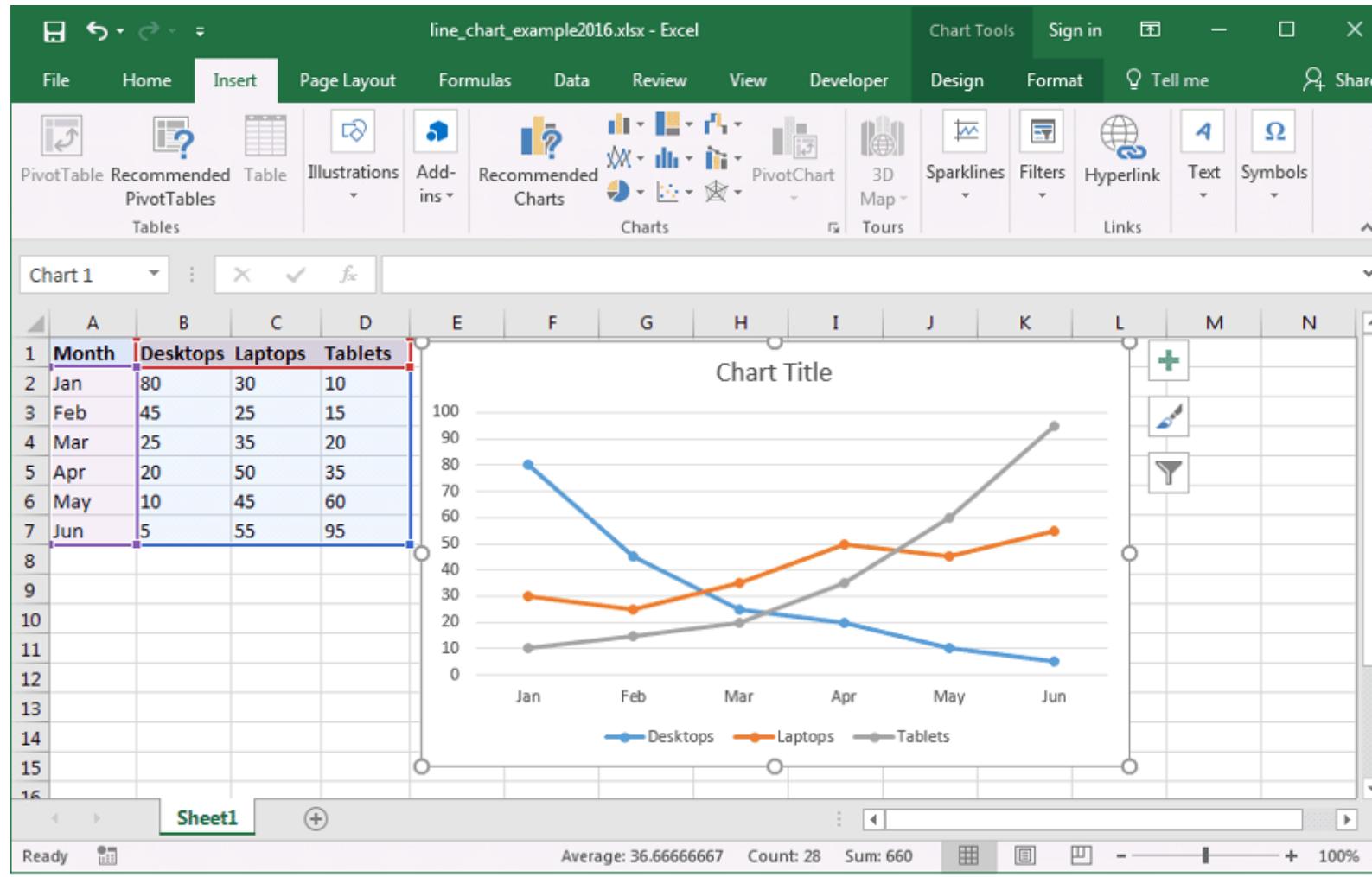


Microsoft Excel (LibreOffice Calc, Google Sheets, etc)



What is it	Spreadsheet software with ability to generate static data visualizations
Access	<ul style="list-style-type: none">- Excel is paid (part of MS Office Suite)- Free alternatives such as Google Sheets and LibreOffice Calc
Reproducible visualizations	<ul style="list-style-type: none">- no

Microsoft Excel (LibreOffice Calc, Google Sheets, etc)



TechOnTheNet.com

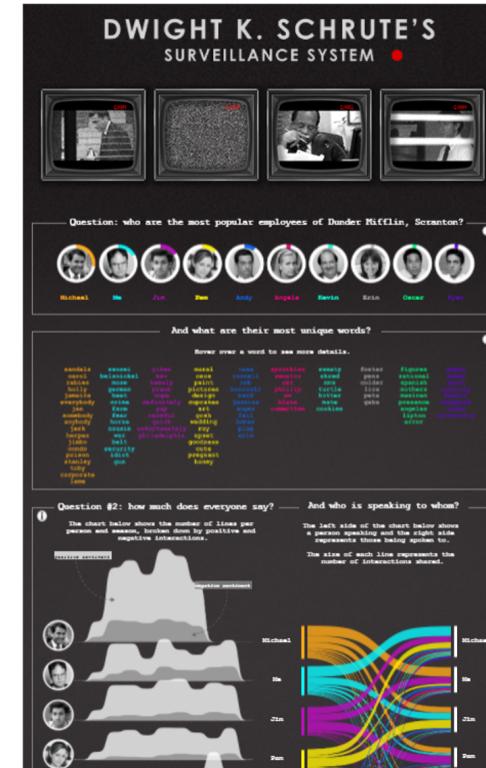
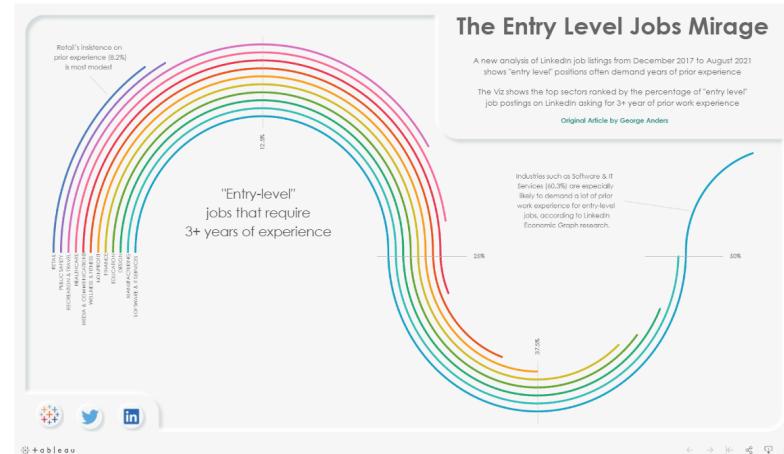


Tableau, Tableau Public

What is it	Combines data from different sources (databases, spreadsheets) into interactive, dynamic visualizations on the web
Access	<ul style="list-style-type: none">- Tableau Server and Desktop are paid- Tableau Public is free but all visualizations are public and not saved locally
Reproducible visualizations	<ul style="list-style-type: none">- no

Tableau, Tableau Public

Click each link to view and interact with public visualizations chosen as Tableau's 'Viz of the Day':
🔗 left, 🔗 middle, 🔗 right





Microsoft Power BI

What is it	Combines data from different sources (databases, spreadsheets) into interactive, dynamic visualizations on the web
Access	Paid (part of MS Office Suite)
Reproducible visualizations	no
Ease of use	Drag and drop to select from pre-made visualizations Can use DAX (Data Analysis

Microsoft Power BI

Sales Report - Power BI Desktop

Kaur Kotadia | Publish

OVERVIEW

Sales Report

Key influencers Top segments

What influences NPS to be 7

Whenthe likelihood of NSAT being 7 increases by

- UnitPrice is 298.5 - 299.94 → 10.20x
- UnitPrice is 197.45 - 199.45 → 10.20x
- Manufacturer is Litware, INC. → 10.20x
- Color is Brown → 10.20x
- StockType is High → 10.20x
- Manufacturer is Contoso, Ltd → 10.20x
- Color is Silver → 10.20x

\$5.3M Australia

\$5.3M Canada

\$2.6M France

\$2.3M Germany

\$3.3M UK

\$21.8M USA

Units by Product and Sale Size

Sales Amount by Brand Name

Sales Amount by Year, Month and Brand Name

Sales Amount by Year, Month and Brand Name

Visualizations >

Fields

Values

Drag data fields here

Drillthrough

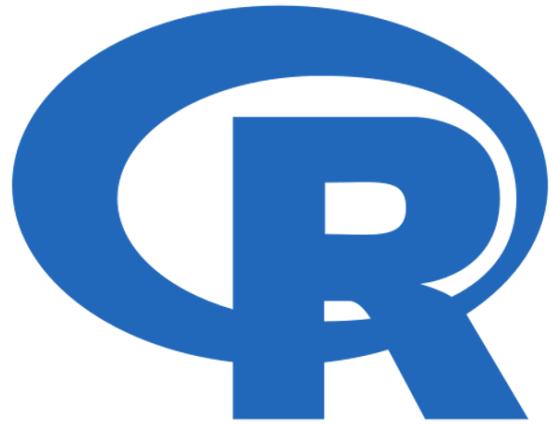
Keep all filters

Off

Drag data fields here

Overview Stores Products +

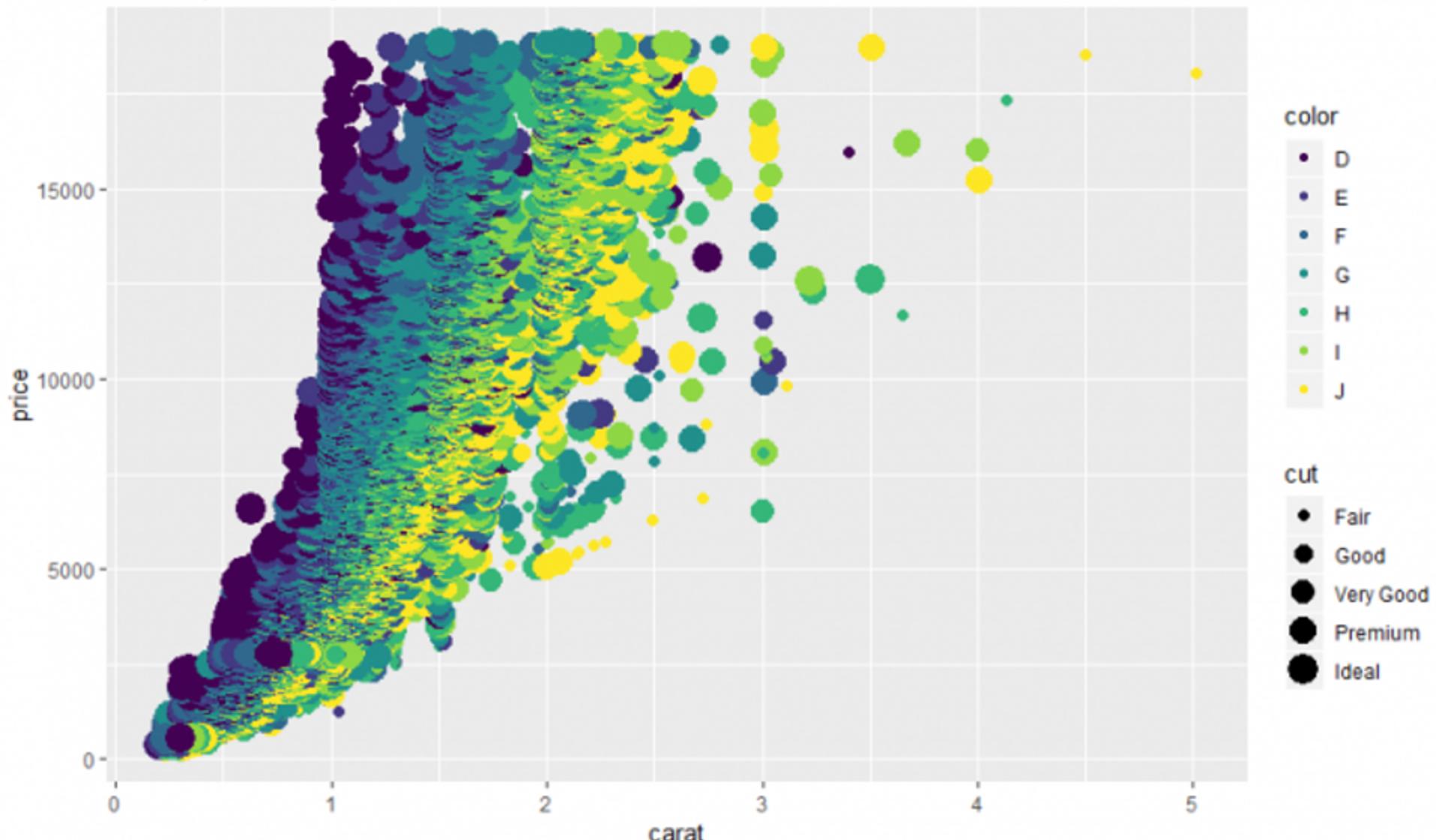
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R

What is it	Programming language with libraries for data visualization (e.g., ggplot2, Plotly, RColorBrewer)
Access	Free and open source (https://www.r-project.org/COPYING)
Reproducible visualizations	yes
Ease of use	Programming language; requires some coding knowledge

Scatterplot example on diamonds dataset

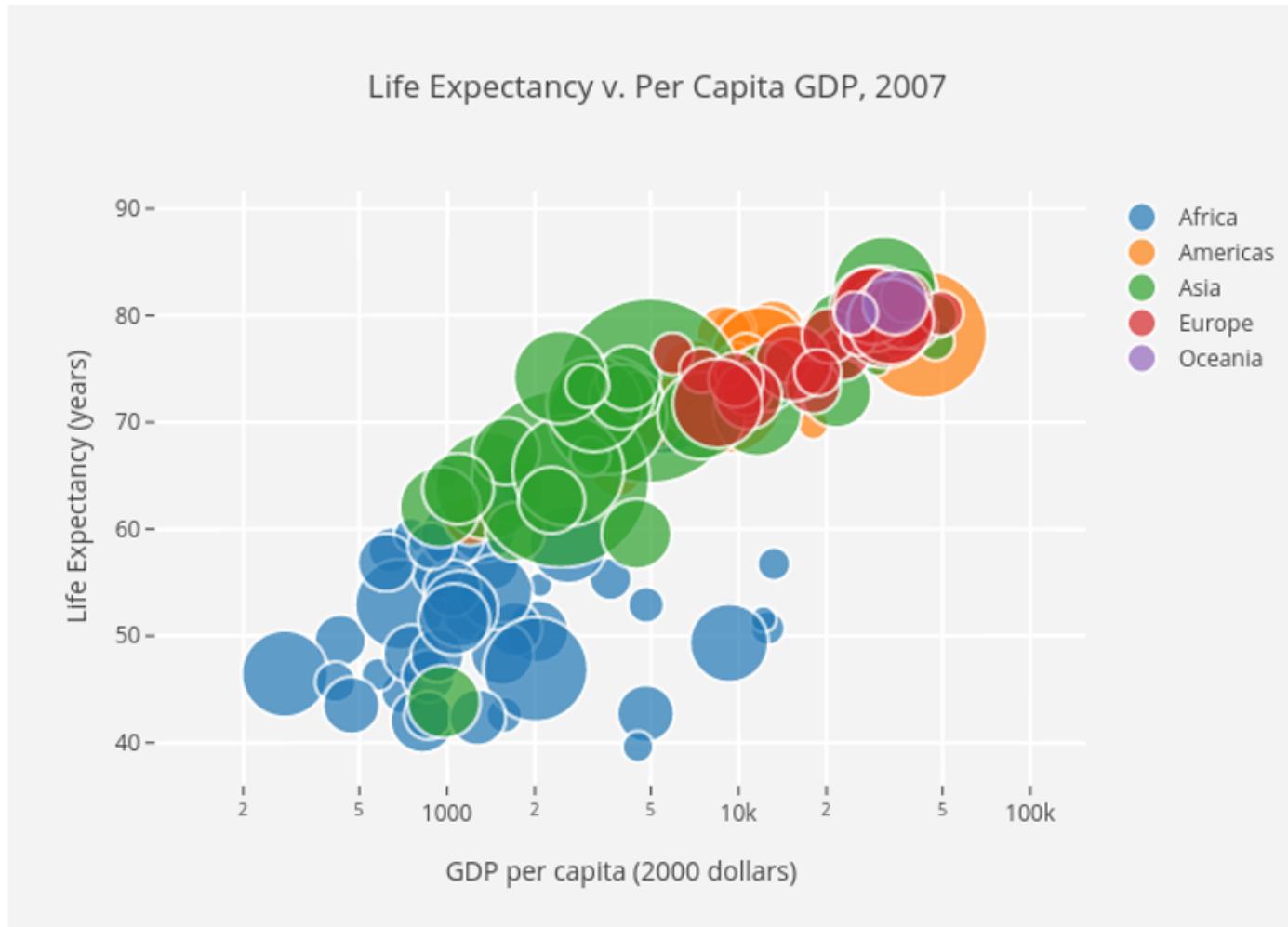




Python

What is it	Programming language with libraries for data visualization (e.g., Matplotlib, Plotly)
Access	Free and open source Python Software Foundation License
Reproducible visualizations	yes
Ease of use	Programming language; requires some coding knowledge

Python



For our purposes

- Step-by-step walkthroughs are focused on Python (Matplotlib)
 - Commonly used tool
 - Free and open source
 - Reproducible
 - LOTS of available resources online

BUT...

- General design principles will apply to creating data visualizations in whichever software you decide to use

What will we cover in this course?

Coming Up in this Course - Topics

- **First Steps**
 - Get started
 - Make a plot (Matplotlib)
 - Thinking about reproducibility
- **Graphing Our Data**
 - Customize our plot appearance
 - Choosing the right visualization (perceptual qualities)

Coming Up in this Course - Topics

- **Visualization with Purpose**
 - Subplots and combining visualizations
 - Colour theory and accessible design
 - Data visualization as advocacy
- **Getting Fancy**
 - Beyond matplotlib (Seaborn)
 - Drawing maps (geoplot)
 - Interactive data visualizations (Plotly)

Learning Objectives of this Course

1. Develop ability to **create and customize data visualizations** start to finish in Python
2. Build an understanding of general design principles for creating **accessible and equitable** data visualizations in Python and other software
3. Build an understanding of **data visualization as purposeful/telling a story** (and the ethical/professional implications thereof)