7 Information visualization

This chapter covers the fundamentals of creating effective visualizations, including the principles of design and interpretation. Effective visualizations require careful design and understanding to appropriately reveal patterns and insights while avoiding common pitfalls like misused graphical elements. The second half of the chapter introduces network visualizations, focusing on their structure, purpose, and the evolving relationships they depict. In addition, the use of AI and ML tools for data visualization will be covered, highlighting their capabilities in predictive modeling and real-time data interaction. Finally, it will address the challenges and ethical considerations of using advanced visualization systems, particularly the risks of overlooking anomalies and overgeneralizing based on past data. Through these topics, this chapter will provide a comprehensive overview of the current state and future potential of information visualizations.

7a Basics of visualization

Bonus content: critical issues in visualization

Recent scholarship draws attention to critical concerns in this area of digital research. The work of feminist scholars questions some of the assumptions about who controls the technology of production and whose values are embodied in the information design process (D'Ignazio and Klein 2016). A cache of hand-drawn works by the African-American activist, W.E.B. Du Bois, sheds light on this formerly little-known aspect of his work and the way he made use of data visualization for advancing critical discussions of race (Mansky 2018). Their hand-drawn quality inflects their presentation, raising questions of equitable access to resources. A very different approach to hand-drawn visualizations appeared in a "Dear Data" project of letters exchanges between Georgia Lupi and Stephanie Posavec, both sophisticated information designers who used the experiment to explore the possibilities of analog presentation (Lupi 2017). Many artists have been intrigued by data flows and visualizations as opportunities for aesthetic investigation, some of which will be touched on ahead in the discussion of complexity.

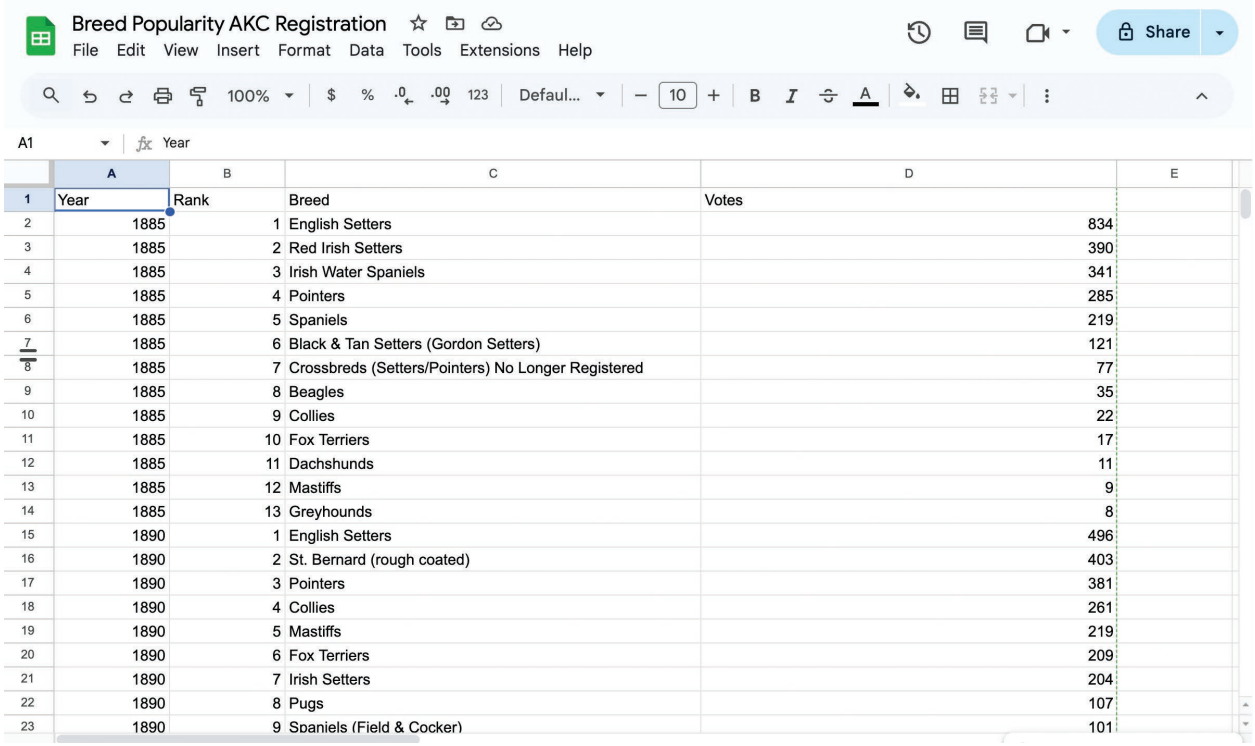
Exercise 7.1: A range of graphs

Try various visualizations for suitability. Take one of these datasets through a series of Microsoft Excel visualizations. Which makes the data more legible? Less?

- United States AKC Registrations: http://images.akc.org/pdf/archives/AKCregstats_1885-1945.pdf.
- My Food Data: https://docs.google.com/spreadsheets/d/1snqE6leDkZlL61qQ4g-vUmiFjizJyN1OCVAhwWWKSm4/edit?usp=sharing.

How-to example

Enter your data into spreadsheet (Figure 7.1).



Breed Popularity AKC Registration

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A1 fx Year

	A	B	C	D	E
1	Year	Rank	Breed	Votes	
2	1885	1	English Setters	834	
3	1885	2	Red Irish Setters	390	
4	1885	3	Irish Water Spaniels	341	
5	1885	4	Pointers	285	
6	1885	5	Spaniels	219	
7	1885	6	Black & Tan Setters (Gordon Setters)	121	
8	1885	7	Crossbreds (Setters/Pointers) No Longer Registered	77	
9	1885	8	Beagles	35	
10	1885	9	Collies	22	
11	1885	10	Fox Terriers	17	
12	1885	11	Dachshunds	11	
13	1885	12	Mastiffs	9	
14	1885	13	Greyhounds	8	
15	1890	1	English Setters	496	
16	1890	2	St. Bernard (rough coated)	403	
17	1890	3	Pointers	381	
18	1890	4	Collies	261	
19	1890	5	Mastiffs	219	
20	1890	6	Fox Terriers	209	
21	1890	7	Irish Setters	204	
22	1890	8	Pugs	107	
23	1890	9	Spaniels (Field & Cocker)	101	

Figure 7.1 Breed popularity AKC registration data in a Google spreadsheet.

Make sure that you clean your data before you visualize it. You will want to make sure that each category, in this case dog breed, is consistently identified in the dataset, in order for it to visualize properly. Since plural identification is typical throughout the dataset, adjust the singular St. Bernard fields to read as plural (St. Bernards), so everything matches (Figure 7.2).

	A	B
4	Black & Tan Setters (Gordon Setters)	173
5	Boston Terriers	292
6	Bull Terriers	183
7	Bulldogs	108
8	Collies	1136
9	Crossbreds (Setters/Pointers) No Longer Registered	77
10	Dachshunds	11
11	English Setters	2732
12	Fox Terriers	796
13	Gordon Setters	55
14	Great Danes	222
15	Greyhounds	8
16	Irish Setters	315
17	Irish Terriers	134
18	Irish Water Spaniels	341
19	Mastiffs	228
20	Pointers	1721
21	Pugs	107
22	Red Irish Setters	390
23	Spaniels	219
24	Spaniels (Field & Cocker)	672
25	St. Bernard (rough coated)	403
26	St. Bernards (rough coated)	1127
27	St. Bernards (smooth coated)	190
28	**Grand Total**	**12027**
29		

Figure 7.2 Detail of single and plural records for St. Bernards in the breed popularity AKC registration spreadsheet.

When you are looking to create different types of visualizations, a pivot table can help by summarizing and organizing large amounts of data into readable tables. If you are working in Google Sheets, go to Insert and Pivot Table (Figure 7.3).

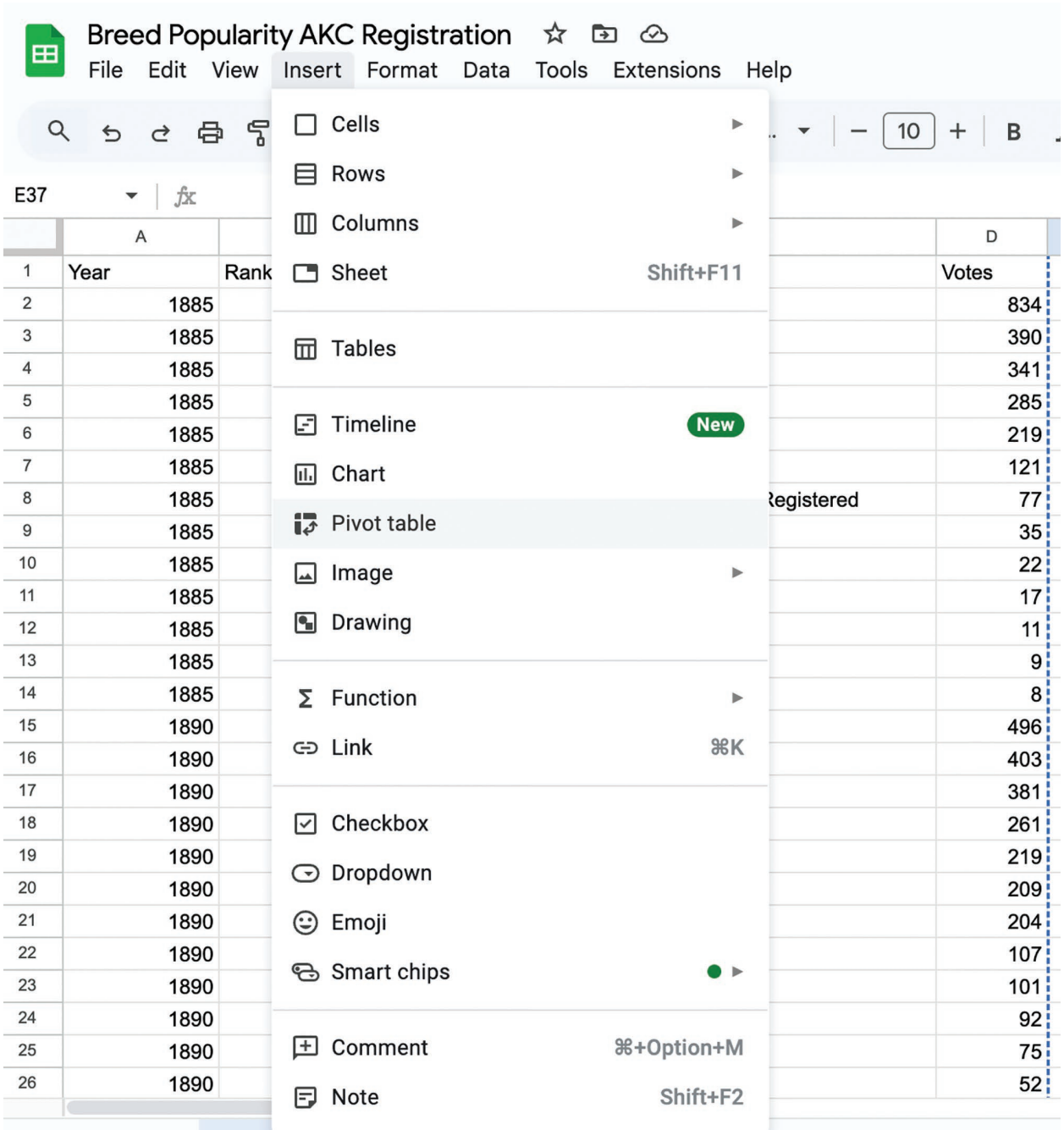
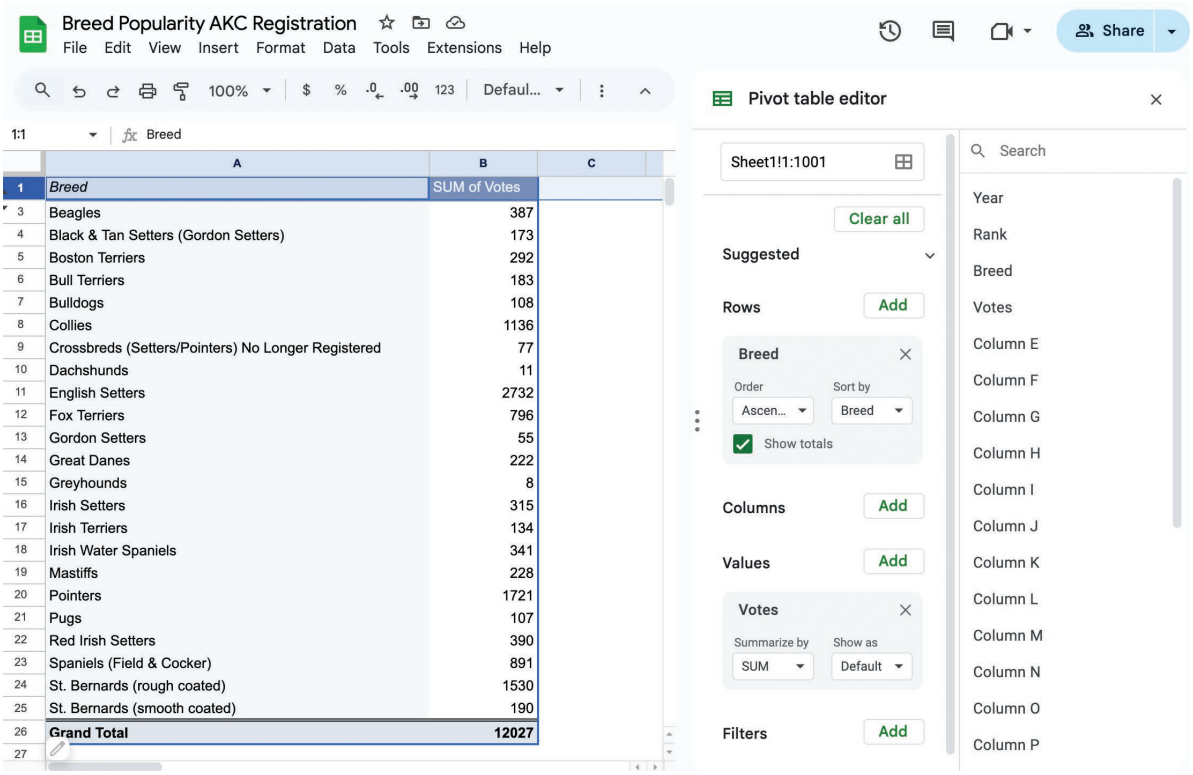


Figure 7.3 Detail of how to insert a pivot table in Google Sheets.

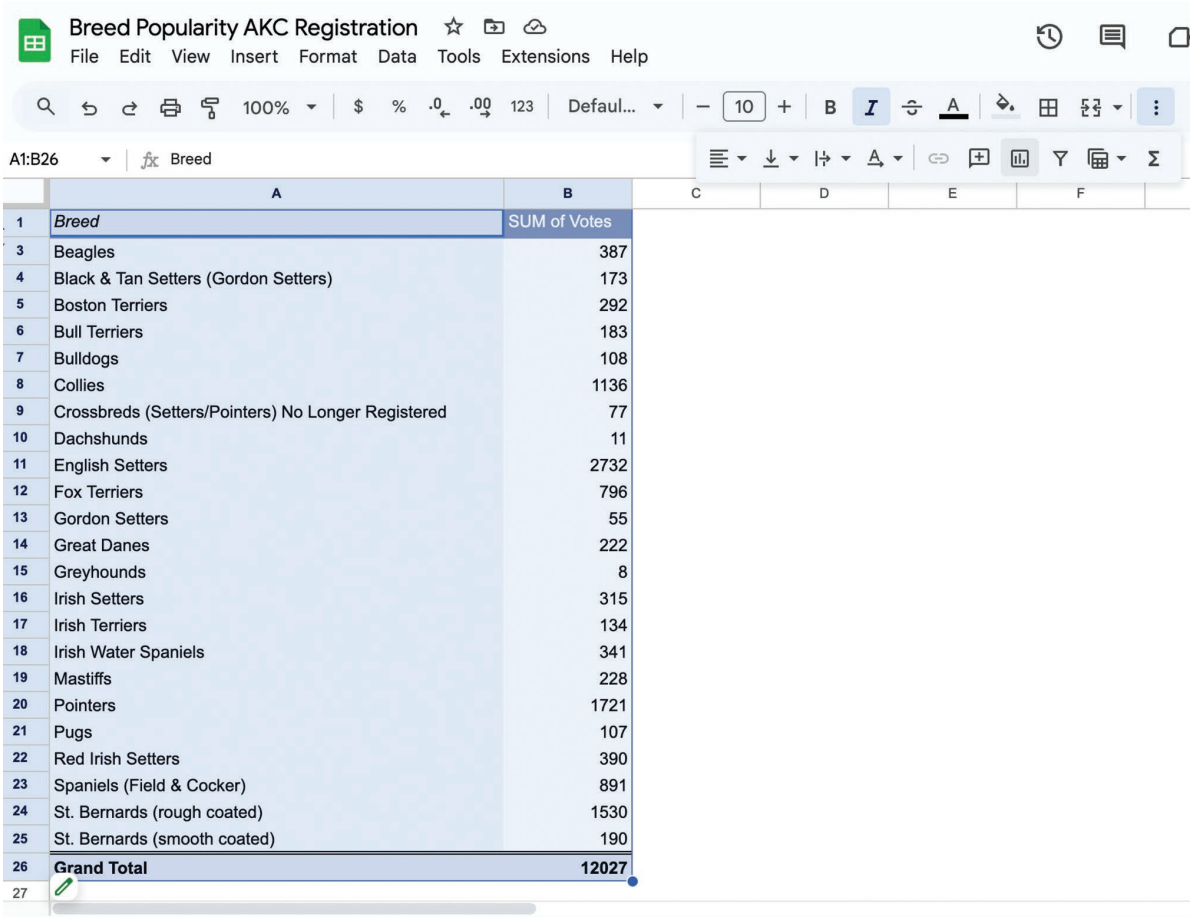
Using the Pivot Table Editor, select Breed for rows and Sum of Votes for Values. This will add up all the votes for each breed, to tell us which breed received the most votes over the 1885–1900 time period (Figure 7.4).



	A	B	C
1	*Breed*	SUM of Votes	
3	Beagles	387	
4	Black & Tan Setters (Gordon Setters)	173	
5	Boston Terriers	292	
6	Bull Terriers	183	
7	Bulldogs	108	
8	Collies	1136	
9	Crossbreds (Setters/Pointers) No Longer Registered	77	
10	Dachshunds	11	
11	English Setters	2732	
12	Fox Terriers	796	
13	Gordon Setters	55	
14	Great Danes	222	
15	Greyhounds	8	
16	Irish Setters	315	
17	Irish Terriers	134	
18	Irish Water Spaniels	341	
19	Mastiffs	228	
20	Pointers	1721	
21	Pugs	107	
22	Red Irish Setters	390	
23	Spaniels (Field & Cocker)	891	
24	St. Bernards (rough coated)	1530	
25	St. Bernards (smooth coated)	190	
26	**Grand Total**	**12027**	
27			

Figure 7.4 Google pivot table of the votes for each dog breed.

When you are finished creating your table, close the editor, select the data you want to visualize, and use the chart icon in the menu bar to create a visualization (Figure 7.5).



	A	B	C	D	E	F
1	*Breed*	SUM of Votes				
3	Beagles	387				
4	Black & Tan Setters (Gordon Setters)	173				
5	Boston Terriers	292				
6	Bull Terriers	183				
7	Bulldogs	108				
8	Collies	1136				
9	Crossbreds (Setters/Pointers) No Longer Registered	77				
10	Dachshunds	11				
11	English Setters	2732				
12	Fox Terriers	796				
13	Gordon Setters	55				
14	Great Danes	222				
15	Greyhounds	8				
16	Irish Setters	315				
17	Irish Terriers	134				
18	Irish Water Spaniels	341				
19	Mastiffs	228				
20	Pointers	1721				
21	Pugs	107				
22	Red Irish Setters	390				
23	Spaniels (Field & Cocker)	891				
24	St. Bernards (rough coated)	1530				
25	St. Bernards (smooth coated)	190				
26	**Grand Total**	**12027**				
27						

Figure 7.5 Detail of how to turn a Google pivot table into a chart.

Then use the chart editor to consider different types of visualizations. Below is the same data shown as a pie chart, a bar chart, and a scatter plot. Typically, pie charts are best used to show parts in relation to a whole and are most legible when under five slices. The scatter plots are best used for comparing two numerical variables. Here, it is just indicating a single number—how many votes each breed received. This is much more legible in the bar graph, where the range is filled in and the difference between the amounts is observable (Figure 7.6–7.8).

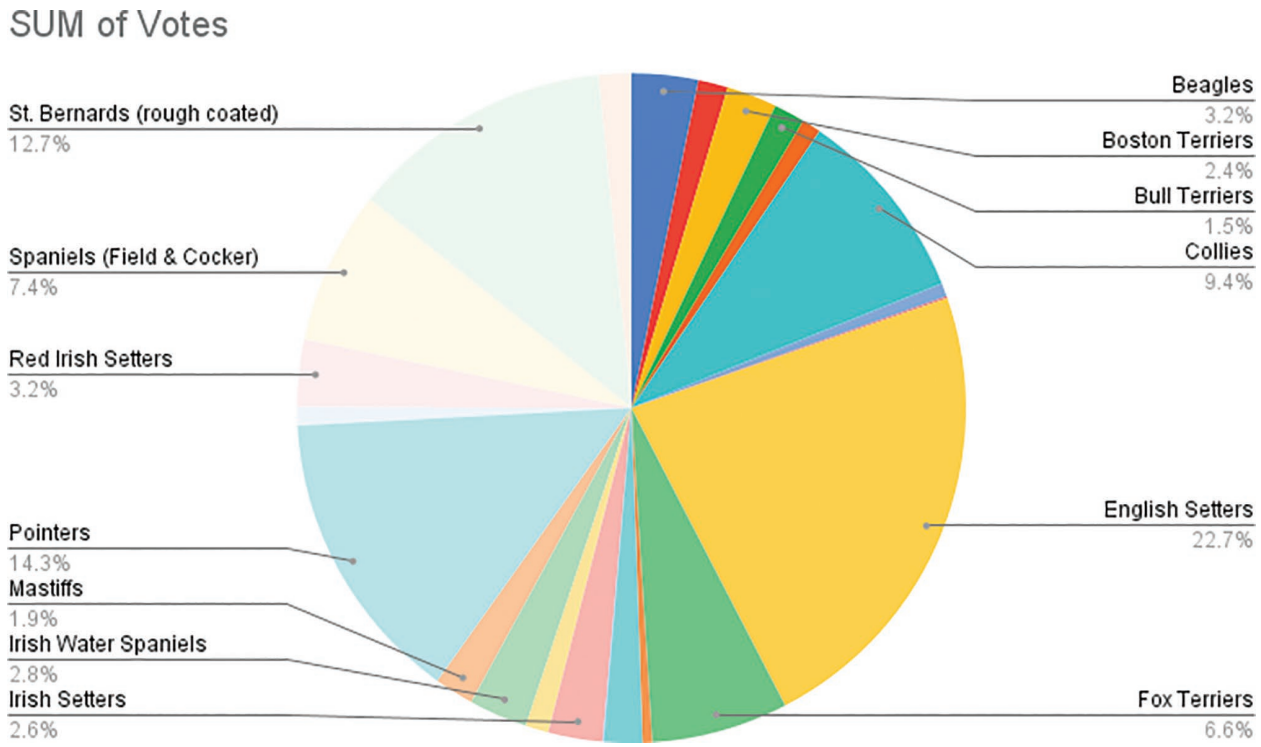


Figure 7.6 Pie chart of the number of votes for each dog breed.

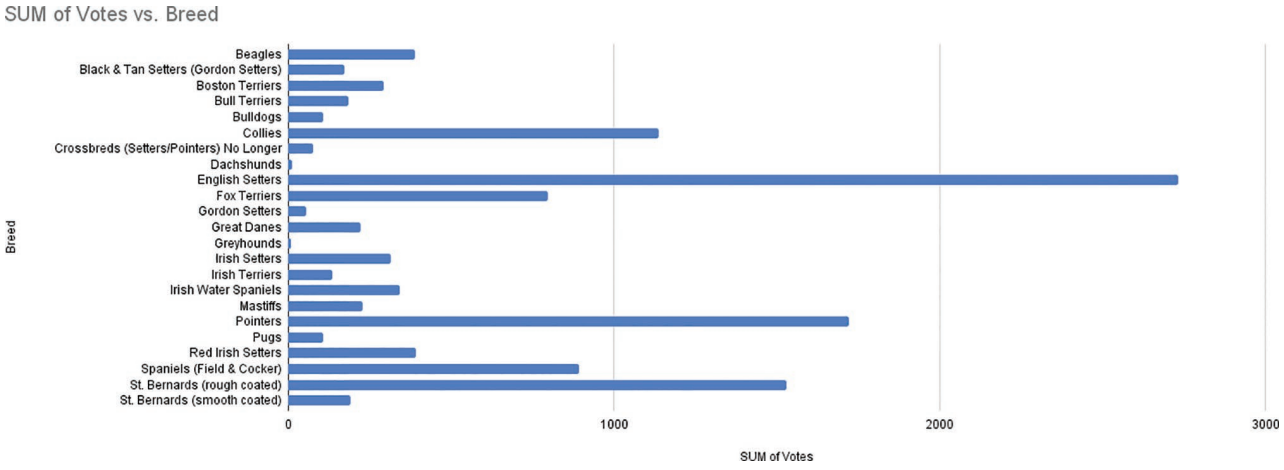


Figure 7.7 Bar chart of the number of votes for each dog breed.

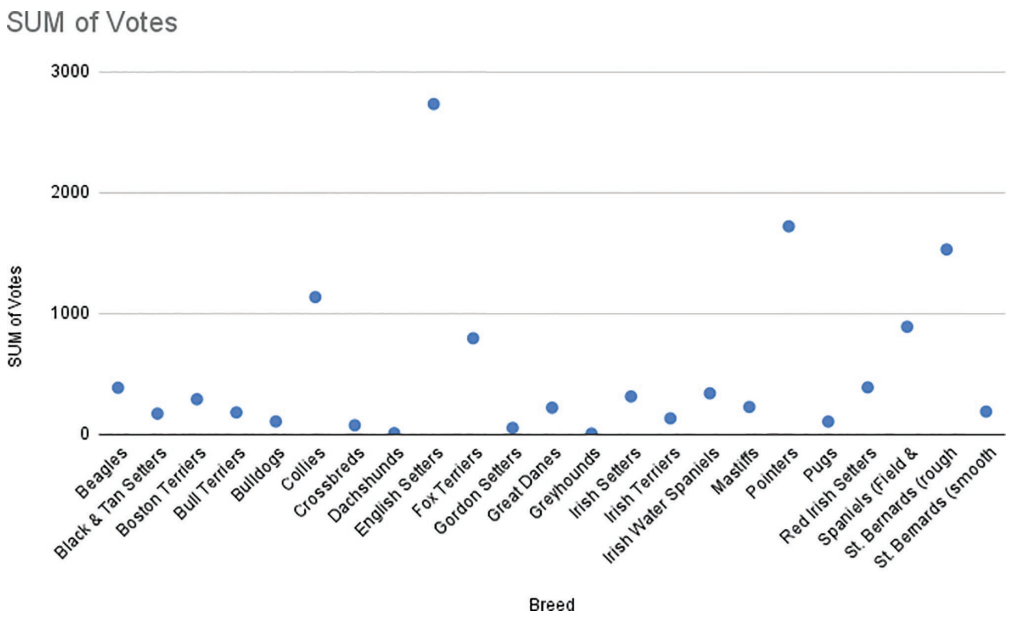
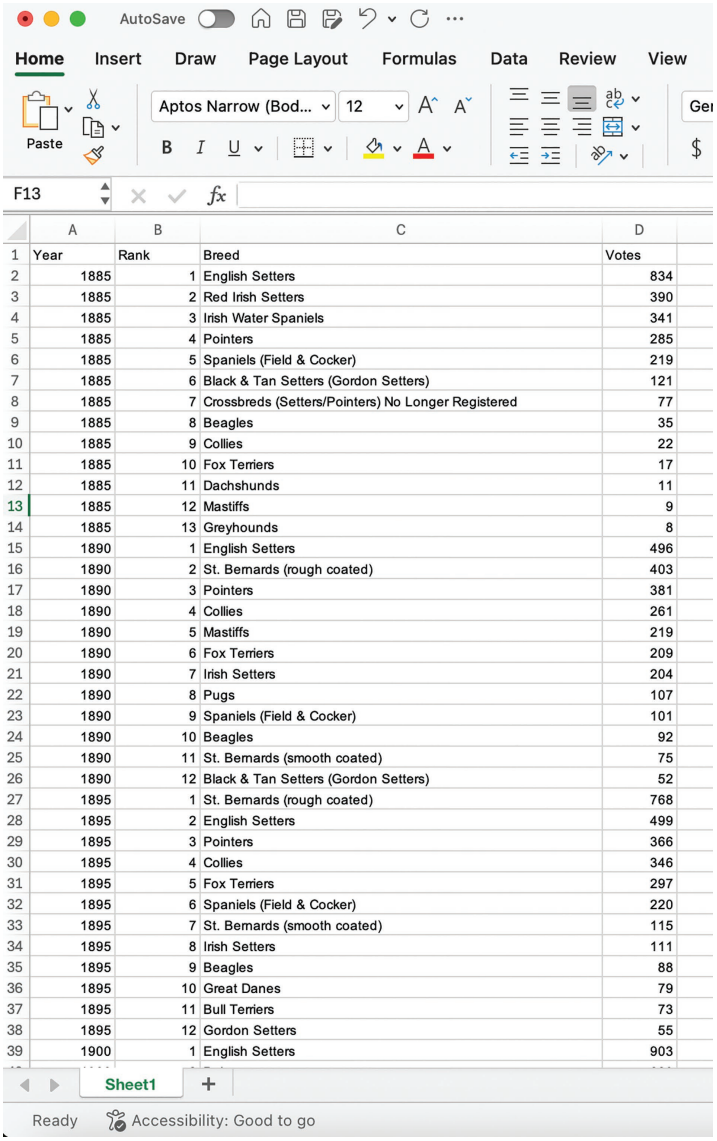


Figure 7.8 Scatter plot of the number of votes for each dog breed.

You can produce the same results using Microsoft Excel. Enter your clean data into a spreadsheet (Figure 7.9).



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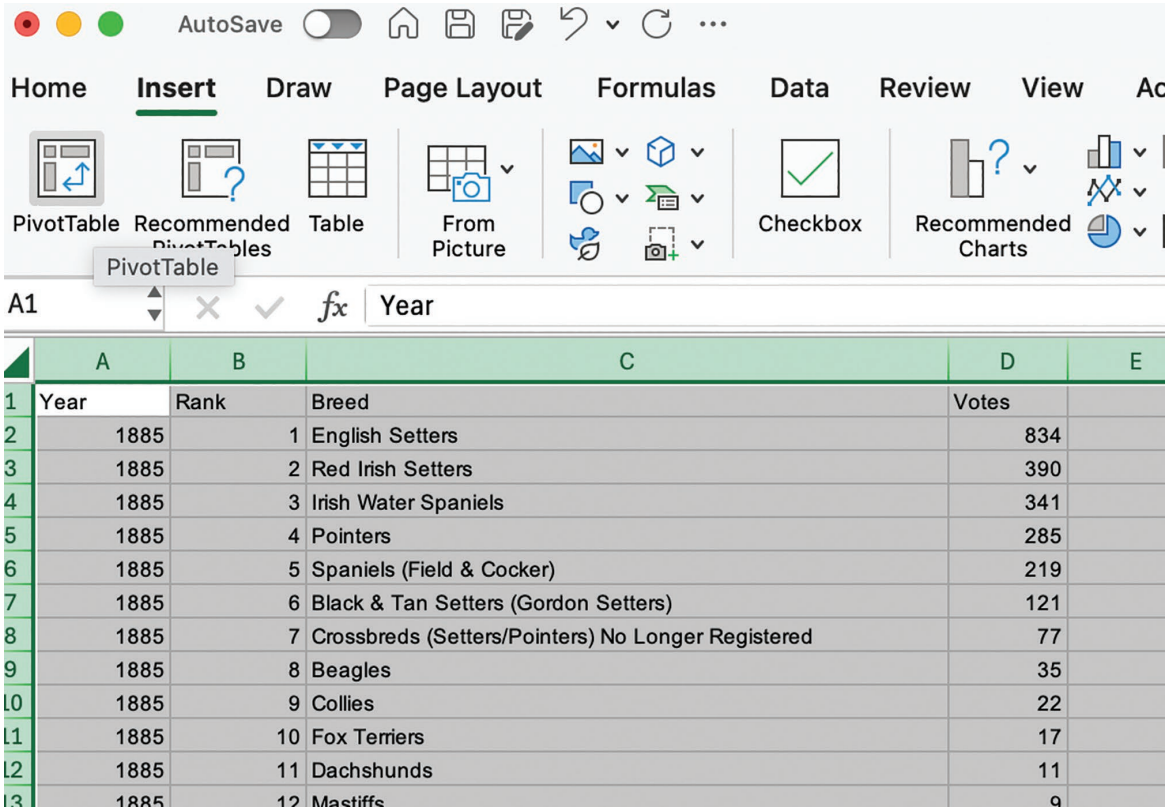
	A	B	C	D
1	Year	Rank	Breed	Votes
2	1885	1	English Setters	834
3	1885	2	Red Irish Setters	390
4	1885	3	Irish Water Spaniels	341
5	1885	4	Pointers	285
6	1885	5	Spaniels (Field & Cocker)	219
7	1885	6	Black & Tan Setters (Gordon Setters)	121
8	1885	7	Crossbreds (Setters/Pointers) No Longer Registered	77
9	1885	8	Beagles	35
10	1885	9	Collies	22
11	1885	10	Fox Terriers	17
12	1885	11	Dachshunds	11
13	1885	12	Mastiffs	9
14	1885	13	Greyhounds	8
15	1890	1	English Setters	496
16	1890	2	St. Bernards (rough coated)	403
17	1890	3	Pointers	381
18	1890	4	Collies	261
19	1890	5	Mastiffs	219
20	1890	6	Fox Terriers	209
21	1890	7	Irish Setters	204
22	1890	8	Pugs	107
23	1890	9	Spaniels (Field & Cocker)	101
24	1890	10	Beagles	92
25	1890	11	St. Bernards (smooth coated)	75
26	1890	12	Black & Tan Setters (Gordon Setters)	52
27	1895	1	St. Bernards (rough coated)	768
28	1895	2	English Setters	499
29	1895	3	Pointers	366
30	1895	4	Collies	346
31	1895	5	Fox Terriers	297
32	1895	6	Spaniels (Field & Cocker)	220
33	1895	7	St. Bernards (smooth coated)	115
34	1895	8	Irish Setters	111
35	1895	9	Beagles	88
36	1895	10	Great Danes	79
37	1895	11	Bull Terriers	73
38	1895	12	Gordon Setters	55
39	1900	1	English Setters	903

Sheet1

Ready Accessibility: Good to go

Figure 7.9 Breed popularity AKC registration data in an Excel spreadsheet.

Select the data you want to visualize, and in the menu, go to Insert and select the Pivot Table icon (Figure 7.10)).



	A	B	C	D	E
1	Year	Rank	Breed	Votes	
2	1885	1	English Setters	834	
3	1885	2	Red Irish Setters	390	
4	1885	3	Irish Water Spaniels	341	
5	1885	4	Pointers	285	
6	1885	5	Spaniels (Field & Cocker)	219	
7	1885	6	Black & Tan Setters (Gordon Setters)	121	
8	1885	7	Crossbreds (Setters/Pointers) No Longer Registered	77	
9	1885	8	Beagles	35	
10	1885	9	Collies	22	
11	1885	10	Fox Terriers	17	
12	1885	11	Dachshunds	11	
13	1885	12	Mastiffs	9	

Figure 7.10 Detail of how to insert a pivot table in Excel.

In the Pivot Table Editor, you will select Breed for Rows, and Votes for Values. This should automatically provide you with a summary of the votes. When you're finished selecting your data, select the Pivot Chart icon in the toolbar to visualize your data (Figure 7.11).

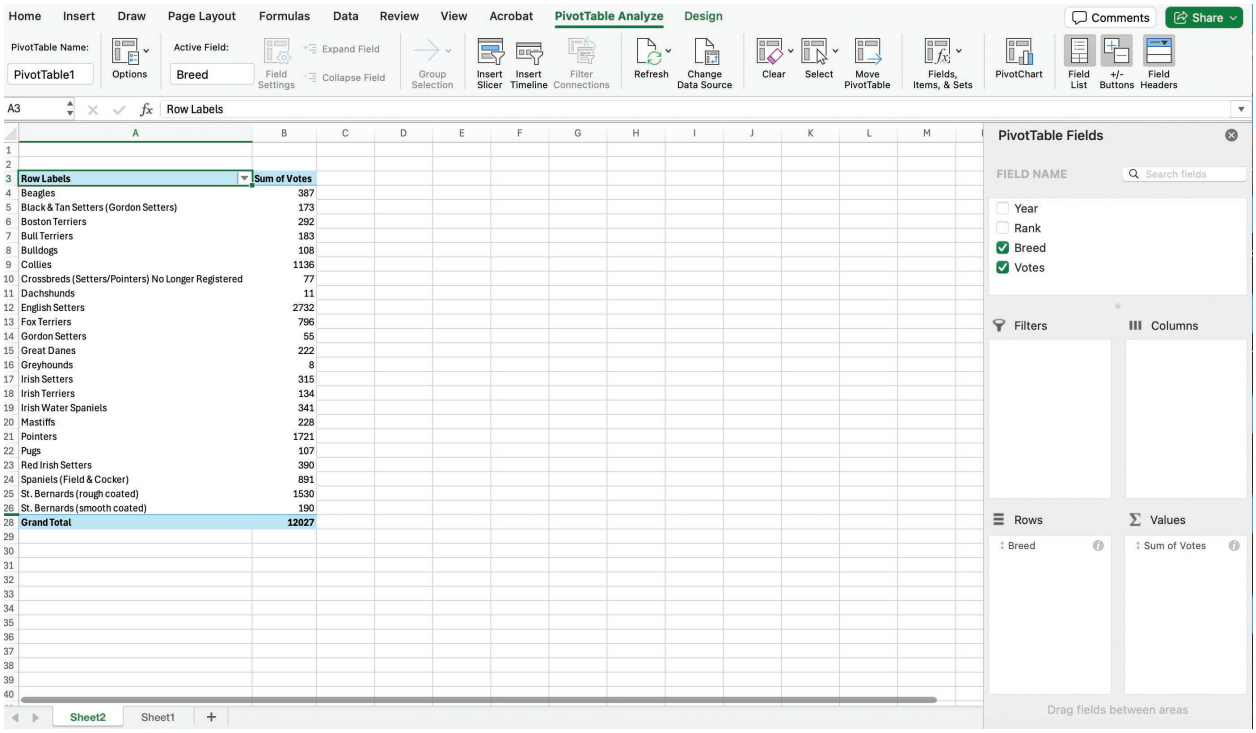


Figure 7.11 Excel pivot table of the votes for each dog breed.

The Pivot Chart tool will automatically produce a bar chart. If you want to try a different visualization, right click on the chart and select Change Chart Type. The fold out menu will give you different options (Figure 7.12).

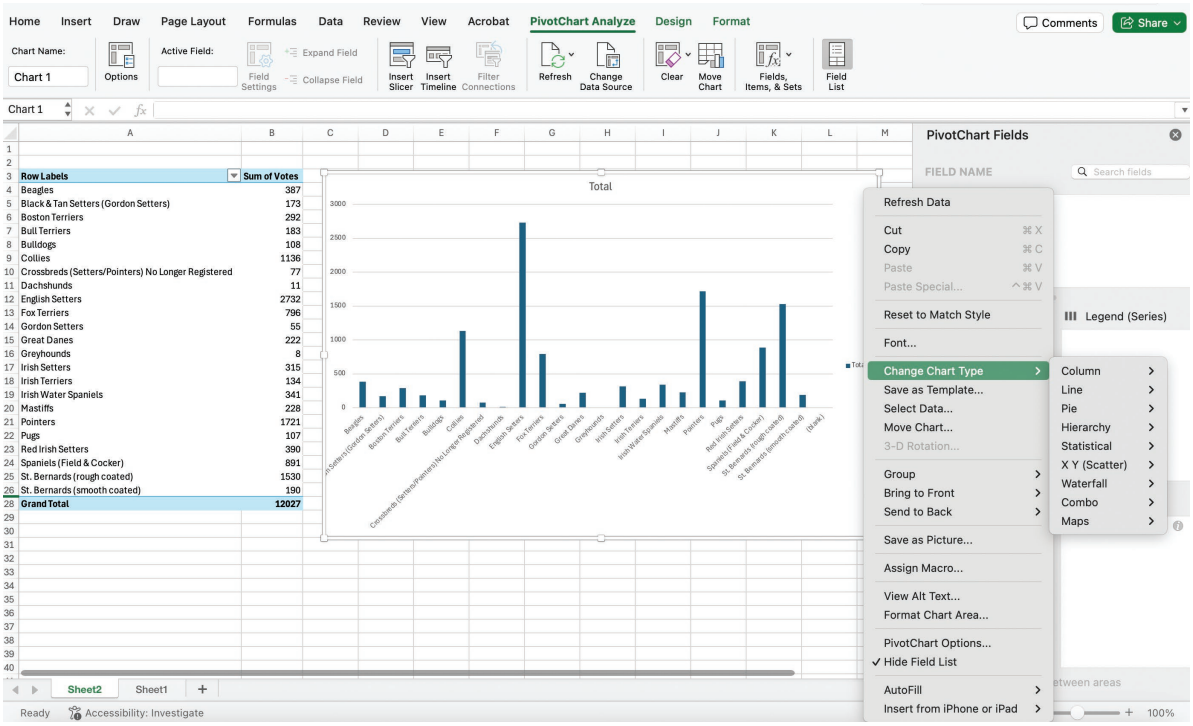


Figure 7.12 Detail of how to turn an Excel pivot table into a chart and select the type.

By selecting a type, you can browse different designs of that chart type that best fit your visualization needs. Here you have the options of flat pie charts, 3-D, or a doughnut chart (Figure 7.13).

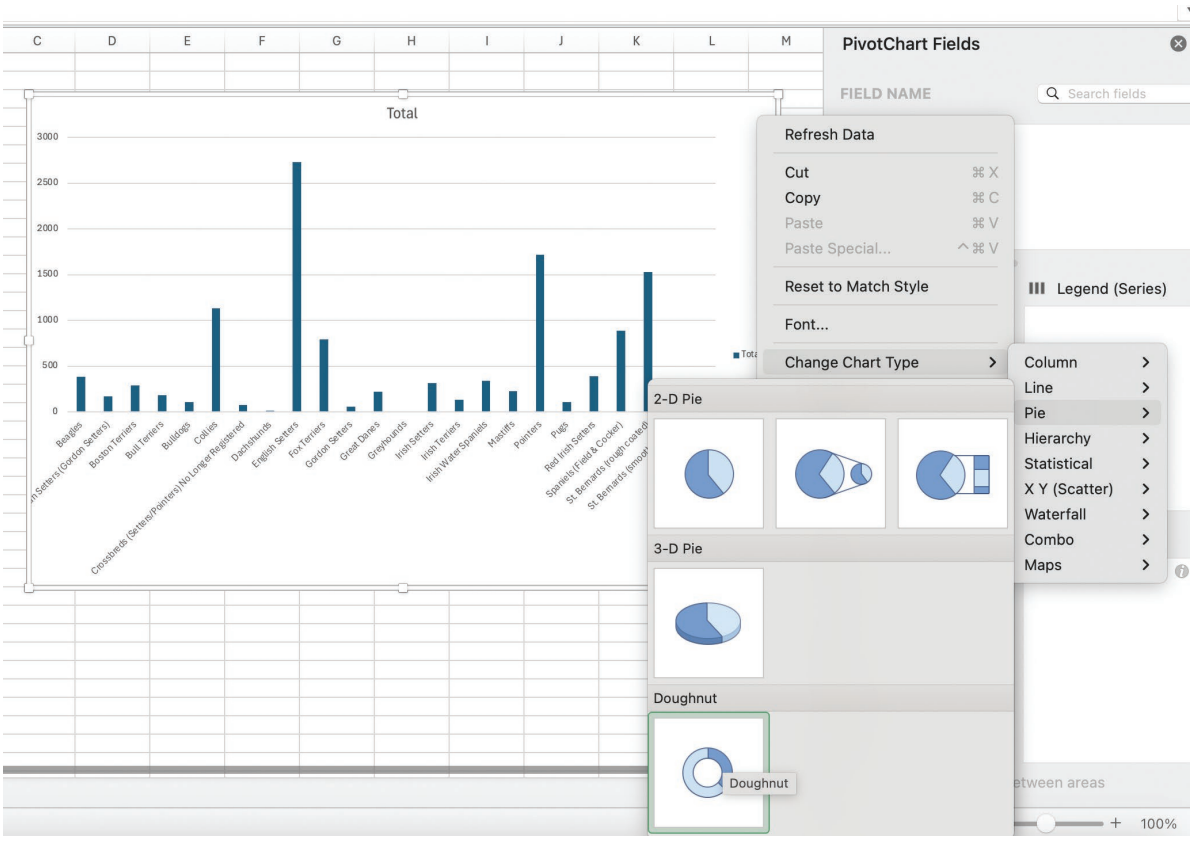


Figure 7.13 Detail of how to select the pie chart type in Excel.

The doughnut chart will present the breeds in a percentage with different colors. Since there are so many different breeds, some of the colors are very similar. This might be difficult to distinguish the different breeds for someone who is colorblind (Figure 7.14).

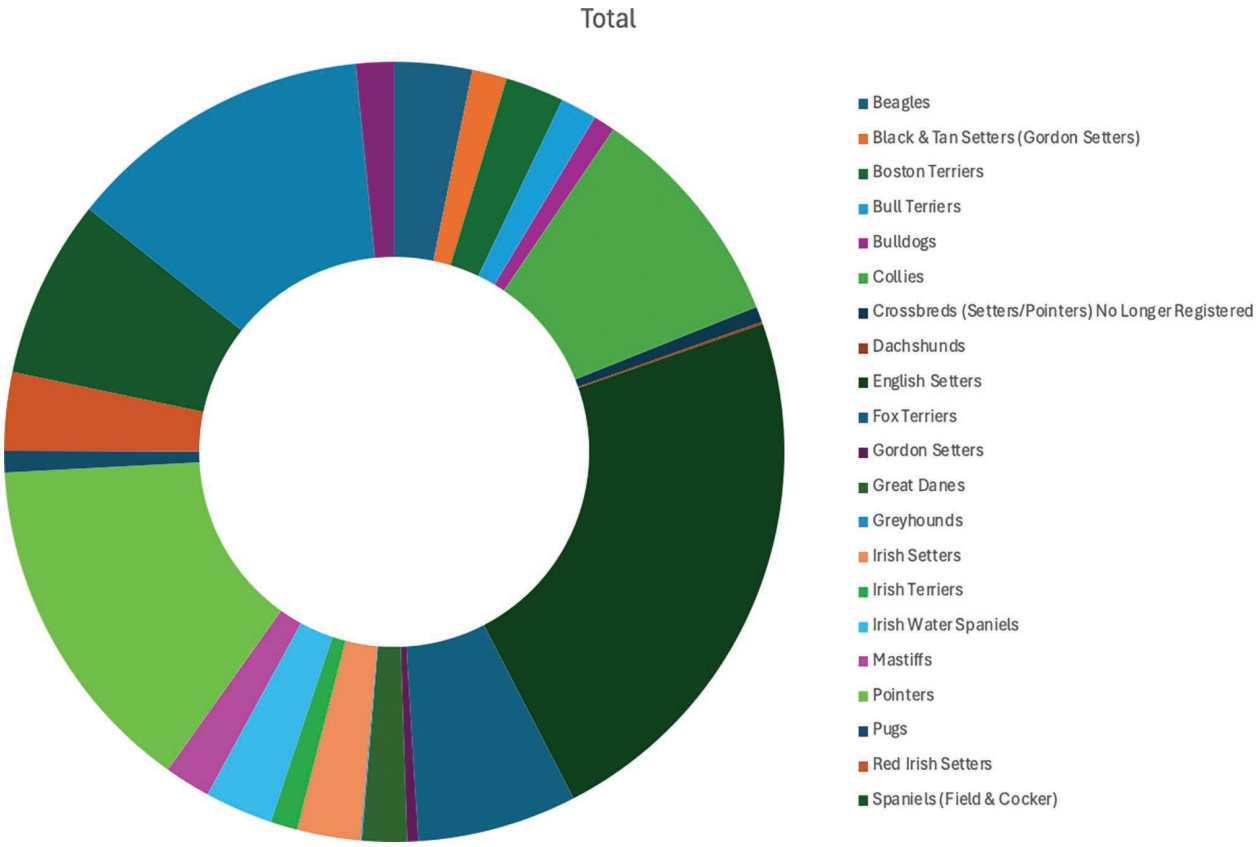


Figure 7.14 Doughnut chart of the number of votes for each dog breed.

Exercise 7.2: Reverse engineering a visualization

Look at https://datacommons.org/ and the visualizations generated from the files. Can you locate the basic components (axes, etc.) and evaluate them for common errors? Consider where the data comes from and what may be missing from its visualization.

How-to example

Look at the axes, labels, legends, and data sources for their accuracy and clarity. Common issues might include unclear axis labels, missing legends, or lack of citations for data sources. Consider the source and recency of the data and whether key variables are missing or oversimplified. For example, in *t*his visualization (https://datacommons.org/tools/visualization#visType%3Dtimeline%26place%3DgeoId%2F0667000%26sv%3D%7B%22dcid%22%3A%22dc%2Fdn2h9yfcgbkg2%22%7D___%7B%22dcid%22%3A%22dc%2Fbre4whrdn7pt7%22%7D___%7B%22dcid%22%3A%22dc%2Fn2vhkpw0slkv5%22%7D___%7B%22dcid%22%3A%22dc%2Fm615rq99fwf2c%22%7D___%7B%22dcid%22%3A%22dc%2Fk33ngtzpqxql6%22%7D___%7B%22dcid%22%3A%22dc%2F6zrlr86zt61yg%22%7D), when you hover over the line graph with your mouse, it is difficult to read the tooltip information (Figure 7.15).

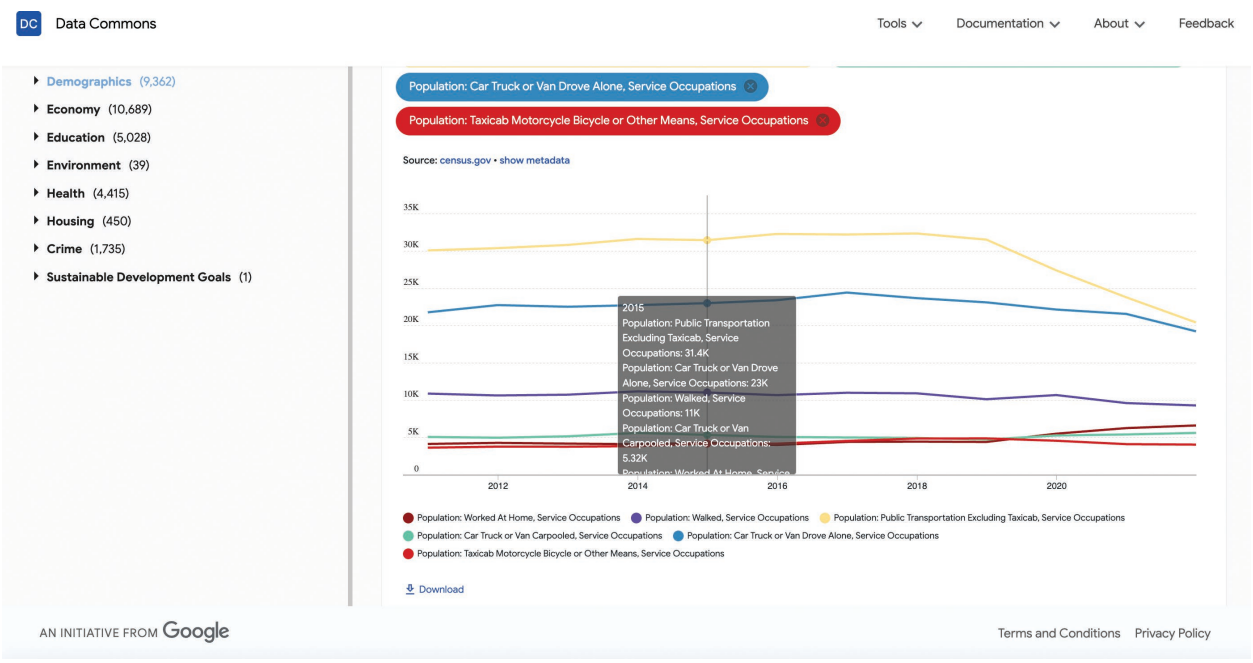


Figure 7.15 Google data commons timeline visualization.

Exercise 7.3: Analyze the data-graphic connection

Imagine you are collecting data from the classroom on (1) classroom use, (2) attention span of students, (3) snack preferences, (4) age, height, and weight comparisons in a group? For what kind of data gathered in the classroom would you use a column chart? Browse this D3 gallery of visualizations (https://observablehq.com/collection/@observablehq/visualization) for other formats.

How-to example

For data like classroom use (e.g., frequency of activities) or snack preferences (e.g., counts of choices), a column chart is suitable because it effectively compares discrete categories.

For inspiration, you can explore diverse visualization styles, like beeswarm plots or bubble charts, from this Observable gallery (https://observablehq.com/collection/@observablehq/visualization). These formats may better represent continuous or relational data, such as attention span trends or age-height correlations, offering more nuanced insights than standard column charts.

Still not sure which chart or graph to use? These resources can help you:

- Which Chart or Graph is Right for You? (https://observablehq.com/collection/@observablehq/visualization)
- How to Choose the Right Graph When Charting Your Data (https://gfchart.com/2021/10/how-to-choose-the-right-graph-when-charting-your-data/#:~:text=Some%20types%20of%20data%20are,bar%20graph%20or%20pie%20chart)

Exercise 7.4: Misleading graphics

What is the concept of the "lie factor" (http://www.datavis.ca/gallery/lie-factor.php) and how is it visible at the following link? In each case, consider legibility, accuracy, or the argument made by the form. What is meant by a graphic argument?

How-to example

The "lie factor" (http://www.datavis.ca/gallery/lie-factor.php), as explained by Edward Tufte, measures how much a graph exaggerates or minimizes data trends compared to actual values. It is calculated as the ratio of the effect size in the visualization to the actual effect size in the data. A higher lie factor indicates misleading design. Examples include inflated bar lengths or altered scales that misrepresent proportional changes, often distorting the argument a graphic makes. Graphics serve as "arguments" by visually asserting claims through data, emphasizing or downplaying elements to influence interpretation. For example, changing the scale can shift the appearance of the graph's bars. In switching the scale, the distance between or length becomes further emphasized and we tend to interpret that as significant. The greater the distance, the more significance we assign to the difference. When this scale is shifted to purposefully exaggerate the

difference between values for this interpretive effect, we must question the integrity of the chart or graph and the motives of its maker.

Want to learn more about how charts lie? Watch this video lecture (https://www.youtube.com/watch?v=Low28hx4wyk) by Alberto Cairo.

Recommended readings

Cairo, Alberto. 2019. *How Charts Lie: Getting Smarter about Visual Information*. First edition. New York: W. W. Norton & Company, Inc.

Chiasson, Trina, Dyanna Gregory, Infoactive, and Donald W. Reynolds Journalism Institute. 2014. *Data + Design: A Simple Introduction to Preparing and Visualizing Information*. Seattle, Washington, DC and Columbia, MO: Infoactive; Donald W. Reynolds Journalism Institute.

Costanza-Chock, Sasha. 2020. *Design Justice: Community-Led Practices to Build the Worlds We Need.* Cambridge: The MIT Press. https://doi.org/10.7551/mitpress/12255.001.0001.

D'Ignazio, and Lauren Klein. 2016. "Feminist Data Visualization." *IEEE*. www.academia.edu/28173807/Feminist_Data_Visualization.

Drucker, Johanna. 2011. "Humanities Approaches to Graphical Display." *Digital Humanities Quarterly*. www.digitalhumanities.org/dhq/vol/5/1/000091/000091.html.

Lupi, Giorgia. 2017. "Data Humanism: The Revolutionary Future of Data Visualization." *PRINT*. www.printmag.com, www.printmag.com/post/data-humanism-future-of-data-visualization.

Yau, Nathan. 2013. *Data Points: Visualization That Means Something*. Indianapolis, IN: Wiley.

7b Networks and complex systems

Bonus content: sketching network concepts

You can sketch a network on paper quite easily. Imagine yourself as a node and then draw lines to everyone you know in your immediate circles (family, friends, clubs, and groups) around you. Draw their links to each other. Think about degrees of proximity and also connections among the individuals in different parts of your network. How many of them are linked to each other as well as to you? If you can code the lines that connect persons to indicate something about the relationship, how does that change the drawing? What attributes of a relationship are readily indicated? Which are not? Think about the difference between how often you exchange communications with someone and how central they are to the exchanges among others. A parent might be someone to whom everyone is connected, but your own communications might be more frequent with your siblings. When a network algorithm processes data, it tries to calculate these properties.

Social networks are familiar and the use of social media has intensified our awareness of the ways social structures emerge from interconnections among individuals. A network may or may not have emergent properties, may or may not be dynamic, and may have varying levels of complexity. Simple networks, like the connection of your computer to various peripheral devices through a wireless router in your home environment, may exhibit very little change over time, at least little observable change. But a network of traffic flow is more like a living organism than it is like a set of static connections. Though nodes may stay in place, as in airline hubs and transfer points, the properties of the network have capacity to vary considerably. This is certainly true with social networks, most of which are highly dynamic, even volatile.

Exercise 7.5: Kindred Britain, a social network project

Explore the Kindred Britain (http://kindred.stanford.edu/#) site and then discuss the selection of individuals, the character and quality of relations, explicit assumptions and implicit ones, and the diagrams and their rhetorical power.

How-to example

The Kindred Britain (http://kindred.stanford.edu/#) project by Stanford University is an engaging and interactive scholarly work that delves into the genealogical connections of nearly 30,000 individuals in British history. By mapping out these connections through family ties of blood, marriage, or affiliation, the project presents British history as a vast familial network. The site showcases an array of individuals, from monarchs and sea captains to composers, novelists, and bankers, emphasizing how diverse figures are linked through familial relationships regardless of their different fortunes and professions.

The relationships depicted are mostly familial, including blood ties, marriages, and affiliations, and are presented as influential factors shaping British history. The project underscores the significance of these connections in bridging gaps across various social, professional, and historical contexts. One explicit assumption of the project is the crucial role of family connections in historical narratives. By visualizing these ties, the project argues that understanding British history requires acknowledging the influence of familial relationships. An implicit assumption may be that the prominence of certain families has been overstated, potentially overshadowing contributions from those outside these networks.

The visualizations on the Kindred Britain site use geospatial, temporal, and network information to illustrate the genealogical ties among the British elite. These diagrams are powerful rhetorical tools, making complex historical relationships more accessible and engaging for users. Through interactive features like dragging circles to connect individuals and exploring detailed profiles, the project makes historical data more engaging and comprehensible.

Overall, the Kindred Britain project offers a unique perspective on British history through the lens of family connections, encouraging users to consider the broader impact of these relationships on historical events and figures. By doing so, it provides an insightful and engaging way to explore the interconnectedness of British history.

Want to try your hand at another social networking project? Try this interactive network (https://dunhamsdata.org/portfolio/visualizations/interactive-network-dunham-company-repertory) that is a part of the Dunham's Data project.

Exercise 7.6: Comparing network diagrams

Go to: https://linkedjazz.org/network/. Determine what information you can reasonably extract from this graph. Now toggle between modes. Does this change your understanding? Or go to: www.databasic.io/en/connectthedots/. Network visualization with interactive sample datasets created by Rahul Bhargava and Catherine D'Ignazio.

How-to example

The graph on the Linked Jazz website illustrates the social and professional connections among jazz musicians. This visualization shows how different musicians are linked through collaborations, performances, and personal relationships. Each node in the graph represents an individual musician, while the connecting lines (edges) demonstrate the relationships between them. By examining the graph, you can identify central figures within the jazz community and understand the frequency and strength of their connections. Additionally, as you toggle between modes, you will notice the graph highlights clusters of musicians who often worked together or were part of the same musical scenes, providing insight into the collaborative nature of jazz and its community dynamics. You can also toggle to emphasize the difference in gender between those within the network.

Exercise 7.7: Cytoscape tutorial

This manual can be accessed without downloading and goes step by step through the basics of network graph construction. It is provided free of charge by the people who designed and maintain the standard platform for this work. Read through the table of contents and introduction (http://manual.cytoscape.org/en/stable/Introduction.html) to get oriented.

Exercise 7.8: Complexity

Look at half a dozen examples on Nathan Yau's FlowingData (https://flowingdata.com/about/) site. What are the dimensions added in complex systems that are different from those of static visualizations? What is the correlation between graphic expression and information? What role does aesthetics play in these projects?

How-to example

Nathan Yau's FlowingData (https://flowingdata.com/about/) site offers insightful visualizations that highlight the additional dimensions in complex systems compared to static visualizations. Complex systems often incorporate multiple dimensions such as time, space, and various interacting attributes, whereas static visualizations usually represent fewer dimensions. The graphic expression in these visualizations is crucial for effectively communicating information, as design choices like color and layout significantly influence how the data is understood (see Chapter 3 (http://flowingdata.com/data-points/DataPoints-Ch3.pdf) of his book for more on this). Aesthetics play a vital role in engaging the audience and making the visualizations more intuitive and accessible, but they should not compromise the accuracy and clarity of the data.

Exercise 7.9: Designing a project using AI

What kind of project can you imagine would benefit from the use of machine learning linked to visualization? Focus on the cultural sector, and think about the use of visualization in studying historical materials, literature, games, in entertainment, government, or museum sites. What would the system be "learning" in your example so that would benefit from the feedback loop of user input and machine capacities? Are there ethical issues in allowing such reinforcement without the user having access to what is happening?

How-to example

In the 2024 article "AI Meets Archives: The Future of Machine Learning in Cultural Heritage" (https://www.clir.org/2024/10/ai-meets-archives-the-future-of-machine-learning-in-cultural-heritage/), Stacey Patton describes how Professor Jane

Winters has been incorporating AI and ML in work within GLAMs (galleries, libraries, archives, and museums). Winters describes both opportunities and challenges in incorporating AI into cultural heritage projects.

Recommended readings

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Resources

- Cytoscape (https://cytoscape.org/)
- Gephi (https://gephi.org/)
- Kindred Britain (http://kindred.stanford.edu/#)
- Network Graphs (Flourish Studio) (https://app.flourish.studio/@flourish/network-graph)
- Norman, Jeremy. 2004–20. "The History of Information." www.historyofinformation.com/detail.php?entryid=2929.
- Social Network Graphs (https://gwu-libraries.github.io/sfm-ui/posts/2017-09-08-sna)
- Visualising Information for Advocacy, visualisingadvocacy.org. https://grassrootsjusticenetwork.org/resources/visualizing-information-for-advocacy-an-introduction-to-information-design/.