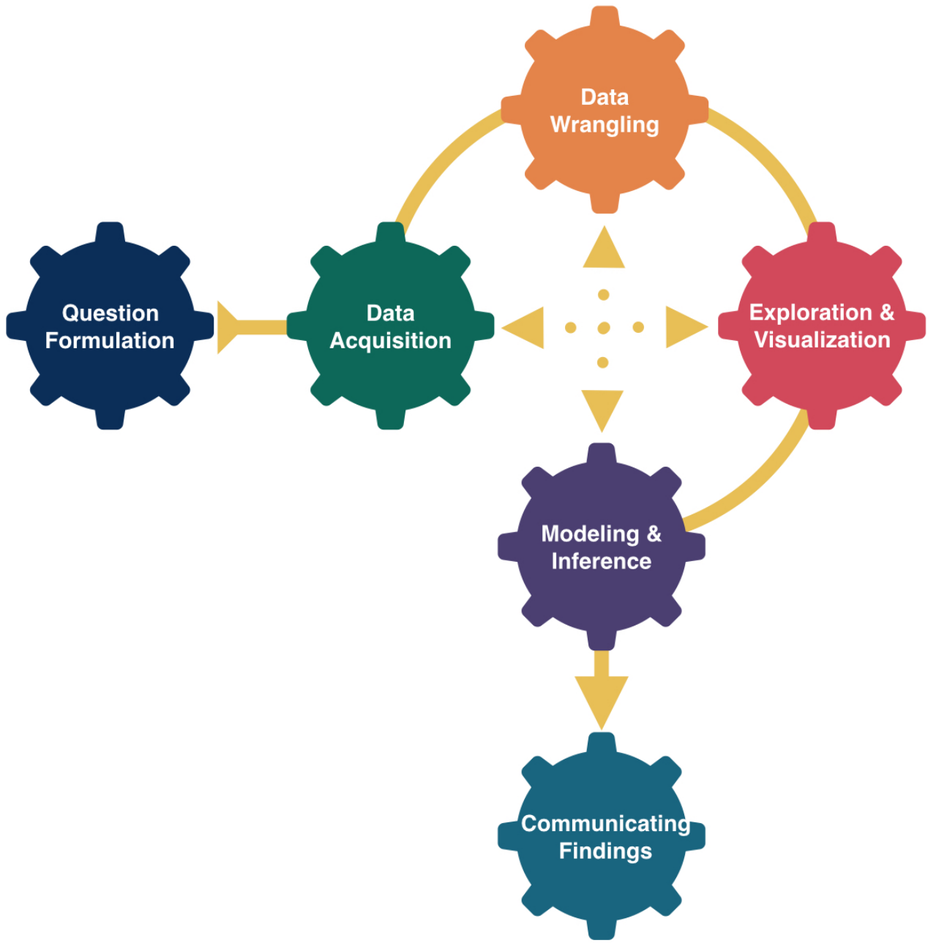


Data Visualization

Kelly McConville

Stat 100

Week 2 | Fall 2023

Announcements

- Class in full swing:
  - Sections: Can find your assigned section in my.harvard but need to go to the linked spreadsheet to find the room!
  - Office hours
    - Fill out this form after your first visit.
  - Wrap-ups on Th 3-4pm and Fri 10:30 - 11:30am in SC 309
  - Lecture quiz will be released in **Gradescope** after class today.

Goals for Today

First Segment:

- Motivate data visualizations.
- Develop **language** to talk about the components of a graphic.
- Practice deconstructing graphics.
- Discuss good graphical practices.

Second Segment:

- Learn the general structure of `ggplot2`.
- Learn a few standard graphs for numerical/quantitative data:
  - **Histogram**: one numerical variable
  - **Side-by-side boxplot**: one numerical variable and one categorical variable
  - **Side-by-side violin plot**: one numerical variable and one categorical variable

Why construct a graph?

To explore the data.

To summarize the data.

To showcase trends and make comparisons.

To tell a compelling story.

Challenger

- On January 27th, 1986, engineers from Morton Thiokol recommended NASA delay launch of space shuttle *Challenger* due to cold weather.
  - Believed cold weather impacted the o-rings that held the rockets together.
  - Used 13 charts in their argument.
- After a two hour conference call, the engineer's recommendation was overruled due to lack of persuasive evidence and the launch proceeded.
- The Challenger exploded 73 seconds into launch.

Challenger

Here's one of those charts.

BLOW BY HISTORY

SRM-15 WORST BLOW-BY

- 2 CASE JOINTS (80°), (110°) ARC
- MUCH WORSE VISUALLY THAN SRM-22

SRM 22 BLOW-BY

- 2 CASE JOINTS (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A

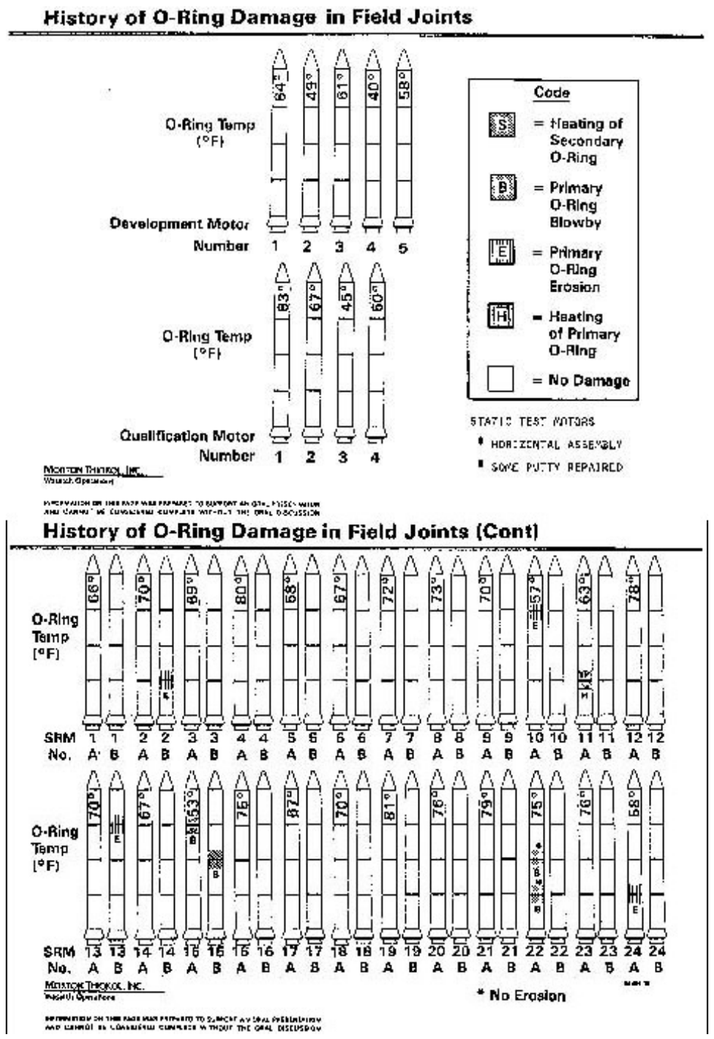
- NOZZLE BLOW-BY

HISTORY OF O-RING TEMPERATURES
(DEGREES-F)

MOTOR	MBT	AMB	O-RING	WIND
DM-1	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29 27	10 MPH 25 MPH

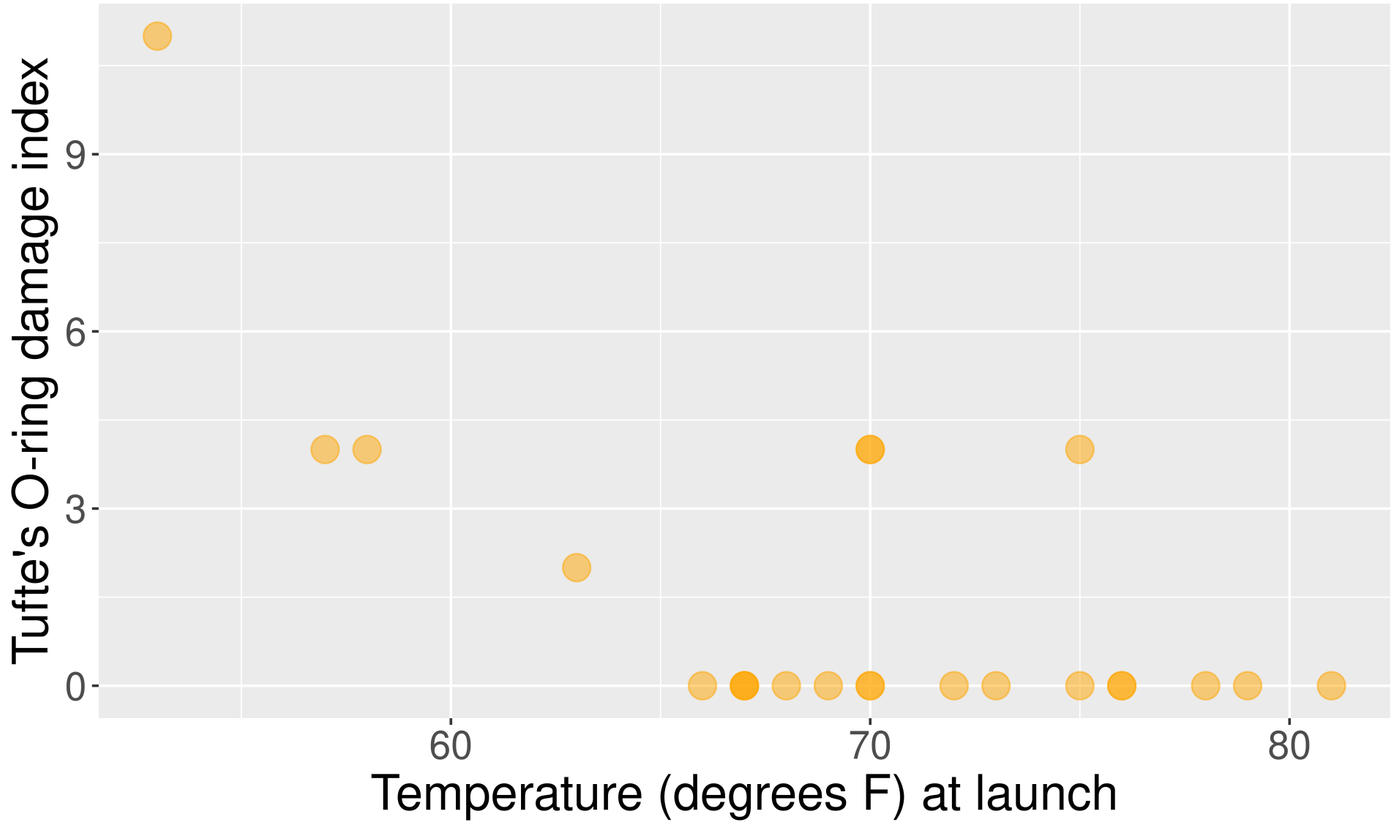
Challenger

Here’s another one of those charts.



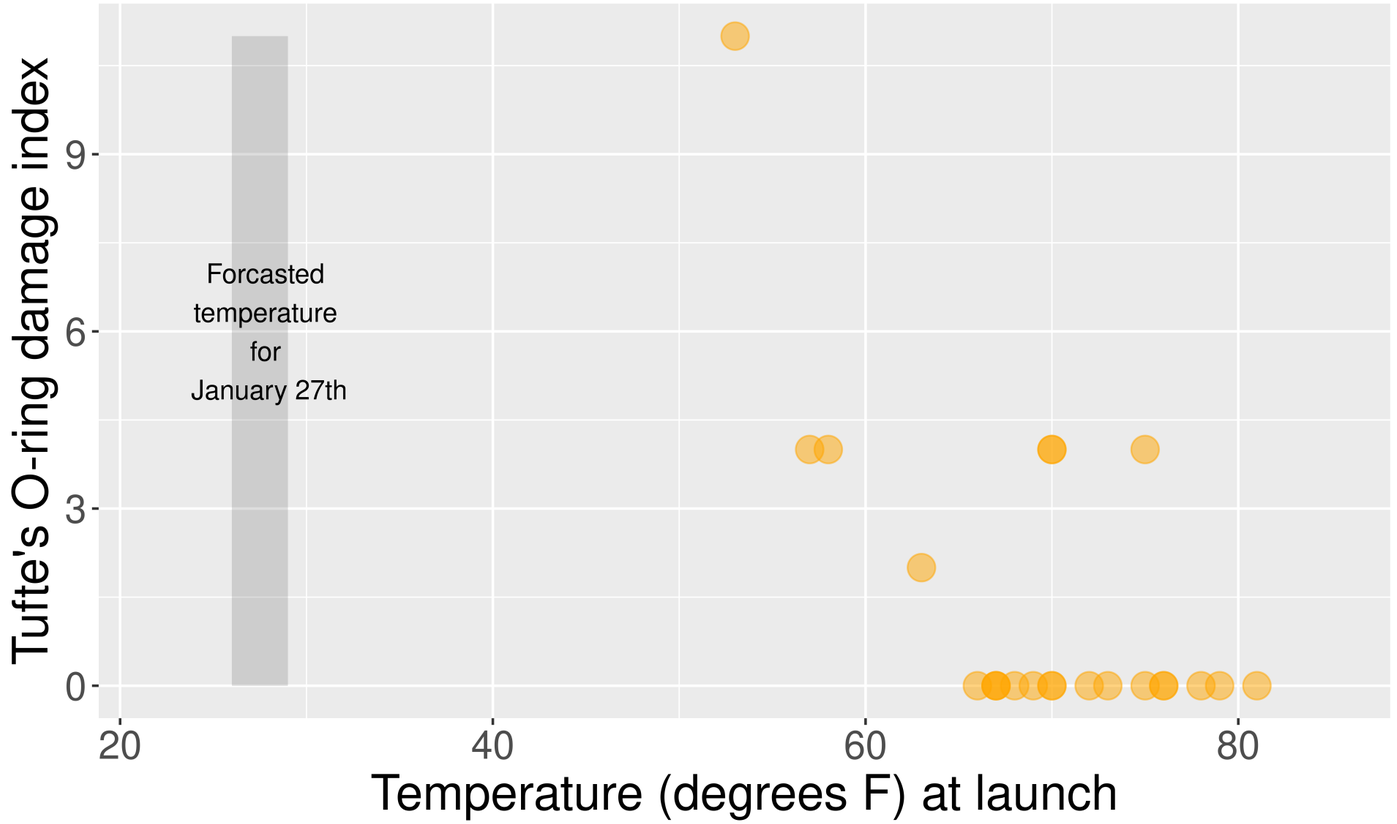
Challenger

Here's a graphic I created from Edward Tufte's data.



Challenger

This adaptation is a recreation of Edward Tufte's graphic.



For more information on this example and other examples, check out Tufte's book

Now let's learn the Grammar of Graphics.

We will use this grammar to:

Decompose and understand existing graphs.

Create our own graphs with the R package `ggplot2`.

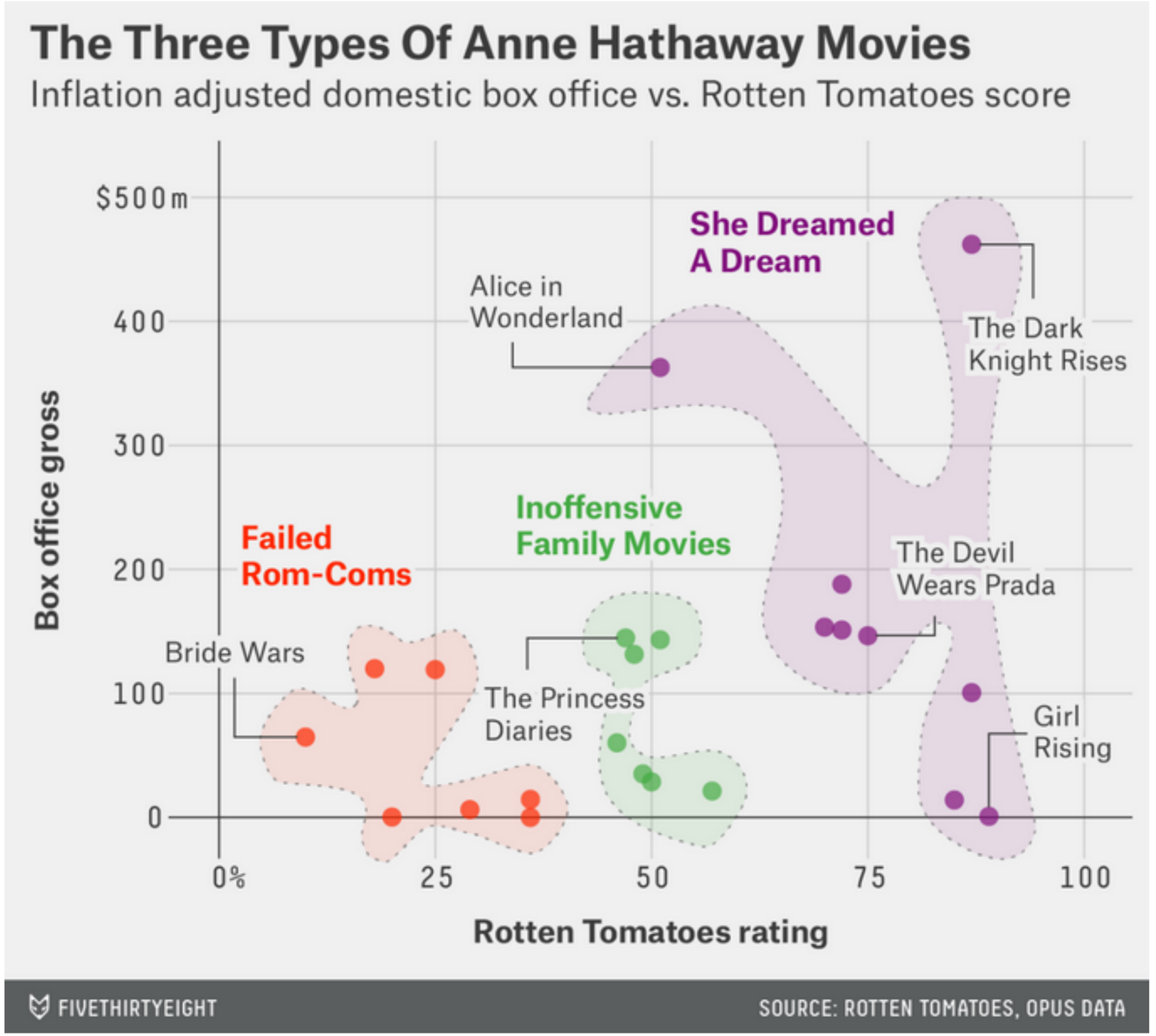
Grammar of Graphics

- **data**: Data frame that contains the raw data
  - Variables used in the graph
- **geom**: Geometric **shape** that the data are mapped to.
  - EX: Point, line, bar, text, …
- **aesthetic**: Visual properties of the **geom**
  - EX: X (horizontal) position, y (vertical) position, color, fill, shape
- **scale**: Controls how data are mapped to the visual values of the aesthetic.
  - EX: particular colors, log scale
- **guide**: Legend/key to help user convert visual display back to the data

For right now, we won't focus on the **names** of particular types of graphs (e.g., scatterplot) but on the **elements** of graphs.

Example 1

- What are the variables?
- What **geom** are the variables map to?
- What are the **aesthetic**s of the **geom**?
- How is each variable mapped to an **aesthetic**?
- What additional context is provided?
- What story is the graph telling?



Example 2

- What are the variables?
- What geom are the variables map to?
- What are the aesthetics of the geom?
- How is each variable mapped to an aesthetic?
- What additional context is provided?
- What story is the graph telling?

Sexual harassment charges, by industry

Among charges filed by women, fiscal years 2005-2015

INDUSTRY	CHARGES FILED
Accommodation and food services	4,801
Retail trade	4,380
Health care and social assistance	3,898
Manufacturing	3,741
Office administration and waste management	2,350
Public administration	2,239
Professional, scientific and technical services	1,944
Transportation and warehousing	1,601
Finance and insurance	1,380
Educational services	1,340
Other services (except public administration)	1,003
Information	962
Construction	774
Wholesale trade	752
Real estate rental and leasing	611
Arts, entertainment and recreation	537
Agriculture, forestry, fishing and hunting	276
Management of companies and enterprises	213
Utilities	211
Mining	157

Not including 35,304 charges filed without a specified industry

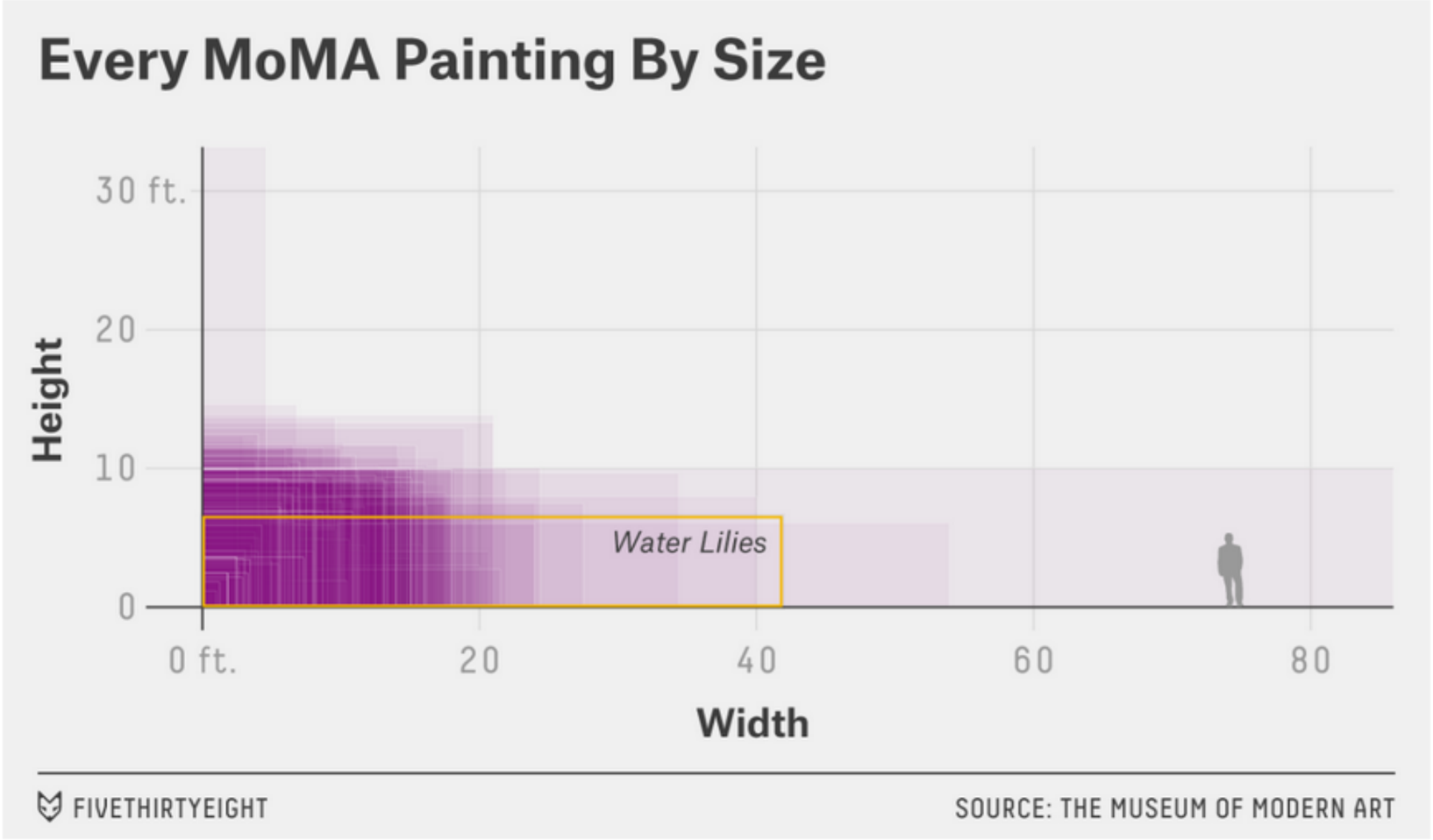
SOURCE: EQUAL EMPLOYMENT OPPORTUNITY COMMISSION

Visualization Considerations

What additional context should my graphs have?

- For context, at a minimum include
  - Axis labels (with units reported).
  - Legends.
  - Data source.
- Think about the **stories/questions** your visualization answers.
- Determine what **context/background information** your viewer needs.
- Visualizing data involves **editorial choices**.
  - What to highlight.
  - What comparisons to make easy to see.
  - What scales to use.

Context Example



What visual cues are easier to compare?

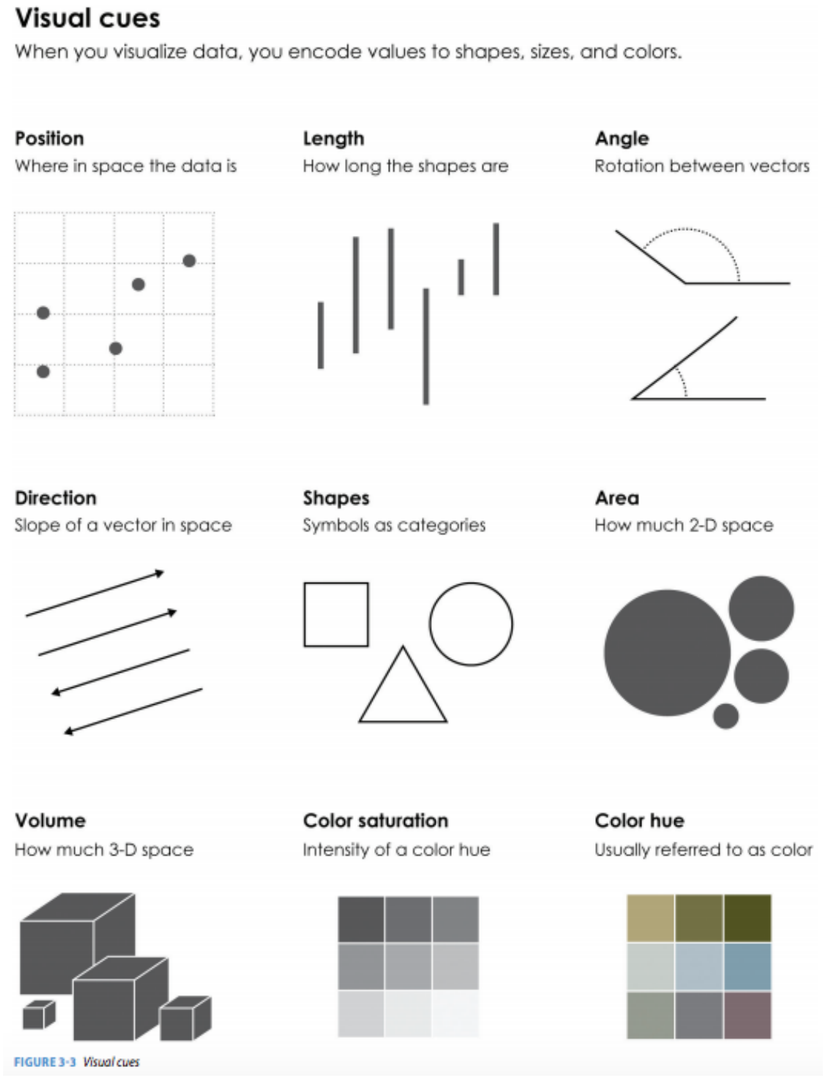
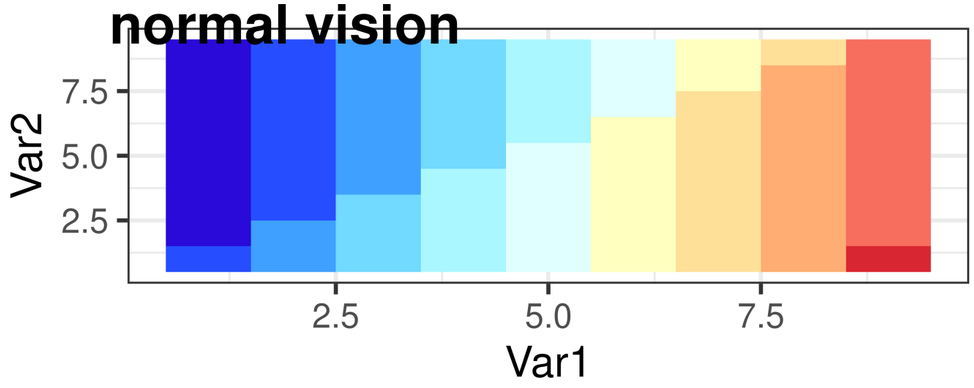
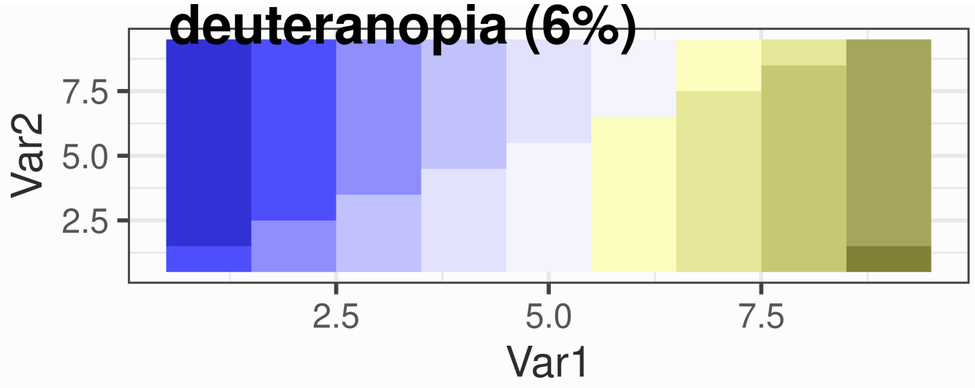


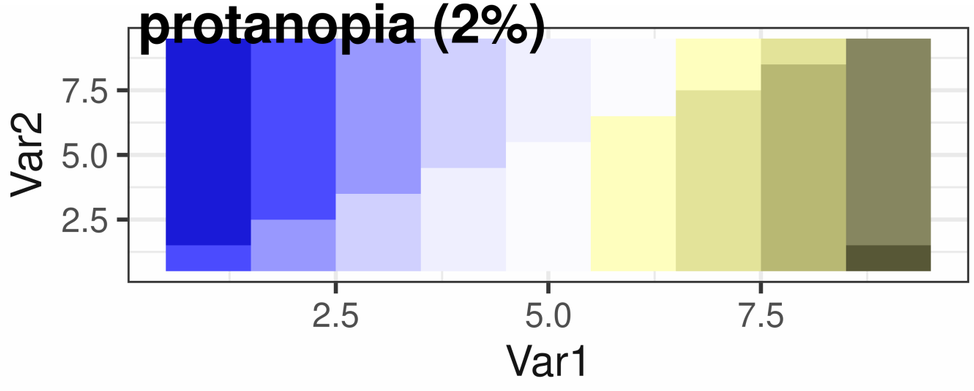
FIGURE 3-3 *Visual cues*

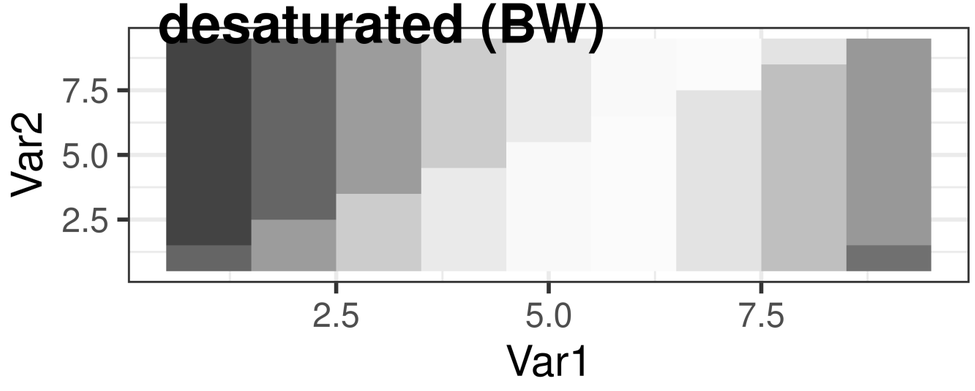
What to consider with color?

Consider color blindness.

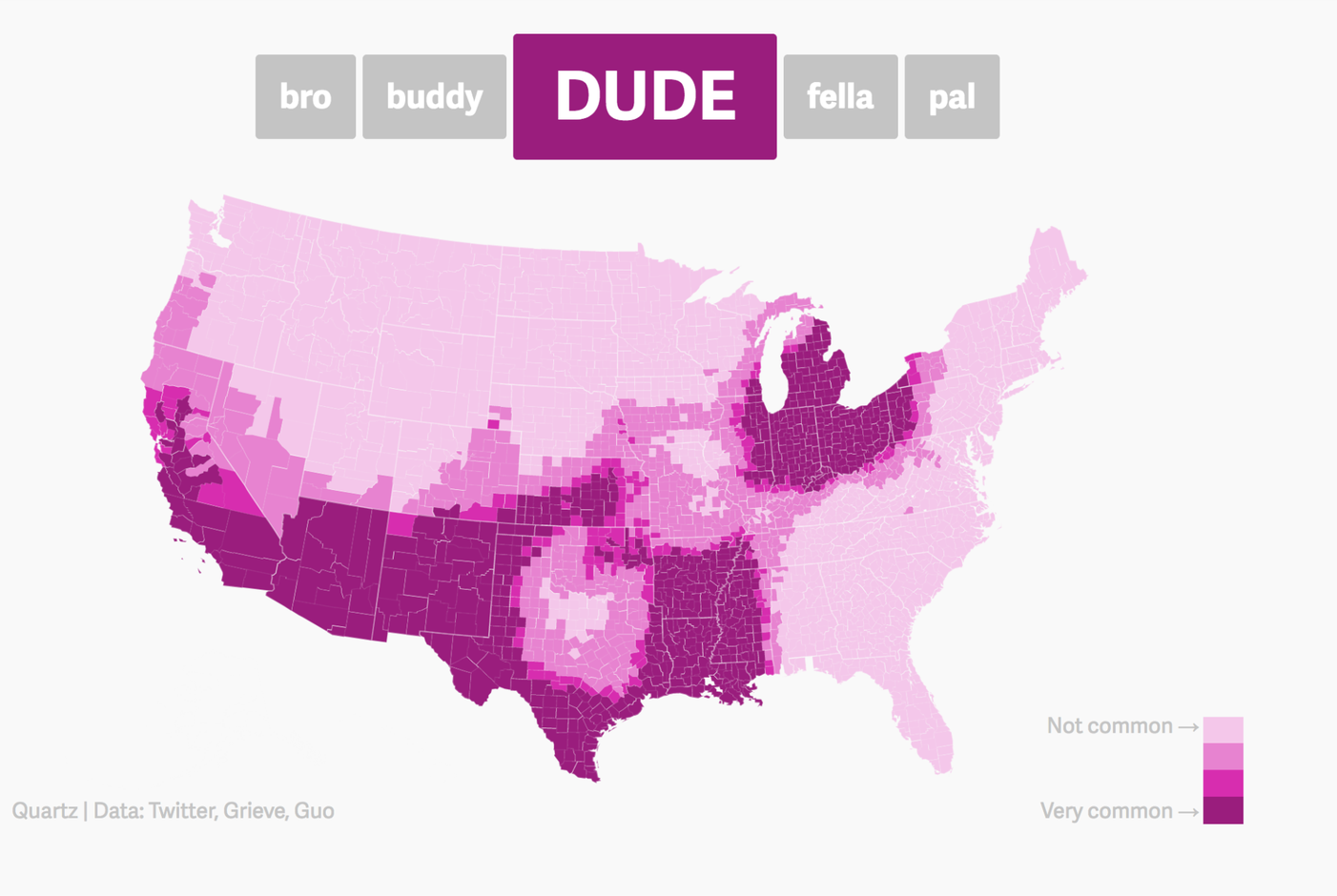






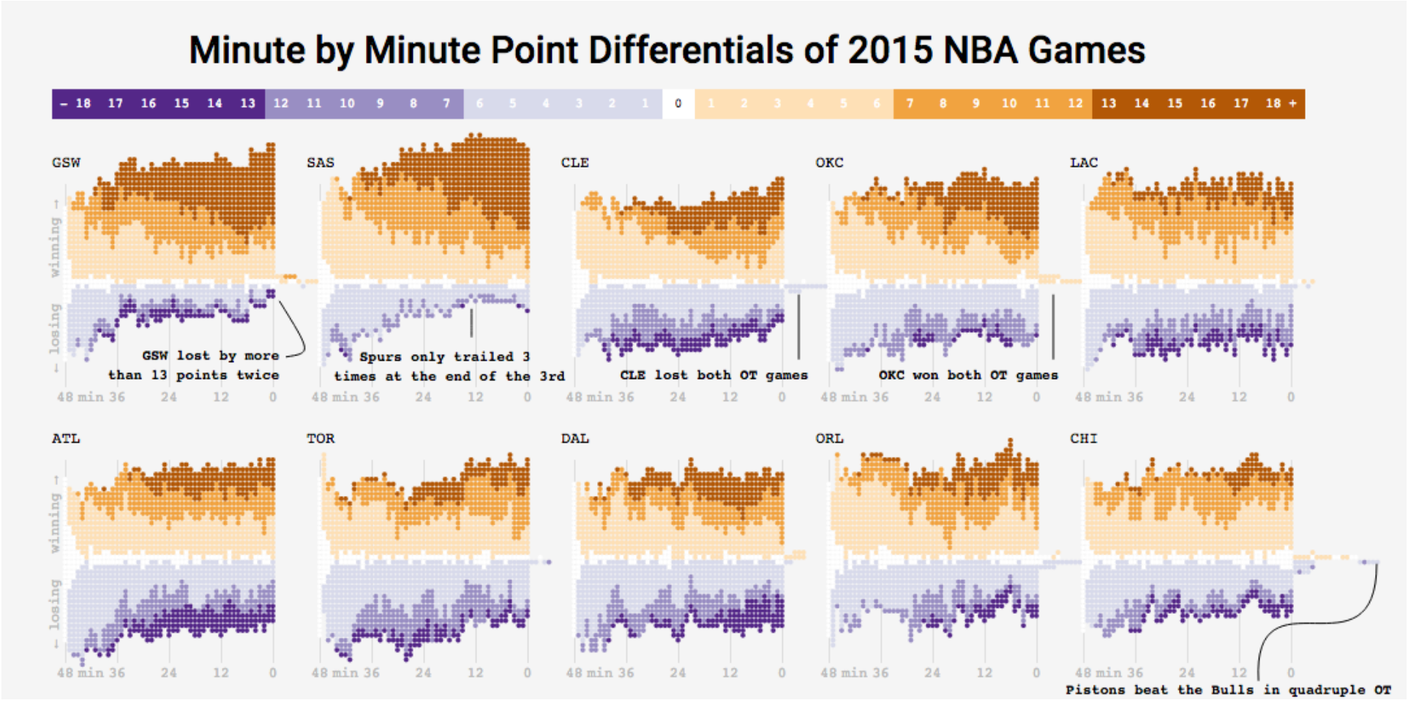


Color Palettes – Sequential



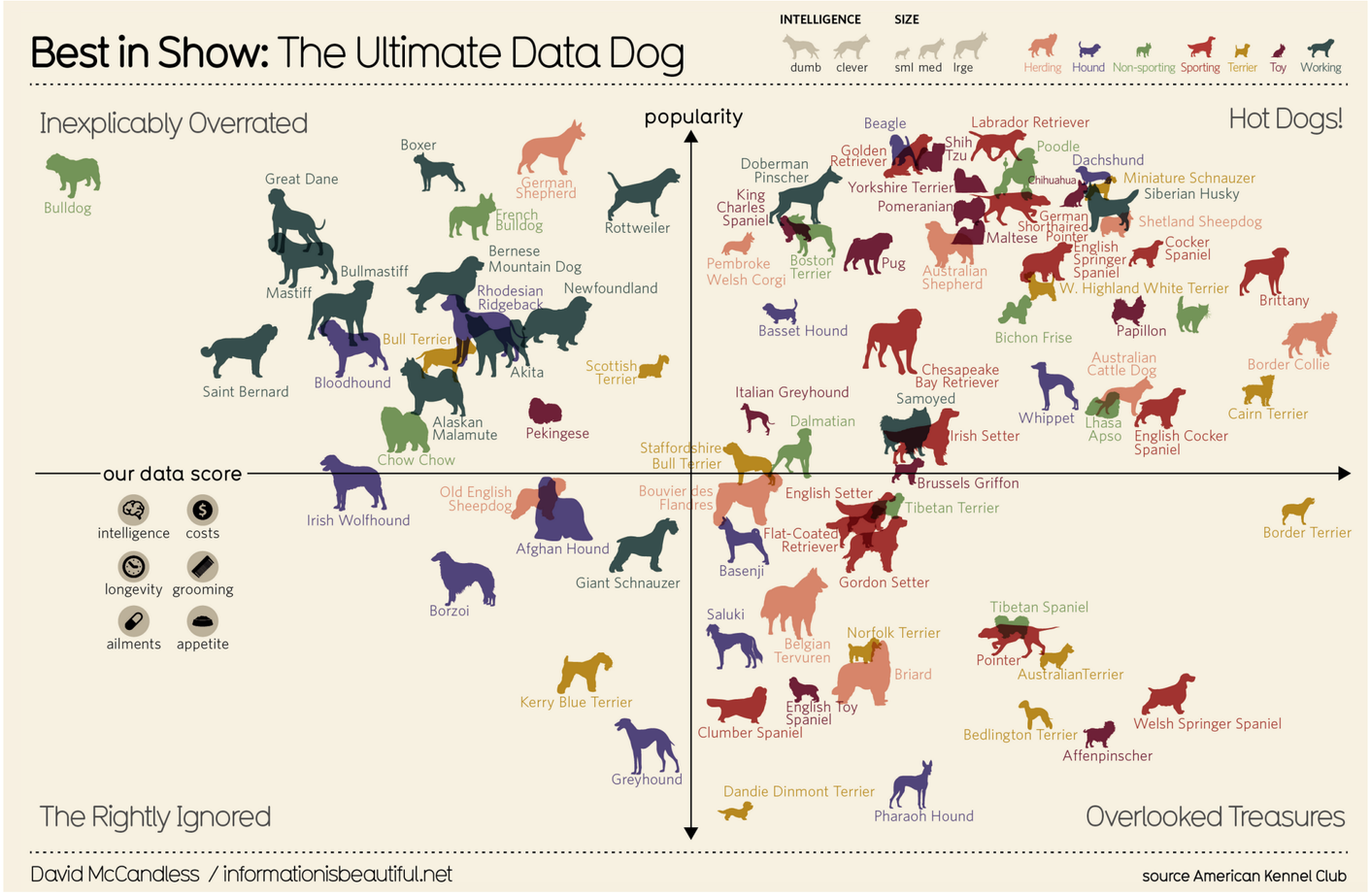
Maps, like the Dude map are also a great way to provide context!

Color Palettes – Diverging



Adam Pearce's 2015 NBA Games

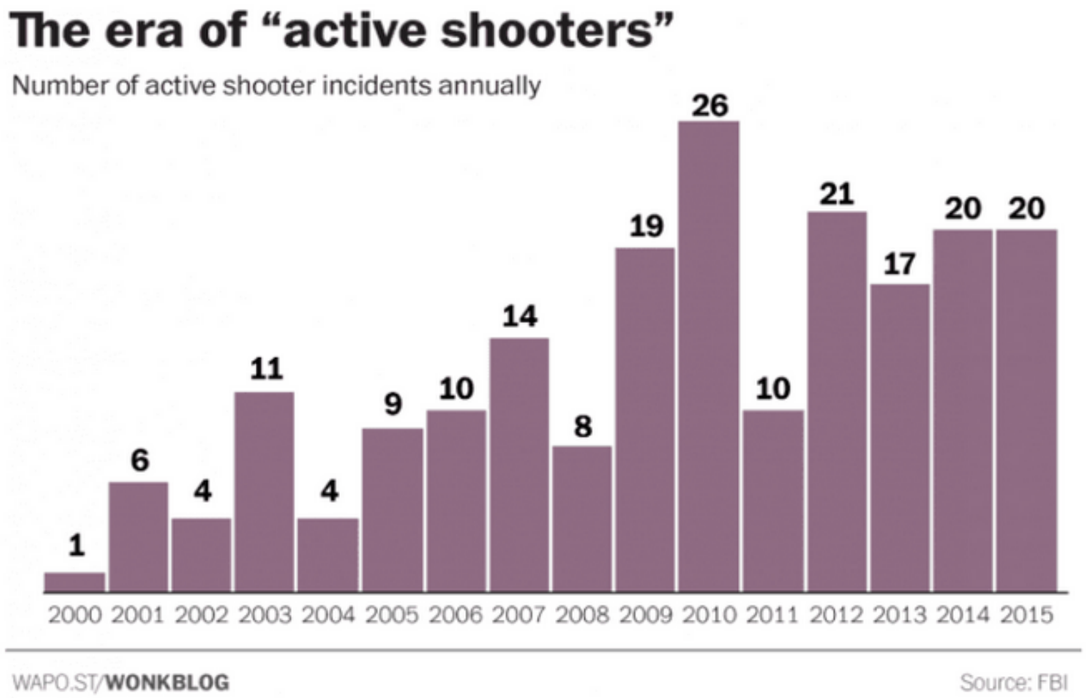
Color Palettes – Diverging



information is beautiful's Best in Show

Many Ways To Visually Tell A Story

Washington Post's Approach:

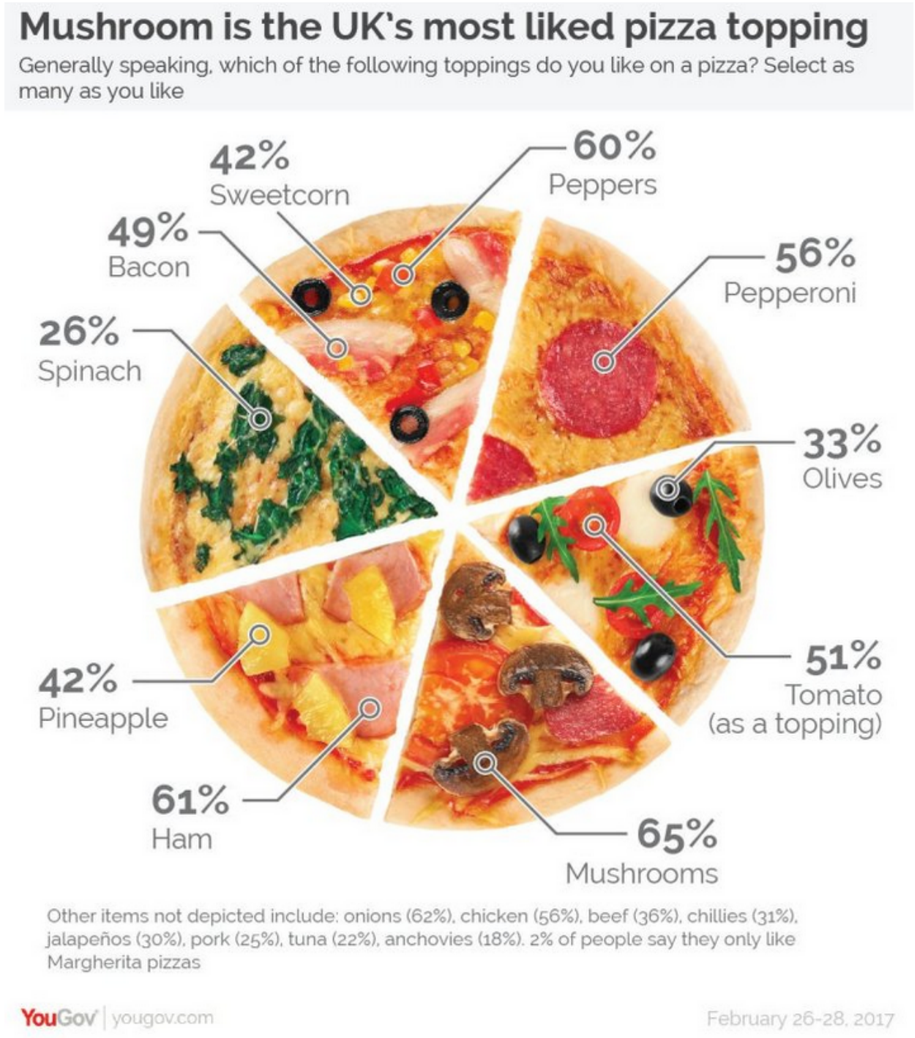


A bar chart of the number of "active shooter" incidents in the United States between 2000 and 2015.
Credit: *The Washington Post* WonkBlog

Periscopic's Approach

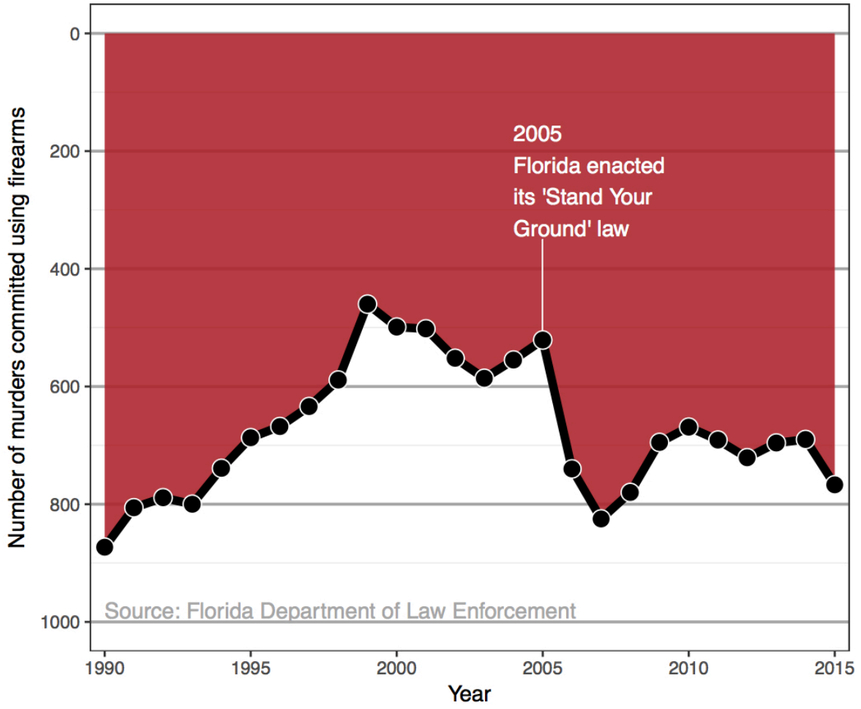
Bad Graphics

Because of all the design choices, it is much easier to make a bad graph than a good graph.



Misleading Graphics

Be careful that your design choices don't cause your viewer to draw incorrect conclusions about the data:

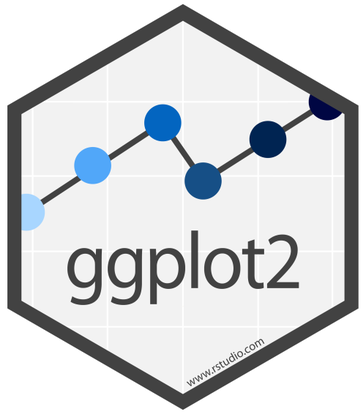


- Just letting the software make all the design choices can still lead to misleading graphs (recall the Georgia COVID graph).

Summary Thoughts on Graphical Considerations

- Good graphics are one's where the findings and insights are **obvious** to the viewer.
  - Add information and key **context**.
- Facilitate the **comparisons** that correspond to the research question.
  - Recall the three Georgia COVID counts graphs from Day 1!
- Data visualizations are **not neutral**.
- It is easier to see the differences and similarities between different types of graphics if we learn the **grammar of graphics**.
- Practicing **decomposing** graphics should make it easier for us to **compose** our own graphics.

Load Necessary Packages



`ggplot2` is part of this collection of data science packages.

```
# Load necessary packages
library(tidyverse)
```

Data Setting: Eco-Totem Broadway Bicycle Count

Import the Data

```
1 july_2019 <- read_csv("data/july_2019.csv")
2
3 # Inspect the data
4 glimpse(july_2019)
```

```
Rows: 192
Columns: 8
$ DateTime  <chr> "07/04/2019 12:00:00 AM", "07/04/2019 12:15:00 AM", "07/04/2…
$ Day       <chr> "Thursday", "Thursday", "Thursday", "Thursday", "Thursday", …
$ Date      <date> 2019-07-04, 2019-07-04, 2019-07-04, 2019-07-04, 2019-07-04,…
$ Time      <time> 00:00:00, 00:15:00, 00:30:00, 00:45:00, 01:00:00, 01:15:00,…
$ Total     <dbl> 2, 3, 2, 0, 3, 2, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, …
$ Westbound <dbl> 2, 3, 1, 0, 2, 2, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, …
$ Eastbound <dbl> 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, …
$ Occasion  <chr> "Fourth of July", "Fourth of July", "Fourth of July", "Fourt…
```

Inspect the Data

```
1 # Look at first few rows
2 head(july_2019)
```

```
# A tibble: 6 × 8
  DateTime             Day   Date       Time  Total Westbound Eastbound Occasion
  <chr>                <chr> <date>     <tim> <dbl>     <dbl>     <dbl> <chr>
1 07/04/2019 12:00:00… Thur… 2019-07-04 00:00     2         2         0 Fourth …
2 07/04/2019 12:15:00… Thur… 2019-07-04 00:15     3         3         0 Fourth …
3 07/04/2019 12:30:00… Thur… 2019-07-04 00:30     2         1         1 Fourth …
4 07/04/2019 12:45:00… Thur… 2019-07-04 00:45     0         0         0 Fourth …
5 07/04/2019 01:00:00… Thur… 2019-07-04 01:00     3         2         1 Fourth …
6 07/04/2019 01:15:00… Thur… 2019-07-04 01:15     2         2         0 Fourth …
```

What does a row represent here?

Inspect the Data

```
# Determine type
# To access one variable: dataset$variable
class(july_2019$Day)
```

```
[1] "character"
```

```
class(july_2019$Total)
```

```
[1] "numeric"
```

```
class(july_2019)
```

```
[1] "spec_tbl_df" "tbl_df"      "tbl"         "data.frame"
```

Grammar of Graphics

- **data**: Data frame that contains the raw data
  - Variables used in the graph
- **geom**: Geometric **shape** that the data are mapped to.
  - EX: Point, line, bar, text, …
- **aesthetic**: Visual properties of the **geom**
  - EX: X (horizontal) position, y (vertical) position, color, fill, shape
- **scale**: Controls how data are mapped to the visual values of the aesthetic.
  - EX: particular colors, log scale
- **guide**: Legend/key to help user convert visual display back to the data

`ggplot2` example code

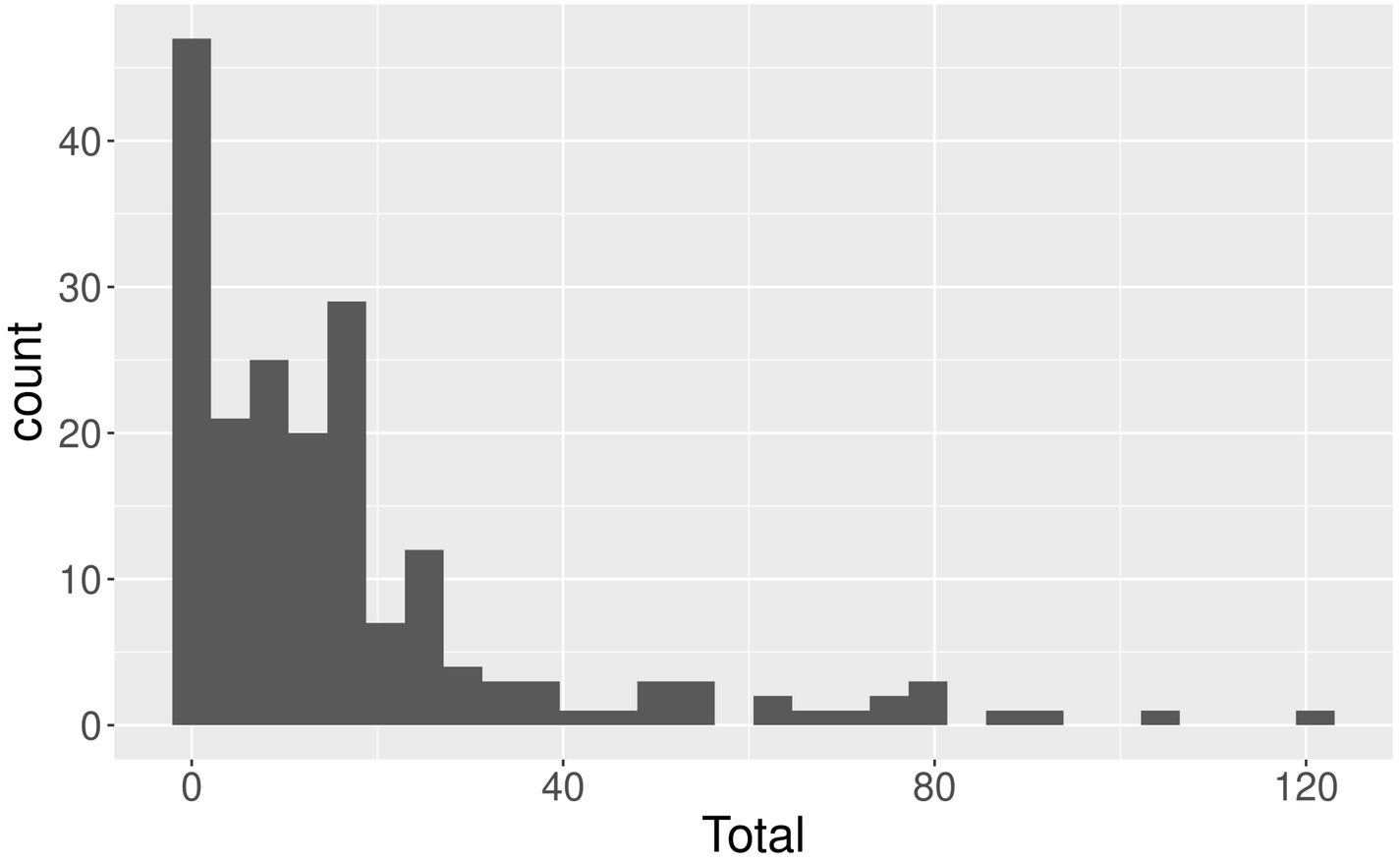
Guiding Principle: We will map variables from the **data** to the **aes**thetic attributes (e.g. location, size, shape, color) of **geom**etric objects (e.g. points, lines, bars).

```
ggplot(data = ---, mapping = aes(---)) +
  geom_---(---)
```

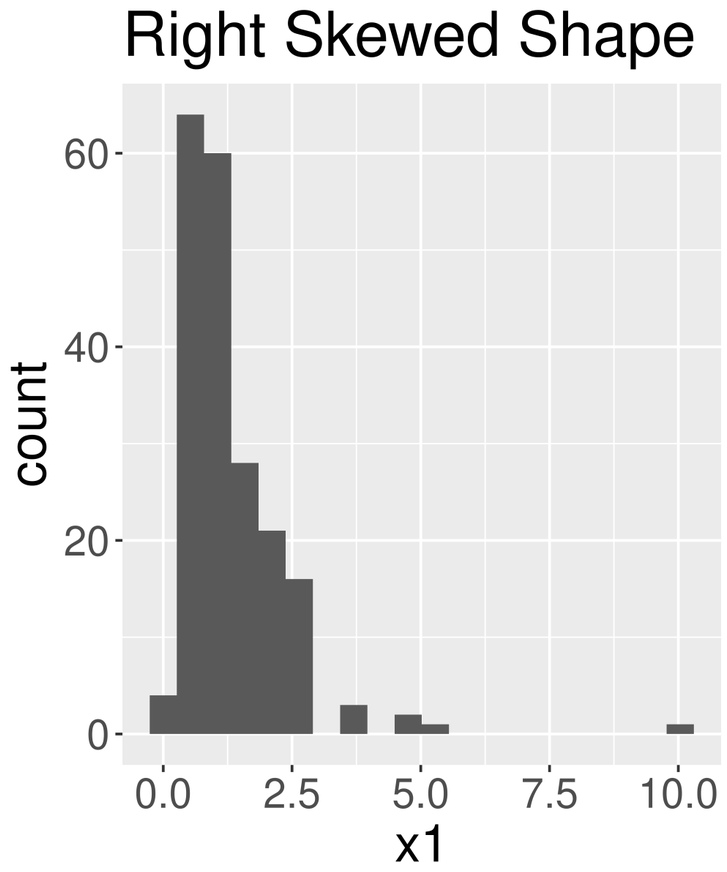
- There are other layers, such as `scales_---_---()` and `labs()`, but we will wait on those.

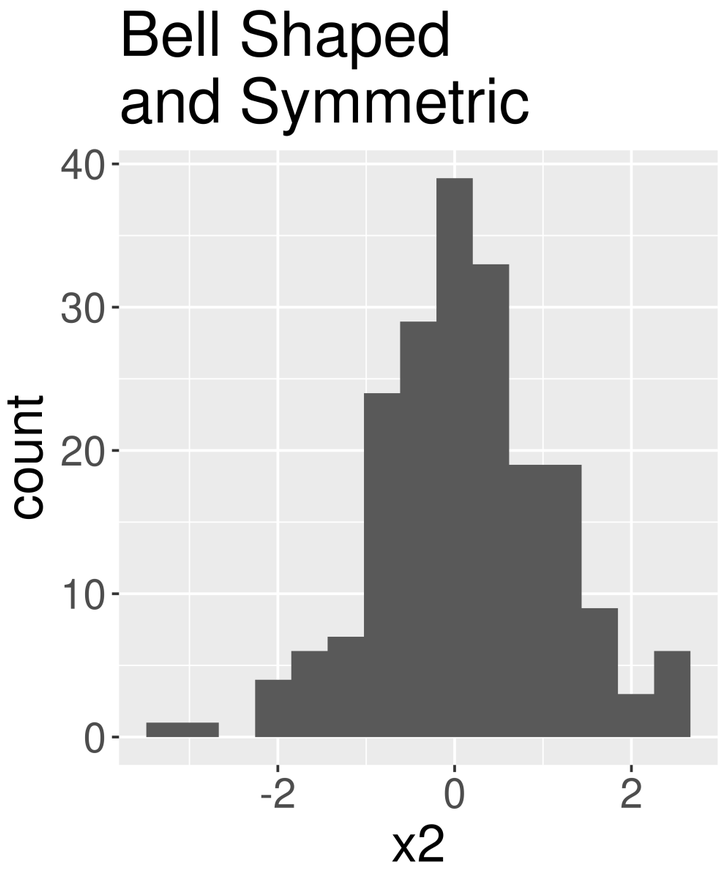
Histograms

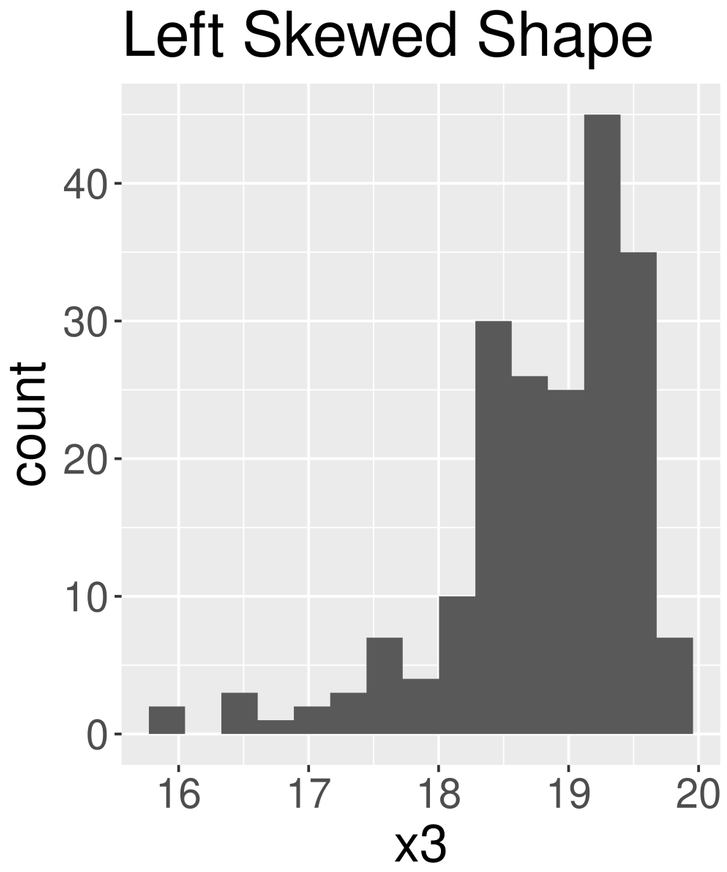
- Binned counts of data.
- Great for assessing shape.



Data Shapes

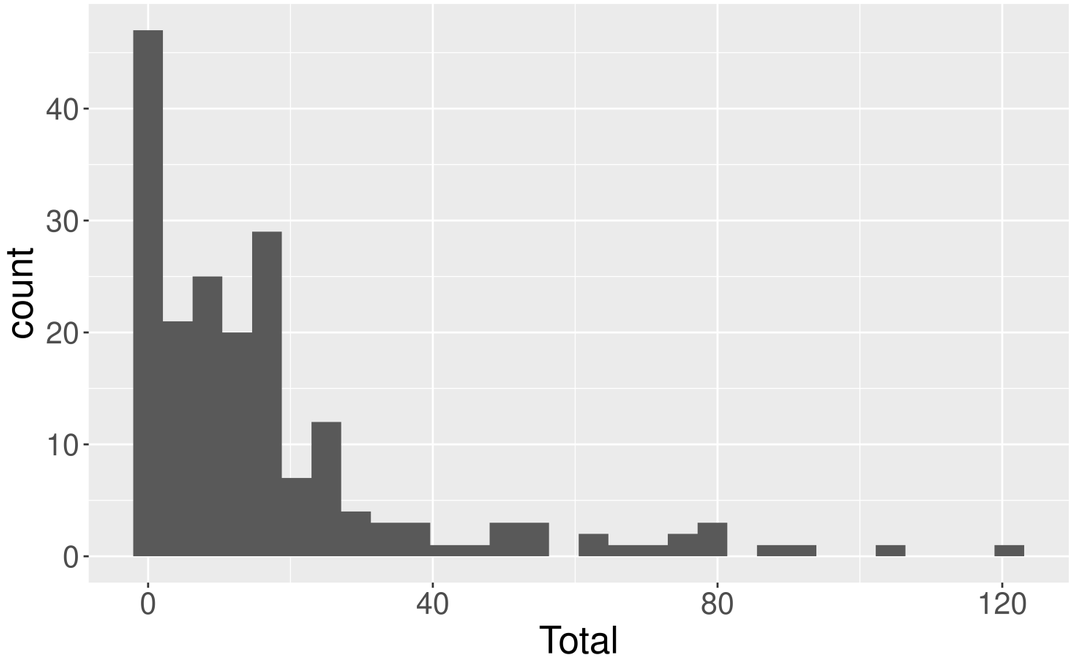

Right Skewed Shape
count
x1
0
20
40
60
0.0
2.5
5.0
7.5
10.0


Bell Shaped
and Symmetric
count
x2
0
10
20
30
40
-2
0
2


Left Skewed Shape
count
x3
0
10
20
30
40
16
17
18
19
20

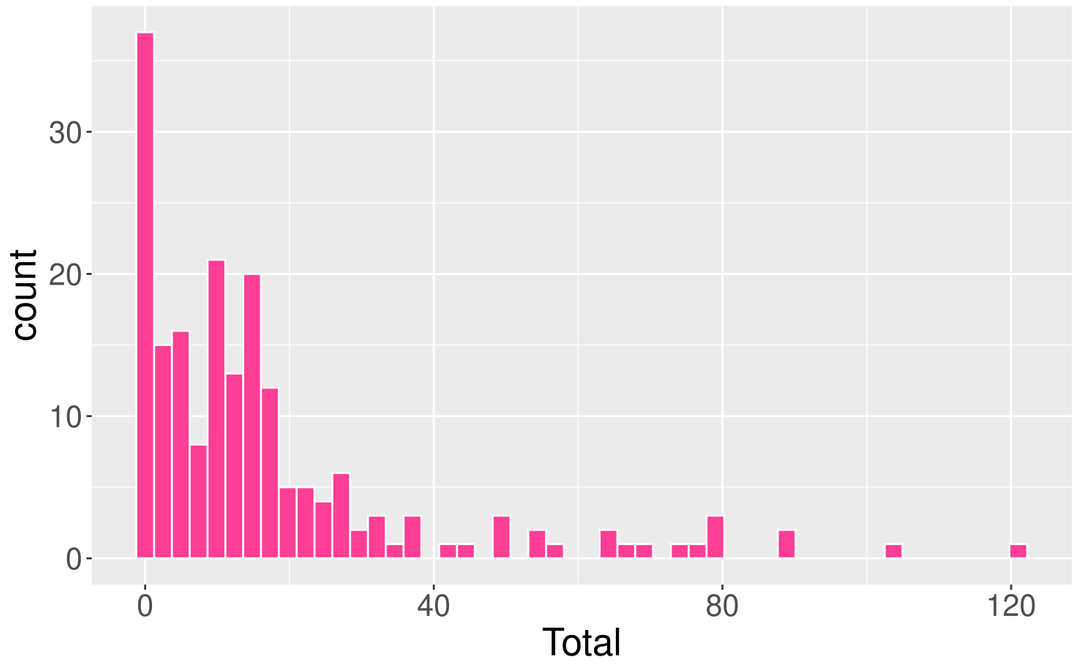
Histograms

```
# Create histogram
ggplot(data = july_2019,
       mapping = aes(x = Total)) +
  geom_histogram()
```



Histograms

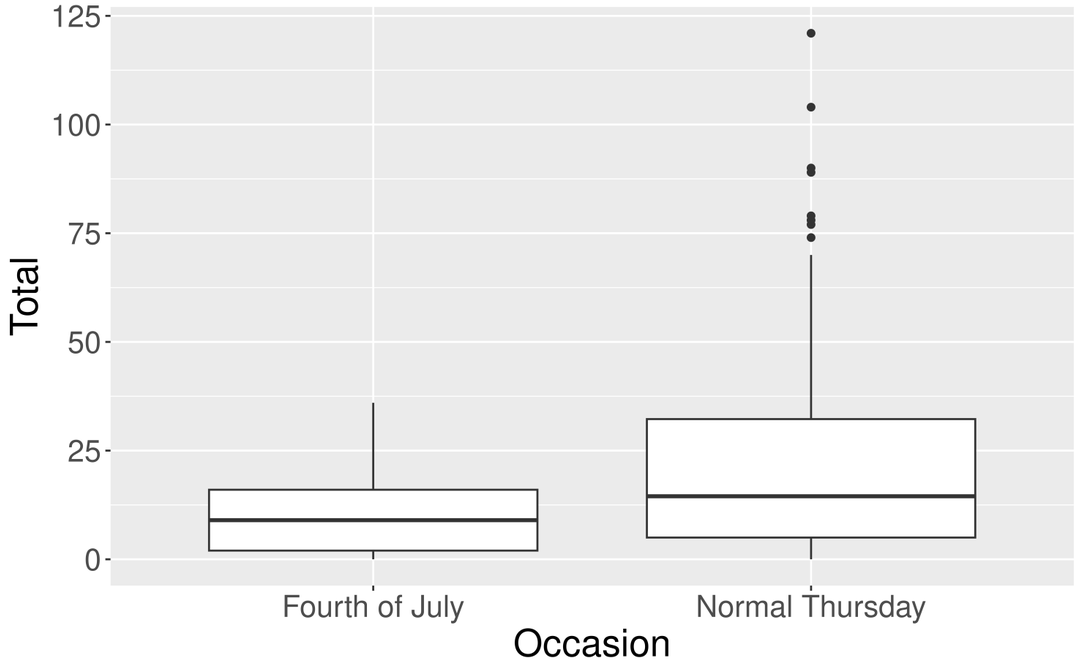
```
# Create histogram
ggplot(data = july_2019,
       mapping = aes(x = Total)) +
  geom_histogram(color = "white",
                 fill = "violetred1",
                 bins = 50)
```



- mapping to a variable goes in `aes()`
- setting to a specific value goes in the `geom_---()`

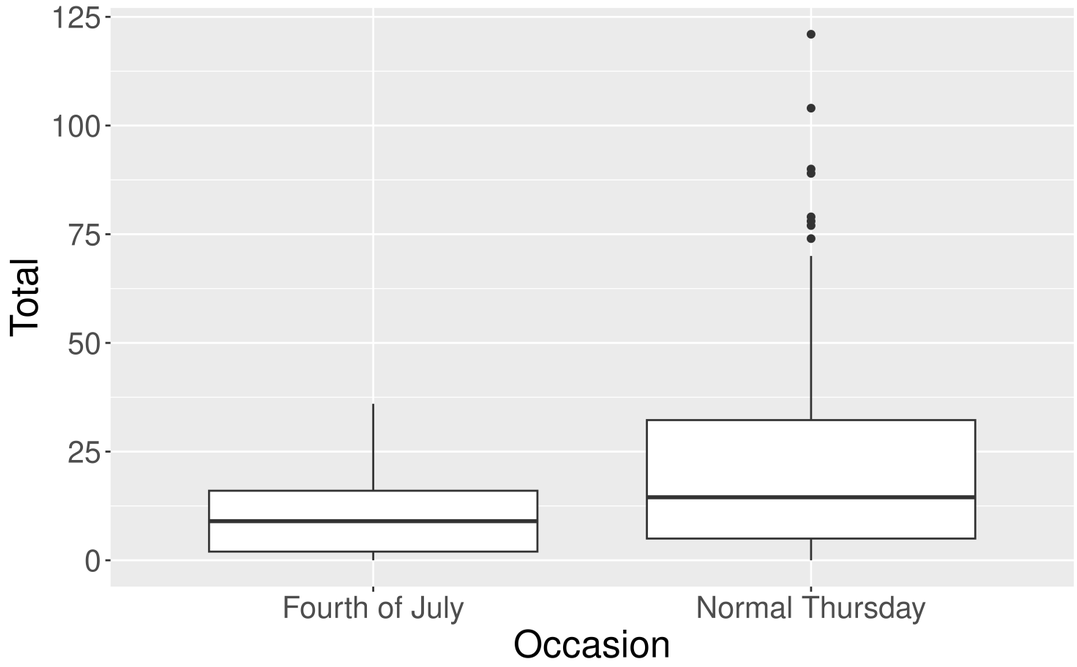
Boxplots

- Five number summary:
  - Minimum
  - First quartile (Q1)
  - Median
  - Third quartile (Q3)
  - Maximum
- Interquartile range (IQR) = Q3 – Q1
- Outliers: unusual points
  - Boxplot defines unusual as being beyond $1.5 * IQR$ from $Q1$ or $Q3$.
- Whiskers: reach out to the furthest point that is NOT an outlier



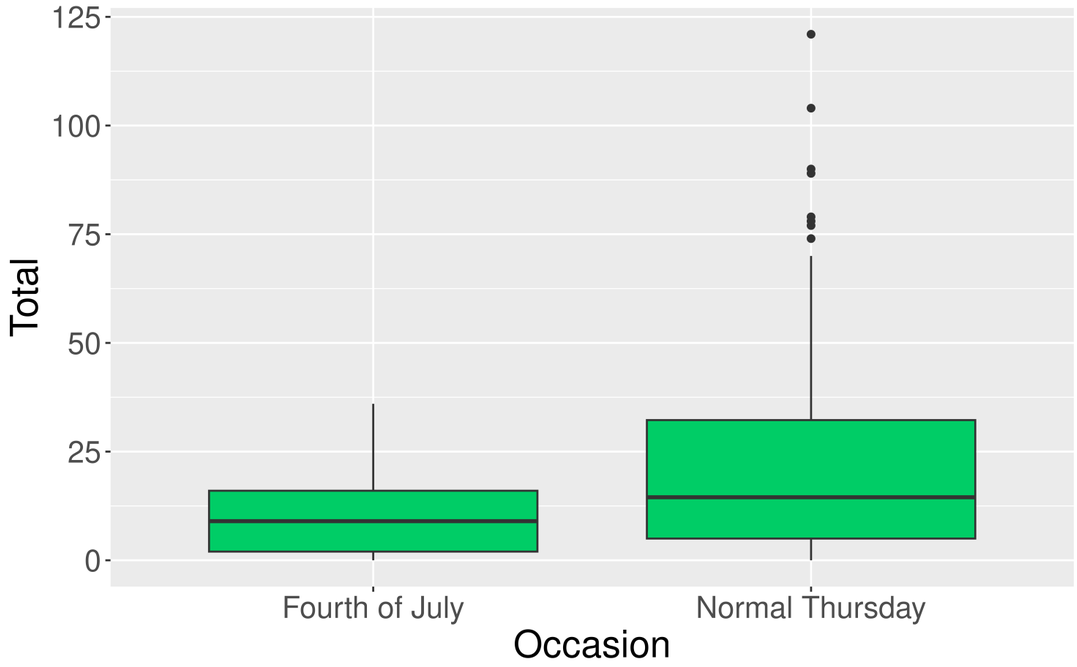
Boxplots

```
# Create boxplot
ggplot(data = july_2019,
       mapping = aes(x = Occasion,
                     y = Total)) +
  geom_boxplot()
```



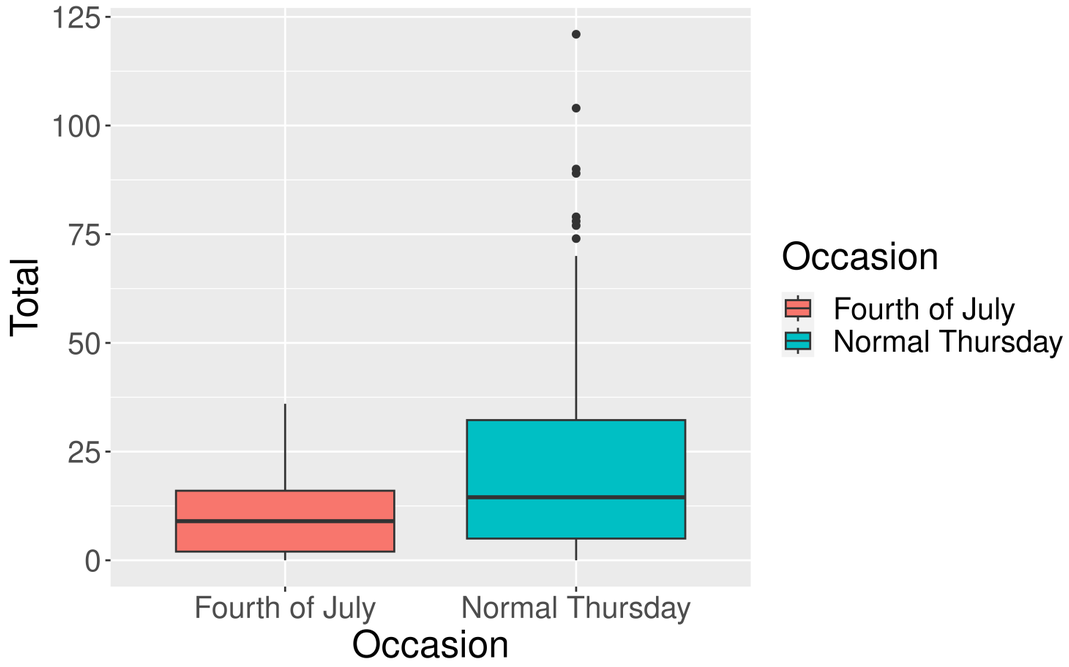
Boxplots

```
ggplot(data = july_2019,
       mapping = aes(x = Occasion,
                     y = Total)) +
  geom_boxplot(fill = "springgreen3")
```



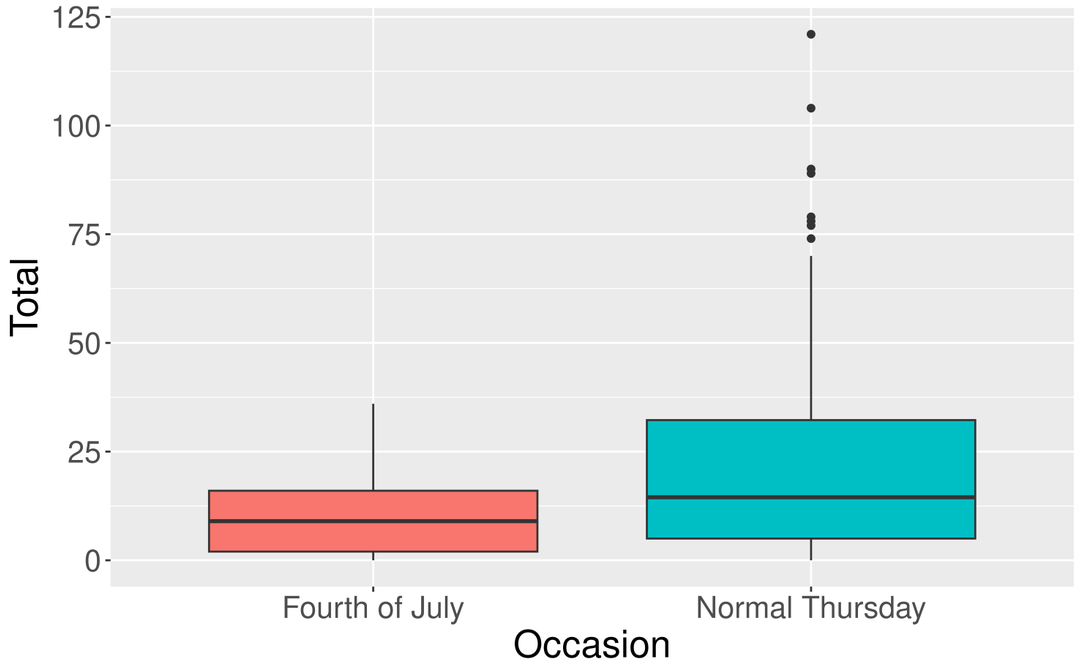
Boxplots

```
ggplot(data = july_2019,
       mapping = aes(x = Occasion,
                     y = Total,
                     fill = Occasion)) +
  geom_boxplot()
```



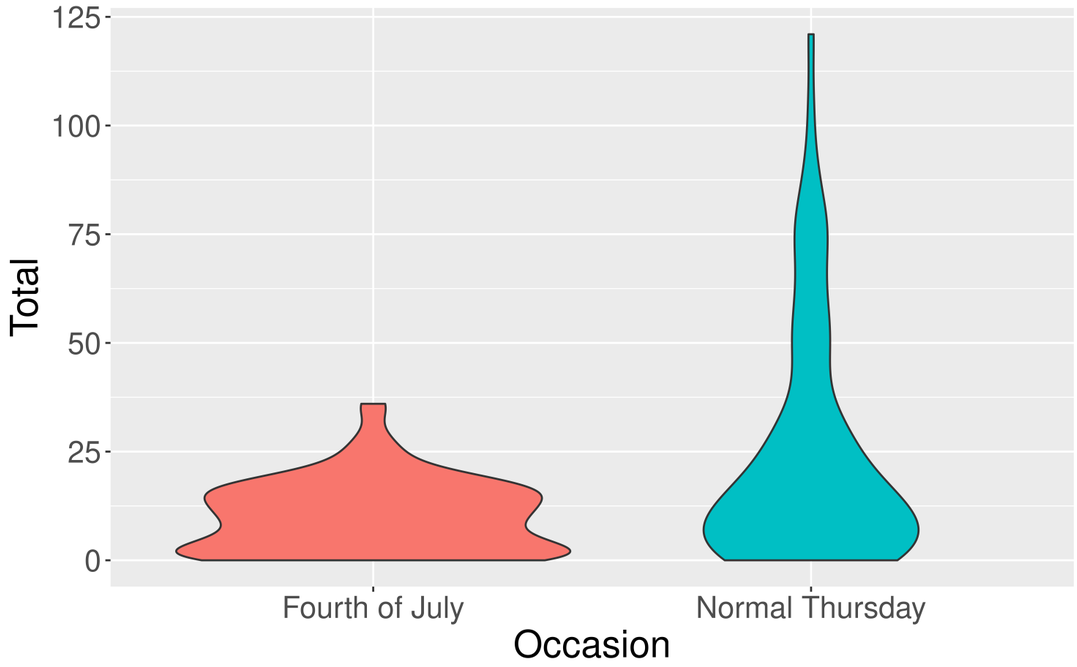
Boxplots

```
ggplot(data = july_2019,
       mapping = aes(x = Occasion,
                     y = Total,
                     fill = Occasion)) +
  geom_boxplot() +
  guides(fill = "none")
```

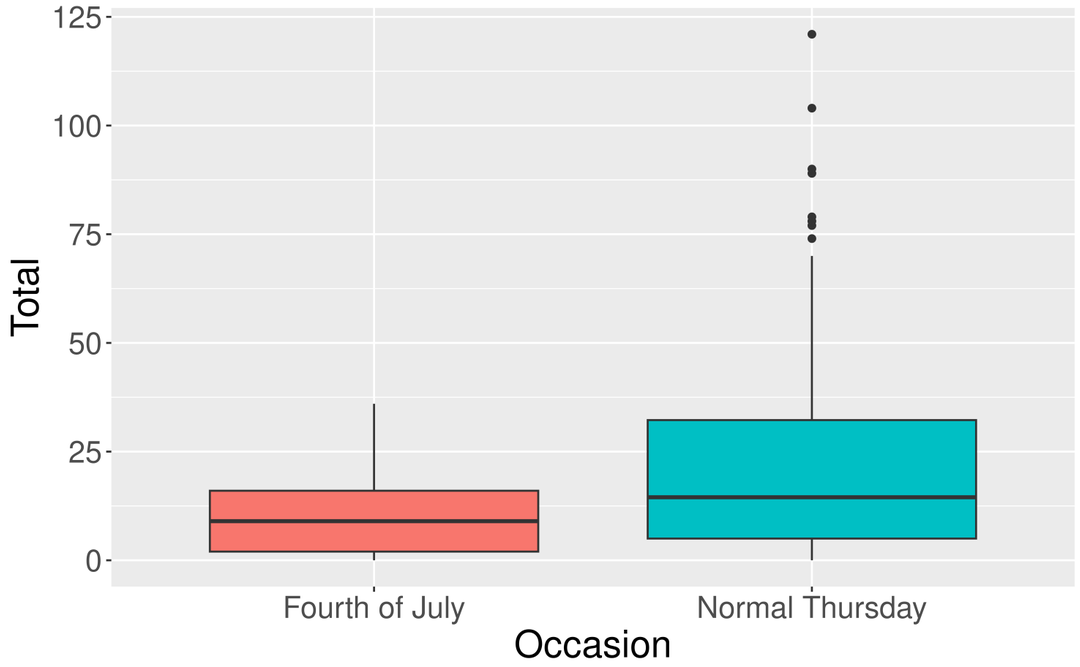


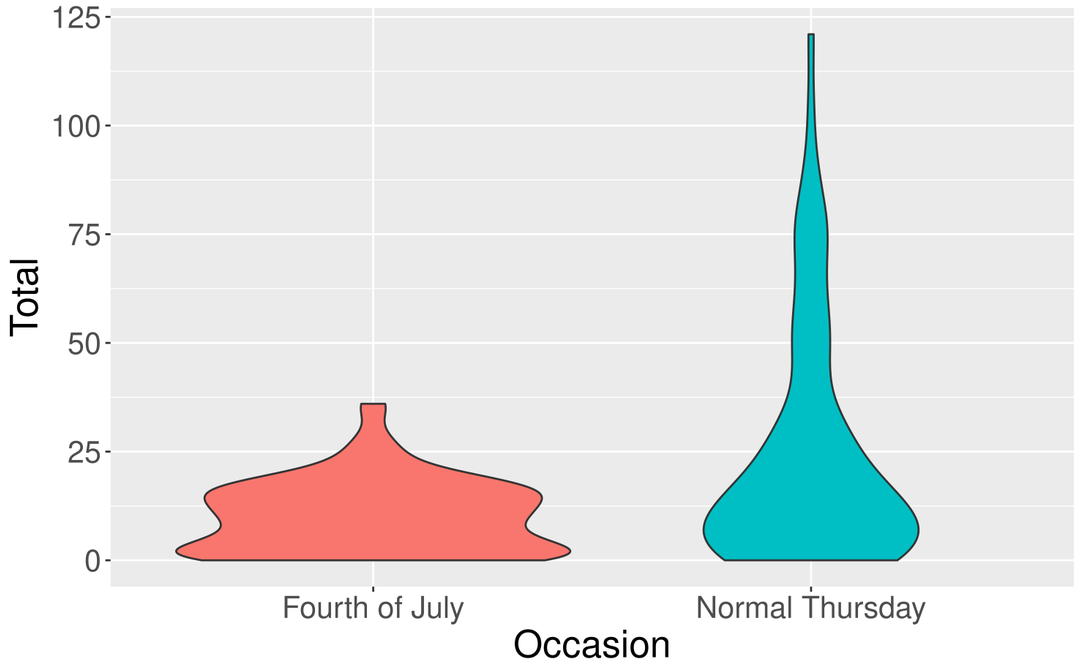
Violin Plots

```
ggplot(data = july_2019,
       mapping = aes(x = Occasion,
                     y = Total,
                     fill = Occasion)) +
  geom_violin() +
  guides(fill = "none")
```



Boxplot Versus Violin Plots





Recap: ggplot2

```
library(tidyverse)
ggplot(data = ---, mapping = aes(---)) +
  geom_---(---)
```

Reminders

- Class in full swing:
  - Sections: Can find your assigned section in my.harvard but need to go to the linked spreadsheet to find the room!
  - Office hours
  - Wrap-ups on Th 3-4pm and Fri 10:30 - 11:30am in SC 309
  - Lecture quiz will be released in **Gradescope** after class today.