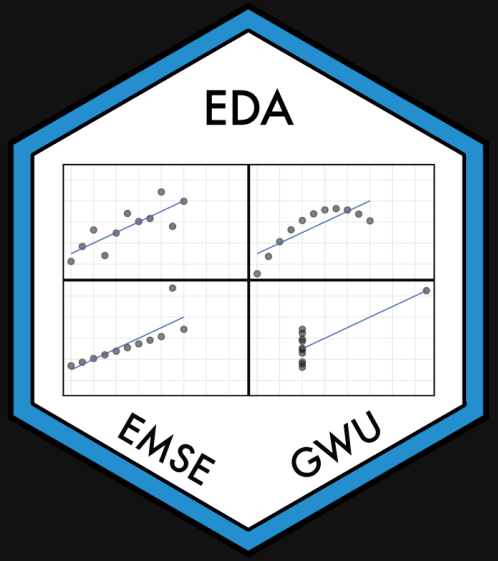

Week 1: *Getting Started*

EMSE 4575: Exploratory Data Analysis

John Paul Helveston

August 31, 2022

Week 1: *Getting Started*

1. Course Goal
2. Course Introduction
3. Break: Install Stuff
4. Workflow & Reading In Data
5. Wrangling Data
6. Visualizing Data

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Course 1: Intro to Programming for Analytics

"Computational Literacy"

- Programming: Conditionals (if/else), loops, functions, testing, data types.
- Analytics: Data structures, import / export, basic data manipulation & visualization.

Course 2: Exploratory Data Analysis

"Data Literacy"

- Strategies for conducting an exploratory data analysis.
- Design principles for visualizing and communicating *information* extracted from data.
- Reproducibility: Reports that contain code, equations, visualizations, and narrative text.

Class goal: translate *data* into *information*

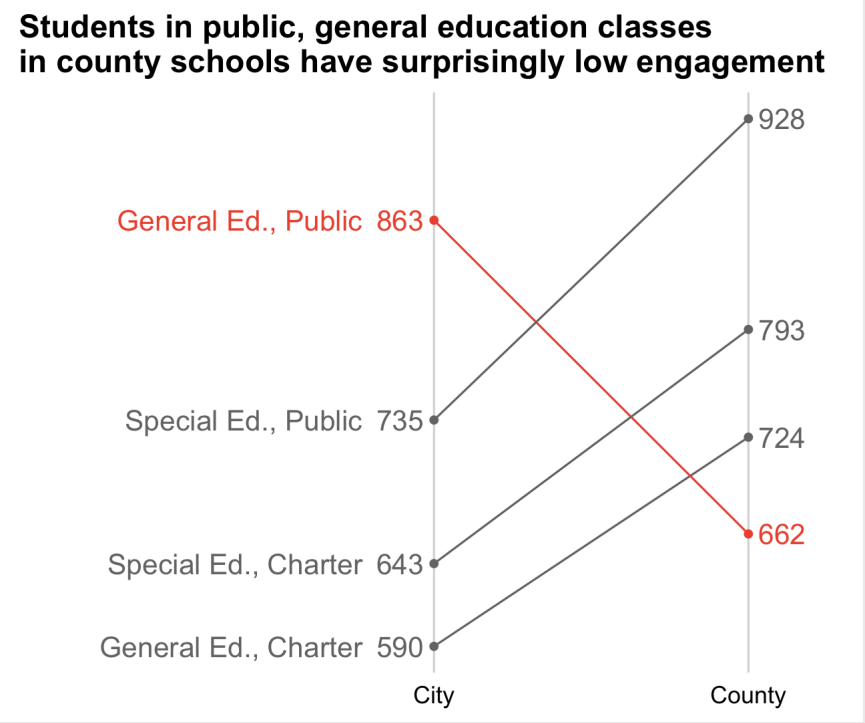
Class goal: translate *data* into *information*

Data

Average student engagement scores

Class	Type	City	County
Special Ed.	Charter	643	793
Special Ed.	Public	735	928
General Ed.	Charter	590	724
General Ed.	Public	863	662

Information



Data exploration: an iterative process

Encode data:

```
engagement_data <- data.frame(
    City   = c(643, 735, 590, 863),
    County = c(793, 928, 724, 662),
    School = c('Special Ed., Charter', 'Special Ed., Pu
               'General Ed., Charter', 'General Ed., Pu
engagement_data
```

```
#>   City County                School
#> 1  643    793 Special Ed., Charter
#> 2  735    928  Special Ed., Public
#> 3  590    724 General Ed., Charter
#> 4  863    662  General Ed., Public
```

Re-format data for plotting:

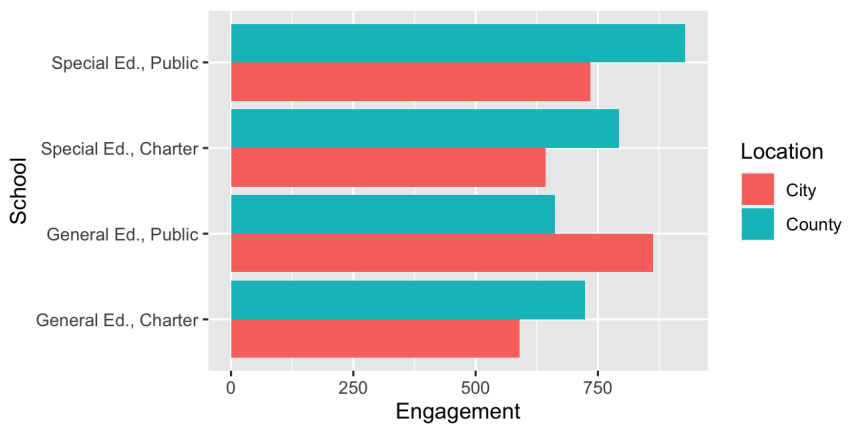
```
engagement_data <- engagement_data %>%
    gather(Location, Engagement, City:County) %>%
    mutate(Location = fct_relevel(
      Location, c('City', 'County')))
engagement_data
```

```
#>                 School Location Engagement
#> 1 Special Ed., Charter     City        643
#> 2  Special Ed., Public     City        735
#> 3 General Ed., Charter     City        590
#> 4  General Ed., Public     City        863
#> 5 Special Ed., Charter   County        793
#> 6  Special Ed., Public   County        928
#> 7 General Ed., Charter   County        724
#> 8  General Ed., Public   County        662
```

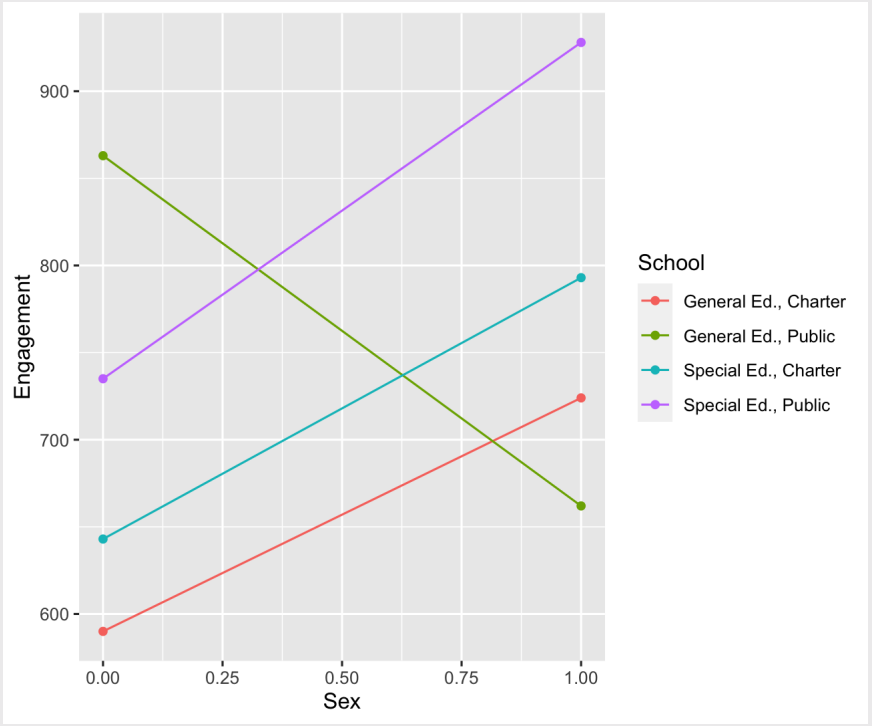
Data exploration: an iterative process

Initial exploratory plotting:

```
engagement_data %>%
    ggplot() +
    geom_col(aes(x = Engagement, y = School,
                 fill = Location),
             position = 'dodge')
```

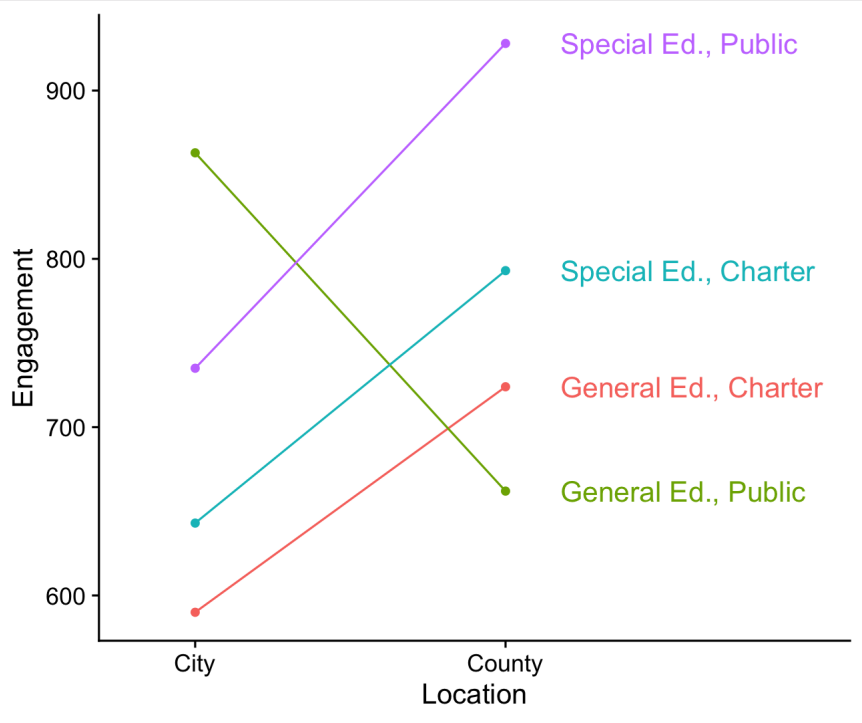


More exploratory plotting: highlight difference

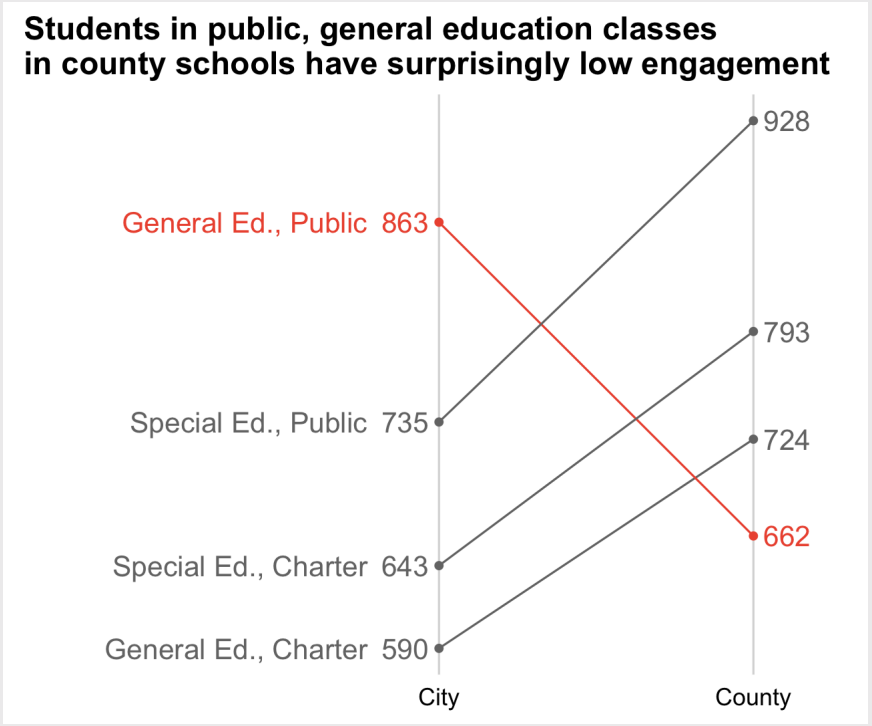


Data exploration: an iterative process

Directly label figure:



Remove unnecessary axes, change colors, fix labels:



A fully reproducible analysis

Code Plot

```
data <- data.frame(
    City   = c(643, 735, 590, 863),
    County = c(793, 928, 724, 662),
    School = c('Special Ed., Charter', 'Special Ed., Public',
               'General Ed., Charter', 'General Ed., Public'),
    Highlight = c(0, 0, 0, 1)) %>%
    gather(Location, Engagement, City:County) %>%
    mutate(
      Location = fct_relevel(Location, c('City', 'County')),
      Highlight = as.factor(Highlight),
      x = ifelse(Location == 'County', 1, 0))
```

```
plot <- ggplot(data, aes(x = x, y = Engagement, group = School, color = Highlight)
    geom_point() +
    geom_line() +
    scale_color_manual(values = c('#757575', '#ed573e')) +
    labs(x = 'Sex', y = 'Engagement',
         title = paste0('Students in public, general education classes\n',
                        'in county schools have surprisingly low engagement')) +
    scale_x_continuous(limits = c(-1.2, 1.2), labels = c('City', 'County'),
                       breaks = c(0, 1)) +
    geom_text_repel(aes(label = Engagement, color = as.factor(Highlight)),
                    data          = subset(engagement, Location == 'County'),
                    size          = 5,
                    nudge_x       = 0.1,
                    segment.color = NA) +
    geom_text_repel(aes(label = Engagement, color = as.factor(Highlight)),
                    data          = subset(engagement, Location == 'City'),
                    size          = 5,
                    nudge_x       = -0.1,
                    segment.color = NA) +
    geom_text_repel(aes(label = School, color = as.factor(Highlight)),
                    data          = subset(engagement, Location == 'City'),
                    size          = 5,
                    nudge_x       = -0.25,
                    hjust         = 1,
                    segment.color = NA) +
    theme_cowplot() +
    background_grid(major = 'x') +
    theme(axis.line = element_blank(),
          axis.title.x = element_blank(),
          axis.title.y = element_blank(),
          axis.text.y = element_blank(),
          axis.ticks = element_blank(),
          legend.position = 'none')
```

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Meet your instructor!

John Helveston, Ph.D.

- 2018 - Present Assistant Professor, Engineering Management & Systems Engineering
- 2016-2018 Postdoc at Institute for Sustainable Energy, Boston University
- 2016 PhD in Engineering & Public Policy at Carnegie Mellon University
- 2015 MS in Engineering & Public Policy at Carnegie Mellon University
- 2010 BS in Engineering Science & Mechanics at Virginia Tech
- Website: www.jhelvy.com

Meet your tutors!

Michael Rossetti

- Graduate Assistant (GA)
- PhD student in EMSE

Meet your tutors!

Eliese Ottinger

- Learning Assistant (LA)
- EMSE Senior & P4A / EDA alumni

Prerequisites

EMSE 4574: Intro to Programming for Analytics

You should be able to:

- Use RStudio to write basic R commands.
- Know the distinctions between different R operators and data types, including numeric, string, and logical data.
- Use **tidyverse** functions to wrangle and manipulate data in R.
- Use the **ggplot2** library to create plots in R.

🏛 Check out R for Analytics Primer

Course website

🌐 Everything you need will be on the course website: https://eda.seas.gwu.edu/2022-Fall/

📅 The schedule is the best starting point

Quizzes (8% of grade)

📅 At the start of class every other week-ish, unscheduled. Make ups only for excused absences (i.e. don't be late).

📅 5 total, lowest dropped

🕒 ~5 - 10 minutes

Why quiz at all? The "retrieval effect" - basically, you have to *practice* remembering things, otherwise your brain won't remember them (see the book "Make It Stick: The Science of Successful Learning")

Assignments

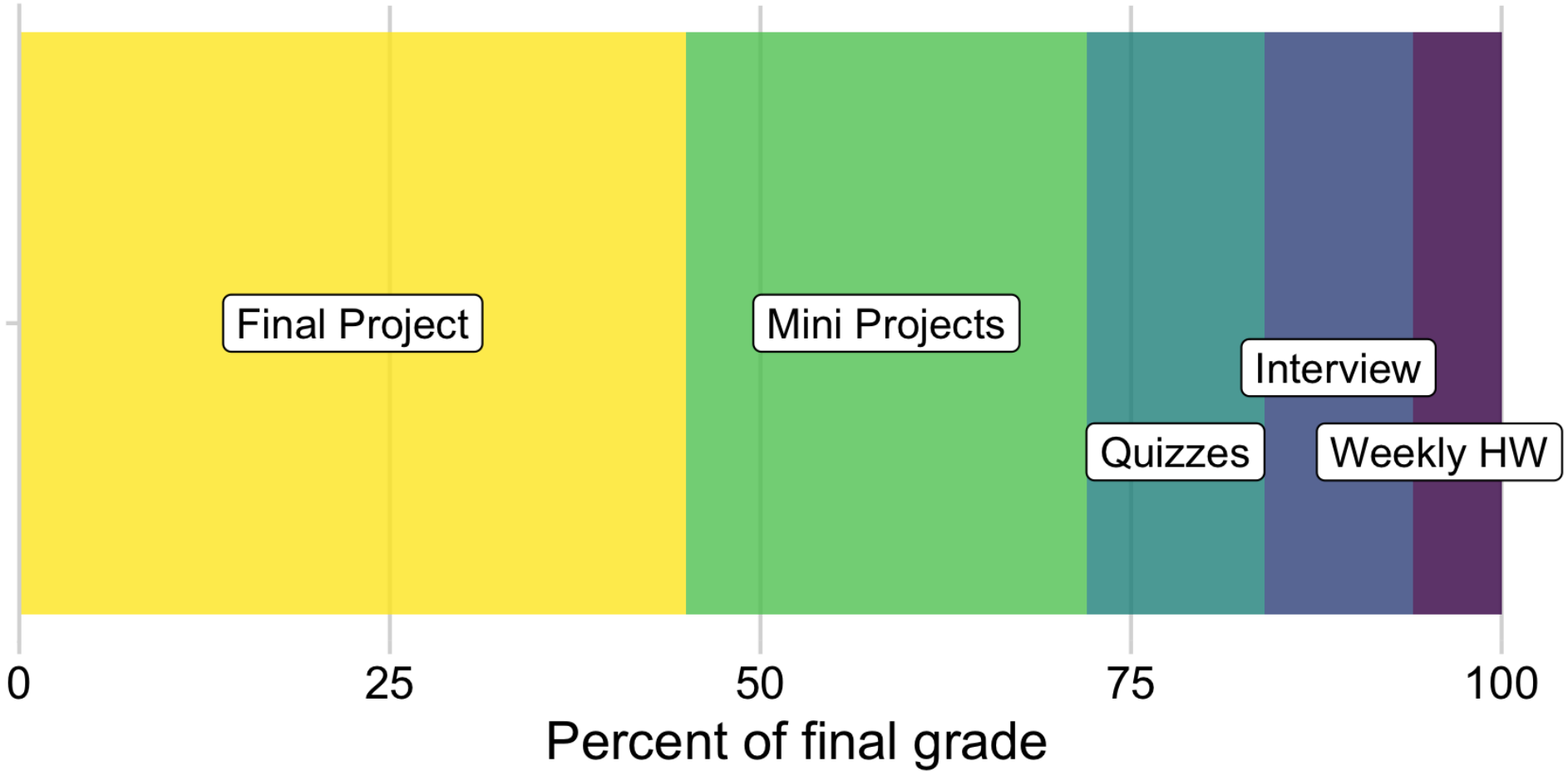
1) 📄 Weekly Homework / Readings: HW1

2) 🚀 3 Mini Projects (due 2 weeks from date assigned)

3) 🚀 Final Project (Teams of 2 - 3 students)

Item	Due Date
Proposal	March 12
Progress Report	April 16
Final Report	April 30
Presentation	May 03
Interview	Exam week

Grades


Final Project
Mini Projects
Interview
Quizzes
Weekly HW
0
25
50
75
100
Percent of final grade

Grades

Item	Weight	Notes
Weekly HW	12 %	
Quizzes	8 %	5 quizzes, lowest dropped
Mini Project 1	8 %	Individual assignments
Mini Project 2	8 %	
Mini Project 3	8 %	
Final Project: Proposal	9 %	Teams of 2-3 students
Final Project: Progress Report	12 %	
Final Project: Report	16 %	
Final Project: Presentation	9 %	
Final Interview	10 %	Individual interview

Course policies

- BE NICE
- BE HONEST
- DON'T CHEAT

Copying is good, stealing is bad

> "Plagiarism is trying to pass someone else's work off as your own. Copying is about reverse-engineering."
>
> -- Austin Kleon, from Steal Like An Artist

Late submissions

- **5** late days - use them anytime, no questions asked
- No more than **2** late days on any one assignment
- Contact me for special cases

How to succeed in this class

- Participate during class!
- Start assignments early and **read carefully**!
- Actually read (before class)!
- Get sleep and take breaks often!
- Ask for help!

Getting Help

Use Slack to ask questions.

Meet with your tutors

Schedule a meeting w/Prof. Helveston:

- Mondays from 8:00-5:00pm
- Wednesdays from 3:20-5:00pm
- Thursdays from 12:00-5:00pm

GW Coders

Course Software

Slack: See bb for link to join;
install on phone and **turn notifications on**!

R & RStudio (Install both)

RStudio Cloud (Register for free!)

Break

Install Stuff

05:00

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Workflow for reading in data

1) Use R Projects (.Rproj files) to organize your analysis - **don't double-click .R files**!

2) Use the `here` package to create file paths

```
path <- here::here("folder", "file.csv")
```

3) Import data with these functions:

File type	Function	Library
`.csv`	`read_csv()`	**readr**
`.txt`	`read.table()`	**utils**
`.xlsx`	`read_excel()`	**readxl**

Importing Comma Separated Values (.csv)

Read in `.csv` files with `read_csv()`:

```
library(tidyverse)
library(here)

csvPath <- here('data', 'milk_production.csv')
milk_production <- read_csv(csvPath)

head(milk_production)
```

```
#> # A tibble: 6 × 4
#>   region    state          year milk_produced
#>   <chr>     <chr>         <dbl>         <dbl>
#> 1 Northeast Maine          1970     619000000
#> 2 Northeast New Hampshire  1970     356000000
#> 3 Northeast Vermont        1970    1970000000
#> 4 Northeast Massachusetts  1970     658000000
#> 5 Northeast Rhode Island   1970      75000000
#> 6 Northeast Connecticut    1970     661000000
```

Importing Text Files (.txt)

Read in `.txt` files with `read.table()`:

```
txtPath <- here('data', 'nasa_global_temps.txt')
global_temps <- read.table(txtPath, skip = 5, header = FALSE)

head(global_temps)
```

```
#>     V1    V2    V3
#> 1 1880 -0.15 -0.08
#> 2 1881 -0.07 -0.12
#> 3 1882 -0.10 -0.15
#> 4 1883 -0.16 -0.19
#> 5 1884 -0.27 -0.23
#> 6 1885 -0.32 -0.25
```

Importing Text Files (.txt)

Read in `.txt` files with `read.table()`:

```
txtPath <- here('data', 'nasa_global_temps.txt')
global_temps <- read.table(txtPath, skip = 5, header = FALSE)
names(global_temps) <- c('year', 'no_smoothing', 'loess') # Add header

head(global_temps)
```

```
#>   year no_smoothing loess
#> 1 1880        -0.15 -0.08
#> 2 1881        -0.07 -0.12
#> 3 1882        -0.10 -0.15
#> 4 1883        -0.16 -0.19
#> 5 1884        -0.27 -0.23
#> 6 1885        -0.32 -0.25
```

Importing Excel Files (.xlsx)

Read in `.xlsx` files with `read_excel()`:

```
library(readxl)

xlsxPath <- here('data', 'pv_cell_production.xlsx')
pv_cells <- read_excel(xlsxPath, sheet = 'Cell Prod by Country', skip = 2)
```

```
glimpse(pv_cells)
```

```
#> Rows: 25
#> Columns: 10
#> $ Year            <chr> NA, NA, "1995", "1996", "1997", "1998", "1999", "2000", "2001", "2002
#> $ China           <chr> "Megawatts", NA, "NA", "NA", "NA", "NA", "NA", "2.5", "3", "10", "13"
#> $ Taiwan          <chr> NA, NA, "NA", "NA", "NA", "NA", "NA", "NA", "3.5", "8", "17", "39.299
#> $ Japan           <dbl> NA, NA, 16.4, 21.2, 35.0, 49.0, 80.0, 128.6, 171.2, 251.1, 363.9, 601
#> $ Malaysia        <chr> NA, NA, "NA", "NA", "NA", "NA", "NA", "NA", "0", "0", "0", "0", "0",
#> $ Germany         <chr> NA, NA, "NA", "NA", "NA", "NA", "NA", "22.5", "23.5", "55", "121.5",
#> $ `South Korea`   <chr> NA, NA, "NA", "NA", "NA", "NA", "NA", "NA", "0", "0", "0", "0", "5.3"
#> $ `United States` <dbl> NA, NA, 34.7500, 38.8500, 51.0000, 53.7000, 60.8000, 75.0000, 100.300
#> $ Others          <chr> NA, NA, "NA", "NA", "NA", "NA", "NA", "48.2000000000000017", "69.80000
#> $ World           <dbl> NA, NA, 77.600, 88.600, 125.800, 154.900, 201.300, 276.800, 371.300,
```

Importing Excel Files (.xlsx)

Read in `.xlsx` files with `read_excel()`:

```
library(readxl)

xlsxPath <- here('data', 'pv_cell_production.xlsx')
pv_cells <- read_excel(xlsxPath, sheet = 'Cell Prod by Country', skip = 2) %>%
  mutate(Year = as.numeric(Year)) %>% # Convert "non-years" to NA
  filter(!is.na(Year)) # Drop NA rows in Year
```

```
glimpse(pv_cells)
```

```
#> Rows: 19
#> Columns: 10
#> $ Year            <dbl> 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 20
#> $ China           <chr> "NA", "NA", "NA", "NA", "NA", "2.5", "3", "10", "13", "40", "128.30000000000001", "341
#> $ Taiwan          <chr> "NA", "NA", "NA", "NA", "NA", "NA", "3.5", "8", "17", "39.299999999999997", "88", "169
#> $ Japan           <dbl> 16.4, 21.2, 35.0, 49.0, 80.0, 128.6, 171.2, 251.1, 363.9, 601.5, 833.0, 926.4, 937.5,
#> $ Malaysia        <chr> "NA", "NA", "NA", "NA", "NA", "NA", "0", "0", "0", "0", "0", "0", "100.1", "397.9", "1
#> $ Germany         <chr> "NA", "NA", "NA", "NA", "NA", "22.5", "23.5", "55", "121.5", "193", "339", "469.1", "8
#> $ `South Korea`   <chr> "NA", "NA", "NA", "NA", "NA", "NA", "0", "0", "0", "0", "5.3", "13", "31.883935905674
#> $ `United States` <dbl> 34.7500, 38.8500, 51.0000, 53.7000, 60.8000, 75.0000, 100.3000, 120.6000, 103.0000, 11
#> $ Others          <chr> "NA", "NA", "NA", "NA", "NA", "48.200000000000017", "69.800000000000011", "97.2999999
#> $ World           <dbl> 77.600, 88.600, 125.800, 154.900, 201.300, 276.800, 371.300, 542.000, 749.400, 1198.80
```

Your turn

10:00

Open the `practice.Rmd` file.

Write code to import the following data files from the "data" folder:

- For `lotr_words.csv`, call the data frame `lotr`
- For `north_america_bear_killings.txt`, call the data frame `bears`
- For `uspto_clean_energy_patents.xlsx`, call the data frame `patents`

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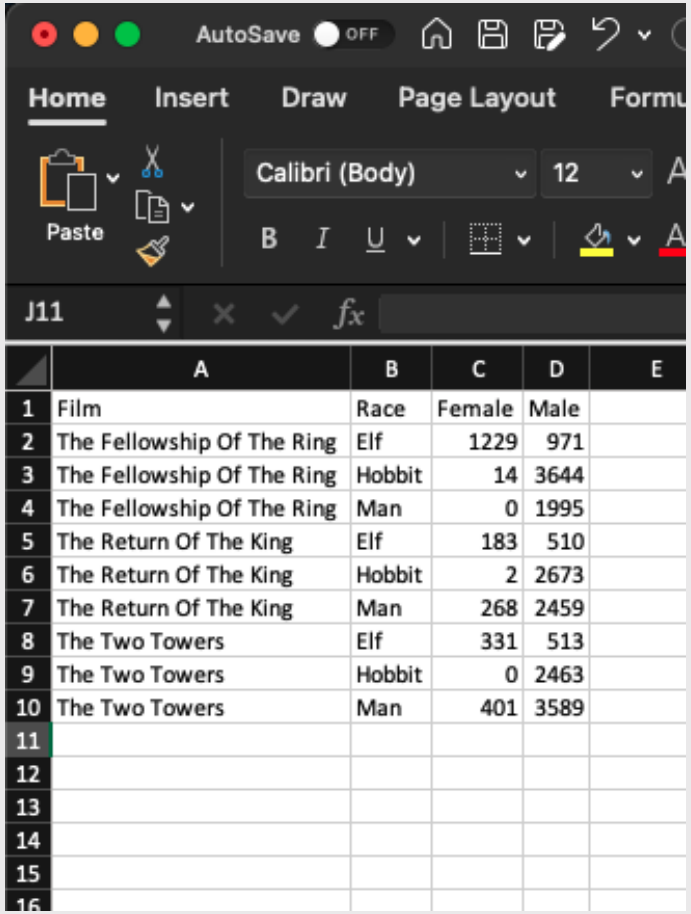
The data frame... in Excel



	A	B	C	D	E
1	Film	Race	Female	Male	
2	The Fellowship Of The Ring	Elf	1229	971	
3	The Fellowship Of The Ring	Hobbit	14	3644	
4	The Fellowship Of The Ring	Man	0	1995	
5	The Return Of The King	Elf	183	510	
6	The Return Of The King	Hobbit	2	2673	
7	The Return Of The King	Man	268	2459	
8	The Two Towers	Elf	331	513	
9	The Two Towers	Hobbit	0	2463	
10	The Two Towers	Man	401	3589	
11					
12					
13					
14					
15					
16					

The data frame... in R

```
lotr
```

```
#> # A tibble: 18 × 4
#>    film                      race   genc
#>    <chr>                     <chr>  <chr
#>  1 The Fellowship Of The Ring Elf    Fema
#>  2 The Fellowship Of The Ring Elf    Male
#>  3 The Fellowship Of The Ring Hobbit Fema
#>  4 The Fellowship Of The Ring Hobbit Male
#>  5 The Fellowship Of The Ring Man    Fema
#>  6 The Fellowship Of The Ring Man    Male
#>  7 The Return Of The King     Elf    Fema
#>  8 The Return Of The King     Elf    Male
#>  9 The Return Of The King     Hobbit Fema
#> 10 The Return Of The King     Hobbit Male
#> 11 The Return Of The King     Man    Fema
#> 12 The Return Of The King     Man    Male
#> 13 The Two Towers             Elf    Fema
```

Columns: *Vectors* of values (must be same data type)

Extract a column using `$`

```
lotr$race
```

```
#>  [1] "Elf"    "Elf"    "Hobbit" "Hobbit" "Man"    "Man"    "Elf"    "Elf"    "Hobbit" "
```

Columns: *Vectors* of values (must be same data type)

Can also use brackets:

```
lotr$race
```

```
#>  [1] "Elf"    "Elf"    "Hobbit" "Hobbit" "Man"    "Man"    "Elf"    "Elf"    "Hobbit" "
```

```
lotr[,2]
```

```
#> # A tibble: 18 × 1
#>    race
#>    <chr>
#>  1 Elf
#>  2 Elf
#>  3 Hobbit
#>  4 Hobbit
#>  5 Man
#>  6 Man
#>  7 Elf
#>  8 Elf
#>  9 Hobbit
```

Rows: Information about individual observations

Information about the first row:

```
lotr[1,]
```

```
#> # A tibble: 1 × 4
#>   film                      race  gender word_count
#>   <chr>                     <chr> <chr>       <dbl>
#> 1 The Fellowship Of The Ring Elf   Female       1229
```

Information about rows 1 & 2:

```
lotr[1:2,]
```

```
#> # A tibble: 2 × 4
#>   film                      race  gender word_count
#>   <chr>                     <chr> <chr>       <dbl>
#> 1 The Fellowship Of The Ring Elf   Female       1229
#> 2 The Fellowship Of The Ring Elf   Male          971
```

Quick Practice

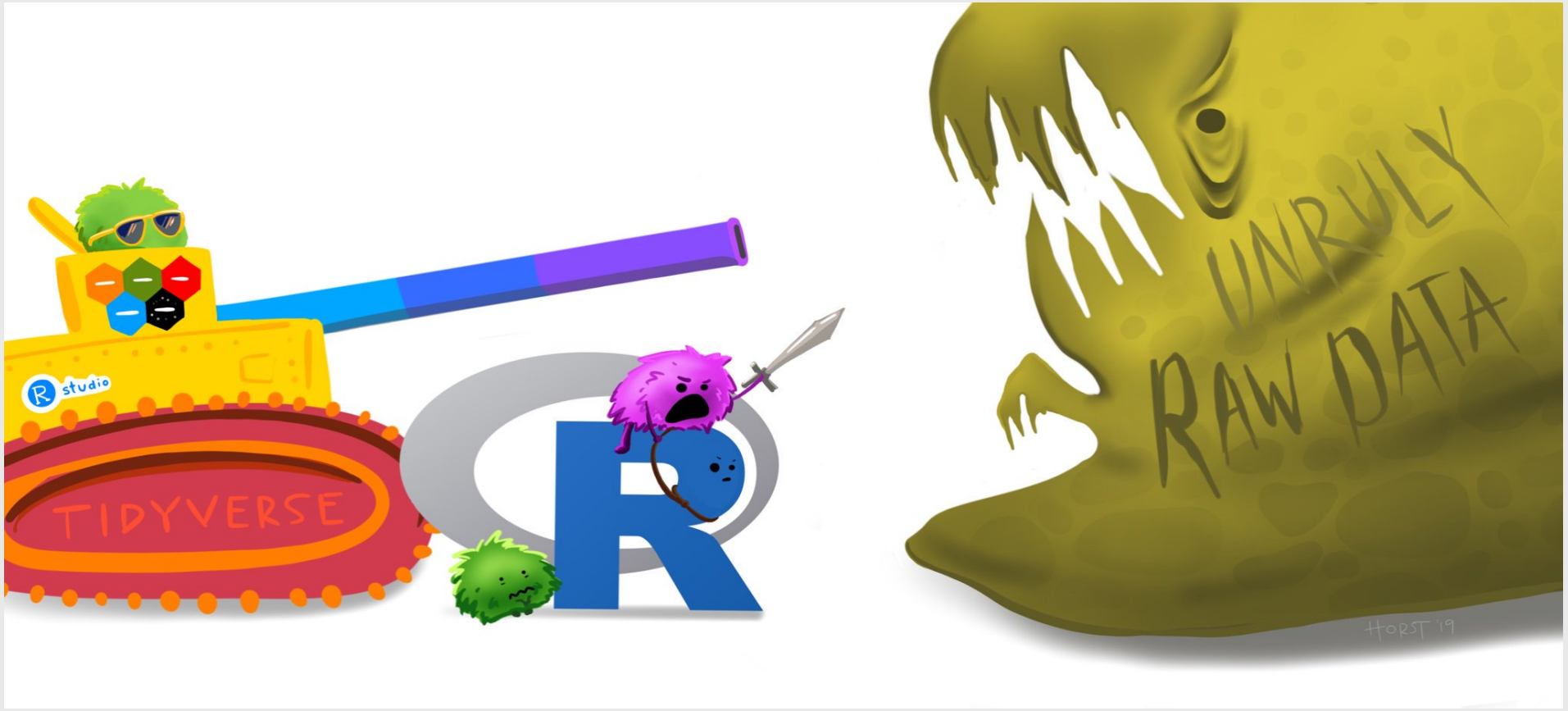
Read in the `data.csv` file in the "data" folder:

```
data <- read_csv(here('data', 'data.csv'))
```

Now answer these questions:

- How many rows and columns are in the data frame?
- What type of data is each column?
- Preview the different columns - what do you think this data is about? What might one row represent?
- How many unique airlines are in the data frame?
- What is the shortest and longest air time for any one flight in the data frame?

The tidyverse: `stringr` + `dplyr` + `readr` + `ggplot2` + ...



Art by Allison Horst

The main `dplyr` "verbs"

"Verb"	What it does
`select()`	Select columns by name
`filter()`	Keep rows that match criteria
`arrange()`	Sort rows based on column(s)
`mutate()`	Create new columns
`summarize()`	Create summary values

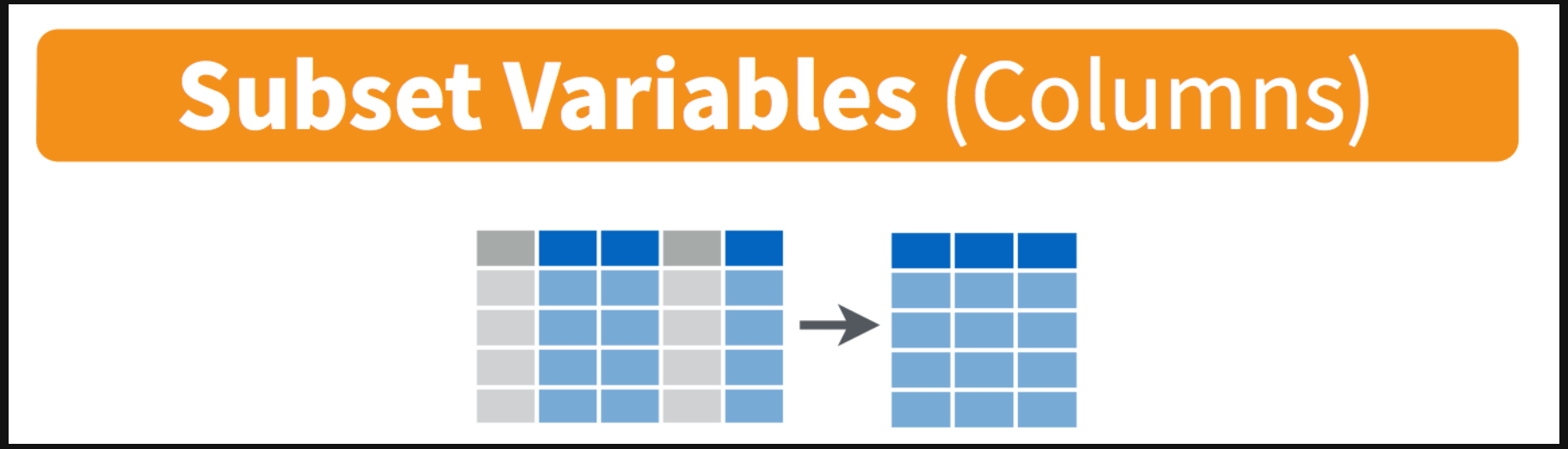
Core `tidyverse` concept:
Chain functions together with "pipes"

%>%

Think of the words "...and then..."

```
data %>%
  do_something() %>%
  do_something_else()
```

Select columns with `select()`



Select columns with `select()`

Select the columns `film` & `race`

```
lotr %>%
  select(film, race)
```

```
#> # A tibble: 18 × 2
#>    film                      race
#>    <chr>                     <chr>
#>  1 The Fellowship Of The Ring Elf
#>  2 The Fellowship Of The Ring Elf
#>  3 The Fellowship Of The Ring Hobbit
#>  4 The Fellowship Of The Ring Hobbit
#>  5 The Fellowship Of The Ring Man
#>  6 The Fellowship Of The Ring Man
#>  7 The Return Of The King     Elf
#>  8 The Return Of The King     Elf
#>  9 The Return Of The King     Hobbit
#> 10 The Return Of The King     Hobbit
#> 11 The Return Of The King     Man
#> 12 The Return Of The King     Man
```

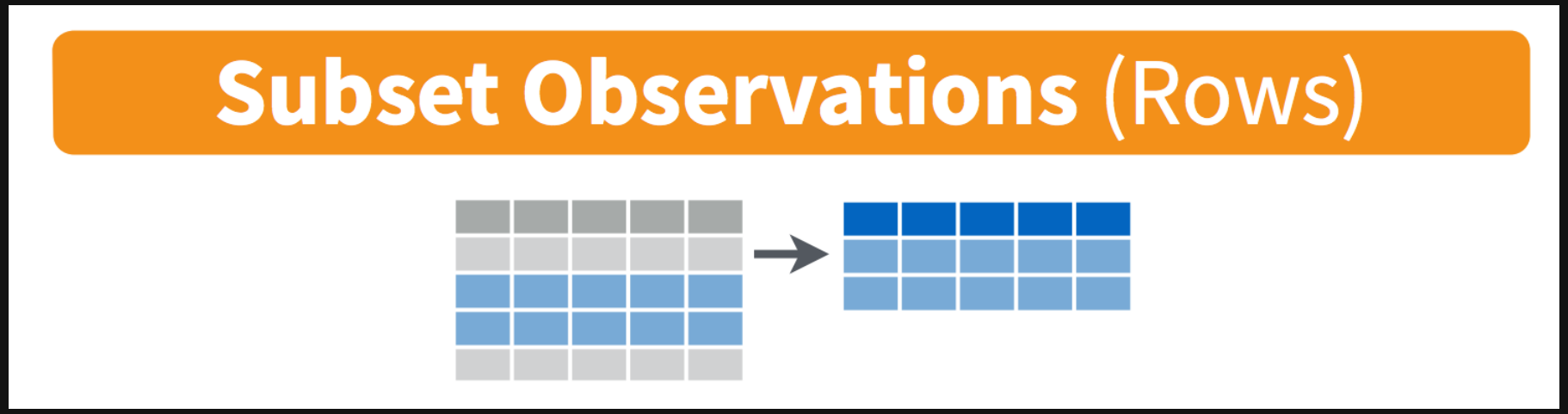
Select columns with `select()`

Use the – sign to drop columns

```
lotr %>%
  select(-film)
```

```
#> # A tibble: 18 × 3
#>    race   gender word_count
#>    <chr>  <chr>       <dbl>
#>  1 Elf    Female       1229
#>  2 Elf    Male          971
#>  3 Hobbit Female         14
#>  4 Hobbit Male         3644
#>  5 Man    Female          0
#>  6 Man    Male         1995
#>  7 Elf    Female        183
#>  8 Elf    Male          510
#>  9 Hobbit Female          2
#> 10 Hobbit Male         2673
#> 11 Man    Female        268
#> 12 Man    Male         2459
```

Filter for rows with `filter()`



Filter for rows with `filter()`

Keep only the rows with Elf characters

```
lotr %>%
    filter(race == "Elf")
```

```
#> # A tibble: 6 × 4
#>   film                      race  gender word_count
#>   <chr>                     <chr> <chr>       <dbl>
#> 1 The Fellowship Of The Ring Elf   Female       1229
#> 2 The Fellowship Of The Ring Elf   Male          971
#> 3 The Return Of The King     Elf   Female        183
#> 4 The Return Of The King     Elf   Male          510
#> 5 The Two Towers             Elf   Female        331
#> 6 The Two Towers             Elf   Male          513
```

Filter for rows with `filter()`

Keep only the rows with Elf or Hobbit characters

```
lotr %>%
    filter((race == "Elf") | (race  == "Hobbit"))
```

```
#> # A tibble: 12 × 4
#>    film                      race   gender word_count
#>    <chr>                     <chr>  <chr>       <dbl>
#>  1 The Fellowship Of The Ring Elf    Female       1229
#>  2 The Fellowship Of The Ring Elf    Male          971
#>  3 The Fellowship Of The Ring Hobbit Female         14
#>  4 The Fellowship Of The Ring Hobbit Male         3644
#>  5 The Return Of The King     Elf    Female       183
#>  6 The Return Of The King     Elf    Male         510
#>  7 The Return Of The King     Hobbit Female         2
#>  8 The Return Of The King     Hobbit Male         2673
#>  9 The Two Towers             Elf    Female       331
#> 10 The Two Towers             Elf    Male         513
#> 11 The Two Towers             Hobbit Female         0
#> 12 The Two Towers             Hobbit Male         2463
```

Filter for rows with `filter()`

Keep only the rows with Elf or Hobbit characters

```
lotr %>%
    filter(race %in% c("Elf", "Hobbit"))
```

```
#> # A tibble: 12 × 4
#>    film                      race   gender word_count
#>    <chr>                     <chr>  <chr>       <dbl>
#>  1 The Fellowship Of The Ring Elf    Female       1229
#>  2 The Fellowship Of The Ring Elf    Male          971
#>  3 The Fellowship Of The Ring Hobbit Female         14
#>  4 The Fellowship Of The Ring Hobbit Male         3644
#>  5 The Return Of The King     Elf    Female       183
#>  6 The Return Of The King     Elf    Male         510
#>  7 The Return Of The King     Hobbit Female         2
#>  8 The Return Of The King     Hobbit Male         2673
#>  9 The Two Towers             Elf    Female       331
#> 10 The Two Towers             Elf    Male         513
#> 11 The Two Towers             Hobbit Female         0
#> 12 The Two Towers             Hobbit Male         2463
```

Logic operators for `filter()`

Description	Example
Values greater than 1	`value > 1`
Values greater than or equal to 1	`value >= 1`
Values less than 1	`value < 1`
Values less than or equal to 1	`value <= 1`
Values equal to 1	`value == 1`
Values not equal to 1	`value != 1`
Values in the set c(1, 4)	`value %in% c(1, 4)`

Combine `filter()` and `select()`

Keep only the rows with Elf characters that spoke more than 1000 words, then select everything but the race column

```
lotr %>%
  filter((race == "Elf") & (word_count > 1000)) %>%
  select(-race)
```

```
#> # A tibble: 1 × 3
#>   film                      gender word_count
#>   <chr>                     <chr>       <dbl>
#> 1 The Fellowship Of The Ring Female       1229
```

Create new variables with `mutate()`

Create new variables with `mutate()`

Create a new variable, `word1000` which is `TRUE` if the character spoke 1,000 or more words

```
lotr %>%
    mutate(word1000 = word_count >= 1000)
```

```
#> # A tibble: 18 × 5
#>    film                      race   gender word_count word1000
#>    <chr>                     <chr>  <chr>       <dbl> <lgl>
#>  1 The Fellowship Of The Ring Elf    Female       1229 TRUE
#>  2 The Fellowship Of The Ring Elf    Male          971 FALSE
#>  3 The Fellowship Of The Ring Hobbit Female         14 FALSE
#>  4 The Fellowship Of The Ring Hobbit Male         3644 TRUE
#>  5 The Fellowship Of The Ring Man    Female          0 FALSE
#>  6 The Fellowship Of The Ring Man    Male         1995 TRUE
#>  7 The Return Of The King     Elf    Female        183 FALSE
#>  8 The Return Of The King     Elf    Male          510 FALSE
#>  9 The Return Of The King     Hobbit Female          2 FALSE
#> 10 The Return Of The King     Hobbit Male         2673 TRUE
#> 11 The Return Of The King     Man    Female        268 FALSE
```

Handling if/else conditions

ifelse(<condition>, <if TRUE>, <else>)

```
lotr %>%
    mutate(word1000 = ifelse(word_count >= 1000, TRUE, FALSE))
```

```
#> # A tibble: 18 × 5
#>    film                      race   gender word_count word1000
#>    <chr>                     <chr>  <chr>       <dbl> <lgl>
#>  1 The Fellowship Of The Ring Elf    Female       1229 TRUE
#>  2 The Fellowship Of The Ring Elf    Male          971 FALSE
#>  3 The Fellowship Of The Ring Hobbit Female         14 FALSE
#>  4 The Fellowship Of The Ring Hobbit Male         3644 TRUE
#>  5 The Fellowship Of The Ring Man    Female          0 FALSE
#>  6 The Fellowship Of The Ring Man    Male         1995 TRUE
#>  7 The Return Of The King     Elf    Female        183 FALSE
#>  8 The Return Of The King     Elf    Male          510 FALSE
#>  9 The Return Of The King     Hobbit Female          2 FALSE
#> 10 The Return Of The King     Hobbit Male         2673 TRUE
#> 11 The Return Of The King     Man    Female        268 FALSE
```

Sort data frame with `arrange()`

Sort the `lotr` data frame by `word_count`

```
lotr %>%
    arrange(word_count)
```

```
#> # A tibble: 18 × 4
#>    film                      race   gender word_count
#>    <chr>                     <chr>  <chr>       <dbl>
#>  1 The Fellowship Of The Ring Man    Female          0
#>  2 The Two Towers            Hobbit Female          0
#>  3 The Return Of The King    Hobbit Female          2
#>  4 The Fellowship Of The Ring Hobbit Female         14
#>  5 The Return Of The King    Elf    Female        183
#>  6 The Return Of The King    Man    Female        268
#>  7 The Two Towers            Elf    Female        331
#>  8 The Two Towers            Man    Female        401
#>  9 The Return Of The King    Elf    Male          510
#> 10 The Two Towers            Elf    Male          513
#> 11 The Fellowship Of The Ring Elf    Male          971
#> 12 The Fellowship Of The Ring Elf    Female       1229
```

Sort data frame with `arrange()`

Use the `desc()` function to sort in descending order

```
lotr %>%
    arrange(desc(word_count))
```

```
#> # A tibble: 18 × 4
#>    film                      race   gender word_count
#>    <chr>                     <chr>  <chr>       <dbl>
#>  1 The Fellowship Of The Ring Hobbit Male         3644
#>  2 The Two Towers            Man    Male         3589
#>  3 The Return Of The King    Hobbit Male         2673
#>  4 The Two Towers            Hobbit Male         2463
#>  5 The Return Of The King    Man    Male         2459
#>  6 The Fellowship Of The Ring Man    Male         1995
#>  7 The Fellowship Of The Ring Elf    Female       1229
#>  8 The Fellowship Of The Ring Elf    Male          971
#>  9 The Two Towers            Elf    Male          513
#> 10 The Return Of The King    Elf    Male          510
#> 11 The Two Towers            Man    Female        401
#> 12 The Two Towers            Elf    Female        331
```

Your turn

10:00

Read in the `data.csv` file in the "data" folder:

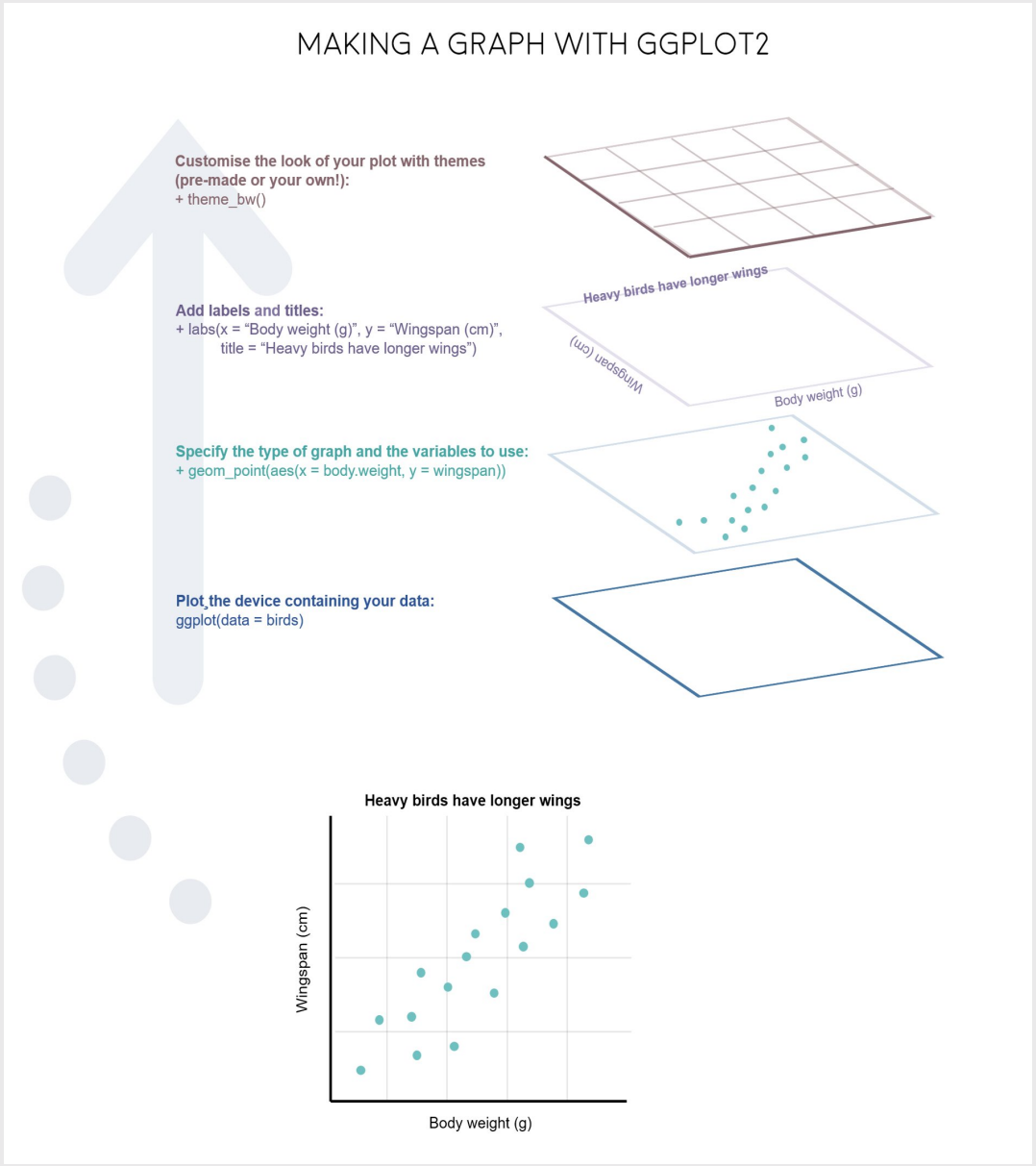
```
data <- read_csv(here('data', 'data.csv'))
```

Now answer these questions:

- Create a new data frame, `flights_fall`, that contains only flights that departed in the fall semester.
- Create a new data frame, `flights_dc`, that contains only flights that flew to DC airports (Reagan or Dulles).
- Create a new data frame, `flights_dc_carrier`, that contains only flights that flew to DC airports (Reagan or Dulles) and only the columns about the month and airline.
- How many unique airlines were flying to DC airports in July?
- Create a new variable, `speed`, in miles per hour using the `time` (minutes) and `distance` (miles) variables.
- Which flight flew the fastest?
- Remove rows that have `NA` for `air_time` and re-arrange the resulting data frame based on the longest air time and longest flight distance.

Week 1: *Getting Started*

1. Course Goal
2. Course Introduction
3. Break: Install Stuff
4. Workflow & Reading In Data
5. Wrangling Data
6. Visualizing Data



"Grammar of Graphics"

Concept developed by Leland Wilkinson (1999)

ggplot2 package developed by Hadley Wickham (2005)

Making plot layers with ggplot2

1. The data
2. The aesthetic mapping (what goes on the axes?)
3. The geometries (points? bars? etc.)
4. The annotations / labels
5. The theme

Layer 1: The data

```
head(mpg)
```

```
#> # A tibble: 6 × 11
#>   manufacturer model displ  year   cyl trans      drv     cty   hwy fl    class
#>   <chr>        <chr> <dbl> <int> <int> <chr>      <chr> <int> <int> <chr> <chr>
#> 1 audi         a4      1.8  1999     4 auto(l5)   f        18    29 p     compact
#> 2 audi         a4      1.8  1999     4 manual(m5) f        21    29 p     compact
#> 3 audi         a4      2    2008     4 manual(m6) f        20    31 p     compact
#> 4 audi         a4      2    2008     4 auto(av)   f        21    30 p     compact
#> 5 audi         a4      2.8  1999     6 auto(l5)   f        16    26 p     compact
#> 6 audi         a4      2.8  1999     6 manual(m5) f        18    26 p     compact
```

Layer 1: The data

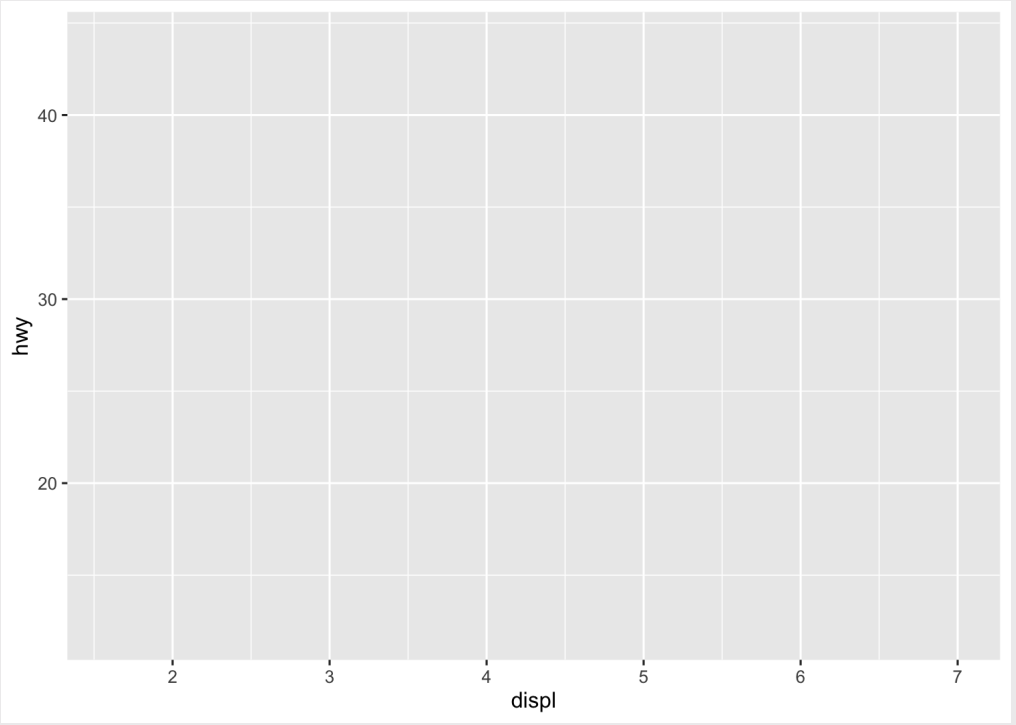
The `ggplot()` function initializes the plot with whatever data you're using

```
mpg %>%
  ggplot()
```

Layer 2: The aesthetic mapping

The `aes()` function determines which variables will be *mapped* to the geometries (e.g. the axes)

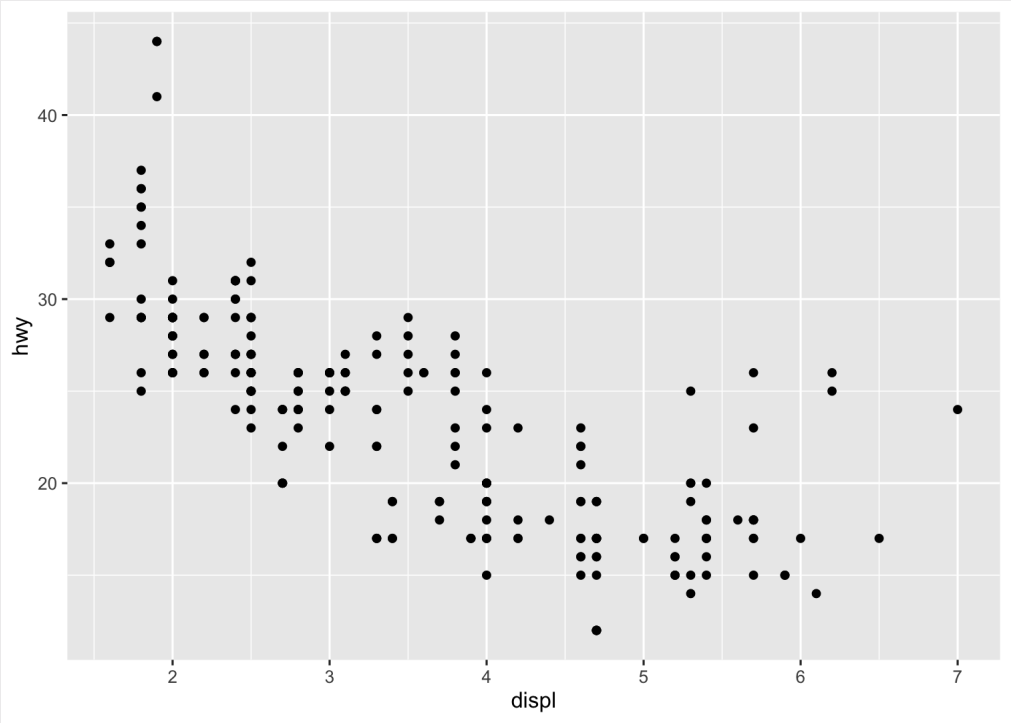
```
mpg %>%
  ggplot(aes(x = displ, y = hwy))
```



Layer 3: The geometries

Use `+` to add geometries, e.g. `geom_points()` for points

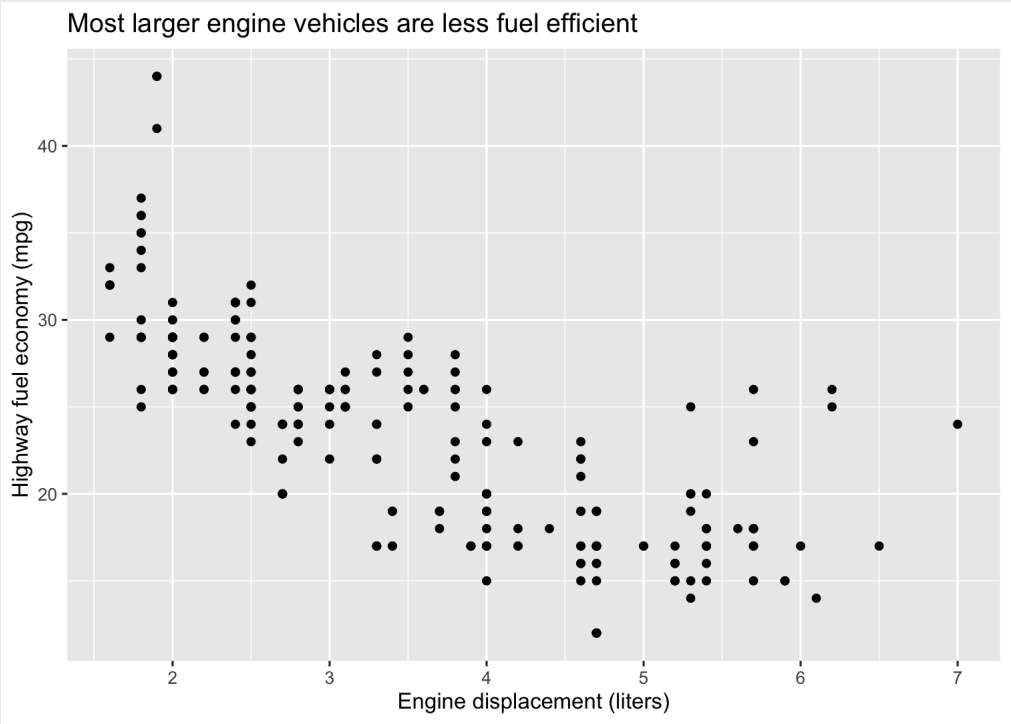
```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point()
```



Layer 4: The annotations / labels

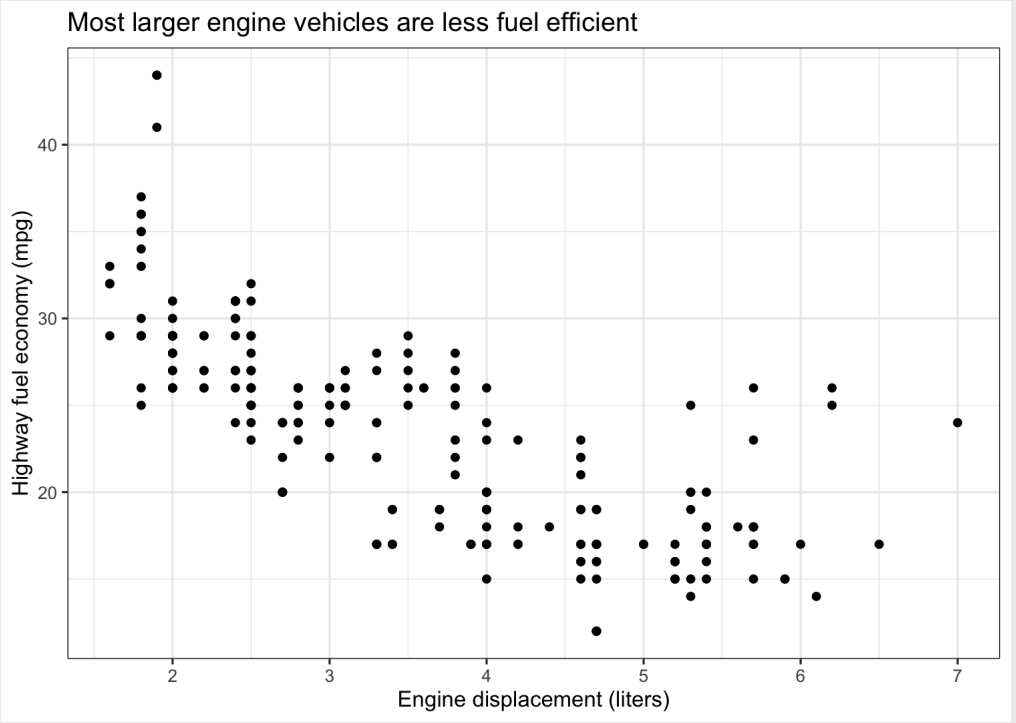
Use `labs()` to modify most labels

```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  labs(
    x = "Engine displacement (liters)",
    y = "Highway fuel economy (mpg)",
    title = "Most larger engine vehicles are
  )
```



Layer 5: The theme

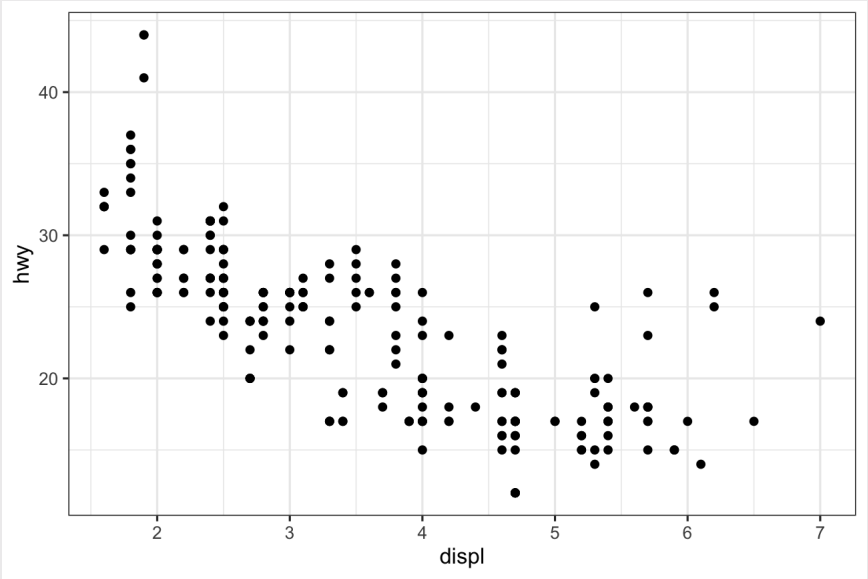
```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  labs(
    x = "Engine displacement (liters)",
    y = "Highway fuel economy (mpg)",
    title = "Most larger engine vehicles are
  ) +
  theme_bw()
```



Common themes

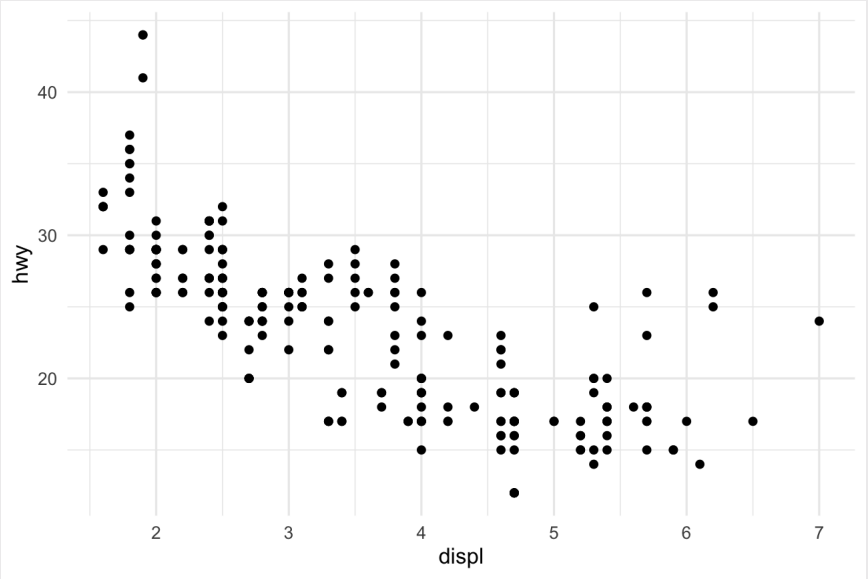
`theme_bw()`

```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  theme_bw()
```



`theme_minimal()`

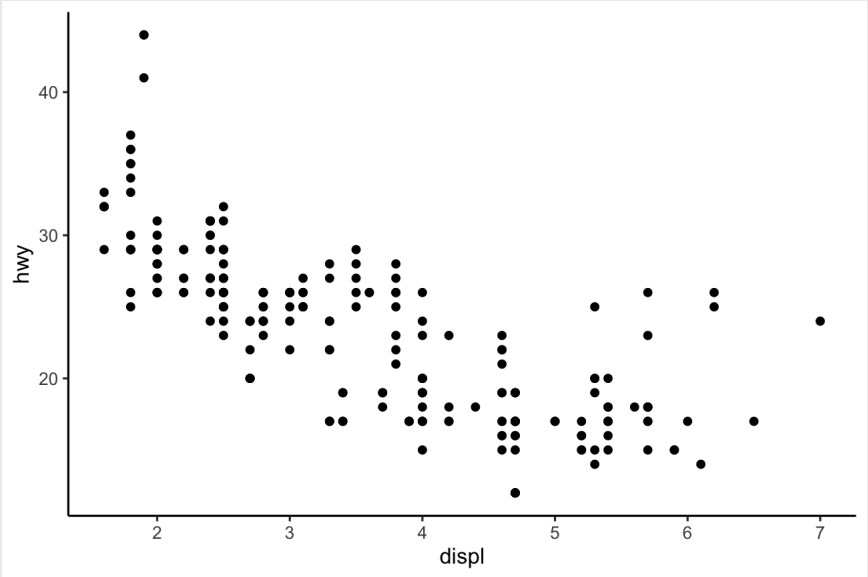
```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  theme_minimal()
```



Common themes

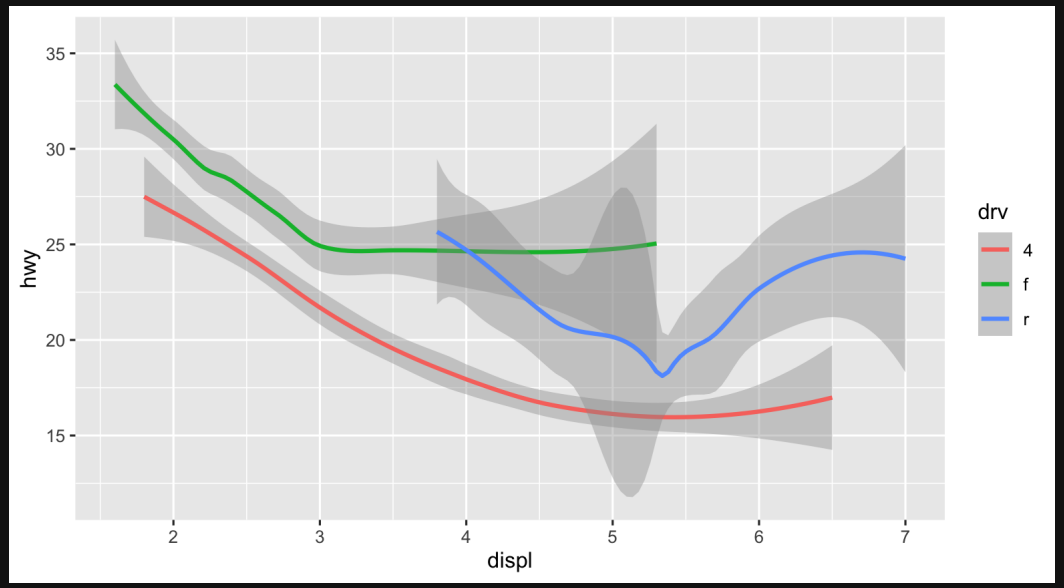
`theme_classic()`

```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  theme_classic()
```



`theme_void()`

```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  theme_void()
```

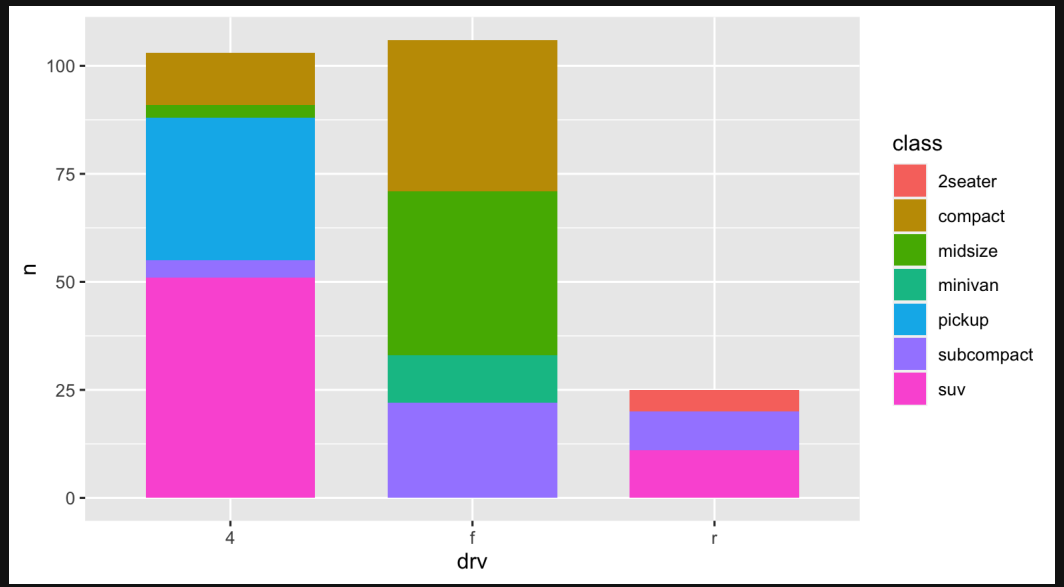


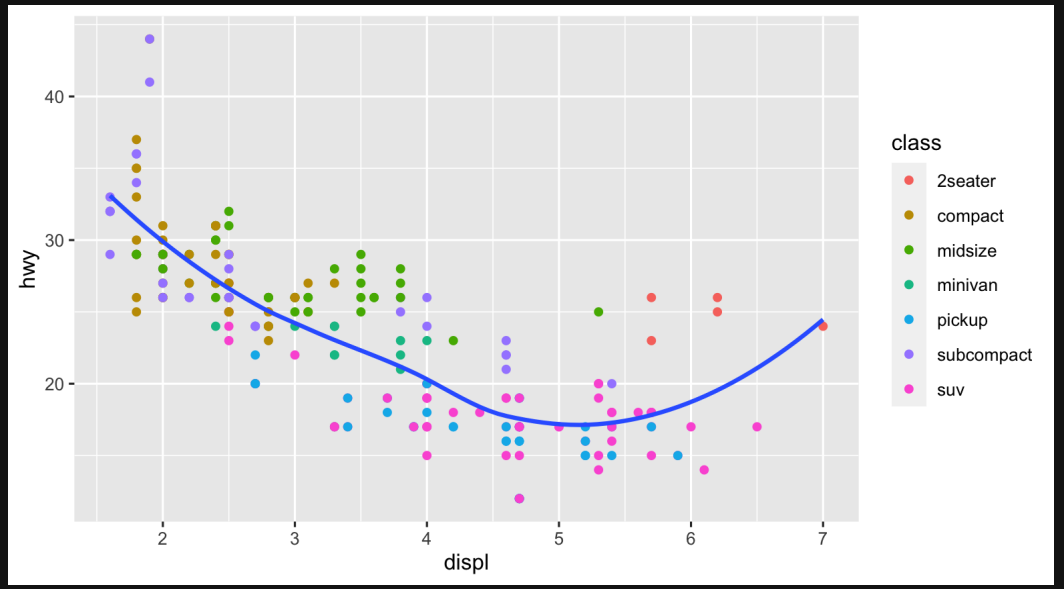
Your turn

15:00

Open `practice.Rmd`

Use the `mpg` data frame and ggplot to create these charts





Extra practice