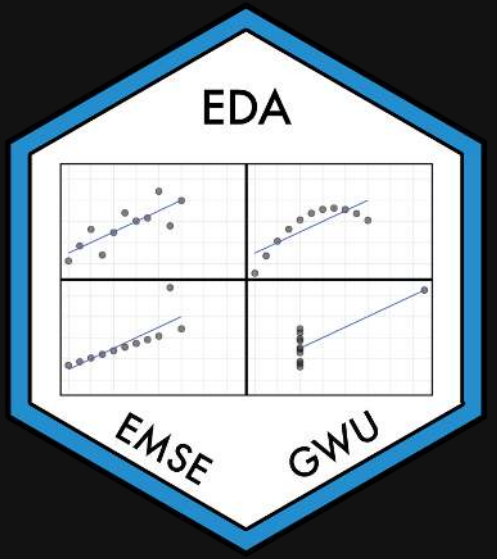

Week 1: *Getting Started*

EMSE 4572/6572: Exploratory Data Analysis

John Paul Helveston

August 27, 2025

Week 1: *Getting Started*

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

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Course 1: Intro to Programming for Analytics

"Computational Literacy"

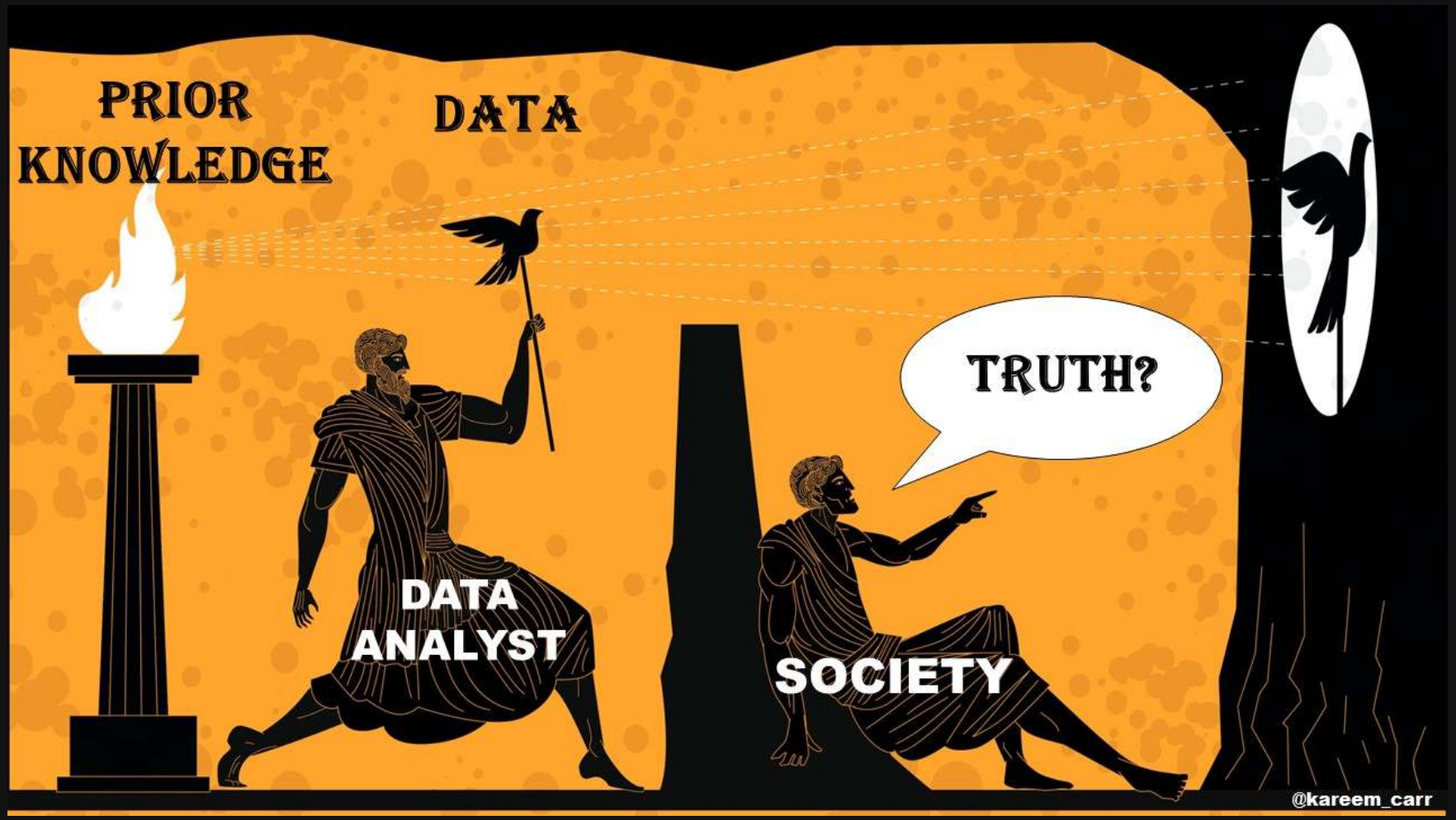
- Programming: Conditionals (if/else), loops, functions, testing, data types.
- Analytics: Data structures, import / export, basic data manipulation & visualization.

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*



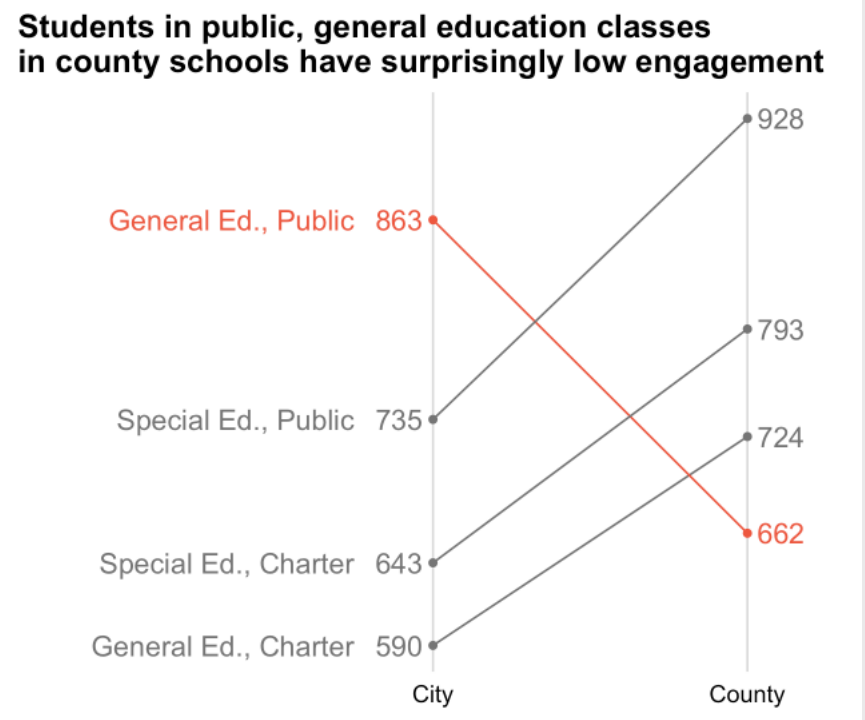
Class goal: translate *data* into *information*

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:

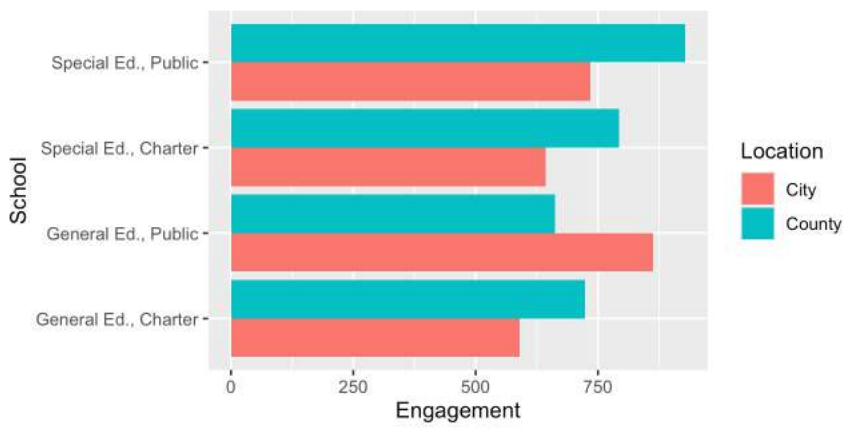
```
engagement_data <- engagement_data %>%
    gather(Location, Engagement, City:County) %>%
    mutate(Location = fct_relevel(
      Location, c('City', 'County')))
engagement_data
```

```
#>                 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
```

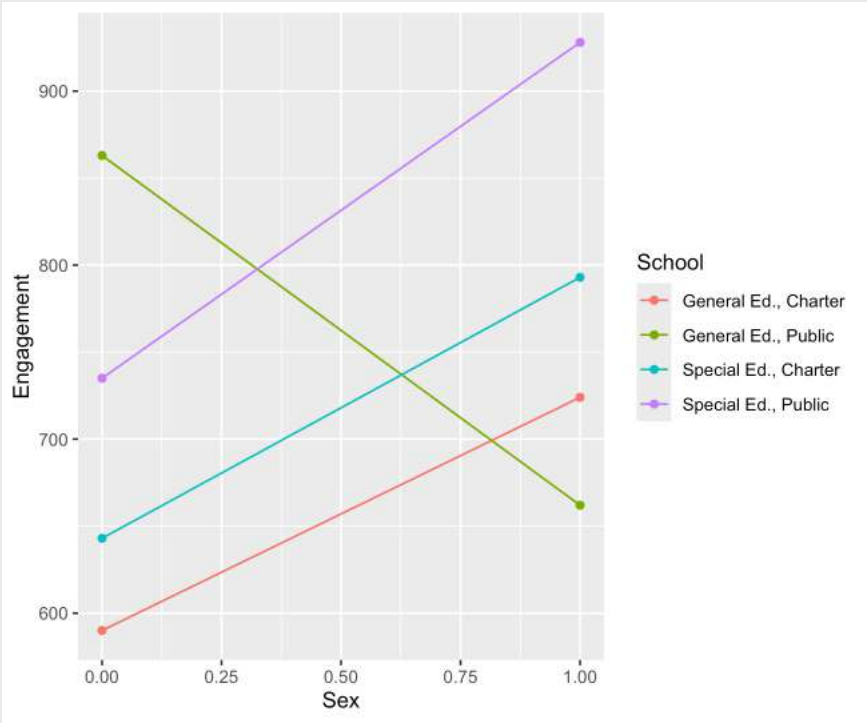
Data exploration: an iterative process

Initial exploratory plotting:

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

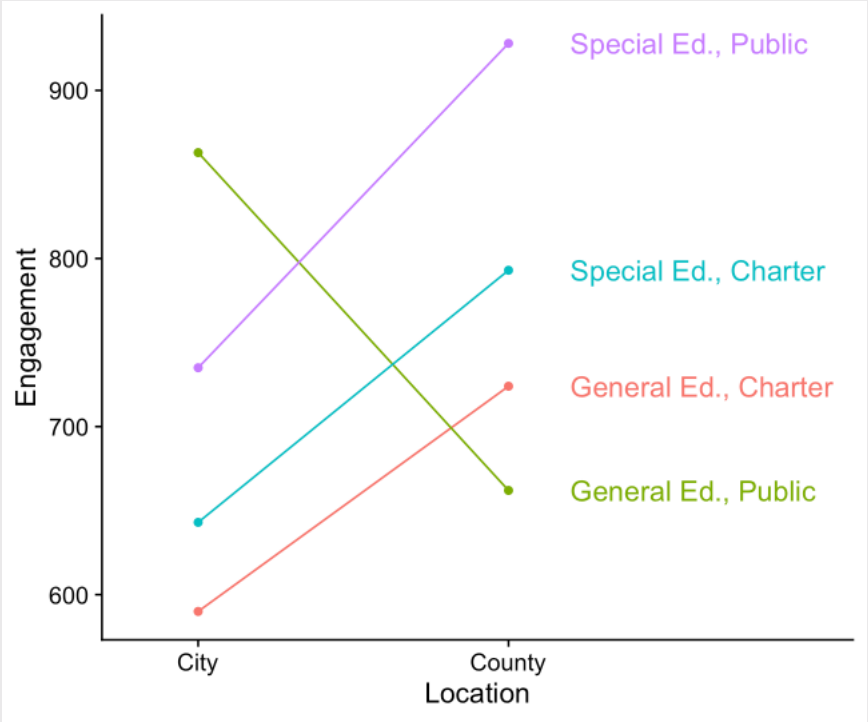


More exploratory plotting: highlight difference

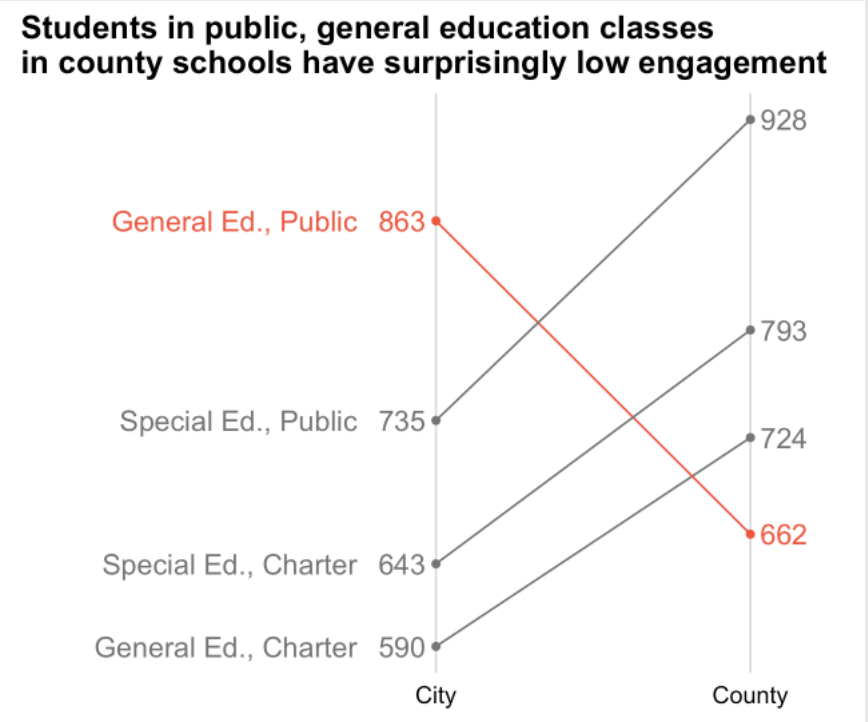


Data exploration: an iterative process

Directly label figure:



Remove unnecessary axes, change colors, fix labels:



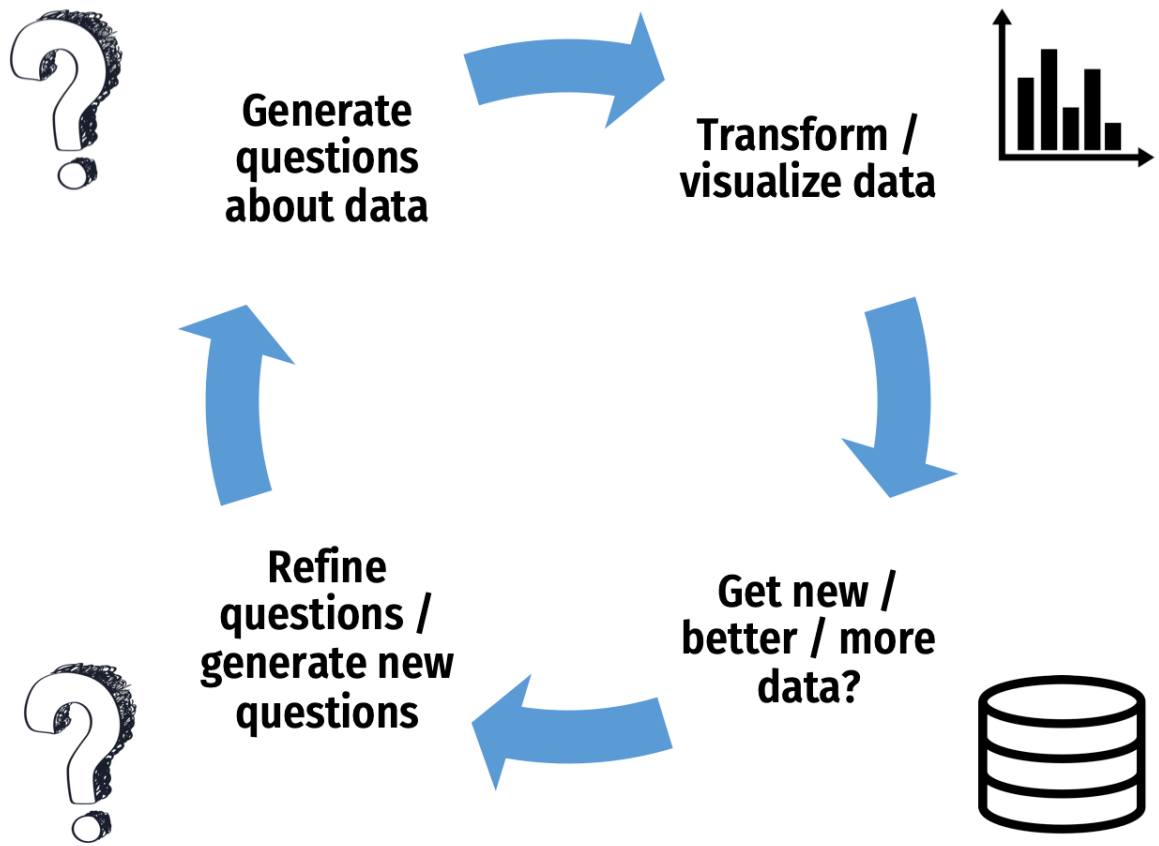
A fully reproducible analysis

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')
```

Data exploration: an iterative process



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Meet your instructor!

John Helveston, Ph.D.

- 2025 - Present: Associate Professor, EMSE
- 2018 - 2025: Assistant Professor, EMSE
- 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!

Pingfan Hu

- Graduate Teaching Assistant (GTA)
- PhD student in EMSE
- Website: www.pingfanhu.com

Meet your tutors!

Bogdan Bunea

- Learning Assistant (LA)
- EMSE Junior & P4A / EDA alumni
- Check out his team's project from 2023

Prerequisites

EMSE 4574 / 6574: 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/2025-Fall/

🗓 The schedule is the best starting point

Quizzes (10% of grade)

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

🗓 5 total, lowest dropped

🕓 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

Undergrads: Teams of 3 - 4 students

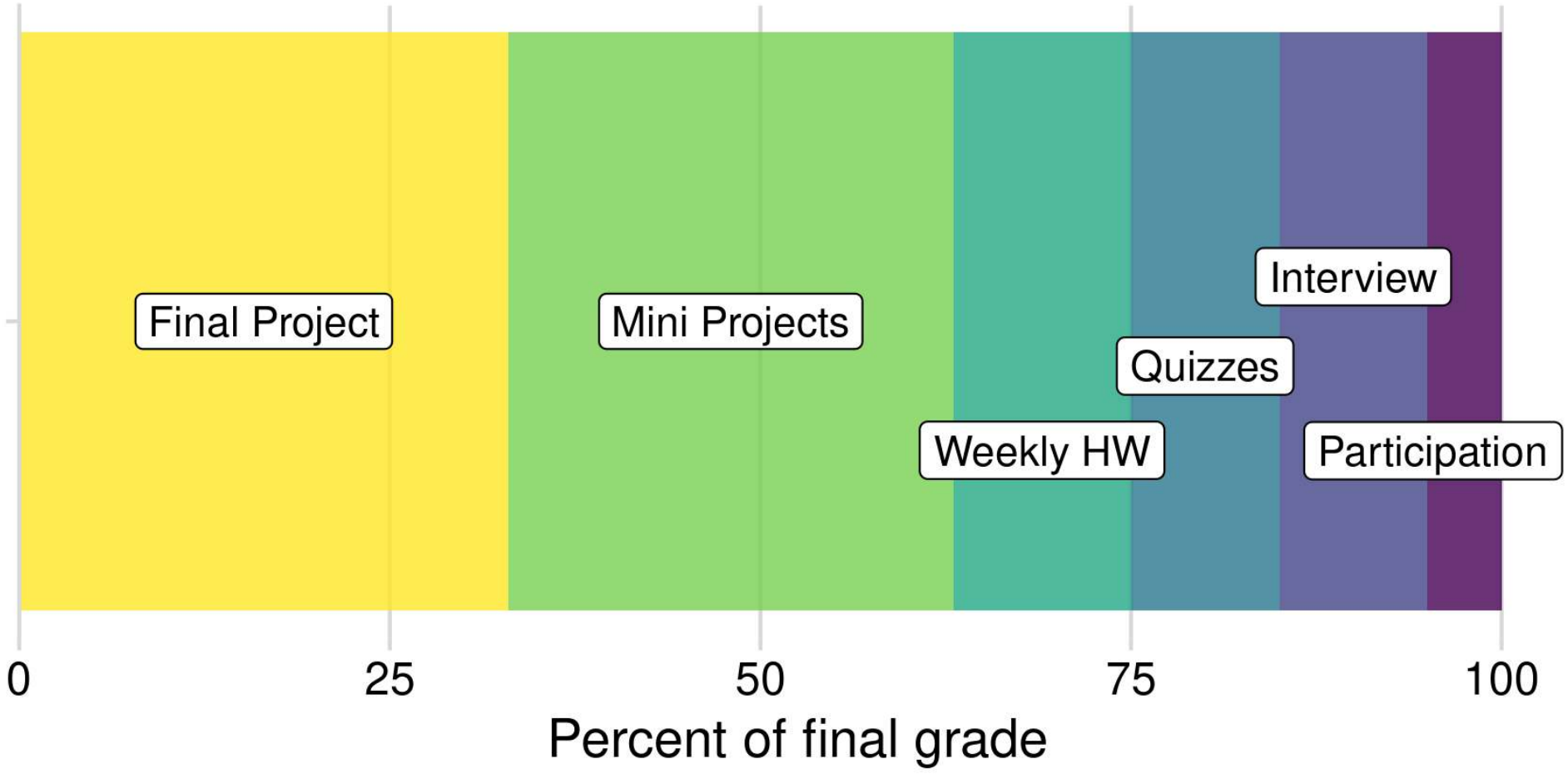
Grads: Teams of 2 students

Item	Due Date
Proposal	Sep 21
Progress Report	Oct 26
Final Report	Dec 07
Presentation	Dec 09

Grades

Item	Weight	Notes
Participation / Attendance	5%	(Yes, I take attendance)
Reflections	12 %	Weekly assignment, lowest dropped)
Quizzes	10 %	5 quizzes, lowest dropped
Mini Project 1	10 %	Individual assignments
Mini Project 2	10 %	
Mini Project 3	10 %	
Final Project: Proposal	6 %	
Final Project: Progress Report	6 %	
Final Project: Report	15 %	
Final Project: Presentation	6 %	
Final Interview	10 %	Individual interview

Grades


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

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

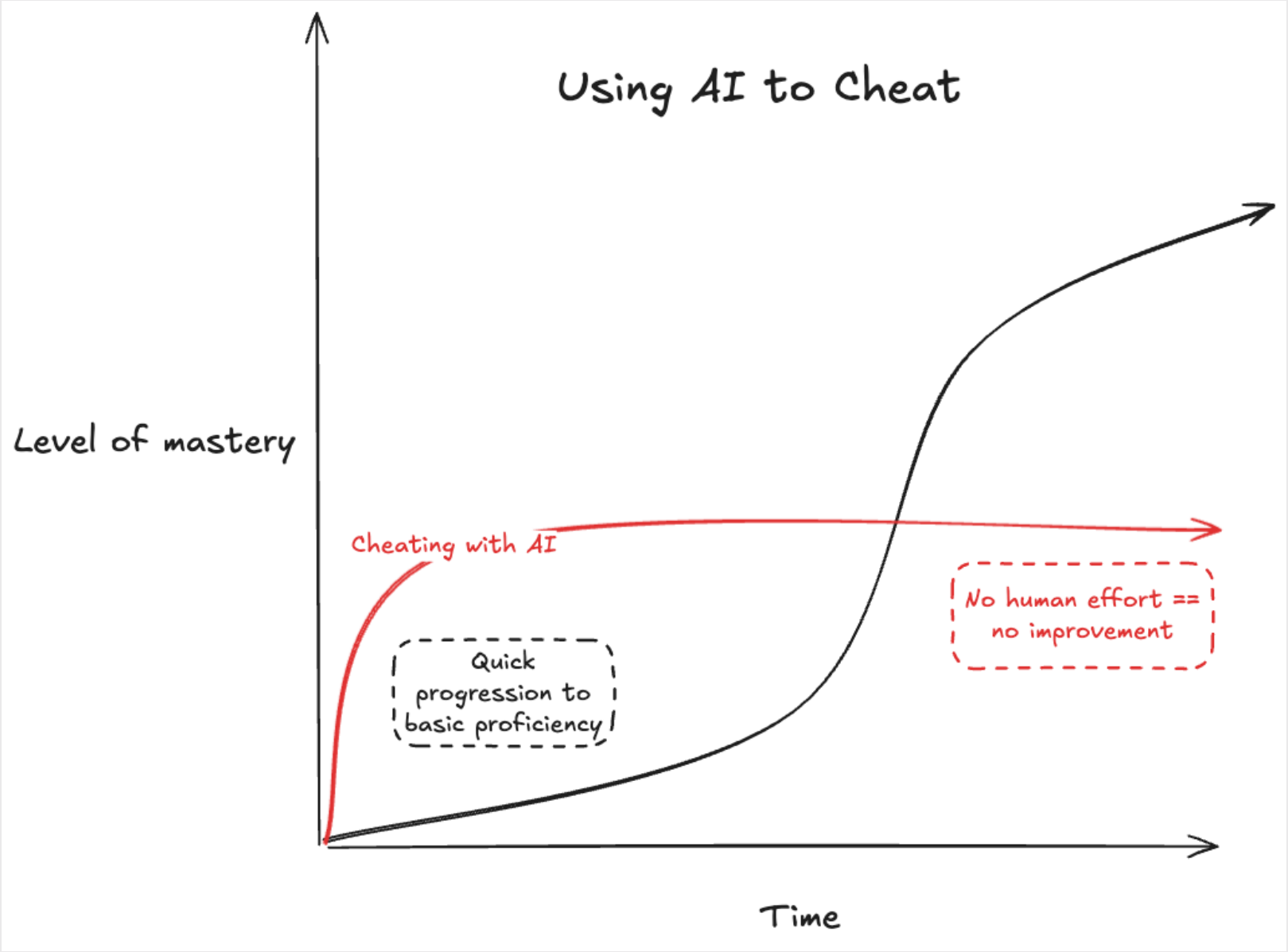
Use of chatGPT and other AI tools

- Large language models (LLMs) are pretty good
- Sometimes they suck.
- I will grade whatever you submit. **It should not suck.**

Ways to not have your work suck:

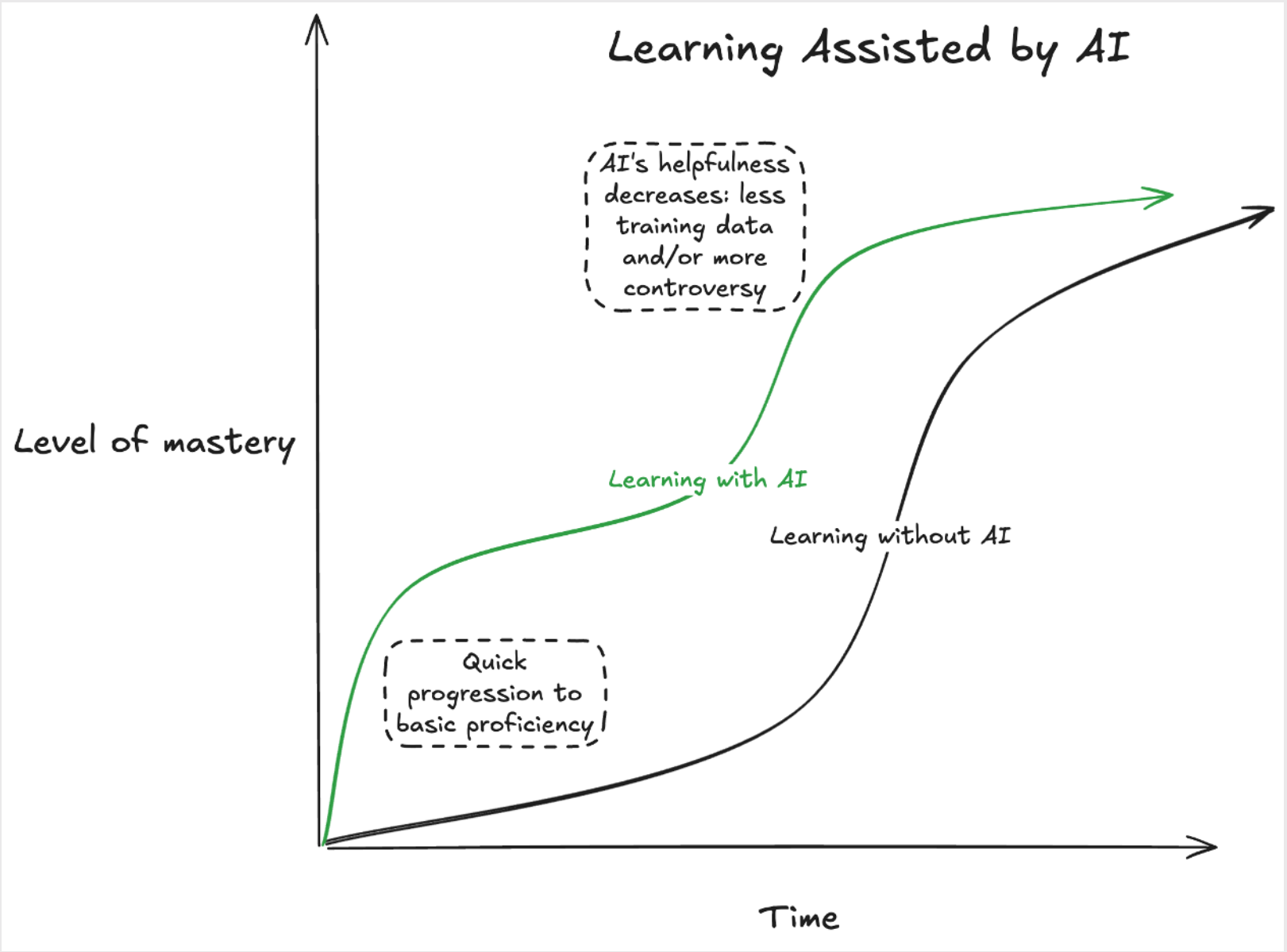
- Don't submit code that doesn't run (actually run it before submitting it).
- Actually read what the AI generates, and **don't submit something you don't understand**. (Ask the LLM how it works)
- There are dozens of ways to do things - **you should use the approach I teach**.
- Ask yourself **"what would I ask Prof. Helveston?"**

Use AI as an assistant, not a solutions manual



The **wrong** ways to use LLMs

Don't copy-paste past the basics - it'll rob you of mastery



The **right** way to use LLMs

- Asking to explain error messages
- Asking to explain *why* something works or doesn't work

Late submissions

- **3** 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 8:00-4:30pm
- Tuesdays from 8:00-4:30pm
- Fridays from 8:00-4:00pm

GW Coders

Course Software

Slack: **turn notifications on**!

R & RStudio (Install both)

Posit Cloud (Register for free!)

Break

1. If you haven't already, install everything on the software page
2. Stand up, meet each other, (maybe form teams?...use this sheet)

05:00

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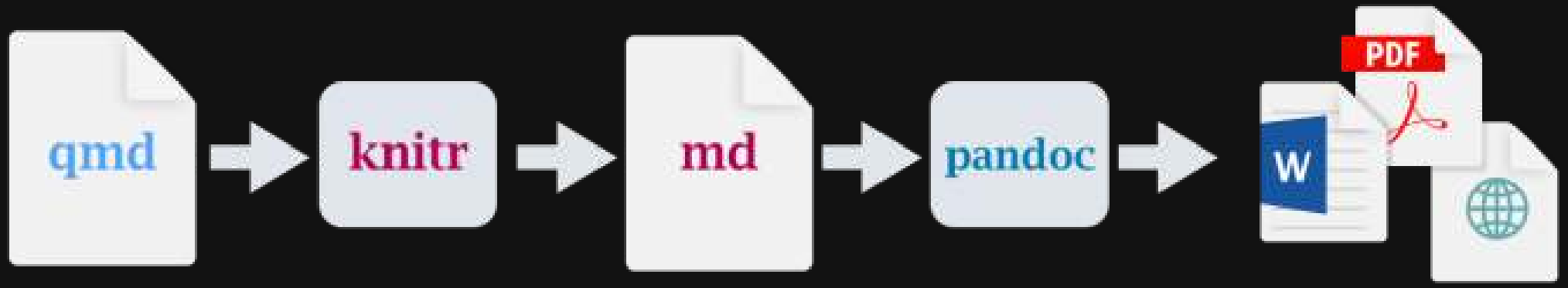
Quick demo

1. Open `quarto_demo.qmd`
2. Click "Render"



Anatomy of a .qmd file

Header

Markdown text

R code

Define overall document options in header

Basic html page

```
---
title: Your title
author: Author name
format: html
---
```

Add table of contents, change theme

```
---
title: Your title
author: Author name
toc: true
format:
  html:
    theme: united
---
```

More on themes at
https://quarto.org/docs/output-formats/html-themes.html

Render to multiple outputs

PDF uses LaTeX

```
---
title: Your title
author: Author name
format: pdf
---
```

If you don't have LaTeX on your computer, install tinytex in R:

```
tinytex::install_tinytex()
```

Microsoft Word

```
---
title: Your title
author: Author name
format: docx
---
```

Anatomy of a .qmd file

~~Header~~

Markdown text

R code

Right now, bookmark this! 👇

https://commonmark.org/help/

(When you have 10 minutes, do this! 👇)

https://commonmark.org/help/tutorial/

Headers

```
# HEADER 1

## HEADER 2

### HEADER 3

#### HEADER 4

##### HEADER 5

###### HEADER 6
```

HEADER 1

HEADER 2

HEADER 3

HEADER 4

HEADER 5

HEADER 6

Basic Text Formatting

Type this...

- `normal text`
- `_italic text_`
- `*italic text*`
- `**bold text**`
- `***bold italic text***`
- `~~strikethrough~~`
- `` `code text` ``

..to get this

- normal text
- *italic text*
- *italic text*
- **bold text**
- ***bold italic text***
- ~~strikethrough~~
- `code text`

Lists

Bullet list:

```
- first item
- second item
- third item
```

- first item
- second item
- third item

Numbered list:

```
1. first item
2. second item
3. third item
```

1. first item
2. second item
3. third item

Links

Simple **url link** to another site:

```
[Download R](http://www.r-project.org/)
```

Download R

Don't want to use Markdown?

Use Visual Mode!

Anatomy of a .qmd file

~~Header (think of this as the "settings")~~

~~Markdown text~~

R code

R Code

Inline code

````
`r insert code here`
````

Code chunks

````
```{r}
insert code here
insert more code here
```
````

Inline R code

```
The sum of 3 and 4 is `r 3 + 4`
```

Produces this:

The sum of 3 and 4 is 7

R Code chunks

This code chunk...

````
```{r}
library(palmerpenguins)

head(penguins)
```
````

...will produce this when compiled:

```r
library(palmerpenguins)

head(penguins)
```

```
#> # A tibble: 6 × 8
#>   species island    bill_length_mm bill_d
#>   <fct>   <fct>              <dbl>
#> 1 Adelie  Torgersen           39.1
#> 2 Adelie  Torgersen           39.5
#> 3 Adelie  Torgersen           40.3
#> 4 Adelie  Torgersen           NA
#> 5 Adelie  Torgersen           36.7
#> 6 Adelie  Torgersen           39.3
```

Chunk options

Control what chunks output using options

All options here

option	default	effect
`eval`	TRUE	Whether to evaluate the code and include its results
`echo`	TRUE	Whether to display code along with its results
`warning`	TRUE	Whether to display warnings
`error`	FALSE	Whether to display errors
`message`	TRUE	Whether to display messages
`tidy`	FALSE	Whether to reformat code in a tidy way when displaying it
`results`	"markup"	"markup", "asis", "hold", or "hide"
`cache`	FALSE	Whether to cache results for future renders
`comment`	"##"	Comment character to preface results with
`fig.width`	7	Width in inches for plots created in chunk
`fig.height`	7	Height in inches for plots created in chunk

Chunk output options

By default, code chunks print **code** + **output**

````
```{r}
#| echo: false

cat('hello world!')
```
````

Prints only **output**
(doesn't show code)

```
#> hello world!
```

````
```{r}
#| eval: false

cat('hello world!')
```
````

Prints only **code**
(doesn't run the code)

```
cat('hello world!')
```

````
```{r}
#| include: false

cat('hello world!')
```
````

Runs, but doesn't print anything

A global `setup` chunk 🌍

````
```{r}
#| label: setup
#| include: false

knitr::opts_chunk$set(
    warning = FALSE,
    message = FALSE,
    fig.path = "figs/",
    fig.width = 7.252,
    fig.height = 4,
    comment = "#>",
    fig.retina = 3
)
```
````

- Typically the first chunk
- All following chunks will use these options (i.e., sets global chunk options)
- You can (and should) use individual chunk options too
- Often where I load libraries, etc.

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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", "34
#> $ Taiwan          <chr> "NA", "NA", "NA", "NA", "NA", "NA", "3.5", "8", "17", "39.299999999999997", "88", "16
#> $ 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.qmd` file.

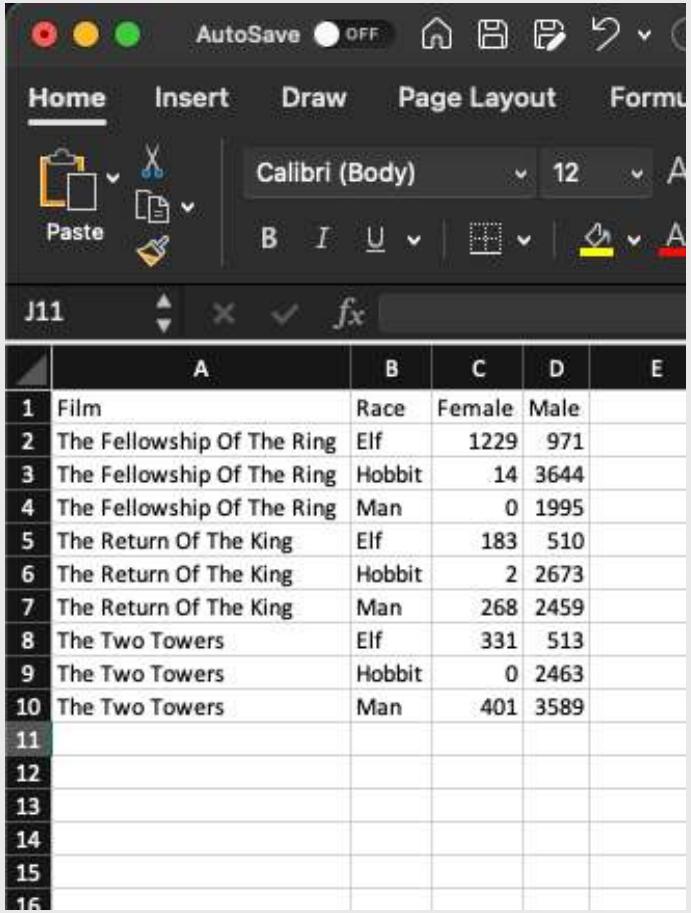
Write code to import the following data files from the "data" folder:

- 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`

Week 1: *Getting Started*

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

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
#> 14 The Two Towers             Elf    Male
```

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

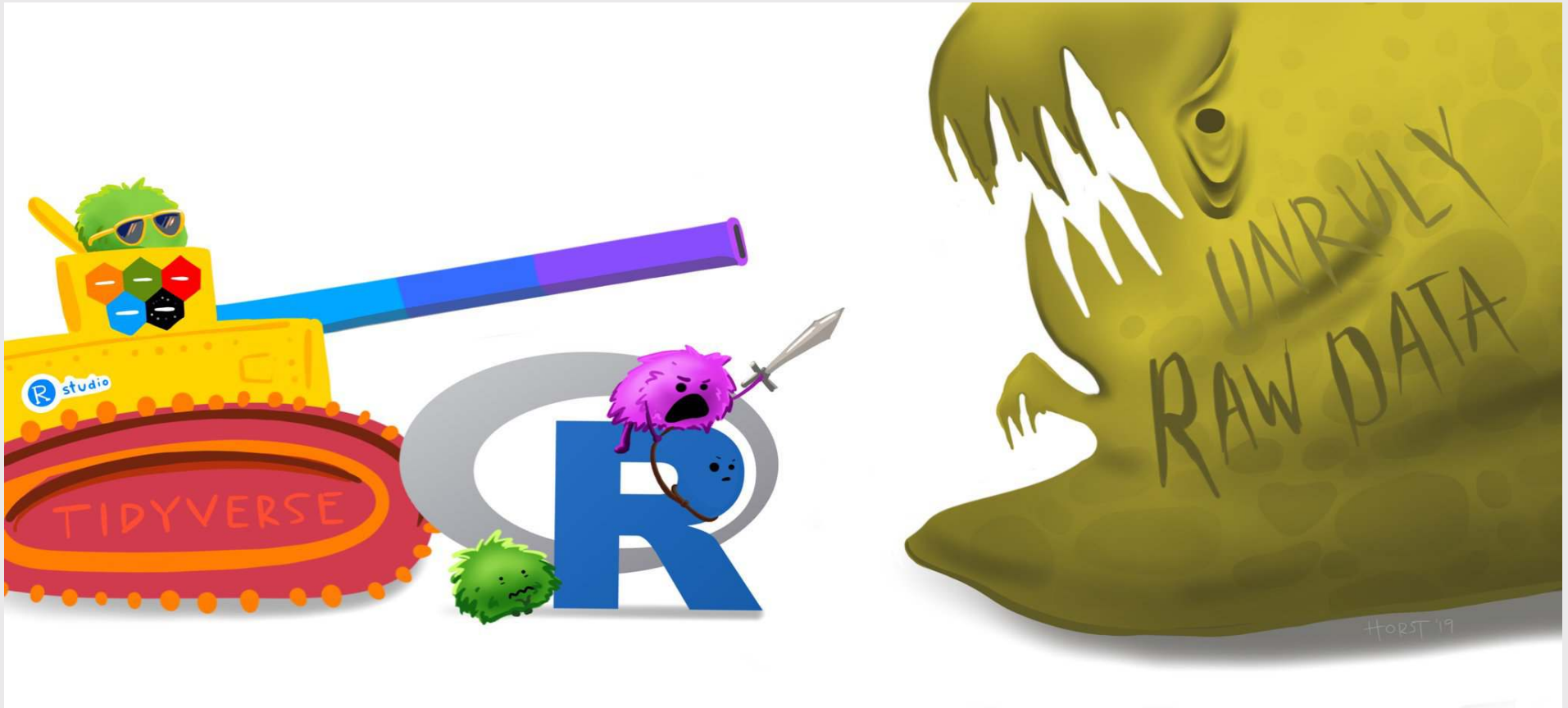
Read in the `data.csv` file in the "data" folder:

```
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

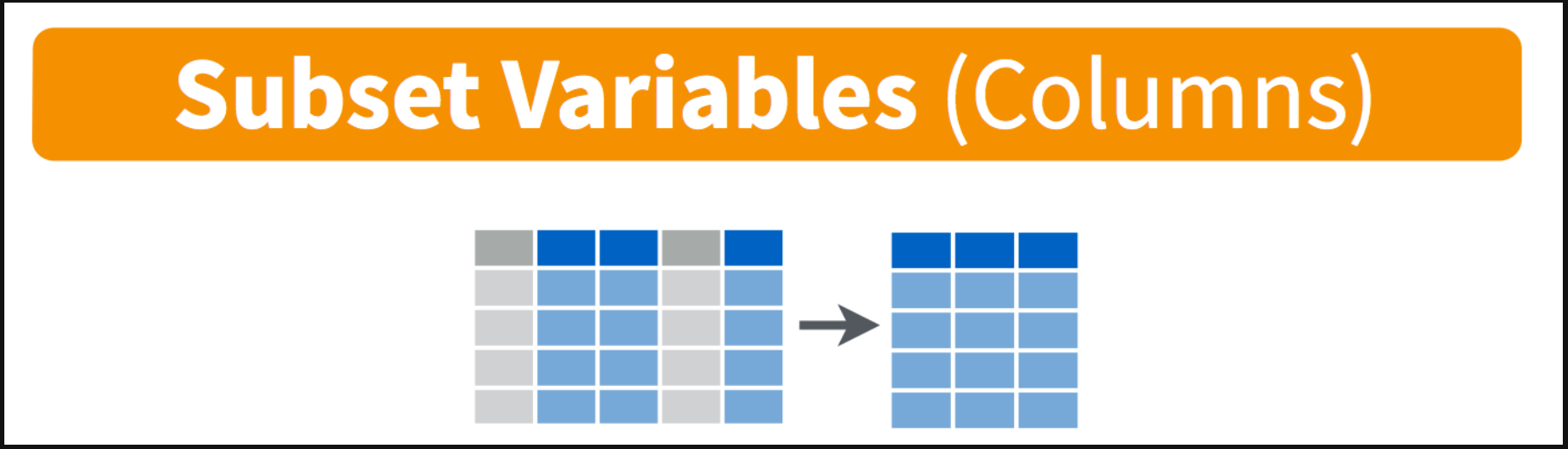
Core `tidyverse` concept:
Chain functions together with "pipes"

`%>%`

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
#> 13 The Two Towers             Elf
```

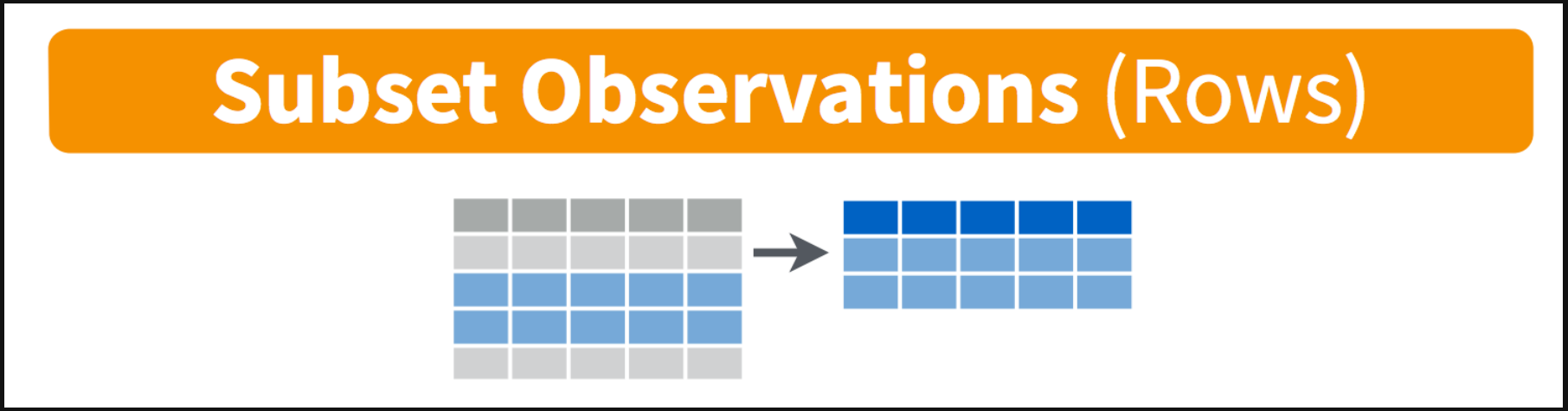
Select columns with `select()`

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
#> 13 Elf    Female        331
```

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
#> 12 The Return Of The King     Man    Male         2459 TRUE
```

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
#> 13 The Fellowship Of The Ring Man    Male         1995
```

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
#> 13 The Return Of The King    Man    Female        268
```

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
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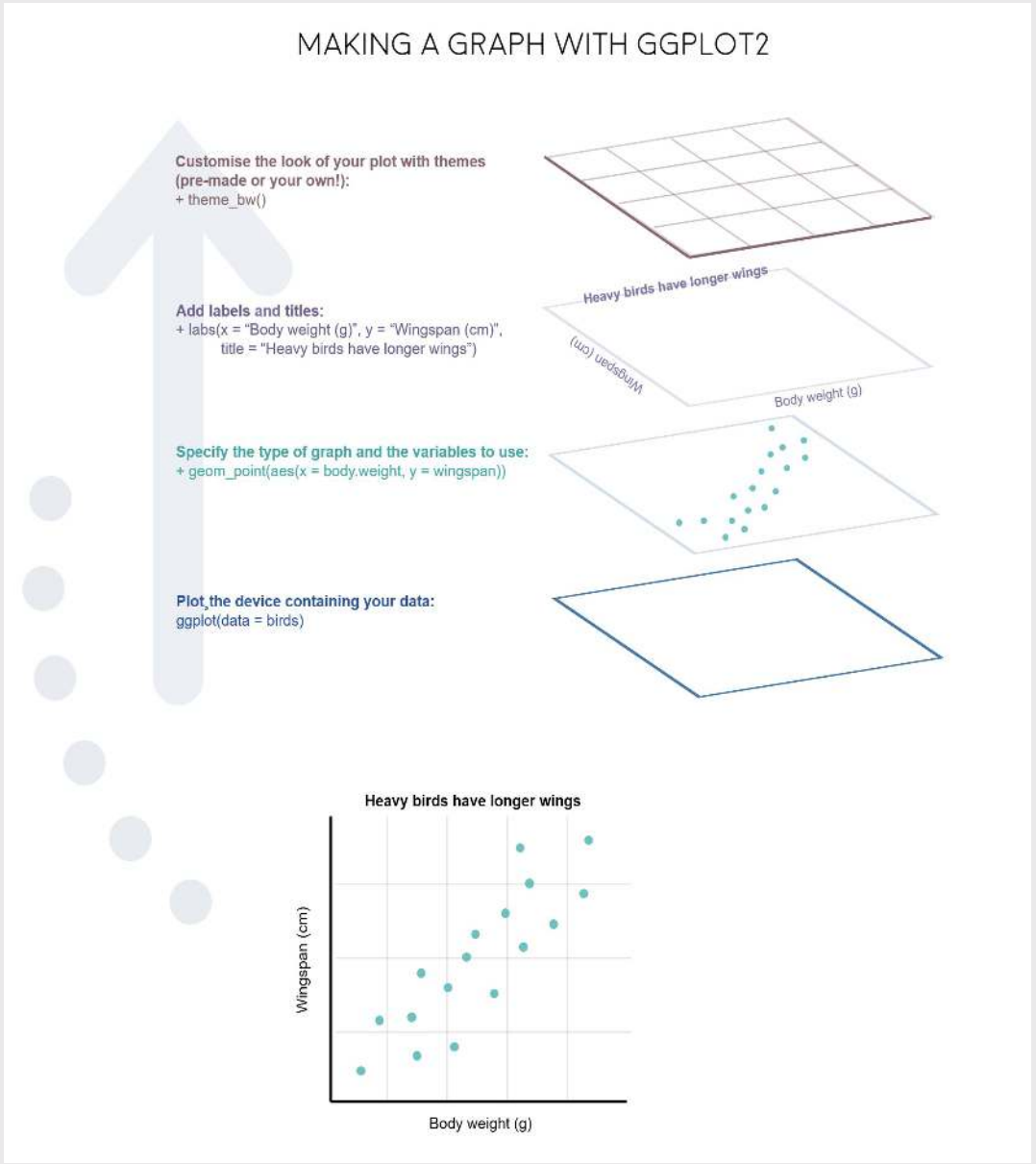
7. Visualizing Data



"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

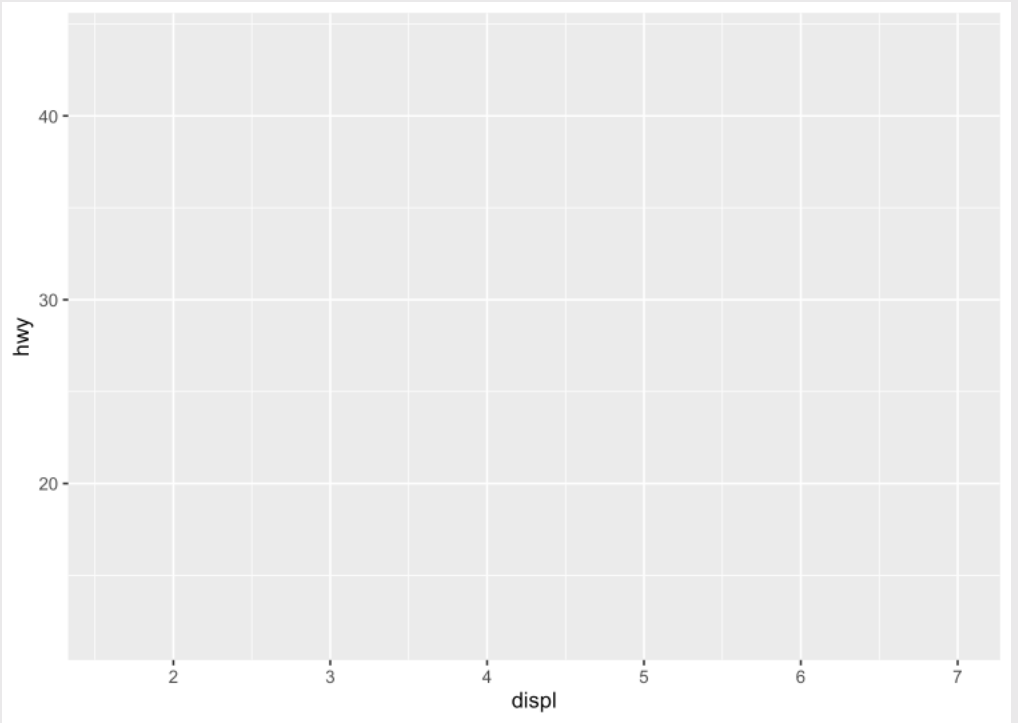
The `ggplot()` function initializes the plot with whatever data you're using

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

Layer 2: The aesthetic mapping

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

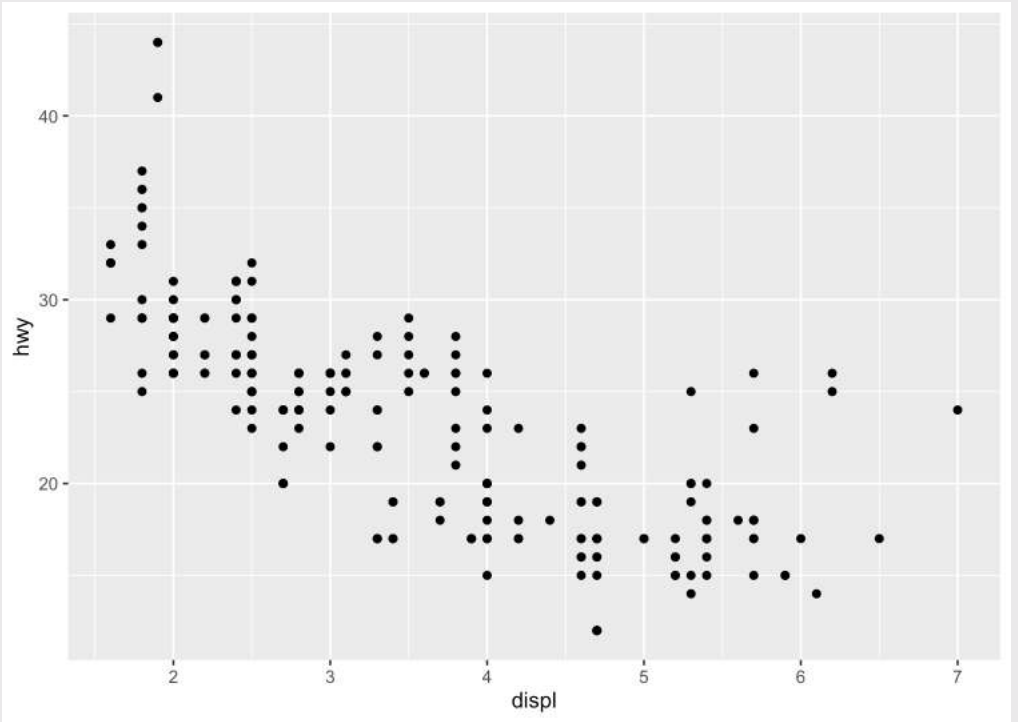
```
mpg %>%
  ggplot(aes(x = displ, y = hwy))
```



Layer 3: The geometries

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

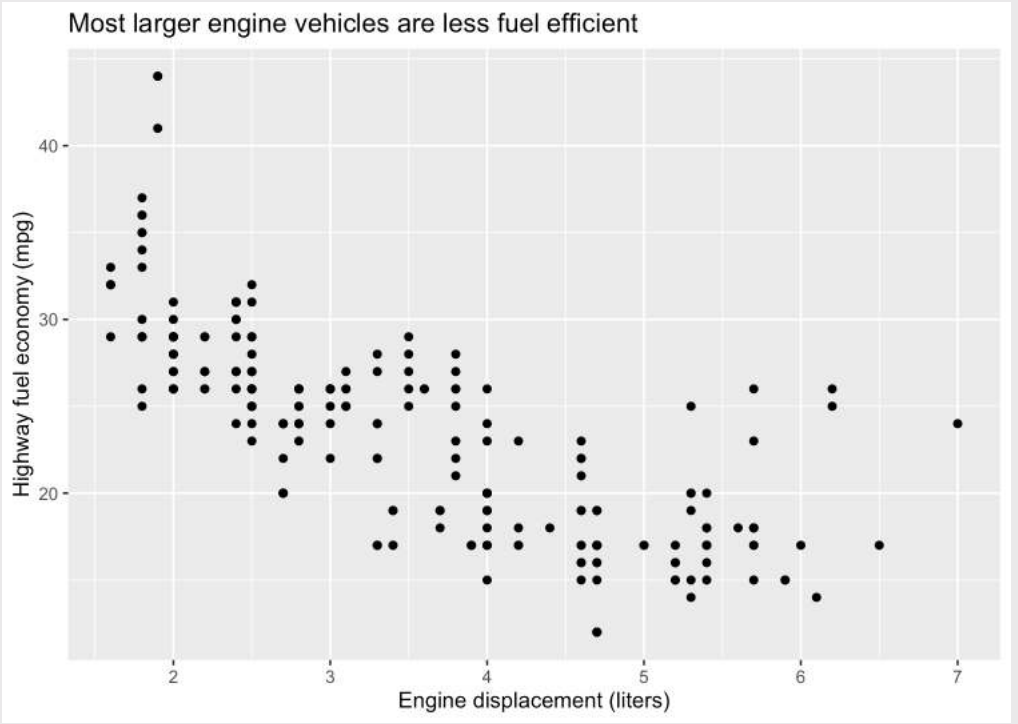
```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point()
```



Layer 4: The annotations / labels

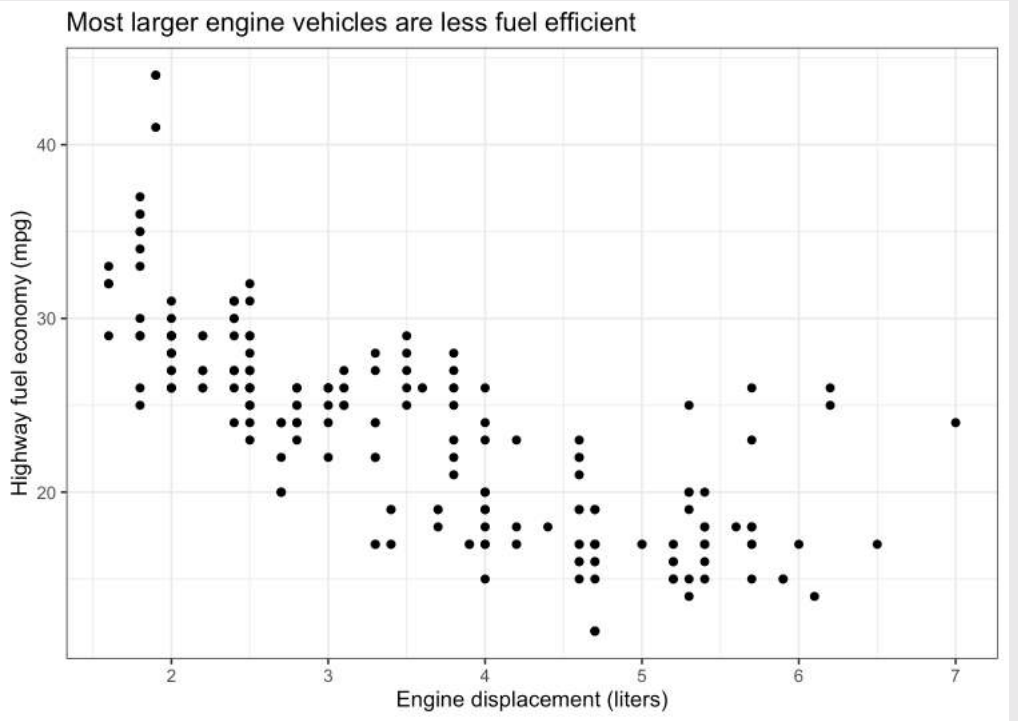
Use `labs()` to modify most labels

```
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

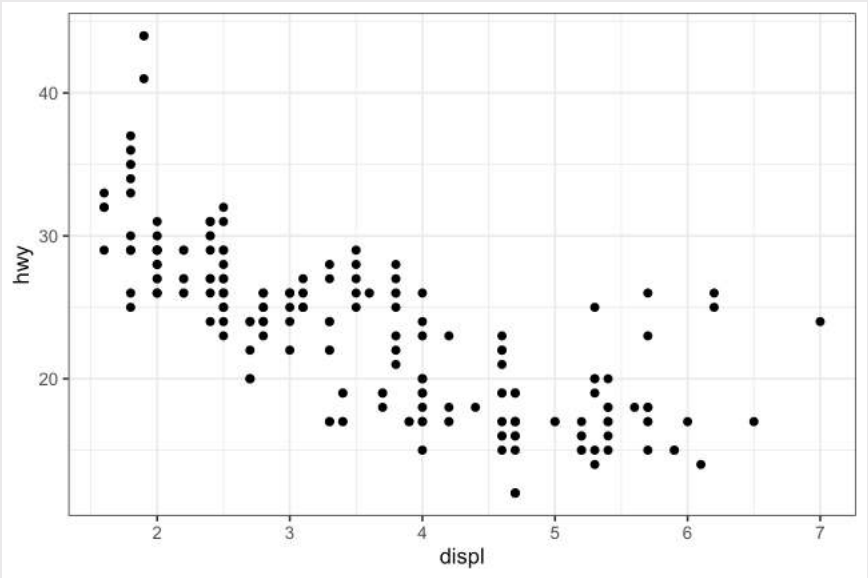
```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  labs(
    x = "Engine displacement (liters)",
    y = "Highway fuel economy (mpg)",
    title = "Most larger engine vehicles are
  ) +
  theme_bw()
```



Common themes

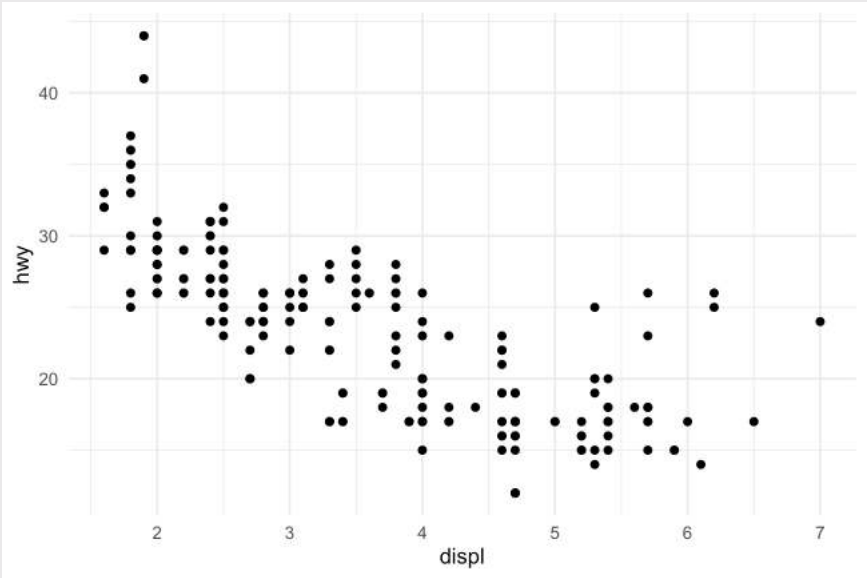
`theme_bw()`

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



`theme_minimal()`

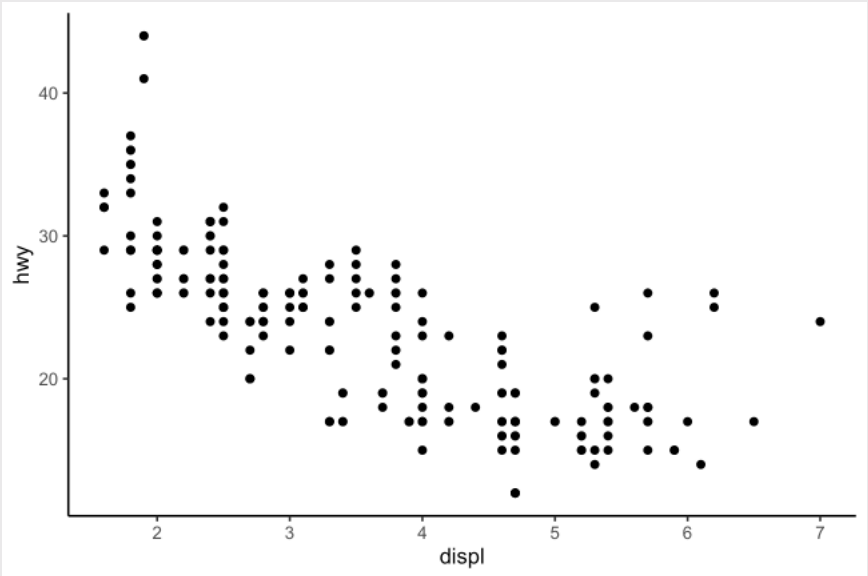
```
mpg %>%
  ggplot(aes(x = displ, y = hwy)) +
  geom_point() +
  theme_minimal()
```



Common themes

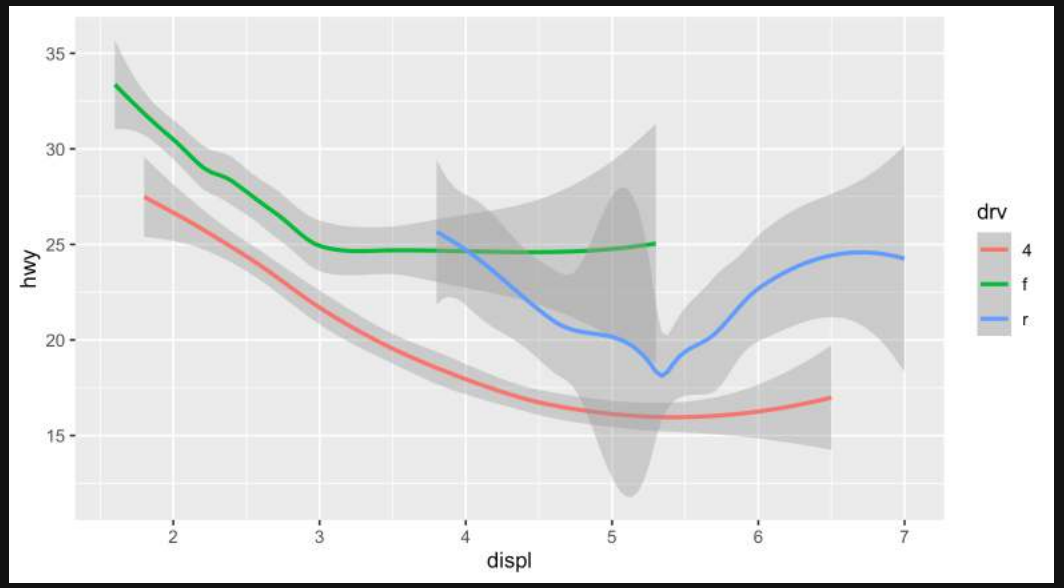
`theme_classic()`

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



`theme_void()`

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

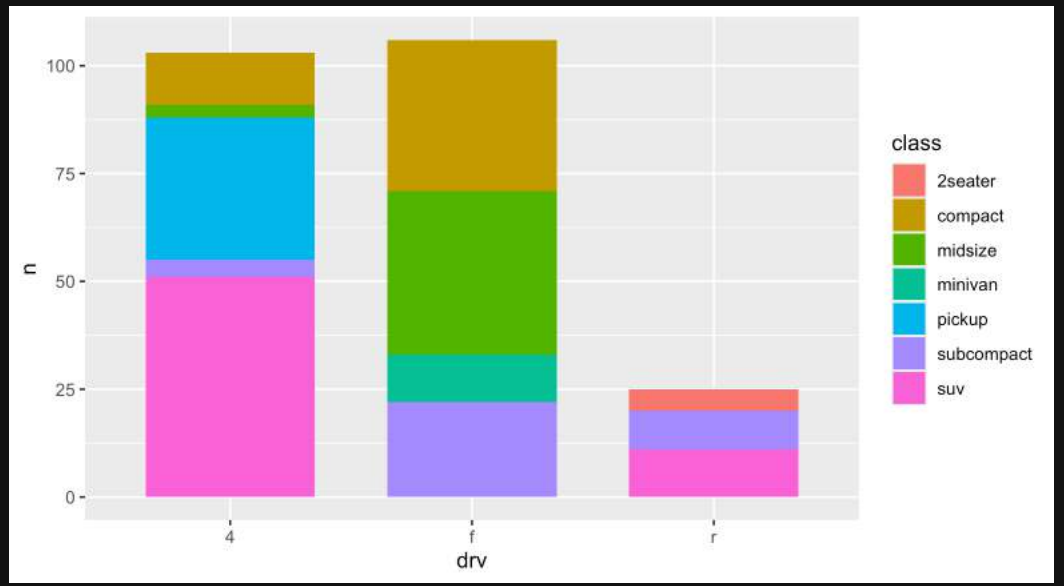


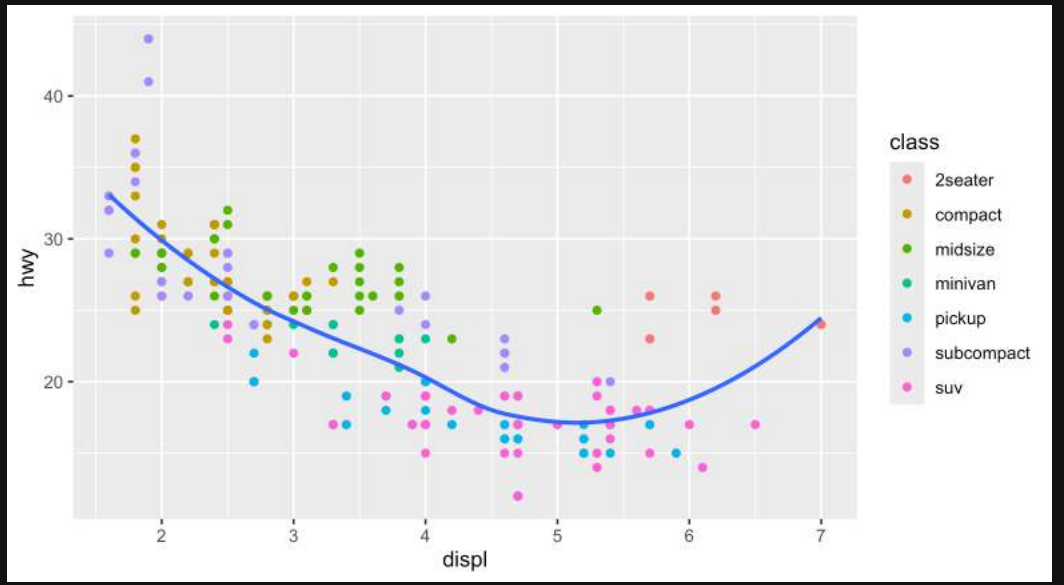
Your turn

15:00

Open `practice.qmd`

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





Extra practice