Module 1: Tidyverse Basics; Data Wrangling & Graphing; Using LLMs to generate R code

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Methods and computing camp

This summer we will together learn and review materials of statistical computing and methods.

What do we do during lectures?

Materials will be available at course website. Lecture notes are created by Rmarkdown.

- **If you have questions, feel free to interrupt or send a message in the chat.**

We will cover 5 modules of statistical methods and computing.

- Each module takes ~1.75 hours.

What contents we will cover?

Module	Topics	References
1	Tidyverse basics; data wrangling & graphing; Using LLMs to generate R code	-
2	Statistical inference (I)	AoS Chp 1-5; AoS Chp 6; C&B Chp 6.3, 7
3	Statistical inference (II)	AoS Chp 8; C&B Chp 8
4	Linear Regression & Generalized Linear Models	AoS Chp 13; C&B Chp 11-12
5	Simulation and parallel computing	C&B Chap 10; AoS Chp 5, 24;

What contents we will not cover?

- Nonparametric inference (STA3000)
- Bayesian inference (STA3000, STA2201)
- Computing of Bayesian inference (STA2201)
- Shiny and blogdown in R

Exercises!

- Available for each module.
- Exercises can be difficult.
- Group discussion is recommended.

Prerequisites:

- Students are expected to have some basic experience with R, Rmarkdown and LaTeX.
- See Module 0 for some background

Code style

- Tidyverse style guide
- `styler` software embedded in Rstudio - allows you to interactively restyle selected text, files, or entire projects.
- `lintr` software embedded in Rstudio - performs automated checks to confirm that you conform to the style guide.

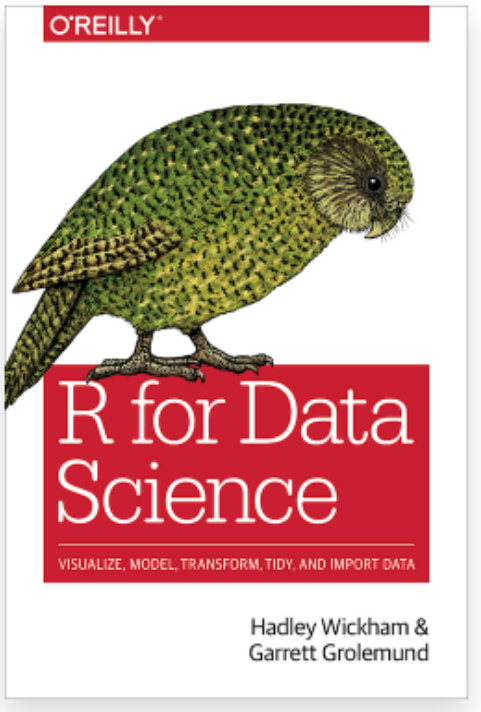
Outline

We will review R, Rstudio, and Syntax of R together.

- Tidy data, processing (tidyverse)
- Graphing (ggplot2)

Resources

- "R for Data Science: Import, Tidy, Transform, Visualize, and Model Data" by Hadley Wickham.
- Brendan R. E. Ansell's "Introduction to R - tidyverse" [link]



Data import

```r
df <- read.table("mtcars.txt", header = TRUE)
head(df) # Show the first 6 rows.
```

```
##   Cntry lper100k weight length
## 1    US     19.8   2178   5.92
## 2 Japan      9.9   1026   4.32
## 3    US     10.8   1188   4.27
## 4    US     12.5   1444   5.11
## 5    US     12.5   1485   5.03
## 6    US     12.5   1485   5.03
```

Other options

CSV files.

- read.csv() in the base r.
- readr::read_csv() in "readr" package (much faster).
- data.table::fread() in "data.table" package (much more faster).

RData.

- load() in the base r.

Tidy data

The goal is to clean the dataset so it is much easier to use.

Specifically,

- Each variable must have its own column.
- Each observation must have its own row.
- Each value must have its own cell.

We will focus on the functions from `tidyverse` package.

```
library(tidyverse)
```

Tidy data 1: pivoting

For a dataset having column names are not names of variables, but values of a variable, e.g.

```
# table4a documents the number
# of documented TB cases in
# Afghanistan, Brazil and China
table4a
```

```
## # A tibble: 3 x 3
##   country     `1999` `2000`
##   <chr>        <dbl>  <dbl>
## 1 Afghanistan    745   2666
## 2 Brazil       37737  80488
## 3 China       212258 213766
```

- Need to change 1999, 2000 to a column? named as "year".
- Need to change the values of 1999, 2000 as "cases".

We can use `pivot_longer()` from the "tidyverse" package.

Pivot longer

```
table4a %>%
  pivot_longer(c(`1999`, `2000`),
               names_to = "year", values_to = "cases")
```

```
## # A tibble: 6 x 3
##   country     year   cases
##   <chr>       <chr>  <dbl>
## 1 Afghanistan 1999     745
## 2 Afghanistan 2000    2666
## 3 Brazil      1999   37737
## 4 Brazil      2000   80488
## 5 China       1999  212258
## 6 China       2000  213766
```

Another example

```
table2 %>% head(5)
```

```
## # A tibble: 5 x 4
##   country      year type           count
##   <chr>       <dbl> <chr>          <dbl>
## 1 Afghanistan  1999 cases            745
## 2 Afghanistan  1999 population 19987071
## 3 Afghanistan  2000 cases           2666
## 4 Afghanistan  2000 population 20595360
## 5 Brazil       1999 cases          37737
```

- case and population are two variables and should be converted into columns.

We can use `pivot_wider()`.

Pivot wider

```
table2 %>%
    pivot_wider(names_from = type, values_from = count)
```

```
## # A tibble: 6 x 4
##   country      year  cases population
##   <chr>       <dbl>  <dbl>      <dbl>
## 1 Afghanistan  1999    745   19987071
## 2 Afghanistan  2000   2666   20595360
## 3 Brazil       1999  37737  172006362
## 4 Brazil       2000  80488  174504898
## 5 China        1999 212258 1272915272
## 6 China        2000 213766 1280428583
```

Transform data

Use the "pipes" (i.e. %>%, |>) from the "tidyverse" package, a powerful tool for clearly expressing a sequence of multiple operations, with the combination of the following functions:

- `select()`
- `filter()`
- `arrange()`
- `mutate()`
- `summarise()`
- `group_by()`

Dataset - Diamonds

A dataset containing the prices and other attributes of almost 54,000 diamonds.

```
head(diamonds)
```

```
## # A tibble: 6 x 10
##   carat cut       color clarity depth table price     x     y     z
##   <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
## 1  0.23 Ideal     E     SI2      61.5    55   326  3.95  3.98  2.43
## 2  0.21 Premium   E     SI1      59.8    61   326  3.89  3.84  2.31
## 3  0.23 Good      E     VS1      56.9    65   327  4.05  4.07  2.31
## 4  0.29 Premium   I     VS2      62.4    58   334  4.2   4.23  2.63
## 5  0.31 Good      J     SI2      63.3    58   335  4.34  4.35  2.75
## 6  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
```

Select

Use `select()` to get a column, e.g. "color"

```
diamonds %>%
  select(color) %>%
  head()
```

```
## # A tibble: 6 x 1
##   color
##   <ord>
## 1 E
## 2 E
## 3 E
## 4 I
## 5 J
## 6 J
```

```
# Equivalent to...
head(diamonds$color)
```

```
## [1] E E E I J J
## Levels: D < E < F < G < H < I < J
```

Select

Use `select()` to remove a column, e.g. "color"

```
diamonds %>%
  select(-color)
```

```
## # A tibble: 53,940 x 9
##    carat cut       clarity depth table price     x     y     z
##    <dbl> <ord>     <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.23 Ideal     SI2      61.5    55   326  3.95  3.98  2.43
##  2  0.21 Premium   SI1      59.8    61   326  3.89  3.84  2.31
##  3  0.23 Good      VS1      56.9    65   327  4.05  4.07  2.31
##  4  0.29 Premium   VS2      62.4    58   334  4.2   4.23  2.63
##  5  0.31 Good      SI2      63.3    58   335  4.34  4.35  2.75
##  6  0.24 Very Good VVS2     62.8    57   336  3.94  3.96  2.48
##  7  0.24 Very Good VVS1     62.3    57   336  3.95  3.98  2.47
##  8  0.26 Very Good SI1      61.9    55   337  4.07  4.11  2.53
##  9  0.22 Fair      VS2      65.1    61   337  3.87  3.78  2.49
## 10  0.23 Very Good VS1      59.4    61   338  4     4.05  2.39
## # i 53,930 more rows
```

```
# Need to assign the change to the original dataset, otherwise, the deletion won't affect the dataset.
diagmonds <- diamonds %>%
  select(-color)
```

Filter

Use `filter()` to filter by some condition, e.g. filter all price $>$ 335

```
diamonds %>%
  filter(price > 335)
```

```
## # A tibble: 53,935 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
##  2  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47
##  3  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53
##  4  0.22 Fair      E     VS2      65.1    61   337  3.87  3.78  2.49
##  5  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39
##  6  0.3  Good      J     SI1      64      55   339  4.25  4.28  2.73
##  7  0.23 Ideal     J     VS1      62.8    56   340  3.93  3.9   2.46
##  8  0.22 Premium   F     SI1      60.4    61   342  3.88  3.84  2.33
##  9  0.31 Ideal     J     SI2      62.2    54   344  4.35  4.37  2.71
## 10  0.2  Premium   E     SI2      60.2    62   345  3.79  3.75  2.27
## # i 53,925 more rows
```

Filters with multiple conditions

```
diamonds %>%
  filter(price > 335 & depth < 64)
```

```
## # A tibble: 51,849 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
##  2  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47
##  3  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53
##  4  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39
##  5  0.23 Ideal     J     VS1      62.8    56   340  3.93  3.9   2.46
##  6  0.22 Premium   F     SI1      60.4    61   342  3.88  3.84  2.33
##  7  0.31 Ideal     J     SI2      62.2    54   344  4.35  4.37  2.71
##  8  0.2  Premium   E     SI2      60.2    62   345  3.79  3.75  2.27
##  9  0.32 Premium   E     I1       60.9    58   345  4.38  4.42  2.68
## 10  0.3  Ideal     I     SI2      62      54   348  4.31  4.34  2.68
## # i 51,839 more rows
```

Filters with multiple conditions

```
diamonds %>%
  filter(cut == "Very Good" | cut == "Fair")
```

```
## # A tibble: 13,692 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
##  2  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47
##  3  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53
##  4  0.22 Fair      E     VS2      65.1    61   337  3.87  3.78  2.49
##  5  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39
##  6  0.3  Very Good J     SI1      62.7    59   351  4.21  4.27  2.66
##  7  0.23 Very Good E     VS2      63.8    55   352  3.85  3.92  2.48
##  8  0.23 Very Good H     VS1      61      57   353  3.94  3.96  2.41
##  9  0.31 Very Good J     SI1      59.4    62   353  4.39  4.43  2.62
## 10  0.31 Very Good J     SI1      58.1    62   353  4.44  4.47  2.59
## # i 13,682 more rows
```

Filter after select

This is an example of "a sequence of operations".

```
diamonds %>%
  select(price) %>%
  filter(price > 335)
```

```
## # A tibble: 53,935 x 1
##    price
##    <int>
##  1   336
##  2   336
##  3   337
##  4   337
##  5   338
##  6   339
##  7   340
##  8   342
##  9   344
## 10   345
## # i 53,925 more rows
```

Arrange

Use `arrange()` to order data.

```
diamonds %>%
  arrange(price)
```

```
## # A tibble: 53,940 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.23 Ideal     E     SI2      61.5    55   326  3.95  3.98  2.43
##  2  0.21 Premium   E     SI1      59.8    61   326  3.89  3.84  2.31
##  3  0.23 Good      E     VS1      56.9    65   327  4.05  4.07  2.31
##  4  0.29 Premium   I     VS2      62.4    58   334  4.2   4.23  2.63
##  5  0.31 Good      J     SI2      63.3    58   335  4.34  4.35  2.75
##  6  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
##  7  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47
##  8  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53
##  9  0.22 Fair      E     VS2      65.1    61   337  3.87  3.78  2.49
## 10  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39
## # i 53,930 more rows
```

Arrange descending order

e.g. from the cheapest!

```
diamonds %>%
  arrange(-price)
```

```
## # A tibble: 53,940 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  2.29 Premium   I     VS2      60.8    60 18823  8.5   8.47  5.16
##  2  2    Very Good G     SI1      63.5    56 18818  7.9   7.97  5.04
##  3  1.51 Ideal     G     IF       61.7    55 18806  7.37  7.41  4.56
##  4  2.07 Ideal     G     SI2      62.5    55 18804  8.2   8.13  5.11
##  5  2    Very Good H     SI1      62.8    57 18803  7.95  8     5.01
##  6  2.29 Premium   I     SI1      61.8    59 18797  8.52  8.45  5.24
##  7  2.04 Premium   H     SI1      58.1    60 18795  8.37  8.28  4.84
##  8  2    Premium   I     VS1      60.8    59 18795  8.13  8.02  4.91
##  9  1.71 Premium   F     VS2      62.3    59 18791  7.57  7.53  4.7
## 10  2.15 Ideal     G     SI2      62.6    54 18791  8.29  8.35  5.21
## # i 53,930 more rows
```

Arrange by multiple conditions

```
diamonds %>%
  arrange(price, cut)
```

```
## # A tibble: 53,940 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.21 Premium   E     SI1      59.8    61   326  3.89  3.84  2.31
##  2  0.23 Ideal     E     SI2      61.5    55   326  3.95  3.98  2.43
##  3  0.23 Good      E     VS1      56.9    65   327  4.05  4.07  2.31
##  4  0.29 Premium   I     VS2      62.4    58   334  4.2   4.23  2.63
##  5  0.31 Good      J     SI2      63.3    58   335  4.34  4.35  2.75
##  6  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
##  7  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47
##  8  0.22 Fair      E     VS2      65.1    61   337  3.87  3.78  2.49
##  9  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53
## 10  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39
## # i 53,930 more rows
```

Filter, select, arrange

```
diamonds %>%
  filter(table < 340) %>%
  select(carat, cut, price) %>%
  arrange(price, cut)
```

```
## # A tibble: 53,940 x 3
##    carat cut       price
##    <dbl> <ord>     <int>
##  1  0.21 Premium     326
##  2  0.23 Ideal       326
##  3  0.23 Good        327
##  4  0.29 Premium     334
##  5  0.31 Good        335
##  6  0.24 Very Good   336
##  7  0.24 Very Good   336
##  8  0.22 Fair        337
##  9  0.26 Very Good   337
## 10  0.23 Very Good   338
## # i 53,930 more rows
```

Mutate

Create new variables using `mutate()`.

- Create a boolean variable, 0 = not affordable, 1 = affordable.

```
diamonds %>%
  mutate(affordable = price < 400)
```

```
## # A tibble: 53,940 x 11
##    carat cut       color clarity depth table price     x     y     z affordable
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl> <lgl>
##  1  0.23 Ideal     E     SI2      61.5    55   326  3.95  3.98  2.43 TRUE
##  2  0.21 Premium   E     SI1      59.8    61   326  3.89  3.84  2.31 TRUE
##  3  0.23 Good      E     VS1      56.9    65   327  4.05  4.07  2.31 TRUE
##  4  0.29 Premium   I     VS2      62.4    58   334  4.2   4.23  2.63 TRUE
##  5  0.31 Good      J     SI2      63.3    58   335  4.34  4.35  2.75 TRUE
##  6  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48 TRUE
##  7  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47 TRUE
##  8  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53 TRUE
##  9  0.22 Fair      E     VS2      65.1    61   337  3.87  3.78  2.49 TRUE
## 10  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39 TRUE
## # i 53,930 more rows
```

Mutate (cont'd)

- Create a variable containing string with `case_when()`:

```
diamonds %>%
  mutate(affordable = case_when(price<400 ~ "affordable",
                                TRUE ~ "not affordable"))
```

```
## # A tibble: 53,940 x 11
##    carat cut       color clarity depth table price     x     y     z affordable
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl> <chr>
##  1  0.23 Ideal     E     SI2      61.5    55   326  3.95  3.98  2.43 affordable
##  2  0.21 Premium   E     SI1      59.8    61   326  3.89  3.84  2.31 affordable
##  3  0.23 Good      E     VS1      56.9    65   327  4.05  4.07  2.31 affordable
##  4  0.29 Premium   I     VS2      62.4    58   334  4.2   4.23  2.63 affordable
##  5  0.31 Good      J     SI2      63.3    58   335  4.34  4.35  2.75 affordable
##  6  0.24 Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48 affordable
##  7  0.24 Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47 affordable
##  8  0.26 Very Good H     SI1      61.9    55   337  4.07  4.11  2.53 affordable
##  9  0.22 Fair      E     VS2      65.1    61   337  3.87  3.78  2.49 affordable
## 10  0.23 Very Good H     VS1      59.4    61   338  4     4.05  2.39 affordable
## # i 53,930 more rows
```

Group by and Summarise

Use `group_by` and `summarise` to group variables:

```
diamonds %>%
  group_by(cut) %>%
  summarise(n = n())
```

```
## # A tibble: 5 x 2
##   cut           n
##   <ord>     <int>
## 1 Fair       1610
## 2 Good       4906
## 3 Very Good 12082
## 4 Premium   13791
## 5 Ideal     21551
```

More examples

```
diamonds %>%
  group_by(cut) %>%
  summarise(n = n(), price_avg = mean(price))
```

```
## # A tibble: 5 x 3
##   cut           n price_avg
##   <ord>     <int>     <dbl>
## 1 Fair       1610     4359.
## 2 Good       4906     3929.
## 3 Very Good 12082     3982.
## 4 Premium   13791     4584.
## 5 Ideal     21551     3458.
```

Proportions

```
diamonds %>%
  group_by(cut) %>%
  summarise(n = n(), price_avg = mean(price)) %>%
  ungroup() %>%
  mutate(prop = n/sum(n))
```

```
## # A tibble: 5 x 4
##   cut           n price_avg   prop
##   <ord>     <int>     <dbl>  <dbl>
## 1 Fair       1610     4359. 0.0298
## 2 Good       4906     3929. 0.0910
## 3 Very Good 12082     3982. 0.224
## 4 Premium   13791     4584. 0.256
## 5 Ideal     21551     3458. 0.400
```

With percentage

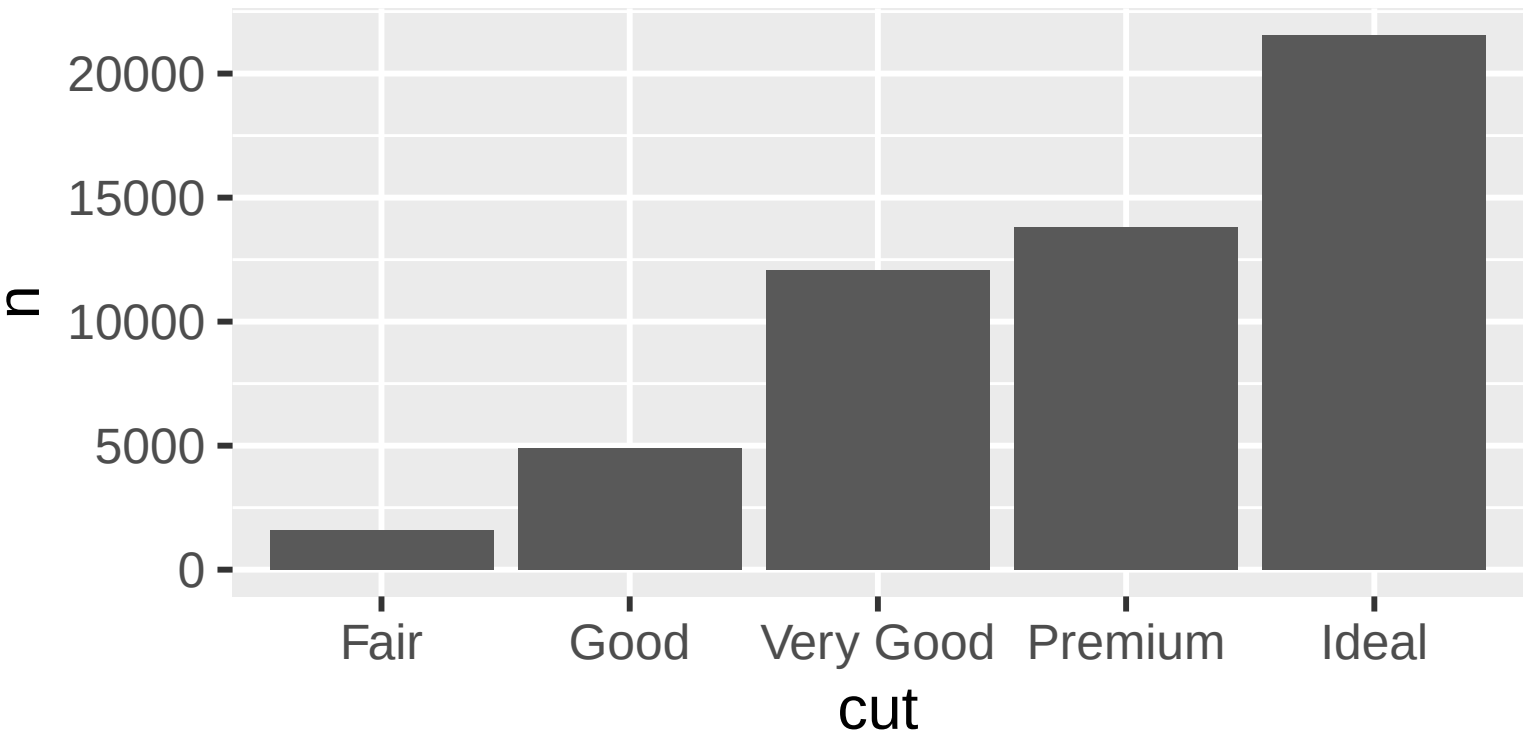
Use `scales::percent()` to add %.

```
diamonds %>%
  group_by(cut) %>%
  summarise(n = n(), price_avg = mean(price)) %>%
  ungroup() %>%
  mutate(prop = scales::percent(n/sum(n)))
```

```
## # A tibble: 5 x 4
##   cut           n price_avg prop
##   <ord>     <int>     <dbl> <chr>
## 1 Fair       1610     4359. 3.0%
## 2 Good       4906     3929. 9.1%
## 3 Very Good 12082     3982. 22.4%
## 4 Premium   13791     4584. 25.6%
## 5 Ideal     21551     3458. 40.0%
```

Graphing after transformation

```
diamonds %>%
  group_by(cut) %>%
  summarise(n = n(), price_avg = mean(price)) %>%
  ggplot() +
  geom_bar(aes(x = cut, y = n), stat = "identity")
```



ggplot

Here we used functions from "ggplot2" package. Same pattern as "tidyverse", but using "+" to connect.

How to write?

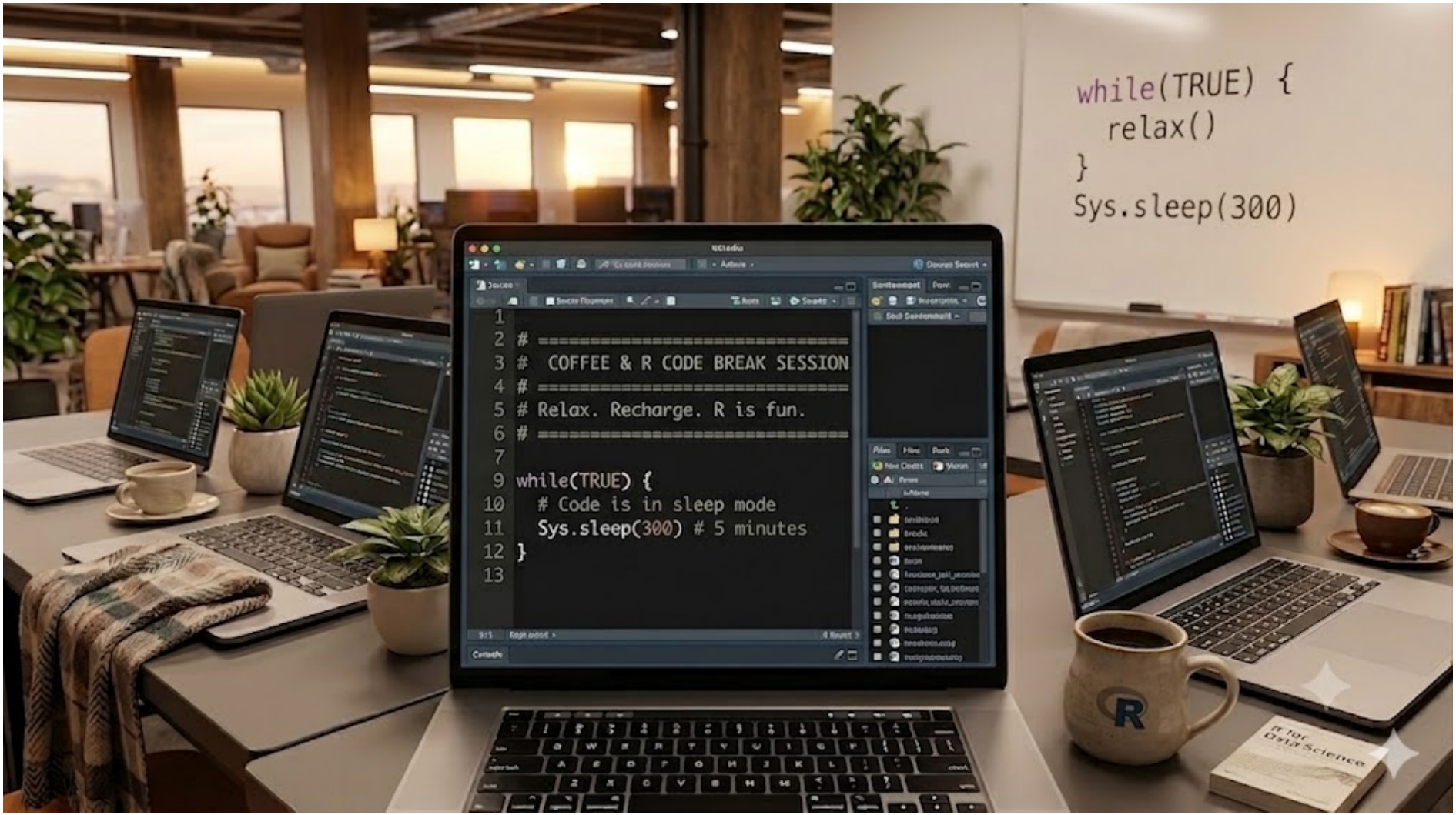
- Specify the data using `ggplot(data = diamonds)`
- Specify the x-/y-axis, `ggplot(data = diamonds, mapping = aes(x = cut))`
- Specify the types of plots with geom, e.g. `+ geom_bar()`

```
ggplot(data = diamonds) +
  geom_bar(mapping = aes(x = cut))
```

More plots

- `geom_histogram()`, `geom_density()`, `geom_line()`, `geom_point()`
- `geom_facet()` generates subplots
- color package
  - `RColorBrewer`
  - `ggsci`
- formatting package
  - `ggthemes`

Break


while(TRUE) {
relax()
}
Sys.sleep(300)
# ==========
# COFFEE & R CODE BREAK SESSION
# ==========
# Relax. Recharge. R is fun.
# ==========
while(TRUE) {
# Code is in sleep mode
Sys.sleep(300) # 5 minutes
}

Install and load package

From what we have learned so far, how to install package? What packages are we going to use?

Install and load package

From what we have learned so far, how to install package? What packages are we going to use?

```
install.packages("palmerpenguins")
```

```
library(tidyverse)
library(palmerpenguins)
```

Skim the data

How many observations? How many variables? What type?

Skim the data

How many observations? How many variables? What type?

```
glimpse(penguins)
```

```
## Rows: 344
## Columns: 8
## $ species           <fct> Adelie, Adelie, Adelie, Adelie, Adelie, Adelie, Adel~
## $ island            <fct> Torgersen, Torgersen, Torgersen, Torgersen, Torgerse~
## $ bill_length_mm    <dbl> 39.1, 39.5, 40.3, NA, 36.7, 39.3, 38.9, 39.2, 34.1, ~
## $ bill_depth_mm     <dbl> 18.7, 17.4, 18.0, NA, 19.3, 20.6, 17.8, 19.6, 18.1, ~
## $ flipper_length_mm <int> 181, 186, 195, NA, 193, 190, 181, 195, 193, 190, 186~
## $ body_mass_g       <int> 3750, 3800, 3250, NA, 3450, 3650, 3625, 4675, 3475, ~
## $ sex               <fct> male, female, female, NA, female, male, female, male~
## $ year              <int> 2007, 2007, 2007, 2007, 2007, 2007, 2007, 2007, 2007~
```

Scatter plot

Consider a scatter plot of flipper length and body mass for `species = "Adelie"`

First let's prepare the data to plot (Hint: filter).

Scatter plot

Consider a scatter plot of flipper length and body mass for `species = "Adelie"`

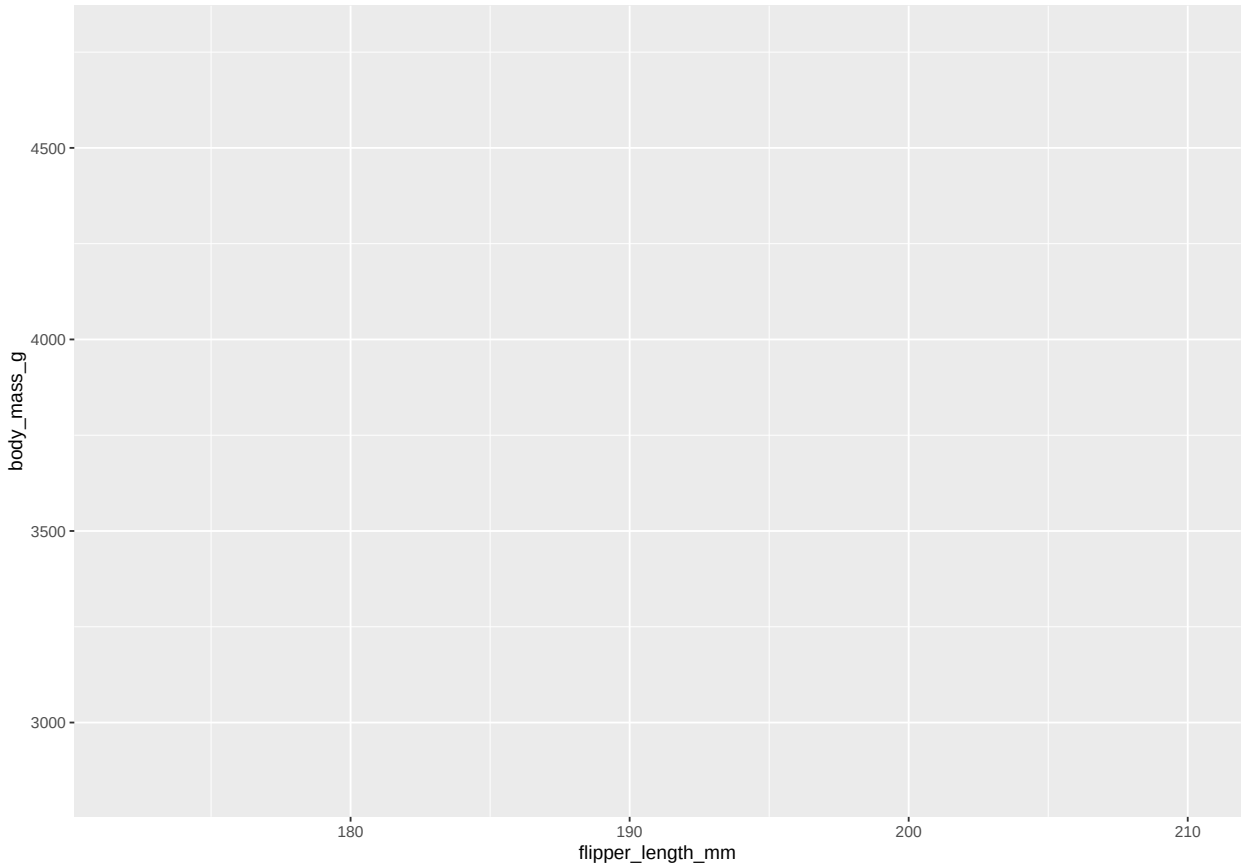
First let's prepare the data to plot (Hint: filter).

```
pdata <- penguins %>%
  filter(species == "Adelie")
```

A blank canvas

`aes` stands for aesthetic and tells ggplot the main characteristics of your plot (x, y, and if the color or fill vary by group)

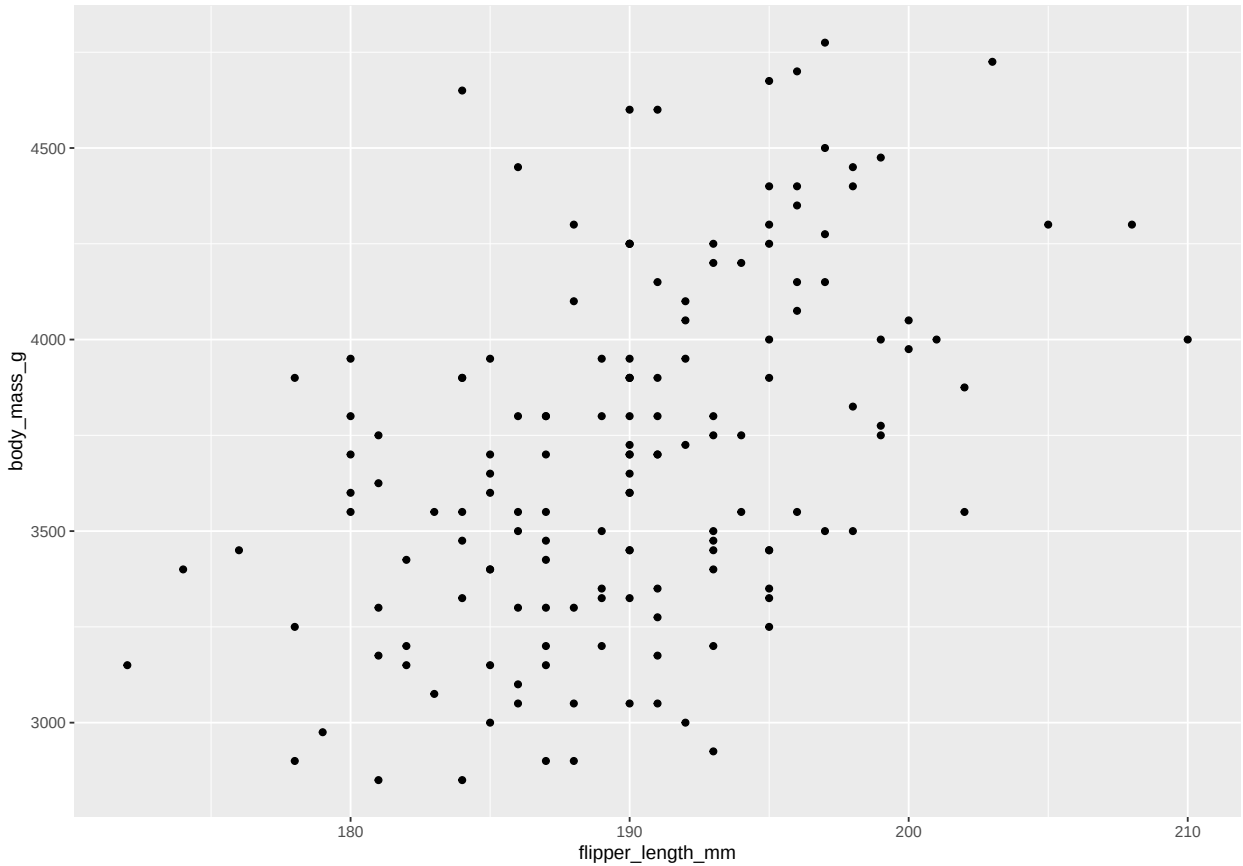
```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g))
```



Add the points

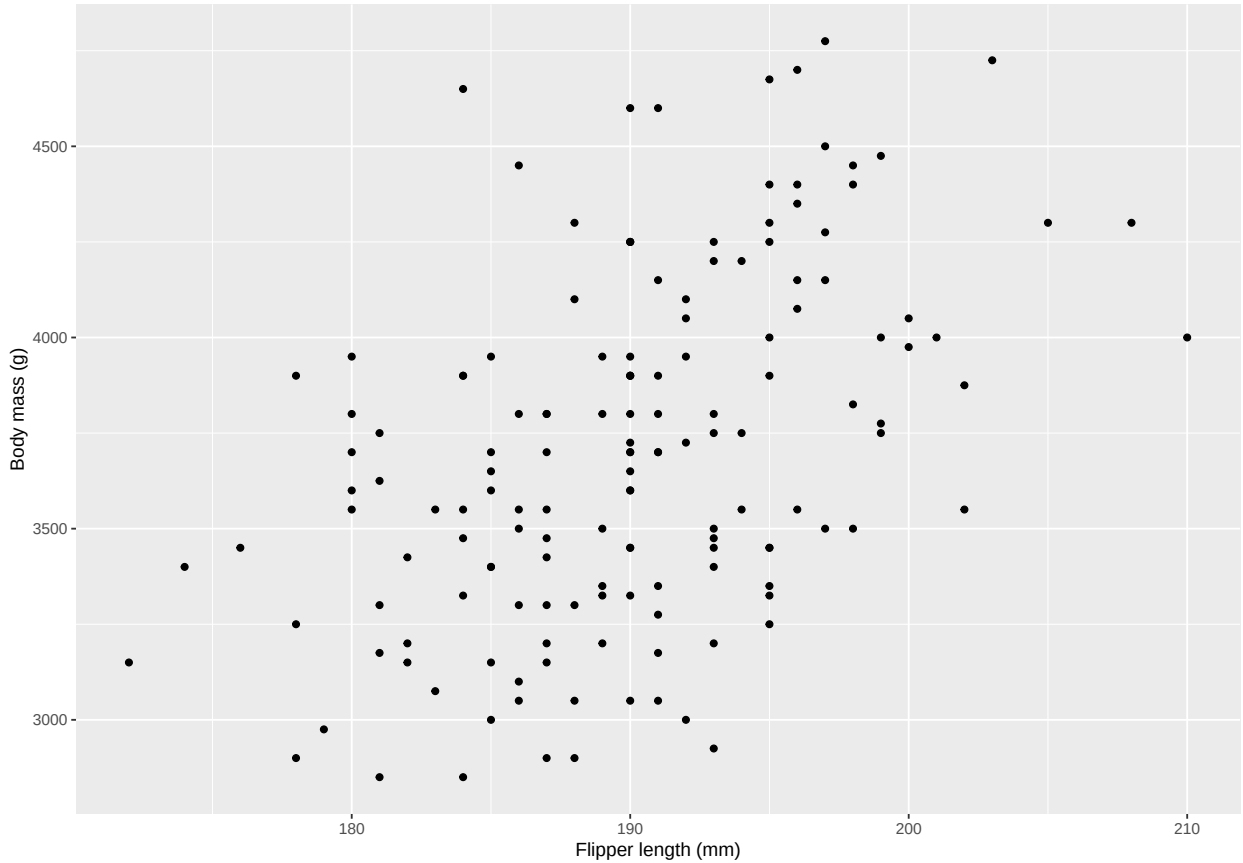
Add layers with ggplot using the +

```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point()
```



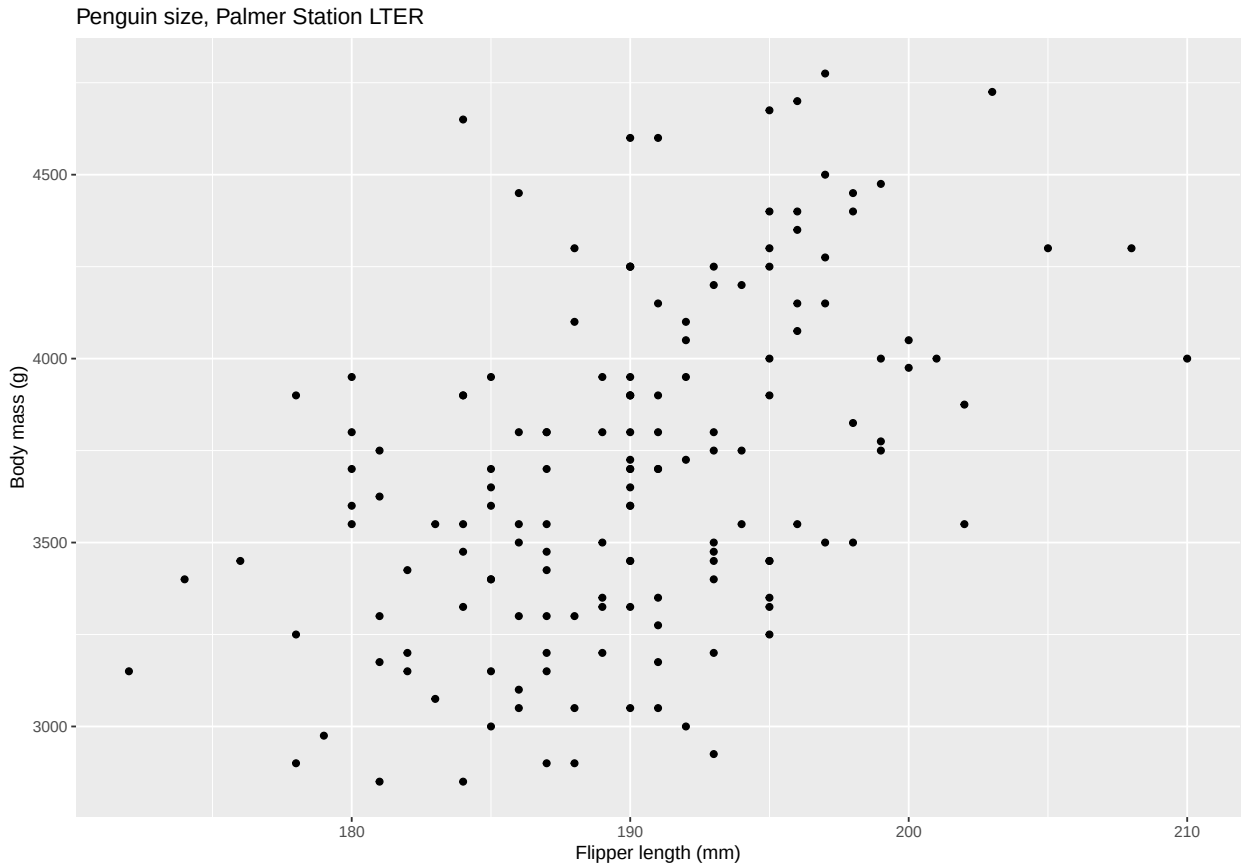
Tidy up labels

```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point() +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)")
```



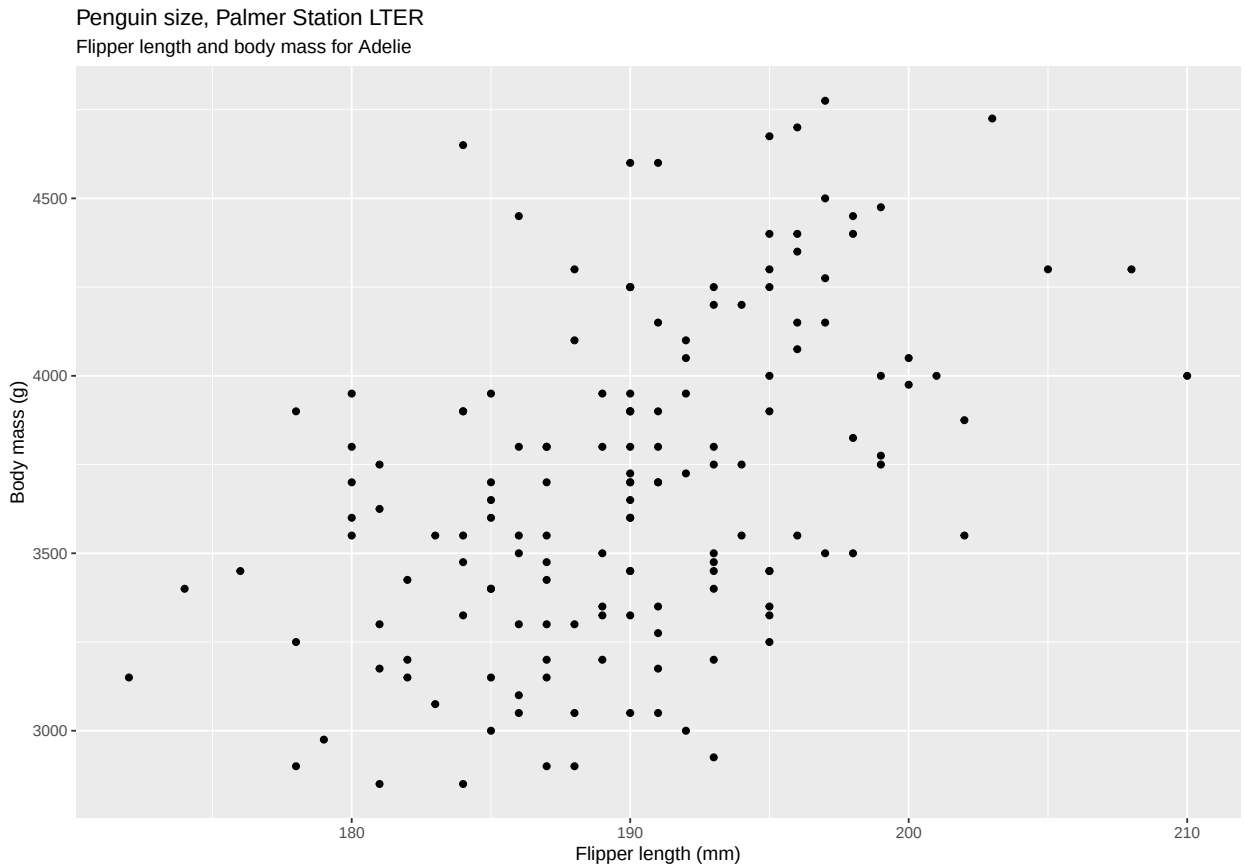
Add a title

```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point() +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER")
```



Subtitle

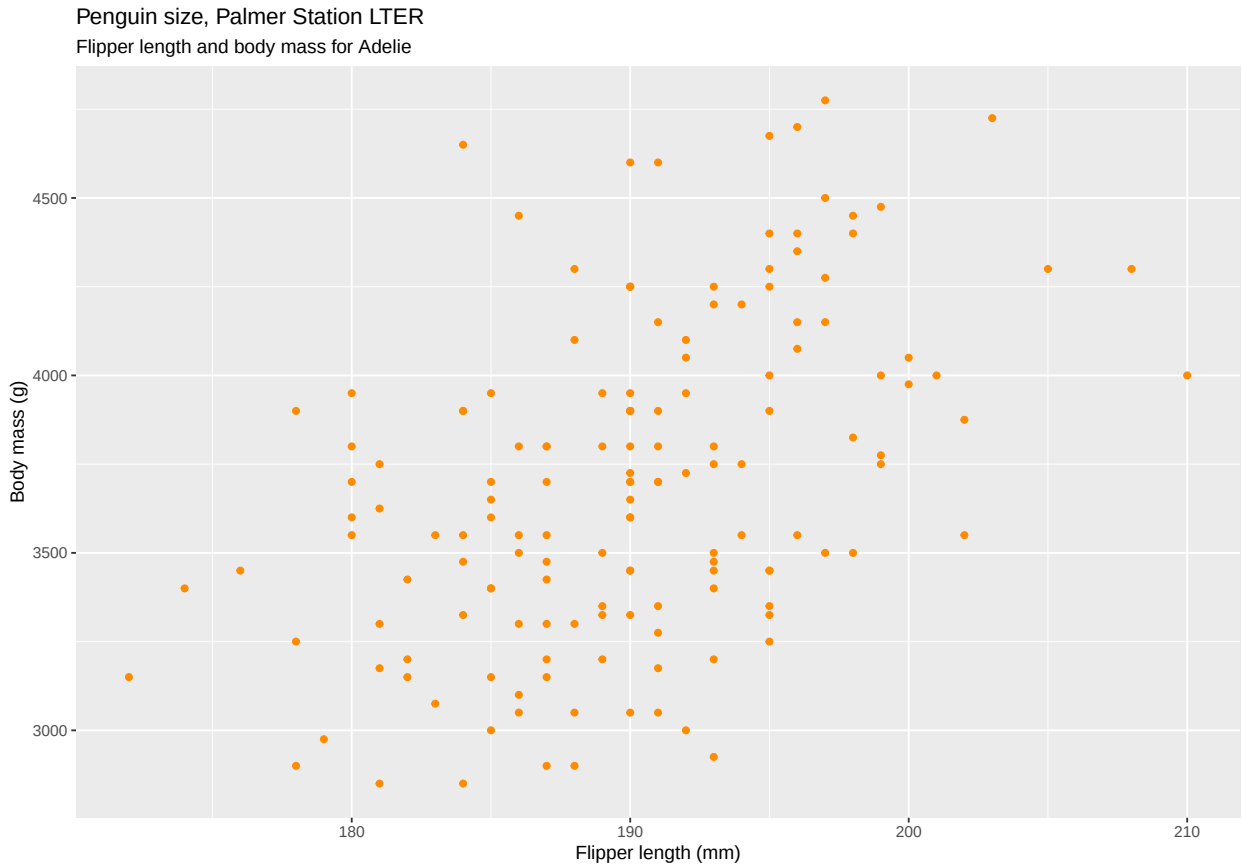
```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point() +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie")
```



Change color of points

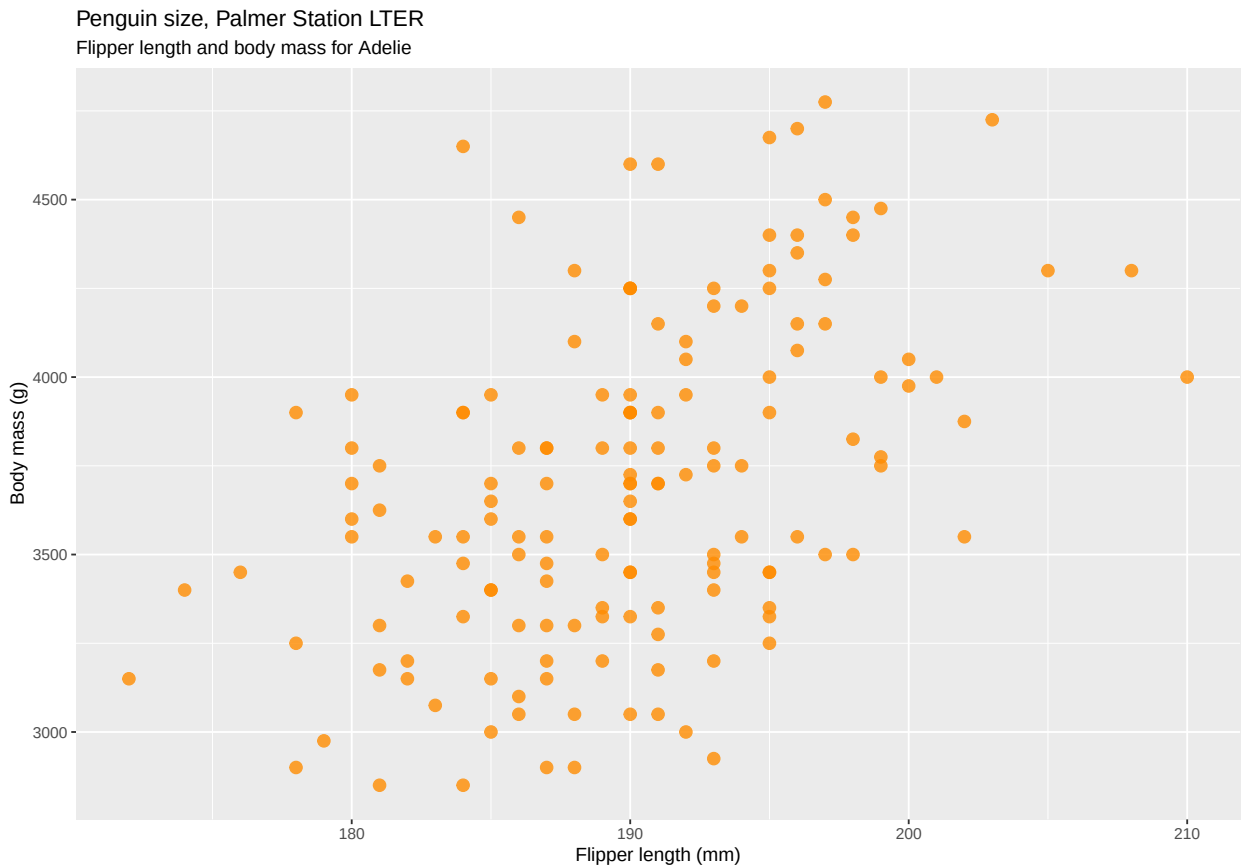
To see all colors, type `colors()`

```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(color = "darkorange") +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie")
```



Size of points

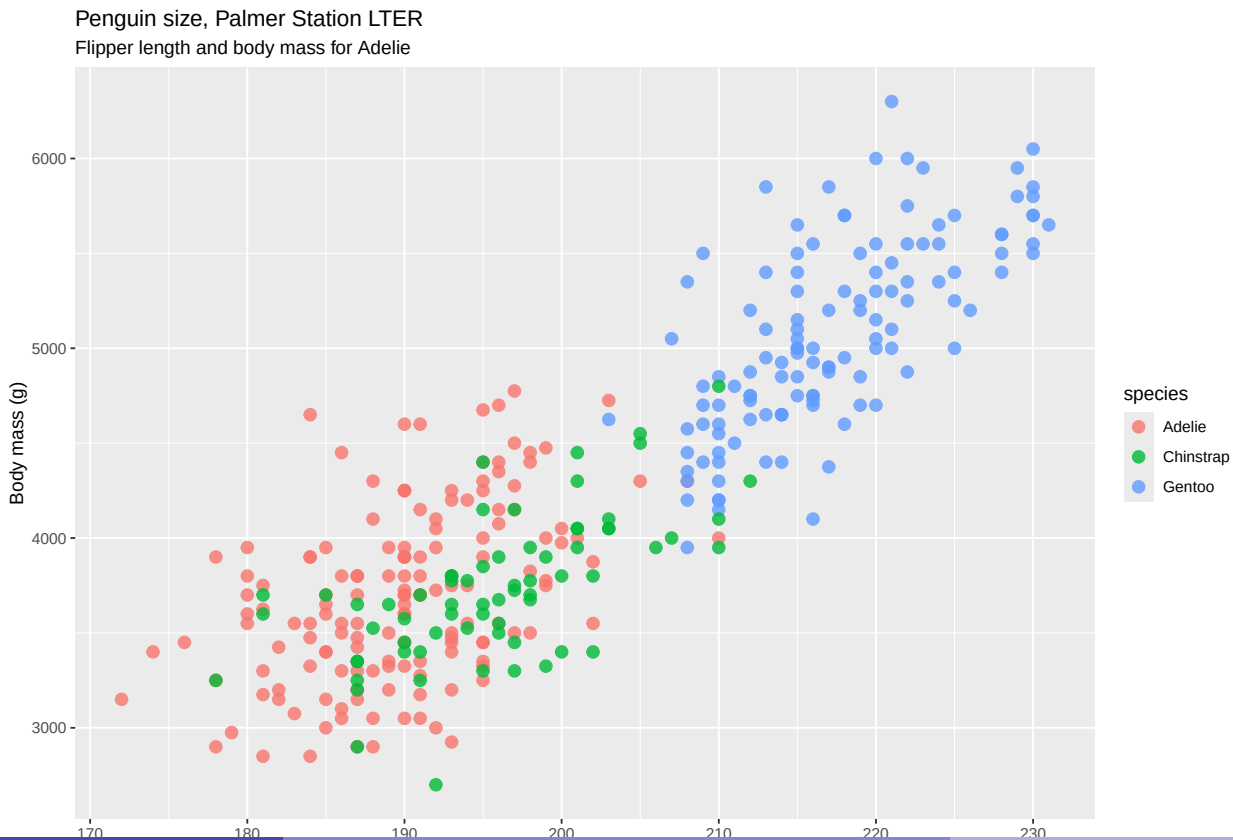
```
ggplot(data = pdata, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(color = "darkorange",
             size = 3,
             alpha = 0.8) +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie")
```



Coloring by group

Now use the whole data `penguins`. Specifying the color in `aes()` because it **depends on the data**.

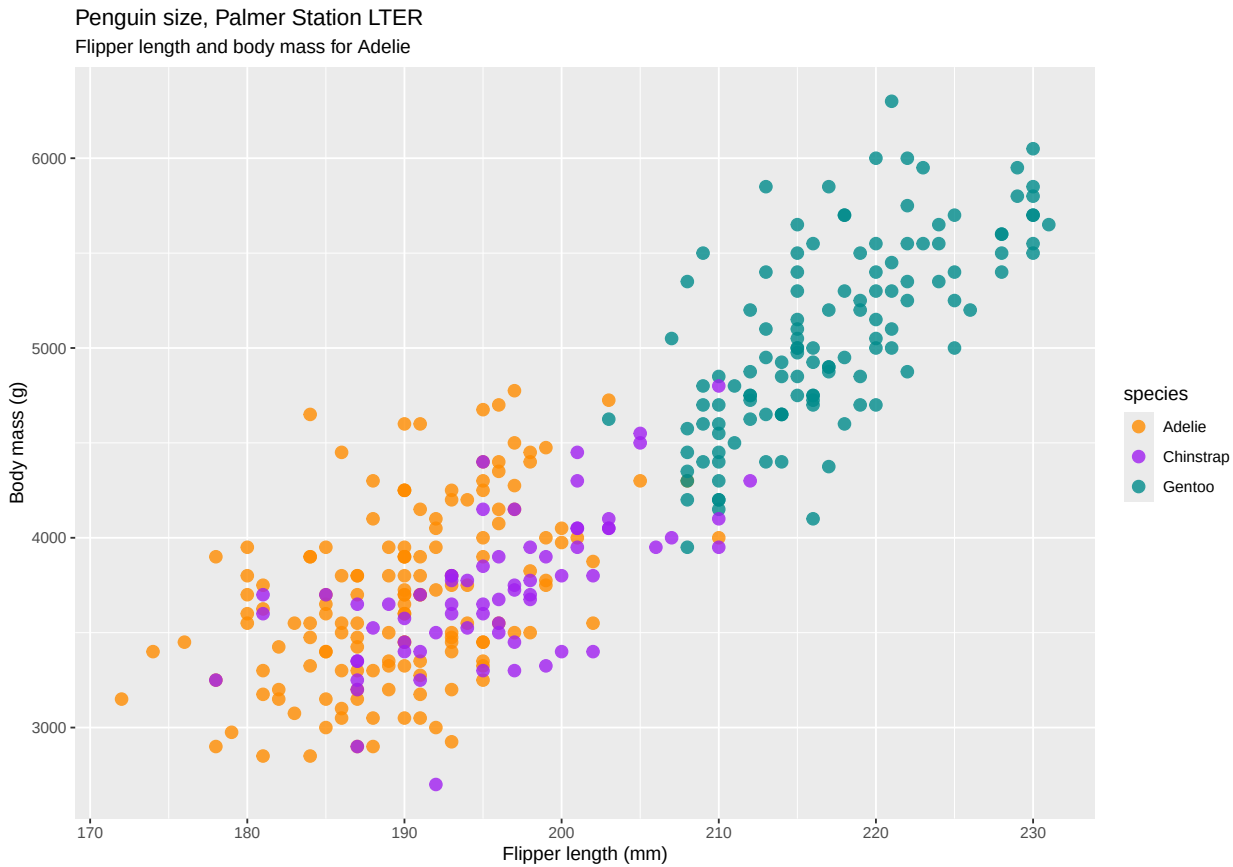
```
ggplot(data = penguins, aes(x = flipper_length_mm, y = body_mass_g, color = species)) +
  geom_point(size = 3, alpha = 0.8) +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie")
```



Change the color manually by group

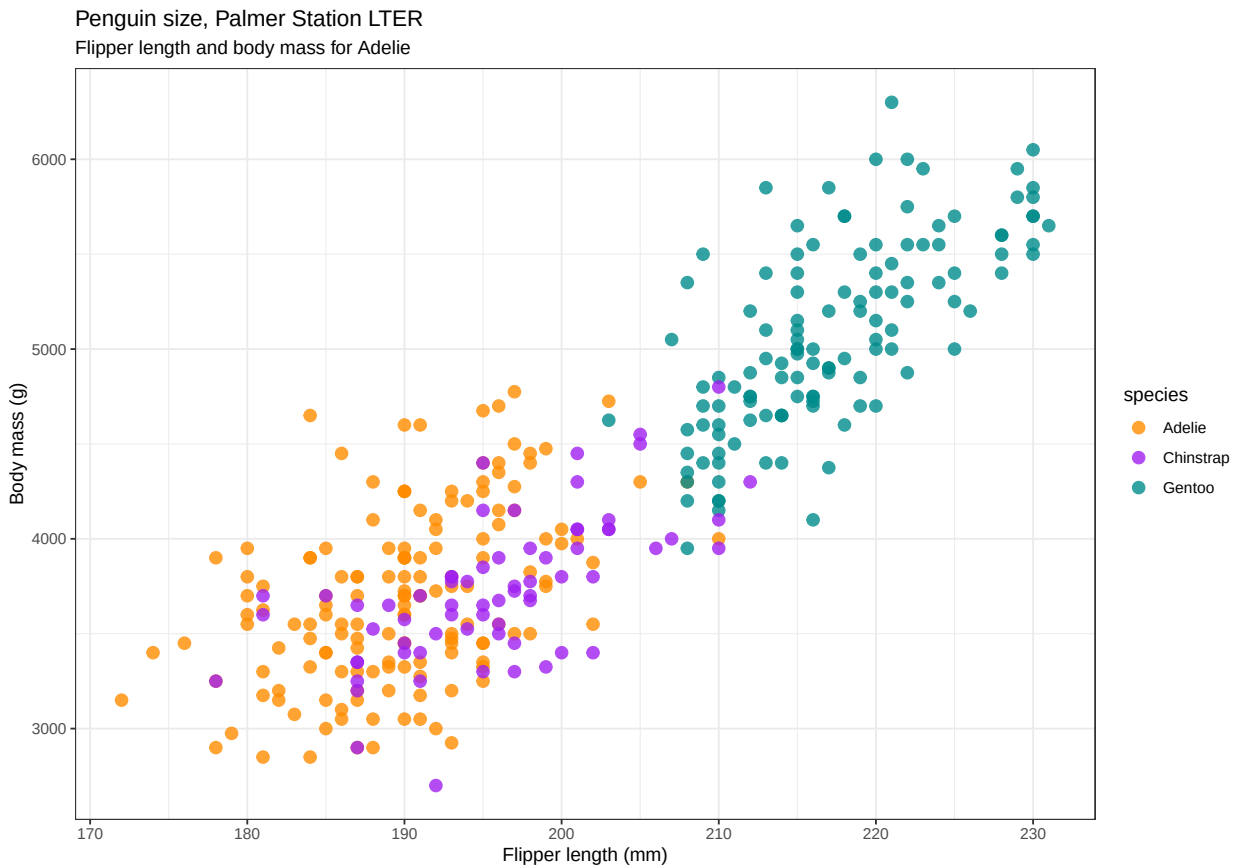
Specifying the color in aes() because it **depends on the data**.

```
ggplot(data = penguins, aes(x = flipper_length_mm, y = body_mass_g, color = species)) +
  geom_point(size = 3, alpha = 0.8) +
  scale_color_manual(values = c("darkorange","purple","cyan4")) +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie")
```



Change the theme

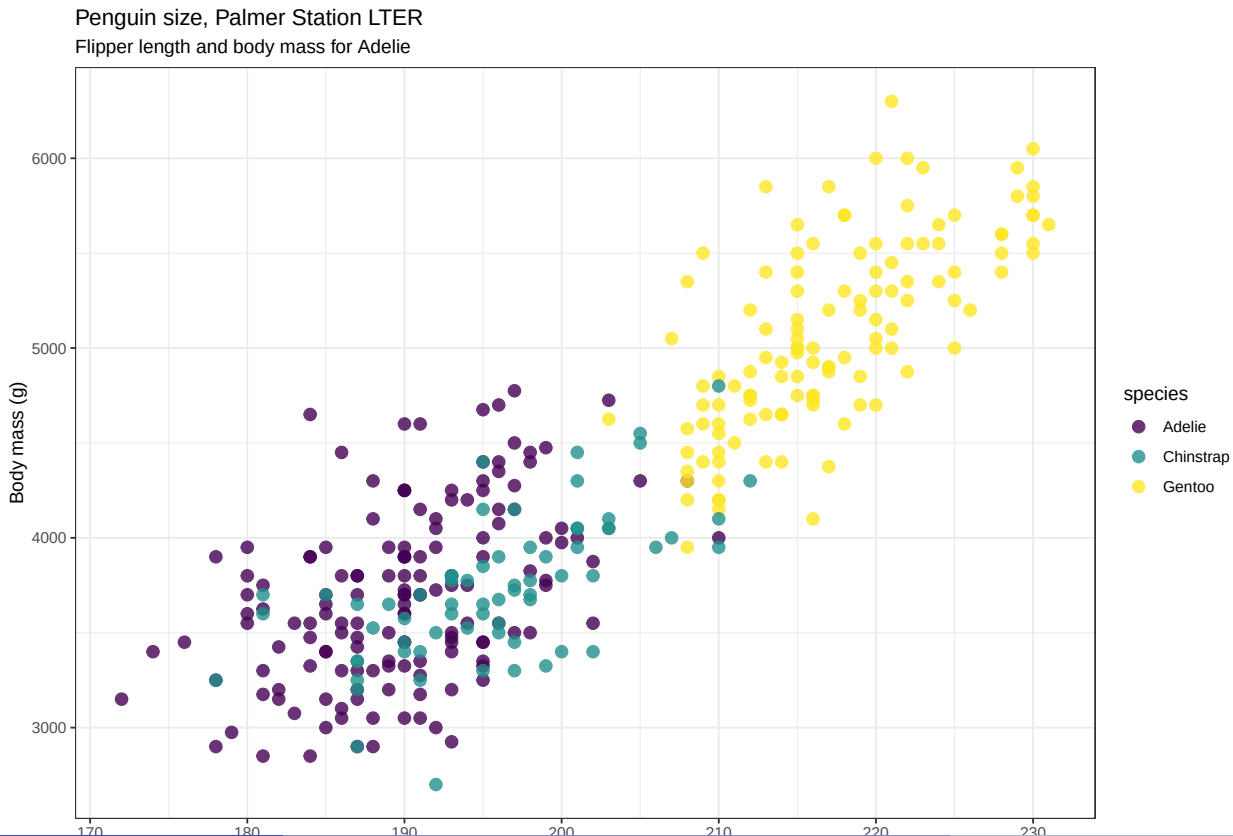
```
ggplot(data = penguins, aes(x = flipper_length_mm, y = body_mass_g, color = species)) +
  geom_point(size = 3, alpha = 0.8) +
  scale_color_manual(values = c("darkorange","purple","cyan4")) +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie") +
  theme_bw()
```



Change the color scheme

Optional: try ggsci functions.

```
ggplot(data = penguins, aes(x = flipper_length_mm, y = body_mass_g, color = species)) +
  geom_point(size = 3, alpha = 0.8) +
  xlab("Flipper length (mm)") +
  ylab("Body mass (g)") +
  labs(title = "Penguin size, Palmer Station LTER",
       subtitle = "Flipper length and body mass for Adelie") +
  theme_bw() +
  scale_color_viridis_d()
```

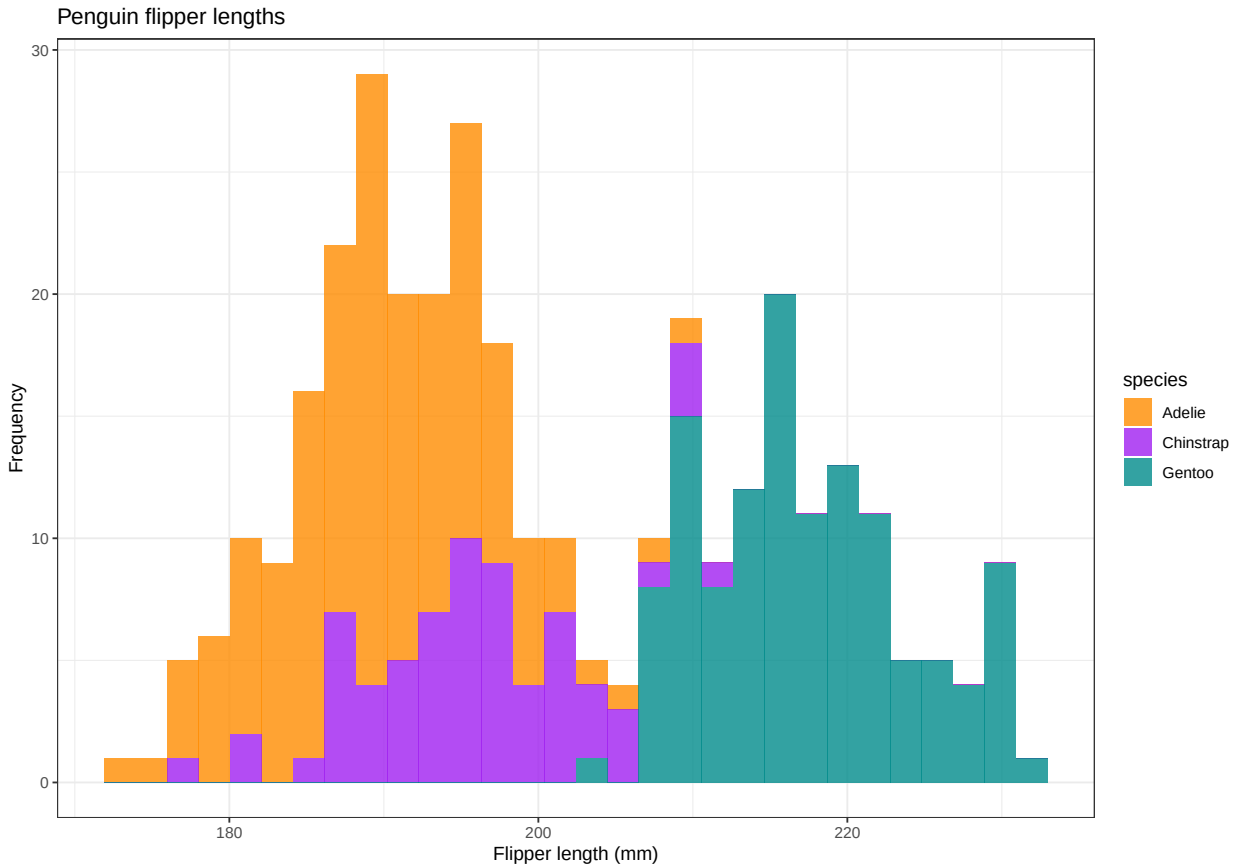


Other plot types?

Other types are also available, e.g. histograms, bar charts, box plots, line graphs and scatter plots.

Histograms

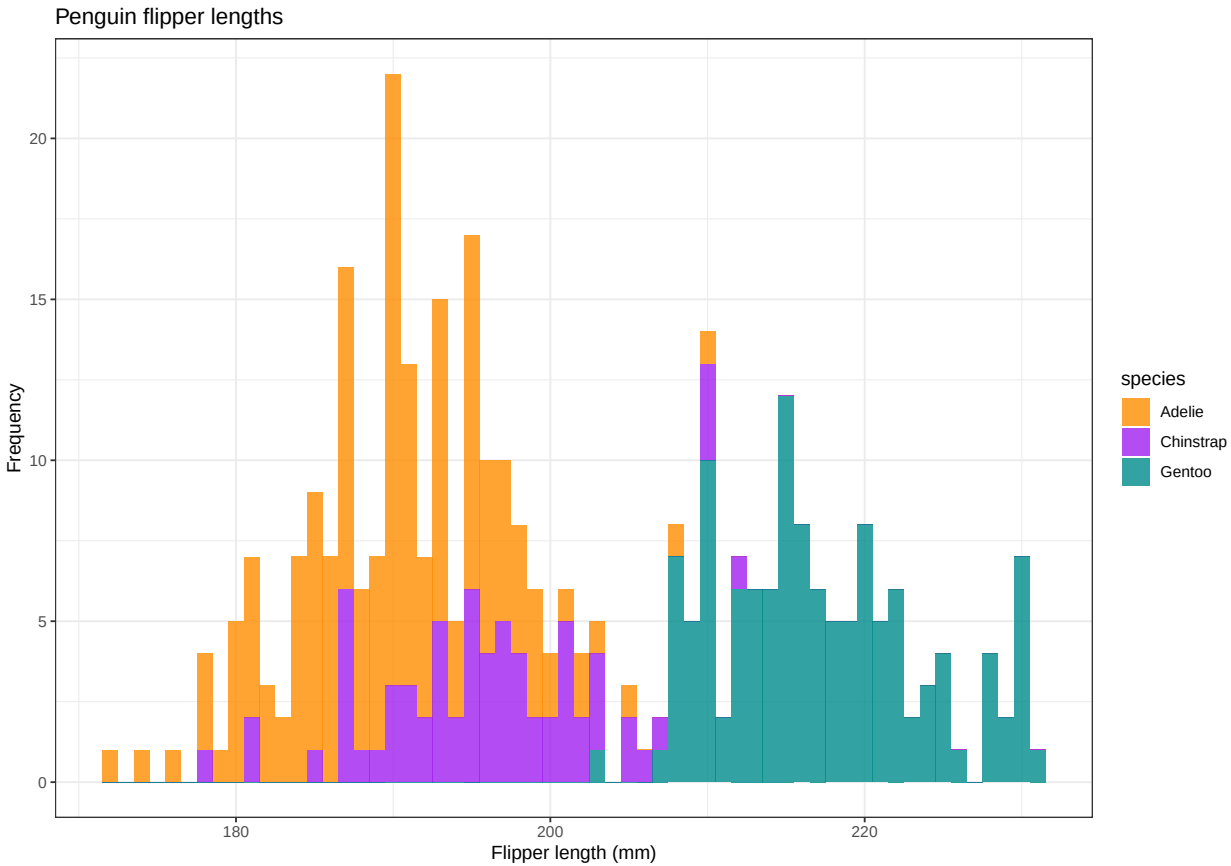
```
ggplot(data = penguins, aes(x = flipper_length_mm, fill = species)) +
  geom_histogram(alpha = 0.8) +
  scale_fill_manual(values = c("darkorange","purple","cyan4")) +
  xlab("Flipper length (mm)") +
  ylab("Frequency") +
  labs(title = "Penguin flipper lengths") +
  theme_bw()
```



Histogram

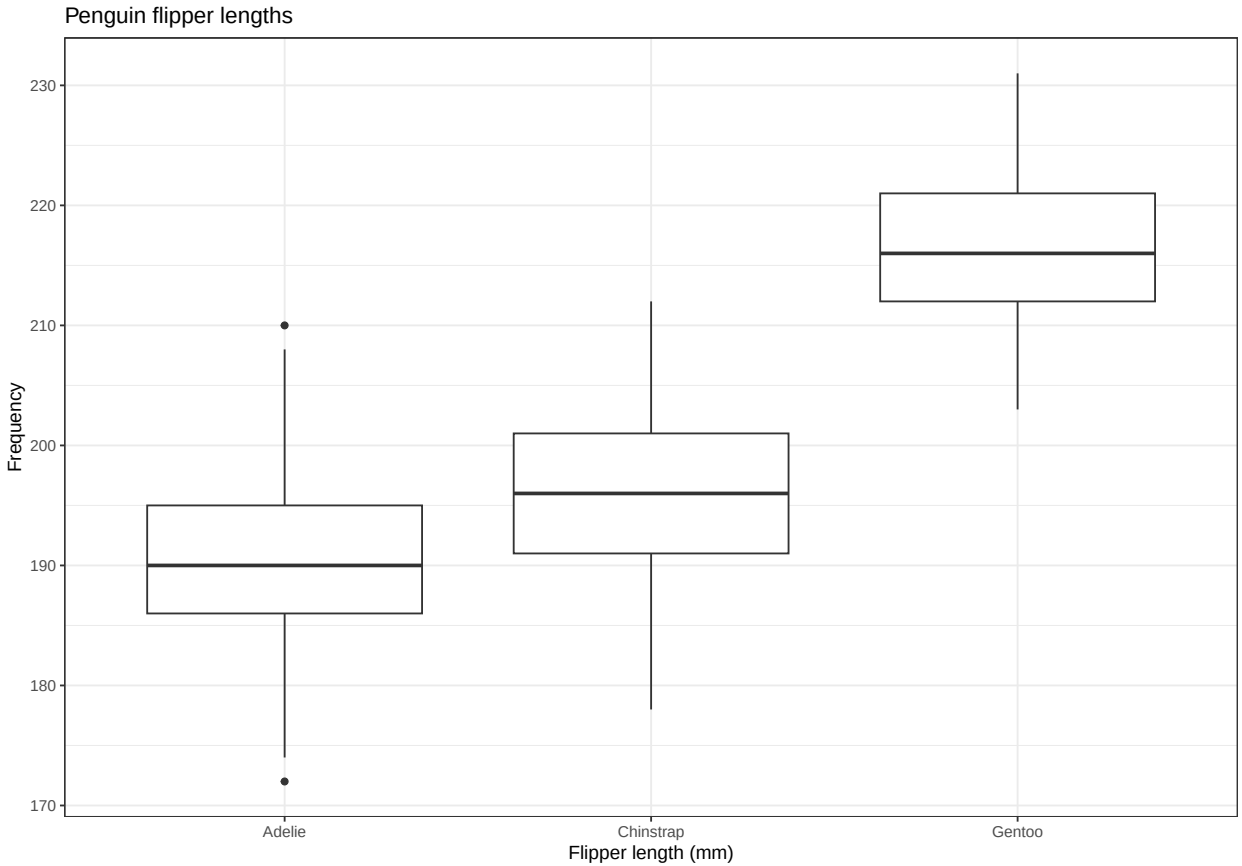
Try `binwidth =` and `bins ==`

```
ggplot(data = penguins, aes(x = flipper_length_mm, fill = species)) +
  geom_histogram(binwidth = 1, alpha = 0.8) +
  scale_fill_manual(values = c("darkorange","purple","cyan4")) +
  xlab("Flipper length (mm)") +
  ylab("Frequency") +
  labs(title = "Penguin flipper lengths") +
  theme_bw()
```



Boxplots

```
ggplot(data = penguins, aes(x = species, y = flipper_length_mm)) +
  geom_boxplot(show.legend = FALSE) +
  xlab("Flipper length (mm)") +
  ylab("Frequency") +
  labs(title = "Penguin flipper lengths") +
  theme_bw()
```



Barcharts

First, try to summarize the penguin data by species and returns the proportion of each penguin types.

Barcharts

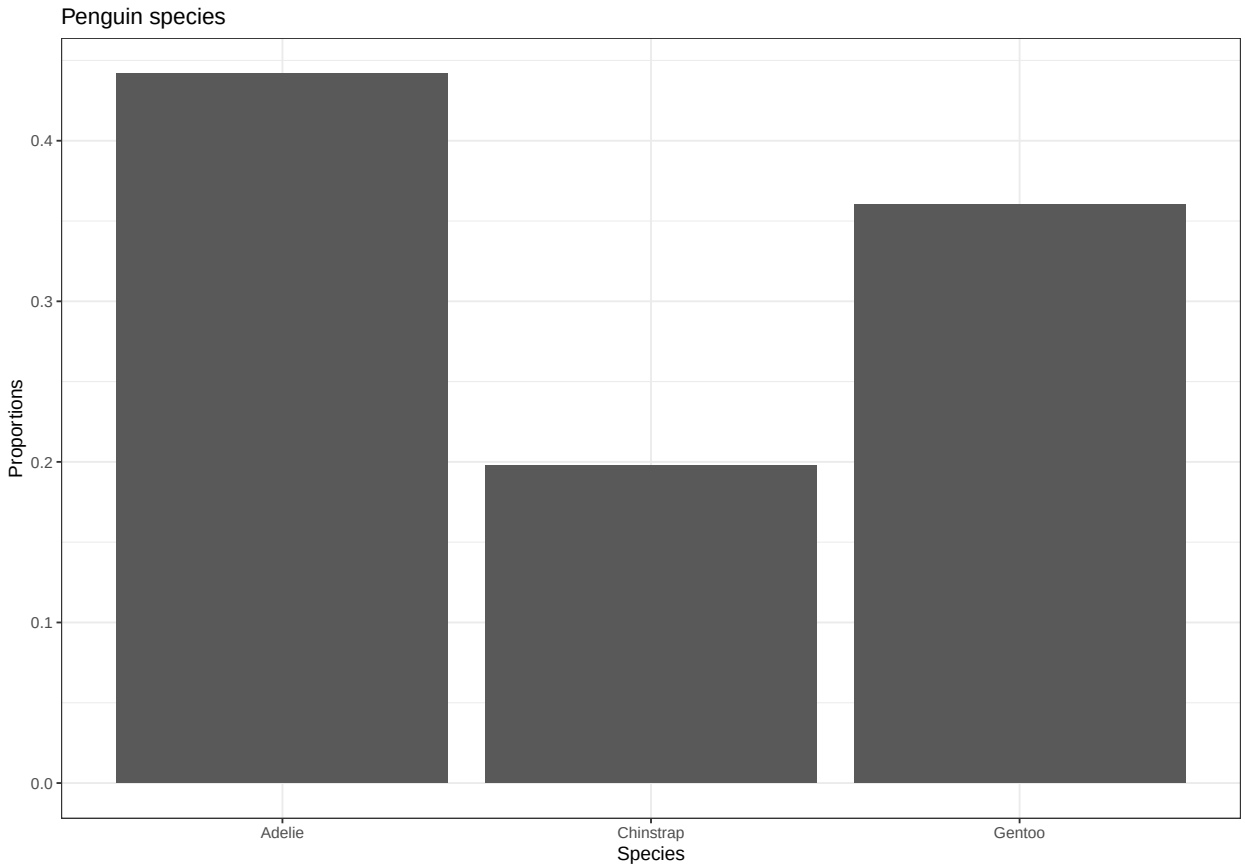
First, try to summarize the penguin data by species and returns the proportion of each penguin types.

```
gplot <- penguins %>%
  group_by(species) %>%
  tally() %>%
  mutate(prop = n / sum(n))
gplot
```

```
## # A tibble: 3 x 3
##   species       n  prop
##   <fct>     <int> <dbl>
## 1 Adelie      152 0.442
## 2 Chinstrap    68 0.198
## 3 Gentoo      124 0.360
```

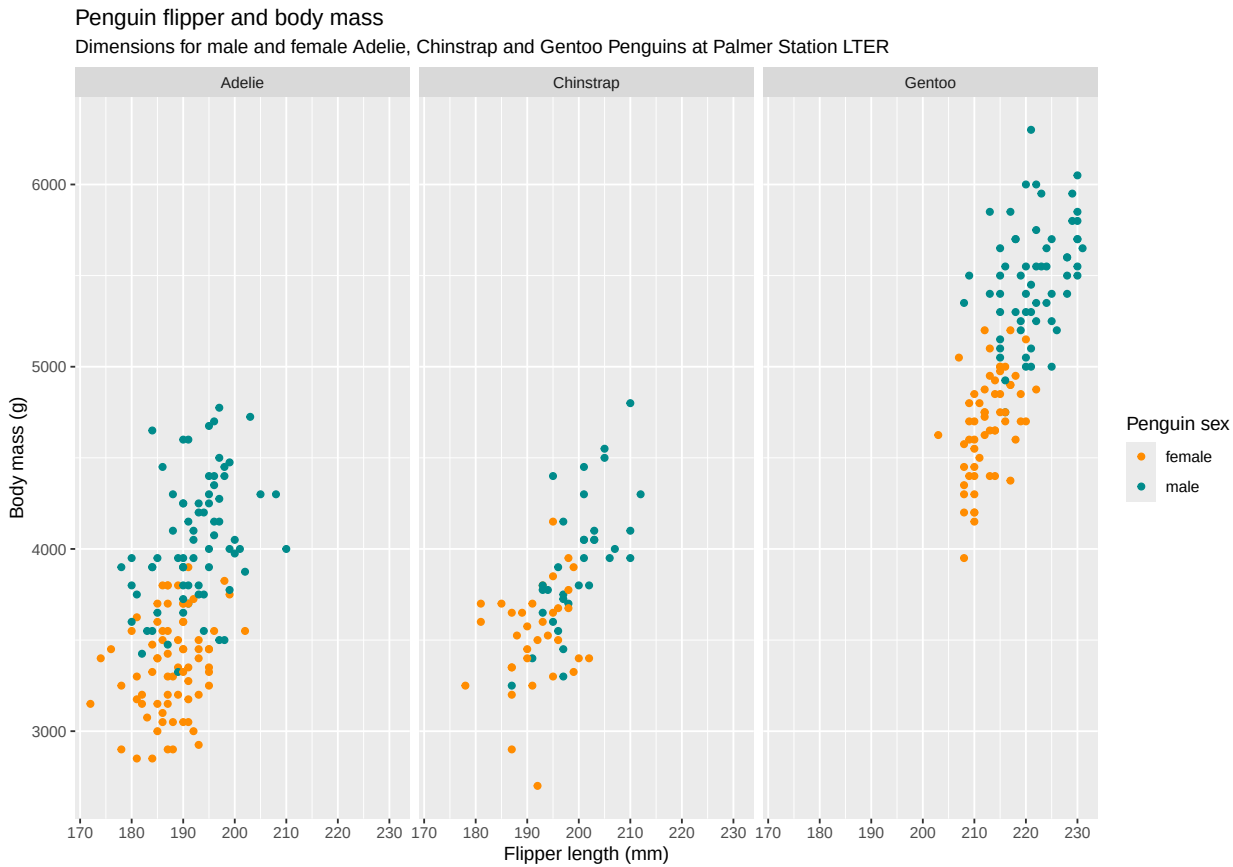
Barcharts

```
ggplot(data = gplot, aes(x = species, y = prop))  +
  geom_bar(stat = "identity") +
  xlab("Species") +
  ylab("Proportions") +
  labs(title = "Penguin species") +
  theme_bw()
```



Faceting

```
ggplot(penguins, aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(aes(color = sex)) +
  scale_color_manual(values = c("darkorange","cyan4"), na.translate = FALSE) +
  labs(title = "Penguin flipper and body mass",
       subtitle = "Dimensions for male and female Adelie, Chinstrap and Gentoo Penguins at Palmer Station LTER",
       x = "Flipper length (mm)",
       y = "Body mass (g)",
       color = "Penguin sex") +
  facet_wrap(~species)
```



Using LLMs for writing R code

Popular LLMs

Online LLMs

- ChatGPT *
- Claude
- Gemeni *
- Grok
- DeepSeek

(∗: My preferred choices)

Local LLMs

- Ollama
  - Open source LLMs.
  - Performance depends on the model choice and your machine
  - Secure, but generally not as good as Online LLMs

Important Tips

- Never provide sensitive data to an LLM
- Do not accept LLM responses for absolute truth (they still make mistakes and overcomplicate!)
- YOU are fully responsible for the accuracy, originality, licensing, and ethical/legal compliance of work that you do.
    - Failure to provide a complete and accurate disclosure of AI usage may be considered an ethical breach in research/work contexts.

Example - Pivot Data

Prompt

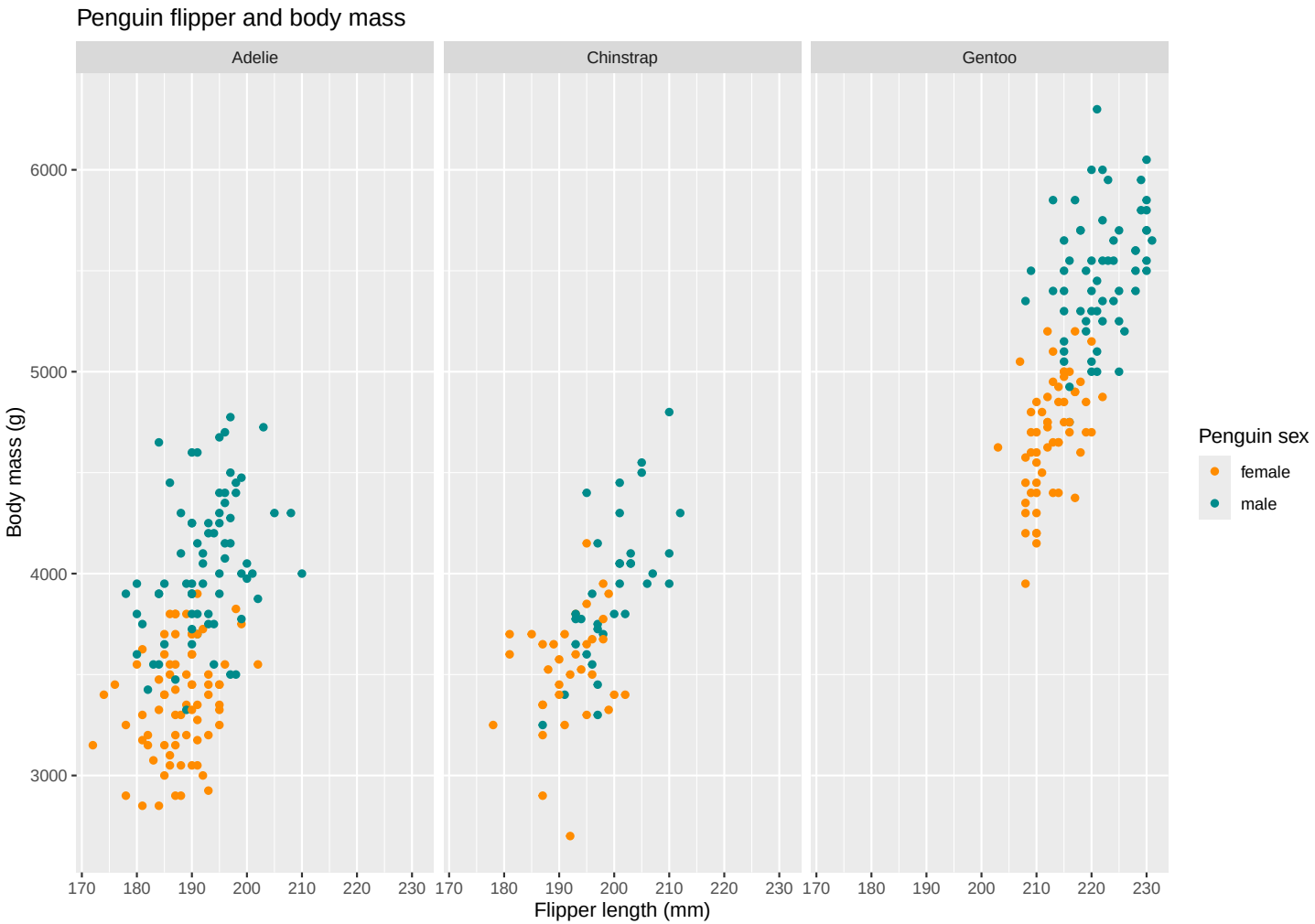
```
I have a wide dataset (called table4a) with the "country" column
as the id variable and columns named "1999" and "2000" that provide
the number of TB cases in each country for that year.

Provide R code that will convert
this wide dataset to long form
```

```r
library(tidyr)

table4a_long <- table4a|>
  pivot_longer(
    cols = c(`1999`, `2000`),
    names_to = "year",
    values_to = "cases"
  )

table4a_long
```

```
## # A tibble: 6 x 3
##   country     year   cases
##   <chr>       <chr>  <dbl>
## 1 Afghanistan 1999     745
## 2 Afghanistan 2000    2666
## 3 Brazil      1999   37737
## 4 Brazil      2000   80488
## 5 China       1999  212258
## 6 China       2000  213766
```

Example - Improve Visualizations

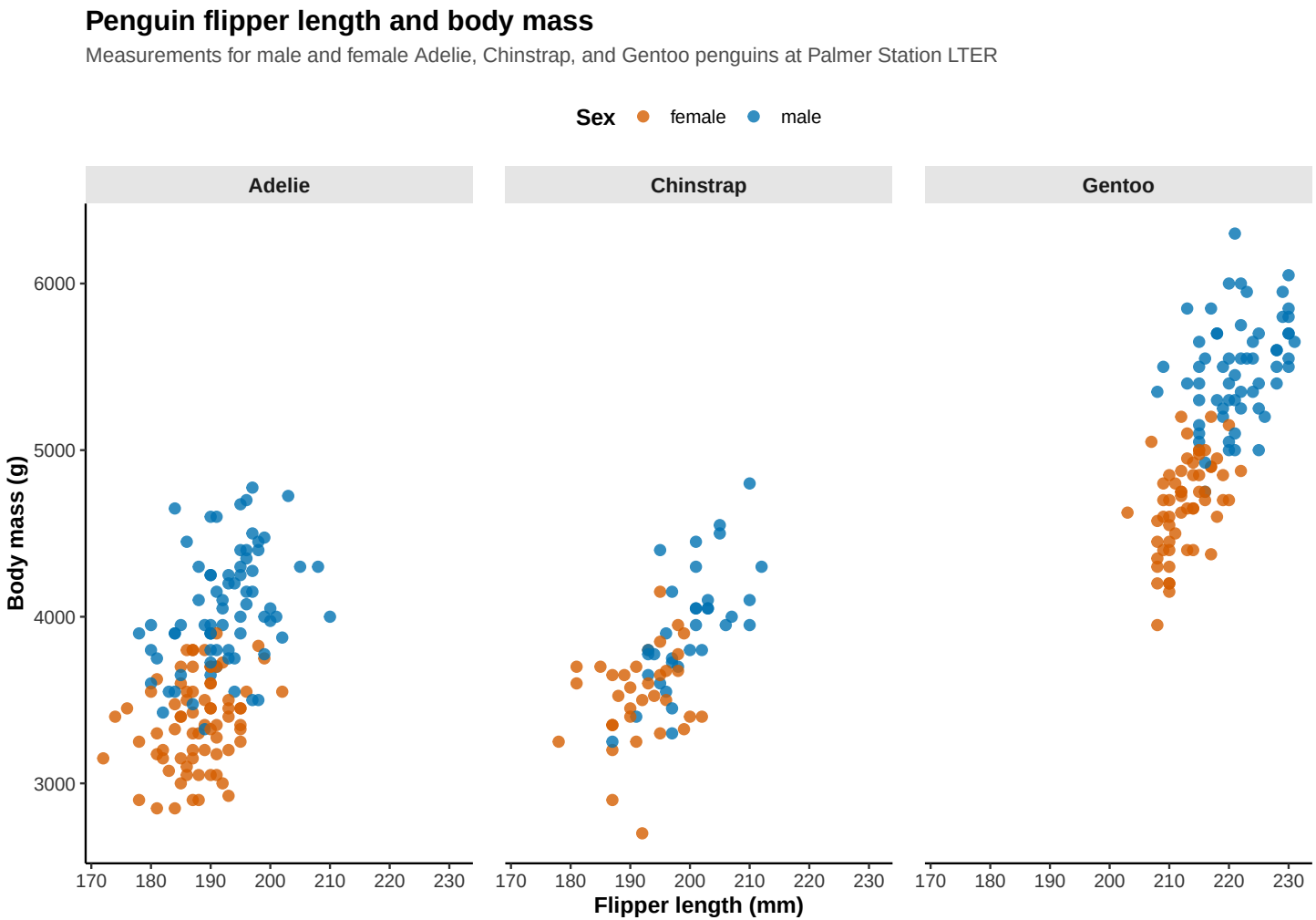
Before



Example - Improve Visualizations

After **Prompt:**

```
I have the following R code:
<PASTE R CODE HERE>

Please update the code so that the rendered visual is publication ready
```



Exercises

Available on course website.