

# **Workspace**

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# Welcome

This Quarto Book<sup>1</sup> is a workspace for the notes and projects of the programming/scripting languages that I am learning.

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<sup>1</sup>[Quarto Books Documentation](#)

# **Part I**

# **Data Science**

# 1 File Organization

When starting any computational project, following a well-documented structure will save the creators and future patrons a lot of troubles, eg, when wanting to replicate findings or locate a particular file.

The structure below is inspired by 2009 William Stafford Noble's paper [A Quick Guide to Organizing Computational Biology Projects](#). On a related topic, see 2014 Greg Wilson et al paper [Best Practices for Scientific Computing](#).

```
+-- data: contains the fixed data sets.  
    +- raw  
    +- processed, if needed  
  
+-- result: contains the computational experiments performed on the data sets  
            in the 'data' directory.  
    - NOTEBOOK: record the progress in details. The entries in this notebook  
                should be dated and relatively verbose with links or embedded  
                images or tables displaying the results of the experiment  
                performed. Also, this notebook should also record any  
                observation, conclusion, or ideas for future work. In case  
                the experiment fails, document how you know that experiment  
                failed to make it clear for those who may read this notebook  
                later. You may also transcribe notes from conversations and  
                emails. This notebook can reside online (e.g., Google Doc)  
                to give access to collaborator about the current status of  
                the project.  
    +- 2018.04.24  
    +- 2018.04.25  
    +- <chronological order>  
  
+-- doc: contains a separate sub-directory for each manuscript.  
    +- paper 1  
    +- paper 2  
    +- ...  
  
+-- src: contains the source code for the project.
```

## 2 EDA

With a new dataset, answer the followings using its codebook if available or via some search and/or asking if not.

- What is its source?
- Who collected it?
- When it was collected?
- What does each column/variable represent?
- What does each row/observation represent?

After that, answer the following questions through computations:

- How many columns/variables?
- How many rows/observations?
- What is the data type of each column/variable?
- What are the top few rows/observations?
- What are the bottom few rows/observations?
- How many missing values in each column/variable?
- How many rows/observations contain 1+ missing values?
- What is the summary statistics of each column/variable?

# 3 Tips

## 3.1 Clean Workspace @ Start

Always start by clearing the workspace to ensure objects created by other files are not used here.

```
rm(list = ls())
```

## 3.2 Insalling Missing Pckages

Although people may not like installing packages on their machines automatically for different reasons, I prefer this route for myself because I use multiple machines and install packages one at a time (after the code breaks multiple time because of the missing packages) is annoying.

Step 1: Store all needed packages to a variables:

```
packages <- c("here", "tidyverse", "janitor")
```

Step 2: Install missing packages

```
install.packages(setdiff(packages, rownames(installed.packages())))
```

## 3.3 Loading Packages

We can then load all the packages using one line.

```
lapply(packages, require, character.only = TRUE)
```

## **Part II**

# **Notebooks**

This section contains notes for the programming/scripting languages that I am learning.

# 4 R

## **Clear Workspace, DON'T EDIT**

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## **List Used Packages, EDIT**

List all the packages that will be used in chunk below.

```
packages <- c("here", "tidyverse", "janitor")
```

## **Load Packages, DON'T EDIT**

### **Install Missing**

Any missing package will be installed automatically. This ensure smoother execution when run by others.

```
# Do NOT modify
install.packages(setdiff(packages, rownames(installed.packages())))
```

### **Load**

Load all packages

```
# Do NOT modify
lapply(packages, require, character.only = TRUE)
```

```
[[1]]  
[1] TRUE
```

## 4.1 General Notes

- When writing R code, create a project instead of a file which will enable saving the workspace settings
- An R package usually includes:
  - a. reusable functions
  - b. documentation describing how to use the function
  - c. sample data
- Before running a project, clear the objects in its workspace environment to avoid mixing up objects created in other files. This can be done either:
  - a. pragmatically as shown below OR
  - b. Environment window -> Broom icon

## 4.2 Data Types

- character
- numeric
- logical
- raw
- imaginary numbers

To know the datatype of an object, run the command:

```
class(x) # give the data type of x
```

To know the type of the variables of each variable.

```
x |>  
  slice(0) |>  
  glimpse()
```

### 4.2.1 Mixing Data Types

- character + numeric -> character
- numeric + logical -> numeric
- numeric + character + logical -> character

## 4.3 Data Structures

- **vector**: hold single type of data

### i Creating Vector

The `c()` function (combine multiple elements) can be used to create vectors in R.

```
x <- c(1, 2, 3, 4)
```

- **matrix**: 2D vector
- **array**: nD vector
- **list**: generic vector, can hold mixed type of data, eg, one element can a character, another a list of integers, and the third could be a logical
- **data frame**: table where columns represent vectors
- **tibbles**: data frames, but slightly tweaked to work better with `tidyverse`—when printing tibbles, only the first few columns that fit into the screen will be shown

### i Printing tibble All Columns

To force the `print()` function to print all the columns of a `tibble`, set the `width` parameter to `Inf` as follows:

```
print(ds, width = Inf)
```

To construct small tibble by hand, use the `tribble` function as follows:

```
df <- tribble(  
  ~var1, ~var2, ~var3  
  "A", 1, TRUE,  
  "B", 2, FALSE,  
  "C", 3, TRUE  
)
```

- **factor**

To know the data structure and length of the object, run the command:

```
str(x) # give the structure type of x  
length(x) # length of structure
```

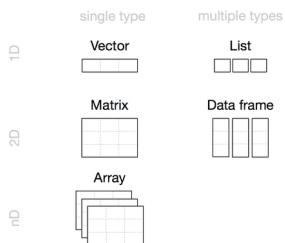


Figure 4.1: Common data structures in R ( taken from [Grolemund, 2014](#))

## 4.4 Basics Operations

### Assignment

```
x <- 3 # assign 3 to x (x gets 3)
(x <- 3) # assign 3 to x (x gets 3) & print the result to console
```

```
[1] 3
```

### Getting Help

```
args(round) # print the argument list of function
?round # show documentation of function in Help window
```

### Dealing with Structure

```
# concatenate set of values to create vector
weight_g <- c(50, 60, 3, 9)
animals <- c("dog", "bat", "cat")

# utilizing logical values to pull specific values
weight_g[weight_g < 10 & weight_g > 60 | weight_g == 50]
```

```
[1] 50
```

```
# pull dog & cat records
animals[animals %in% c("dog", "cat")]
```

```
[1] "dog" "cat"
```

```
animals[animals == "dog" | animals == "cat"]
```

```
[1] "dog" "cat"
```

Statistics

```
# signaling missing data using NA
heights <- c(2, 3, NA, 4)

# get mean while ignoring missing data
mean(heights, na.rm = TRUE)
```

```
[1] 3
```

```
# how to use mean
# ?mean
```

## 4.5 Exploratory Operations

The `here` package makes it easy to point to files starting from the project main directory.

```
library("here", "janitor")
```

Loading file from repository and saving it locally on disk. It is always a good idea to structure the workspace—for more information, see [Best Practices for Scientific Computing](#) paper.

```
download.file(
  url = "https://ndownloader.figshare.com/files/2292169",
  destfile = here("data", "portal_data_joined.csv")
)
```

Load file to R as data frame

```
surveys <- read.csv(here("data", "portal_data_joined.csv"))

glimpse(surveys)
```

```

Rows: 34,786
Columns: 13
$ record_id      <int> 1, 72, 224, 266, 349, 363, 435, 506, 588, 661, 748, 84-
$ month          <int> 7, 8, 9, 10, 11, 11, 12, 1, 2, 3, 4, 5, 6, 8, 9, 10, 1-
$ day            <int> 16, 19, 13, 16, 12, 12, 10, 8, 18, 11, 8, 6, 9, 5, 4, ~
$ year           <int> 1977, 1977, 1977, 1977, 1977, 1977, 1977, 1978, 1978, ~
$ plot_id        <int> 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, ~
$ species_id     <chr> "NL", "NL", "NL", "NL", "NL", "NL", "NL", "NL", ~
$ sex             <chr> "M", "M", "", "", "", "", "", "M", "", "", "M", "M-
$ hindfoot_length <int> 32, 31, NA, NA, NA, NA, NA, NA, NA, NA, NA, 32, NA, 34-
$ weight          <int> NA, NA, NA, NA, NA, NA, NA, 218, NA, NA, 204, 200, ~
$ genus           <chr> "Neotoma", "Neotoma", "Neotoma", "Neotoma", "Neotoma", ~
$ species         <chr> "albigula", "albigula", "albigula", "albigula", "albig-
$ taxa            <chr> "Rodent", "Rodent", "Rodent", "Rodent", "Rodent", "Rod-
$ plot_type       <chr> "Control", "Control", "Control", "Control", "Control", ~

```

Clean names

```

surveys <- surveys |>
  janitor::clean_names()

```

Inspecting data frame

```
class(surveys) # data type
```

```
[1] "data.frame"
```

```
str(surveys) # structure
```

```
'data.frame': 34786 obs. of 13 variables:
 $ record_id      : int  1 72 224 266 349 363 435 506 588 661 ...
 $ month          : int  7 8 9 10 11 11 12 1 2 3 ...
 $ day            : int  16 19 13 16 12 12 10 8 18 11 ...
 $ year           : int  1977 1977 1977 1977 1977 1977 1977 1978 1978 1978 ...
 $ plot_id        : int  2 2 2 2 2 2 2 2 2 2 ...
 $ species_id     : chr  "NL" "NL" "NL" "NL" ...
 $ sex             : chr  "M" "M" "" "" ...
 $ hindfoot_length: int  32 31 NA NA NA NA NA NA NA ...
 $ weight          : int  NA NA NA NA NA NA NA 218 NA ...
 $ genus           : chr  "Neotoma" "Neotoma" "Neotoma" "Neotoma" ...
```

```
$ species      : chr  "albigula" "albigula" "albigula" "albigula" ...
$ taxa        : chr  "Rodent"   "Rodent"   "Rodent"   "Rodent"   ...
$ plot_type    : chr  "Control"  "Control"  "Control"  "Control"  ...
```

```
surveys |>
  slice(0) |>
  glimpse()
```

```
Rows: 0
Columns: 13
$ record_id     <int>
$ month         <int>
$ day           <int>
$ year          <int>
$ plot_id       <int>
$ species_id    <chr>
$ sex           <chr>
$ hindfoot_length <int>
$ weight         <int>
$ genus          <chr>
$ species        <chr>
$ taxa           <chr>
$ plot_type      <chr>
```

```
dim(surveys) # dimensions
```

```
[1] 34786    13
```

```
nrow(surveys)
```

```
[1] 34786
```

```
ncol(surveys)
```

```
[1] 13
```

```
summary(surveys)
```

record_id	month	day	year	plot_id
Min. : 1	Min. : 1.000	Min. : 1.0	Min. :1977	Min. : 1.00
1st Qu.: 8964	1st Qu.: 4.000	1st Qu.: 9.0	1st Qu.:1984	1st Qu.: 5.00
Median :17762	Median : 6.000	Median :16.0	Median :1990	Median :11.00
Mean :17804	Mean : 6.474	Mean :16.1	Mean :1990	Mean :11.34
3rd Qu.:26655	3rd Qu.:10.000	3rd Qu.:23.0	3rd Qu.:1997	3rd Qu.:17.00
Max. :35548	Max. :12.000	Max. :31.0	Max. :2002	Max. :24.00

species_id	sex	hindfoot_length	weight
Length:34786	Length:34786	Min. : 2.00	Min. : 4.00
Class :character	Class :character	1st Qu.:21.00	1st Qu.: 20.00
Mode :character	Mode :character	Median :32.00	Median : 37.00
		Mean :29.29	Mean : 42.67
		3rd Qu.:36.00	3rd Qu.: 48.00
		Max. :70.00	Max. :280.00
		NA's :3348	NA's :2503

genus	species	taxa	plot_type
Length:34786	Length:34786	Length:34786	Length:34786
Class :character	Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character	Mode :character

Show first/last few objects/records/rows

```
head(surveys)
```

record_id	month	day	year	plot_id	species_id	sex	hindfoot_length	weight
1	1	7	16 1977	2	NL	M	32	NA
2	72	8	19 1977	2	NL	M	31	NA
3	224	9	13 1977	2	NL		NA	NA
4	266	10	16 1977	2	NL		NA	NA
5	349	11	12 1977	2	NL		NA	NA
6	363	11	12 1977	2	NL		NA	NA

genus	species	taxa	plot_type
1 Neotoma albigena	Rodent	Control	
2 Neotoma albigena	Rodent	Control	
3 Neotoma albigena	Rodent	Control	
4 Neotoma albigena	Rodent	Control	
5 Neotoma albigena	Rodent	Control	

```
6 Neotoma albigenula Rodent Control
```

```
tail(surveys)
```

	record_id	month	day	year	plot_id	species_id	sex	hindfoot_length	weight
34781	26787	9	27	1997	7	PL	F	21	16
34782	26966	10	25	1997	7	PL	M	20	16
34783	27185	11	22	1997	7	PL	F	21	22
34784	27792	5	2	1998	7	PL	F	20	8
34785	28806	11	21	1998	7	PX		NA	NA
34786	30986	7	1	2000	7	PX		NA	NA
	genus	species	taxa		plot_type				
34781	Peromyscus	leucopus	Rodent	Rodent	Exclosure				
34782	Peromyscus	leucopus	Rodent	Rodent	Exclosure				
34783	Peromyscus	leucopus	Rodent	Rodent	Exclosure				
34784	Peromyscus	leucopus	Rodent	Rodent	Exclosure				
34785	Chaetodipus	sp.	Rodent	Rodent	Exclosure				
34786	Chaetodipus	sp.	Rodent	Rodent	Exclosure				

#### 4.5.1 Retrieve specific element/row/column

```
surveys[1, 1] # element[1,1]
```

```
[1] 1
```

```
surveys[1, ] # row 1
```

	record_id	month	day	year	plot_id	species_id	sex	hindfoot_length	weight
1	1	7	16	1977	2	NL	M	32	NA
	genus	species	taxa	plot_type					
1	Neotoma	albigula	Rodent	Control					

```
head(surveys[, 1]) # column 1
```

```
[1] 1 72 224 266 349 363
```

```
head(surveys$sex) # column by name
```

```
[1] "M" "M" "" "" "" "
```

### 4.5.2 Dealing with factor (categorical) columns

R converts columns that contain characters to factors by default. Factors are treated as integer vectors. By default, R sorts levels in alphabetical order.

```
levels(surveys$sex)
```

```
NULL
```

```
nlevels(surveys$sex)
```

```
[1] 0
```

Reorder factors (to get better plots)

```
surveys$sex_ordered <- factor(surveys$sex, level = c("F", "M", ""))
str(surveys$sex_ordered)
```

```
Factor w/ 3 levels "F","M","": 2 2 3 3 3 3 3 3 3 2 3 ...
```

```
levels(surveys$sex_ordered)
```

```
[1] "F" "M" "
```

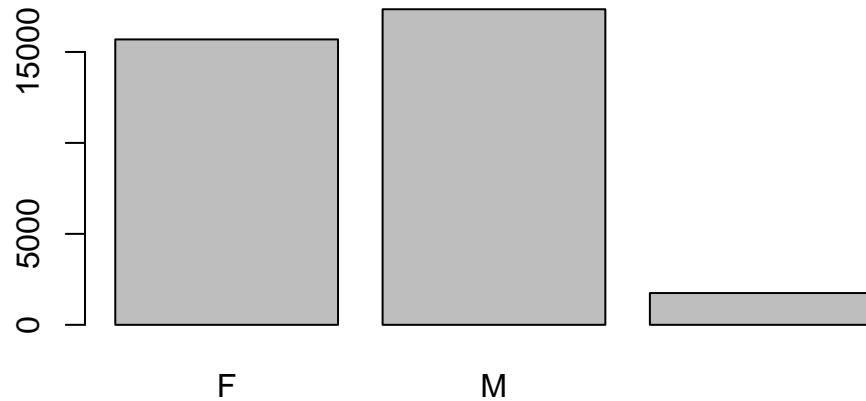
```
nlevels(surveys$sex_ordered)
```

```
[1] 3
```

### 4.5.3 Basic Plotting

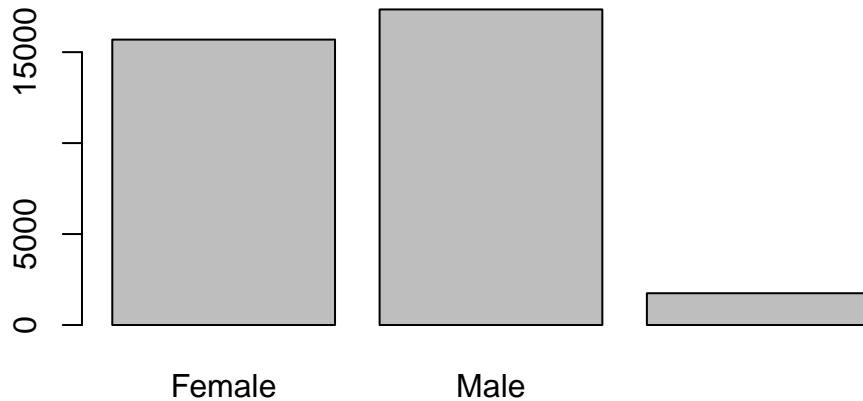
Histogram

```
# plot(surveys$sex) # not possible  
plot(surveys$sex_ordered)
```



Enhance the plot

```
levels(surveys$sex_ordered)[1] <- "Female"  
levels(surveys$sex_ordered)[2] <- "Male"  
plot(surveys$sex_ordered)
```



## 4.6 Data Manipulation

- **tidyverse**
  - makes manipulation of data easier
  - built to work with data frames directly
  - can directly work with data stored in an external database which give the advantage of only bringing what we need to the memory to work on without having to bring the whole database
- **tidyverse**
  - allows to swiftly convert b/w different data formats for plotting & analysis in order to accommodate the different requirements by different functions
    - \* sometime we want one row per measurement
    - \* other times we want the data aggregated like when plotting

Before using **tidyverse** and **tidyverse**:

- Install **tidyverse** package: umbrella-package that install several packages (tidyverse, dplyr, ggplot2, tibble, magrittr, etc.)
- Load the package each session

Load packages

```
library("tidyverse")
```

Load & inspect data

```
# notice the '_' instead of '.' of basic R
surveys <- read_csv(here("data", "portal_data_joined.csv"))
```

```
Rows: 34786 Columns: 13
-- Column specification -----
Delimiter: ","
chr (6): species_id, sex, genus, species, taxa, plot_type
dbl (7): record_id, month, day, year, plot_id, hindfoot_length, weight

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
str(surveys) # structure:tbl_df (tibble)
```

```
spc_tbl_ [34,786 x 13] (S3: spec_tbl_df/tbl_df/tbl/data.frame)
$ record_id      : num [1:34786] 1 72 224 266 349 ...
$ month          : num [1:34786] 7 8 9 10 11 ...
$ day            : num [1:34786] 16 19 13 16 12 ...
$ year           : num [1:34786] 1977 1977 1977 1977 ...
$ plot_id        : num [1:34786] 2 2 2 2 2 ...
$ species_id     : chr [1:34786] "NL" "NL" "NL" ...
$ sex             : chr [1:34786] "M" "M" NA ...
$ hindfoot_length: num [1:34786] 32 31 NA ...
$ weight          : num [1:34786] NA ...
$ genus           : chr [1:34786] "Neotoma" ...
$ species         : chr [1:34786] "albigula" ...
$ taxa            : chr [1:34786] "Rodent" ...
$ plot_type       : chr [1:34786] "Control" ...
- attr(*, "spec")=
.. cols(
..   record_id = col_double(),
..   month = col_double(),
..   day = col_double(),
..   year = col_double(),
..   plot_id = col_double(),
```

```

..   species_id = col_character(),
..   sex = col_character(),
..   hindfoot_length = col_double(),
..   weight = col_double(),
..   genus = col_character(),
..   species = col_character(),
..   taxa = col_character(),
..   plot_type = col_character()
.. )
- attr(*, "problems")=<externalptr>

# view(surveys) # preview in the viewer window, avoid when rendering

```

#### 4.6.1 Selection

Select certain columns

```
select(surveys, plot_id, species_id, weight)
```

```

# A tibble: 34,786 x 3
  plot_id species_id weight
  <dbl> <chr>      <dbl>
1       2 NL          NA
2       2 NL          NA
3       2 NL          NA
4       2 NL          NA
5       2 NL          NA
6       2 NL          NA
7       2 NL          NA
8       2 NL          NA
9       2 NL         218
10      2 NL          NA
# i 34,776 more rows

```

Select all columns except ...

```
select(surveys, -sex)
```

```

# A tibble: 34,786 x 12
  record_id month   day   year plot_id species_id hindfoot_length weight genus
  <dbl>     <dbl> <dbl> <dbl> <dbl> <chr>           <dbl>        <dbl> <chr>
1       1      1     1    2011     1  1             100.        100.  A
2       1      1     1    2011     1  1             100.        100.  A
3       1      1     1    2011     1  1             100.        100.  A
4       1      1     1    2011     1  1             100.        100.  A
5       1      1     1    2011     1  1             100.        100.  A
6       1      1     1    2011     1  1             100.        100.  A
7       1      1     1    2011     1  1             100.        100.  A
8       1      1     1    2011     1  1             100.        100.  A
9       1      1     1    2011     1  1             100.        100.  A
10      1      1     1    2011     1  1             100.        100.  A
# i 34,776 more rows

```

```

<dbl> <dbl> <dbl> <dbl> <dbl> <chr> <dbl> <dbl> <chr>
1      1     7    16  1977      2  NL    32   NA Neotoma
2     72     8    19  1977      2  NL    31   NA Neotoma
3    224     9    13  1977      2  NL    NA   NA Neotoma
4    266    10    16  1977      2  NL    NA   NA Neotoma
5    349    11    12  1977      2  NL    NA   NA Neotoma
6    363    11    12  1977      2  NL    NA   NA Neotoma
7    435    12    10  1977      2  NL    NA   NA Neotoma
8    506     1     8  1978      2  NL    NA   NA Neotoma
9    588     2    18  1978      2  NL    NA  218 Neotoma
10   661     3    11  1978      2  NL    NA   NA Neotoma
# i 34,776 more rows
# i 3 more variables: species <chr>, taxa <chr>, plot_type <chr>
```

Select rows based on criteria

```
filter(surveys, year == 1995)
```

```

# A tibble: 1,180 x 13
  record_id month day year plot_id species_id sex hindfoot_length weight
  <dbl> <dbl> <dbl> <dbl> <dbl> <chr> <chr> <dbl> <dbl>
1 22314     6     7  1995      2  NL     M       34   NA
2 22728     9     23 1995      2  NL     F       32   165
3 22899    10    28 1995      2  NL     F       32   171
4 23032    12     2 1995      2  NL     F       33   NA
5 22003     1    11 1995      2  DM     M       37   41
6 22042     2     4 1995      2  DM     F       36   45
7 22044     2     4 1995      2  DM     M       37   46
8 22105     3     4 1995      2  DM     F       37   49
9 22109     3     4 1995      2  DM     M       37   46
10 22168    4     1 1995      2  DM     M      36   48
# i 1,170 more rows
# i 4 more variables: genus <chr>, species <chr>, taxa <chr>, plot_type <chr>
```

## 4.6.2 Piping

Sending the results of one function to another

```

# in multiple steps
survey_less5 <- filter(surveys, weight < 5)
survey_sml <- select(survey_less5, species_id, sex, weight)
```

```
# in one long step
survey_sml <- select(filter(surveys, weight < 5), species_id, sex, weight)

# using pipe %>% of magritter package.  Use Ctrl + Shift + M to add
survey_sml <- surveys %>%
  filter(weight < 5) %>%
  select(species_id, sex, weight)
```

### 4.6.3 Summary

Summary of groups (1+ columns)

one factor

```
surveys %>%
  group_by(sex) %>%
  summarise(mean_weight = mean(weight, na.rm = TRUE))
```

```
# A tibble: 3 x 2
  sex    mean_weight
  <chr>     <dbl>
1 F          42.2
2 M          43.0
3 <NA>       64.7
```

two factors

```
surveys %>%
  group_by(sex, species) %>%
  summarise(mean_weight = mean(weight, na.rm = TRUE))
```

`summarise()` has grouped output by 'sex'. You can override using the `groups` argument.

```
# A tibble: 81 x 3
# Groups:   sex [3]
  sex    species    mean_weight
  <chr> <chr>           <dbl>
1 F      albigula     154.
```

```

2 F    baileyi        30.2
3 F    eremicus       22.8
4 F    flavus         7.97
5 F    fulvescens     13.7
6 F    fulviventer    69
7 F    hispidus        69.0
8 F    leucogaster     31.1
9 F    leucopus         19.3
10 F   maniculatus      22.1
# i 71 more rows

```

```

surveys %>%
  group_by(species, sex) %>%
  summarise(mean_weight = mean(weight, na.rm = TRUE))

```

``summarise()` has grouped output by 'species'. You can override using the  
.groups` argument.`

```

# A tibble: 81 x 3
# Groups:   species [40]
  species      sex  mean_weight
  <chr>       <chr>     <dbl>
1 albigula     F      154.
2 albigula     M      166.
3 albigula     <NA>     168.
4 audubonii    <NA>     NaN
5 baileyi      F      30.2
6 baileyi      M      33.8
7 baileyi      <NA>     30.6
8 bilineata    <NA>     NaN
9 brunneicapillus <NA>     NaN
10 chlorurus   <NA>     NaN
# i 71 more rows

```

to avoid using `na.rm = FALSE` each statistics

```

surveys %>%
  filter(!is.na(weight)) %>%
  group_by(species, sex) %>%
  summarise(mean_weight = mean(weight), sd_weight = sd(weight), sd_count = n())

```

```
`summarise()` has grouped output by 'species'. You can override using the
`.groups` argument.
```

```
# A tibble: 59 x 5
# Groups:   species [22]
  species sex   mean_weight sd_weight sd_count
  <chr>   <chr>     <dbl>      <dbl>     <int>
1 albigula F       154.       39.2      652
2 albigula M       166.       49.0      484
3 albigula <NA>    168.       44.2      16
4 baileyi F        30.2       5.27     1617
5 baileyi M        33.8       8.27     1188
6 baileyi <NA>    30.6       9.96      5
7 eremicus F       22.8       4.57     568
8 eremicus M       20.6       3.49     689
9 eremicus <NA>   17.7       0.577     3
10 flavus F        7.97       1.69     742
# i 49 more rows
```

arrange by mean weight

```
surveys %>%
  filter(!is.na(weight)) %>%
  group_by(species, sex) %>%
  summarise(mean_weight = mean(weight), sd_weight = sd(weight), sd_count = n()) %>%
  arrange(mean_weight)
```

```
`summarise()` has grouped output by 'species'. You can override using the
`.groups` argument.
```

```
# A tibble: 59 x 5
# Groups:   species [22]
  species sex   mean_weight sd_weight sd_count
  <chr>   <chr>     <dbl>      <dbl>     <int>
1 flavus  <NA>      6         1.63      4
2 taylori M       7.36      0.842     14
3 flavus  M       7.89      1.59     802
4 flavus  F       7.97      1.69     742
5 taylori F       9.16      2.24     31
6 montanus M      9.5       1.29      4
7 megalotis M    10.1       1.73    1339
```

```

8 montanus F          11      2.16      4
9 megalotis <NA>    11.1     2.57      12
10 megalotis F       11.1     2.56     1184
# i 49 more rows

```

in descending order

```

surveys %>%
  filter(!is.na(weight)) %>%
  group_by(species, sex) %>%
  summarise(mean_weight = mean(weight), sd_weight = sd(weight), sd_count = n()) %>%
  arrange(desc(mean_weight))

```

`summarise()` has grouped output by 'species'. You can override using the `groups` argument.

```

# A tibble: 59 x 5
# Groups:   species [22]
  species   sex   mean_weight   sd_weight   sd_count
  <chr>     <chr>     <dbl>       <dbl>       <int>
1 albigula  <NA>      168.        44.2       16
2 albigula  M         166.        49.0      484
3 albigula  F         154.        39.2      652
4 hispidus  <NA>      130         NA          1
5 spilosoma M         130         NA          1
6 spectabilis M        122.       24.0      1220
7 spectabilis <NA>    120         18.5       18
8 spectabilis F        118.       21.5      1106
9 fulviventer F       69          37.8       16
10 hispidus F        69.0        29.7       98
# i 49 more rows

```

by count

```

surveys %>%
  filter(!is.na(weight)) %>%
  group_by(species, sex) %>%
  summarise(mean_weight = mean(weight), sd_weight = sd(weight), sd_count = n()) %>%
  arrange(sd_count)

```

```
`summarise()` has grouped output by 'species'. You can override using the
`.groups` argument.
```

```
# A tibble: 59 x 5
# Groups:   species [22]
  species     sex   mean_weight   sd_weight   sd_count
  <chr>      <chr>     <dbl>       <dbl>       <int>
1 hispidus    <NA>      130        NA          1
2 intermedius <NA>      18         NA          1
3 leucopus     <NA>      25         NA          1
4 spilosoma    F          57         NA          1
5 spilosoma    M          130        NA          1
6 fulviventer <NA>      40.5       6.36        2
7 leucogaster  <NA>      29         11.3        2
8 eremicus     <NA>      17.7       0.577       3
9 ordii        <NA>      50.7       6.51        3
10 sp.          F          20.7       1.15        3
# i 49 more rows
```

#### 4.6.4 Count

Count of a categorical column

```
surveys %>%
  count(sex)
```

```
# A tibble: 3 x 2
  sex     n
  <chr> <int>
1 F      15690
2 M      17348
3 <NA>   1748
```

#### 4.6.5 Reshaping

Using gather & spread

prepare the needed data first

```

surveys_gw <- surveys %>%
  filter(!is.na(weight)) %>%
  group_by(genus, plot_id) %>%
  summarize(mean_weight = mean(weight))

```

`summarise()` has grouped output by 'genus'. You can override using the `.`groups` argument.

creating a 2D table where each dimension represent a category the cell will represent a statistics

```

surveys_spread <- surveys_gw %>%
  spread(key = genus, value = mean_weight)
str(surveys_spread)

```

```

tibble [24 x 11] (S3: tbl_df/tbl/data.frame)
$ plot_id      : num [1:24] 1 2 3 4 5 6 7 8 9 10 ...
$ Baiomys     : num [1:24] 7 6 8.61 NA 7.75 ...
$ Chaetodipus : num [1:24] 22.2 25.1 24.6 23 18 ...
$ Dipodomys   : num [1:24] 60.2 55.7 52 57.5 51.1 ...
$ Neotoma     : num [1:24] 156 169 158 164 190 ...
$ Onychomys   : num [1:24] 27.7 26.9 26 28.1 27 ...
$ Perognathus : num [1:24] 9.62 6.95 7.51 7.82 8.66 ...
$ Peromyscus  : num [1:24] 22.2 22.3 21.4 22.6 21.2 ...
$ Reithrodontomys: num [1:24] 11.4 10.7 10.5 10.3 11.2 ...
$ Sigmodon    : num [1:24] NA 70.9 65.6 82 82.7 ...
$ Spermophilus: num [1:24] NA NA NA NA NA NA NA NA NA ...

```

```
head(surveys_spread)
```

```

# A tibble: 6 x 11
  plot_id Baiomys Chaetodipus Dipodomys Neotoma Onychomys Perognathus Peromyscus
  <dbl>    <dbl>     <dbl>     <dbl>    <dbl>    <dbl>     <dbl>     <dbl>
1       1      7        22.2      60.2    156.     27.7      9.62    22.2
2       2      6        25.1      55.7    169.     26.9      6.95    22.3
3       3     8.61      24.6      52.0    158.     26.0      7.51    21.4
4       4     NA        23.0      57.5    164.     28.1      7.82    22.6
5       5     7.75      18.0      51.1    190.     27.0      8.66    21.2
6       6     NA        24.9      58.6    180.     25.9      7.81    21.8
# i 3 more variables: Reithrodontomys <dbl>, Sigmodon <dbl>, Spermophilus <dbl>

```

bring spread back

```
surveys_gw <- surveys_spread %>%
  gather(key = genus, value = mean_weight, -plot_id)
str(surveys_gw)

tibble [240 x 3] (S3:tbl_df/tbl/data.frame)
$ plot_id    : num [1:240] 1 2 3 4 5 6 7 8 9 10 ...
$ genus      : chr [1:240] "Baiomys" "Baiomys" "Baiomys" "Baiomys" ...
$ mean_weight: num [1:240] 7 6 8.61 NA 7.75 ...
```

```
head(surveys_gw)
```

```
# A tibble: 6 x 3
  plot_id genus   mean_weight
  <dbl> <chr>     <dbl>
1       1 Baiomys     7
2       2 Baiomys     6
3       3 Baiomys    8.61
4       4 Baiomys    NA
5       5 Baiomys    7.75
6       6 Baiomys    NA
```

#### 4.6.6 Filtering

Remove missing data

```
survey_complete <- surveys %>%
  filter(!is.na(weight), !is.na(hindfoot_length), !is.na(sex))
```

Filter those that has sample greater than 50

```
species_counts <- survey_complete %>%
  count(species_id) %>%
  filter(n >= 50)
```

filter only those in the indicated category

```
surveys_com <- surveys %>%
  filter(species_id %in% c("albigula", "eremicus"))
```

#### 4.6.7 Saving to disk

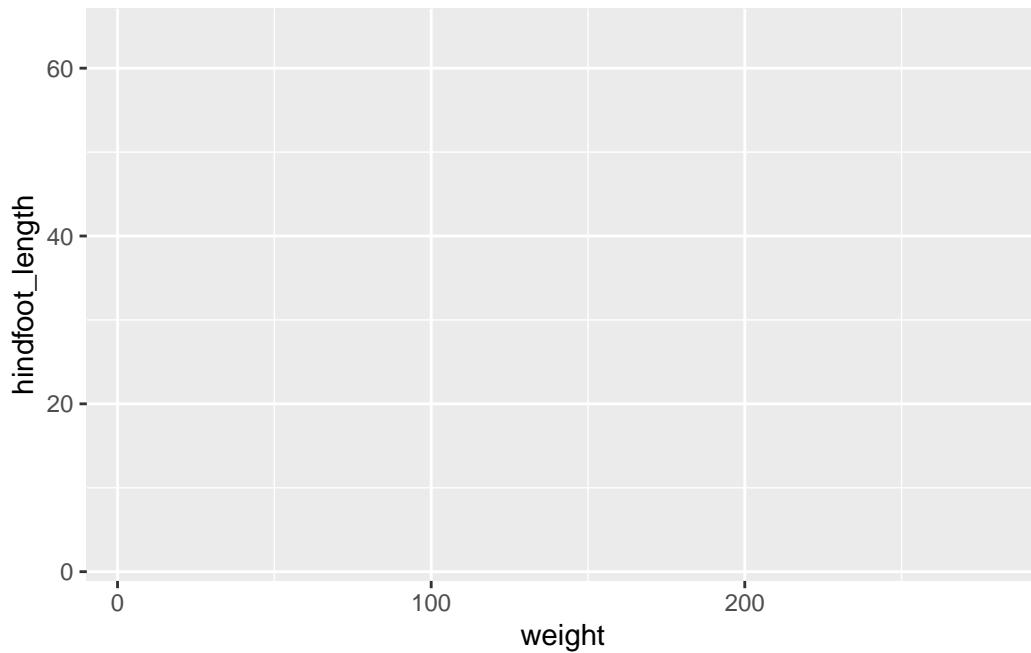
```
write_csv()
```

### 4.7 Visualization

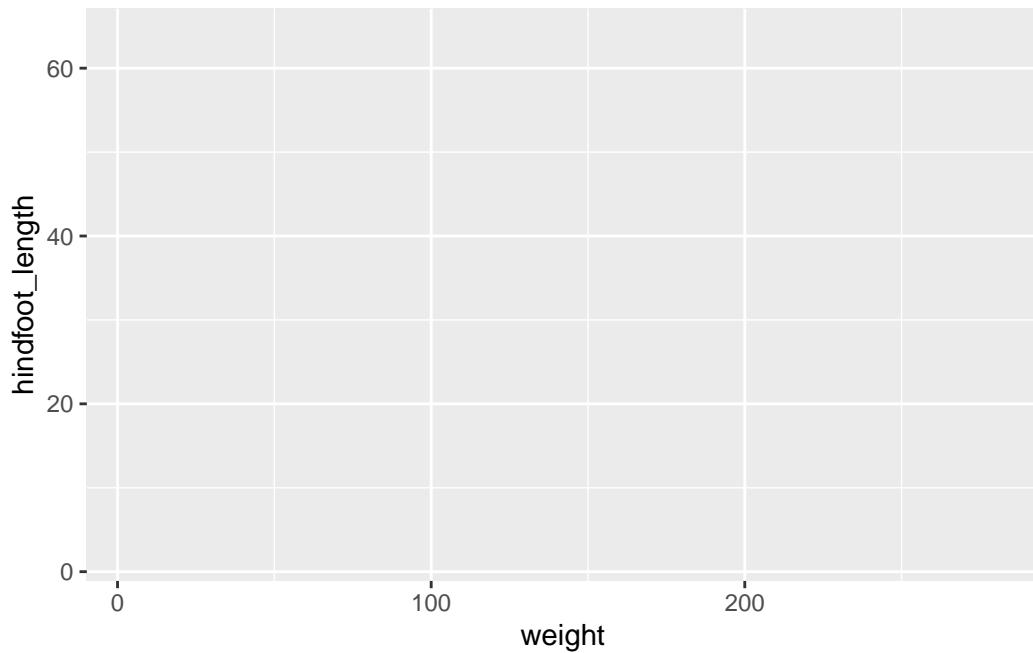
- Help in making complex plots from data frames in simple steps
- ggplot graphics are built step by step by adding new elements; this makes it flexible as well as customization
- To get list of ggplot2 geometric objects: `help.search("geom_ ", package="ggplot2")`
- To know the aesthetic specification each geom\_ can take: `vignette("ggplot2-specs")`

Step 1: Bind the plot to specific data frame

```
surveys_plot <- ggplot(
  data = survey_complete,
  mapping = aes(x = weight, y = hindfoot_length)
)
surveys_plot
```



```
# Color for each group
surveys_plot <- ggplot(
  data = survey_complete,
  mapping = aes(x = weight, y = hindfoot_length),
  color = species_id
)
surveys_plot
```

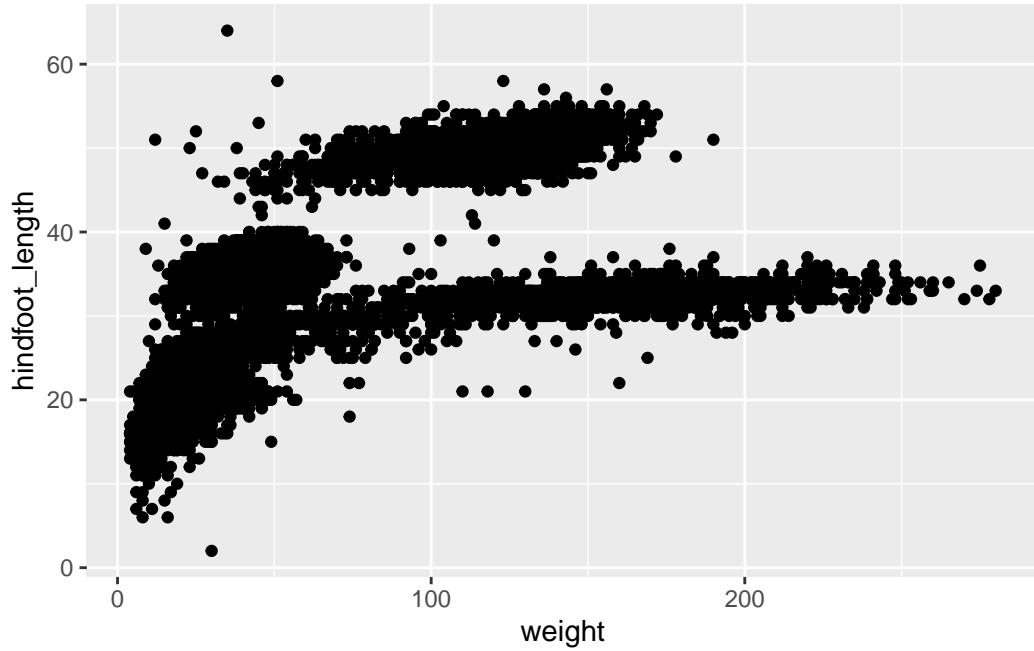


Step 2: Select the type of the plot

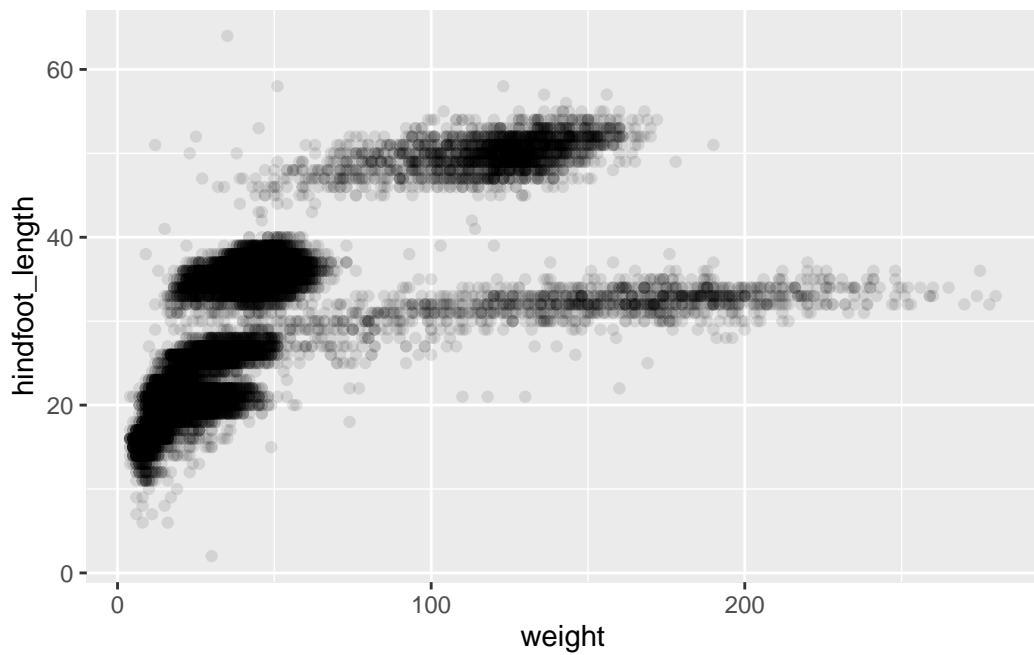
- scatter plot, dot plots, etc. > `geom_point()`
- boxplots > `geom_boxplot()`
- trend lines, time series, etc. > `geom_line()`

#### 4.7.1 Scatter plot

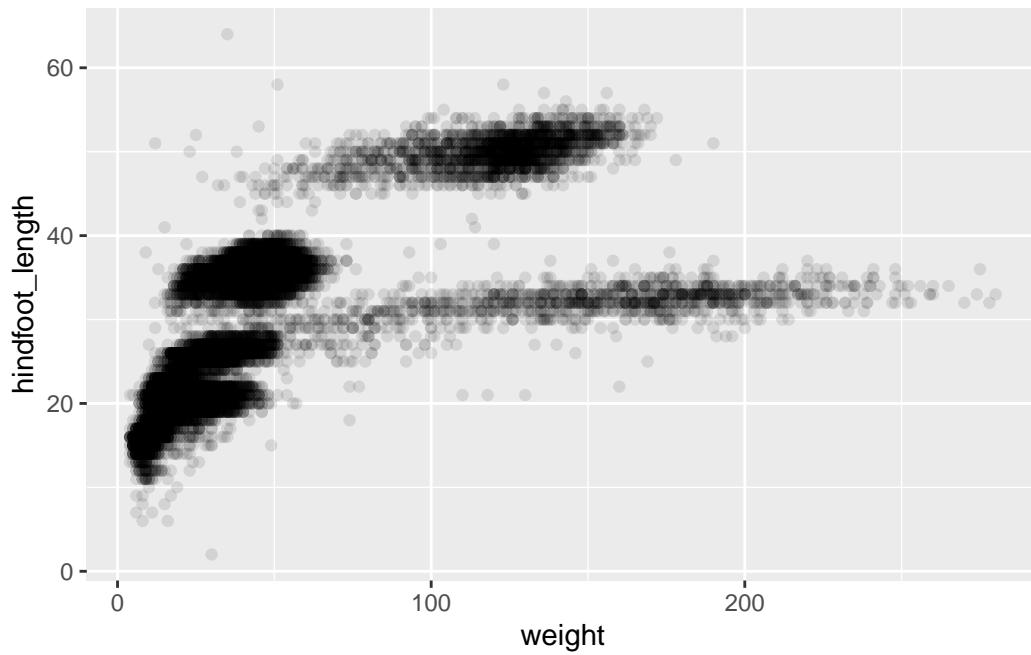
```
surveys_plot + geom_point()
```



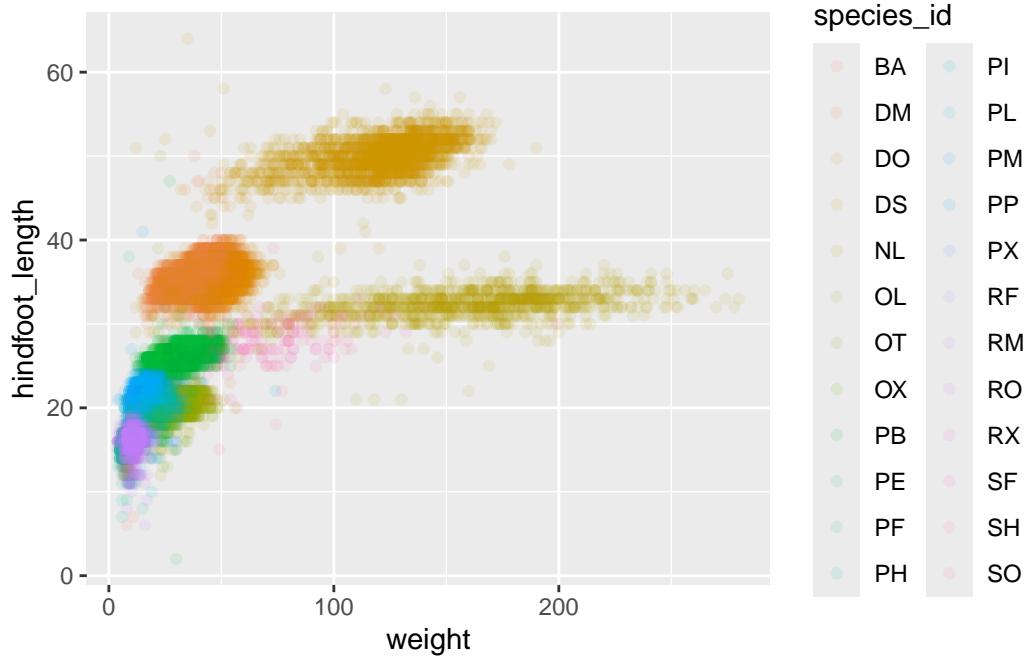
```
# add transparency  
surveys_plot + geom_point(alpha = 0.1)
```



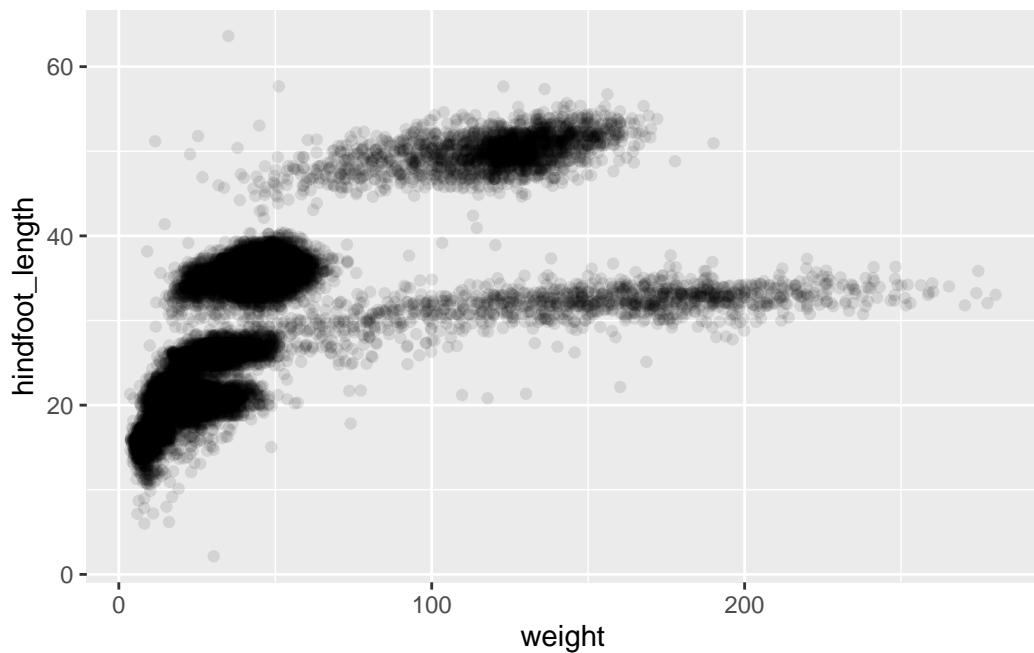
```
# color if not used in binding  
surveys_plot + geom_point(alpha = 0.1, color = "black")
```



```
# add color if not used in binding  
surveys_plot + geom_point(alpha = 0.1, aes(color = species_id))
```

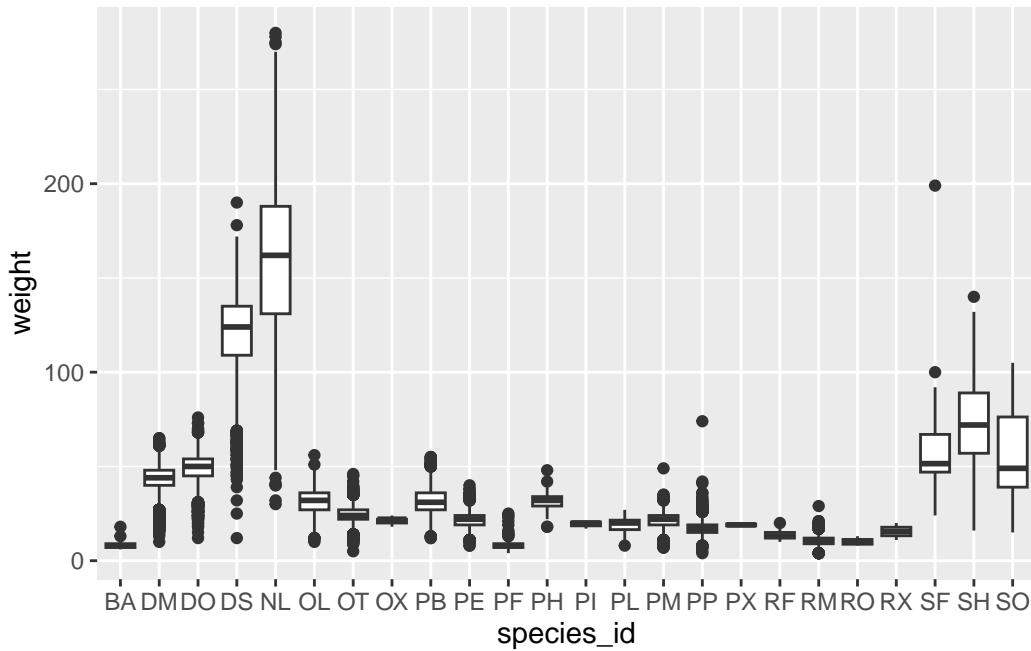


```
# make the color blend by introducing small random variation in points locations
# used when having small data sets
surveys_plot + geom_jitter(alpha = 0.1)
```

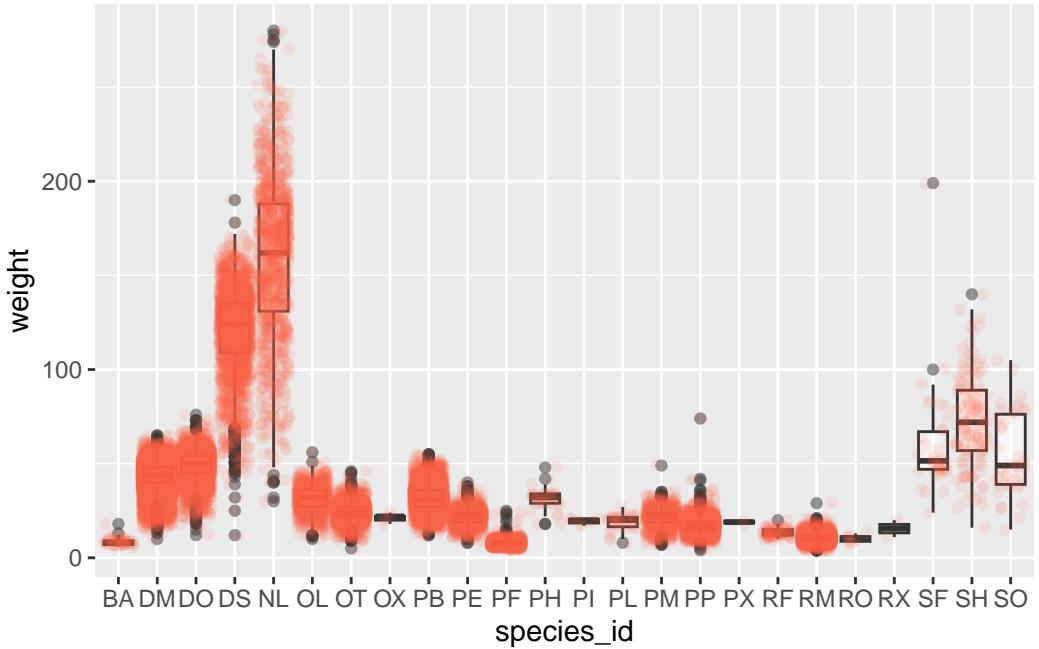


#### 4.7.2 Boxplot

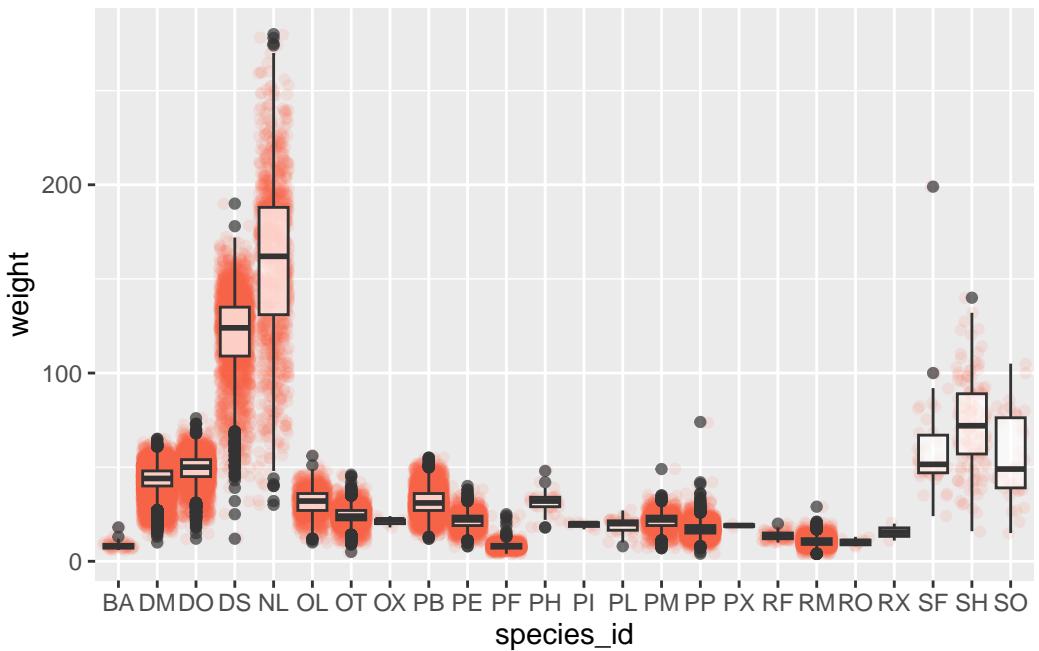
```
surveys_plot <- ggplot(  
  data = survey_complete,  
  mapping = aes(x = species_id, y = weight)  
)  
  
surveys_plot + geom_boxplot()
```



```
# show data  
surveys_plot + geom_boxplot(alpha = 0.5) +  
  geom_jitter(alpha = 0.1, color = "tomato")
```



```
# bring boxplot layer in front
surveys_plot + geom_jitter(alpha = 0.1, color = "tomato") +
  geom_boxplot(alpha = 0.7)
```

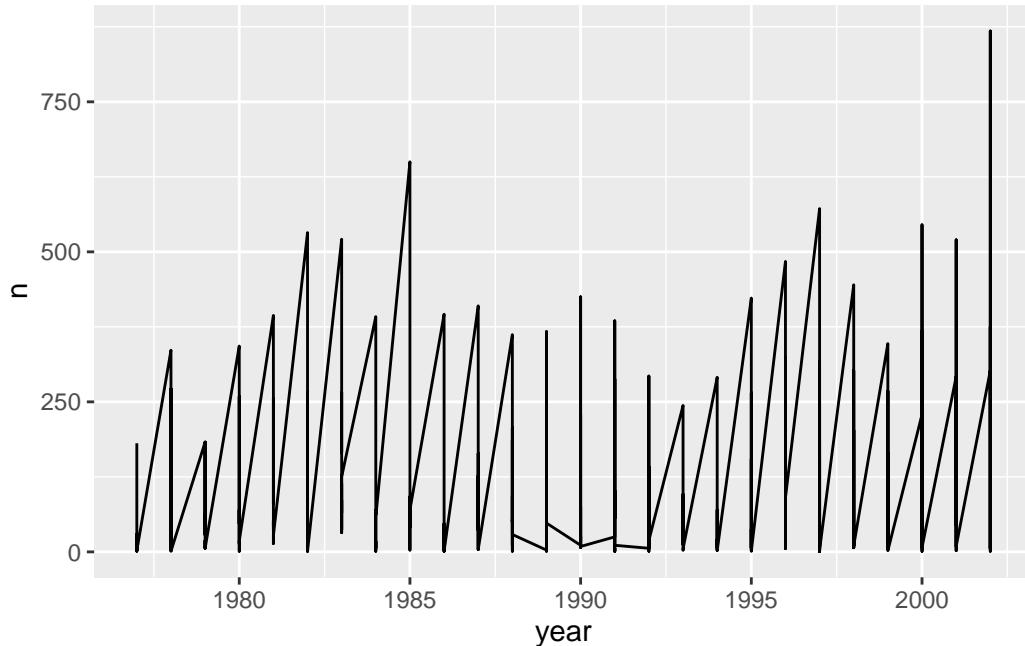


#### 4.7.3 Time series data

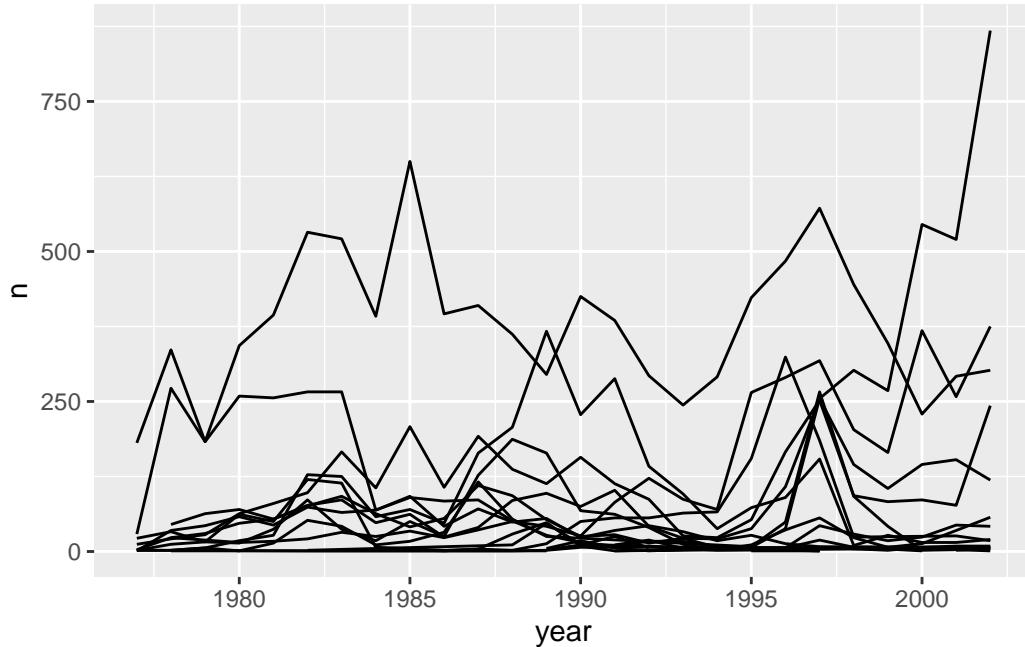
```
# create appropriate dataset
yearly_count <- survey_complete %>%
  count(year, species_id)

surveys_plot <- ggplot(
  data = yearly_count,
  mapping = aes(x = year, y = n)
)

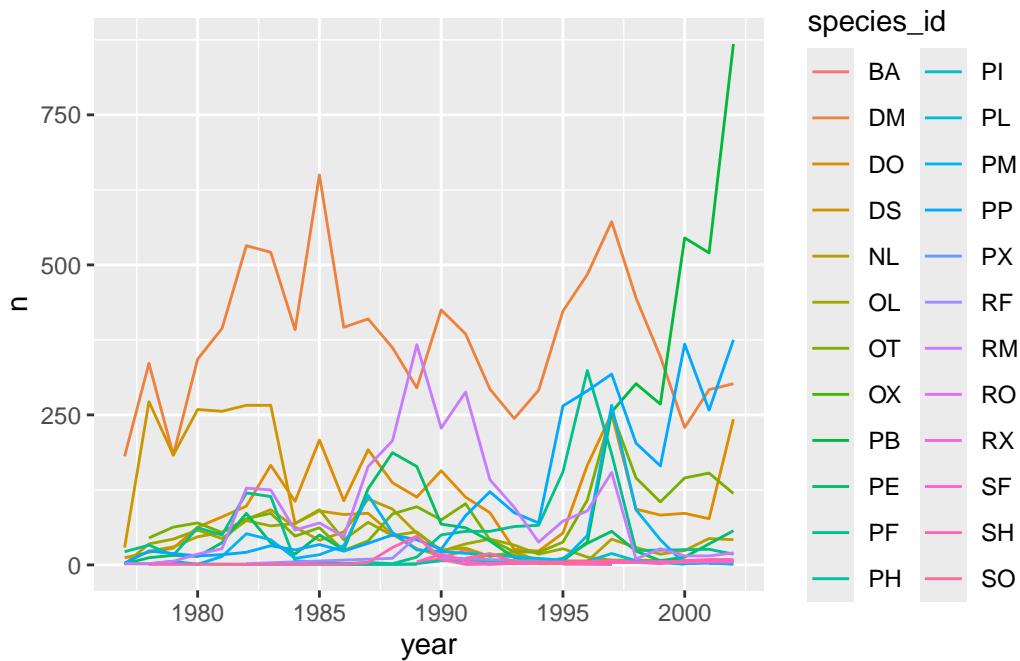
surveys_plot + geom_line()
```



```
# make it more meaningful by breaking it by category
surveys_plot + geom_line(aes(group = species_id))
```

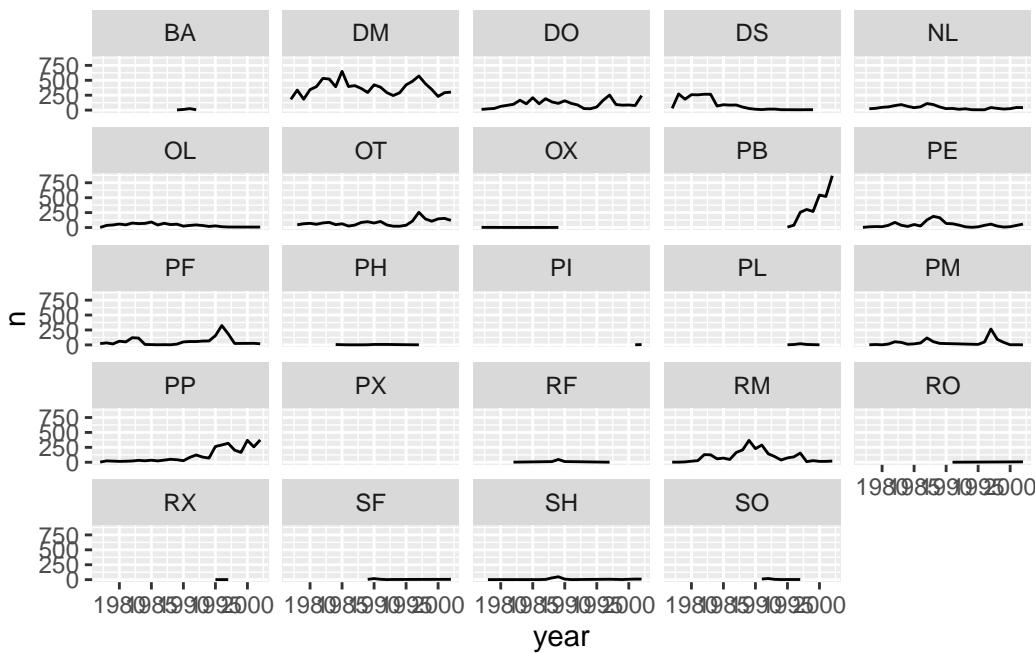


```
# make it more colorful
surveys_plot + geom_line(aes(color = species_id))
```



```
# split into multiple plots
surveys_plot + geom_line() + facet_wrap(~species_id)
```

`geom\_line()`: Each group consists of only one observation.  
i Do you need to adjust the group aesthetic?

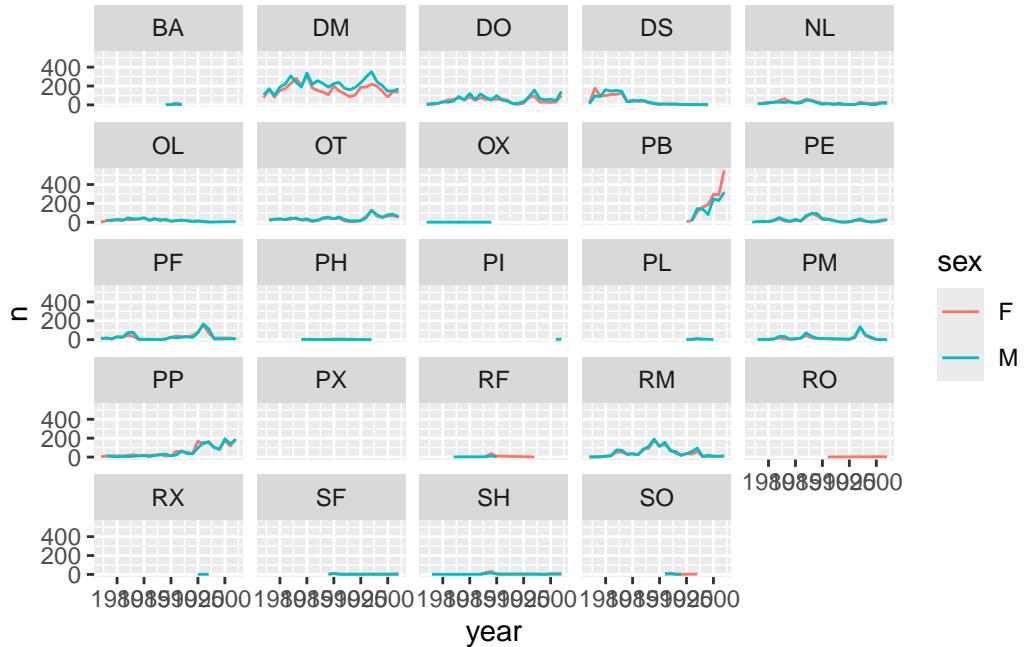


```
# split the line in each plot by sex
yearly_sex_counts <- survey_complete %>%
  count(year, species_id, sex)

surveys_plot <- ggplot(
  data = yearly_sex_counts,
  mapping = aes(x = year, y = n)
)

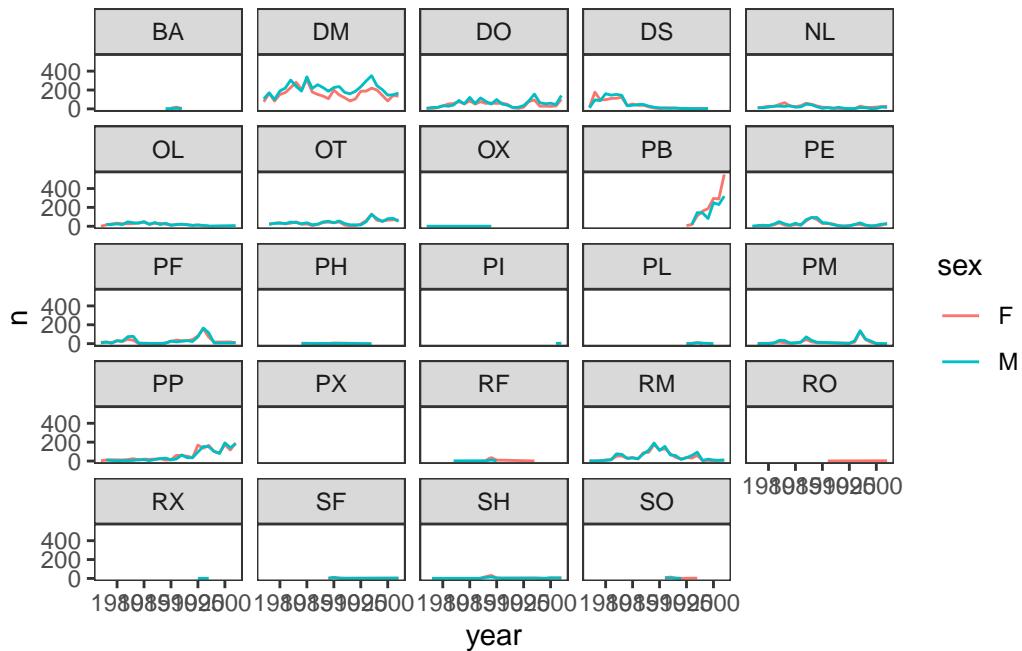
surveys_plot + geom_line(aes(color = sex)) +
  facet_wrap(~species_id)
```

`geom\_line()`: Each group consists of only one observation.  
i Do you need to adjust the group aesthetic?



```
# remove background
surveys_plot + geom_line(aes(color = sex)) +
  facet_wrap(~species_id) +
  theme_bw() +
  theme(panel.grid = element_blank())
```

`geom\_line()`: Each group consists of only one observation.  
i Do you need to adjust the group aesthetic?



## 4.8 References

- OU Software Carpentry Workshop (check other workshops [here](#))
  - [Main Tutorial](#)
  - [Data Carpentry with R](#)
  - [Software Carpentry with R](#)
  - [Etherpad](#)
  - [Google Doc](#)
- [Intro to ggplot by Allison Horst](#)
- [R for Data Science book by Garrett Grolemund and Hadley Wickham](#)
- [Best Practices for Scientific Computing paper](#)

# 5 Quarto

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages <- c()
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run by others.

```
# Do NOT modify
install.packages(setdiff(packages, rownames(installed.packages())))
```

### 5.0.1 Load

Load all packages {-}

```
# Do NOT modify
lapply(packages, require, character.only = TRUE)
```

```
list()
```

## 5.1 Render & Review

1. VSCode/RStudio -> *Render* button
2. Terminal -> `quarto preview`
3. Terminal -> `quarto preview help`

## 5.2 Render w/o Review

1. Terminal -> `quarto render`
2. Terminal -> `quarto render help`

## 5.3 Import Content

To import a document to another use the following shortcodes:

```
<!-- {{{ include file.qmd }}} -->
```

## 5.4 References

- [Quarto Reference](#)

# 6 RStudio

## 6.1 Keyboard Shortcuts

### Mac Users

In place of **Ctrl** in the keyboard shortcuts below, use **Cmd**.

### RStudio Tips

[RStudio Tip](#) on X on how to use RStudio IDE effectively.

Below is a set of helpful keyboard shortcut. The full list can be reached by clicking Tools -> Keyboard Shortcut Help (**Alt+Shift+K**) -> See All Shortcuts

- **Ctrl+Enter**: execute the code statement at which cursor is standing and move the cursor to the beginning of the next statement
- **Ctrl+Shift+S**: execute the whole R script
- **Ctrl+Alt+I**: insert new code chunk
- **Ctrl+Shift+C**: comment/un-comment
- **Alt- : move line up**
- **Alt- : move line down**
- **Ctrl+D**: delete line
- **Ctrl+Shift+A**: format code
- **Ctrl+M**: add pipe `|>` operator—to change from `%>%`, go to Tools -> Global Options... -> Code section -> Editing tab -> check Use native pipe operator, `|>` (requires R 4.1+)
- **Ctrl++**: increase font size of all windows
- **Ctrl--**: decrease font size of all windows
- **Alt+-** : insert assignment `<-`. Notice:
  - the inserted assignment it is surrounded by spaces
  - the action happen when the cursor is inside an R chunk or R script file

## 6.2 Notes

- **Working Directory** is the location where R looks for files and store files. RStudio showed this location at the top of the *console* window. The location can be printed to the console using the R command `getwd()` (get working directory).
- A data-science project typically contains multiple types of data. Each type is recommended to be kept in separate folder. These types of data are:
  - Data
  - Scripts
  - Results
  - Figures
- When creating project using RStudio, a file with the extension `.Rproj` will be created. Clicking this file will automatically open the project in RStudio.
- Whenever inside a project, one should only use *relative paths* (relative to the working directory, ie, the project home) except for file hosted on the internet which require using *absolute paths*.

# **7 Microsoft Windows**

## **7.1 CMD Command**

- To know which software has update: run cmd as administrator -> type `winget upgrade`.  
To update all of at once, type `winget upgrade --all`

# **Part III**

# **R for Data Science (2e)**

This section contains replications for the examples used in the [R for Data Science \(2e\) book](#), one Quarto file per chapter of the book.

# 8 Data Visualization

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages = c("palmerpenguins", "ggthemes", "ggplot2", "dplyr", "here", "knitr")
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run by others.

! Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify  
lapply(packages, require, character.only = TRUE)
```

```
[[1]]  
[1] TRUE
```

```
[[2]]  
[1] TRUE
```

```
[[3]]  
[1] TRUE
```

```
[[4]]  
[1] TRUE
```

```
[[5]]  
[1] TRUE
```

```
[[6]]  
[1] TRUE
```

## 8.1 Introduction

This page introduces the plot creation vocabulary step by step

## 8.2 Plot Creation Process

### 8.2.1 Load Dataset

The `penguins` dataset from the `palmerpenguins` package will be used for plotting. Typically, the package is loaded using the `library` function as shown in the code chunk below. However, a better approach is the one outlined in `?@sec-packages`.

```
library(palmerpenguins)
```

Explore the dataset

```
help(penguins)
```

Size measurements for adult foraging penguins near Palmer Station,  
Antarctica

Description:

Includes measurements for penguin species, island in Palmer Archipelago, size (flipper length, body mass, bill dimensions), and sex. This is a subset of 'penguins\_raw'.

Usage:

```
penguins
```

Format:

A tibble with 344 rows and 8 variables:

species a factor denoting penguin species (Adélie, Chinstrap and Gentoo)

island a factor denoting island in Palmer Archipelago, Antarctica (Biscoe, Dream or Torgersen)

bill\_length\_mm a number denoting bill length (millimeters)

bill\_depth\_mm a number denoting bill depth (millimeters)

flipper\_length\_mm an integer denoting flipper length (millimeters)

body\_mass\_g an integer denoting body mass (grams)

sex a factor denoting penguin sex (female, male)

year an integer denoting the study year (2007, 2008, or 2009)

Source:

Adélie penguins: Palmer Station Antarctica LTER and K. Gorman.

2020. Structural size measurements and isotopic signatures of foraging among adult male and female Adélie penguins (*Pygoscelis adeliae*) nesting along the Palmer Archipelago near Palmer Station, 2007–2009 ver 5. Environmental Data Initiative. doi: 10.6073/pasta/98b16d7d563f265cb52372c8ca99e60f (URL: <https://doi.org/10.6073/pasta/98b16d7d563f265cb52372c8ca99e60f>)

Gentoo penguins: Palmer Station Antarctica LTER and K. Gorman. 2020. Structural size measurements and isotopic signatures of foraging among adult male and female Gentoo penguin (*Pygoscelis papua*) nesting along the Palmer Archipelago near Palmer Station, 2007–2009 ver 5. Environmental Data Initiative. doi: 10.6073/pasta/7fcfa67fb28d56ee2ffa3d9370ebda689 (URL: <https://doi.org/10.6073/pasta/7fcfa67fb28d56ee2ffa3d9370ebda689>)

Chinstrap penguins: Palmer Station Antarctica LTER and K. Gorman. 2020. Structural size measurements and isotopic signatures of foraging among adult male and female Chinstrap penguin (*Pygoscelis antarcticus*) nesting along the Palmer Archipelago near Palmer Station, 2007–2009 ver 6. Environmental Data Initiative. doi: 10.6073/pasta/c14dfcfada8ea13a17536e73eb6fbe9e (URL: <https://doi.org/10.6073/pasta/c14dfcfada8ea13a17536e73eb6fbe9e>)

Originally published in: Gorman KB, Williams TD, Fraser WR (2014) Ecological Sexual Dimorphism and Environmental Variability within a Community of Antarctic Penguins (Genus *Pygoscelis*). PLoS ONE 9(3): e90081. doi:10.1371/journal.pone.0090081

Explore the dataset differently

```
dplyr::glimpse(penguins)
```

```
Rows: 344
Columns: 8
$ species      <fct> Adelie, Adelie, Adelie, Adelie, Adelie, Adelie, Adel-
$ island        <fct> Torgersen, Torgersen, Torgersen, Torgersen, Torgers-
$ 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-
```

### 8.2.2 Load Plotting Package

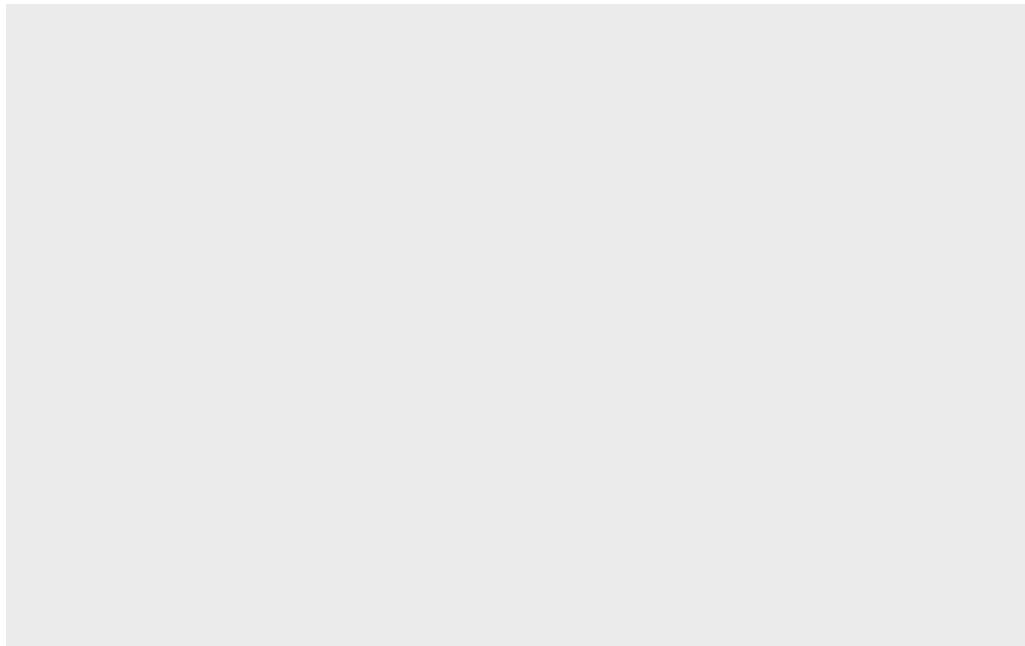
The `ggplot2` package will be used for plotting. The package is typically loaded using the `library` function as shown in the code chunk below. However, a better approach is the one outlined in `?@sec-packages`.

```
library(ggplot2)
```

### 8.2.3 Create ggplot object

Create an empty canvas by instantiating a `ggplot` object using the `ggplot()` function.

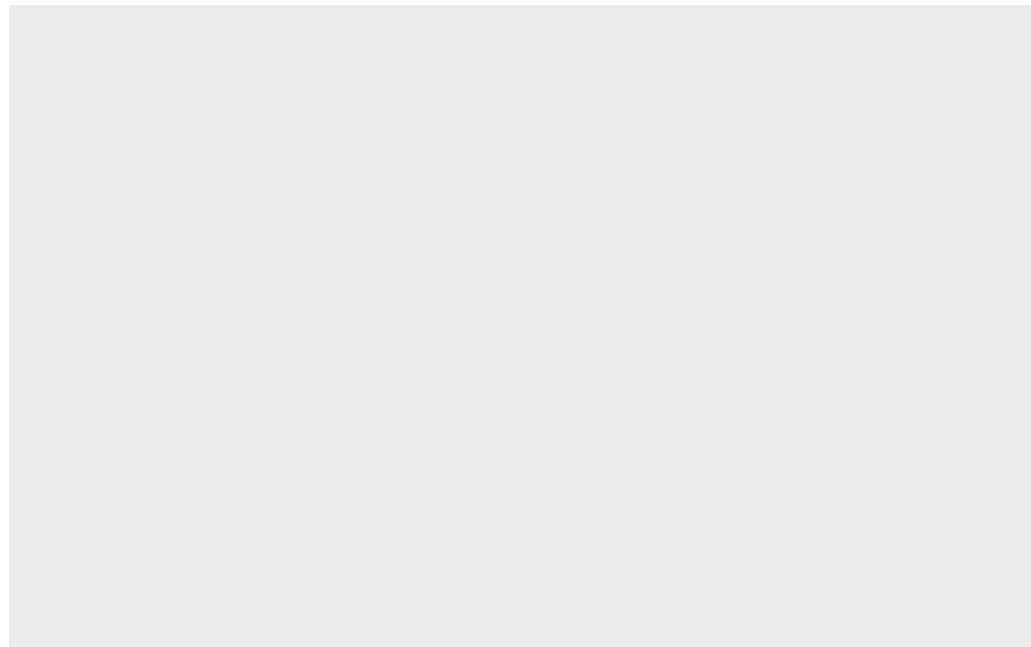
```
ggplot()
```



### 8.2.4 Link Dataset

Link the dataset with the instantiated `ggplot` object using the `data` parameter.

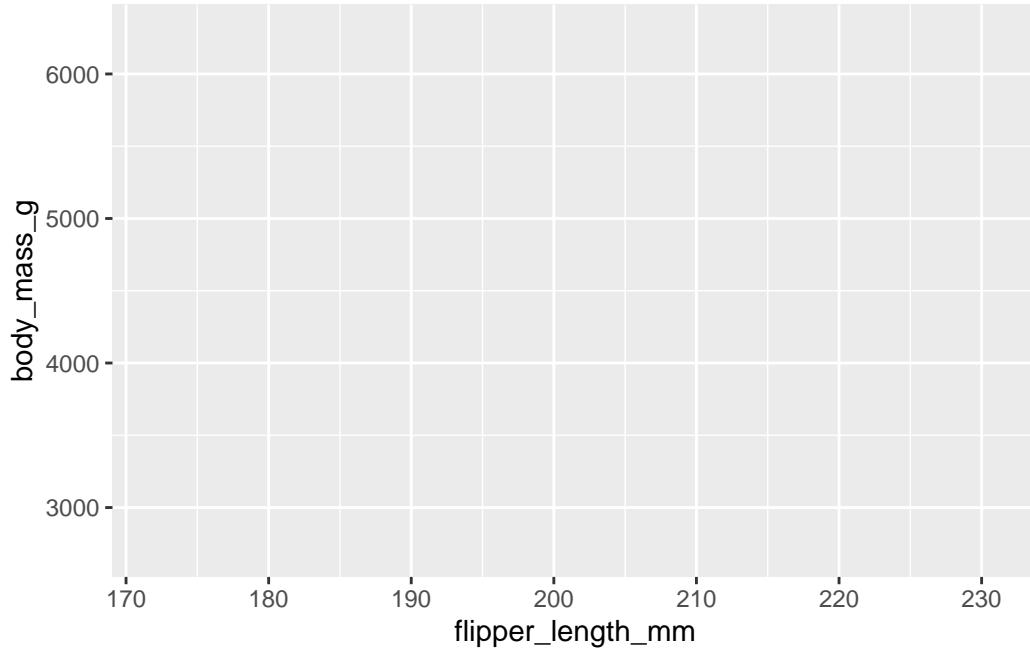
```
ggplot(data = penguins)
```



### 8.2.5 Map Two Variables

Specify which of the variables in the dataset will be used as the plot aesthetics (visual properties) using the `mapping` argument done via the `aes()` function.

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

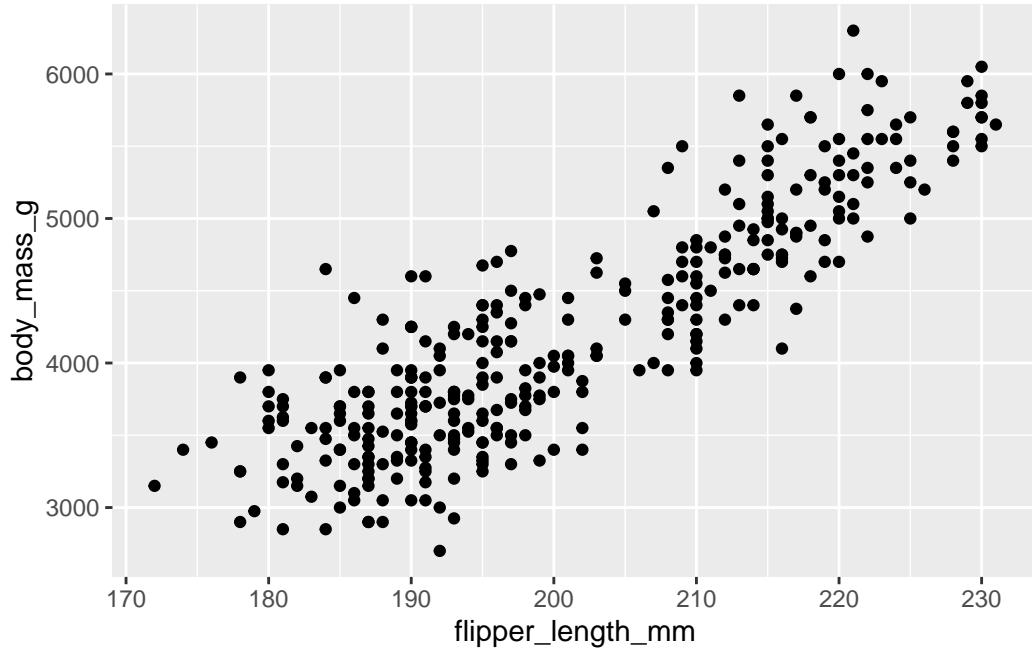


### 8.2.6 Display Data

Specify how the data (observations) will be represented geometrically on the plot, eg, bars, points, or line. The functions starting with `geom_` is used for this purpose. These functions add layer of the selected geometric object to the plot.

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

Warning: Removed 2 rows containing missing values or values outside the scale range  
(`geom\_point()`).

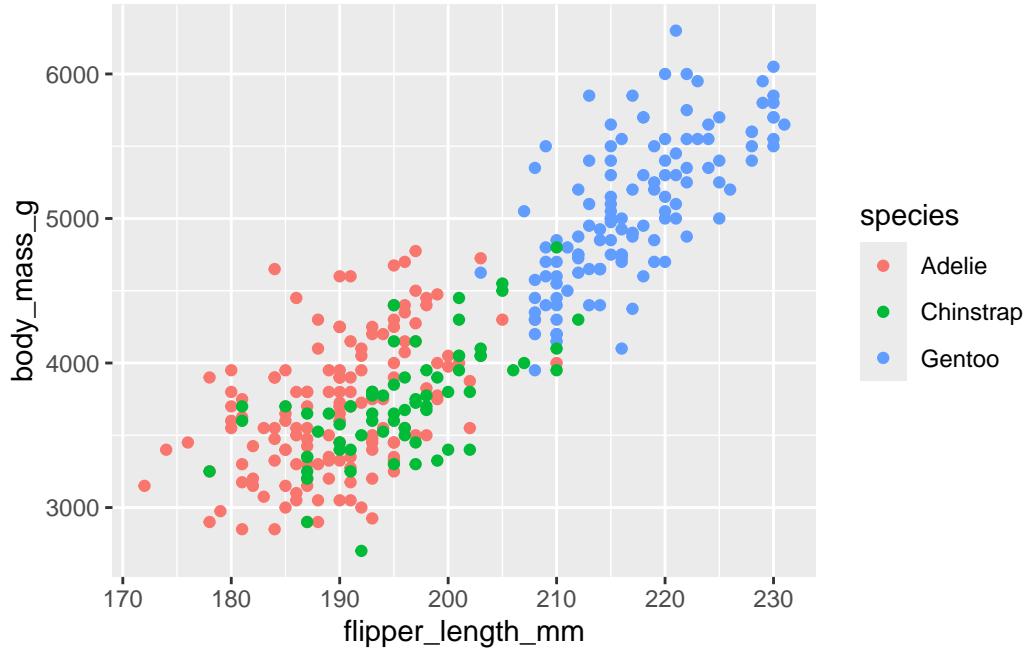


### 8.2.7 Map Third Variables

Other variables in the dataset can be linked to plot aesthetics (visual properties) using the `mapping` argument done via the `aes()` function.

```
ggplot(
  data = penguins,
  mapping = aes(x = flipper_length_mm, y = body_mass_g, color = species)
) +
  geom_point()
```

Warning: Removed 2 rows containing missing values or values outside the scale range (`geom\_point()`).



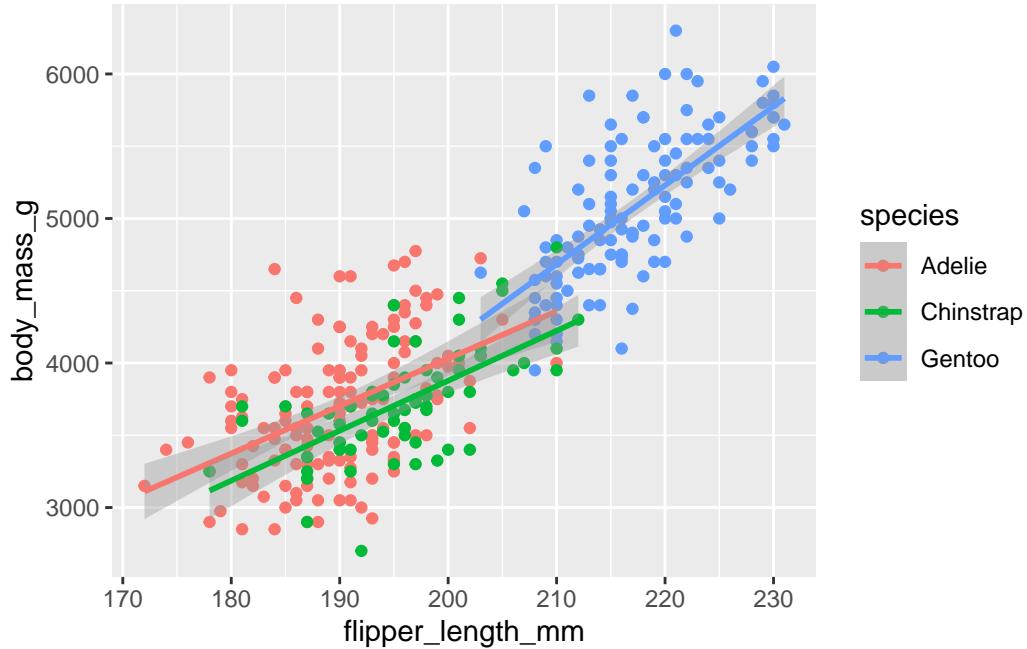
### 8.2.8 Display Three Trendlines

More geometric representations for the data can be specified using the functions starting with `geom_` which will add layer of the selected geometric object to the plot.

```
ggplot(
  data = penguins,
  mapping = aes(x = flipper_length_mm, y = body_mass_g, color = species)
) +
  geom_point() +
  geom_smooth(method = "lm")
`geom_smooth()` using formula = 'y ~ x'

Warning: Removed 2 rows containing non-finite outside the scale range
(`stat_smooth()`).

Warning: Removed 2 rows containing missing values or values outside the scale range
(`geom_point()`).
```



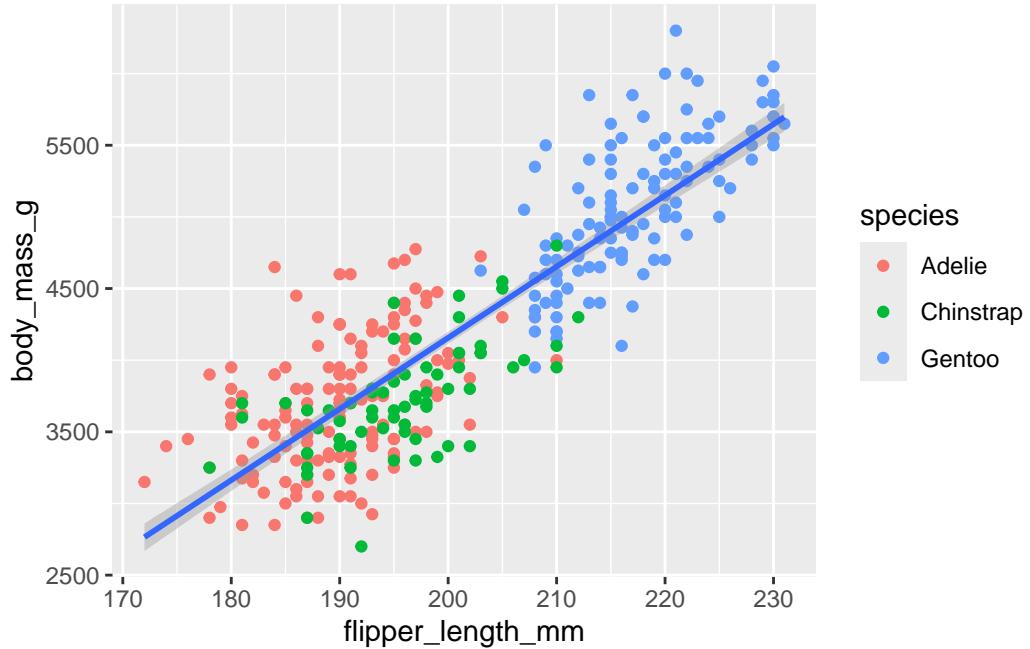
### 8.2.9 Display One Trendline

The aesthetic mapping defined in the `ggplot()` function is *global* meaning that all the `geom_()` functions inherit it. However, the aesthetic mapping defined in the `geom_()` functions are *local*, ie, not shared with other `geom_()` functions.

```
ggplot(data = penguins,
       mapping = aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(mapping = aes(color = species)) +
  geom_smooth(method = "lm")`geom_smooth()` using formula = 'y ~ x'
```

Warning: Removed 2 rows containing non-finite outside the scale range  
(`stat\_smooth()`).

Warning: Removed 2 rows containing missing values or values outside the scale range  
(`geom\_point()`).



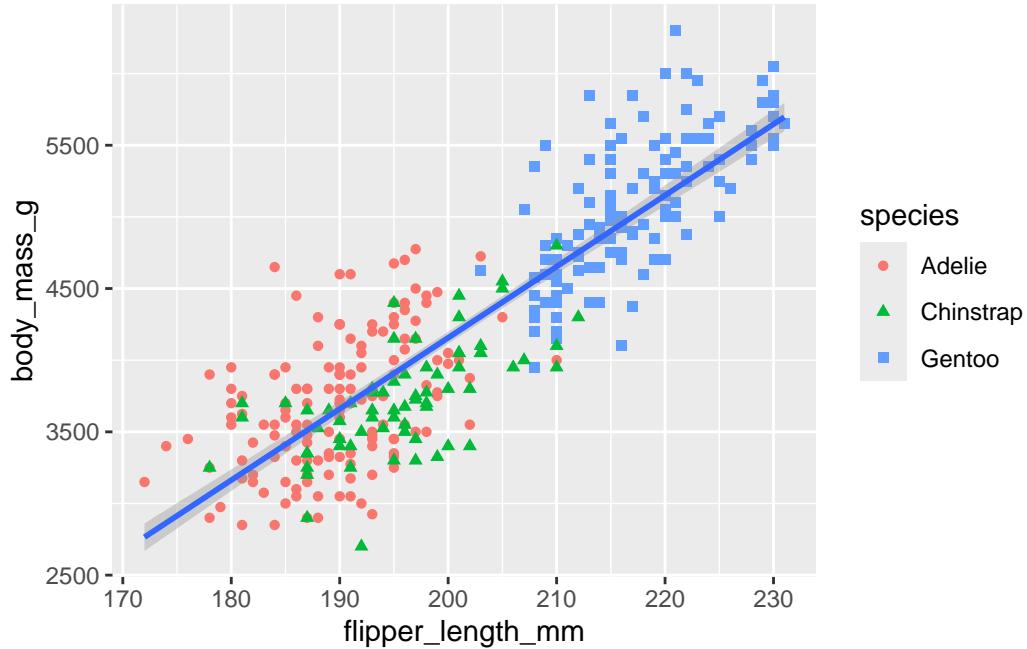
### 8.2.10 Map One Variable Twice

We can link the same variable to multiple plot aesthetics (visual properties) using the `mapping` parameter done via the `aes()` function.

```
ggplot(data = penguins,
       mapping = aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(mapping = aes(color = species, shape = species)) +
  geom_smooth(method = "lm")`geom_smooth()` using formula = 'y ~ x'
```

Warning: Removed 2 rows containing non-finite outside the scale range  
(`stat\_smooth()`).

Warning: Removed 2 rows containing missing values or values outside the scale range  
(`geom\_point()`).



### 8.2.11 Fix Labels

The `labs()` function can be used to make the plot more accessible. The function will add new layer to the plot and the following items can be added to the layer using the corresponding parameters

- a title using the `title` parameter
- a sub-title, if necessary, using the `subtitle` parameter
- x-axis title using the `x` parameter
- y-axis title using the `y` parameter
- data-series label or legend using the `color` and/or `shape` parameters

```
ggplot(data = penguins,
       mapping = aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(mapping = aes(color = species, shape = species)) +
  geom_smooth(method = "lm") +
  labs(
    title = 'Palmer Three Species Penguins',
    subtitle = 'The flipper length has a moderately strong positive linear relationship with',
    x = 'Flipper length (mm)',
    y = 'Body mass (g)',
    shape = 'Species',
```

```

    color = 'Species'
)
`geom_smooth()` using formula = 'y ~ x'

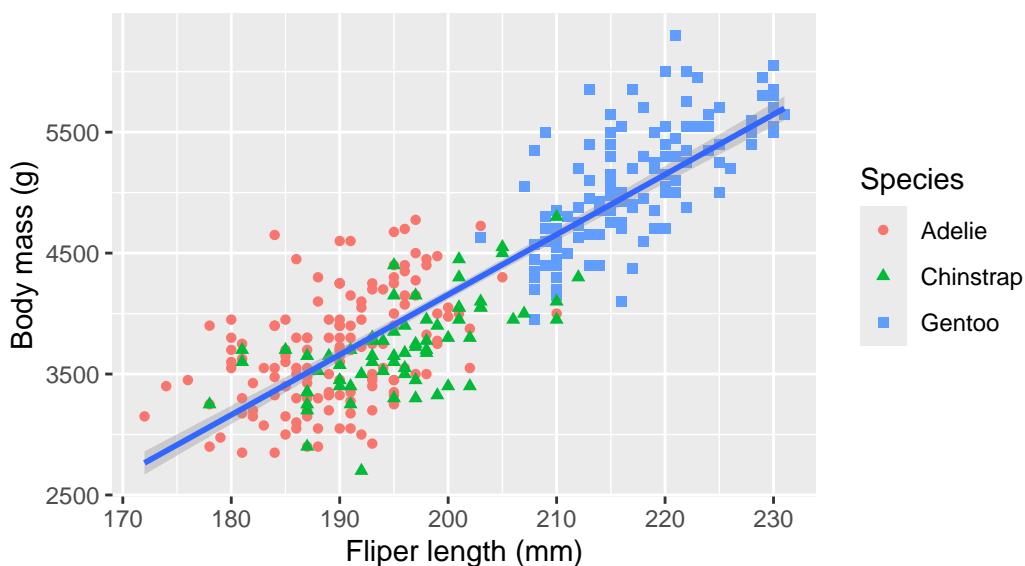
```

Warning: Removed 2 rows containing non-finite outside the scale range  
(`stat\_smooth()`).

Warning: Removed 2 rows containing missing values or values outside the scale range  
(`geom\_point()`).

### Palmer Three Species Penguins

The flipper length has a moderately strong positive linear relationship with



Other types of texts can be added using other functions. The other types of texts are:

- x-axis label
- y-axis label
- data labels, if necessary
- annotation for interesting or important data, if exist

### 8.2.12 Ensure Color-blind Safe

Make the plot more color-blind safe by using the `scale_color_colorblind()` function from the `ggthemes` package which will add new layer to the plot.

```
ggplot(data = penguins,
       mapping = aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(mapping = aes(color = species, shape = species)) +
  geom_smooth(method = "lm") +
  labs(
    title = 'Palmer Three Species Penguins',
    subtitle = 'The flipper length has a moderately strong positive linear relationship with',
    x = 'Flipper length (mm)',
    y = 'Body mass (g)',
    shape = 'Species',
    color = 'Species'
  ) +
  scale_color_colorblind()

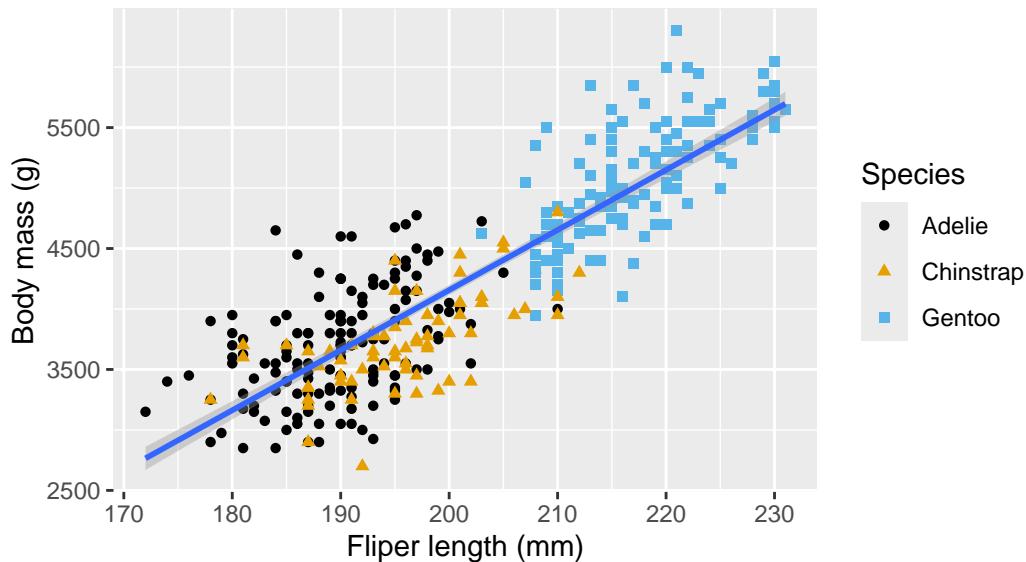
`geom_smooth()` using formula = 'y ~ x'
```

Warning: Removed 2 rows containing non-finite outside the scale range  
(`stat\_smooth()`).

Warning: Removed 2 rows containing missing values or values outside the scale range  
(`geom\_point()`).

## Palmer Three Species Penguins

The fliper length has a moderattly strong positive linear relationship with



### 8.2.13 Can Call Implicitly

The first one or two arguments of functions are so important that scientists should know them by heart. Hence, to save some typing, the name of these arguments are usually omitted and only the values assigned to them are kept, ie, the names becomes implicit and no more explicit. Hence, the above call can be written as follows—the arguments `data` and `mapping` were omitted.

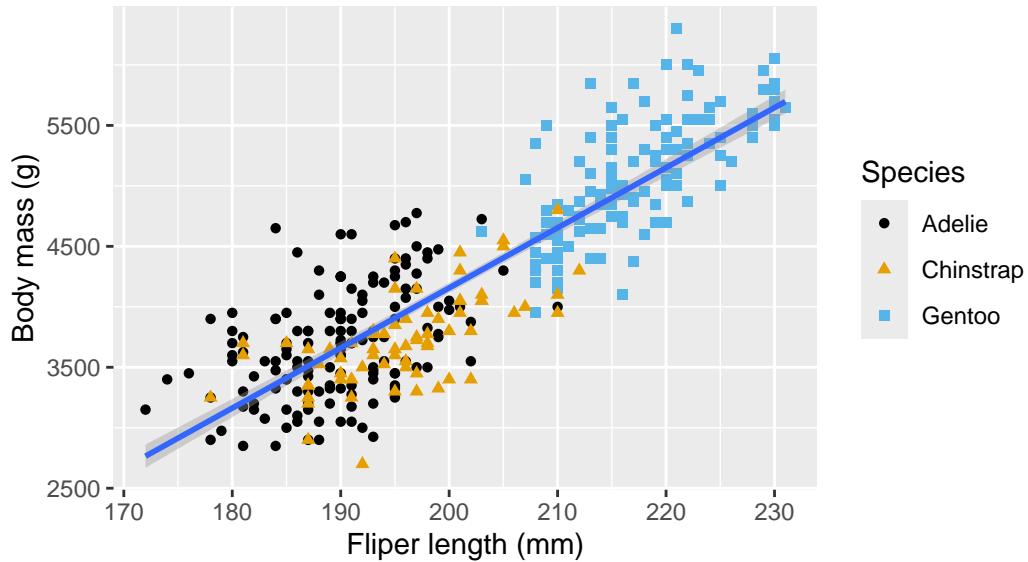
```
ggplot(penguins, aes(x = flipper_length_mm, y = body_mass_g)) +  
  geom_point(aes(color = species, shape = species)) +  
  geom_smooth(method = "lm") +  
  labs(  
    title = 'Palmer Three Species Penguins',  
    subtitle = 'The fliper length has a moderattly strong positive linear relationship with  
    x = 'Fliper length (mm)',  
    y = 'Body mass (g)',  
    shape = 'Species',  
    color = 'Species'  
) +  
  scale_color_colorblind()  
  
`geom_smooth()` using formula = 'y ~ x'
```

```
Warning: Removed 2 rows containing non-finite outside the scale range
(`stat_smooth()`).
```

```
Warning: Removed 2 rows containing missing values or values outside the scale range
(`geom_point()`).
```

## Palmer Three Species Penguins

The flipper length has a moderately strong positive linear relationship with



### 8.2.14 Use Pipe Operator

The pipe operator `\>` (shortcut: `Ctrl+M`) can be used to make the code tidy. The above code can be re-written as follows—notice the dataset was pulled before the call to the `ggplot()` function.

```
penguins |>
  ggplot(aes(x = flipper_length_mm, y = body_mass_g)) +
  geom_point(aes(color = species, shape = species)) +
  geom_smooth(method = "lm") +
  labs(
    title = 'Palmer Three Species Penguins',
    subtitle = 'The flipper length has a moderately strong positive linear relationship with',
    x = 'Fliper length (mm)',
    y = 'Body mass (g)',
```

```

    shape = 'Species',
    color = 'Species'
) +
scale_color_colorblind()

```

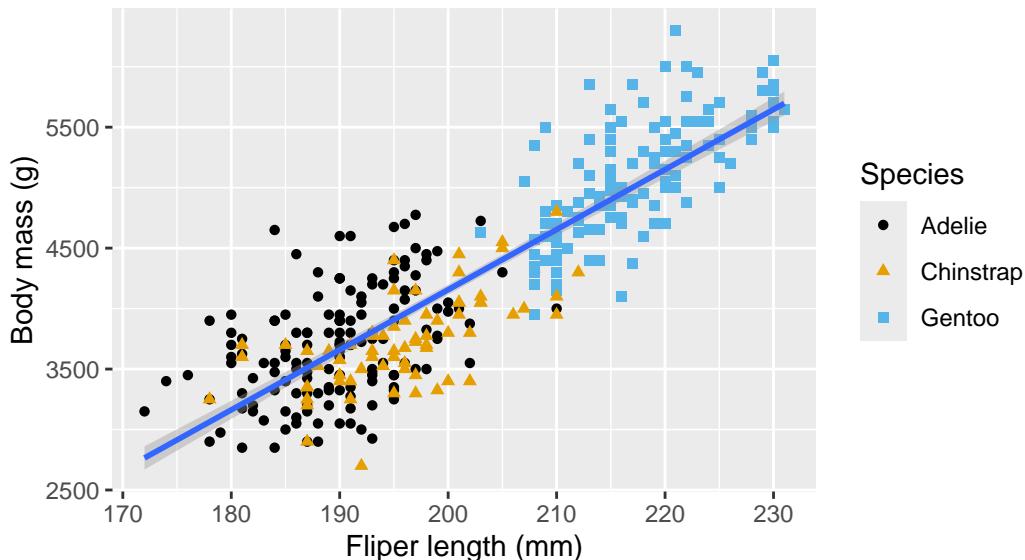
```
`geom_smooth()` using formula = 'y ~ x'
```

Warning: Removed 2 rows containing non-finite outside the scale range  
(`stat\_smooth()`).

Warning: Removed 2 rows containing missing values or values outside the scale range  
(`geom\_point()`).

## Palmer Three Species Penguins

The fliper length has a moderately strong positive linear relationship with



## 8.3 Visualizing Distribution

### 8.3.1 Categorical Variables

Plot options to visualize how a categorical variable is distributed:

- bar chart, if the counts are not computed, using `geom_bar()` function
- column chart, if the counts are computed, `geom_col()` function

### 8.3.2 Numerical Variables

Plot options to visualize how a numerical (discrete or continuous) variable is distributed:

- histogram, using `geom_histogram()` function

#### Histogram Bin Width

The bin width of the histogram is in the unit of the variable mapped to the plot `x` (or `y`) aesthetic (visual property)

- density plot, using `geom_density()` function
- boxplot, using `geom_boxplot()` function

#### Boxplot Components

As described beautifully in [R4DS](#), a boxplot consists of:

1. A box that describes the range of the middle half of the data, a distance known as the interquartile range (IQR), stretching from the 25th percentile of the distribution to the 75th percentile.
2. A line in the middle of the box displaying the median, ie, the 50th percentile, of the distribution.
3. The box and the line give sense of the spread of the distribution and whether or not the distribution is symmetric about the median or skewed to one side
4. Visual points that display the observations that fall more than 1.5 time the IQR from either edge of the box. These outlying points (hence called outliers) are unusual so are plotted individually
5. A whisker that extend from each end of the box and goes to the farthest non-outlier point in the distribution

Below is the diagram from [R4DS](#) showing the above components and how the boxplot is created.

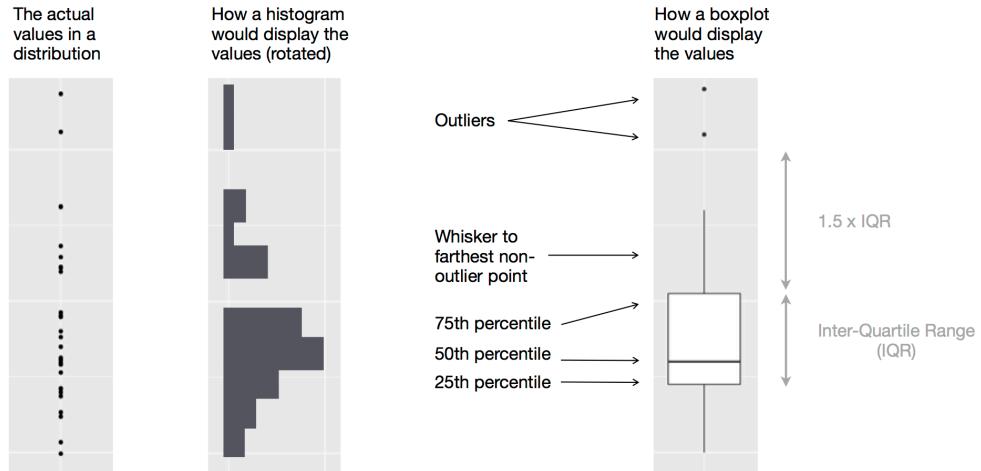


Figure 8.1: Boxplot Components (taken from [R4DS](#))

## 8.4 Visualizing Relationships

### 8.4.1 One Categorical + One Numerical

For each category of the categorical variable, We can use any of the plot options mentioned above for the numerical variables

### 8.4.2 Two Categoricals

Each category of one of the categorical variables will be placed on the x-axis (or the y-axis) by mapping it to the plot `x` (or `y`) aesthetic (visual property) of the `geom_bar()` and the distribution of the categories of the other categorical variables by mapping it to the plot `fill` aesthetic (visual property). The second variable can be shown as:

- pure counts (stacked bar chart), or
- percentages (percent stack bar chart) by setting the `position` attribute of the `geom_bar()` to `fill`.

### 8.4.3 Two Numerical

Plot options to show the relationship between two numerical variables are:

- Scatter plot using the `geom_point()` function
- trend line using `geom_smooth()` function
- line graph using `geom_line()` function if one of the variables is monotonic, eg, time or date.

### 8.4.4 Three or More Variables

To visualize 3+ variables, We can either

- map variables to other aesthetics of the plot, eg, `color`, `size`, and `shape`
- split plot into facets, subplots that each display one subset of the data, based on a categorical variable using `facet_wrap()` function where its first argument is a formula created using `~` followed by a (categorical) variable name.

# 9 Workflow: Basics

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages <- c()
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run by others.

! Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify  
lapply(packages, require, character.only = TRUE)
```

```
list()
```

## 9.1 Introduction

This page covers basic concepts when working with R. I took note for those that were new to me or found useful to remind myself with.

## 9.2 Comments

Use comments to explain the *why* of your code, eg, you changed the default value of a parameter of a function from say .2 to .9, why?

## 9.3 Naming Objects Rules

- Allowed characters when naming objects
  - letters
  - numbers
  - \_
  - .
- All names must start with a letter
- R is case-sensitive, ie, `var`, `Var`, and `VAR` are different names

# 10 Data Transformation

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages = c("nycflights13", "ggplot2", "dplyr")
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run by others.

! Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify
lapply(packages, require, character.only = TRUE)
```

```
[[1]]
[1] TRUE
```

```
[[2]]
[1] TRUE
```

```
[[3]]
[1] TRUE
```

## 10.1 Introduction

This page introduces the `dplyr` package used to transform data such as creating new variables, editing existing variables, filtering out observations, and creating summaries.

## 10.2 dplyr Functions (Verbs)

### 10.2.1 Four Groups

`dplyr` functions (verbs) can be grouped into functions that work on:

- rows, eg, `filter()`, `arrange()`, `distinct()`, `count()`
- columns, eg, `mutate()`, `select()`, `rename()`, `relocate()`
- groups, eg, `summarize()`, `slice_max`, `group_by`, `ungroup()`, `.by`
- tables

### 10.2.2 Common Characteristics

All the functions have the followings in common:

- their first argument is always a data frame
- their subsequent arguments typically describe which columns to operate on using variable names *without quotes*
- they always output a new data frame, they don't modify the passed one

### 10.2.3 Pipe |> Operator

- The pipe |> operator takes what on its left and pass it to the function on its right so that `x |> f(y)` (pronounced as `x then f(y)`) is equivalent to `f(x, y)` and `x |> f(y) |> g(z)` (pronounced as `x then f(y) then g(z)`) is equivalent to `g(f(x, y), z)`
- The base R pipe operator |> was introduced in R 4.1.0 in 2021 while the tidyverse `magrittr` pipe operator %>% was introduced in 2014. Using |> instead of %>% makes our code run when we don't use tidyverse

### 10.2.4 Row Functions

- The following `filter()` statements are equivalent:
  - `filter(ds, var == 1 or var == 2)`
  - `filter(ds, var == 1 | var == 2)`
  - `filter(ds, var %in% c(1,2))`
- The following `filter()` statements are equivalent:
  - `filter(ds, var == 1 and var == 2)`
  - `filter(ds, var == 1, var == 2)`
- The following `arrange()` statements order data differently
  - `arrange(ds, var)` ascendant order
  - `arrange(ds, desc(var))` decedent order
- The following `distinct()` statements return different data frames
  - `distinct(ds, var1, var2)` only keep columns `var1` and `var2`
  - `distinct(ds, var1, var2, .keep_all = TRUE)` keep all the columns—find the *first* observation where `var1` and `var2` are distinct and discard the rest
- The following `count()` statements order the results differently
  - `count(ds, var1, var2)` arrange results in order they are encountered
  - `count(ds, var1, var2, sort = TRUE)` arrange results in descending order of number of occurrence

### 10.2.5 Column Functions

- `mutate()`
  - Instead of adding the newly created variable to the right hand side of the data frame, we can instruct `mutate()` to add before a variable using the `.before` attribute or after a variable using the `.after` attribute

- To only keep the variables involved in the creation of the new variables, we can instruct `mutate()` to do so by setting the `.keep = "used"` attribute
- `select()`
  - select range of variables: `select(ds, var_x:var_y)`
  - select all variables except certain range: `select(ds, !var_x:var_y)`
  - select character variables only: `select(ds, where(is.character))`
  - select variables whose name start with something: `select(ds, start_with("m"))`
  - select variables whose name end with something: `select(ds, end_with("m"))`
  - select variables whose name contain something: `select(ds, contains("m"))`
  - select variables whose name follow some range: `select(ds, num_range("x", 1:3))`
  - select and rename variable: `select(ds, var1_new = var1, var2_new = var2)`
- `rename()`
  - to rename many columns, it is better to use `janitor::clean_names()` function
- `relocate()`
  - By default, bring columns to left hand side of the data frame
  - `relocate(ds, var1, .after = var2)` puts `var1` after `var2`
  - `relocate(ds, var1, .before = var2)` puts `var1` before `var2`

### 10.2.6 Groups Functions

- `group_by()`
  - divides the data into groups so that subsequent operations work on these groups
  - it added a *class* to the dataset to indicate the grouping
- `summarize()` or `summarise()`
  - To prevent summary statistics functions, eg, `mean()` to give `NA` due to some groups has `NA` (missing) values, set their argument: `na.rm = TRUE`
  - The summary statistics function `n()` gives the number of observations in the group
  - Each summary peels off the last group. To prevent this behavior, change the default value `drop_last` of the `.groups` argument of the summary statistic function to either `keep` to keep all groups or `drop` to drop all groups
- ``slice_` functions`
  - The functions are: `slice_head()`, `slice_tail()`, `slice_min()`, `slice_max()`, and `slice_sample()`
  - To slice a number of rows from each group, use the `n` arguments, eg, `n = 1`

- To slice percentage of rows from each group, use the `prop` argument, eg, `prop = .1 (10%)`
- To prevent ties from showing, use `with_ties = FALSE` argument
- ``.by` argument`
  - New addition to dplyr 1.1.0 (more information at [dplyr 1.1.0 blog post](#))
  - Per-operation grouping—can be used all verbs. The advantage is that we don't need to use the `.groups` argument to suppress the warning message raised by `summarize()` when grouping by multiple variables and we don't need to use `ungroup()` when done with our summary.

# 11 Workflow: Code Style

## **Clear Workspace, DON'T EDIT**

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## **List Used Packages, EDIT**

List all the packages that will be used in chunk below.

```
packages <- c("styler")
```

## **Load Packages, DON'T EDIT**

### **Install Missing**

Any missing package will be installed automatically. This ensure smoother execution when run by others.

**!** Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify  
lapply(packages, require, character.only = TRUE)
```

```
[[1]]  
[1] TRUE
```

## 11.1 Introduction

This page covers code style concepts when working with R. I took note for those that were new to me or found useful to remind myself with.

### Code Style & Punctuation

Code style is like punctuation, when used correctly, it make code read easily.

## 11.2 Styling Overview

### 11.2.1 Consistency

Although there are styling guidelines (see below for example) that one can follow, it is important that a programmer pick one and stick with it to make easy for other including future self to read your work.

### 11.2.2 Guidelines

There is not official styling guideline for R. However, there are different styling guidelines that one can adopt, below are some of those found by search R styling guidelines ([html](#)):

- tidyverse Style Guide ([html](#)) by Hadley Wickham. **This is the adopted guidelines in these notes.**
- R Style Guide ([html](#)) by Google
- R Coding Conventions ([html](#)) by Henrik Bengtsson, Assoc Professor, Dept of Statistics, University of California, Berkeley
- Coding Style ([html](#)) by Bioconductor project ([website](#))

- R Style Guide ([html](#)) by Jean Fan ([GitHub](#)), Assistant Professor, Center for Computational Biology, Department of Biomedical Engineering, Johns Hopkins University

### 11.2.3 Automatic

There are packages that can be used to automatically style existing code. Below are some of those:

- `styler` package ([website](#)) by Lorenz Walthert ([website](#)). After installing the package, launch RStudio's command palette using the keyboard shortcut `Ctrl+Shift+P`, type `styler`, and select from the available commands

## 11.3 Styling Specifics

### 11.3.1 Names

- Use meaningful names
- `snake_case` is used to separate `multi_word_variables`
- variables with certain theme should start with the same common word/letter to make use of the auto-complete functionality

### 11.3.2 Spaces

- Except `^`, put spaces on both sides of mathematical operators
- Put spaces on both sides of the assignment operator, `<-`

```
# Strive for
z <- (a + b)^2 / d

# Avoid
z<-( a + b ) ^ 2/d
```

- Don't put spaces inside or outside parentheses for regular function calls
- Always put a space after a comma

```
# Strive for
mean(x, na.rm = TRUE)

# Avoid
mean (x ,na.rm=TRUE)
```

- It is okay to use extra space so align things.

```
flights |>
  mutate(
    speed      = distance / air_time,
    dep_hour   = dep_time %% 100,
    dep_minute = dep_time %% 100
  )
```

### 11.3.3 Pipes |>

The roles for pipes are nicely summarized in [R4DS](#). Most of them are copied below.

- Put a space before it
- It should typically be the last thing on a line. This makes it easy to
  - add new steps
  - rearrange existing steps
  - modify elements within a step
  - quickly skip the verbs on the left-hand side
- After the first step of the pipeline, indent each line by two spaces

```
# Strive for
flights |>
  filter(!is.na(arr_delay), !is.na(tailnum)) |>
  count(dest)

# Avoid
flights|>filter(!is.na(arr_delay), !is.na(tailnum))|>count(dest)
```

- If piping to a function without named arguments and its arguments fit on one line,
  - put all of them on one line.
- If piping to a function with named arguments OR the function has no named arguments but the arguments do not fit on one line,
  - put each argument on new line indented by two spaces
  - make sure the ) is on its own line and un-indented to match the horizontal position of the function name

```

# Strive for
flights |>
  group_by(tailnum) |>
  summarize(
    delay = mean(arr_delay, na.rm = TRUE),
    n = n()
  )

# Avoid
flights |>
  group_by(
    tailnum
  ) |>
  summarize(delay = mean(arr_delay, na.rm = TRUE), n = n())

# Avoid
flights|>
  group_by(tailnum) |>
  summarize(
    delay = mean(arr_delay, na.rm = TRUE),
    n = n()
  )

# Avoid
flights|>
  group_by(tailnum) |>
  summarize(
    delay = mean(arr_delay, na.rm = TRUE),
    n = n()
  )

```

### Long Pipeline

Break long pipelines (tasks) to meaningful pipelines (sub-tasks) and save the intermediate steps. This will make the code more readable and easy to check and debug.

## 11.3.4 ggplot2

The same rules from pipe can be applied to ggplot2.

```
flights |>
  group_by(dest) |>
  summarize(
    distance = mean(distance),
    speed = mean(distance / air_time, na.rm = TRUE)
  ) |>
  ggplot(aes(x = distance, y = speed)) +
  geom_smooth(
    method = "loess",
    span = 0.5,
    se = FALSE,
    color = "white",
    linewidth = 4
  ) +
  geom_point()
```

### 11.3.5 Sectioning Comments

When writing long scripts, it is advisable to break the code into sections and using *sectioning* comments to label them. The RStudio keyboard shortcut to create such comment is **Cnrl+Shift+R**.

```
# Load data -----
# Plot data -----
```

# 12 Data Tidying

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages <- c("styler", "dplyr", "tidyverse")
```

## Load Packages, DON'T EDIT

### Install Missing

! Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

Any missing package will be installed automatically. This ensure smoother execution when run by others.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify  
lapply(packages, require, character.only = TRUE)
```

```
[[1]]  
[1] TRUE
```

```
[[2]]  
[1] TRUE
```

```
[[3]]  
[1] TRUE
```

## 12.1 Introduction

This page explains how use the `tidyverse` package to put data in tidy form where:

- each row represents an observation
- each column represents a variable
- each cell contain a single value

Putting data in tidy form will make it easy to process using tidyverse packages.

### Data Transformation Bottom-Line

Tidying is 1-to-1 process—the data takes different form but it can be put back into its original form which mean that no values are lost.

## 12.2 Lengthening Data, `pivot_longer`

### ‘pivot\_longer’ Idea

When pivoting longer, the number of the rows in the dataset increases while the number of columns decreases.

## 12.2.1 One Variable in Column Headers

### 12.2.1.1 Toy Dataset

The following toy dataset will be used to illustrate the concepts in this section. The book used `tidyverse::billboard` dataset.

```
ds <- tribble(
  ~id, ~A, ~B_1, ~B_2,
  "A", 1, 10.1, 10.2,
  "B", 2, 20.1, NA,
  "C", 3, NA, 30.2
)

ds
```

```
# A tibble: 3 x 4
  id      A    B_1    B_2
  <chr> <dbl> <dbl> <dbl>
1 A        1    10.1   10.2
2 B        2    20.1   NA
3 C        3    NA     30.2
```

### 12.2.1.2 Lengthen

I want the values in all the columns that start with `B_` to be placed into a (single) column named `value`. To distinguish which value belong to which column, create a new column called `B_type` for this purpose.

#### i Dimensions of New Dataset

Assume the dimensions of the old dataset are:

- number of cols: co
- number of rows: ro

The dimensions of the new dataset are:

- number of cols: co - number of combined columns - 1
- number of rows: ro \* (number of combined columns - 1)

```

ds_lengthen <- ds |>
  pivot_longer(
    cols = starts_with("B_"),
    names_to = "B_type",
    values_to = "value"
  )

```

ds\_lengthen

```

# A tibble: 6 x 4
  id      A B_type value
  <chr> <dbl> <chr>   <dbl>
1 A         1 B_1     10.1
2 A         1 B_2     10.2
3 B         2 B_1     20.1
4 B         2 B_2     NA
5 C         3 B_1     NA
6 C         3 B_2     30.2

```

### 12.2.1.3 Remove NA

Use the argument `values_drop_na = TRUE`

```

ds_lengthen <- ds |>
  pivot_longer(
    cols = starts_with("B_"),
    names_to = "B_type",
    values_to = "value",
    values_drop_na = TRUE
  )

```

ds\_lengthen

```

# A tibble: 4 x 4
  id      A B_type value
  <chr> <dbl> <chr>   <dbl>
1 A         1 B_1     10.1
2 A         1 B_2     10.2
3 B         2 B_1     20.1
4 C         3 B_2     30.2

```

#### 12.2.1.4 Fix Cell Values

Use the `readr::parse_number()` function to extract the first number from `var2` variable and ignore all other text.

```
ds_lengthen <- ds |>
  pivot_longer(
    cols = starts_with("B_"),
    names_to = "B_type",
    values_to = "value",
    values_drop_na = TRUE
  ) |>
  mutate(
    B_type = readr::parse_number(B_type)
  )

ds_lengthen
```

```
# A tibble: 4 x 4
  id      A B_type value
  <chr> <dbl> <dbl> <dbl>
1 A        1 10.1
2 A        1 10.2
3 B        2 20.1
4 C        3 30.2
```

### 12.2.2 Multiple Variables in Column Headers

#### 12.2.2.1 Toy Dataset

The following toy dataset will be used to illustrate the concepts in this section. The book used `tidyr::who2` dataset.

```
ds2 <- tribble(
  ~id, ~A, ~B1_C1, ~B1_C2, ~B2_C1, ~B2_C2,
  "A", 1, 10.11, 10.12, 10.21, 10.22,
  "B", 2, 20.11, 20.12, NA, 20.22,
  "C", 3, 30.11, NA, 30.21, 30.22
)

ds2
```

```
# A tibble: 3 x 6
  id      A B1_C1 B1_C2 B2_C1 B2_C2
  <chr> <dbl> <dbl> <dbl> <dbl>
1 A       1   10.1  10.1  10.2  10.2
2 B       2   20.1  20.1  NA     20.2
3 C       3   30.1  NA     30.2  30.2
```

### 12.2.2.2 Lengthening w/o Separating Variables

```
ds_lengthen <- ds2 |>
  pivot_longer(
    cols = starts_with("B"),
    names_to = "B_C",
    values_to = "value"
  )

ds_lengthen
```

```
# A tibble: 12 x 4
  id      A B_C  value
  <chr> <dbl> <chr> <dbl>
1 A       1 B1_C1  10.1
2 A       1 B1_C2  10.1
3 A       1 B2_C1  10.2
4 A       1 B2_C2  10.2
5 B       2 B1_C1  20.1
6 B       2 B1_C2  20.1
7 B       2 B2_C1  NA
8 B       2 B2_C2  20.2
9 C       3 B1_C1  30.1
10 C      3 B1_C2  NA
11 C      3 B2_C1  30.2
12 C      3 B2_C2  30.2
```

### 12.2.2.3 Lengthening w/ Separating Variables

```
ds_lengthen <- ds2 |>
  pivot_longer(
```

```

cols = !(id:A),
names_sep = "_",
names_to = c("B", "C"),
values_to = "value"
)

ds_lengthen

```

		A	B	C	value
		<chr>	<dbl>	<chr>	<dbl>
1	A	1	B1	C1	10.1
2	A	1	B1	C2	10.1
3	A	1	B2	C1	10.2
4	A	1	B2	C2	10.2
5	B	2	B1	C1	20.1
6	B	2	B1	C2	20.1
7	B	2	B2	C1	NA
8	B	2	B2	C2	20.2
9	C	3	B1	C1	30.1
10	C	3	B1	C2	NA
11	C	3	B2	C1	30.2
12	C	3	B2	C2	30.2

#### 12.2.2.4 Dropping NA

```

ds_lengthen <- ds2 |>
pivot_longer(
  cols = !(id:A),
  names_sep = "_",
  names_to = c("B", "C"),
  values_to = "value",
  values_drop_na = TRUE
)

ds_lengthen

```

		A	B	C	value
		<chr>	<dbl>	<chr>	<dbl>
1		1	B1	C1	10.1
2		1	B1	C2	10.1
3		1	B2	C1	10.2
4		1	B2	C2	10.2
5		2	B1	C1	20.1
6		2	B1	C2	20.1
7		2	B2	C1	NA
8		2	B2	C2	20.2
9		3	B1	C1	30.1
10		3	B1	C2	NA
11		3	B2	C1	30.2
12		3	B2	C2	30.2

```

<chr> <dbl> <chr> <chr> <dbl>
1 A      1 B1    C1    10.1
2 A      1 B1    C2    10.1
3 A      1 B2    C1    10.2
4 A      1 B2    C2    10.2
5 B      2 B1    C1    20.1
6 B      2 B1    C2    20.1
7 B      2 B2    C2    20.2
8 C      3 B1    C1    30.1
9 C      3 B2    C1    30.2
10 C     3 B2   C2    30.2

```

### 12.2.3 Data and Variable Names in Column Headers

#### 12.2.3.1 Toy Dataset

The following toy dataset will be used to illustrate the concepts in this section. The book used `tidyverse::household` dataset.

```

ds3 <- tribble(
  ~id, ~child1_name, ~child1_age, ~child2_name, ~child2_age,
  "A", "A1", 11, "A2", 12,
  "B", "B1", 21, NA, NA,
  "C", NA, NA, "C2", 32
)

ds3

```

```

# A tibble: 3 x 5
  id    child1_name child1_age child2_name child2_age
  <chr> <chr>        <dbl> <chr>        <dbl>
1 A      A1           11  A2           12
2 B      B1           21  <NA>          NA
3 C      <NA>          NA  C2           32

```

#### 12.2.3.2 Lengthening w/o Removing NA

```

ds_lengthen <- ds3 |>
  pivot_longer(
    cols = starts_with("child"),

```

```

    names_sep = "_",
    names_to = c("child", ".value")
  )

ds_lengthen

```

```

# A tibble: 6 x 4
  id    child  name   age
  <chr> <chr>  <chr> <dbl>
1 A     child1 A1     11
2 A     child2 A2     12
3 B     child1 B1     21
4 B     child2 <NA>    NA
5 C     child1 <NA>    NA
6 C     child2 C2     32

```

### 12.2.3.3 Lengthening w Removing NA

```

ds_lengthen <- ds3 |>
  pivot_longer(
    cols = starts_with("child"),
    names_sep = "_",
    names_to = c("child", ".value"),
    values_drop_na = TRUE
  )

ds_lengthen

```

```

# A tibble: 4 x 4
  id    child  name   age
  <chr> <chr>  <chr> <dbl>
1 A     child1 A1     11
2 A     child2 A2     12
3 B     child1 B1     21
4 C     child2 C2     32

```

#### 12.2.3.4 Fixing Cell Values

```
ds_lengthen <- ds3 |>
  pivot_longer(
    cols = starts_with("child"),
    names_sep = "_",
    names_to = c("child", ".value"),
    values_drop_na = TRUE
  ) |>
  mutate(
    child = readr::parse_number(child)
  )

ds_lengthen
```

```
# A tibble: 4 x 4
  id    child name    age
  <chr> <dbl> <chr> <dbl>
1 A        1 A1     11
2 A        2 A2     12
3 B        1 B1     21
4 C        2 C2     32
```

### 12.3 Widening Data, pivot-wider

#### i ‘pivot\_wider’ Idea

When pivoting wider, the number of the columns in the dataset increases while the number of rows decreases.

#### 12.3.1 No Missing Values

##### 12.3.1.1 Toy Dataset

Notice that each unique value in the `id` column has a single value for each of the unique values in the `M` column.

```

ds <- tribble(
  ~id, ~M, ~V,
  "A", "M1", 10,
  "A", "M2", 11,
  "B", "M1", 20,
  "B", "M2", 21,
  "C", "M1", 30,
  "C", "M2", 31
)

ds

```

```

# A tibble: 6 x 3
  id      M      V
  <chr> <chr> <dbl>
1 A      M1     10
2 A      M2     11
3 B      M1     20
4 B      M2     21
5 C      M1     30
6 C      M2     31

```

### 12.3.1.2 Widening

```

ds_widen <- ds |>
  pivot_wider(
    names_from = M,
    values_from = V
  )

ds_widen

```

```

# A tibble: 3 x 3
  id      M1      M2
  <chr> <dbl> <dbl>
1 A        10     11
2 B        20     21
3 C        30     31

```

### 12.3.2 Missing Values

#### 12.3.2.1 Toy Dataset

Notice that NOT each unique value in the `id` column has a single value for each of the unique values in the `M` column—`B` does not have value for the `M2` value.

```
ds <- tribble(
  ~id, ~M, ~V,
  "A", "M1", 10,
  "A", "M2", 11,
  "B", "M1", 20,
  "C", "M1", 30,
  "C", "M2", 31
)

ds
```

```
# A tibble: 5 x 3
  id     M     V
  <chr> <chr> <dbl>
1 A      M1     10
2 A      M2     11
3 B      M1     20
4 C      M1     30
5 C      M2     31
```

#### 12.3.2.2 Widening

Notice that `B` observation will be assigned `NA` as its value in the `M2` column.

```
ds_widen <- ds |>
  pivot_wider(
    names_from = M,
    values_from = V
  )

ds_widen
```

```
# A tibble: 3 x 3
  id       M1     M2
  <chr> <dbl> <dbl>
1 A        10    NA
2 B        20    NA
3 C        30    31
```

```

<chr> <dbl> <dbl>
1 A      10     11
2 B      20     NA
3 C      30     31

```

### 12.3.3 Duplicate Values

#### 12.3.3.1 Toy Dataset

Notice that NOT each unique value in the `id` column has a single value for each of the unique values in the `M` column—B has multiple value for `M2`.

```

ds <- tribble(
  ~id, ~M, ~V,
  "A", "M1", 10,
  "A", "M2", 11,
  "B", "M1", 20,
  "B", "M2", 21,
  "B", "M2", 22,
  "C", "M1", 30,
  "C", "M2", 31
)

ds

```

```

# A tibble: 7 x 3
  id    M      V
  <chr> <chr> <dbl>
1 A     M1     10
2 A     M2     11
3 B     M1     20
4 B     M2     21
5 B     M2     22
6 C     M1     30
7 C     M2     31

```

#### 12.3.3.2 Widening

Notice that the generated values are `list-cols`—see the warning message for details.

```
ds_widen <- ds |>
  pivot_wider(
    names_from = M,
    values_from = V
  )
```

```
Warning: Values from `V` are not uniquely identified; output will contain list-cols.
* Use `values_fn = list` to suppress this warning.
* Use `values_fn = {summary_fun}` to summarise duplicates.
* Use the following dplyr code to identify duplicates.
{data} |>
dplyr::summarise(n = dplyr::n(), .by = c(id, M)) |>
dplyr::filter(n > 1L)
```

```
ds_widen
```

```
# A tibble: 3 x 3
  id      M1      M2
  <chr> <list>   <list>
1 A      <dbl [1]> <dbl [1]>
2 B      <dbl [1]> <dbl [2]>
3 C      <dbl [1]> <dbl [1]>
```

## 12.4 Reference

- Wickham, H. . (2014). Tidy Data. Journal of Statistical Software, 59(10), 1–23.  
<https://doi.org/10.18637/jss.v059.i10> ([webpage](#))
  - details the history and underlying theory behind tidy data

# 13 Workflow: Scripts & Projects

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages <- c("tidyverse")
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run by others.

! Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify
lapply(packages, require, character.only = TRUE)
```

```
Loading required package: tidyverse
```

```
-- Attaching core tidyverse packages ----- tidyverse 2.0.0 --
v dplyr     1.1.4     v readr     2.1.5
v forcats   1.0.0     v stringr   1.5.1
v ggplot2   3.5.1     v tibble    3.2.1
v lubridate 1.9.3     v tidyr    1.3.1
v purrr     1.0.2
-- Conflicts -----
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become non-conflicting
```

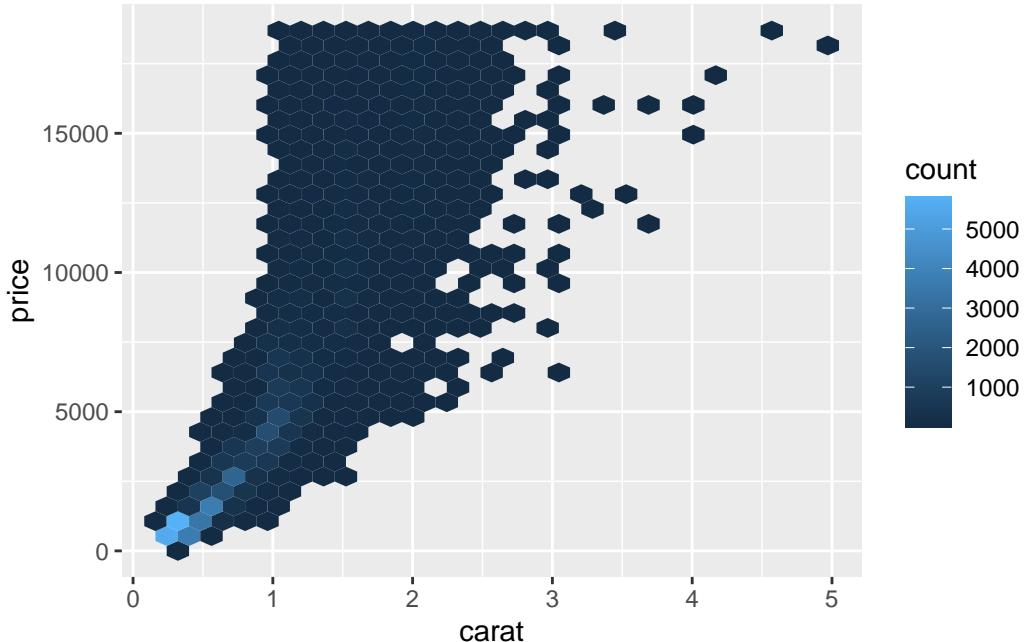
```
[[1]]
[1] TRUE
```

## 13.1 Introduction

This chapter is about how to organize project files.

## 13.2 Diamond Example

```
diamonds |>
  ggplot(aes(x = carat, y = price)) +
  geom_hex()
```



```
# ggsave("figures/diamonds.png")  
  
# write_csv(diamonds, "data/diamonds.csv")
```

# 14 Data Import

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages <- c()
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run on another machine.

! Installing Packages on Other People Machine

Be aware that people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify  
install.packages(setdiff(packages, rownames(installed.packages())))
```

## **Load**

Load all packages

```
# Do NOT modify  
lapply(packages, require, character.only = TRUE)
```

```
list()
```

## **14.1 Introduction**

# **Part IV**

# **Projects**

# 15 Topic Modeling in R

## Clear Workspace, DON'T EDIT

Always start by clearing the workspace. This ensure objects created in other files are not used here.

```
rm(list = ls())
```

## List Used Packages, EDIT

List all the packages that will be used in chunk below.

```
packages <- c("gutenbergr", # download books from Project Gutenberg using book ID
             "tidyverse",
             "tidytext",
             "ggplot2",
             "stm", # for do topic modeling
             "quanteda") # great text mining, will be used to structure the input to stm
```

## Load Packages, DON'T EDIT

### Install Missing

Any missing package will be installed automatically. This ensure smoother execution when run by others.

! Installing Packages on Other People Machine

Be aware the people may not like installing packages into their machine automatically. This might break some of their previous code.

```
# Do NOT modify
install.packages(setdiff(packages, rownames(installed.packages())))
```

## Load

Load all packages

```
# Do NOT modify
lapply(packages, require, character.only = TRUE)
```

```
[[1]]
[1] TRUE
```

```
[[2]]
[1] TRUE
```

```
[[3]]
[1] TRUE
```

```
[[4]]
[1] TRUE
```

```
[[5]]
[1] TRUE
```

```
[[6]]
[1] TRUE
```

## 15.1 Introduction

An attempt to understand Sherlock Holmes short stories found in Adventures of Sherlock Holmes book by Arthur Conan Doyle. After inspecting the table of content, the book seems to have 12 stories, one story per chapter. The analysis is inspired by [Julia Silge's YouTube video Topic modeling with R and tidy data principles](#)

## 15.2 Download Book

```
# Download the book, each line of the book is read into a seperate row
sherlock_raw <- gutenberg_download(48320)
```

```
Determining mirror for Project Gutenberg from https://www.gutenberg.org/robot/harvest
```

```
Using mirror http://aleph.gutenberg.org
```

```
dim(sherlock_raw)
```

```
[1] 12350      2
```

```
head(sherlock_raw)
```

```
# A tibble: 6 x 2
  gutenberg_id text
    <int> <chr>
1     48320 "ADVENTURES OF SHERLOCK HOLMES"
2     48320 ""
3     48320 ""
4     48320 ""
5     48320 ""
6     48320 "[Illustration:"
```

```
tail(sherlock_raw)
```

```
# A tibble: 6 x 2
  gutenberg_id text
    <int> <chr>
1     48320 "  boisterous fashion, and on the whole _changed to_"
2     48320 "  boisterous fashion, and on the whole"
3     48320 ""
4     48320 "  Page 297"
5     48320 "  wrapt in the peaceful beauty _changed to_"
6     48320 "  rapt in the peaceful beauty"
```

## 15.3 Wrangle: Label Stories

```
sherlock <- sherlock_raw %>%  
  
  # determine start of each story/chapter  
  mutate(story = ifelse(str_detect(text, "^(A SCANDAL IN BOHEMIA|THE RED-HEADED LEAGUE|A CASE OF  
  # determine lines belonging to each story/chapter by  
  # filling down the N/A rows of story column  
  fill(story) %>%  
  
  # remove the part that does not belong to any story/chapter,  
  # i.e, the introduction  
  filter(!is.na(story)) %>%  
  
  # convert story column to factor  
  mutate(story = factor(story))
```

## 15.4 Wrangle: Put in Tidy Format

The row of `text` column contains multiple words/tokens. We want to put each word/token of each `text` row into a separate row. This makes the dataframe follows the tidy format and hence makes it easy to process.

```
tidy_sherlock <- sherlock %>%  
  
  # number the rows  
  mutate(line = row_number()) %>%  
  
  # break the text column into multiple row where each row contain one token  
  unnest_tokens(word, text) %>%  
  
  # remove the stopwords--the rows where the word column is a stopword  
  anti_join(stop_words) %>%  
  
  # remove holmes rows which might affect our topic models  
  filter(word != "holmes")  
  
Joining with `by = join_by(word)`
```

## 15.5 Explore tf-idf

- To see which words are important in each story/chapter, i.e., the words that appear many times in that story but few or none in the other stories.
- tf-idf (term frequency-inverse document frequency) is a great exploratory tool before starting with topic modeling

```
tidy_sherlock %>%

# count number of occurrence of words in stories
count(story, word, sort = TRUE) %>%

# compute and add tf, idf, and tf_idf values for words
bind_tf_idf(word, story, n) %>%

# group by story
group_by(story) %>%

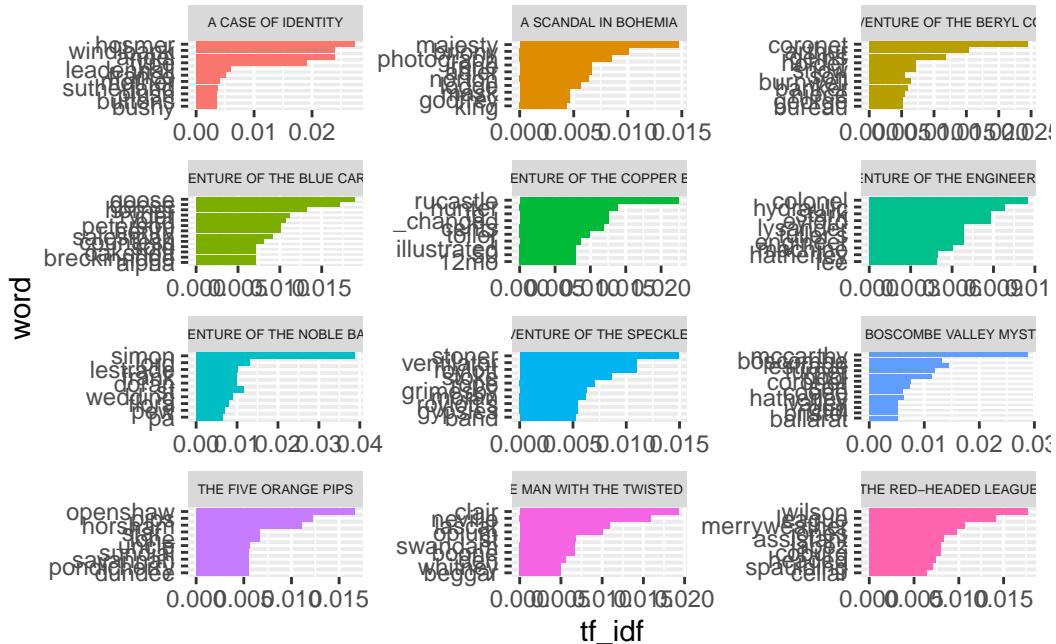
# take top 10 words of each story with highest tf_idf (last column)
top_n(10) %>%

# unpack
ungroup() %>%

# turn words into factors and order them based on their tf_idf values
# NOTE: This will not affect order the dataframe rows which is can be
#       done via the arrange function
# NOTE: Recording the word column this way is for ggplot to visualize them
#       as desired from top tf_idf to lowest
mutate(word = reorder(word, tf_idf)) %>%

# plot
ggplot(aes(word, tf_idf, fill = story)) +
  geom_col(show.legend = FALSE) +
  facet_wrap(~story, scales = "free", ncol = 3) +
  theme(strip.text.x = element_text(size = 5)) +
  coord_flip()
```

Selecting by tf\_idf



## 15.6 Implement Topic Modeling

Training the model for the topics

```
# Convert from tidy form to quanteda form (document x term matrix)
sherlock_stm <- tidy_sherlock %>%
  count(story, word, sort = TRUE) %>%
  cast_dfm(story, word, n)

# Train the model
topic_model <- stm(sherlock_stm, K=6, init.type = "Spectral")
```

```
Beginning Spectral Initialization
Calculating the gram matrix...
Finding anchor words...
.....
Recovering initialization...
.....
Initialization complete.
.....
Completed E-Step (0 seconds).
```

```
Completed M-Step.  
Completing Iteration 1 (approx. per word bound = -7.785)  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Completing Iteration 2 (approx. per word bound = -7.593, relative change = 2.458e-02)  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Completing Iteration 3 (approx. per word bound = -7.481, relative change = 1.473e-02)  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Completing Iteration 4 (approx. per word bound = -7.455, relative change = 3.469e-03)  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Completing Iteration 5 (approx. per word bound = -7.450, relative change = 7.612e-04)  
Topic 1: st, simon, lord, day, lady  
Topic 2: door, miss, house, rucastle, matter  
Topic 3: hat, goose, stone, bird, geese  
Topic 4: father, time, mccarthy, son, hand  
Topic 5: house, time, night, door, heard  
Topic 6: red, time, wilson, business, headed  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Completing Iteration 6 (approx. per word bound = -7.449, relative change = 1.233e-04)  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Completing Iteration 7 (approx. per word bound = -7.449, relative change = 1.168e-05)  
.....  
Completed E-Step (0 seconds).  
Completed M-Step.  
Model Converged
```

```
summary(topic_model)
```

A topic model with 6 topics, 12 documents and a 7709 word dictionary.

Topic 1 Top Words:

Highest Prob: st, simon, lord, day, lady, found, matter  
 FREX: simon, clair, neville, lascar, opium, doran, flora  
 Lift: aloysius, ceremony, doran, millar, 2\_s, aberdeen, absurdly  
 Score: simon, st, clair, neville, \_danseuse\_, lestrade, doran

Topic 2 Top Words:

Highest Prob: door, miss, house, rucastle, matter, street, lady  
 FREX: rucastle, hosmer, hunter, angel, windibank, \_changed, 1  
 Lift: advertised, angel, annoyance, brothers, employed, factor, fowler  
 Score: rucastle, hosmer, angel, windibank, hunter, type, 1

Topic 3 Top Words:

Highest Prob: hat, goose, stone, bird, geese, baker, sir  
 FREX: geese, horner, ryder, henry, peterson, salesman, countess  
 Lift: battered, bet, bred, brixton, cosmopolitan, covent, cream  
 Score: goose, geese, horner, \_alias\_, ryder, henry, peterson

Topic 4 Top Words:

Highest Prob: father, time, mccarthy, son, hand, lestrade, left  
 FREX: mccarthy, pool, boscombe, openshaw, pips, horsham, turner  
 Lift: bone, dundee, horsham, pondicherry, presumption, savannah, sundial  
 Score: mccarthy, pool, lestrade, boscombe, openshaw, \_détour\_, turner

Topic 5 Top Words:

Highest Prob: house, time, night, door, heard, hand, round  
 FREX: coronet, stoner, arthur, roylott, ventilator, gems, stoke  
 Lift: \_absolute\_, \_all\_, \_en, 1100, 16a, 3d, 4000  
 Score: coronet, arthur, stoner, gems, 4000, roylott, ventilator

Topic 6 Top Words:

Highest Prob: red, time, wilson, business, headed, day, league  
 FREX: wilson, league, merryweather, jones, coburg, jabez, headed  
 Lift: daring, saturday, vincent, \_employé\_, \_october, \_partie, 17  
 Score: wilson, league, merryweather, \_employé\_, jones, headed, coburg

## 15.7 Contribution of Words in Topics

Looking at which words contribute the most in each topic.

```
# Extracting betas and putting them in a tidy format
tm_beta <- tidy(topic_model)

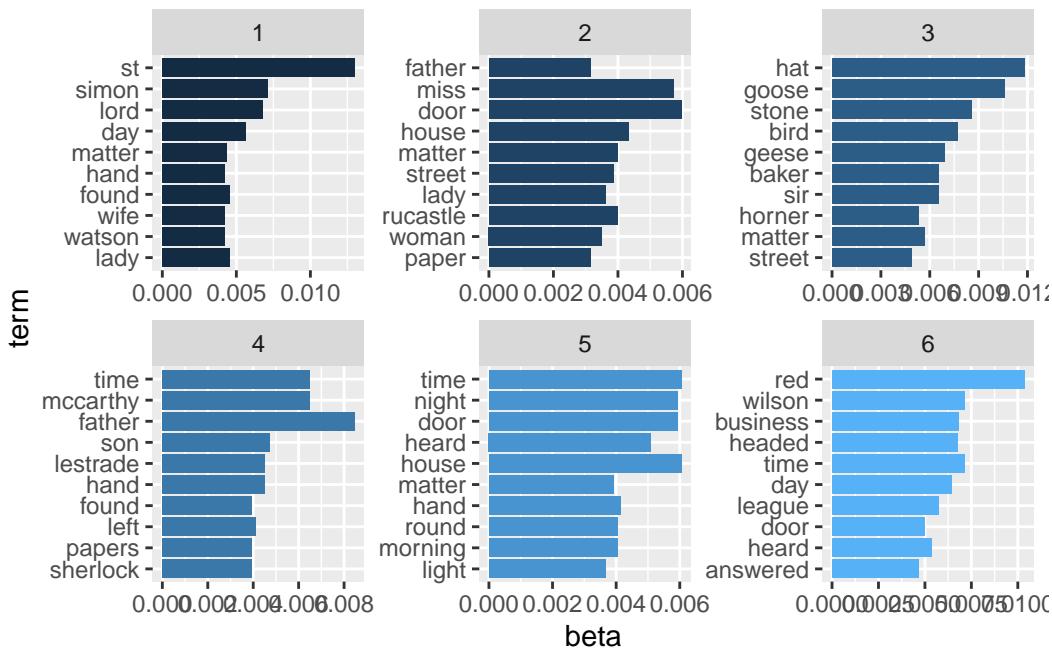
# Visualizing the top words contributing to each topic
tm_beta %>%
  group_by(topic) %>%
  # top 10 word in each topic with highest beta (last column)
```

```

top_n(10) %>%
ungroup() %>%
# turn words into factors and order them based on their tf_idf values
# NOTE: This will not affect order the dataframe rows which is can be
# done via the arrange function
# NOTE: Recording the word column this way is for ggplot to visualize them
# as desired from top tf_idf to lowest
mutate(term = reorder(term, beta)) %>%
ggplot(aes(term, beta, fill = topic)) +
geom_col(show.legend = FALSE) +
facet_wrap(~topic, scales = "free", ncol = 3) +
coord_flip()

```

Selecting by beta



## 15.8 Distribution of Topics in Stories

Looking at how the stories are associated with each topic and how strong each association is.

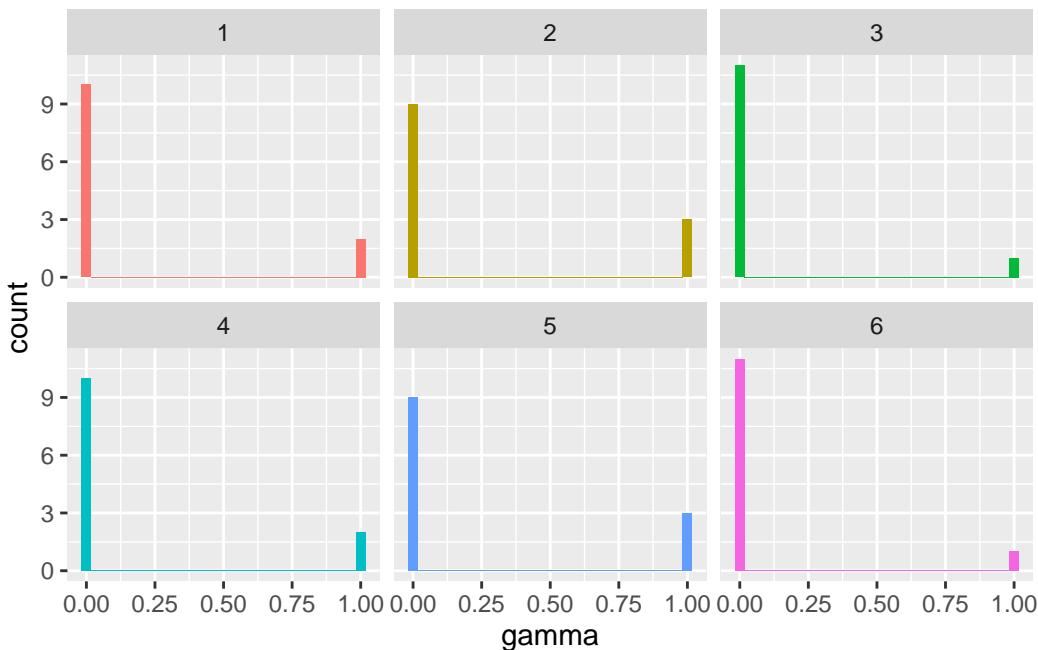
```

# Extracting gammas and putting them in a tidy format
tm_gamma <- tidy(topic_model, matrix = "gamma",
                  # use the names of the stories instead of the default numbers
                  document_names = rownames(sherlock_stm))

# Visualizing the number of stories belonging to each topics and the confidence
#   of the belonging
tm_gamma %>%
  ggplot(aes(gamma, fill = as.factor(topic))) +
  geom_histogram(show.legend = FALSE) +
  facet_wrap(~topic, ncol = 3)

```

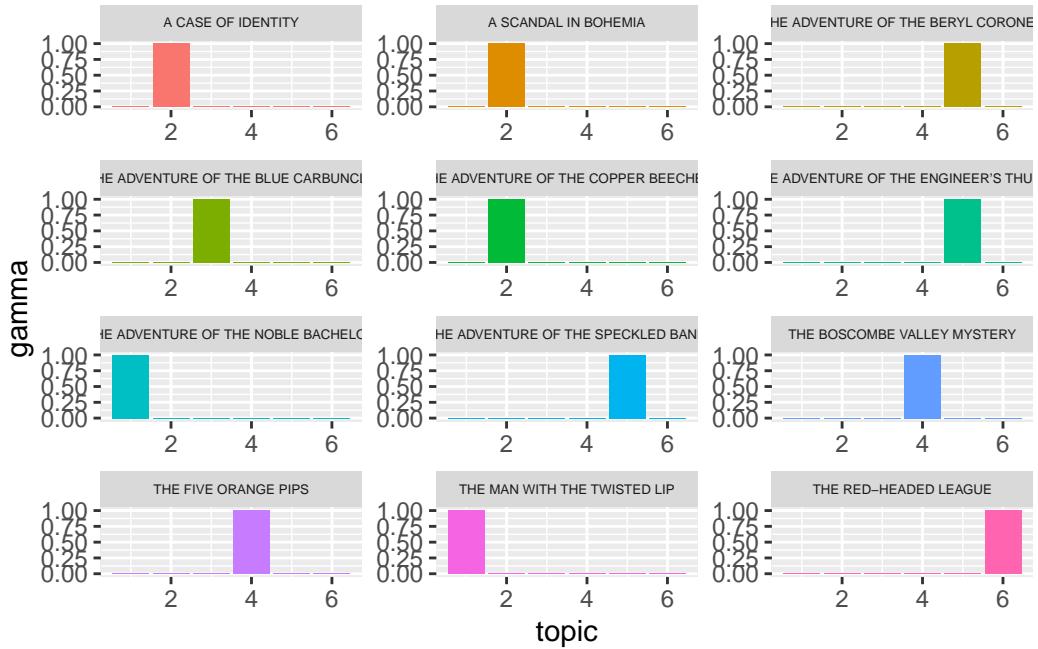
`stat\_bin()` using `bins = 30`. Pick better value with `binwidth`.



```

# Visualizing how much each topic appear in each story
tm_gamma %>%
  ggplot(aes(topic, gamma, fill = document)) +
  geom_col(show.legend = FALSE) +
  facet_wrap(~document, scales = "free", ncol = 3) +
  theme(strip.text.x = element_text(size = 5))

```



The model did an excellent job strongly associating the stories into one or more topics. This perfect association is rare in the world of topic modeling. The reason behind this perfect association here could be due to the small number of documents that we have.

## 15.9 References

- Adventures of Sherlock Holmes book by Arthur Conan Doyle on Project Gutenberg
- [Regular Expressions 101](#)

# 16 Scrap Mac Registrar Website

## 16.1 Bibliography

- Control a web browser from R to web scrap static and dynamic websites using `chromote` (YouTube)