Week 10: *Data Frames*

EMSE 4571: Intro to Programming for Analytics

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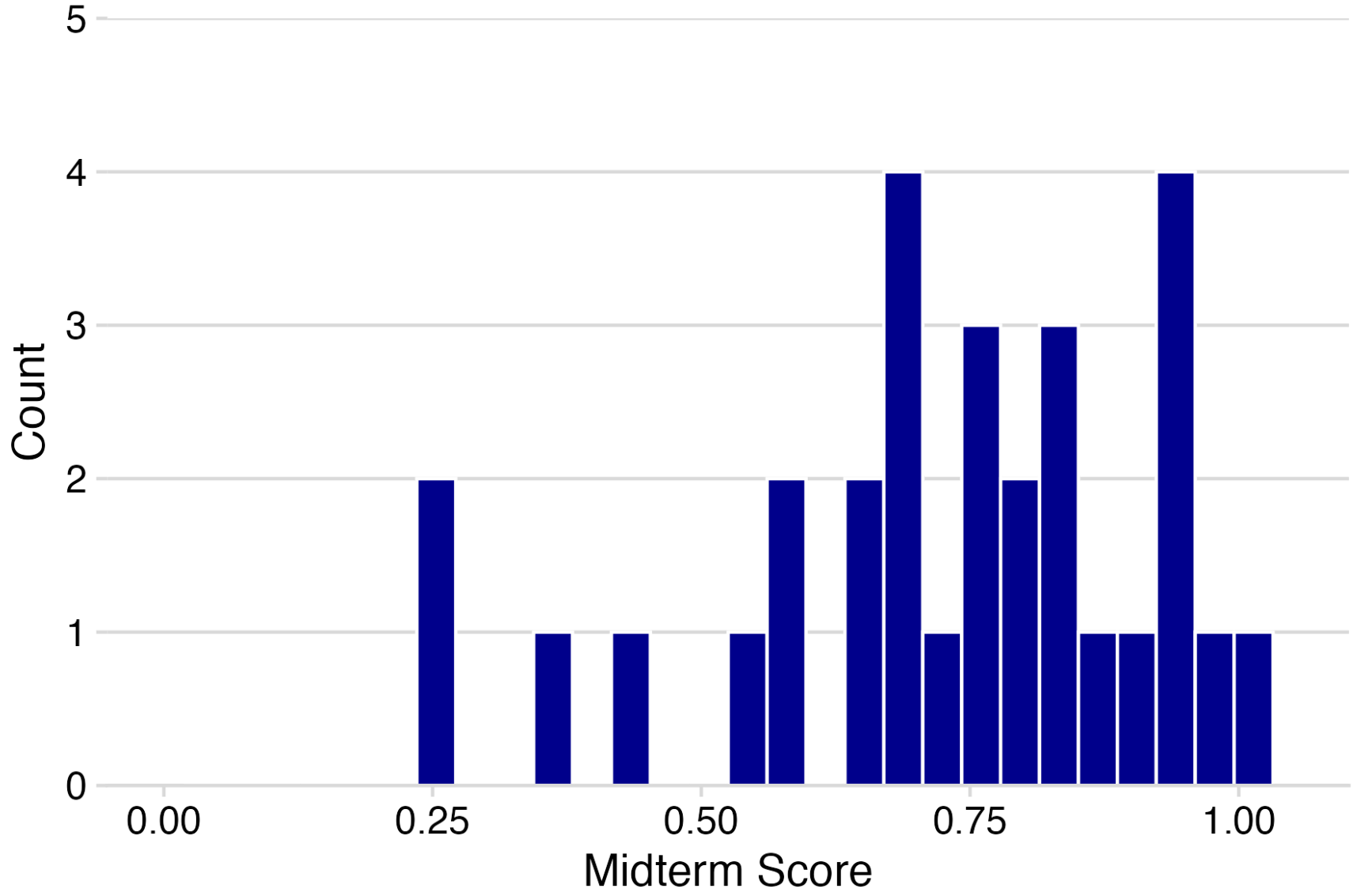

5
4
3
2
1
0
Count
0.00
0.25
0.50
0.75
1.00
Midterm Score

Before we start

Make sure you have these packages installed and loaded:

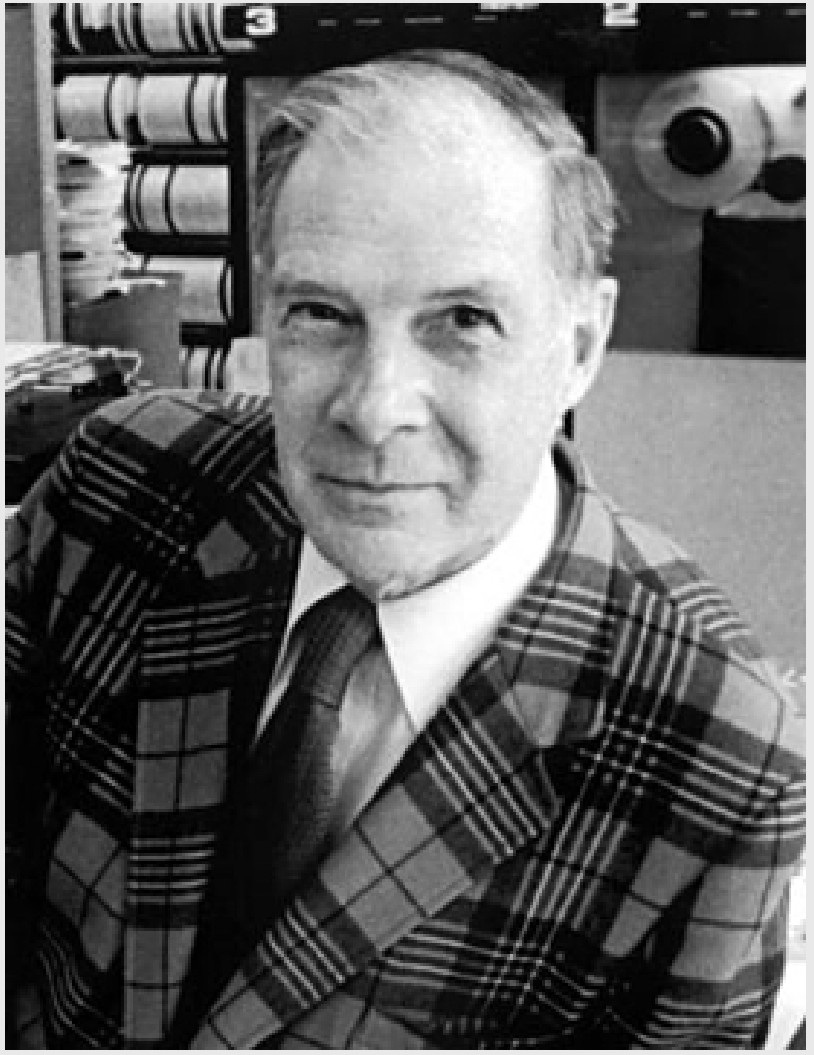
```
install.packages("stringr")
install.packages("dplyr")
install.packages("ggplot2")
install.packages("readr")
install.packages("here")
```

(At the top of the `practice.R` file)

Remember: you only need to install them once!

"The purpose of computing is *insight*, not numbers"

- Richard Hamming



Week 10: *Data Frames*

1. Basics

2. Slicing

BREAK

3. External data

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1. Basics
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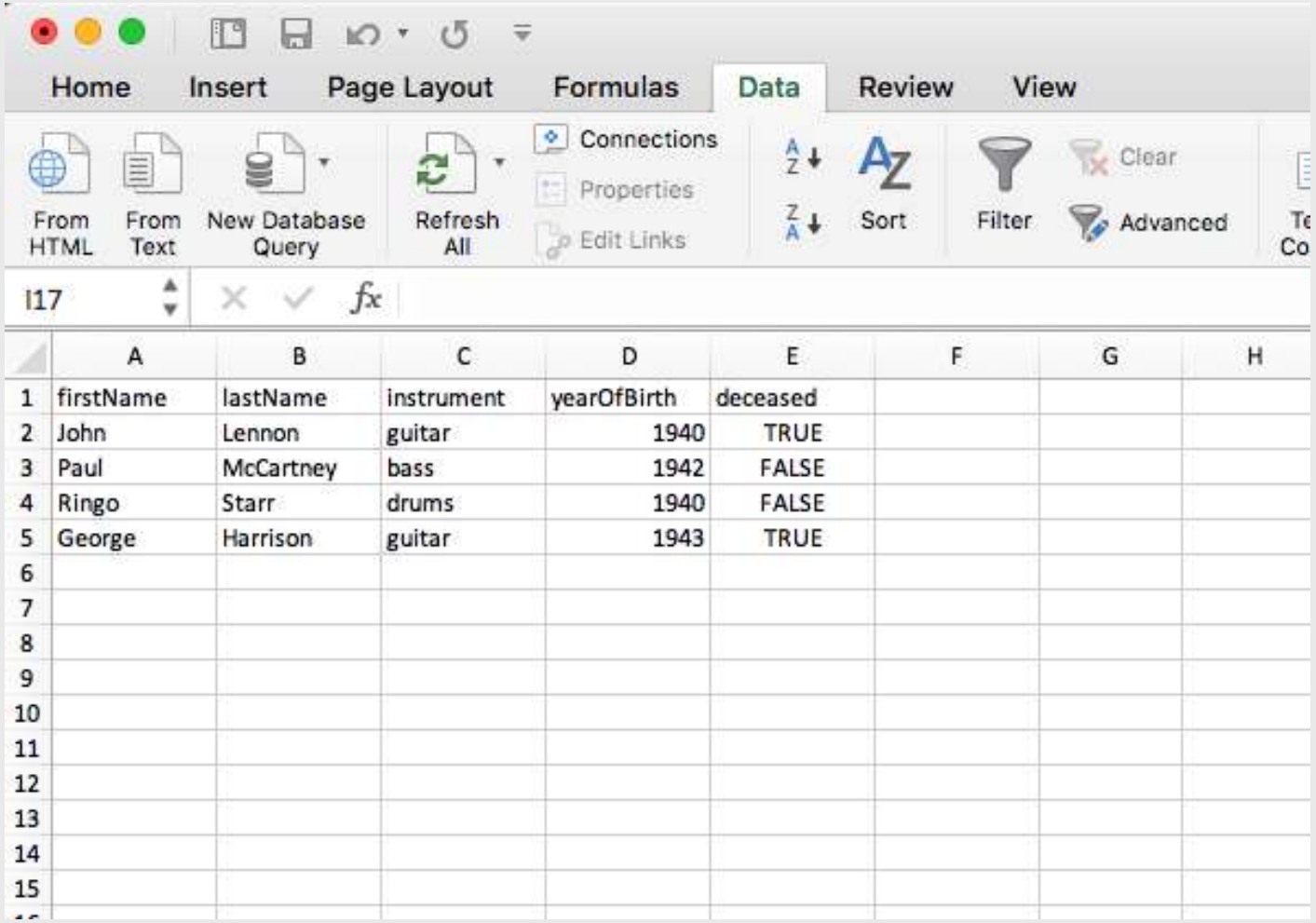
BREAK

3. External data

The data frame...in Excel



	A	B	C	D	E	F	G	H
1	firstName	lastName	instrument	yearOfBirth	deceased			
2	John	Lennon	guitar	1940	TRUE			
3	Paul	McCartney	bass	1942	FALSE			
4	Ringo	Starr	drums	1940	FALSE			
5	George	Harrison	guitar	1943	TRUE			
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

The data frame...in R

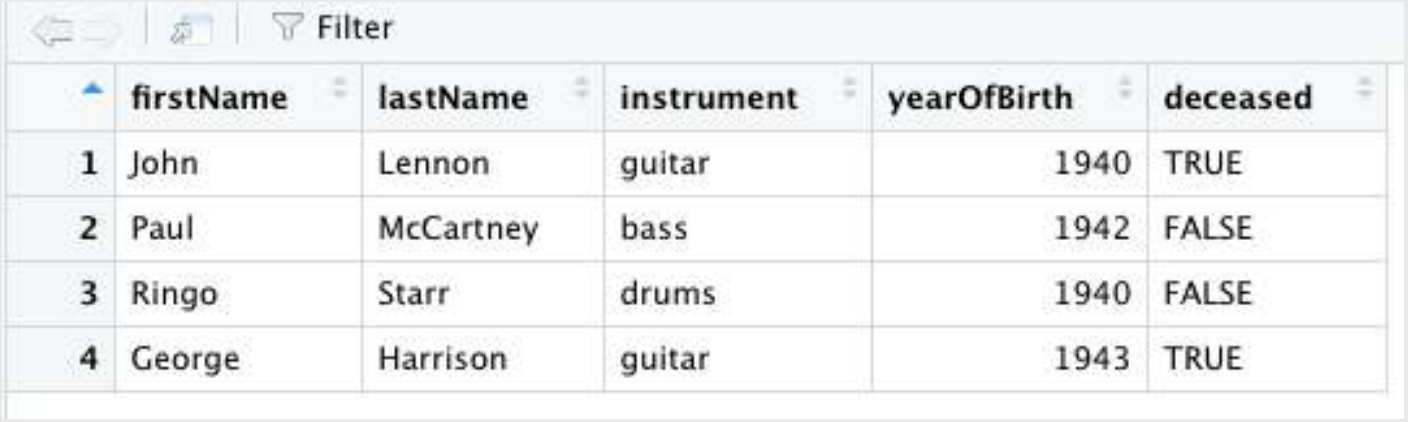
```
beatles <- tibble(
    firstName   = c("John", "Paul", "Ringo", "George"),
    lastName    = c("Lennon", "McCartney", "Starr", "Harrison"),
    instrument  = c("guitar", "bass", "drums", "guitar"),
    yearOfBirth = c(1940, 1942, 1940, 1943),
    deceased    = c(TRUE, FALSE, FALSE, TRUE)
)

beatles
```

```
#> # A tibble: 4 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 John      Lennon    guitar            1940 TRUE
#> 2 Paul      McCartney bass              1942 FALSE
#> 3 Ringo     Starr     drums             1940 FALSE
#> 4 George    Harrison  guitar            1943 TRUE
```

The data frame...in RStudio

```
View(beatles)
```



Filter

	firstName	lastName	instrument	yearOfBirth	deceased
1	John	Lennon	guitar	1940	TRUE
2	Paul	McCartney	bass	1942	FALSE
3	Ringo	Starr	drums	1940	FALSE
4	George	Harrison	guitar	1943	TRUE

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

```
beatles
```

```
#> # A tibble: 4 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 John      Lennon    guitar            1940 TRUE
#> 2 Paul      McCartney bass              1942 FALSE
#> 3 Ringo     Starr     drums             1940 FALSE
#> 4 George    Harrison  guitar            1943 TRUE
```

Extract a column using `$`

```
beatles$firstName
```

```
#> [1] "John"   "Paul"   "Ringo"  "George"
```

Rows: Information about individual observations

Information about *John Lennon* is in the first row:

```
beatles[1,]
```

```
#> # A tibble: 1 × 5
#>   firstName lastName instrument yearOfBirth deceased
#>   <chr>     <chr>    <chr>            <dbl> <lgl>
#> 1 John      Lennon   guitar            1940 TRUE
```

Information about *Paul McCartney* is in the second row:

```
beatles[2,]
```

```
#> # A tibble: 1 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 Paul      McCartney bass              1942 FALSE
```

Make a data frame with `data.frame()`

```
beatles <- data.frame(
    firstName   = c("John", "Paul", "Ringo", "George"),
    lastName    = c("Lennon", "McCartney", "Starr", "Harrison"),
    instrument  = c("guitar", "bass", "drums", "guitar"),
    yearOfBirth = c(1940, 1942, 1940, 1943),
    deceased    = c(TRUE, FALSE, FALSE, TRUE)
)
```

```
beatles
```

```
#>   firstName  lastName instrument yearOfBirth deceased
#> 1      John    Lennon     guitar        1940     TRUE
#> 2      Paul McCartney       bass        1942    FALSE
#> 3     Ringo     Starr      drums        1940    FALSE
#> 4    George  Harrison     guitar        1943     TRUE
```

Make a data frame with `tibble()`

```
library(dplyr)
```

```
beatles <- tibble(
    firstName   = c("John", "Paul", "Ringo", "George"),
    lastName    = c("Lennon", "McCartney", "Starr", "Harrison"),
    instrument  = c("guitar", "bass", "drums", "guitar"),
    yearOfBirth = c(1940, 1942, 1940, 1943),
    deceased    = c(TRUE, FALSE, FALSE, TRUE)
)
```

```
beatles
```

```
#> # A tibble: 4 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 John      Lennon    guitar            1940 TRUE
#> 2 Paul      McCartney bass              1942 FALSE
#> 3 Ringo     Starr     drums             1940 FALSE
#> 4 George    Harrison  guitar            1943 TRUE
```

Why I use `tibble()` instead of `data.frame()`

1. The `tibble()` shows the **dimensions** and **data type**.

2. A tibble will only print the first few rows of data when you enter the object name
   Example: `faithful` vs. `as_tibble(faithful)`

3. Columns of class `character` are *never* converted into factors (don't worry about this for now...just know that tibbles make life easier with strings).

Note: I use the word **"data frame"** to refer to both `tibble()` and `data.frame()` objects

Data frame vectors must have the same length

```
beatles <- tibble(
    firstName   = c("John", "Paul", "Ringo", "George", "Bob"), # Added "Bob"
    lastName    = c("Lennon", "McCartney", "Starr", "Harrison"),
    instrument  = c("guitar", "bass", "drums", "guitar"),
    yearOfBirth = c(1940, 1942, 1940, 1943),
    deceased    = c(TRUE, FALSE, FALSE, TRUE)
)
```

```
#> Error:
#> ! Tibble columns must have compatible sizes.
#> • Size 5: Existing data.
#> • Size 4: Column `lastName`.
#> ℹ Only values of size one are recycled.
```

Use NA for missing values

```
beatles <- tibble(
    firstName   = c("John", "Paul", "Ringo", "George", "Bob"),
    lastName    = c("Lennon", "McCartney", "Starr", "Harrison", NA), # Added NAs
    instrument  = c("guitar", "bass", "drums", "guitar", NA),
    yearOfBirth = c(1940, 1942, 1940, 1943, NA),
    deceased    = c(TRUE, FALSE, FALSE, TRUE, NA)
)
```

```
beatles
```

```
#> # A tibble: 5 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 John      Lennon    guitar            1940 TRUE
#> 2 Paul      McCartney bass              1942 FALSE
#> 3 Ringo     Starr     drums             1940 FALSE
#> 4 George    Harrison  guitar            1943 TRUE
#> 5 Bob       <NA>      <NA>                NA NA
```

Dimensions: `nrow()`, `ncol()`, & `dim()`

```
nrow(beatles) # Number of rows
```

```
#> [1] 5
```

```
ncol(beatles) # Number of columns
```

```
#> [1] 5
```

```
dim(beatles)  # Number of rows and columns
```

```
#> [1] 5 5
```

Use `names()` or `colnames()` to see the available variables

Get the names of columns:

```
names(beatles)
```

```
#> [1] "firstName"   "lastName"    "instrument"  "yearOfBirth" "deceased"
```

```
colnames(beatles)
```

```
#> [1] "firstName"   "lastName"    "instrument"  "yearOfBirth" "deceased"
```

Get the names of rows (rarely needed):

```
rownames(beatles)
```

```
#> [1] "1" "2" "3" "4" "5"
```

Changing the column names

Change the column names with `names()` or `colnames()`:

```
names(beatles) <- c('one', 'two', 'three', 'four', 'five')
beatles
```

```
#> # A tibble: 5 × 5
#>   one    two       three   four five
#>   <chr>  <chr>     <chr>  <dbl> <lgl>
#> 1 John   Lennon    guitar  1940 TRUE
#> 2 Paul   McCartney bass    1942 FALSE
#> 3 Ringo  Starr     drums   1940 FALSE
#> 4 George Harrison  guitar  1943 TRUE
#> 5 Bob    <NA>      <NA>      NA NA
```

Changing the column names

Make all the column names upper-case:

```
colnames(beatles) <- stringr::str_to_upper(colnames(beatles))
beatles
```

```
#> # A tibble: 5 × 5
#>   FIRSTNAME LASTNAME  INSTRUMENT YEAROFBIRTH DECEASED
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 John      Lennon    guitar            1940 TRUE
#> 2 Paul      McCartney bass              1942 FALSE
#> 3 Ringo     Starr     drums             1940 FALSE
#> 4 George    Harrison  guitar            1943 TRUE
#> 5 Bob       <NA>      <NA>                NA NA
```

Combine data frames by columns using `bind_cols()`

Note: `bind_cols()` is from the **dplyr** library

```
names <- tibble(
    firstName = c("John", "Paul", "Ringo", "George"),
    lastName  = c("Lennon", "McCartney", "Starr", "Harrison"))

instruments <- tibble(
    instrument = c("guitar", "bass", "drums", "guitar"))
```

```
bind_cols(names, instruments)
```

```
#> # A tibble: 4 × 3
#>   firstName lastName  instrument
#>   <chr>     <chr>     <chr>
#> 1 John      Lennon    guitar
#> 2 Paul      McCartney bass
#> 3 Ringo     Starr     drums
#> 4 George    Harrison  guitar
```

Combine data frames by rows using `bind_rows()`

Note: `bind_rows()` is from the **dplyr** library

```
members1 <- tibble(
    firstName = c("John", "Paul"),
    lastName  = c("Lennon", "McCartney"))

members2 <- tibble(
    firstName = c("Ringo", "George"),
    lastName  = c("Starr", "Harrison"))
```

```
bind_rows(members1, members2)
```

```
#> # A tibble: 4 × 2
#>   firstName lastName
#>   <chr>     <chr>
#> 1 John      Lennon
#> 2 Paul      McCartney
#> 3 Ringo     Starr
#> 4 George    Harrison
```

Note: `bind_rows()` requires the **same** columns names:

```
colnames(members2) <- c("firstName", "LastName")
bind_rows(members1, members2)
```

```
#> # A tibble: 4 × 3
#>   firstName lastName  LastName
#>   <chr>     <chr>     <chr>
#> 1 John      Lennon    <NA>
#> 2 Paul      McCartney <NA>
#> 3 Ringo     <NA>      Starr
#> 4 George    <NA>      Harrison
```

Note how <NA>s were created

Your turn

06:00

Answer these questions using the `animals_farm` and `animals_pet` data frames:

1. Write code to find how many *rows* are in the `animals_farm` data frame?
2. Write code to find how many *columns* are in the `animals_pet` data frame?
3. Create a new data frame, `animals`, by combining `animals_farm` and `animals_pet`.
4. Change the column names of `animals` to title case.
5. Add a new column to `animals` called `type` that tells if an animal is a `"farm"` or `"pet"` animal.

Week 10: *Data Frames*

1. Basics

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BREAK

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Access data frame columns using the $ symbol

```
beatles$firstName
```

```
#> [1] "John"   "Paul"   "Ringo"  "George"
```

```
beatles$lastName
```

```
#> [1] "Lennon"    "McCartney" "Starr"     "Harrison"
```

Creating new variables with the $ symbol

Add the hometown of the bandmembers:

```
beatles$hometown <- 'Liverpool'
beatles
```

```
#> # A tibble: 4 × 6
#>   firstName lastName  instrument yearOfBirth deceased hometown
#>   <chr>     <chr>     <chr>            <dbl> <lgl>    <chr>
#> 1 John      Lennon    guitar            1940 TRUE     Liverpool
#> 2 Paul      McCartney bass              1942 FALSE    Liverpool
#> 3 Ringo     Starr     drums             1940 FALSE    Liverpool
#> 4 George    Harrison  guitar            1943 TRUE     Liverpool
```

Creating new variables with the $ symbol

Add a new `alive` variable:

```
beatles$alive <- c(FALSE, TRUE, TRUE, FALSE)
beatles
```

```
#> # A tibble: 4 × 7
#>   firstName lastName  instrument yearOfBirth deceased hometown  alive
#>   <chr>     <chr>     <chr>            <dbl> <lgl>    <chr>     <lgl>
#> 1 John      Lennon    guitar            1940 TRUE     Liverpool FALSE
#> 2 Paul      McCartney bass              1942 FALSE    Liverpool TRUE
#> 3 Ringo     Starr     drums             1940 FALSE    Liverpool TRUE
#> 4 George    Harrison  guitar            1943 TRUE     Liverpool FALSE
```

You can compute new variables from current ones

Compute and add the age of the bandmembers:

```
beatles$age <- 2023 - beatles$yearOfBirth
beatles
```

```
#> # A tibble: 4 × 8
#>   firstName lastName  instrument yearOfBirth deceased hometown  alive   age
#>   <chr>     <chr>     <chr>            <dbl> <lgl>    <chr>     <lgl> <dbl>
#> 1 John      Lennon    guitar            1940 TRUE     Liverpool FALSE    83
#> 2 Paul      McCartney bass              1942 FALSE    Liverpool TRUE     81
#> 3 Ringo     Starr     drums             1940 FALSE    Liverpool TRUE     83
#> 4 George    Harrison  guitar            1943 TRUE     Liverpool FALSE    80
```

Access elements by index: `DF[row, column]`

General form for indexing elements:

```
DF[row, column]
```

Select the element in row 1, column 2:

```
beatles[1, 2]
```

```
#> # A tibble: 1 × 1
#>   lastName
#>   <chr>
#> 1 Lennon
```

Select the elements in rows 1 & 2 and columns 2 & 3:

```
beatles[c(1, 2), c(2, 3)]
```

```
#> # A tibble: 2 × 2
#>   lastName  instrument
#>   <chr>     <chr>
#> 1 Lennon    guitar
#> 2 McCartney bass
```

Leave row or column "blank" to select all

```
beatles[c(1, 2),] # Selects all COLUMNS for rows 1 & 2
```

```
#> # A tibble: 2 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 John      Lennon    guitar            1940 TRUE
#> 2 Paul      McCartney bass              1942 FALSE
```

```
beatles[,c(1, 2)] # Selects all ROWS for columns 1 & 2
```

```
#> # A tibble: 4 × 2
#>   firstName lastName
#>   <chr>     <chr>
#> 1 John      Lennon
#> 2 Paul      McCartney
#> 3 Ringo     Starr
#> 4 George    Harrison
```

Negative indices exclude row / column

```
beatles[-1, ] # Select all ROWS except the first
```

```
#> # A tibble: 3 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 Paul      McCartney bass              1942 FALSE
#> 2 Ringo     Starr     drums             1940 FALSE
#> 3 George    Harrison  guitar            1943 TRUE
```

```
beatles[,-1] # Select all COLUMNS except the first
```

```
#> # A tibble: 4 × 4
#>   lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>           <dbl> <lgl>
#> 1 Lennon    guitar           1940 TRUE
#> 2 McCartney bass             1942 FALSE
#> 3 Starr     drums            1940 FALSE
#> 4 Harrison  guitar           1943 TRUE
```

You can select columns by their names

Note: you don't need the comma to select an entire column

One column

```
beatles['firstName']
```

```
#> # A tibble: 4 × 1
#>   firstName
#>   <chr>
#> 1 John
#> 2 Paul
#> 3 Ringo
#> 4 George
```

Multiple columns

```
beatles[c('firstName', 'lastName')]
```

```
#> # A tibble: 4 × 2
#>   firstName lastName
#>   <chr>     <chr>
#> 1 John      Lennon
#> 2 Paul      McCartney
#> 3 Ringo     Starr
#> 4 George    Harrison
```

Use logical indices to *filter* rows

Which Beatles members are still alive?
Create a logical vector using the `deceased` column:

```
beatles$deceased == FALSE
```

```
#> [1] FALSE  TRUE  TRUE FALSE
```

Insert this logical vector in the ROW position of `beatles[,]`:

```
beatles[beatles$deceased == FALSE,]
```

```
#> # A tibble: 2 × 5
#>   firstName lastName  instrument yearOfBirth deceased
#>   <chr>     <chr>     <chr>            <dbl> <lgl>
#> 1 Paul      McCartney bass              1942 FALSE
#> 2 Ringo     Starr     drums             1940 FALSE
```

Your turn

10:00

Answer these questions using the `beatles` data frame:

1. Create a new column, `playsGuitar`, which is `TRUE` if the band member plays the guitar and `FALSE` otherwise.
2. Filter the data frame to select only the rows for the band members who have four-letter first names.
3. Create a new column, `fullName`, which contains the band member's first and last name separated by a space (e.g. `"John Lennon"`)

Break

05:00

Week 10: *Data Frames*

1. Basics

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BREAK

3. External data

Getting data into R

Options:

1. Load external packages

2. Read in external files (usually a `.csv`* file)

*csv = "comma-separated values"

Data from an R package

```
library(ggplot2)
```

See which data frames are available in a package:

```
data(package = "ggplot2")
```

Find out about package data sets with ?

```
?msleep
```

```
msleep {ggplot2}

An updated and expanded version of the mammals sleep dataset

Description

This is an updated and expanded version of the mammals sleep dataset. Updated sleep times
```

Previewing data frames: `msleep`

Look at the data in a "spreadsheet"-like way:

```
View(msleep)
```

This is "read-only" so you can't corrupt the data 😄

My favorite quick summary: `glimpse()`

Preview each variable with `str()` or `glimpse()`

```
glimpse(msleep)
```

```
#> Rows: 83
#> Columns: 11
#> $ name         <chr> "Cheetah", "Owl monkey", "Mountain beaver", "Greater short-t
#> $ genus        <chr> "Acinonyx", "Aotus", "Aplodontia", "Blarina", "Bos", "Bradyp
#> $ vore         <chr> "carni", "omni", "herbi", "omni", "herbi", "herbi", "carni",
#> $ order        <chr> "Carnivora", "Primates", "Rodentia", "Soricomorpha", "Artiod
#> $ conservation <chr> "lc", NA, "nt", "lc", "domesticated", NA, "vu", NA, "domesti
#> $ sleep_total  <dbl> 12.1, 17.0, 14.4, 14.9, 4.0, 14.4, 8.7, 7.0, 10.1, 3.0, 5.3,
#> $ sleep_rem    <dbl> NA, 1.8, 2.4, 2.3, 0.7, 2.2, 1.4, NA, 2.9, NA, 0.6, 0.8, 0.7
#> $ sleep_cycle  <dbl> NA, NA, NA, 0.1333333, 0.6666667, 0.7666667, 0.3833333, NA,
#> $ awake        <dbl> 11.90, 7.00, 9.60, 9.10, 20.00, 9.60, 15.30, 17.00, 13.90, 2
#> $ brainwt      <dbl> NA, 0.01550, NA, 0.00029, 0.42300, NA, NA, NA, 0.07000, 0.09
#> $ bodywt       <dbl> 50.000, 0.480, 1.350, 0.019, 600.000, 3.850, 20.490, 0.045,
```

Also very useful for quick checks: `head()` and `tail()`

View the **first** 6 rows with `head()`

```
head(msleep)
```

```
#> # A tibble: 6 × 11
#>   name                          genus
#>   <chr>                         <chr>
#> 1 Cheetah                       Acinonyx
#> 2 Owl monkey                    Aotus
#> 3 Mountain beaver               Aplodonti
#> 4 Greater short-tailed shrew    Blarina
#> 5 Cow                           Bos
#> 6 Three-toed sloth              Bradypus
```

View the **last** 6 rows with `tail()`

```
tail(msleep)
```

```
#> # A tibble: 6 × 11
#>   name                  genus    vore
#>   <chr>                 <chr>    <chr>
#> 1 Tenrec                Tenrec   omni
#> 2 Tree shrew            Tupaia   omni
#> 3 Bottle-nosed dolphin  Tursiops carni
#> 4 Genet                 Genetta  carni
#> 5 Arctic fox            Vulpes   carni
#> 6 Red fox               Vulpes   carni
```

Importing an external data file

Note the `data.csv` file in your `data` folder.

- **DO NOT** double-click it!
- **DO NOT** open it in Excel!

Excel can **corrupt** your data!

(Don't believe me? read this)

If you **must** open it in Excel:

- Make a copy
- Open the copy

Steps to importing external data files

1. Create a path to the data

```
library(here)
pathToData <- here('data', 'data.csv')
pathToData
```

```
#> [1] "/Users/jhelvy/gh/teaching/P4A/2023-Spring/class/8-data-frames/data/data.csv"
```

2. Import the data

```
library(readr)
df <- read_csv(pathToData)
```

Using the **here** package to make file paths

The `here()` function builds the path to your **root** to your *working directory*
(this is where your `.Rproj` file lives!)

```
here()
```

```
#> [1] "/Users/jhelvy/gh/teaching/P4A/2023-Spring/class/8-data-frames"
```

The `here()` function builds the path to files *inside* your working directory

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

```
#> [1] "/Users/jhelvy/gh/teaching/P4A/2023-Spring/class/8-data-frames/data/data.csv"
```

Avoid hard-coding file paths!

(they can break on different computers)

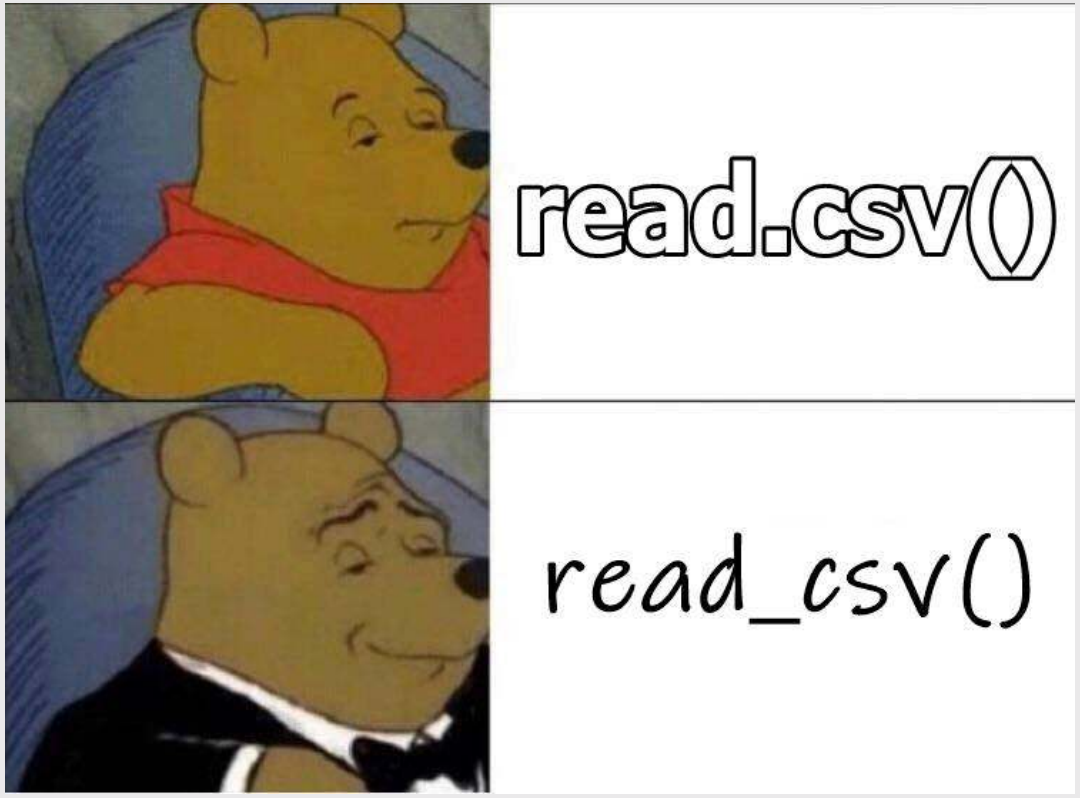
```
path_to_data <- 'data/data.csv'
path_to_data
```

```
#> [1] "data/data.csv"
```


Use the **here** package to make file paths

Art by Allison Horst

Use `read_csv()`, not `read.csv()`




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

Your turn

10:00

1) Use the `here()` and `read_csv()` functions to load the `data.csv` file that is in the `data` folder. Name the data frame object `df`.

2) Use the `df` object to answer the following questions:

- How many rows and columns are in the data frame?
- Preview the different columns. What do you think this data is about? What might one row represent? What type of data is each column? (don't need to type this out...just inspect the data)
- How many unique airports are in the data frame?
- What is the earliest and latest observation in the data frame?
- What is the lowest and highest cost of any one repair in the data frame?

Next week: better data wrangling with **dplyr**

Art by Allison Horst

Select rows with `filter()`

Example: Filter rows to find which Beatles members are still alive?

Base R:

```
beatles[beatles$deceased == FALSE,]
```

dplyr:

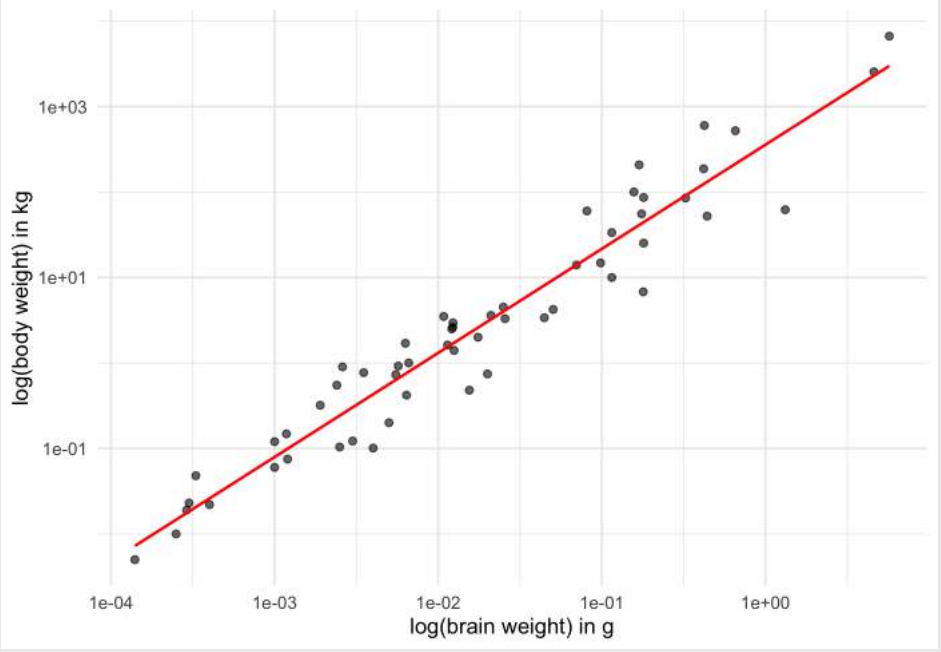
```
filter(beatles, deceased == FALSE)
```

In 2 weeks: plotting with **ggplot2**

Translate *data*...

```
#> # A tibble: 11 × 2
#>    brainwt   bodywt
#>      <dbl>    <dbl>
#>  1 0.001      0.06
#>  2 0.0066     1
#>  3 0.00014    0.005
#>  4 0.0108     3.5
#>  5 0.0123     2.95
#>  6 0.0063     1.7
#>  7 4.60    2547
#>  8 0.0003     0.023
#>  9 0.655    521
#> 10 0.419    187
#> 11 0.0035     0.77
```

...into *information*



A note about HW 9

- You have what you need to start now.
- It will be *much* easier if you use the **dplyr** functions (i.e. read ahead).

Extra Practice!

08:00

1. Install the **dslabs** package.
2. Load the package, then use `data(package = "dslabs")` to see the different data sets in this package.
3. Pick one.
4. Answer these questions:

- What is the dataset about?
- How many observations are in the data frame?
- What is the original source of the data?
- What type of data is each variable?
- Find one thing interesting about it to share.