



Week 10: *Data Frames*

🏛️ EMSE 4571: Intro to Programming for Analytics

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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 screenshot of the Microsoft Excel application interface. The ribbon at the top is visible with tabs for Home, Insert, Page Layout, Formulas, Data (which is selected), Review, and View. Below the ribbon, there are several icons for importing data from various sources like HTML, Text, and Database, along with refresh and connection tools. On the far right of the ribbon, there are buttons for sorting (AZ, ZA), filtering, and advanced filtering. The active cell is I17, indicated by a red border. The data starts at row 1 and continues down to row 15. The columns are labeled A through H. The data consists of five rows of information about the Beatles, with the first row serving as the header.

	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)

	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

06 : 00

Your turn

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

2. **Slicing**

BREAK

3. External data

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

2. Slicing

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", "Aplopontia", "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)
```

10:00

Your turn

- 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:

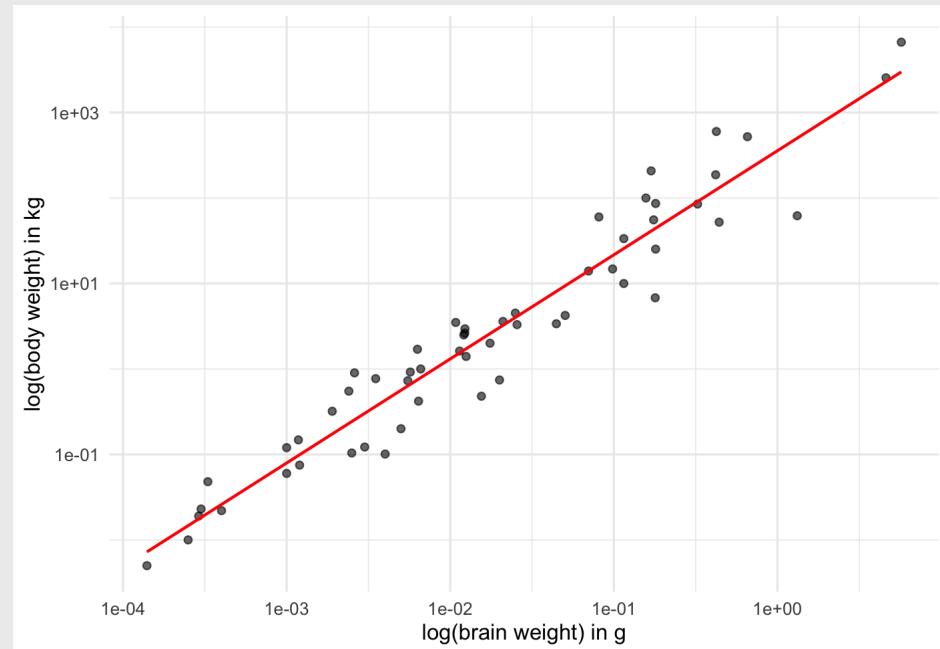
```
filter(beatles, deceased == FALSE)
```

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).

08 : 00

Extra Practice!

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.