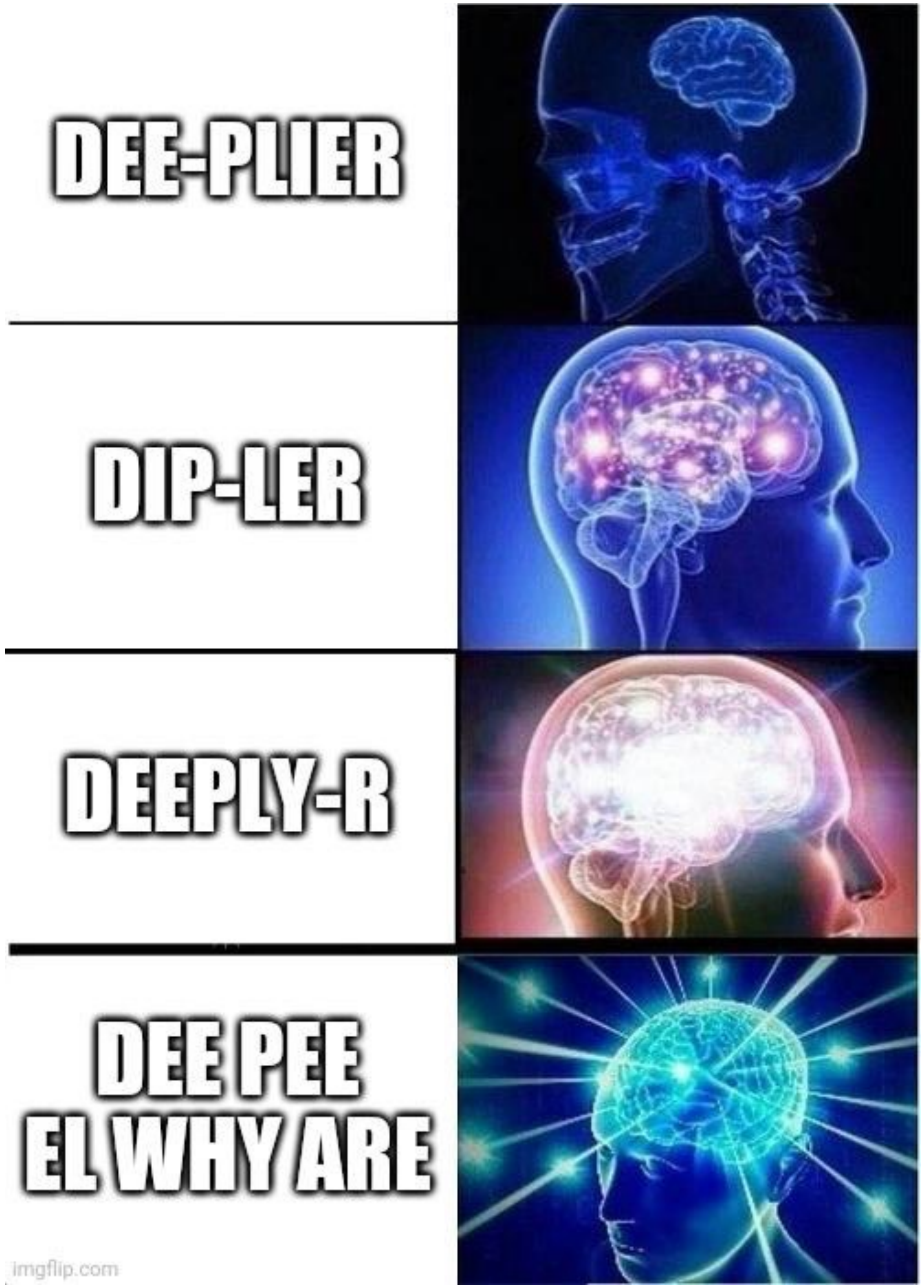
Introduction to Data Wrangling

Data Wrangling

- Real-world data is NOT clean!!
- We have to process it. More efficiency, better time use.
- This is where dplyr comes in: aka A Grammar of Data Manipulation.
- Hadley Wickham, 2014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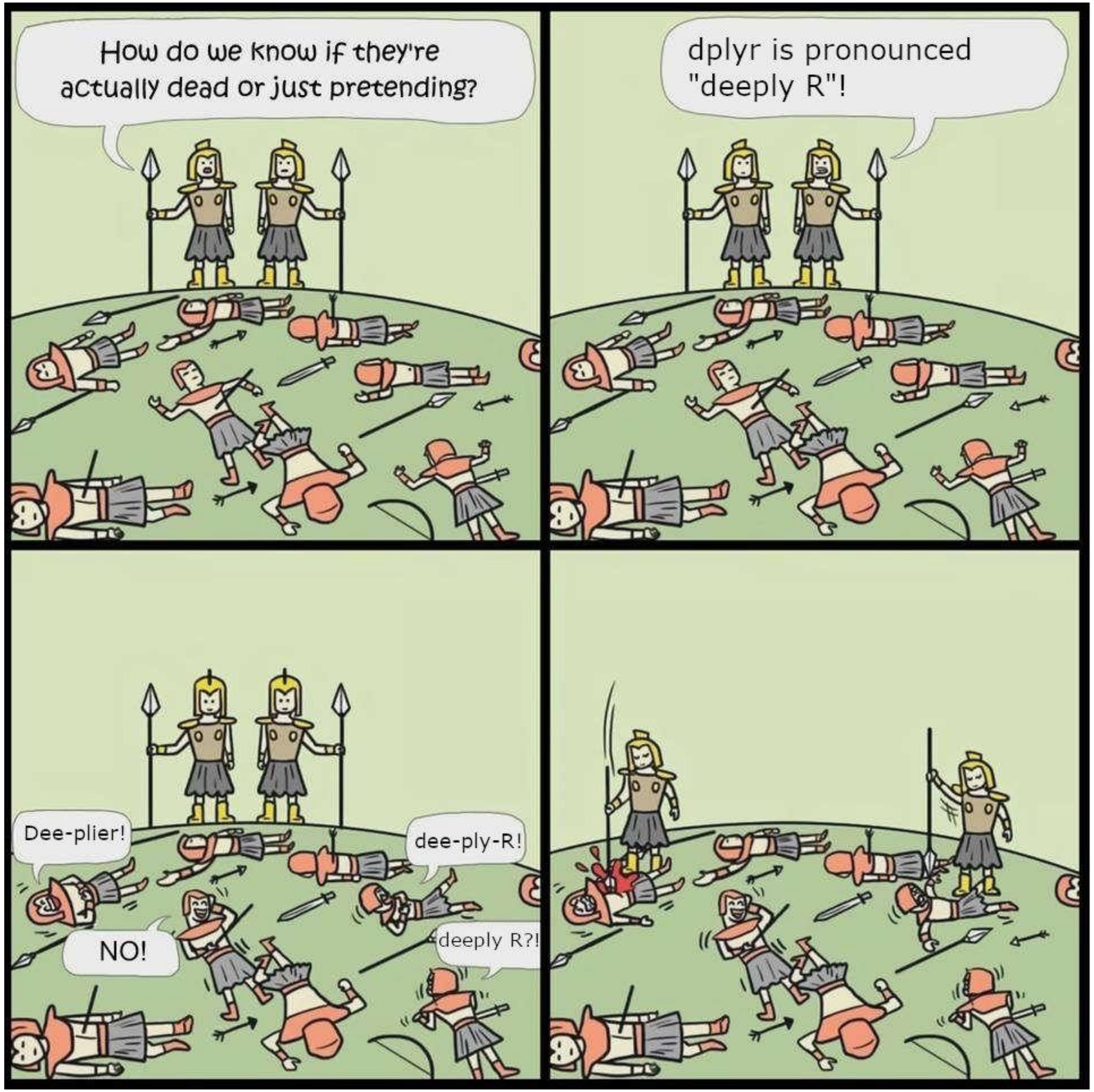

How do we know if they're actually dead or just pretending?
dplyr is pronounced "deeply R"!
Dee-plier!
NO!
dee-ply-R!
deeply R?!

Note about installing `dplyr`

You can use the `install.packages` command to install the `dplyr` package.

After installing the package, you can load it into the workspace using the `library` command. Note that while you only need to install a package once, you need to load it into the workspace whenever you want to access it.

Alternatively, `dplyr` gets loaded automatically if you call `tidyverse` package, so you can skip this step. `Tidyverse` includes `ggplot2` too, and more.

```
> install.packages("dplyr")
> library(dplyr)

Attaching package: 'dplyr'

The following object is masked from 'package:MASS':

    select

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

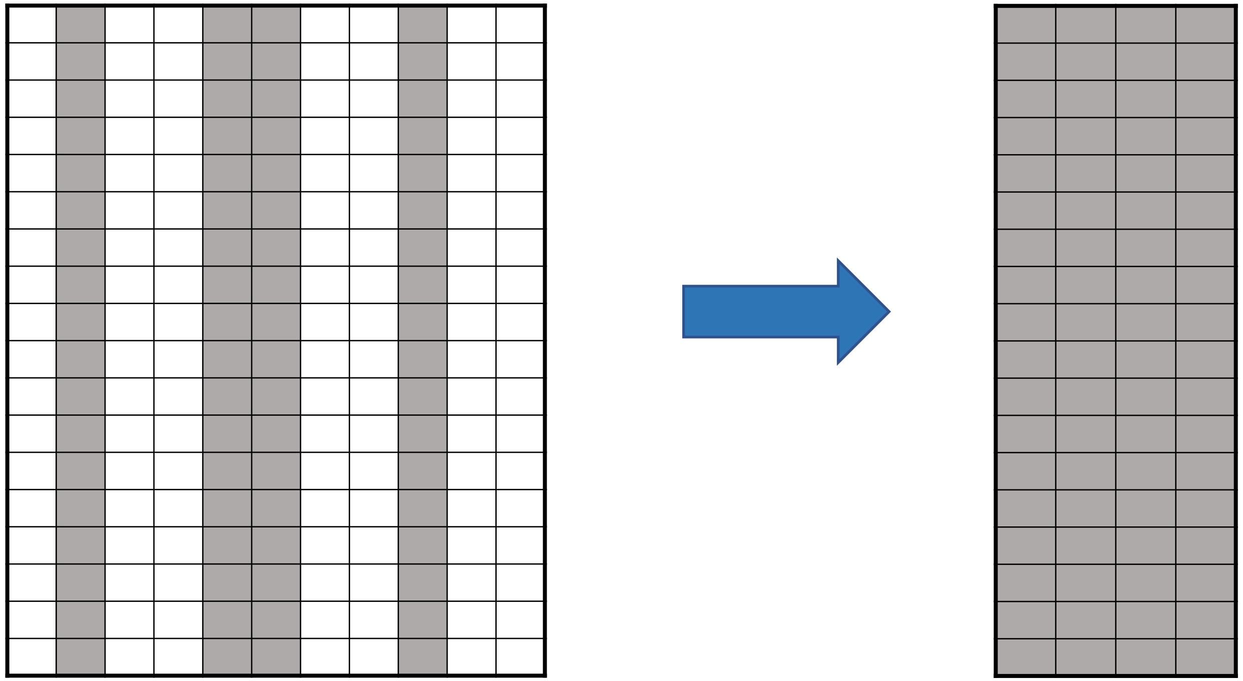
What is this telling us?

If we just type the object name, we get the object in the *last package loaded*. i.e., order matters. What is we want `select` from the `MASS` package?

```
> MASS::select
```

Our 1st function!: The `select` Function

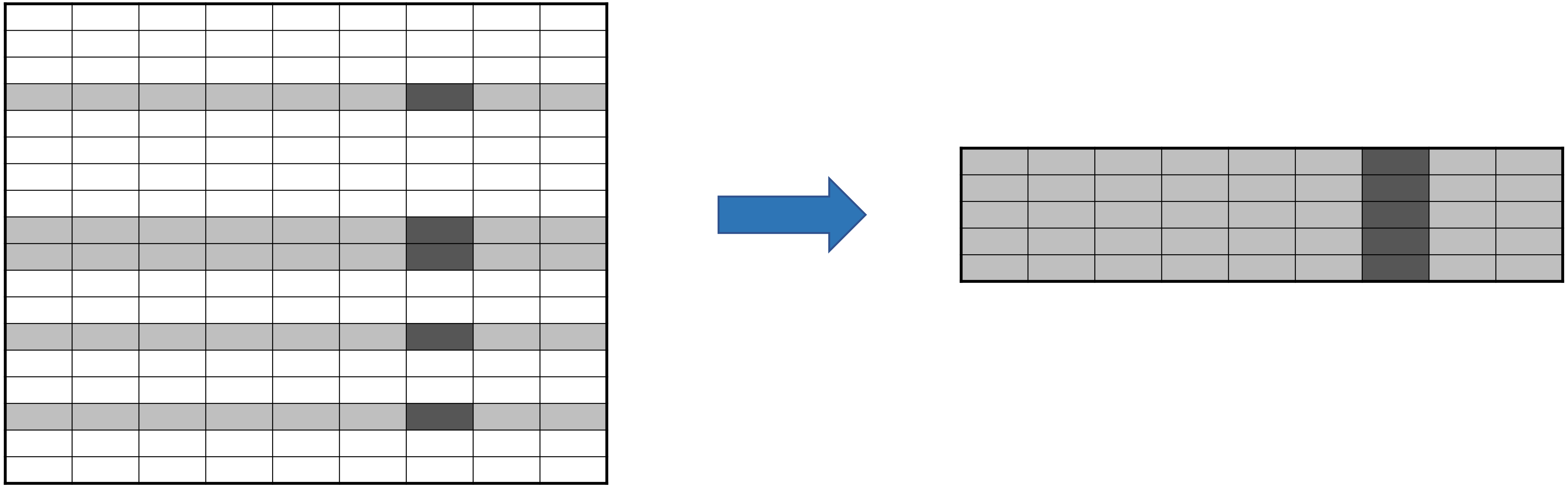
The `select` function allows you to create a new data frame that is a subset of an existing data frame by choosing a set of the columns of the original data frame.



The general syntax is `select(data_frame, Var_name_1, Var_name_2,…)`. Note that the entire column is transferred to the new data frame by the `select` function.

The `filter` Function

The `filter` function allows you to create a new data frame that is a subset of an existing data frame by choosing a set of the rows of the original data frame based on a collection of specified conditions.



The general syntax is `filter(data_frame, Condition,…)`. The `condition` can include logical operators for the row selection. Note that the entire row is transferred to the new data frame by the `filter` function.

Examples from the `Cars93` Data Frame

Recall the `Cars93` data frame contains data for 93 cars sold in the U.S. during the year 1993. The first six rows of the data frame can be viewed using the `head` function.

```
> head(Cars93)
  Manufacturer   Model    Type Min.Price Price Max.Price MPG.city MPG.highway            AirBags DriveTrain
1        Acura Integra   Small      12.9  15.9      18.8       25          31               None      Front
2        Acura  Legend Midsize      29.2  33.9      38.7       18          25 Driver & Passenger      Front
3         Audi      90 Compact      25.9  29.1      32.3       20          26        Driver only      Front
4         Audi     100 Midsize      30.8  37.7      44.6       19          26 Driver & Passenger      Front
5          BMW    535i Midsize      23.7  30.0      36.2       22          30        Driver only       Rear
6        Buick Century Midsize      14.2  15.7      17.3       22          31        Driver only      Front
  Cylinders EngineSize Horsepower  RPM Rev.per.mile Man.trans.avail Fuel.tank.capacity Passengers Length
1         4        1.8        140 6300         2890             Yes               13.2          5    177
2         6        3.2        200 5500         2335             Yes               18.0          5    195
3         6        2.8        172 5500         2280             Yes               16.9          5    180
4         6        2.8        172 5500         2535             Yes               21.1          6    193
5         4        3.5        208 5700         2545             Yes               21.1          4    186
6         4        2.2        110 5200         2565              No               16.4          6    189
  Wheelbase Width Turn.circle Rear.seat.room Luggage.room Weight  Origin          Make
1       102    68          37           26.5           11   2705 non-USA Acura Integra
2       115    71          38           30.0           15   3560 non-USA  Acura Legend
3       102    67          37           28.0           14   3375 non-USA       Audi 90
4       106    70          37           31.0           17   3405 non-USA      Audi 100
5       109    69          39           27.0           13   3640 non-USA      BMW 535i
6       105    69          41           28.0           16   2880     USA Buick Century
```

The `select` Function: `Cars93` Example, and the `%>%` Operator

```
> Cars93_Ex1<-Cars93 %>% select(Type,EngineSize,DriveTrain,MPG.city)
> head(Cars93_Ex1)
     Type EngineSize DriveTrain MPG.city
1   Small        1.8      Front       25
2 Midsize        3.2      Front       18
3 Compact        2.8      Front       20
4 Midsize        2.8      Front       19
5 Midsize        3.5       Rear       22
6 Midsize        2.2      Front       22
```

Notes:

- An arbitrary number of variable names can be passed into the function.
- The order of the variables in the new data frame matches the order they are entered into the function.
- The variable names are not in quotations in the function input.
- c() function is not used to combine column name objects.
- Keyboard shortcut for pipe: Ctrl + Shift + M (MacOS: Cmd + Shift + M)

The `filter` Function: `Cars93` Example

```
> Cars93_Ex2<-Cars93 %>% filter(Type=="Small")
> head(Cars93_Ex2)
  Manufacturer   Model  Type Min.Price Price Max.Price MPG.city MPG.highway     AirBags DriveTrain Cylinders
1        Acura Integra Small      12.9  15.9      18.8       25          31        None      Front         4
2        Dodge    Colt Small       7.9   9.2      10.6       29          33        None      Front         4
3        Dodge  Shadow Small       8.4  11.3      14.2       23          29 Driver only      Front         4
4        Eagle  Summit Small       7.9  12.2      16.5       29          33        None      Front         4
5         Ford Festiva Small       6.9   7.4       7.9       31          33        None      Front         4
6         Ford  Escort Small       8.4  10.1      11.9       23          30        None      Front         4
  EngineSize Horsepower  RPM Rev.per.mile Man.trans.avail Fuel.tank.capacity Passengers Length Wheelbase
1        1.8        140 6300         2890             Yes               13.2          5    177       102
2        1.5         92 6000         3285             Yes               13.2          5    174        98
3        2.2         93 4800         2595             Yes               14.0          5    172        97
4        1.5         92 6000         2505             Yes               13.2          5    174        98
5        1.3         63 5000         3150             Yes               10.0          4    141        90
6        1.8        127 6500         2410             Yes               13.2          5    171        98
  Width Turn.circle Rear.seat.room Luggage.room Weight  Origin          Make
1    68          37           26.5           11   2705 non-USA Acura Integra
2    66          32           26.5           11   2270     USA    Dodge Colt
3    67          38           26.5           13   2670     USA  Dodge Shadow
4    66          36           26.5           11   2295     USA  Eagle Summit
5    63          33           26.0           12   1845     USA  Ford Festiva
6    67          36           28.0           12   2530     USA   Ford Escort
```

The == is a test for equality and we need to enter the “Small” in quotations since we are filtering for rows where the Type variable is equal to “Small”.

Combining the `filter` and `select` Functions:

When we have several operations to complete that need to be nested, the *pipe operator* `%>%` can result in nice and readable code.

```
> Cars93_Ex8<-Cars93 %>%
       filter(Type %in% c("Sporty","Compact") & Horsepower >=120) %>%
       select(Model,Type,EngineSize,Cylinders,Horsepower,MPG.highway)
> head(Cars93_Ex8)
     Model    Type EngineSize Cylinders Horsepower MPG.highway
1       90 Compact        2.8         6        172          26
2   Camaro  Sporty        3.4         6        160          28
3 Corvette  Sporty        5.7         8        300          25
4  LeBaron Compact        3.0         4        141          28
5  Stealth  Sporty        3.0         6        300          24
6  Prelude  Sporty        2.3         4        160          31
```

The *pipe* above accomplishes the same set of operations as the code below (not so readable)

```
> Cars93_Ex7<-select(filter(Cars93, Type %in% c("Sporty","Compact") & Horsepower >=120),
+ Model,Type,EngineSize,Cylinders,Horsepower,MPG.highway)
```

The %in% Operator

A long list of criteria can be cumbersome to type. We can use the %in% operator to check whether a value is in a list of possible values.

```
➢ Cars93_Ex7<-Cars93 %>%
                filter(Type %in% c(“Sporty”,”Compact”) & Horsepower >= 120) %>%
                select(Model,Type,EngineSize,Cylinders,Horsepower,MPG.highway)
> head(Cars93_Ex7)
     Model    Type EngineSize Cylinders Horsepower MPG.highway
1       90 Compact        2.8         6        172          26
2   Camaro  Sporty        3.4         6        160          28
3 Corvette  Sporty        5.7         8        300          25
4  LeBaron Compact        3.0         4        141          28
5  Stealth  Sporty        3.0         6        300          24
6  Prelude  Sporty        2.3         4        160          31
```

Here, the cars are returned that have a Type of either Sporty or Compact and have Horsepower greater than 120.

Practice time: `msleep`

Run `data(msleep)` to load `msleep` in, `?msleep` for the codebook

Use `filter()` to filter `msleep` to

1. only herbivores
2. any animal that is awake for at least 12 hours a day
3. only herbivores + that are awake for at least 12 hours of a day.
4. `Name` and `awake` columns for only herbivores + that are awake for at least 12 hours of a day.

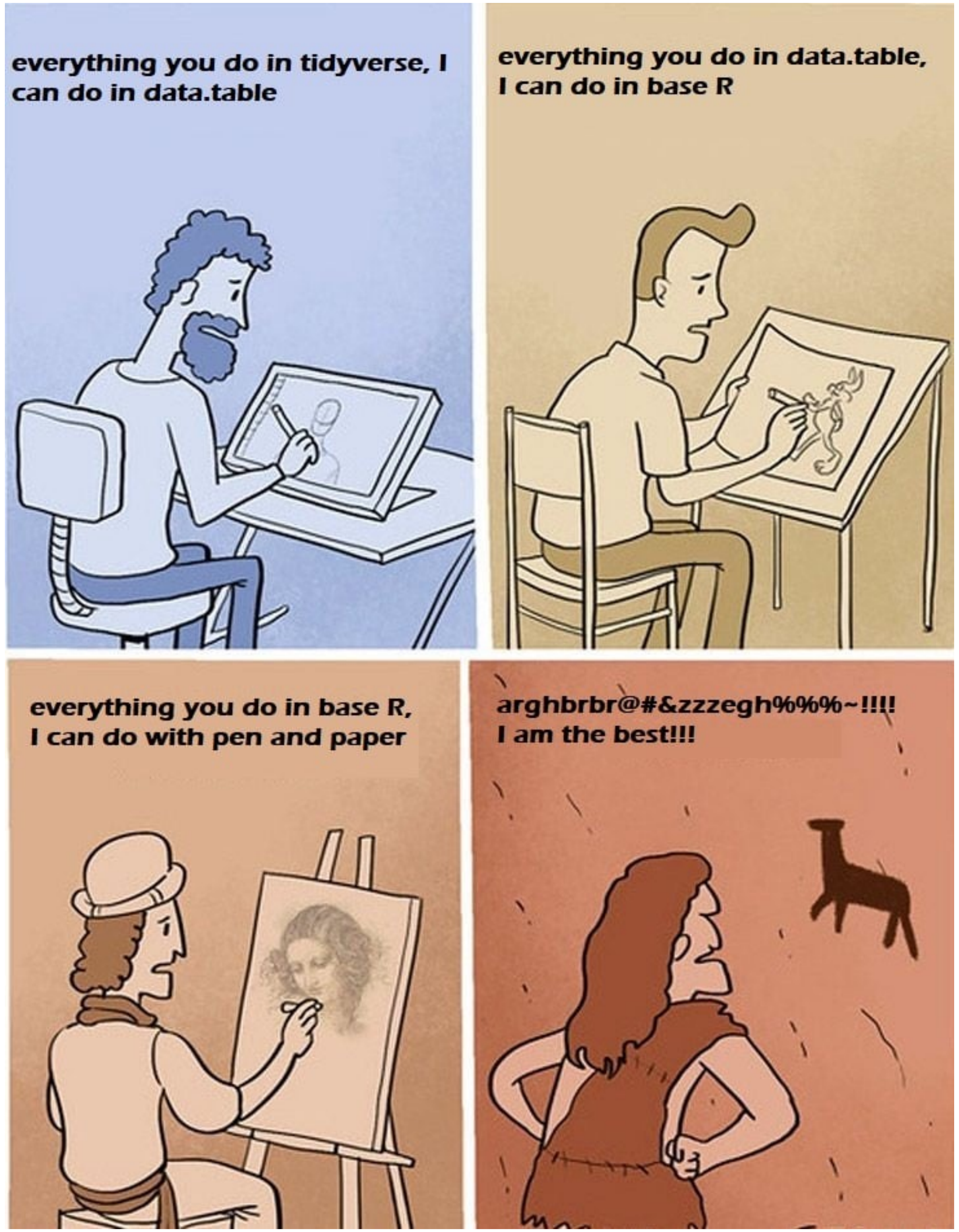
Do it using base R, and `dplyr`.

Hint: if you get a slightly different output, try adding `%>% drop_na(colname)`

Practice `%in%`:

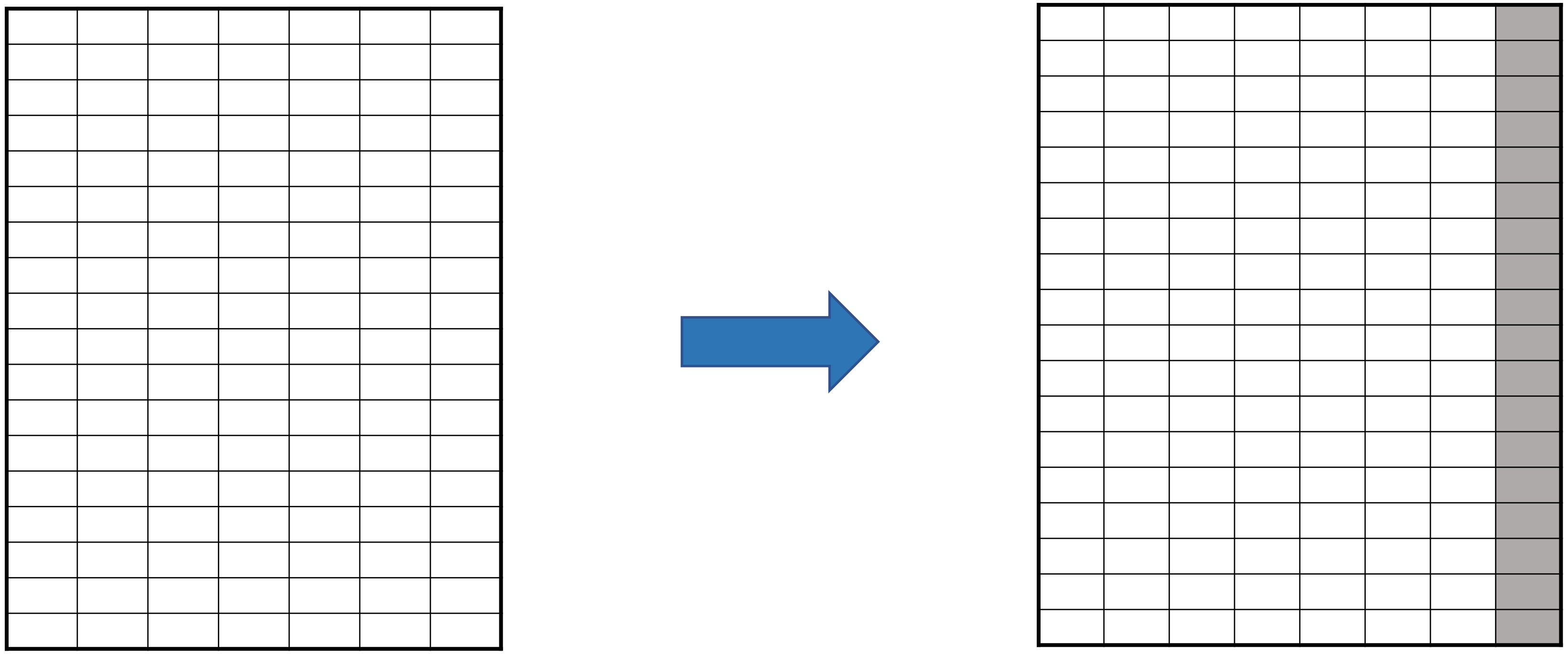
Return herbivores and carnivores that sleep at least 12 hours a day

Do it using `%in%` and `"|"` which is the symbol for “or”


everything you do in tidyverse, I can do in data.table
everything you do in data.table, I can do in base R
everything you do in base R, I can do with pen and paper
arghbrbr@#&zzzegh%%%~!!!! I am the best!!!

The `mutate` Function

The `mutate` function allows you to create a new data frame consisting of the original data frame with a column appended on the right end.



The general syntax is `mutate(data_frame, Var_Name = function(…))`. The new column will have the name given in `Var_Name` and be computed from the function provided.

Example of the `mutate` Function

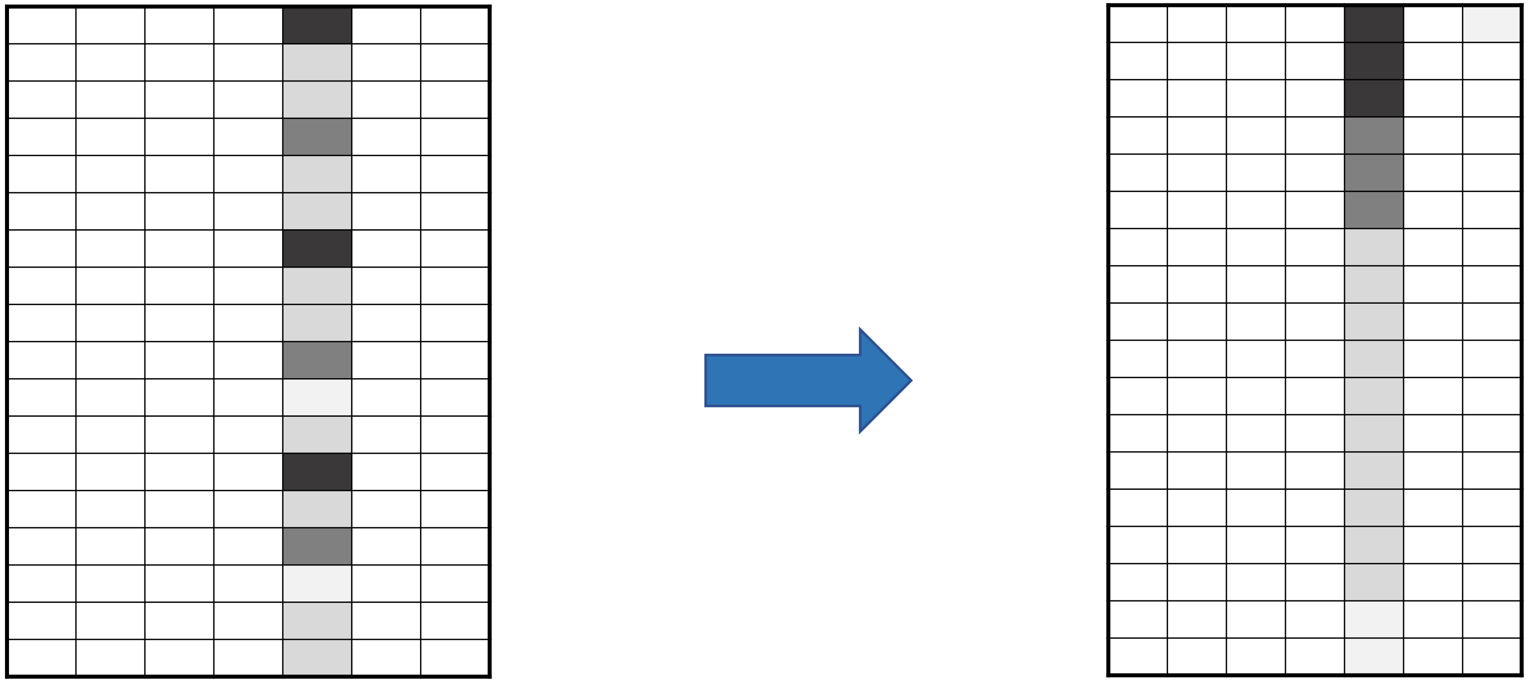
We now add a column to the `Cars93` data frame containing the horsepower per liter of engine size. That is, we define the new variable `HPpLiter` by the function

$$\text{HPpLiter} = \frac{\text{Horsepower}}{\text{EngineSize}}$$

```
> Cars93_Ex9<-Cars93 %>%
               mutate(HPpLiter=Horsepower/EngineSize) %>%
               select(Model,Type,EngineSize,Cylinders,Horsepower,MPG.highway,HPpLiter)
> head(Cars93_Ex9)
    Model    Type EngineSize Cylinders Horsepower MPG.highway HPpLiter
1 Integra   Small        1.8         4        140          31 77.77778
2  Legend Midsize        3.2         6        200          25 62.50000
3      90 Compact        2.8         6        172          26 61.42857
4     100 Midsize        2.8         6        172          26 61.42857
5    535i Midsize        3.5         4        208          30 59.42857
6 Century Midsize        2.2         4        110          31 50.00000
```

The `arrange` Function

The `arrange` function allows you to sort a data frame by variable producing a new data frame ordered by that variable.



The general syntax is `arrange(data_frame, Var_Name1, Var_Name2, …)`. The rows are sorted by the variables selected in the order they are entered. That is, on `Var_Name1` first, with ties broken by `Var_Name2`, etc. The default is ascending order, and descending order can be selected by using `desc(Var_Name1)` when passing in the variable name.

Example of the `arrange` Function

In the previous example we used the `mutate` function to add a column to the `Cars93` data frame containing the horsepower per liter. We now sort this new data frame first by the number of cylinders and then by the engine's horsepower.

```
> Cars93_Ex10<-Cars93 %>%
              mutate(HPpLiter=Horsepower/EngineSize) %>%
              select(Model,Type,EngineSize,Cylinders,Horsepower,MPG.highway,HPpLiter) %>%
              arrange(Cylinders,desc(Horsepower))
> head(Cars93_Ex10)
```

```
    Model    Type EngineSize Cylinders Horsepower MPG.highway HPpLiter
1   Justy   Small        1.2         3         73          37 60.83333
2   Swift   Small        1.3         3         70          43 53.84615
3   Metro   Small        1.0         3         55          50 55.00000
4    535i Midsize        3.5         4        208          30 59.42857
5     626 Compact        2.5         4        164          34 65.60000
6 Prelude  Sporty        2.3         4        160          31 69.56522
```

Observe that we used `desc(Horsepower)` to sort on this variable from highest to lowest.

The rename Function

The rename function allows you to rename columns in a data frame.

The syntax is rename(data_frame, New_Name1=Old_Name1, New_Name2=Old_Name2 …). The variable named Old_Name is renamed with the value entered for New_Name in the output data frame. Rows are not affected, and the column order remains unchanged.

Example: We can rename two of the columns in the data frame from the previous example using the rename function as follows:

```
➢ Cars93_Ex11<- Cars93_Ex10 %>%
                 rename(HP=Horsepower, MPG_Highway=MPG.highway)
> head(Cars93_Ex11)
    Model    Type EngineSize Cylinders  HP MPG_Highway HPpLiter
1   Justy   Small        1.2         3  73          37 60.83333
2   Swift   Small        1.3         3  70          43 53.84615
3   Metro   Small        1.0         3  55          50 55.00000
4    535i Midsize        3.5         4 208          30 59.42857
5     626 Compact        2.5         4 164          34 65.60000
6 Prelude  Sporty        2.3         4 160          31 69.56522
```

More Examples with the mutate Function

Suppose we are interested in the engines of the various cars. We previously used the mutate function to add a column containing the horsepower per liter of engine size.

```
> head(Cars93_Ex11)
    Model    Type EngineSize Cylinders  HP MPG_Highway HPpLiter
1   Justy   Small        1.2         3  73          37 60.83333
2   Swift   Small        1.3         3  70          43 53.84615
3   Metro   Small        1.0         3  55          50 55.00000
4    535i Midsize        3.5         4 208          30 59.42857
5     626 Compact        2.5         4 164          34 65.60000
6 Prelude  Sporty        2.3         4 160          31 69.56522
```

What if we wanted the data in the HPpLiter column to be rounded to the nearest tenth? (Note that we could have done this when we first added the column, but we forgot). We can use the mutate function to accomplish this as well.

```
➤ Cars93_Ex12<- Cars93_Ex11 %>%
                mutate(HPpLiter=round(HPpLiter,1))
```

Observe that we have entered a variable name that is already in the data frame. How does the mutate function process this request?

More Examples with the `mutate` Function

Viewing the function output produces

```
> head(Cars93_Ex12)
    Model    Type EngineSize Cylinders  HP MPG_Highway HPpLiter
1   Justy   Small        1.2         3  73          37     60.8
2   Swift   Small        1.3         3  70          43     53.8
3   Metro   Small        1.0         3  55          50     55.0
4    535i Midsize        3.5         4 208          30     59.4
5     626 Compact        2.5         4 164          34     65.6
6 Prelude  Sporty        2.3         4 160          31     69.6
```

The `mutate` function did not append a new column on the end of the data frame, but rather **replaced** the existing column with the matching name with the updated information.

Suppose that engines producing 65 horsepower or more per liter of displacement can be considered high-performance while those producing less than this value are regular performance. How can we add a column indicating this to our data frame?

More Examples with the mutate Function

We can combine the mutate function with the ifelse function to obtain this result

```
➢ Cars93_Ex13<- Cars93_Ex12 %>%
                   Mutate(Performance=(HPpLiter>=65)*1)
> head(Cars93_Ex13)
    Model    Type EngineSize Cylinders  HP MPG_Highway HPpLiter Performance
1   Justy   Small        1.2         3  73          37     60.8           0
2   Swift   Small        1.3         3  70          43     53.8           0
3   Metro   Small        1.0         3  55          50     55.0           0
4    535i Midsize        3.5         4 208          30     59.4           0
5     626 Compact        2.5         4 164          34     65.6           1
6 Prelude  Sporty        2.3         4 160          31     69.6           1
```

Note that the condition inside returns a boolean vector, which can multiplied by a number to get integer output. The mutate function appends the result on the right side of the data frame. We can obtain further information using

```
> table(Cars93_Ex13$Performance)

 0  1 
79 14
```

The summarize Function

- The summarize function allows you to produce a data frame with user chosen statistics calculated from the columns of the input data frame.
- Often used with the group_by function which allows the statistics to be computed for particular groups in the input data frame.

Example: We have the data on the engines in the Cars93_Ex14 data frame.

```
> head(Cars93_Ex14)
    Model    Type EngineSize Cylinders  HP MPG_Highway HPpLiter Performance
1   Justy   Small        1.2         3  73          37     60.8     Regular
2   Swift   Small        1.3         3  70          43     53.8         Low
3   Metro   Small        1.0         3  55          50     55.0     Regular
4    535i Midsize        3.5         4 208          30     59.4     Regular
5     626 Compact        2.5         4 164          34     65.6        High
6 Prelude  Sporty        2.3         4 160          31     69.6        High
```

We can use the summarize function to obtain information about the engines grouped by, for example, the car Type or the Cylinders variable.

The `summarize` Function

An example of the `summarize` function is provided in the following pipeline:

```
> Engine_Summary<-Cars93_Ex14 %>%
group_by(Type) %>%
summarize(Num=n(),Min_Size=min(EngineSize),Max_Size=max(EngineSize),Ave_HP=mean(HP),
Median_MPG_HWY=median(MPG_Highway),Num_High_Performance=sum(Performance=="High"))
`summarize()` ungrouping output (override with `.groups` argument)
> Engine_Summary
     Type Num Min_Size Max_Size   Ave_HP Median_MPG_HWY Num_High_Performance
1 Compact  16      2.0      3.0 131.0000           30.0                    4
2   Large  11      3.3      5.7 179.4545           26.0                    0
3 Midsize  22      2.0      4.6 173.0909           26.5                    4
4   Small  21      1.0      2.2  91.0000           33.0                    5
5  Sporty  14      1.3      5.7 160.1429           28.5                    3
6     Van   9      2.4      4.3 149.4444           22.0                    0
```

The code above creates five new variables of interest and calculates them for the groups determined by the `group_by` function. The `n()` function gives the number of units in the group. The output of the function is a tibble we convert to a data frame using the `data.frame` function.

Example of the summarize Function

A second example of the summarize function is provided in the following pipeline:

```
> Engine_Summary_2<-Cars93_Ex14 %>%
group_by(Cylinders) %>%
summarise(Num=n(),Min_Size=min(EngineSize),Max_Size=max(EngineSize),Ave_HP=mean(HP),
Median_MPG_HWY=median(MPG_Highway),Num_High_Performance=sum(Performance=="High"))
`summarise()` ungrouping output (override with `.groups` argument)
> Engine_Summary_2
  Cylinders Num Min_Size Max_Size    Ave_HP Median_MPG_HWY Num_High_Performance
1         3   3      1.0      1.3  66.0000           43.0                    0
2         4  49      1.3      3.5 113.4694           31.0                   10
3         5   2      2.4      2.5 138.5000           24.5                    1
4         6  31      2.8      5.7 175.5806           26.0                    4
5         8   7      4.5      5.7 234.7143           25.0                    0
6    rotary   1      1.3      1.3 255.0000           25.0                    1
```

The same five new variables of interest are calculated but this time the engines are grouped by the Cylinders variable. Again, we which we convert the tibble output to a data frame using the data.frame function.

Tibbles

A core component of the tidyverse is the tibble. Tibbles are a modern rework of the standard data.frame, with some internal improvements to make code more reliable. They are similar to data frames, but do not follow all of the same rules. For example, tibbles can have numbers/symbols for column names, which is not allowed in base R.

If you use a function from the `dplyr` package that returns a tibble as output, you can convert it to a data frame using the `data.frame` function. For example

```
> Result
# A tibble: 3 x 4
    cyl     N Mean_HP Mean_mpg
  <dbl> <int>   <dbl>    <dbl>
1     4    11    82.6     26.7
2     6     7   122.      19.7
3     8    14   209.      15.1
> Result<-data.frame(Result)
> Result
  cyl  N   Mean_HP Mean_mpg
1   4 11  82.63636 26.66364
2   6  7 122.28571 19.74286
3   8 14 209.21429 15.10000
```

Practice time: `msleep`

Return average awake time by `vore` sorted by average awake time in descending order.

Create a new column `brain_per` that shows the percentage of body weight that brain takes (use the ratio `brainwt/bodywt`)

What is the average `brain_per`? (Hint: use `na.rm=T`) What does its distribution look like? (Hint: you can combine `dplyr` with `ggplot2` in one line!)

Return the top 5 animals with the highest `brain_per`.

Make a scatterplot showing `brain_per` against `awake`.

Make a scatterplot showing `brain_per` against `awake` with different colors by `vore`.