Plan for the week

- M: Introduction to R
- W: dplyr
  - More advanced R functionality (sort, filter, group by, etc.)
- F: Section
  - Visualization (i.e., plotting) in R

Introduction to R

Programming with data

- Figure out what you want to do
    - Describe those tasks in code, i.e., as a computer program
    - Execute your program and interpret the output
    - Repeat until your program is bug-free
- Repeat, because what you want to do has inevitably changed (for the better)

Statistical tools are central to data science

- One could define data science as a set of methods that can be used to draw robust conclusions from partial information
- But before data science, this goal was already a goal of statistics, which explains why statistics is integral to data science
- R is a tool for statistical computation; it is a facilitator for both data science and statistics to achieve this goal

What is R, more specifically?

- Some nifty things R can do include:
  - Basic maths (arithmetic, probability, statistics)
  - Machine learning (clustering, classification, regression)
  - Numerical optimization and mathematical programming
  - Visualizations: static and dynamic graphics
- In this course, we will use R for almost all of the above (not so much mathematical programming)

Before we start...

- Style matters in programming!
  - But you don’t want to be original!
  - Code is hard to read, even for expert programmers.
  - Abide by this style guide to make it easier for other R programmers (including your later self!) to read what you write.
- Testing is essential!
  - You must test every single line of code you write.
  - We will test our code manually, by running each and every line in turn, and observing the outputs, one after another.
- So is commenting! (Code is written for computers to read, not people!)

Let’s Get Started

Values in R

The most basic R values (or data types) are: numerics, characters, and logicals.

```
>> TRUE         # expression
TRUE            # value

>> 100          # expression
100             # value

>> “fun”        # expression
“fun”           # value
```

Note: In other programming languages, logicals are called booleans.

Values in R

The most basic R values (or data types) are: numerics, characters, and logicals.

```
>> TRUE        # expression     >> true        # expression
TRUE           # value          Error: object true not found

>> 100         # expression
100            # value

>> “fun”       # expression     >> “true”      # expression
“fun”          # value          “true”         # value
```

Note: In other programming languages, logicals are called booleans.

Expressions in R

Expressions: Programs are made of up expressions, which built up from values, and are the sentences the language can "understand," and hence evaluate.

```
>> 3 + 4         # expression
7                # value

>> 3 - 4         # expression
-1               # value

>> 3 * 4         # expression
12               # value

>> 3 / 4         # expression
0.75             # value
```

Logical Expressions in R

Logical expressions involve and evaluate to logicals.

```
>> TRUE && TRUE         # expression
TRUE                    # value

>> TRUE && FALSE        # expression
FALSE                   # value

>> TRUE || TRUE         # expression
TRUE                    # value

>> TRUE || FALSE        # expression
TRUE                    # value

>> !TRUE                # expression
FALSE                   # value
```

String Manipulations in R

- To find the length of a string:

```
>> nchar(“hello”)          # expression
5                          # value
```

- To combine (concatenate) strings:

```
>> paste(“Mary”, “had”, “a”, “little”, “lamb”)
“Mary had a little lamb”

>> paste(“Mary”, “had”, “a”, “little”, “lamb”, sep = “-”)
“Mary-had-a-little-lamb”
```

Variables in R

Variables are names used to store, and then later reference, data

```
>> x <- 5   # assigns value of x
>> y <- 10    # assigns value of y
>> x * y      # expression
50            # value

>> z <- 5   # assigns value of z
>> z <- z + 1 # updates value of z
>> z          # expression
6             # value

>> z <- z - 1 + y   # updates value of z
>> z                # expression
15                  # value
```

Conditionals

- A conditional expression, or just conditional for short, is used in code with a logical dependence
- A conditional in R looks like this:

```
if (logical) {
    expression
}
```

- The expression is evaluated only if the logical is `TRUE`

Examples in R

```
>> if (TRUE) {               # if TRUE
    a <- 100                 # assign a the value 100
}
>> a                         # what is a’s value?
100                          # a is equal to 100

>> if (!TRUE) {              # if not TRUE (i.e., FALSE)
    a <- a - 100             # update a’s value
}
>> a                         # what is a’s value?
100                          # a is still equal to 100
```

Predicates

- A predicate is a special kind of expression that evaluates to a logical, meaning true or false
- Examples:
  - It is raining today
  - The value of x is greater than 0
- They are used, generally, to test a condition to decide whether or not to do one thing or another
  - If it is raining today, then I should carry an umbrella
  - If the value of x is greater than 0, then I can withdraw money from my account

More Examples in R

```
>> if (0 == 1) {        # if TRUE
    a <- a - 100           # assign a the value 100
}
>> a                    # what is a’s value?
100                     # a is still equal to 100

>> if (0 != 1) {        # if not TRUE (i.e., FALSE)
    a <- a - 100        # update a’s value
}
>> a                    # what is a’s value?
0                       # a’s value is now 0
```

More complicated examples in R

```
>> x <- 5               # sets value of x to 5
>> y <- 10              # sets value of y to 10
>> y                    # what is y’s value?
10                      # y is equal to 10

>> if (x == 5) {        # if x is equal to 5,
       y <- y + 20      # update y’s value to be
   }                    # its original value plus 20
>> y                    # what is y’s value?
30                      # y is now equal to 30
```

More complicated conditionals

- It is possible to include an else clause in a conditional

```
if (condition) {
    trueExpression
} else {
    falseExpression
}
```

```
if (It is a weekday) {
    Get up early
} else {
    Sleep late
}
```

More complicated examples in R

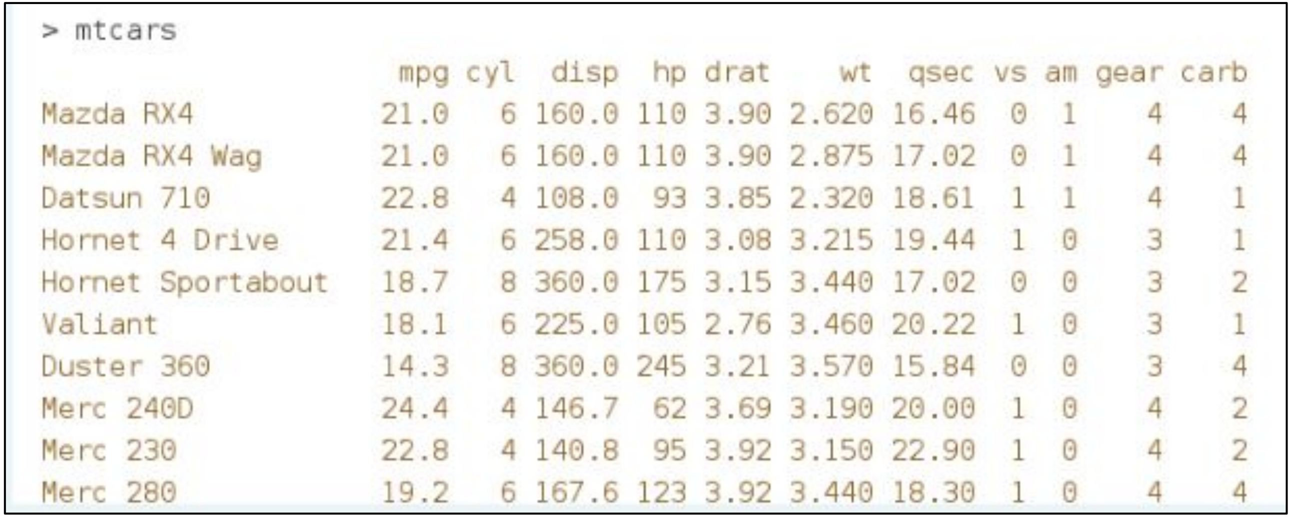
```
>> if (x != 5) {        # if x is NOT equal to 5,
   y <- y + 20          # update y’s value to be
                        # its original value plus 20
} else {
   y <- y - 10          # update y’s value to be
}                       # its original value minus 10

>> y                    # what is y’s value?
20                      # y is now equal to 20
```

Beyond Values: Data Structures

Data Frames

Data frames

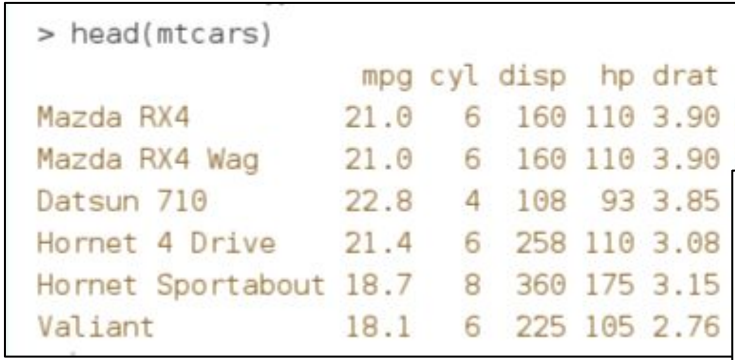
- Used for storing databases
- R has plenty of built-in data frames
    - iris, mtcars (motor trend cars), USArrests, ToothGrowth, etc.



```
> mtcars
                   mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
Duster 360        14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
Merc 230          22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
Merc 280          19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
```

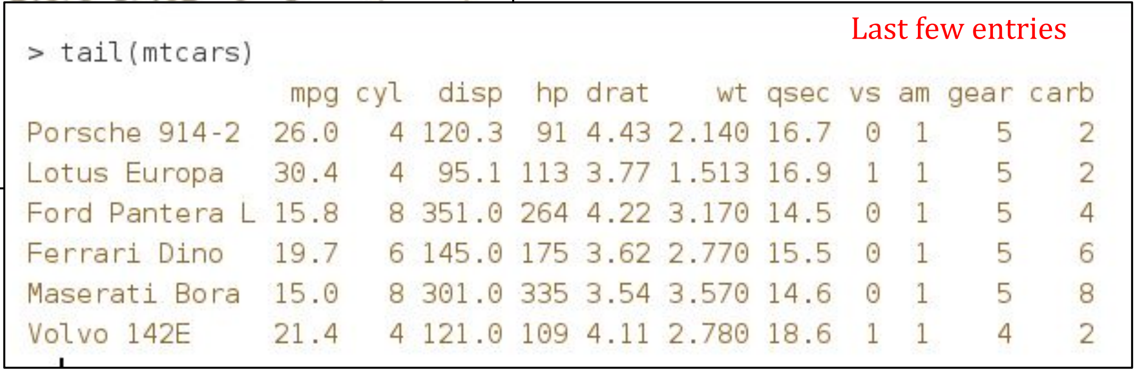
Manipulating data frames in R

- Use head to see the first few entries of a data frame
- Use tail to see the last few



```
> head(mtcars)
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85
Hornet 4 Drive    21.4   6  258 110 3.08
Hornet Sportabout 18.7   8  360 175 3.15
Valiant           18.1   6  225 105 2.76
```

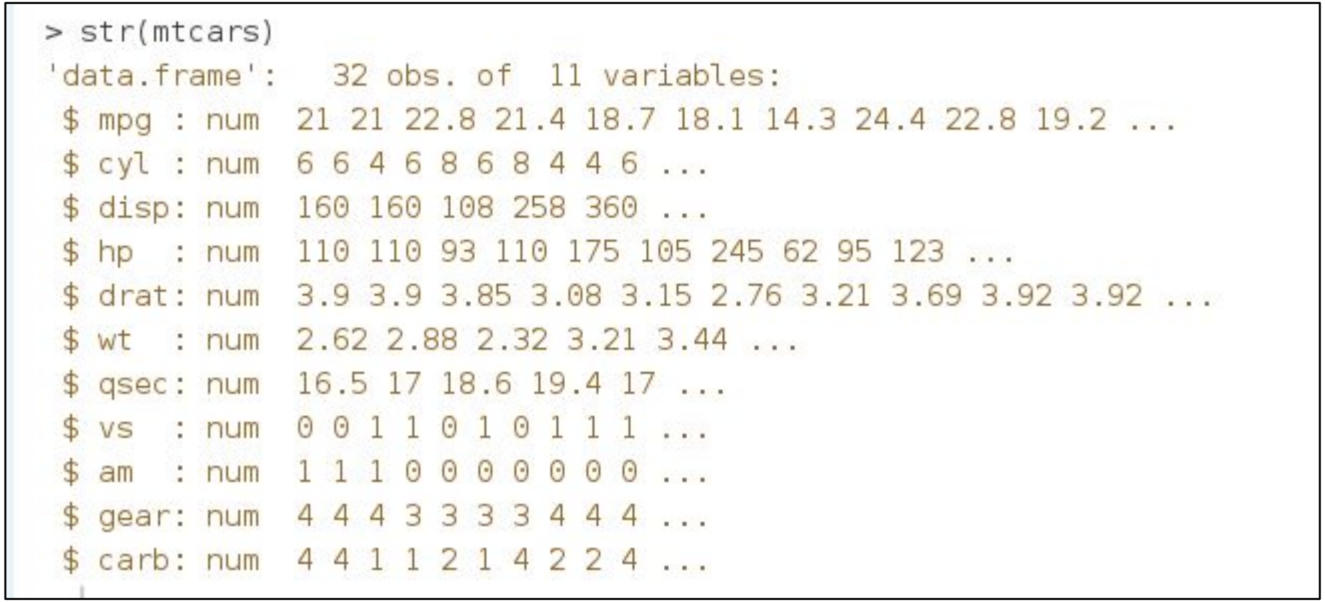
First few entries



Last few entries

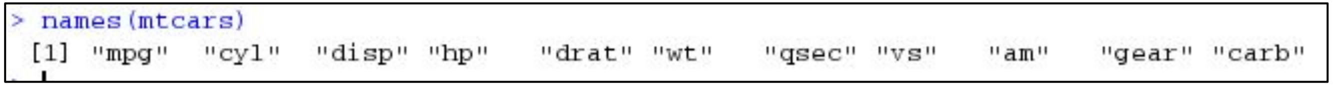
```
> tail(mtcars)
                mpg cyl  disp  hp drat    wt qsec vs am gear carb
Porsche 914-2  26.0   4 120.3  91 4.43 2.140 16.7  0  1    5    2
Lotus Europa   30.4   4  95.1 113 3.77 1.513 16.9  1  1    5    2
Ford Pantera L 15.8   8 351.0 264 4.22 3.170 14.5  0  1    5    4
Ferrari Dino   19.7   6 145.0 175 3.62 2.770 15.5  0  1    5    6
Maserati Bora  15.0   8 301.0 335 3.54 3.570 14.6  0  1    5    8
Volvo 142E     21.4   4 121.0 109 4.11 2.780 18.6  1  1    4    2
```

- Use str to see the overall structure



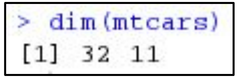
```
> str(mtcars)
'data.frame':   32 obs. of  11 variables:
 $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
 $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
 $ disp: num  160 160 108 258 360 ...
 $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
 $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
 $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
 $ qsec: num  16.5 17 18.6 19.4 17 ...
 $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
 $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
 $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
 $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

- Use names to see the variable names (i.e., column headers)



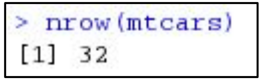
```
> names(mtcars)
 [1] "mpg"  "cyl"  "disp" "hp"   "drat" "wt"   "qsec" "vs"   "am"   "gear" "carb"
```

- Use dim to see the dimensions (number of rows and columns)

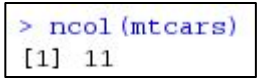


```
> dim(mtcars)
[1] 32 11
```

- Or, if you want the number of rows and columns as individual integers, use nrow and ncol

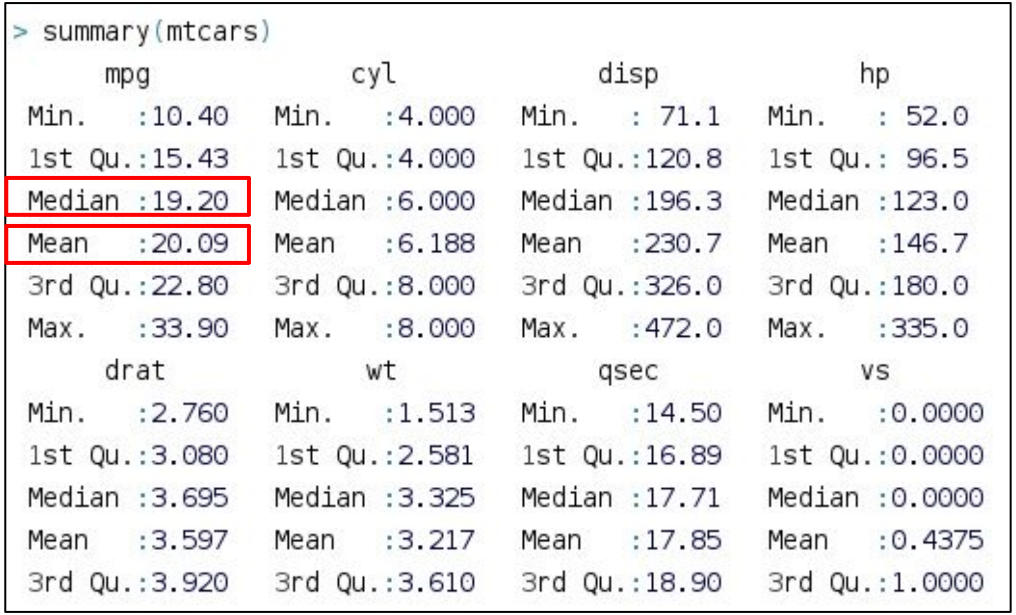


```
> nrow(mtcars)
[1] 32
```



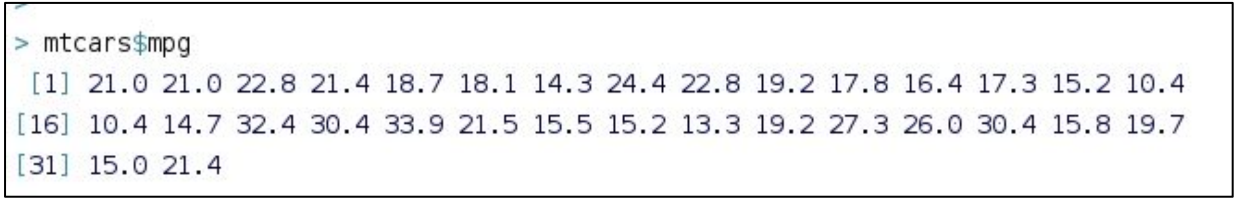
```
> ncol(mtcars)
[1] 11
```

- Use summary to summarize the values of each variable (min, 1st quartile, median, mean, 3rd quartile, max)



```
> summary(mtcars)
      mpg             cyl             disp             hp       
 Min.   :10.40   Min.   :4.000   Min.   : 71.1   Min.   : 52.0  
 1st Qu.:15.43   1st Qu.:4.000   1st Qu.:120.8   1st Qu.: 96.5  
 Median :19.20   Median :6.000   Median :196.3   Median :123.0  
 Mean   :20.09   Mean   :6.188   Mean   :230.7   Mean   :146.7  
 3rd Qu.:22.80   3rd Qu.:8.000   3rd Qu.:326.0   3rd Qu.:180.0  
 Max.   :33.90   Max.   :8.000   Max.   :472.0   Max.   :335.0  
      drat             wt             qsec             vs        
 Min.   :2.760   Min.   :1.513   Min.   :14.50   Min.   :0.0000  
 1st Qu.:3.080   1st Qu.:2.581   1st Qu.:16.89   1st Qu.:0.0000  
 Median :3.695   Median :3.325   Median :17.71   Median :0.0000  
 Mean   :3.597   Mean   :3.217   Mean   :17.85   Mean   :0.4375  
 3rd Qu.:3.920   3rd Qu.:3.610   3rd Qu.:18.90   3rd Qu.:1.0000  
```

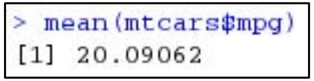
- Use $ to select a single column in a data frame



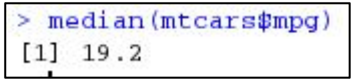
```
> mtcars$mpg
 [1] 21.0 21.0 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 17.8 16.4 17.3 15.2 10.4
[16] 10.4 14.7 32.4 30.4 33.9 21.5 15.5 15.2 13.3 19.2 27.3 26.0 30.4 15.8 19.7
[31] 15.0 21.4
```

Everything in the mpg column

- Apply a summarization function to a single column

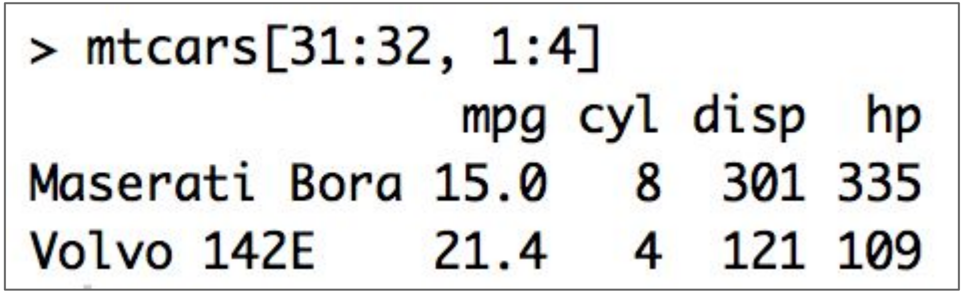


```
> mean(mtcars$mpg)
[1] 20.09062
```



```
> median(mtcars$mpg)
[1] 19.2
```

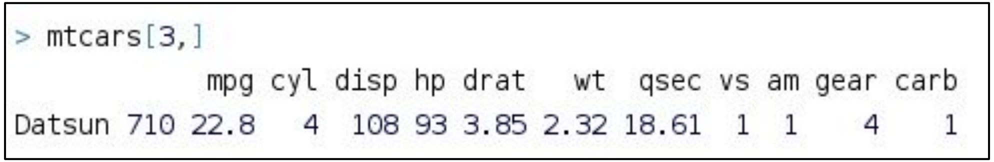
- You can also select a portion of the data frame



```
> mtcars[31:32, 1:4]
               mpg cyl disp  hp
Maserati Bora 15.0   8  301 335
Volvo 142E    21.4   4  121 109
```

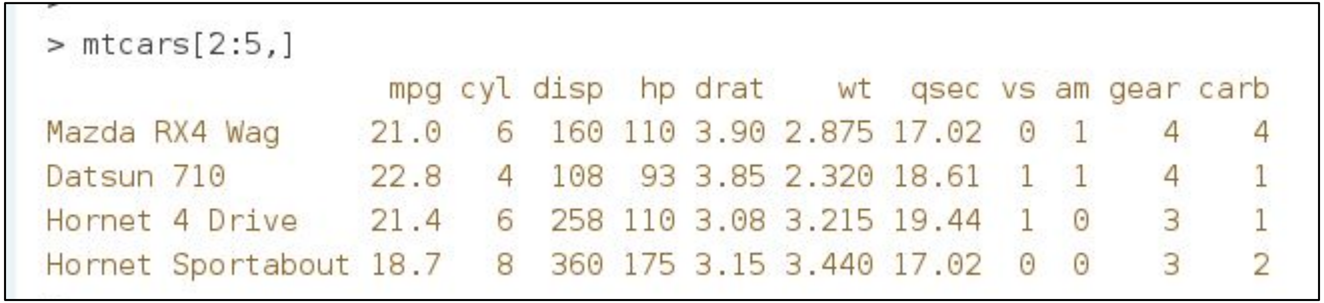
Selection of rows 31 and 32, and columns 1 through 4, only

- You can also select a single row, or a few rows



```
> mtcars[3,]
            mpg cyl disp hp drat   wt  qsec vs am gear carb
Datsun 710 22.8   4  108 93 3.85 2.32 18.61  1  1    4    1
```

Selection of row 3 only

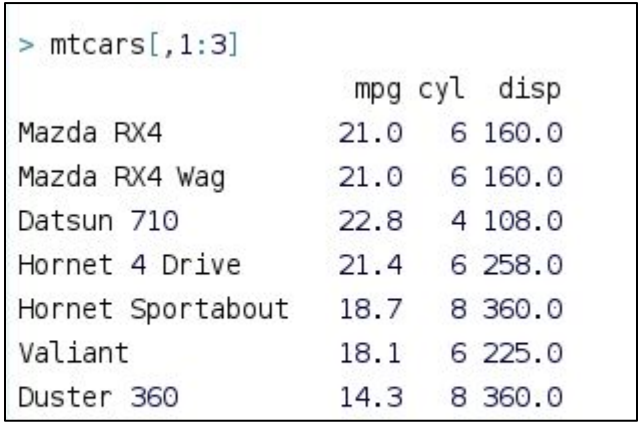


```
> mtcars[2:5,]
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
```

Selection of rows 2 through 5

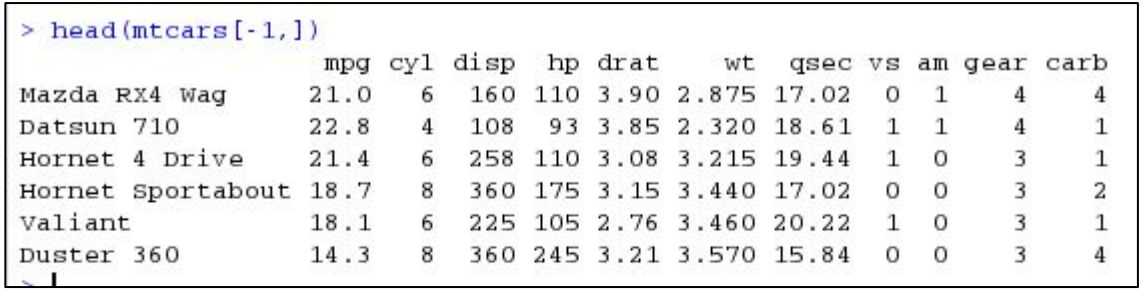
- Here is the analog of selecting rows: selecting columns

Multiple columns



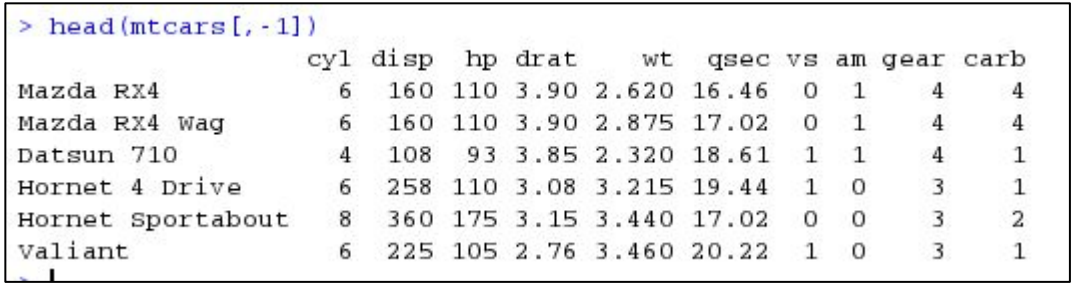
```
> mtcars[,1:3]
                   mpg cyl  disp
Mazda RX4         21.0   6 160.0
Mazda RX4 Wag     21.0   6 160.0
Datsun 710        22.8   4 108.0
Hornet 4 Drive    21.4   6 258.0
Hornet Sportabout 18.7   8 360.0
Valiant           18.1   6 225.0
Duster 360        14.3   8 360.0
```

- You can also select all but a single row or column with –



```
> head(mtcars[-1,])
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
Duster 360        14.3   8  360 245 3.21 3.570 15.84  0  0    3    4
>
```

Selection of all but row 1: `Mazda RX4`



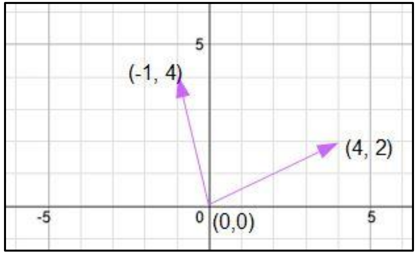
```
> head(mtcars[,-1])
                  cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4           6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag       6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710          4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive      6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant             6  225 105 2.76 3.460 20.22  1  0    3    1
>
```

Selection of all but column 1: `mpg`

Vectors

Vectors

- A vector is a sequence of objects (can be numbers, strings, etc.)
  - Points in the Cartesian plane are two-dimensional vectors



- Vectors can also be 3, 4, 5, etc. dimensions:
  - (1, 2, 3) is a 3-dimensional vector
  - (10, -20, 30, -40) is a 4-dimensional vector
  - (1.1, -2.2, -3.3, -4.4., 5.5) is a 5-dimensional vector

Representing vectors in R

We use the `c` function to create a vector in R:

```
>> x <- c(1, 2, 3, 4)         # creates vector x
1 2 3 4

>> y <- c(-1, -2 ,-3, -4)     # creates vector y
-1 -2 -3 -4

>> z <- c(“hello”, “world”)   # creates vector z
“hello” “world”

>> w <- c(TRUE, TRUE, FALSE)  # creates vector w
TRUE TRUE FALSE
```

Computing with numerical vectors in R

Many common mathematical functions apply to (i.e., across) vectors:

```
>> x <- c(1, 2, 3, 4)   # creates vector x
>> y <- c(-1, -2, -3, -4)  # creates vector y
>> x + y                   # sums two vectors
0 0 0 0

>> y * -1               # multiples vector by -1
1 2 3 4

>> x * y                   # multiplies two vectors
-1 -4 -9 -16
```

Computing with logical vectors in R

Logical functions can also be applied to (i.e., across) vectors:

```
>> x <- c(TRUE, FALSE, FALSE)
>> y <- c(FALSE, FALSE, TRUE)

>> x & y                      # vector logical AND
FALSE FALSE FALSE

>> x | y                      # vector logical OR
TRUE FALSE TRUE
```

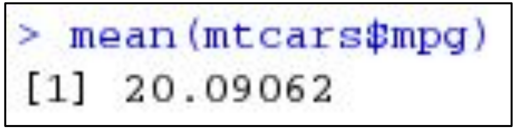
Summarizing numerical vectors in R

Other mathematical functions summarize vectors:
sum, mean, min, max, etc.

```
>> x <- c(1, 2, 3, 4)      # creates vector x
>> sum(x)                  # sums elements of x
10

>> mean(x)                 # calculates mean of x
2.5

>> min(x)                  # calculates min of x
1
```

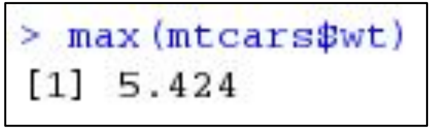
What can we learn about cars?

- The mean `mpg` is roughly 20



```
> mean(mtcars$mpg)
[1] 20.09062
```

- The heaviest car weighs in at 5424 lbs



```
> max(mtcars$wt)
[1] 5.424
```

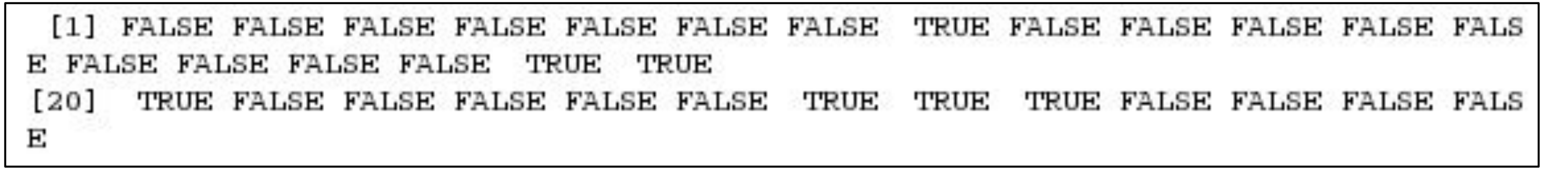
Computing with string vectors in R

We can also apply functions across vectors of strings:

```
>> days <- c(“Mon”, “Tues”, “Wednes”, “Thurs”, “Fri”)
>> week <- paste(days, “day”, sep = “”)
>> week
(“Monday”, ”Tuesday”, ”Wednesday”, ”Thursday”, “Friday”)

>> week <- paste(“day”, days, sep = “”)
>> week
(“dayMon”, ”dayTues”, ”dayWednes”, ”dayThurs”, “dayFri”)
```

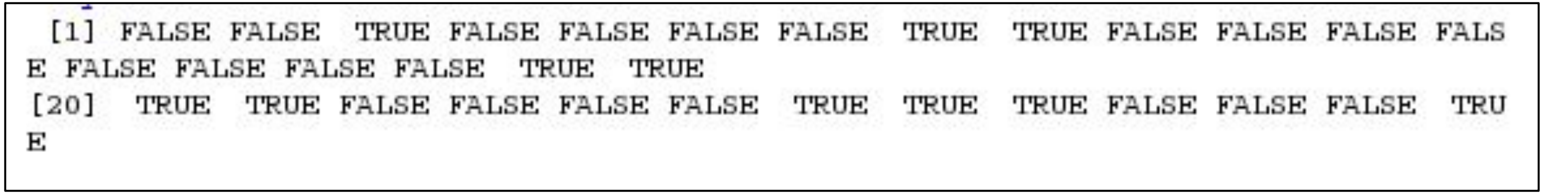
Logical vectors in R

```
>> mtcars$mpg > 23
```



```
 [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE FALSE  TRUE  TRUE
[20]  TRUE FALSE FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALS
E
```

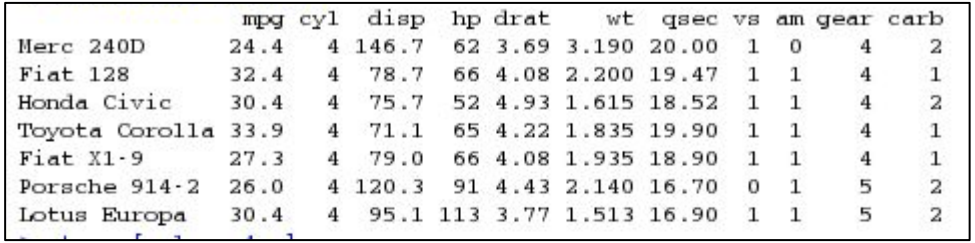
```
>> mtcars$cyl == 4
```



```
 [1] FALSE FALSE  TRUE FALSE FALSE FALSE FALSE  TRUE  TRUE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE FALSE  TRUE  TRUE
[20]  TRUE  TRUE FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE FALSE FALSE FALSE  TRU
E
```

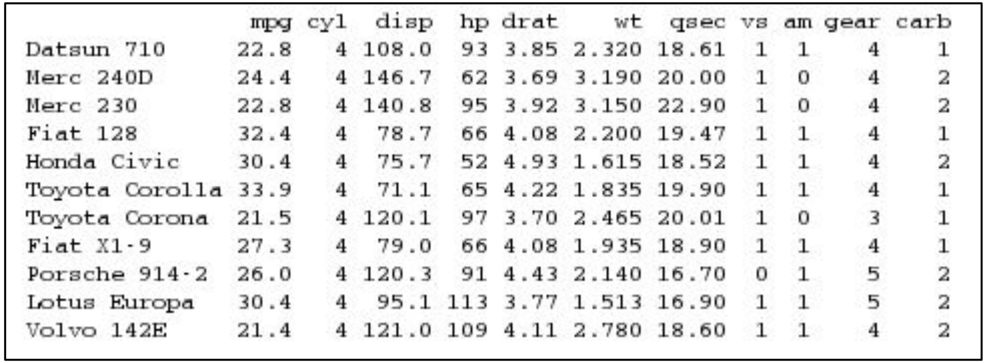
Computing with logical vectors in R: Filter

```
>> mtcars[mtcars$mpg > 23, ]
```



```
                mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Merc 240D      24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
Fiat 128       32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
Honda Civic    30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
Toyota Corolla 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
Fiat X1-9      27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
Porsche 914-2  26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
Lotus Europa   30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
```

```
>> mtcars[mtcars$cyl == 4, ]
```



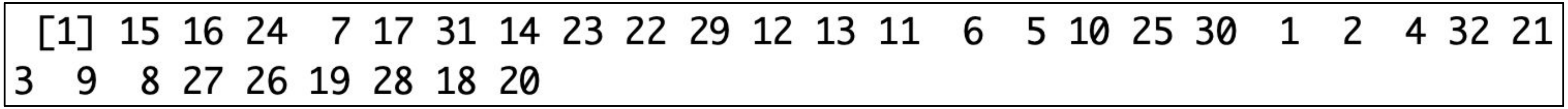
```
                mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Datsun 710     22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
Merc 240D      24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
Merc 230       22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
Fiat 128       32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
Honda Civic    30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
Toyota Corolla 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
Toyota Corona  21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
Fiat X1-9      27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
Porsche 914-2  26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
Lotus Europa   30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
Volvo 142E     21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

Computing with logical vectors in R: Sort

```
>> ex1 <- c(“b”, “a”, “c”)
>> order(ex1)
2 1 3

>> ex1[order(ex1)]
“a” “b” “c”

>> sort(ex1)
“a” “b” “c”
```

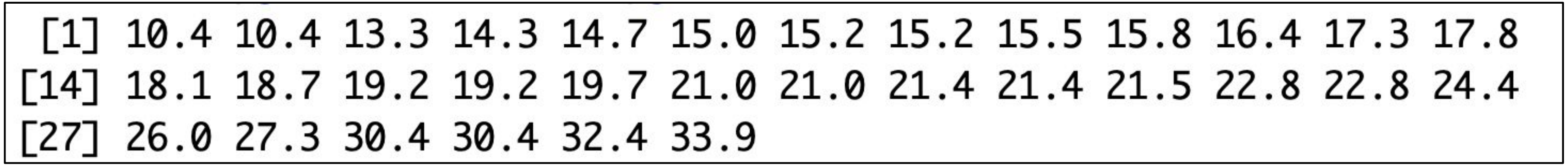
More Ways to Sort

```
>> order(mtcars$mpg)
```



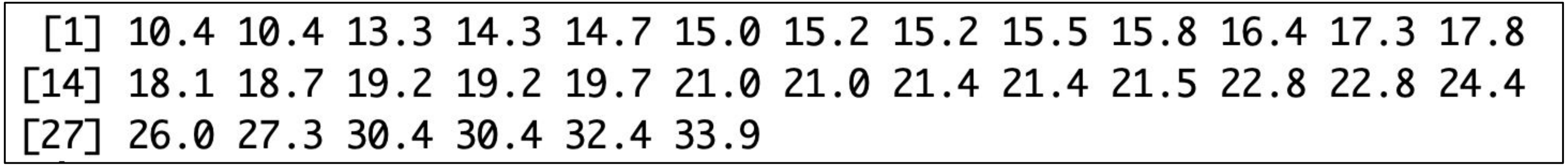
```
 [1] 15 16 24  7 17 31 14 23 22 29 12 13 11  6  5 10 25 30  1  2  4 32 21
3  9  8 27 26 19 28 18 20
```

```
>> mtcars$mpg[(order(mtcars$mpg))]
```



```
 [1] 10.4 10.4 13.3 14.3 14.7 15.0 15.2 15.2 15.5 15.8 16.4 17.3 17.8
[14] 18.1 18.7 19.2 19.2 19.7 21.0 21.0 21.4 21.4 21.5 22.8 22.8 24.4
[27] 26.0 27.3 30.4 30.4 32.4 33.9
```

```
>> sort(mtcars$mpg)
```



```
 [1] 10.4 10.4 13.3 14.3 14.7 15.0 15.2 15.2 15.5 15.8 16.4 17.3 17.8
[14] 18.1 18.7 19.2 19.2 19.7 21.0 21.0 21.4 21.4 21.5 22.8 22.8 24.4
[27] 26.0 27.3 30.4 30.4 32.4 33.9
```

Factors

Categorical data: Nominal

Factors are used to represent categorical data in R

```
>> survey <- c(“M”, “F”, “M”, “O”, “F”)
>> survey
“M”, “F”, “M”, “O”, “F”

>> new_survey <- factor(survey)
M F M O F
Levels: F M O
```

Categorical data: Ordinal

Factors are used to represent categorical data in R

```
>> survey <- c(“small”, “medium”, “large”, “medium”)
>> survey
“small” “medium” “large” “medium”


>> new_survey <- factor(survey, ordered = TRUE,
                 levels = c(“small”, “medium”, “large”))
>> new_survey
small medium large medium
Levels: small < medium < large
```

NA (no answer)

`NA` is a special logical value

```
>> survey <- c(“M”, “F”, “M”, NA, “F”)
>> survey
“M”, “F”, “M”, NA, “F”


>> is.na(survey)
FALSE FALSE FALSE TRUE FALSE

>> survey[!is.na(survey)]
“M”, “F”, “M”, “F”
```

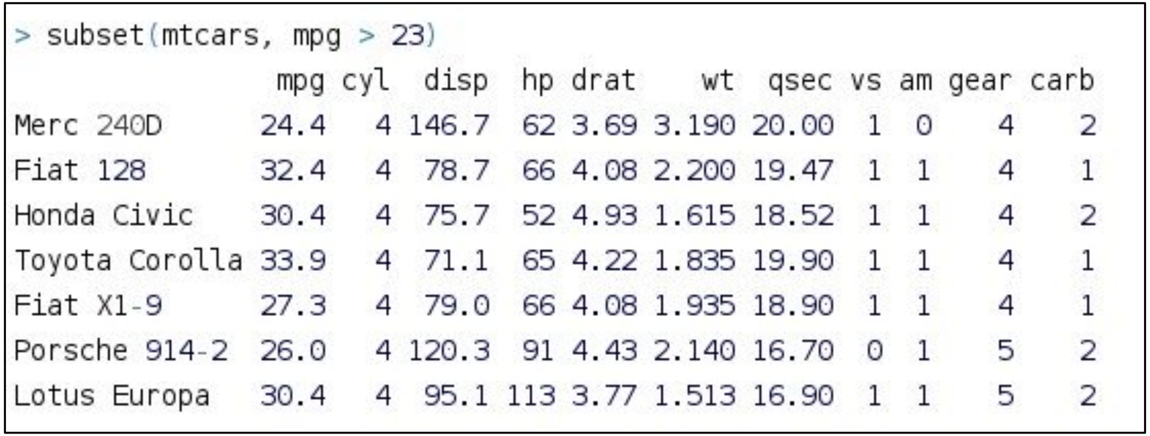
Data Wrangling

Filter, Sort, & Merge

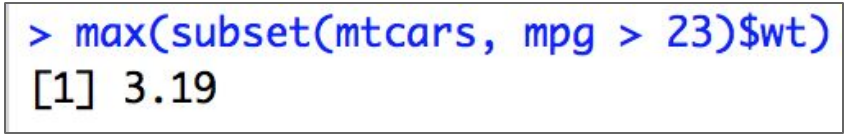
Quick shortcut

```
>> mean(mtcars$mpg)
20.09062

>> attach(mtcars)
>> mean(mpg)
20.09062
```

- Filter: select a subset of rows, depending on some condition

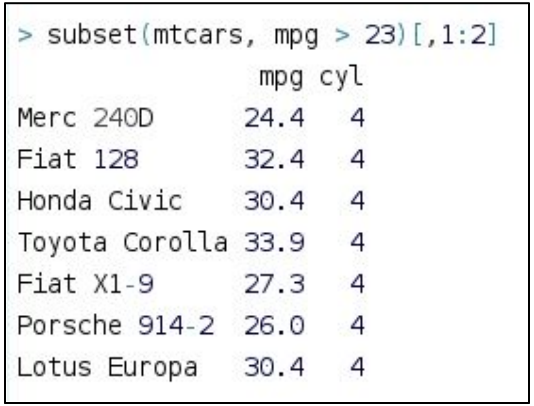


```
> subset(mtcars, mpg > 23)
                mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Merc 240D      24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
Fiat 128       32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
Honda Civic    30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
Toyota Corolla 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
Fiat X1-9      27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
Porsche 914-2  26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
Lotus Europa   30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
```



```
> max(subset(mtcars, mpg > 23)$wt)
[1] 3.19
```

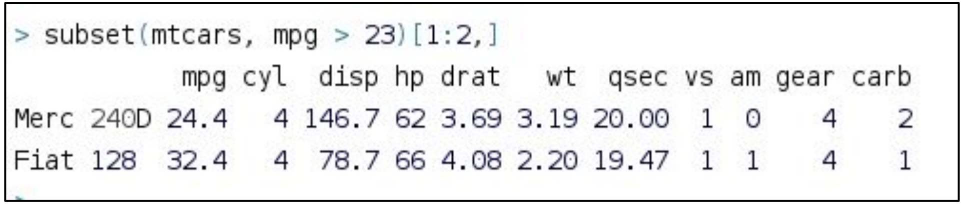
- Subset: selecting rows and columns



```
> subset(mtcars, mpg > 23)[,1:2]
                mpg cyl
Merc 240D      24.4   4
Fiat 128       32.4   4
Honda Civic    30.4   4
Toyota Corolla 33.9   4
Fiat X1-9      27.3   4
Porsche 914-2  26.0   4
Lotus Europa   30.4   4
```

Selection of the first two columns of the subset of rows containing cars with mpg greater than 23

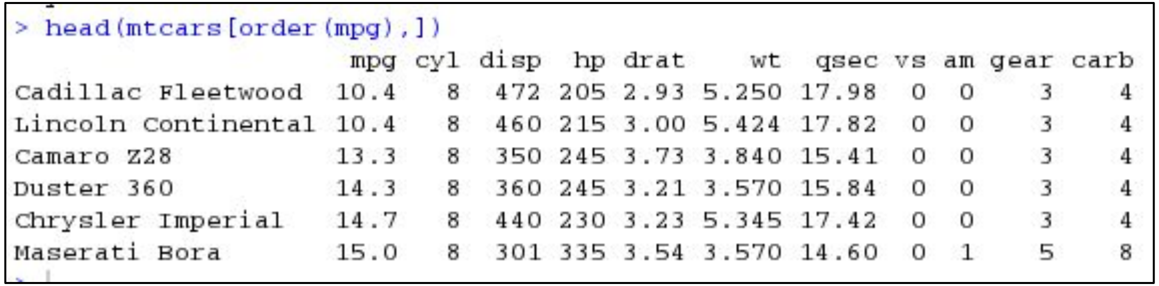
Selection of the first two rows among the subset of rows containing cars with mpg greater than 23



```
> subset(mtcars, mpg > 23)[1:2,]
           mpg cyl  disp hp drat   wt  qsec vs am gear carb
Merc 240D 24.4   4 146.7 62 3.69 3.19 20.00  1  0    4    2
Fiat 128  32.4   4  78.7 66 4.08 2.20 19.47  1  1    4    1
```

- # Sort

```
>> mtcars[order(mpg), ]
```

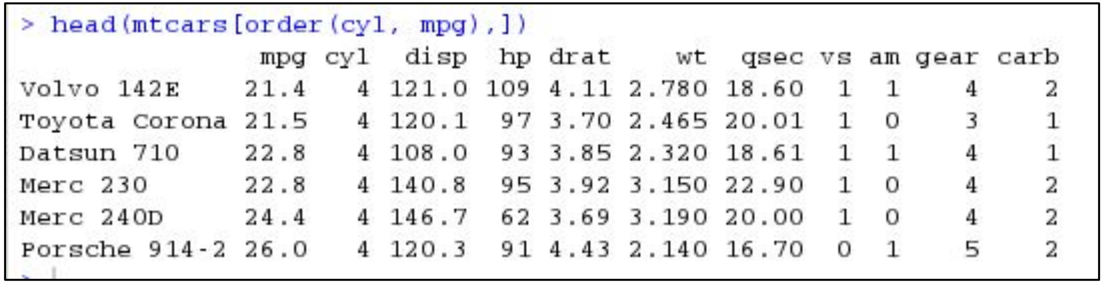


```
> head(mtcars[order(mpg),])
                     mpg cyl disp  hp drat    wt  qsec vs am gear carb
Cadillac Fleetwood  10.4   8  472 205 2.93 5.250 17.98  0  0    3    4
Lincoln Continental 10.4   8  460 215 3.00 5.424 17.82  0  0    3    4
Camaro Z28          13.3   8  350 245 3.73 3.840 15.41  0  0    3    4
Duster 360          14.3   8  360 245 3.21 3.570 15.84  0  0    3    4
Chrysler Imperial   14.7   8  440 230 3.23 5.345 17.42  0  0    3    4
Maserati Bora       15.0   8  301 335 3.54 3.570 14.60  0  1    5    8
```

Sort by mpg, in ascending order

- Sort (cont'd)

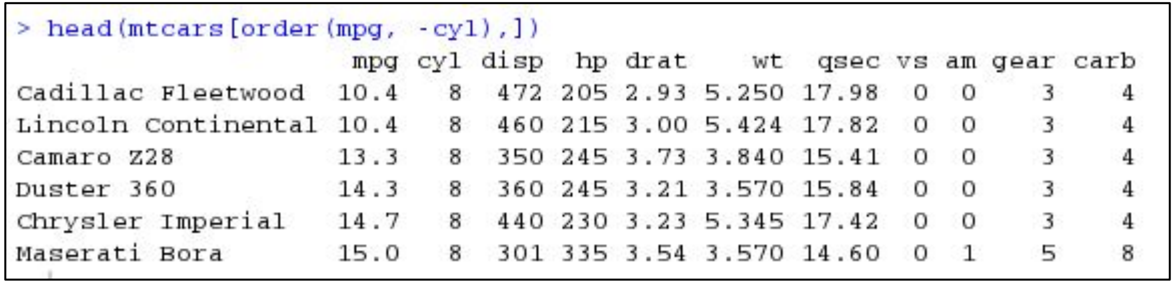
```
>> mtcars[order(cyl, mpg), ]
```



```
> head(mtcars[order(cyl, mpg),])
               mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Volvo 142E    21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
Toyota Corona 21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
Datsun 710    22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
Merc 230      22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
Merc 240D     24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
Porsche 914-2 26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
```

Sort by cyl, and then mpg (both in ascending order)

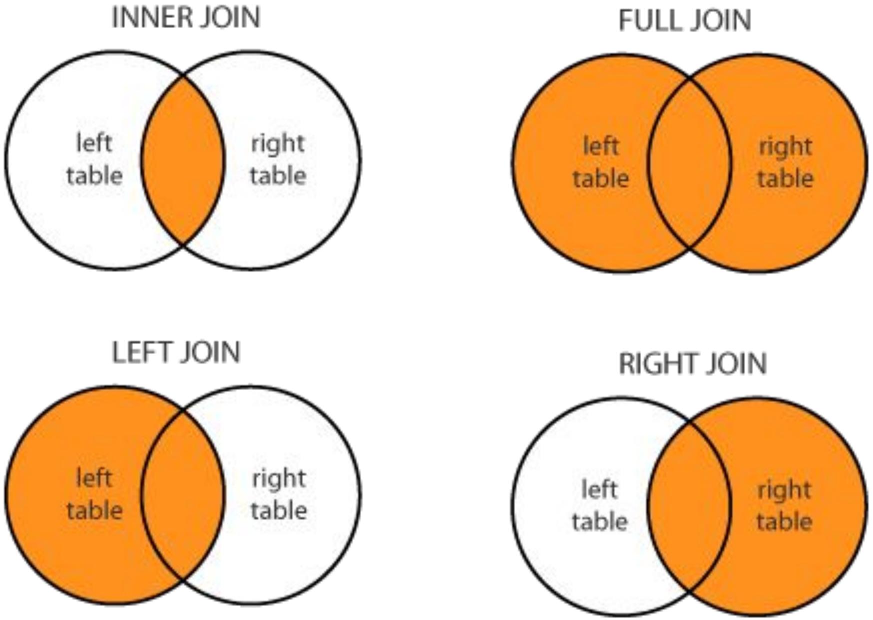
```
>> mtcars[order(mpg, -cyl), ]
```



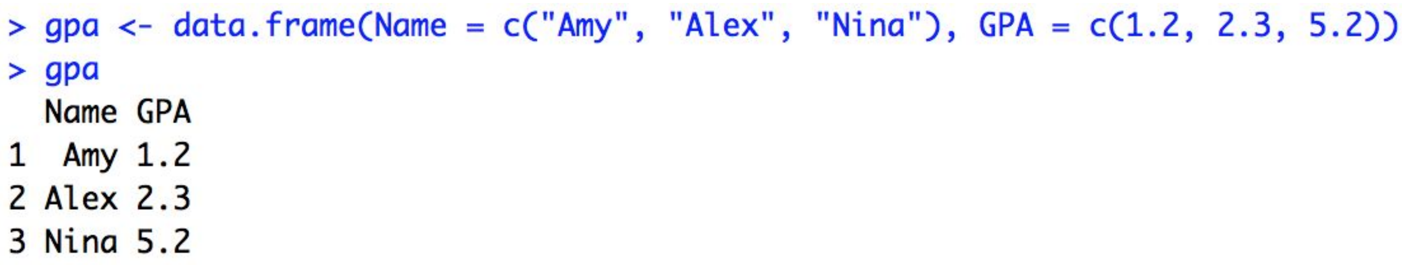
```
> head(mtcars[order(mpg, -cyl),])
                     mpg cyl disp  hp drat    wt  qsec vs am gear carb
Cadillac Fleetwood  10.4   8  472 205 2.93 5.250 17.98  0  0    3    4
Lincoln Continental 10.4   8  460 215 3.00 5.424 17.82  0  0    3    4
Camaro Z28          13.3   8  350 245 3.73 3.840 15.41  0  0    3    4
Duster 360          14.3   8  360 245 3.21 3.570 15.84  0  0    3    4
Chrysler Imperial   14.7   8  440 230 3.23 5.345 17.42  0  0    3    4
Maserati Bora       15.0   8  301 335 3.54 3.570 14.60  0  1    5    8
```

Sort by mpg (ascending), and then cyl (descending)

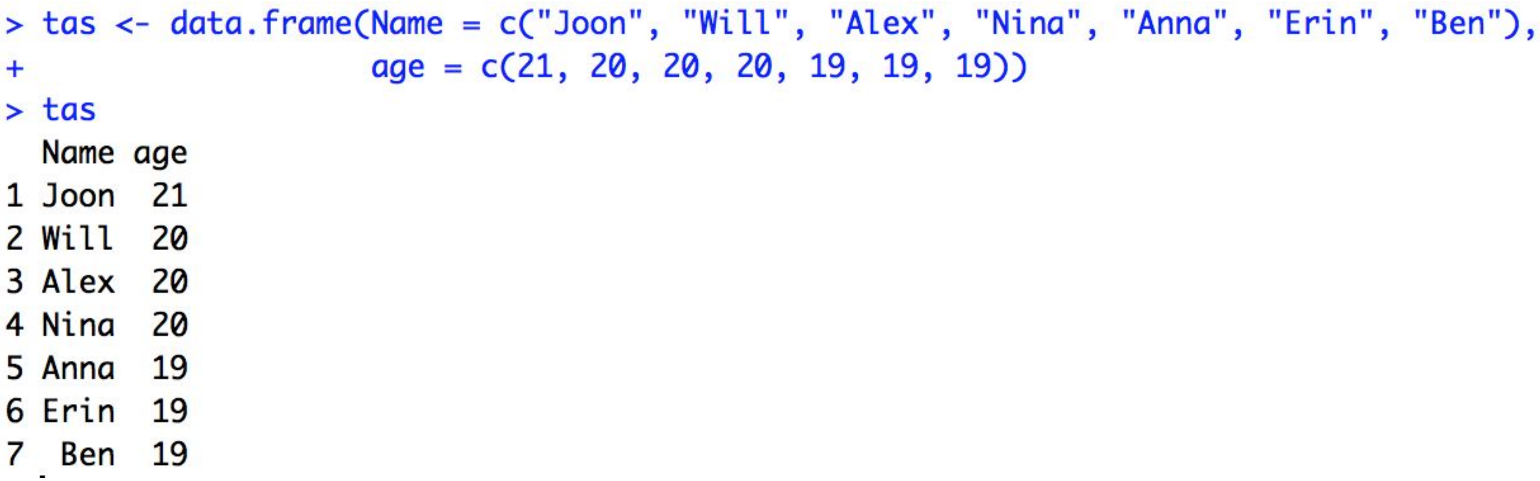
Join


INNER JOIN
left table
right table
FULL JOIN
left table
right table
LEFT JOIN
left table
right table
RIGHT JOIN
left table
right table

- Merge



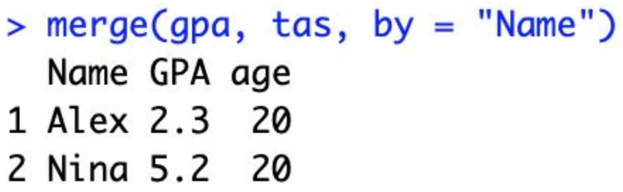
```
> gpa <- data.frame(Name = c("Amy", "Alex", "Nina"), GPA = c(1.2, 2.3, 5.2))
> gpa
  Name GPA
1  Amy 1.2
2 Alex 2.3
3 Nina 5.2
```



```
> tas <- data.frame(Name = c("Joon", "Will", "Alex", "Nina", "Anna", "Erin", "Ben"),
+                   age = c(21, 20, 20, 20, 19, 19, 19))
> tas
  Name age
1 Joon  21
2 Will  20
3 Alex  20
4 Nina  20
5 Anna  19
6 Erin  19
7  Ben  19
```

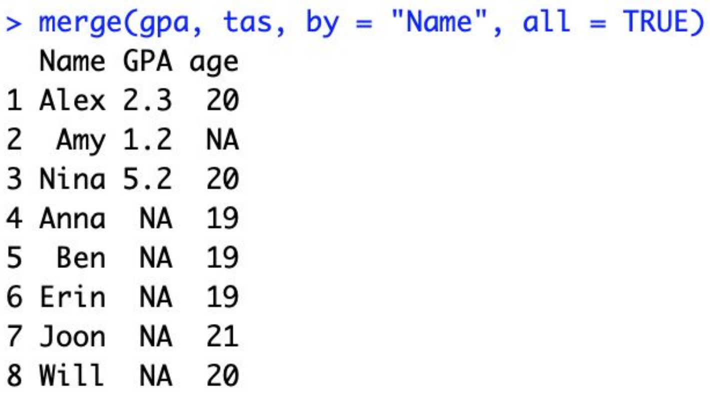
- Merge (cont’d)

Inner join (default)



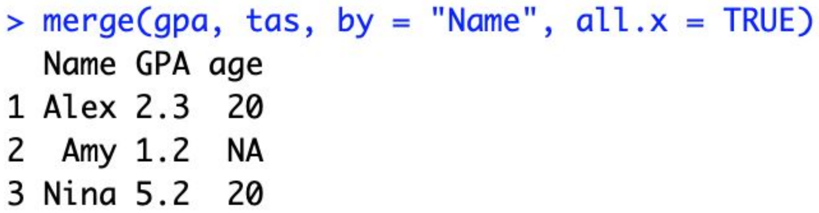
```
> merge(gpa, tas, by = "Name")
  Name GPA age
1 Alex 2.3  20
2 Nina 5.2  20
```

Outer join



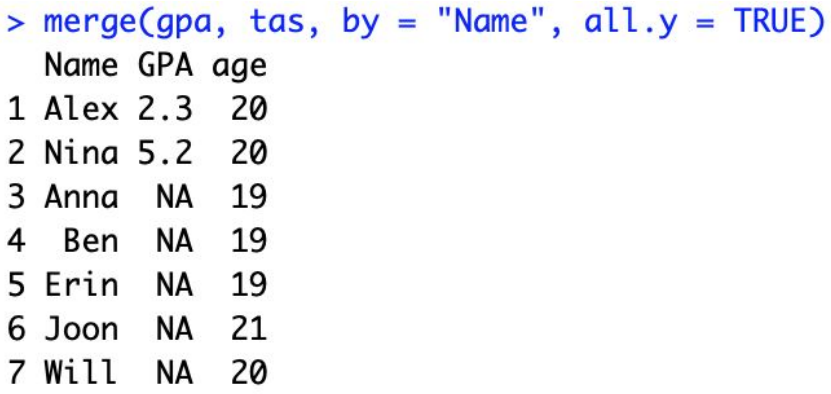
```
> merge(gpa, tas, by = "Name", all = TRUE)
  Name GPA age
1 Alex 2.3  20
2  Amy 1.2  NA
3 Nina 5.2  20
4 Anna  NA  19
5  Ben  NA  19
6 Erin  NA  19
7 Joon  NA  21
8 Will  NA  20
```

Left outer join



```
> merge(gpa, tas, by = "Name", all.x = TRUE)
  Name GPA age
1 Alex 2.3  20
2  Amy 1.2  NA
3 Nina 5.2  20
```

Right outer join



```
> merge(gpa, tas, by = "Name", all.y = TRUE)
  Name GPA age
1 Alex 2.3  20
2 Nina 5.2  20
3 Anna  NA  19
4  Ben  NA  19
5 Erin  NA  19
6 Joon  NA  21
7 Will  NA  20
```

In-class survey

A survey on the blue bear (Blueno)

Let’s imagine a survey where we ask Brown students:

- Their year
- On a scale of 1 to 5 (1 being hate, and 5 love), how much do they like the blue bear?
- Should it stay?

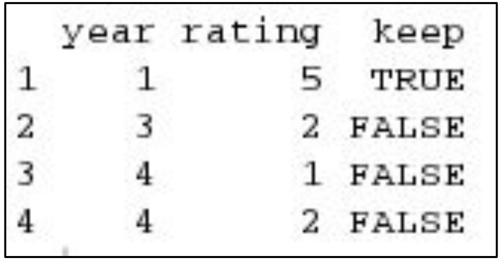
To create your own data frame

Here’s a sample of responses from some imaginary students:

```
year <- c(1, 3, 4, 4)
rating <- c(5, 2, 1, 2)
keep <- c(TRUE, FALSE, FALSE, FALSE)
```

Here’s how to create a data frame from these vectors:

```
df <- data.frame(year, rating, keep)
```



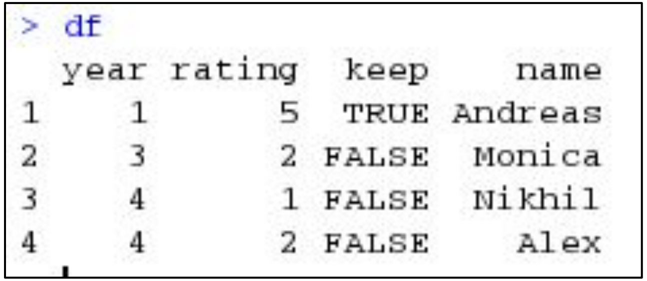
```
  year rating  keep
1    1      5  TRUE
2    3      2 FALSE
3    4      1 FALSE
4    4      2 FALSE
```

Add a column to your data frame

There are a number of ways to do this:

```
df$name <- c(“Andreas”, “Monica”, “Nikhil”, “Alex”)
df[[“name”]] <- c(“Andreas”, “Monica”, “Nikhil”, “Alex”)
df[, “name”] <- c(“Andreas”, “Monica”, “Nikhil”, “Alex”)
```

All produce the same result:



```
> df
  year rating  keep    name
1    1      5  TRUE Andreas
2    3      2 FALSE  Monica
3    4      1 FALSE  Nikhil
4    4      2 FALSE    Alex
```

We can see that Andreas is a first-year who loves the bear, and Monica, Nikhil, and Alex are upperclassmen who dislike it.

iClicker Q

What is your year?

A) First year
B) Sophomore
C) Junior
D) Senior
E) Grad student

iClicker Q

On a scale of 1 to 5 (1 being hate, and 5 love), how much do you like the blue bear?

iClicker Q

Should it stay?

A) Yes

B) No

Summary

- Basic R values: numerics, characters, logicals
- R objects: data frames, vectors
- Data wrangling, so far:
    - Select (variables)
    - Filter (observations)
    - Sort (rearrange data)
    - Summarize (e.g., mean)
    - Transform (e.g., add columns)
- Still to come: Grouping