

# Macquarie R Users Group - An Introduction to R

## (written in R Notebook (Markdown))

### Prerequisite

Please install the latest versions of R and RStudio. See Installing R and R Studio below!

### Installing R and R Studio

Instructions courtesy of Data carpentries, see [here](#) for full instruction and linux install.

#### Windows

**If you already have R and RStudio installed:** 1. Open RStudio 2. Click on “Help” > “Check for updates”. 3. If a new version is available, quit RStudio, and download the latest version for RStudio. 4. To check which version of R you are using, start RStudio and the first thing that appears in the console indicates the version of R you are running. Alternatively, you can type `sessionInfo()`, which will also display which version of R you are running. 5. Go on the CRAN website and check whether a more recent version is available. If so, please download and install it. You can check [here](#) for more information on how to remove old versions from your system if you wish to do so.

**If you don't have R and RStudio installed:** 1. Download R from the CRAN website. 2. Run the `.exe` file that was just downloaded 3. Go to the RStudio download page 4. Under Installers select **RStudio x.yy.zzz - Windows Vista/7/8/10** (where x, y, and z represent version numbers) 5. Double click the file to install it 6. Once it's installed, open RStudio to make sure it works and you don't get any error messages.

#### macOS

**If you already have R and RStudio installed:** 1. Open RStudio 2. Click on “Help” > “Check for updates”. 3. If a new version is available, quit RStudio, and download the latest version for RStudio. 4. To check which version of R you are using, start RStudio and the first thing that appears in the console indicates the version of R you are running. Alternatively, you can type `sessionInfo()`, which will also display which version of R you are running. 5. Go on the CRAN website and check whether a more recent version is available. If so, please download and install it. You can check [here](#) for more information on how to remove old versions from your system if you wish to do so.

**If you don't have R and RStudio installed:** 1. Download R from the CRAN website. 2. Select the `.pkg` file for the latest R version 3. Once downloaded double click on the file to install R. 4. To download Rstudio go to the RStudio download page 5. Under Installers select **RStudio x.yy.zzz - Mac OS X 10.6+ (64-bit)** (where x, y, and z represent version numbers) 6. Double click the file to install RStudio 7. Once it's installed, open RStudio to make sure it works and you don't get any error messages.

### Section 1

- Sit together in pairs. Envision yourself as navigator and programmer. Swap tasks once in a while.

## Goals

1. Getting comfortable with R Studio Interface and finding out what it is all about.
2. Using basic commands.
3. Loading and saving data.
4. Basic statistics.
5. Plotting.
6. Not being scared of coding!

## What is R?

“R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS.” (CRAN)

“In its broadest definition, R is a computer language that allows the user to program algorithms and use tools that have been programmed by others.” (Zuur et al 2009 - A Beginner’s Guide to R:14)

## But what can it actually do?

- R as a calculator
- Manipulate data
- Conduct any statistical test
- Import software ‘packages’ with specialised functions (more on this later)
- Automate analyses
- Design simple or complicated graphs

## Why you should use it?

- It is free and open-source
- R has been receiving contributions from many programmers around the globe
- Listed as 3rd most used languages in Data Science
- Massive community for online support
- Very specific problems are mostly addressed with a package
- It is widely used with many books published in the last years

## Awesome! Why is not everyone using it?

- A bit of a learning curve
- Coding necessary (eh!)

**\*\* BUT \*\***

- The most basic syntax (grammar) can be used for most of the things in R
- R studio makes it easier to code in R, providing a user friendly interface
- Once you get used to programming you can adopt new languages easier

**There are a lot of online courses, videos and texts available for understanding R, its packages etc.**

## Let’s have a look at R Studio

What’s what:

- Console: your code is run here and you will see the results of your coding.
- R-Script: your code is written and saved here, just like in a normal text-document.
- Environment: all the loaded data and objects are listed here, you can even take a look at your data tables or the structure of your data.
- History: shows the history of your executed code.
- Files: what is in your source folder, i.e. is my data table in the folder?
- Plots: this is where your plots will be shown, you can also export them from here (but there are better ways).
- Packages: load and search for new packages and your installed packages are listed here.
- Help: look for help or specific vignettes (support documents) for each package. Also access via `?function`
- Viewer: can be used to view local web content for web graphics generated using packages like googleVis, htmlwidgets, and rCharts, or even a local web application created using Shiny, Rook, or OpenCPU.

R-studio gives you a more intuitive interface and takes the scariness out of coding. It also provides functions that simplify the process of developing your code. ‘Tab completion’ is one of such function.

### Some basic R syntax: objects and functions and arguments

```
# output<-function1(argument1, argument2, ...) + function2(argument)

# flat_white <- froth(milk, hot) + extract(coffee)
# flat_white = froth(milk, hot) + extract(coffee)

# verb(argument)
# argument can be a "noun" (being acted upon) or an "adverb" (modifying its behavior)

# Example1: boiling milk normally
# boiled_milk <- boil (milk)

# Example2: boiling milk for a long time
# boiled_milk <- boil (milk, long_time)
```

`froth()` and `extract()` are *functions*, `milk`, `hot` and `coffee` are *arguments*

functions are sets of instructions used to do something to arguments. They can be stored in an *object* (`flat_white`). Objects can be used as arguments.

*arguments* are used to tell functions what *objects* to act on, and any details of how to perform the action

Functions need arguments to fulfill the purpose they were designed for. e.g. `froth()` needs to know what kind of milk to froth and how hot to make it.

*packages* are precoded sets of instructions (functions) that were written by someone and are available for everyone to use

**Now it's time to play around in R. We will create some dummy data and create a basic scatterplot.**

1. We can assign (`<-`) a basic calculation to the object ‘a’ and call the content of ‘a’. Execute your code using Ctrl+Enter

```
a <- 1+2 # here R works like a calculator
a       # print a to see what it contains
```

```
## [1] 3
```

2. We use function `c()` to combine specific values into a vector. Assign this new vector to object 'x'.

```
x <- c(1,2,3,4) # 'c' is a function that combines values into the vector x (object), the numbers are ar
```

A vector is a sequence of data *components* of the same basic type (i.e. numbers or letters)

3. Using function `mean()`, we can extract the mean of our vector.

```
mean(x) # mean() is a function
```

```
## [1] 2.5
```

4. Create two vectors (they are going to be numeric in our case) using `seq()` and assign them the object `seq_a` and `seq_b`. object `seq_a` contains a vector with the components 1 to 10 and is increasing by 1. `seq_b` contains the components 1 to 25 and increases by 2. If you are not sure how to use a function, such as `seq()`, just call `?seq` and have a look what arguments can be used.

```
seq_a <- seq(from=1,to=10,by=1)
seq_b <- seq(from=1,to=25,by=2)
```

5. Using `cbind()` you can bind two vectors to create a *matrix* (a kind of table). Use `cbind()` to bind `seq_a` and `seq_b`. Assign it to the object 'c'. For help, call `?cbind`

```
# uncomment this next line and pay attention to what happens when this line is run
```

```
# c <- cbind(seq_a,seq_b)
```

6. Oops! Let's see what went wrong. Can you decipher the error message? Have a look at `seq_a` and `seq_b`. Just type `seq_a` and `seq_b` and execute both. No worries, debugging (resolving errors) is a major part of programming.

```
seq_a
```

```
## [1] 1 2 3 4 5 6 7 8 9 10
```

```
seq_b
```

```
## [1] 1 3 5 7 9 11 13 15 17 19 21 23 25
```

7. To make the problem more obvious, let's check the length of each object. Use `length()`.

```
length(seq_a)
```

```
## [1] 10
```

```
length(seq_b)
```

```
## [1] 13
```

8. To `cbind()` two vectors they have to have the same length. Let's overwrite `seq_a` and create a vector of the same length as `seq_b`. Check if the length is matching the other vector and bind them using `cbind()`. Assign this object to a new object, 'c'. What class has 'c'? Check it!

```
seq_a<- seq(1,13,by=1)
```

```
length(seq_a)
```

```
## [1] 13
```

```
c <- cbind(seq_a,seq_b)
```

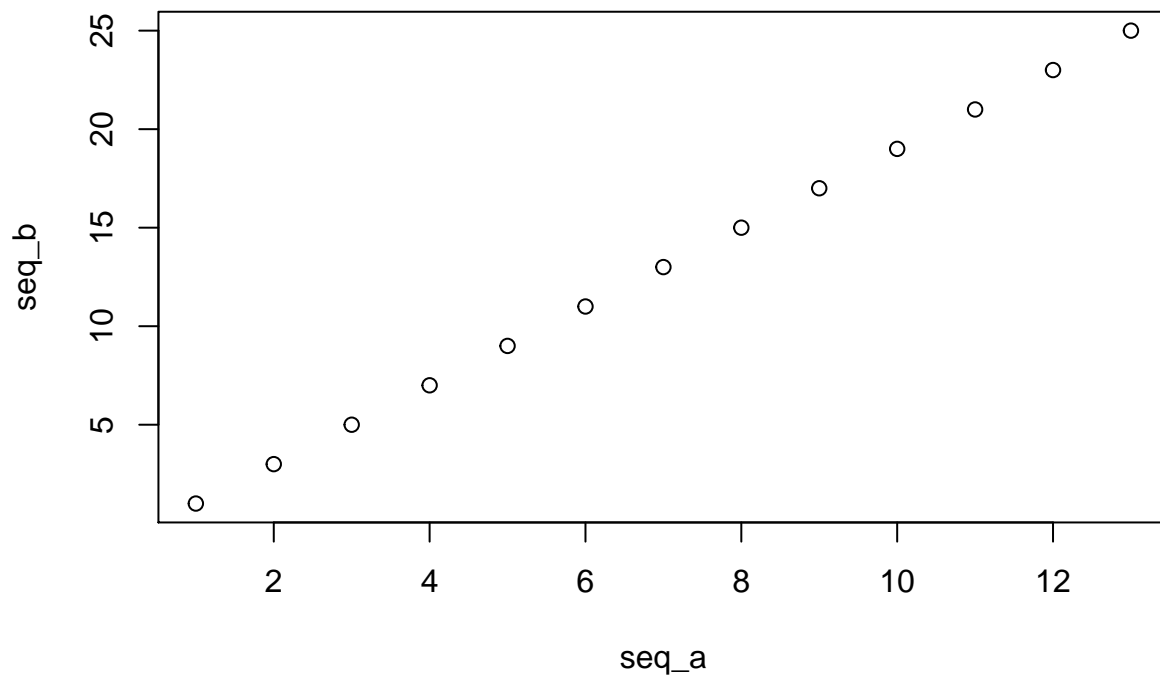
```
class(c) #class() can figure out if you are working with vectors, matrices, dataframes, lists etc....it
```

```
## [1] "matrix"
```

**\*\*Note:** The counterpart to cbind() is rbind() if you would like to connect rows instead of columns.

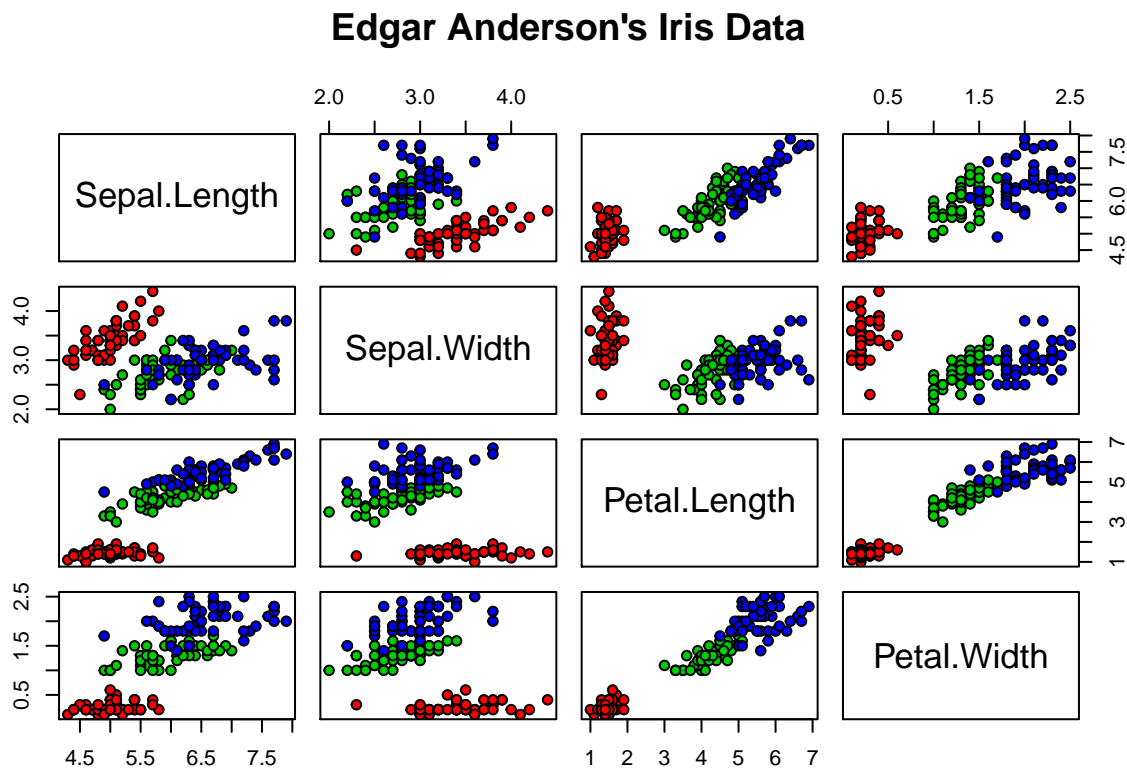
9. Plot 'c' by using plot()

```
plot(c)
```



**Note:** If we wanted to, we could modify the appearance of this plot completely. Labelling axis, change tickmarks and intervals, add text or shapes...more than you can think of now. With just a few lines of code we can create beautiful plots. Once a plot is coded we can use it over and over again and also easily modify it. See here:

```
pairs(iris[1:4], main = "Edgar Anderson's Iris Data", pch = 21, bg = c("red", "green3", "blue"))[unclass(i
```



### What we have learned:

- Get an idea of what R can possibly do
- Discover R Studio
- Become familiar with some basic expressions
- Encounter error messages
- Create some first data
- Have an idea that there are different classes that R can use (different packages want different classes)
- See what a basic plot looks like and how it could look like (Know that there are different ways/ packages of plotting something)

## Section 2

### Getting Data into R

#### How do we get started?

- Save your current script: File > Save
- Create a new project folder for our R users introduction course: File/R project > New project > New directory > New project > Browse and name it: 'My first R project'.
- Create 3 subfolders within the project and name them 'input', 'output' and 'scripts'
- Move both files datasets found within input folder from the original workshop folder to our new input folder we just created.

- Move our script RUsersGroup\_BeginnerSession\_2020.R to the newly created script folder and reopen it
- We can also create new scripts: File > New File > R script

1. Let's import our data and see what it looks like

```
# if the dataset is build in R, it is unnecessary to export it as csv and import it, you just need the
# it is the case with iris and PlantGrowth datasets, so they can be loaded using:
data(iris)
data(PlantGrowth)
```

- or

```
irisdata <- read.csv("input/irisdata.csv")
irisdata
```

##	X	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
## 1	1	5.1	3.5	1.4	0.2	setosa
## 2	2	4.9	3.0	1.4	0.2	setosa
## 3	3	4.7	3.2	1.3	0.2	setosa
## 4	4	4.6	3.1	1.5	0.2	setosa
## 5	5	5.0	3.6	1.4	0.2	setosa
## 6	6	5.4	3.9	1.7	0.4	setosa
## 7	7	4.6	3.4	1.4	0.3	setosa
## 8	8	5.0	3.4	1.5	0.2	setosa
## 9	9	4.4	2.9	1.4	0.2	setosa
## 10	10	4.9	3.1	1.5	0.1	setosa
## 11	11	5.4	3.7	1.5	0.2	setosa
## 12	12	4.8	3.4	1.6	0.2	setosa
## 13	13	4.8	3.0	1.4	0.1	setosa
## 14	14	4.3	3.0	1.1	0.1	setosa
## 15	15	5.8	4.0	1.2	0.2	setosa
## 16	16	5.7	4.4	1.5	0.4	setosa
## 17	17	5.4	3.9	1.3	0.4	setosa
## 18	18	5.1	3.5	1.4	0.3	setosa
## 19	19	5.7	3.8	1.7	0.3	setosa
## 20	20	5.1	3.8	1.5	0.3	setosa
## 21	21	5.4	3.4	1.7	0.2	setosa
## 22	22	5.1	3.7	1.5	0.4	setosa
## 23	23	4.6	3.6	1.0	0.2	setosa
## 24	24	5.1	3.3	1.7	0.5	setosa
## 25	25	4.8	3.4	1.9	0.2	setosa
## 26	26	5.0	3.0	1.6	0.2	setosa
## 27	27	5.0	3.4	1.6	0.4	setosa
## 28	28	5.2	3.5	1.5	0.2	setosa
## 29	29	5.2	3.4	1.4	0.2	setosa
## 30	30	4.7	3.2	1.6	0.2	setosa
## 31	31	4.8	3.1	1.6	0.2	setosa
## 32	32	5.4	3.4	1.5	0.4	setosa
## 33	33	5.2	4.1	1.5	0.1	setosa
## 34	34	5.5	4.2	1.4	0.2	setosa
## 35	35	4.9	3.1	1.5	0.2	setosa
## 36	36	5.0	3.2	1.2	0.2	setosa

## 37	37	5.5	3.5	1.3	0.2	setosa
## 38	38	4.9	3.6	1.4	0.1	setosa
## 39	39	4.4	3.0	1.3	0.2	setosa
## 40	40	5.1	3.4	1.5	0.2	setosa
## 41	41	5.0	3.5	1.3	0.3	setosa
## 42	42	4.5	2.3	1.3	0.3	setosa
## 43	43	4.4	3.2	1.3	0.2	setosa
## 44	44	5.0	3.5	1.6	0.6	setosa
## 45	45	5.1	3.8	1.9	0.4	setosa
## 46	46	4.8	3.0	1.4	0.3	setosa
## 47	47	5.1	3.8	1.6	0.2	setosa
## 48	48	4.6	3.2	1.4	0.2	setosa
## 49	49	5.3	3.7	1.5	0.2	setosa
## 50	50	5.0	3.3	1.4	0.2	setosa
## 51	51	7.0	3.2	4.7	1.4	versicolor
## 52	52	6.4	3.2	4.5	1.5	versicolor
## 53	53	6.9	3.1	4.9	1.5	versicolor
## 54	54	5.5	2.3	4.0	1.3	versicolor
## 55	55	6.5	2.8	4.6	1.5	versicolor
## 56	56	5.7	2.8	4.5	1.3	versicolor
## 57	57	6.3	3.3	4.7	1.6	versicolor
## 58	58	4.9	2.4	3.3	1.0	versicolor
## 59	59	6.6	2.9	4.6	1.3	versicolor
## 60	60	5.2	2.7	3.9	1.4	versicolor
## 61	61	5.0	2.0	3.5	1.0	versicolor
## 62	62	5.9	3.0	4.2	1.5	versicolor
## 63	63	6.0	2.2	4.0	1.0	versicolor
## 64	64	6.1	2.9	4.7	1.4	versicolor
## 65	65	5.6	2.9	3.6	1.3	versicolor
## 66	66	6.7	3.1	4.4	1.4	versicolor
## 67	67	5.6	3.0	4.5	1.5	versicolor
## 68	68	5.8	2.7	4.1	1.0	versicolor
## 69	69	6.2	2.2	4.5	1.5	versicolor
## 70	70	5.6	2.5	3.9	1.1	versicolor
## 71	71	5.9	3.2	4.8	1.8	versicolor
## 72	72	6.1	2.8	4.0	1.3	versicolor
## 73	73	6.3	2.5	4.9	1.5	versicolor
## 74	74	6.1	2.8	4.7	1.2	versicolor
## 75	75	6.4	2.9	4.3	1.3	versicolor
## 76	76	6.6	3.0	4.4	1.4	versicolor
## 77	77	6.8	2.8	4.8	1.4	versicolor
## 78	78	6.7	3.0	5.0	1.7	versicolor
## 79	79	6.0	2.9	4.5	1.5	versicolor
## 80	80	5.7	2.6	3.5	1.0	versicolor
## 81	81	5.5	2.4	3.8	1.1	versicolor
## 82	82	5.5	2.4	3.7	1.0	versicolor
## 83	83	5.8	2.7	3.9	1.2	versicolor
## 84	84	6.0	2.7	5.1	1.6	versicolor
## 85	85	5.4	3.0	4.5	1.5	versicolor
## 86	86	6.0	3.4	4.5	1.6	versicolor
## 87	87	6.7	3.1	4.7	1.5	versicolor
## 88	88	6.3	2.3	4.4	1.3	versicolor
## 89	89	5.6	3.0	4.1	1.3	versicolor
## 90	90	5.5	2.5	4.0	1.3	versicolor



## 91	91	5.5	2.6	4.4	1.2	versicolor
## 92	92	6.1	3.0	4.6	1.4	versicolor
## 93	93	5.8	2.6	4.0	1.2	versicolor
## 94	94	5.0	2.3	3.3	1.0	versicolor
## 95	95	5.6	2.7	4.2	1.3	versicolor
## 96	96	5.7	3.0	4.2	1.2	versicolor
## 97	97	5.7	2.9	4.2	1.3	versicolor
## 98	98	6.2	2.9	4.3	1.3	versicolor
## 99	99	5.1	2.5	3.0	1.1	versicolor
## 100	100	5.7	2.8	4.1	1.3	versicolor
## 101	101	6.3	3.3	6.0	2.5	virginica
## 102	102	5.8	2.7	5.1	1.9	virginica
## 103	103	7.1	3.0	5.9	2.1	virginica
## 104	104	6.3	2.9	5.6	1.8	virginica
## 105	105	6.5	3.0	5.8	2.2	virginica
## 106	106	7.6	3.0	6.6	2.1	virginica
## 107	107	4.9	2.5	4.5	1.7	virginica
## 108	108	7.3	2.9	6.3	1.8	virginica
## 109	109	6.7	2.5	5.8	1.8	virginica
## 110	110	7.2	3.6	6.1	2.5	virginica
## 111	111	6.5	3.2	5.1	2.0	virginica
## 112	112	6.4	2.7	5.3	1.9	virginica
## 113	113	6.8	3.0	5.5	2.1	virginica
## 114	114	5.7	2.5	5.0	2.0	virginica
## 115	115	5.8	2.8	5.1	2.4	virginica
## 116	116	6.4	3.2	5.3	2.3	virginica
## 117	117	6.5	3.0	5.5	1.8	virginica
## 118	118	7.7	3.8	6.7	2.2	virginica
## 119	119	7.7	2.6	6.9	2.3	virginica
## 120	120	6.0	2.2	5.0	1.5	virginica
## 121	121	6.9	3.2	5.7	2.3	virginica
## 122	122	5.6	2.8	4.9	2.0	virginica
## 123	123	7.7	2.8	6.7	2.0	virginica
## 124	124	6.3	2.7	4.9	1.8	virginica
## 125	125	6.7	3.3	5.7	2.1	virginica
## 126	126	7.2	3.2	6.0	1.8	virginica
## 127	127	6.2	2.8	4.8	1.8	virginica
## 128	128	6.1	3.0	4.9	1.8	virginica
## 129	129	6.4	2.8	5.6	2.1	virginica
## 130	130	7.2	3.0	5.8	1.6	virginica
## 131	131	7.4	2.8	6.1	1.9	virginica
## 132	132	7.9	3.8	6.4	2.0	virginica
## 133	133	6.4	2.8	5.6	2.2	virginica
## 134	134	6.3	2.8	5.1	1.5	virginica
## 135	135	6.1	2.6	5.6	1.4	virginica
## 136	136	7.7	3.0	6.1	2.3	virginica
## 137	137	6.3	3.4	5.6	2.4	virginica
## 138	138	6.4	3.1	5.5	1.8	virginica
## 139	139	6.0	3.0	4.8	1.8	virginica
## 140	140	6.9	3.1	5.4	2.1	virginica
## 141	141	6.7	3.1	5.6	2.4	virginica
## 142	142	6.9	3.1	5.1	2.3	virginica
## 143	143	5.8	2.7	5.1	1.9	virginica
## 144	144	6.8	3.2	5.9	2.3	virginica

```
## 145 145      6.7      3.3      5.7      2.5 virginica
## 146 146      6.7      3.0      5.2      2.3 virginica
## 147 147      6.3      2.5      5.0      1.9 virginica
## 148 148      6.5      3.0      5.2      2.0 virginica
## 149 149      6.2      3.4      5.4      2.3 virginica
## 150 150      5.9      3.0      5.1      1.8 virginica
```

- We used class to see how our object was structured e.g. vectors, matrices, dataframes. When working with dataframes we can use str() to find the class of each column

```
str(irisdata)
```

```
## 'data.frame':  150 obs. of  6 variables:
## $ X      : int  1 2 3 4 5 6 7 8 9 10 ...
## $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
## $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
## $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
## $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
## $ Species     : Factor w/ 3 levels "setosa","versicolor",...: 1 1 1 1 1 1 1 1 1 1 ...
```

```
head(irisdata)
```

```
##   X Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1 1      5.1      3.5      1.4      0.2 setosa
## 2 2      4.9      3.0      1.4      0.2 setosa
## 3 3      4.7      3.2      1.3      0.2 setosa
## 4 4      4.6      3.1      1.5      0.2 setosa
## 5 5      5.0      3.6      1.4      0.2 setosa
## 6 6      5.4      3.9      1.7      0.4 setosa
```

```
tail(irisdata)
```

```
##   X Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 145 145      6.7      3.3      5.7      2.5 virginica
## 146 146      6.7      3.0      5.2      2.3 virginica
## 147 147      6.3      2.5      5.0      1.9 virginica
## 148 148      6.5      3.0      5.2      2.0 virginica
## 149 149      6.2      3.4      5.4      2.3 virginica
## 150 150      5.9      3.0      5.1      1.8 virginica
```

- Why using .csv instead of Excel sheets (.xls and .xlsx)?

2. We can easily call some summary stats now.

```
summary(irisdata)
```

```
##      X      Sepal.Length      Sepal.Width      Petal.Length
## Min.   : 1.00   Min.   :4.300   Min.   :2.000   Min.   :1.000
## 1st Qu.:38.25   1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600
## Median :75.50   Median :5.800   Median :3.000   Median :4.350
```

```
## Mean      : 75.50      Mean      :5.843      Mean      :3.057      Mean      :3.758
## 3rd Qu.:112.75      3rd Qu.:6.400      3rd Qu.:3.300      3rd Qu.:5.100
## Max.      :150.00     Max.      :7.900      Max.      :4.400      Max.      :6.900
## Petal.Width      Species
## Min.      :0.100     setosa      :50
## 1st Qu.:0.300     versicolor:50
## Median :1.300     virginica  :50
## Mean      :1.199
## 3rd Qu.:1.800
## Max.      :2.500
```

3. We can also access specific values in this dataset. For vectors, matrices and dataframes we can use “[]”, and the “\$” is useful only for dataframes. If we use “[]” then we must think of it like this: [rows,columns]

```
irisdata[,1] # all values in column 1
```

```
## [1] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
## [18] 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
## [35] 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51
## [52] 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68
## [69] 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
## [86] 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102
## [103] 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119
## [120] 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136
## [137] 137 138 139 140 141 142 143 144 145 146 147 148 149 150
```

```
irisdata[1,1] # value at row 1, column 1
```

```
## [1] 1
```

```
irisdata[,1:3] # all values in columns 1 to 3
```

```
##      X Sepal.Length Sepal.Width
## 1      1           5.1          3.5
## 2      2           4.9          3.0
## 3      3           4.7          3.2
## 4      4           4.6          3.1
## 5      5           5.0          3.6
## 6      6           5.4          3.9
## 7      7           4.6          3.4
## 8      8           5.0          3.4
## 9      9           4.4          2.9
## 10    10           4.9          3.1
## 11    11           5.4          3.7
## 12    12           4.8          3.4
## 13    13           4.8          3.0
## 14    14           4.3          3.0
## 15    15           5.8          4.0
## 16    16           5.7          4.4
## 17    17           5.4          3.9
## 18    18           5.1          3.5
```

## 19	19	5.7	3.8
## 20	20	5.1	3.8
## 21	21	5.4	3.4
## 22	22	5.1	3.7
## 23	23	4.6	3.6
## 24	24	5.1	3.3
## 25	25	4.8	3.4
## 26	26	5.0	3.0
## 27	27	5.0	3.4
## 28	28	5.2	3.5
## 29	29	5.2	3.4
## 30	30	4.7	3.2
## 31	31	4.8	3.1
## 32	32	5.4	3.4
## 33	33	5.2	4.1
## 34	34	5.5	4.2
## 35	35	4.9	3.1
## 36	36	5.0	3.2
## 37	37	5.5	3.5
## 38	38	4.9	3.6
## 39	39	4.4	3.0
## 40	40	5.1	3.4
## 41	41	5.0	3.5
## 42	42	4.5	2.3
## 43	43	4.4	3.2
## 44	44	5.0	3.5
## 45	45	5.1	3.8
## 46	46	4.8	3.0
## 47	47	5.1	3.8
## 48	48	4.6	3.2
## 49	49	5.3	3.7
## 50	50	5.0	3.3
## 51	51	7.0	3.2
## 52	52	6.4	3.2
## 53	53	6.9	3.1
## 54	54	5.5	2.3
## 55	55	6.5	2.8
## 56	56	5.7	2.8
## 57	57	6.3	3.3
## 58	58	4.9	2.4
## 59	59	6.6	2.9
## 60	60	5.2	2.7
## 61	61	5.0	2.0
## 62	62	5.9	3.0
## 63	63	6.0	2.2
## 64	64	6.1	2.9
## 65	65	5.6	2.9
## 66	66	6.7	3.1
## 67	67	5.6	3.0
## 68	68	5.8	2.7
## 69	69	6.2	2.2
## 70	70	5.6	2.5
## 71	71	5.9	3.2
## 72	72	6.1	2.8

## 73	73	6.3	2.5
## 74	74	6.1	2.8
## 75	75	6.4	2.9
## 76	76	6.6	3.0
## 77	77	6.8	2.8
## 78	78	6.7	3.0
## 79	79	6.0	2.9
## 80	80	5.7	2.6
## 81	81	5.5	2.4
## 82	82	5.5	2.4
## 83	83	5.8	2.7
## 84	84	6.0	2.7
## 85	85	5.4	3.0
## 86	86	6.0	3.4
## 87	87	6.7	3.1
## 88	88	6.3	2.3
## 89	89	5.6	3.0
## 90	90	5.5	2.5
## 91	91	5.5	2.6
## 92	92	6.1	3.0
## 93	93	5.8	2.6
## 94	94	5.0	2.3
## 95	95	5.6	2.7
## 96	96	5.7	3.0
## 97	97	5.7	2.9
## 98	98	6.2	2.9
## 99	99	5.1	2.5
## 100	100	5.7	2.8
## 101	101	6.3	3.3
## 102	102	5.8	2.7
## 103	103	7.1	3.0
## 104	104	6.3	2.9
## 105	105	6.5	3.0
## 106	106	7.6	3.0
## 107	107	4.9	2.5
## 108	108	7.3	2.9
## 109	109	6.7	2.5
## 110	110	7.2	3.6
## 111	111	6.5	3.2
## 112	112	6.4	2.7
## 113	113	6.8	3.0
## 114	114	5.7	2.5
## 115	115	5.8	2.8
## 116	116	6.4	3.2
## 117	117	6.5	3.0
## 118	118	7.7	3.8
## 119	119	7.7	2.6
## 120	120	6.0	2.2
## 121	121	6.9	3.2
## 122	122	5.6	2.8
## 123	123	7.7	2.8
## 124	124	6.3	2.7
## 125	125	6.7	3.3
## 126	126	7.2	3.2

```
## 127 127      6.2      2.8
## 128 128      6.1      3.0
## 129 129      6.4      2.8
## 130 130      7.2      3.0
## 131 131      7.4      2.8
## 132 132      7.9      3.8
## 133 133      6.4      2.8
## 134 134      6.3      2.8
## 135 135      6.1      2.6
## 136 136      7.7      3.0
## 137 137      6.3      3.4
## 138 138      6.4      3.1
## 139 139      6.0      3.0
## 140 140      6.9      3.1
## 141 141      6.7      3.1
## 142 142      6.9      3.1
## 143 143      5.8      2.7
## 144 144      6.8      3.2
## 145 145      6.7      3.3
## 146 146      6.7      3.0
## 147 147      6.3      2.5
## 148 148      6.5      3.0
## 149 149      6.2      3.4
## 150 150      5.9      3.0
```

```
irisdata[c(1,3,5), c(4,6)] # value at row 1, 3, and 5, column 4 and 6
```

```
##   Petal.Length Species
## 1          1.4  setosa
## 3          1.3  setosa
## 5          1.4  setosa
```

```
irisdata['Species'] # all values in column with column name 'Species'
```

```
##   Species
## 1  setosa
## 2  setosa
## 3  setosa
## 4  setosa
## 5  setosa
## 6  setosa
## 7  setosa
## 8  setosa
## 9  setosa
## 10 setosa
## 11 setosa
## 12 setosa
## 13 setosa
## 14 setosa
## 15 setosa
## 16 setosa
## 17 setosa
## 18 setosa
```

```
## 19      setosa
## 20      setosa
## 21      setosa
## 22      setosa
## 23      setosa
## 24      setosa
## 25      setosa
## 26      setosa
## 27      setosa
## 28      setosa
## 29      setosa
## 30      setosa
## 31      setosa
## 32      setosa
## 33      setosa
## 34      setosa
## 35      setosa
## 36      setosa
## 37      setosa
## 38      setosa
## 39      setosa
## 40      setosa
## 41      setosa
## 42      setosa
## 43      setosa
## 44      setosa
## 45      setosa
## 46      setosa
## 47      setosa
## 48      setosa
## 49      setosa
## 50      setosa
## 51 versicolor
## 52 versicolor
## 53 versicolor
## 54 versicolor
## 55 versicolor
## 56 versicolor
## 57 versicolor
## 58 versicolor
## 59 versicolor
## 60 versicolor
## 61 versicolor
## 62 versicolor
## 63 versicolor
## 64 versicolor
## 65 versicolor
## 66 versicolor
## 67 versicolor
## 68 versicolor
## 69 versicolor
## 70 versicolor
## 71 versicolor
## 72 versicolor
```

## 73 versicolor  
## 74 versicolor  
## 75 versicolor  
## 76 versicolor  
## 77 versicolor  
## 78 versicolor  
## 79 versicolor  
## 80 versicolor  
## 81 versicolor  
## 82 versicolor  
## 83 versicolor  
## 84 versicolor  
## 85 versicolor  
## 86 versicolor  
## 87 versicolor  
## 88 versicolor  
## 89 versicolor  
## 90 versicolor  
## 91 versicolor  
## 92 versicolor  
## 93 versicolor  
## 94 versicolor  
## 95 versicolor  
## 96 versicolor  
## 97 versicolor  
## 98 versicolor  
## 99 versicolor  
## 100 versicolor  
## 101 virginica  
## 102 virginica  
## 103 virginica  
## 104 virginica  
## 105 virginica  
## 106 virginica  
## 107 virginica  
## 108 virginica  
## 109 virginica  
## 110 virginica  
## 111 virginica  
## 112 virginica  
## 113 virginica  
## 114 virginica  
## 115 virginica  
## 116 virginica  
## 117 virginica  
## 118 virginica  
## 119 virginica  
## 120 virginica  
## 121 virginica  
## 122 virginica  
## 123 virginica  
## 124 virginica  
## 125 virginica  
## 126 virginica



```
## 127 virginica
## 128 virginica
## 129 virginica
## 130 virginica
## 131 virginica
## 132 virginica
## 133 virginica
## 134 virginica
## 135 virginica
## 136 virginica
## 137 virginica
## 138 virginica
## 139 virginica
## 140 virginica
## 141 virginica
## 142 virginica
## 143 virginica
## 144 virginica
## 145 virginica
## 146 virginica
## 147 virginica
## 148 virginica
## 149 virginica
## 150 virginica
```

```
irisdata$Sepal.Length # all values in column with column name 'Sepal.length'
```

```
## [1] 5.1 4.9 4.7 4.6 5.0 5.4 4.6 5.0 4.4 4.9 5.4 4.8 4.8 4.3 5.8 5.7 5.4
## [18] 5.1 5.7 5.1 5.4 5.1 4.6 5.1 4.8 5.0 5.0 5.2 5.2 4.7 4.8 5.4 5.2 5.5
## [35] 4.9 5.0 5.5 4.9 4.4 5.1 5.0 4.5 4.4 5.0 5.1 4.8 5.1 4.6 5.3 5.0 7.0
## [52] 6.4 6.9 5.5 6.5 5.7 6.3 4.9 6.6 5.2 5.0 5.9 6.0 6.1 5.6 6.7 5.6 5.8
## [69] 6.2 5.6 5.9 6.1 6.3 6.1 6.4 6.6 6.8 6.7 6.0 5.7 5.5 5.5 5.8 6.0 5.4
## [86] 6.0 6.7 6.3 5.6 5.5 5.5 6.1 5.8 5.0 5.6 5.7 5.7 6.2 5.1 5.7 6.3 5.8
## [103] 7.1 6.3 6.5 7.6 4.9 7.3 6.7 7.2 6.5 6.4 6.8 5.7 5.8 6.4 6.5 7.7 7.7
## [120] 6.0 6.9 5.6 7.7 6.3 6.7 7.2 6.2 6.1 6.4 7.2 7.4 7.9 6.4 6.3 6.1 7.7
## [137] 6.3 6.4 6.0 6.9 6.7 6.9 5.8 6.8 6.7 6.7 6.3 6.5 6.2 5.9
```

```
#as.matrix(irisdata)$Sepal.Length
```

```
# this won't work, atomic vectors = (logical, integer, double (sometimes called numeric), and character)
```

```
# this will work
```

```
as.matrix(irisdata)
```

```
##      X      Sepal.Length Sepal.Width Petal.Length Petal.Width
## [1,] " 1" "5.1"         "3.5"         "1.4"         "0.2"
## [2,] " 2" "4.9"         "3.0"         "1.4"         "0.2"
## [3,] " 3" "4.7"         "3.2"         "1.3"         "0.2"
## [4,] " 4" "4.6"         "3.1"         "1.5"         "0.2"
## [5,] " 5" "5.0"         "3.6"         "1.4"         "0.2"
## [6,] " 6" "5.4"         "3.9"         "1.7"         "0.4"
## [7,] " 7" "4.6"         "3.4"         "1.4"         "0.3"
## [8,] " 8" "5.0"         "3.4"         "1.5"         "0.2"
```

##	[9,]	" 9"	"4.4"	"2.9"	"1.4"	"0.2"
##	[10,]	" 10"	"4.9"	"3.1"	"1.5"	"0.1"
##	[11,]	" 11"	"5.4"	"3.7"	"1.5"	"0.2"
##	[12,]	" 12"	"4.8"	"3.4"	"1.6"	"0.2"
##	[13,]	" 13"	"4.8"	"3.0"	"1.4"	"0.1"
##	[14,]	" 14"	"4.3"	"3.0"	"1.1"	"0.1"
##	[15,]	" 15"	"5.8"	"4.0"	"1.2"	"0.2"
##	[16,]	" 16"	"5.7"	"4.4"	"1.5"	"0.4"
##	[17,]	" 17"	"5.4"	"3.9"	"1.3"	"0.4"
##	[18,]	" 18"	"5.1"	"3.5"	"1.4"	"0.3"
##	[19,]	" 19"	"5.7"	"3.8"	"1.7"	"0.3"
##	[20,]	" 20"	"5.1"	"3.8"	"1.5"	"0.3"
##	[21,]	" 21"	"5.4"	"3.4"	"1.7"	"0.2"
##	[22,]	" 22"	"5.1"	"3.7"	"1.5"	"0.4"
##	[23,]	" 23"	"4.6"	"3.6"	"1.0"	"0.2"
##	[24,]	" 24"	"5.1"	"3.3"	"1.7"	"0.5"
##	[25,]	" 25"	"4.8"	"3.4"	"1.9"	"0.2"
##	[26,]	" 26"	"5.0"	"3.0"	"1.6"	"0.2"
##	[27,]	" 27"	"5.0"	"3.4"	"1.6"	"0.4"
##	[28,]	" 28"	"5.2"	"3.5"	"1.5"	"0.2"
##	[29,]	" 29"	"5.2"	"3.4"	"1.4"	"0.2"
##	[30,]	" 30"	"4.7"	"3.2"	"1.6"	"0.2"
##	[31,]	" 31"	"4.8"	"3.1"	"1.6"	"0.2"
##	[32,]	" 32"	"5.4"	"3.4"	"1.5"	"0.4"
##	[33,]	" 33"	"5.2"	"4.1"	"1.5"	"0.1"
##	[34,]	" 34"	"5.5"	"4.2"	"1.4"	"0.2"
##	[35,]	" 35"	"4.9"	"3.1"	"1.5"	"0.2"
##	[36,]	" 36"	"5.0"	"3.2"	"1.2"	"0.2"
##	[37,]	" 37"	"5.5"	"3.5"	"1.3"	"0.2"
##	[38,]	" 38"	"4.9"	"3.6"	"1.4"	"0.1"
##	[39,]	" 39"	"4.4"	"3.0"	"1.3"	"0.2"
##	[40,]	" 40"	"5.1"	"3.4"	"1.5"	"0.2"
##	[41,]	" 41"	"5.0"	"3.5"	"1.3"	"0.3"
##	[42,]	" 42"	"4.5"	"2.3"	"1.3"	"0.3"
##	[43,]	" 43"	"4.4"	"3.2"	"1.3"	"0.2"
##	[44,]	" 44"	"5.0"	"3.5"	"1.6"	"0.6"
##	[45,]	" 45"	"5.1"	"3.8"	"1.9"	"0.4"
##	[46,]	" 46"	"4.8"	"3.0"	"1.4"	"0.3"
##	[47,]	" 47"	"5.1"	"3.8"	"1.6"	"0.2"
##	[48,]	" 48"	"4.6"	"3.2"	"1.4"	"0.2"
##	[49,]	" 49"	"5.3"	"3.7"	"1.5"	"0.2"
##	[50,]	" 50"	"5.0"	"3.3"	"1.4"	"0.2"
##	[51,]	" 51"	"7.0"	"3.2"	"4.7"	"1.4"
##	[52,]	" 52"	"6.4"	"3.2"	"4.5"	"1.5"
##	[53,]	" 53"	"6.9"	"3.1"	"4.9"	"1.5"
##	[54,]	" 54"	"5.5"	"2.3"	"4.0"	"1.3"
##	[55,]	" 55"	"6.5"	"2.8"	"4.6"	"1.5"
##	[56,]	" 56"	"5.7"	"2.8"	"4.5"	"1.3"
##	[57,]	" 57"	"6.3"	"3.3"	"4.7"	"1.6"
##	[58,]	" 58"	"4.9"	"2.4"	"3.3"	"1.0"
##	[59,]	" 59"	"6.6"	"2.9"	"4.6"	"1.3"
##	[60,]	" 60"	"5.2"	"2.7"	"3.9"	"1.4"
##	[61,]	" 61"	"5.0"	"2.0"	"3.5"	"1.0"
##	[62,]	" 62"	"5.9"	"3.0"	"4.2"	"1.5"

##	[63,]	" 63"	"6.0"	"2.2"	"4.0"	"1.0"
##	[64,]	" 64"	"6.1"	"2.9"	"4.7"	"1.4"
##	[65,]	" 65"	"5.6"	"2.9"	"3.6"	"1.3"
##	[66,]	" 66"	"6.7"	"3.1"	"4.4"	"1.4"
##	[67,]	" 67"	"5.6"	"3.0"	"4.5"	"1.5"
##	[68,]	" 68"	"5.8"	"2.7"	"4.1"	"1.0"
##	[69,]	" 69"	"6.2"	"2.2"	"4.5"	"1.5"
##	[70,]	" 70"	"5.6"	"2.5"	"3.9"	"1.1"
##	[71,]	" 71"	"5.9"	"3.2"	"4.8"	"1.8"
##	[72,]	" 72"	"6.1"	"2.8"	"4.0"	"1.3"
##	[73,]	" 73"	"6.3"	"2.5"	"4.9"	"1.5"
##	[74,]	" 74"	"6.1"	"2.8"	"4.7"	"1.2"
##	[75,]	" 75"	"6.4"	"2.9"	"4.3"	"1.3"
##	[76,]	" 76"	"6.6"	"3.0"	"4.4"	"1.4"
##	[77,]	" 77"	"6.8"	"2.8"	"4.8"	"1.4"
##	[78,]	" 78"	"6.7"	"3.0"	"5.0"	"1.7"
##	[79,]	" 79"	"6.0"	"2.9"	"4.5"	"1.5"
##	[80,]	" 80"	"5.7"	"2.6"	"3.5"	"1.0"
##	[81,]	" 81"	"5.5"	"2.4"	"3.8"	"1.1"
##	[82,]	" 82"	"5.5"	"2.4"	"3.7"	"1.0"
##	[83,]	" 83"	"5.8"	"2.7"	"3.9"	"1.2"
##	[84,]	" 84"	"6.0"	"2.7"	"5.1"	"1.6"
##	[85,]	" 85"	"5.4"	"3.0"	"4.5"	"1.5"
##	[86,]	" 86"	"6.0"	"3.4"	"4.5"	"1.6"
##	[87,]	" 87"	"6.7"	"3.1"	"4.7"	"1.5"
##	[88,]	" 88"	"6.3"	"2.3"	"4.4"	"1.3"
##	[89,]	" 89"	"5.6"	"3.0"	"4.1"	"1.3"
##	[90,]	" 90"	"5.5"	"2.5"	"4.0"	"1.3"
##	[91,]	" 91"	"5.5"	"2.6"	"4.4"	"1.2"
##	[92,]	" 92"	"6.1"	"3.0"	"4.6"	"1.4"
##	[93,]	" 93"	"5.8"	"2.6"	"4.0"	"1.2"
##	[94,]	" 94"	"5.0"	"2.3"	"3.3"	"1.0"
##	[95,]	" 95"	"5.6"	"2.7"	"4.2"	"1.3"
##	[96,]	" 96"	"5.7"	"3.0"	"4.2"	"1.2"
##	[97,]	" 97"	"5.7"	"2.9"	"4.2"	"1.3"
##	[98,]	" 98"	"6.2"	"2.9"	"4.3"	"1.3"
##	[99,]	" 99"	"5.1"	"2.5"	"3.0"	"1.1"
##	[100,]	"100"	"5.7"	"2.8"	"4.1"	"1.3"
##	[101,]	"101"	"6.3"	"3.3"	"6.0"	"2.5"
##	[102,]	"102"	"5.8"	"2.7"	"5.1"	"1.9"
##	[103,]	"103"	"7.1"	"3.0"	"5.9"	"2.1"
##	[104,]	"104"	"6.3"	"2.9"	"5.6"	"1.8"
##	[105,]	"105"	"6.5"	"3.0"	"5.8"	"2.2"
##	[106,]	"106"	"7.6"	"3.0"	"6.6"	"2.1"
##	[107,]	"107"	"4.9"	"2.5"	"4.5"	"1.7"
##	[108,]	"108"	"7.3"	"2.9"	"6.3"	"1.8"
##	[109,]	"109"	"6.7"	"2.5"	"5.8"	"1.8"
##	[110,]	"110"	"7.2"	"3.6"	"6.1"	"2.5"
##	[111,]	"111"	"6.5"	"3.2"	"5.1"	"2.0"
##	[112,]	"112"	"6.4"	"2.7"	"5.3"	"1.9"
##	[113,]	"113"	"6.8"	"3.0"	"5.5"	"2.1"
##	[114,]	"114"	"5.7"	"2.5"	"5.0"	"2.0"
##	[115,]	"115"	"5.8"	"2.8"	"5.1"	"2.4"
##	[116,]	"116"	"6.4"	"3.2"	"5.3"	"2.3"

##	[117,]	"117"	"6.5"	"3.0"	"5.5"	"1.8"
##	[118,]	"118"	"7.7"	"3.8"	"6.7"	"2.2"
##	[119,]	"119"	"7.7"	"2.6"	"6.9"	"2.3"
##	[120,]	"120"	"6.0"	"2.2"	"5.0"	"1.5"
##	[121,]	"121"	"6.9"	"3.2"	"5.7"	"2.3"
##	[122,]	"122"	"5.6"	"2.8"	"4.9"	"2.0"
##	[123,]	"123"	"7.7"	"2.8"	"6.7"	"2.0"
##	[124,]	"124"	"6.3"	"2.7"	"4.9"	"1.8"
##	[125,]	"125"	"6.7"	"3.3"	"5.7"	"2.1"
##	[126,]	"126"	"7.2"	"3.2"	"6.0"	"1.8"
##	[127,]	"127"	"6.2"	"2.8"	"4.8"	"1.8"
##	[128,]	"128"	"6.1"	"3.0"	"4.9"	"1.8"
##	[129,]	"129"	"6.4"	"2.8"	"5.6"	"2.1"
##	[130,]	"130"	"7.2"	"3.0"	"5.8"	"1.6"
##	[131,]	"131"	"7.4"	"2.8"	"6.1"	"1.9"
##	[132,]	"132"	"7.9"	"3.8"	"6.4"	"2.0"
##	[133,]	"133"	"6.4"	"2.8"	"5.6"	"2.2"
##	[134,]	"134"	"6.3"	"2.8"	"5.1"	"1.5"
##	[135,]	"135"	"6.1"	"2.6"	"5.6"	"1.4"
##	[136,]	"136"	"7.7"	"3.0"	"6.1"	"2.3"
##	[137,]	"137"	"6.3"	"3.4"	"5.6"	"2.4"
##	[138,]	"138"	"6.4"	"3.1"	"5.5"	"1.8"
##	[139,]	"139"	"6.0"	"3.0"	"4.8"	"1.8"
##	[140,]	"140"	"6.9"	"3.1"	"5.4"	"2.1"
##	[141,]	"141"	"6.7"	"3.1"	"5.6"	"2.4"
##	[142,]	"142"	"6.9"	"3.1"	"5.1"	"2.3"
##	[143,]	"143"	"5.8"	"2.7"	"5.1"	"1.9"
##	[144,]	"144"	"6.8"	"3.2"	"5.9"	"2.3"
##	[145,]	"145"	"6.7"	"3.3"	"5.7"	"2.5"
##	[146,]	"146"	"6.7"	"3.0"	"5.2"	"2.3"
##	[147,]	"147"	"6.3"	"2.5"	"5.0"	"1.9"
##	[148,]	"148"	"6.5"	"3.0"	"5.2"	"2.0"
##	[149,]	"149"	"6.2"	"3.4"	"5.4"	"2.3"
##	[150,]	"150"	"5.9"	"3.0"	"5.1"	"1.8"
##		Species				
##	[1,]	"setosa"				
##	[2,]	"setosa"				
##	[3,]	"setosa"				
##	[4,]	"setosa"				
##	[5,]	"setosa"				
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## [127,] "virginica"
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## [150,] "virginica"
```

```
# why won't this run?
```

```
# irisdata[1, 1:7] # first row only of values in columns 1 to 7
```

```
# fixed
```

```
irisdata[1, 1:6]
```

```
##      X Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1 1          5.1          3.5          1.4          0.2  setosa
```

```
dim(irisdata) #shows dimensions
```

```
## [1] 150  6
```

- What is the X column in irisdata?

```
irisdata
```

```
##      X Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1 1          5.1          3.5          1.4          0.2  setosa
## 2 2          4.9          3.0          1.4          0.2  setosa
## 3 3          4.7          3.2          1.3          0.2  setosa
## 4 4          4.6          3.1          1.5          0.2  setosa
## 5 5          5.0          3.6          1.4          0.2  setosa
## 6 6          5.4          3.9          1.7          0.4  setosa
## 7 7          4.6          3.4          1.4          0.3  setosa
## 8 8          5.0          3.4          1.5          0.2  setosa
```

## 9	9	4.4	2.9	1.4	0.2	setosa
## 10	10	4.9	3.1	1.5	0.1	setosa
## 11	11	5.4	3.7	1.5	0.2	setosa
## 12	12	4.8	3.4	1.6	0.2	setosa
## 13	13	4.8	3.0	1.4	0.1	setosa
## 14	14	4.3	3.0	1.1	0.1	setosa
## 15	15	5.8	4.0	1.2	0.2	setosa
## 16	16	5.7	4.4	1.5	0.4	setosa
## 17	17	5.4	3.9	1.3	0.4	setosa
## 18	18	5.1	3.5	1.4	0.3	setosa
## 19	19	5.7	3.8	1.7	0.3	setosa
## 20	20	5.1	3.8	1.5	0.3	setosa
## 21	21	5.4	3.4	1.7	0.2	setosa
## 22	22	5.1	3.7	1.5	0.4	setosa
## 23	23	4.6	3.6	1.0	0.2	setosa
## 24	24	5.1	3.3	1.7	0.5	setosa
## 25	25	4.8	3.4	1.9	0.2	setosa
## 26	26	5.0	3.0	1.6	0.2	setosa
## 27	27	5.0	3.4	1.6	0.4	setosa
## 28	28	5.2	3.5	1.5	0.2	setosa
## 29	29	5.2	3.4	1.4	0.2	setosa
## 30	30	4.7	3.2	1.6	0.2	setosa
## 31	31	4.8	3.1	1.6	0.2	setosa
## 32	32	5.4	3.4	1.5	0.4	setosa
## 33	33	5.2	4.1	1.5	0.1	setosa
## 34	34	5.5	4.2	1.4	0.2	setosa
## 35	35	4.9	3.1	1.5	0.2	setosa
## 36	36	5.0	3.2	1.2	0.2	setosa
## 37	37	5.5	3.5	1.3	0.2	setosa
## 38	38	4.9	3.6	1.4	0.1	setosa
## 39	39	4.4	3.0	1.3	0.2	setosa
## 40	40	5.1	3.4	1.5	0.2	setosa
## 41	41	5.0	3.5	1.3	0.3	setosa
## 42	42	4.5	2.3	1.3	0.3	setosa
## 43	43	4.4	3.2	1.3	0.2	setosa
## 44	44	5.0	3.5	1.6	0.6	setosa
## 45	45	5.1	3.8	1.9	0.4	setosa
## 46	46	4.8	3.0	1.4	0.3	setosa
## 47	47	5.1	3.8	1.6	0.2	setosa
## 48	48	4.6	3.2	1.4	0.2	setosa
## 49	49	5.3	3.7	1.5	0.2	setosa
## 50	50	5.0	3.3	1.4	0.2	setosa
## 51	51	7.0	3.2	4.7	1.4	versicolor
## 52	52	6.4	3.2	4.5	1.5	versicolor
## 53	53	6.9	3.1	4.9	1.5	versicolor
## 54	54	5.5	2.3	4.0	1.3	versicolor
## 55	55	6.5	2.8	4.6	1.5	versicolor
## 56	56	5.7	2.8	4.5	1.3	versicolor
## 57	57	6.3	3.3	4.7	1.6	versicolor
## 58	58	4.9	2.4	3.3	1.0	versicolor
## 59	59	6.6	2.9	4.6	1.3	versicolor
## 60	60	5.2	2.7	3.9	1.4	versicolor
## 61	61	5.0	2.0	3.5	1.0	versicolor
## 62	62	5.9	3.0	4.2	1.5	versicolor



## 63	63	6.0	2.2	4.0	1.0 versicolor
## 64	64	6.1	2.9	4.7	1.4 versicolor
## 65	65	5.6	2.9	3.6	1.3 versicolor
## 66	66	6.7	3.1	4.4	1.4 versicolor
## 67	67	5.6	3.0	4.5	1.5 versicolor
## 68	68	5.8	2.7	4.1	1.0 versicolor
## 69	69	6.2	2.2	4.5	1.5 versicolor
## 70	70	5.6	2.5	3.9	1.1 versicolor
## 71	71	5.9	3.2	4.8	1.8 versicolor
## 72	72	6.1	2.8	4.0	1.3 versicolor
## 73	73	6.3	2.5	4.9	1.5 versicolor
## 74	74	6.1	2.8	4.7	1.2 versicolor
## 75	75	6.4	2.9	4.3	1.3 versicolor
## 76	76	6.6	3.0	4.4	1.4 versicolor
## 77	77	6.8	2.8	4.8	1.4 versicolor
## 78	78	6.7	3.0	5.0	1.7 versicolor
## 79	79	6.0	2.9	4.5	1.5 versicolor
## 80	80	5.7	2.6	3.5	1.0 versicolor
## 81	81	5.5	2.4	3.8	1.1 versicolor
## 82	82	5.5	2.4	3.7	1.0 versicolor
## 83	83	5.8	2.7	3.9	1.2 versicolor
## 84	84	6.0	2.7	5.1	1.6 versicolor
## 85	85	5.4	3.0	4.5	1.5 versicolor
## 86	86	6.0	3.4	4.5	1.6 versicolor
## 87	87	6.7	3.1	4.7	1.5 versicolor
## 88	88	6.3	2.3	4.4	1.3 versicolor
## 89	89	5.6	3.0	4.1	1.3 versicolor
## 90	90	5.5	2.5	4.0	1.3 versicolor
## 91	91	5.5	2.6	4.4	1.2 versicolor
## 92	92	6.1	3.0	4.6	1.4 versicolor
## 93	93	5.8	2.6	4.0	1.2 versicolor
## 94	94	5.0	2.3	3.3	1.0 versicolor
## 95	95	5.6	2.7	4.2	1.3 versicolor
## 96	96	5.7	3.0	4.2	1.2 versicolor
## 97	97	5.7	2.9	4.2	1.3 versicolor
## 98	98	6.2	2.9	4.3	1.3 versicolor
## 99	99	5.1	2.5	3.0	1.1 versicolor
## 100	100	5.7	2.8	4.1	1.3 versicolor
## 101	101	6.3	3.3	6.0	2.5 virginica
## 102	102	5.8	2.7	5.1	1.9 virginica
## 103	103	7.1	3.0	5.9	2.1 virginica
## 104	104	6.3	2.9	5.6	1.8 virginica
## 105	105	6.5	3.0	5.8	2.2 virginica
## 106	106	7.6	3.0	6.6	2.1 virginica
## 107	107	4.9	2.5	4.5	1.7 virginica
## 108	108	7.3	2.9	6.3	1.8 virginica
## 109	109	6.7	2.5	5.8	1.8 virginica
## 110	110	7.2	3.6	6.1	2.5 virginica
## 111	111	6.5	3.2	5.1	2.0 virginica
## 112	112	6.4	2.7	5.3	1.9 virginica
## 113	113	6.8	3.0	5.5	2.1 virginica
## 114	114	5.7	2.5	5.0	2.0 virginica
## 115	115	5.8	2.8	5.1	2.4 virginica
## 116	116	6.4	3.2	5.3	2.3 virginica

## 117 117	6.5	3.0	5.5	1.8	virginica
## 118 118	7.7	3.8	6.7	2.2	virginica
## 119 119	7.7	2.6	6.9	2.3	virginica
## 120 120	6.0	2.2	5.0	1.5	virginica
## 121 121	6.9	3.2	5.7	2.3	virginica
## 122 122	5.6	2.8	4.9	2.0	virginica
## 123 123	7.7	2.8	6.7	2.0	virginica
## 124 124	6.3	2.7	4.9	1.8	virginica
## 125 125	6.7	3.3	5.7	2.1	virginica
## 126 126	7.2	3.2	6.0	1.8	virginica
## 127 127	6.2	2.8	4.8	1.8	virginica
## 128 128	6.1	3.0	4.9	1.8	virginica
## 129 129	6.4	2.8	5.6	2.1	virginica
## 130 130	7.2	3.0	5.8	1.6	virginica
## 131 131	7.4	2.8	6.1	1.9	virginica
## 132 132	7.9	3.8	6.4	2.0	virginica
## 133 133	6.4	2.8	5.6	2.2	virginica
## 134 134	6.3	2.8	5.1	1.5	virginica
## 135 135	6.1	2.6	5.6	1.4	virginica
## 136 136	7.7	3.0	6.1	2.3	virginica
## 137 137	6.3	3.4	5.6	2.4	virginica
## 138 138	6.4	3.1	5.5	1.8	virginica
## 139 139	6.0	3.0	4.8	1.8	virginica
## 140 140	6.9	3.1	5.4	2.1	virginica
## 141 141	6.7	3.1	5.6	2.4	virginica
## 142 142	6.9	3.1	5.1	2.3	virginica
## 143 143	5.8	2.7	5.1	1.9	virginica
## 144 144	6.8	3.2	5.9	2.3	virginica
## 145 145	6.7	3.3	5.7	2.5	virginica
## 146 146	6.7	3.0	5.2	2.3	virginica
## 147 147	6.3	2.5	5.0	1.9	virginica
## 148 148	6.5	3.0	5.2	2.0	virginica
## 149 149	6.2	3.4	5.4	2.3	virginica
## 150 150	5.9	3.0	5.1	1.8	virginica

- We can remove the X column by accessing only values from columns 2 to 6

```
irisdata[:,2:6]
```

##	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
## 1	5.1	3.5	1.4	0.2	setosa
## 2	4.9	3.0	1.4	0.2	setosa
## 3	4.7	3.2	1.3	0.2	setosa
## 4	4.6	3.1	1.5	0.2	setosa
## 5	5.0	3.6	1.4	0.2	setosa
## 6	5.4	3.9	1.7	0.4	setosa
## 7	4.6	3.4	1.4	0.3	setosa
## 8	5.0	3.4	1.5	0.2	setosa
## 9	4.4	2.9	1.4	0.2	setosa
## 10	4.9	3.1	1.5	0.1	setosa
## 11	5.4	3.7	1.5	0.2	setosa
## 12	4.8	3.4	1.6	0.2	setosa
## 13	4.8	3.0	1.4	0.1	setosa

## 14	4.3	3.0	1.1	0.1	setosa
## 15	5.8	4.0	1.2	0.2	setosa
## 16	5.7	4.4	1.5	0.4	setosa
## 17	5.4	3.9	1.3	0.4	setosa
## 18	5.1	3.5	1.4	0.3	setosa
## 19	5.7	3.8	1.7	0.3	setosa
## 20	5.1	3.8	1.5	0.3	setosa
## 21	5.4	3.4	1.7	0.2	setosa
## 22	5.1	3.7	1.5	0.4	setosa
## 23	4.6	3.6	1.0	0.2	setosa
## 24	5.1	3.3	1.7	0.5	setosa
## 25	4.8	3.4	1.9	0.2	setosa
## 26	5.0	3.0	1.6	0.2	setosa
## 27	5.0	3.4	1.6	0.4	setosa
## 28	5.2	3.5	1.5	0.2	setosa
## 29	5.2	3.4	1.4	0.2	setosa
## 30	4.7	3.2	1.6	0.2	setosa
## 31	4.8	3.1	1.6	0.2	setosa
## 32	5.4	3.4	1.5	0.4	setosa
## 33	5.2	4.1	1.5	0.1	setosa
## 34	5.5	4.2	1.4	0.2	setosa
## 35	4.9	3.1	1.5	0.2	setosa
## 36	5.0	3.2	1.2	0.2	setosa
## 37	5.5	3.5	1.3	0.2	setosa
## 38	4.9	3.6	1.4	0.1	setosa
## 39	4.4	3.0	1.3	0.2	setosa
## 40	5.1	3.4	1.5	0.2	setosa
## 41	5.0	3.5	1.3	0.3	setosa
## 42	4.5	2.3	1.3	0.3	setosa
## 43	4.4	3.2	1.3	0.2	setosa
## 44	5.0	3.5	1.6	0.6	setosa
## 45	5.1	3.8	1.9	0.4	setosa
## 46	4.8	3.0	1.4	0.3	setosa
## 47	5.1	3.8	1.6	0.2	setosa
## 48	4.6	3.2	1.4	0.2	setosa
## 49	5.3	3.7	1.5	0.2	setosa
## 50	5.0	3.3	1.4	0.2	setosa
## 51	7.0	3.2	4.7	1.4	versicolor
## 52	6.4	3.2	4.5	1.5	versicolor
## 53	6.9	3.1	4.9	1.5	versicolor
## 54	5.5	2.3	4.0	1.3	versicolor
## 55	6.5	2.8	4.6	1.5	versicolor
## 56	5.7	2.8	4.5	1.3	versicolor
## 57	6.3	3.3	4.7	1.6	versicolor
## 58	4.9	2.4	3.3	1.0	versicolor
## 59	6.6	2.9	4.6	1.3	versicolor
## 60	5.2	2.7	3.9	1.4	versicolor
## 61	5.0	2.0	3.5	1.0	versicolor
## 62	5.9	3.0	4.2	1.5	versicolor
## 63	6.0	2.2	4.0	1.0	versicolor
## 64	6.1	2.9	4.7	1.4	versicolor
## 65	5.6	2.9	3.6	1.3	versicolor
## 66	6.7	3.1	4.4	1.4	versicolor
## 67	5.6	3.0	4.5	1.5	versicolor

## 68	5.8	2.7	4.1	1.0 versicolor
## 69	6.2	2.2	4.5	1.5 versicolor
## 70	5.6	2.5	3.9	1.1 versicolor
## 71	5.9	3.2	4.8	1.8 versicolor
## 72	6.1	2.8	4.0	1.3 versicolor
## 73	6.3	2.5	4.9	1.5 versicolor
## 74	6.1	2.8	4.7	1.2 versicolor
## 75	6.4	2.9	4.3	1.3 versicolor
## 76	6.6	3.0	4.4	1.4 versicolor
## 77	6.8	2.8	4.8	1.4 versicolor
## 78	6.7	3.0	5.0	1.7 versicolor
## 79	6.0	2.9	4.5	1.5 versicolor
## 80	5.7	2.6	3.5	1.0 versicolor
## 81	5.5	2.4	3.8	1.1 versicolor
## 82	5.5	2.4	3.7	1.0 versicolor
## 83	5.8	2.7	3.9	1.2 versicolor
## 84	6.0	2.7	5.1	1.6 versicolor
## 85	5.4	3.0	4.5	1.5 versicolor
## 86	6.0	3.4	4.5	1.6 versicolor
## 87	6.7	3.1	4.7	1.5 versicolor
## 88	6.3	2.3	4.4	1.3 versicolor
## 89	5.6	3.0	4.1	1.3 versicolor
## 90	5.5	2.5	4.0	1.3 versicolor
## 91	5.5	2.6	4.4	1.2 versicolor
## 92	6.1	3.0	4.6	1.4 versicolor
## 93	5.8	2.6	4.0	1.2 versicolor
## 94	5.0	2.3	3.3	1.0 versicolor
## 95	5.6	2.7	4.2	1.3 versicolor
## 96	5.7	3.0	4.2	1.2 versicolor
## 97	5.7	2.9	4.2	1.3 versicolor
## 98	6.2	2.9	4.3	1.3 versicolor
## 99	5.1	2.5	3.0	1.1 versicolor
## 100	5.7	2.8	4.1	1.3 versicolor
## 101	6.3	3.3	6.0	2.5 virginica
## 102	5.8	2.7	5.1	1.9 virginica
## 103	7.1	3.0	5.9	2.1 virginica
## 104	6.3	2.9	5.6	1.8 virginica
## 105	6.5	3.0	5.8	2.2 virginica
## 106	7.6	3.0	6.6	2.1 virginica
## 107	4.9	2.5	4.5	1.7 virginica
## 108	7.3	2.9	6.3	1.8 virginica
## 109	6.7	2.5	5.8	1.8 virginica
## 110	7.2	3.6	6.1	2.5 virginica
## 111	6.5	3.2	5.1	2.0 virginica
## 112	6.4	2.7	5.3	1.9 virginica
## 113	6.8	3.0	5.5	2.1 virginica
## 114	5.7	2.5	5.0	2.0 virginica
## 115	5.8	2.8	5.1	2.4 virginica
## 116	6.4	3.2	5.3	2.3 virginica
## 117	6.5	3.0	5.5	1.8 virginica
## 118	7.7	3.8	6.7	2.2 virginica
## 119	7.7	2.6	6.9	2.3 virginica
## 120	6.0	2.2	5.0	1.5 virginica
## 121	6.9	3.2	5.7	2.3 virginica

```
## 122      5.6      2.8      4.9      2.0 virginica
## 123      7.7      2.8      6.7      2.0 virginica
## 124      6.3      2.7      4.9      1.8 virginica
## 125      6.7      3.3      5.7      2.1 virginica
## 126      7.2      3.2      6.0      1.8 virginica
## 127      6.2      2.8      4.8      1.8 virginica
## 128      6.1      3.0      4.9      1.8 virginica
## 129      6.4      2.8      5.6      2.1 virginica
## 130      7.2      3.0      5.8      1.6 virginica
## 131      7.4      2.8      6.1      1.9 virginica
## 132      7.9      3.8      6.4      2.0 virginica
## 133      6.4      2.8      5.6      2.2 virginica
## 134      6.3      2.8      5.1      1.5 virginica
## 135      6.1      2.6      5.6      1.4 virginica
## 136      7.7      3.0      6.1      2.3 virginica
## 137      6.3      3.4      5.6      2.4 virginica
## 138      6.4      3.1      5.5      1.8 virginica
## 139      6.0      3.0      4.8      1.8 virginica
## 140      6.9      3.1      5.4      2.1 virginica
## 141      6.7      3.1      5.6      2.4 virginica
## 142      6.9      3.1      5.1      2.3 virginica
## 143      5.8      2.7      5.1      1.9 virginica
## 144      6.8      3.2      5.9      2.3 virginica
## 145      6.7      3.3      5.7      2.5 virginica
## 146      6.7      3.0      5.2      2.3 virginica
## 147      6.3      2.5      5.0      1.9 virginica
## 148      6.5      3.0      5.2      2.0 virginica
## 149      6.2      3.4      5.4      2.3 virginica
## 150      5.9      3.0      5.1      1.8 virginica
```

- There is another way to do this by selecting the column we would like to remove using a minus “-”
- Give this a go below and assign it to the object called iris\_without\_rownames

```
iris_without_rownames <- irisdata[,-1]
```

```
head(iris_without_rownames)
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1          3.5          1.4          0.2   setosa
## 2          4.9          3.0          1.4          0.2   setosa
## 3          4.7          3.2          1.3          0.2   setosa
## 4          4.6          3.1          1.5          0.2   setosa
## 5          5.0          3.6          1.4          0.2   setosa
## 6          5.4          3.9          1.7          0.4   setosa
```

4. If we make any changes to our data, we can save our new data in a spreadsheet.

```
write.csv(irisdata, 'output/new_irisdata.csv', row.names=FALSE) # Why am I using row.names=FALSE?
write.csv(irisdata, 'output/new_irisdata_incl_rownames.csv')
```

Nice! We have learned a lot about manipulating data so far! Use R cheat sheets (just google R cheatsheets) to look up all those functions over and over again!

## Last part! Our first data analysis!

1. Now we want to read in a new dataset called PlantGrowth.csv found in the input folder. Give this a go your yourself!

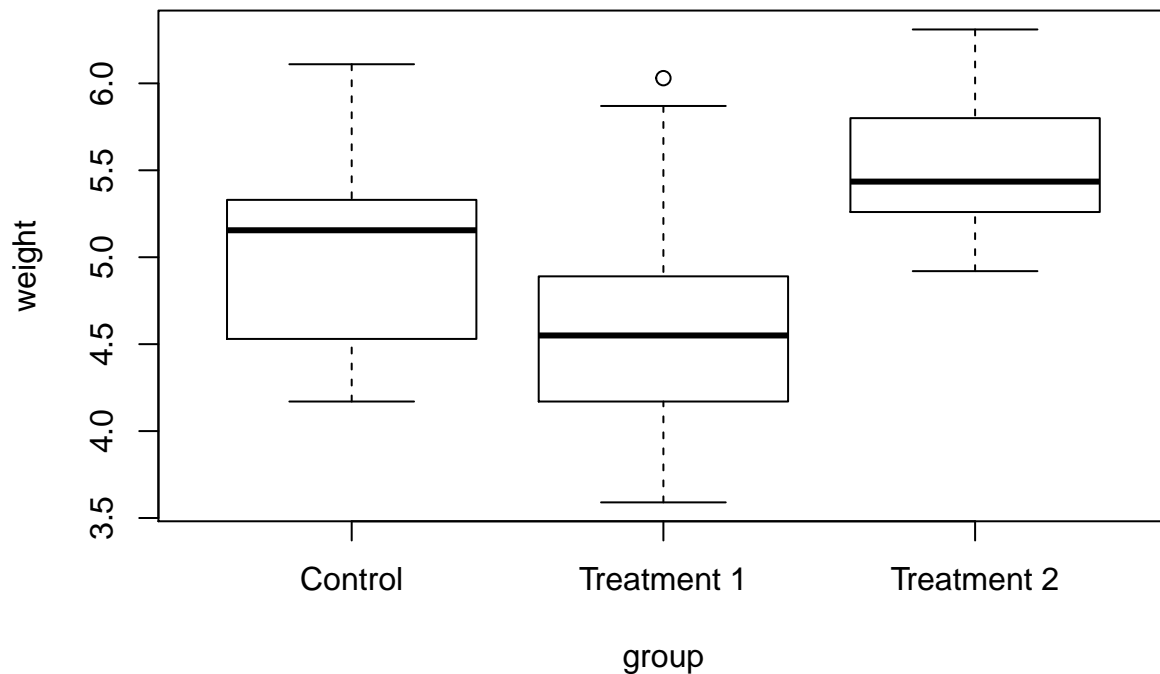
```
plant.df <- read.csv("input/PlantGrowth.csv")
```

2. Clean the data up a bit and specify that the group is a factor variable.

```
plant.df$group <- factor(plant.df$group,  
  labels = c("Control", "Treatment 1", "Treatment 2"))
```

3. Visualise our data with a boxplot.

```
boxplot(weight~group, plant.df)
```



4. Create a folder to store the results.

```
# this line can be different for Mac users  
dir.create("output/plots")
```

```
## Warning in dir.create("output/plots"): 'output\plots' already exists
```

And save it as a .pdf file in the output folder.

```
pdf('output/My Boxplot.pdf', width = 20, height = 10 , paper = 'a4r')
boxplot(weight~group, plant.df, ylab='Dried weight of plants [g]')
dev.off()
```

```
## pdf
## 2
```

4. Start statistical analysis. This is a simple linear model with an ANOVA.

```
plant.mod1 <- lm(weight ~ group, data = plant.df) # we're using lm() to create a pretty different object
summary(plant.mod1) # summary() extracts some of this data and prints it out neatly for us
```

```
##
## Call:
## lm(formula = weight ~ group, data = plant.df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.0710 -0.4180 -0.0060  0.2627  1.3690
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      5.0320     0.1971  25.527  <2e-16 ***
## groupTreatment 1  -0.3710     0.2788  -1.331   0.1944
## groupTreatment 2   0.4940     0.2788   1.772   0.0877 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6234 on 27 degrees of freedom
## Multiple R-squared:  0.2641, Adjusted R-squared:  0.2096
## F-statistic: 4.846 on 2 and 27 DF,  p-value: 0.01591
```

- We're using `lm()` to create a pretty different object called a list, which has lots of data in it, organised in a defined structure.
- Variable on the left-hand side of a tilde ( `~` ) (weight) is the dependent variable, while the right-hand side are the independent variables

```
anova(plant.mod1)
```

```
## Analysis of Variance Table
##
## Response: weight
##      Df Sum Sq Mean Sq F value Pr(>F)
## group    2  3.7663   1.8832  4.8461 0.01591 *
## Residuals 27 10.4921   0.3886
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
class(weight ~ group) # this is our formula
```

```
## [1] "formula"
```

```
plant.mod1
```

```
##  
## Call:  
## lm(formula = weight ~ group, data = plant.df)  
##  
## Coefficients:  
##      (Intercept) groupTreatment 1 groupTreatment 2  
##           5.032          -0.371           0.494
```

```
anova(plant.mod1)
```

```
## Analysis of Variance Table  
##  
## Response: weight  
##      Df Sum Sq Mean Sq F value Pr(>F)  
## group    2  3.7663   1.8832   4.8461 0.01591 *  
## Residuals 27 10.4921   0.3886  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
names(plant.mod1)
```

```
## [1] "coefficients" "residuals"      "effects"      "rank"  
## [5] "fitted.values" "assign"         "qr"           "df.residual"  
## [9] "contrasts"     "xlevels"        "call"         "terms"  
## [13] "model"
```

```
plant.mod1$coefficients
```

```
##      (Intercept) groupTreatment 1 groupTreatment 2  
##           5.032          -0.371           0.494
```

5. There are hundreds of packages in R that have ready functions for us to use. All you need to do is look up which package you need, install it and load it into R.

```
# function to use an improved read.csv function
```

```
#install.packages('readr') #install  
library(readr) #load
```

Now all we have to do is use a function within the newly loaded package!



```
irisdata <- read.csv("input/irisdata.csv") #old
irisdata <- read_csv("input/irisdata.csv") #new
```

```
## Warning: Missing column names filled in: 'X1' [1]
```

```
## Parsed with column specification:
## cols(
##   X1 = col_double(),
##   Sepal.Length = col_double(),
##   Sepal.Width = col_double(),
##   Petal.Length = col_double(),
##   Petal.Width = col_double(),
##   Species = col_character()
## )
```

```
irisdata
```

```
## # A tibble: 150 x 6
##       X1 Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl> <chr>
## 1     1         5.1         3.5         1.4         0.2 setosa
## 2     2         4.9         3         1.4         0.2 setosa
## 3     3         4.7         3.2         1.3         0.2 setosa
## 4     4         4.6         3.1         1.5         0.2 setosa
## 5     5         5         3.6         1.4         0.2 setosa
## 6     6         5.4         3.9         1.7         0.4 setosa
## 7     7         4.6         3.4         1.4         0.3 setosa
## 8     8         5         3.4         1.5         0.2 setosa
## 9     9         4.4         2.9         1.4         0.2 setosa
## 10    10         4.9         3.1         1.5         0.1 setosa
## # ... with 140 more rows
```

## More Information

**Resources to learn R coding** \* Book A Beginner's Guide to R (Use R!) - Alain Zuur, Elena Ieno and Eric Meesters \* Package (Swirl)

**Resources to learn plotting with R Base Graphics** \* R Graph Cookbook - Hrishi V. Mittal

**Resources to learn plotting with ggplot2** \* ggplot2 (Use R!) - Hadley Wickham

**Resources to learn data manipulation in R** \* Data manipulation with R (Use R!) - Phil Spector

**Resources to learn stats in R** \* Introductory statistics with R (Use R!) - Peter Dalgaard

## What we have learned

- Get familiar with R Studio and the differences to R
- How to import and export data in R?
- What do projects and setwd() have in common and what is its purpose?
- How to manipulate data?
- Your first data analysis
- How to proceed on your own