

Introduction to the Command Line (Terminal) and the R Language Syntax

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1) Basics of R

1.1) Basic Steps

- R can be accessed by clicking an icon or entering the command “R” at the system command line, also referred to as Terminal
- This produces a console window or causes R to start up as an interactive program at the current terminal window
- R works fundamentally by a question-and-answer model: enter a line with a command and press Enter
- Then the program does something relevant
- In this course, we will use RStudio and a file format called R Markdown, which allows us to code using not only R, but bash and Python, two other languages we may refer to as the course progresses

1.2) Library ISwR

- This Notebook was inspired in the book Introductory Statistics with R, by Peter Dalgaard
- For the book, R library ISwR (Introductory Statistics with R) can be freely downloaded
- All examples in the book used as reference should run provided that ISwR library is not only installed but also loaded into the current search path
- Library can be installed and loaded by typing the following command into an R chunk

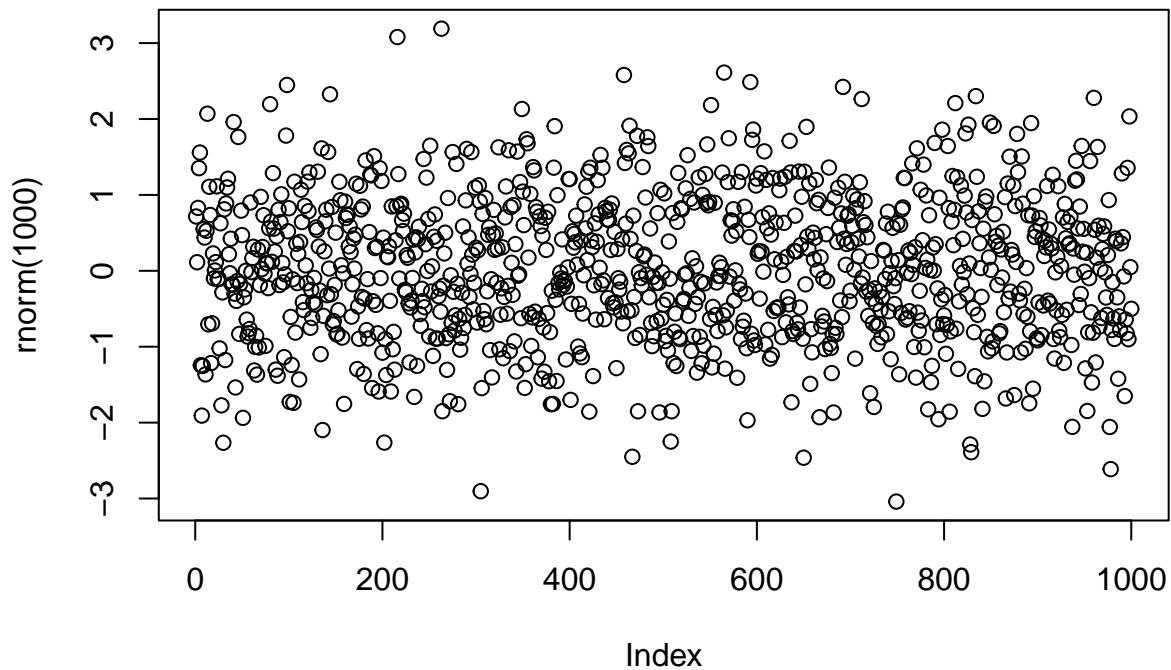
```
install.packages("ISwR")  
library("ISwR")
```

- For a first impression of what R can do, let's try plotting a graph

1.3) Plot Random Numbers

- Need to insert the R chunk and use the plot function

```
plot(rnorm(1000))
```



1.4) A Potent Calculator

- R can process simple and complex arithmetic expression and produce a result for the user

```
2 + 2
```

```
## [1] 4
```

- R can also be used to do other standard calculations. Here is how to calculate e to the power of -2

```
exp(-2)
```

```
## [1] 0.1353353
```

- Other than the R chunks, these calculations can be made using the RStudio Console

1.5) Assignments

- Assignments made based on the necessity to store results of calculations and use these results in downstream processing steps in an entire pipeline
- Like other languages, R has symbolic variables: names that can be used to represent values
- To assign value 2 to variable x, one can enter

```
x <- 2
```

- The character <- is called the assignment operator
- There is no immediate visible result, but from now on, x has the value 2 and can be used in subsequent arithmetic operations

1.6) Operations after Variable assignment

- Below, our variable x, is used to perform other calculations

```
x
## [1] 2
x + x ## Addition
## [1] 4
5*x ## Multiplication
## [1] 10
x^3 ## Potentiation
## [1] 8
```

1.7) Vectorized Arithmetic

- It is not useful to use one number at a time to run statistics
- One strenght of R is that it can handle entire data vectors as single objects
- A data vector is an array of numbers and a vector variable can be constructed like this

```
weight <- c(60, 72, 57, 90, 95, 72)
## To look at the vector variable, just type its name again
weight
## [1] 60 72 57 90 95 72
```

- You can do calculations with vectors just like ordinary numbers, so long as they have the same length
- One exception to this rule that we will see will be when we use the mean of weigths of persons (represented by xbar)
- In that case, the mean will be one single number, which will be subtracted from each sample value

1.7) Vectorized Arithmetic

- Suppose the weight vector indicates the weight of men in kilograms
- One simple formula to indicate whether a person is obese or not, is the body mass index (BMI)
- BMI is calculated by dividing the person's weight by the square of their height, in meters
- Therefore, in R, we need to have a vector with the height values to calculate the bmi vector, containing the body-mass index for the individuals indicated in the weight vector

```
height <- c(1.75, 1.80, 1.65, 1.90, 1.74, 1.91)
bmi <- weight/height^2
bmi
## [1] 19.59184 22.22222 20.93664 24.93075 31.37799 19.73630
```

1.8) Calculate the Mean of the variable weight

- The mean is calculated by the sum of the observations divided by the total number of observations

$$\bar{x} = \sum x_i / n$$

- Let's calculate the mean of the variable weight

```
sum(weight)
```

```
## [1] 446
```

```
sum(weight)/length(weight)
```

```
## [1] 74.33333
```

1.9) Calculate the Standard-Deviation of the variable weight

- Standard-deviation can be calculated with the following equation

$$SD = \sqrt{(\sum (x_i - \bar{x})^2) / (n - 1)}$$

- xbar, the mean of variable weight, can be calculated using the sum and length of variable weight

```
xbar <- sum(weight)/length(weight)
```

```
xbar
```

```
## [1] 74.33333
```

- Now we can calculate the difference of each replicate in the weight variable and the mean of the weight variable, one by one

```
weight - xbar
```

```
## [1] -14.333333 -2.333333 -17.333333 15.666667 20.666667 -2.333333
```

- Notice how R uses xbar, which has length one, to calculate the new weight - xbar data vector
- xbar is recycled and subtracted from every element in the weight variable (weight data vector)

1.10) Calculation of the Standard Deviation

- Calculate the squared deviations

```
(weight - xbar)^2
```

```
## [1] 205.444444 5.444444 300.444444 245.444444 427.111111 5.444444
```

- Calculate the sum of squared deviations

```
sum((weight - xbar)^2)
```

```
## [1] 1189.333
```

- Calculate the standard deviation

```
sqrt(
  sum(
    (weight - xbar)^2/
    (length(weight)-1)
  )
)
```

```
## [1] 15.42293
```

1.11) Standard Statistical Procedures

- It is a standard medical practice to assess whether a person is obese or not using validated scientific criteria
- As a simple procedure to show this concept, let's assume that an individual with a normal weight should have a BMI in the range 20-25
- We want to know if our data deviates from the normal range of BMI
- In R, this can be done using a statistical test called t-test
- You do not need to understand what a t-test is, just remember that it is used to evaluate the distribution of sample values compared to the normal distribution
- You can use a one-sample t-test to assess whether the six persons' BMI can be assumed to have mean 22.5 given that they come from a normal distribution
- You can do that using the function `t.test`

1.11) Standard Statistical Procedures: t-test

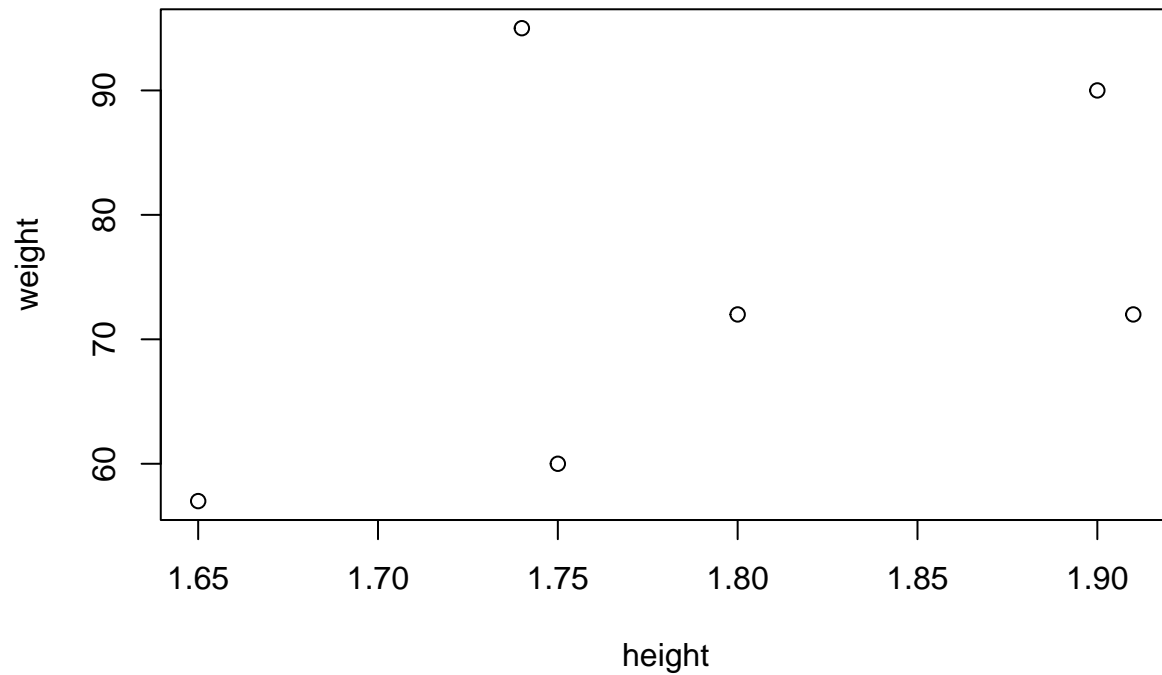
```
t.test(
  bmi,
  mu = 22.5
)
```

```
##
## One Sample t-test
##
## data:  bmi
## t = 0.34488, df = 5, p-value = 0.7442
## alternative hypothesis: true mean is not equal to 22.5
## 95 percent confidence interval:
##  18.41734 27.84791
## sample estimates:
## mean of x
##  23.13262
```

1.12) Plot Graphics

- Let's now plot a scatterplot of the height and weight of individuals

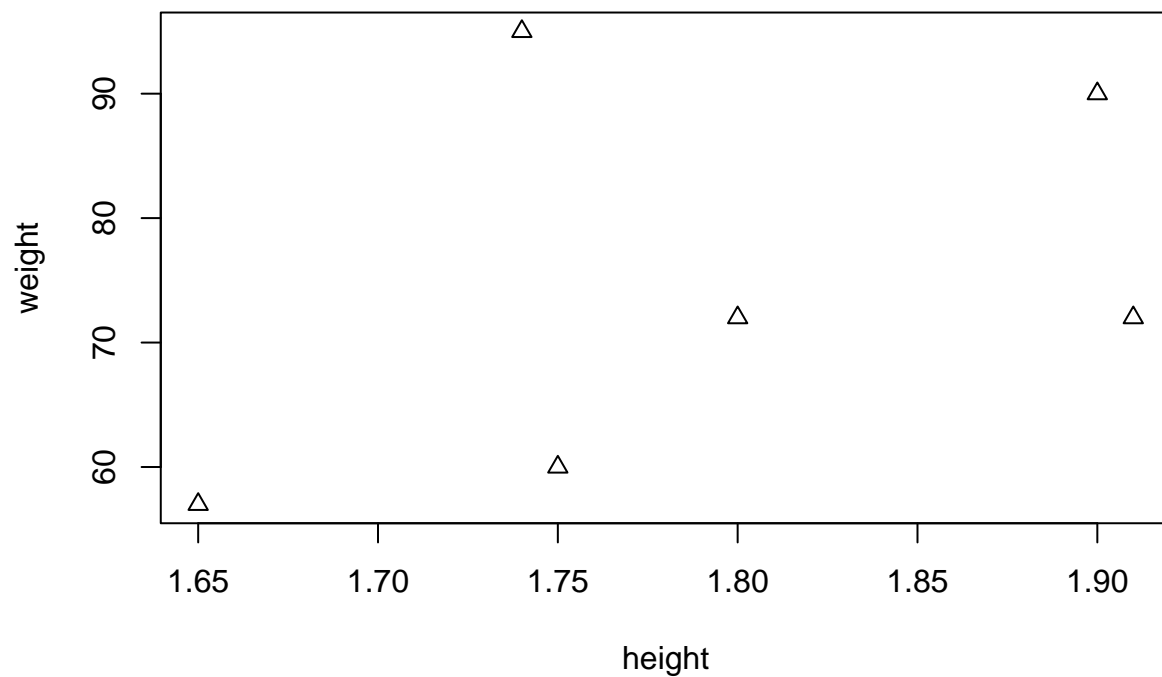
```
plot(height, weight)
```



1.12) Plot Graphics Modifying the plotting character

- You will frequently want to modify drawing of your graphs in various ways
- One way is using the parameter “plotting character”, pch

```
plot(height, weight, pch = 2)
```



1.13) Plot an expected Line for BMI

```
hh <- 22.5*(height)^2
```

1.14) Vectors

- The weight and height vectors are called numeric vectors
- Besides numeric vectors, there are numeric and character vectors

2) Using other libraries

2.1) The iris data-frame

- Now we have a better understanding of what R can give us, let us use another library more commonly used datasets
- At times, it is possible that you will need to figure out different ways to install a library to use it

```
library(datasets)
```

- In the next chunk, we access the iris data, and look at a summary of the dataset

```
data(iris)
summary(iris)
```

```
##   Sepal.Length   Sepal.Width   Petal.Length   Petal.Width
##   Min.    :4.300   Min.    :2.000   Min.    :1.000   Min.    :0.100
##   1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300
##   Median :5.800   Median :3.000   Median :4.350   Median :1.300
##   Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
##   3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
##   Max.    :7.900   Max.    :4.400   Max.    :6.900   Max.    :2.500
##           Species
##   setosa    :50
##   versicolor:50
##   virginica :50
##
##
##
```

2.1) The iris data-frame

- Another form to look at the iris data-frame is typing its name

```
iris
```

```
##      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

3.1) More Visualization of the iris dataset

We need to cover these basic R functions:

- `dim()`
- `head()`
- `View()`
- `class()`
- `str()`

```
dim(iris)
head(iris)
View(iris)
```

```
class(iris)
str(iris)
```

3.2) Visualize iris dataset with basic R functions

- head

```
head(iris, n = 10)
```

```
##      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
```

- number of columns and rows

```
dim(iris)
```

```
## [1] 150   5
```

- the class() function

```
class(iris)
```

```
## [1] "data.frame"
```

4) More Visualization

4.1) Scatterplot

```
plot(data=iris, iris$Sepal.Length, iris$Sepal.Width) ## R will complain about this command
```

```
## Warning in plot.window(...): "data" is not a graphical parameter
```

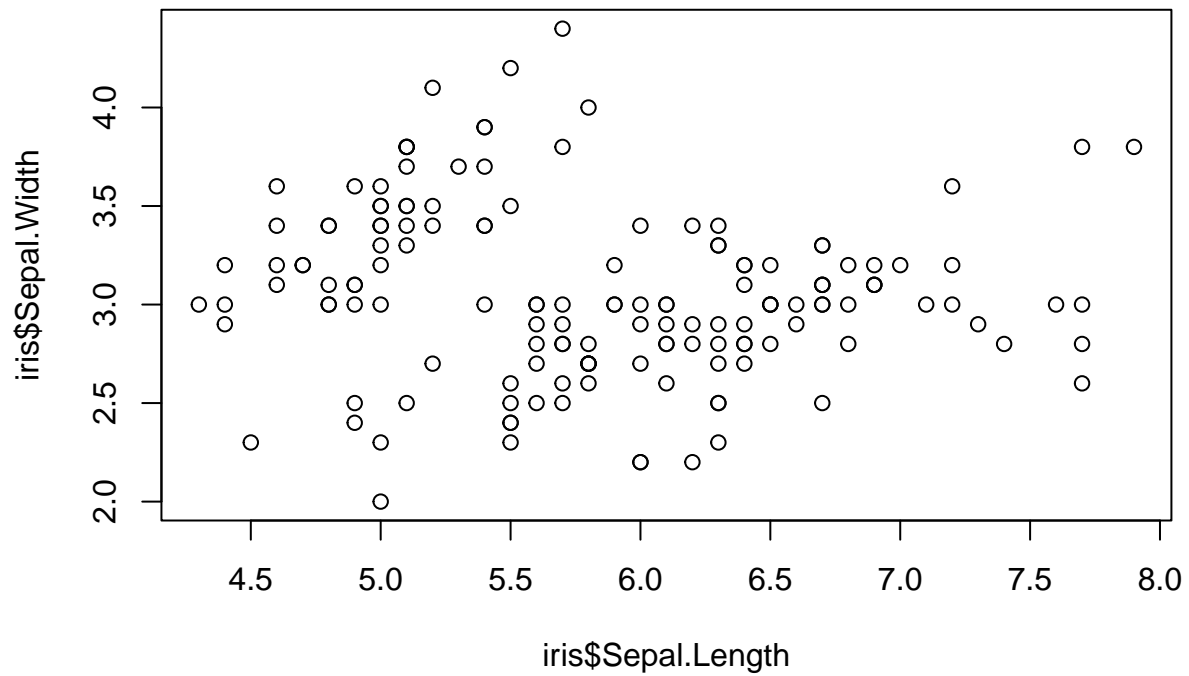
```
## Warning in plot.xy(xy, type, ...): "data" is not a graphical parameter
```

```
## Warning in axis(side = side, at = at, labels = labels, ...): "data" is not a
## graphical parameter
```

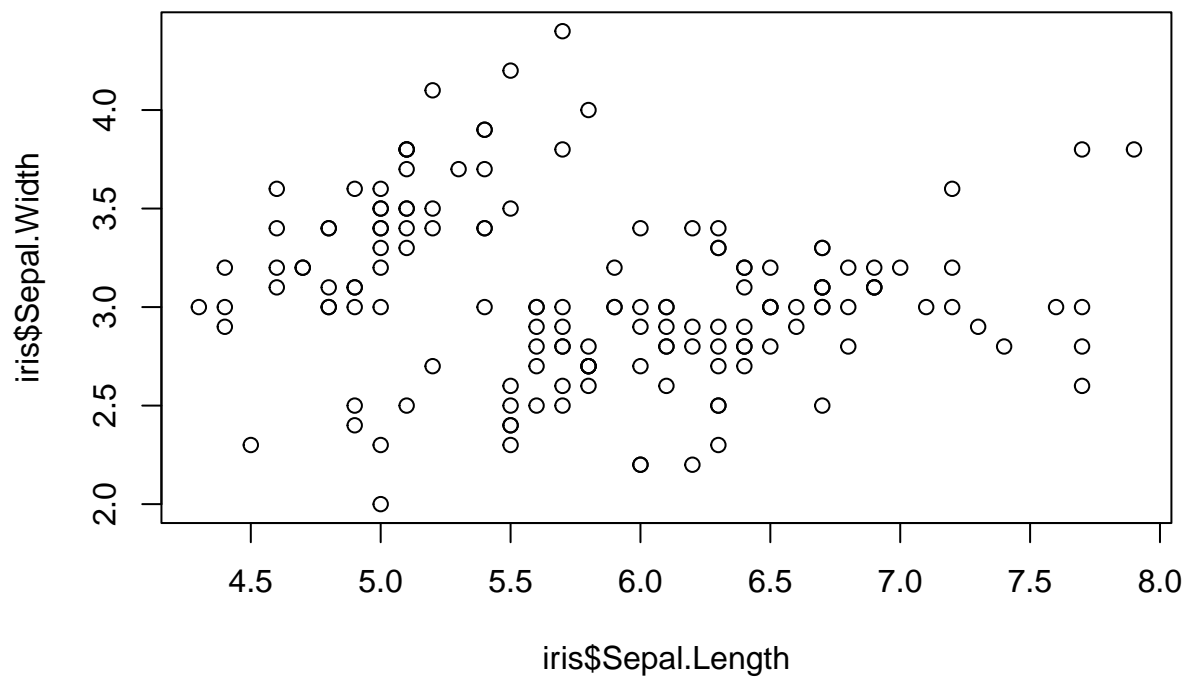
```
## Warning in axis(side = side, at = at, labels = labels, ...): "data" is not a
## graphical parameter
```

```
## Warning in box(...): "data" is not a graphical parameter
```

```
## Warning in title(...): "data" is not a graphical parameter
```

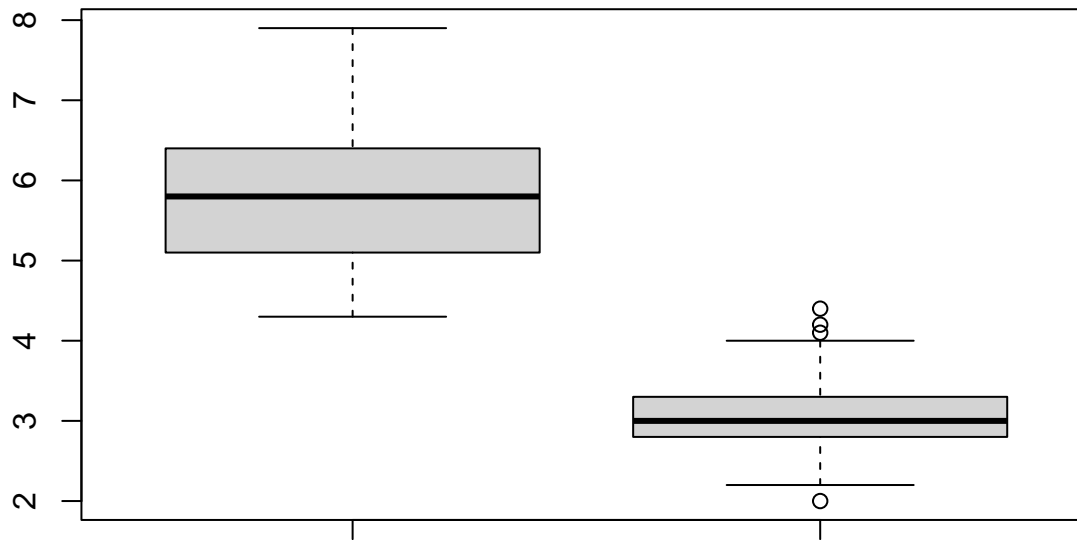


`plot(iris$Sepal.Length, iris$Sepal.Width) ## According to the error, this was plotted using a different`



4.2) Boxplot

```
boxplot(data=iris, iris$Sepal.Length, iris$Sepal.Width)
```

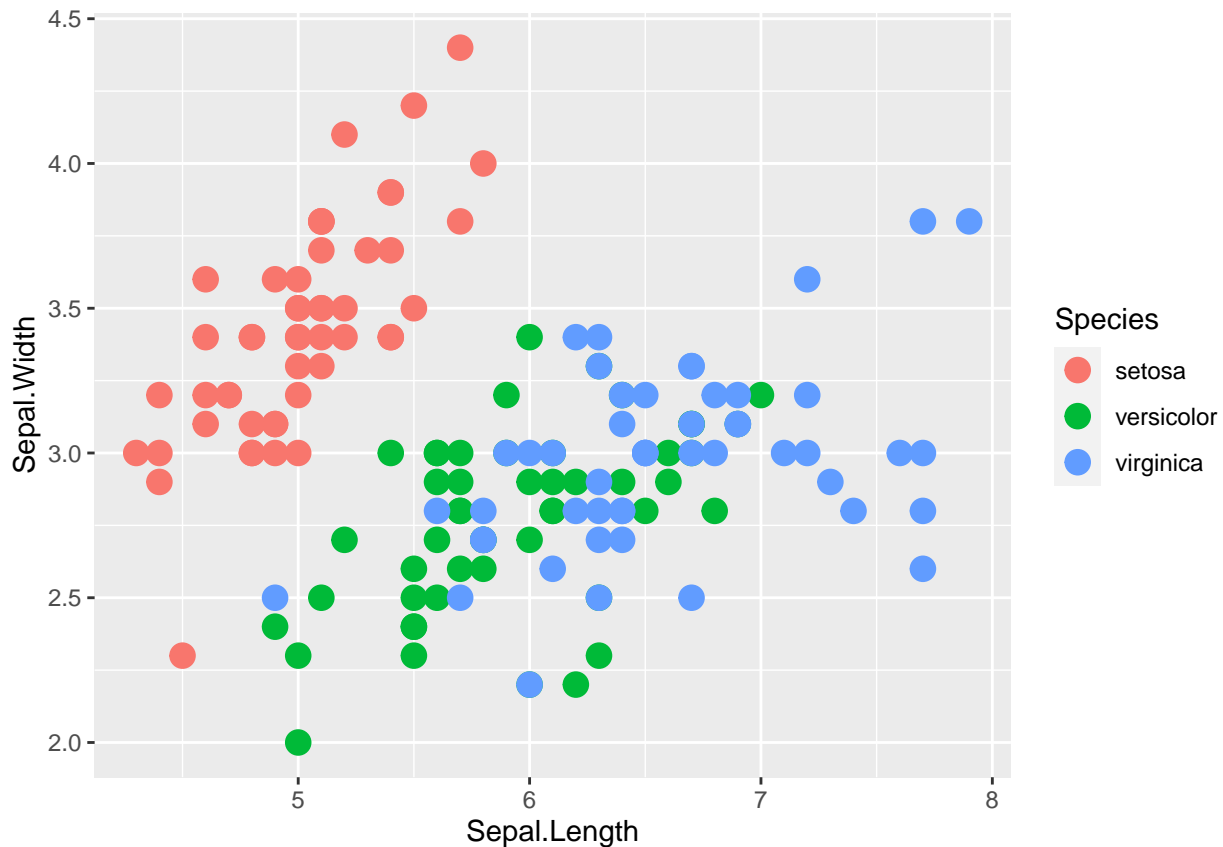


5) Data Visualization with specialized libraries

- In R, there are packages designed with the purpose of making good-looking graphics. This is the case with the ggplot2. The chunk below installs the ggplot2 library, loads the library into the R environment and then plots the data present in the iris data-frame.
- You can uncomment the installation line if you need to install it

5.1) Ggplot2

```
#install.packages("ggplot2")  
library(ggplot2)  
ggplot(data=iris, aes(x=Sepal.Length, y=Sepal.Width, color=Species)) + geom_point(size=4)
```



In our activities to visualize human genomic data, we will use a library called qqman, to visualize the biological association, through a plot known as the Manhattan plot.

5.2) Visualizing GWAS

- The simplest definition of a GWAS is the statistical or significant association between a phenotype (trait) and a genotype. This association can also be called *biological association*.
- Information about association of SNPs with Huntington's Disease can be found at the Chaves 2019 Huntington's disease paper

5.3.1) Package installation

- We need to install and load package qqman

```
## install.packages("qqman")
library(qqman)
```

```
##
```

```
## For example usage please run: vignette('qqman')
```

```
##
```

```
## Citation appreciated but not required:
```

```
## Turner, (2018). qqman: an R package for visualizing GWAS results using Q-Q and manhattan plots. Journal of Statistical Software
```

```
##
```

- After, we load data-frame to be visualized
- Exact location of text file in your system needs to be determined

```
GWAS_TABLE <- read.table("~/Desktop/Arquivos/chr4.txt",  
                          sep = " ",  
                          header = T)
```

5.3.3) Get information about object with head()

- Use head() function to inspect the data-frame just loaded

```
head(GWAS_TABLE, n = 10)
```

```
##      CHR      SNP      BP      P  
## 1      4 chr4:128096 128096 0.0133500  
## 2      4 chr4:516586 516586 0.0076260  
## 3      4 chr4:523979 523979 0.0024960  
## 4      4 chr4:527217 527217 0.0217400  
## 5      4 chr4:566177 566177 0.0008988  
## 6      4 chr4:578679 578679 0.0162100  
## 7      4 chr4:578790 578790 0.0103700  
## 8      4 chr4:579307 579307 0.0334600  
## 9      4 chr4:580259 580259 0.0190400  
## 10     4 chr4:585318 585318 0.0317600
```

5.3.4) Plotting GWAS data-frame

- In this section we use functions plot() and boxplot() to visualize data-frame
- In the y access, we see genomic coordinates and in the x access, p-valoues of the biological association
- Note that depending on the synthax used for plotting, R may complain

```
plot(data=GWAS_TABLE, GWAS_TABLE$BP, GWAS_TABLE$P) ## R complains
```

```
## Warning in plot.window(...): "data" is not a graphical parameter
```

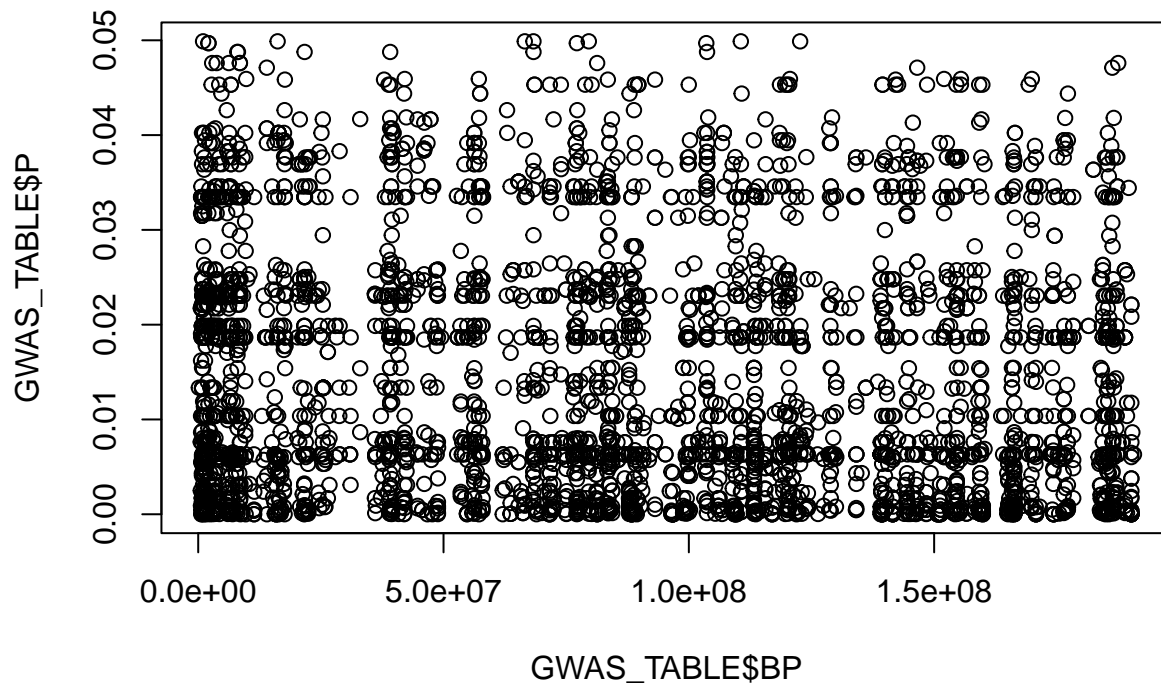
```
## Warning in plot.xy(xy, type, ...): "data" is not a graphical parameter
```

```
## Warning in axis(side = side, at = at, labels = labels, ...): "data" is not a  
## graphical parameter
```

```
## Warning in axis(side = side, at = at, labels = labels, ...): "data" is not a  
## graphical parameter
```

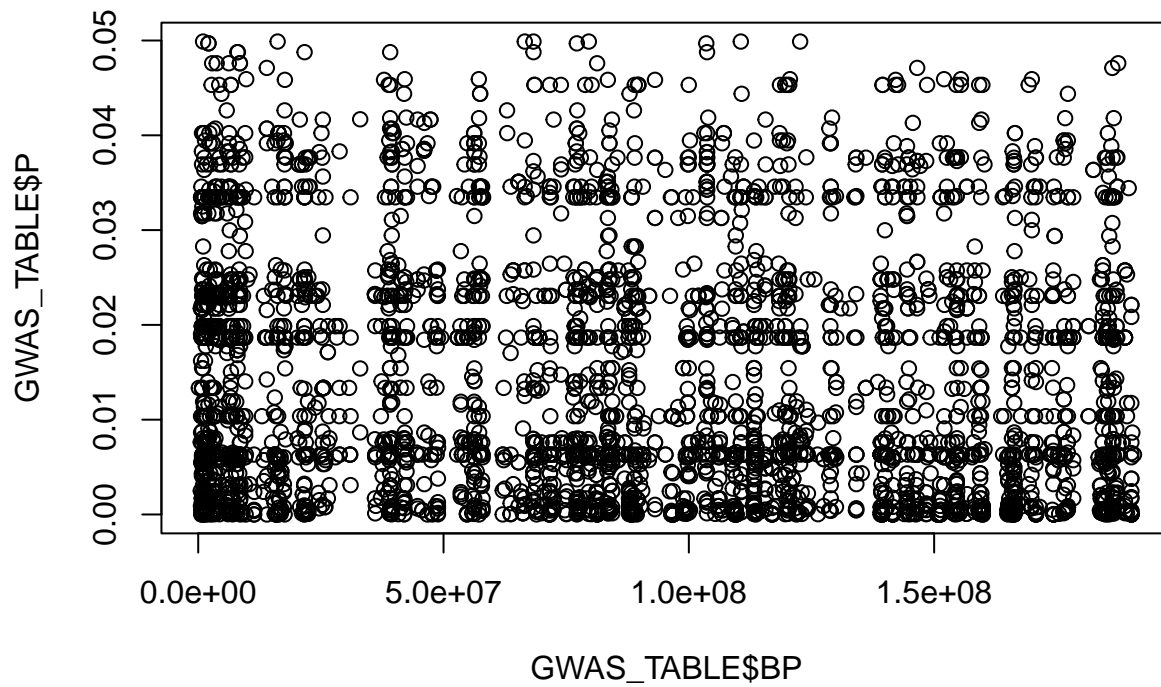
```
## Warning in box(...): "data" is not a graphical parameter
```

```
## Warning in title(...): "data" is not a graphical parameter
```



5.3.4) Plotting GWAS data-frame

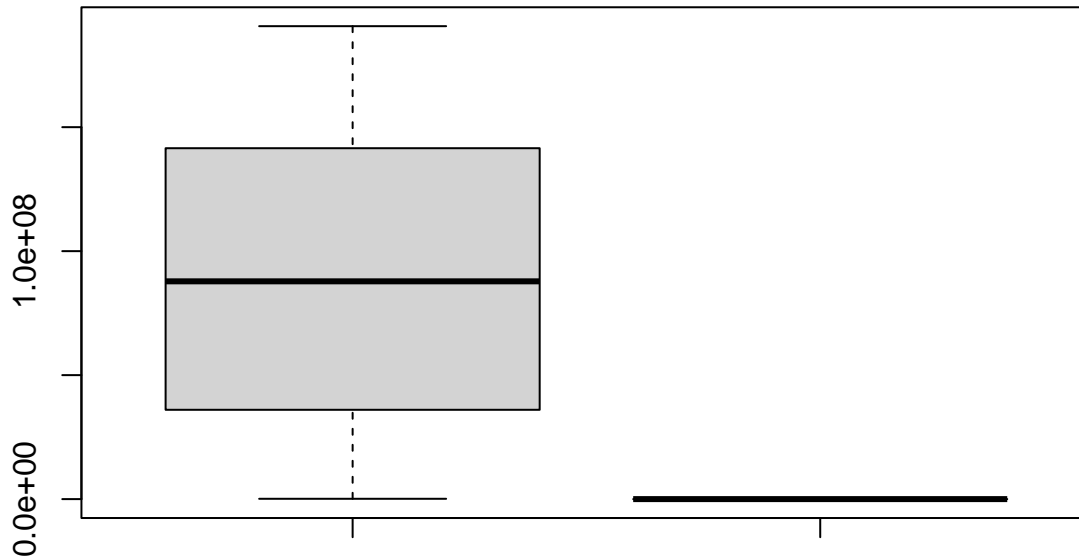
```
plot(GWAS_TABLE$BP, GWAS_TABLE$P) ## R does not complain
```



5.4) Boxplot

- Boxplot

```
boxplot(data=GWAS_TABLE, GWAS_TABLE$BP, GWAS_TABLE$P)
```



5.5) Boxplot

- Compare the chromosomal coordinates and the values of the p-values in the boxplot above
- The chunk below allows one to omit NA values in data-frame

```
GWAS_TABLE_Ommit <- na.omit(GWAS_TABLE)
```

A seguir, criamos uma variável que armazena as posições das SNPs a serem realçadas em verde no Manhattan plot. Estas SNPs são mutações biológica e estatisticamente associadas à Doença de Huntington no gene de uma sortilina, localizada em proximidade física ao gene da proteína huntingtina mutada, a qual é a causadora medeliana (segue as leis de segregação genética de Mendel) da Doença de Huntington.

5.6) Create vector to highlight genome coordinates in Manhattan plot

```
SNP_HIGHLIGHT <- c("chr4:3043512", "chr4:3043513", "chr4:3048207", "chr4:3224216",  
  "chr4:3231772", "chr4:3233844", "chr4:3235081", "chr4:3235084",  
  "chr4:3236881", "chr4:3236883", "chr4:3241845", "chr4:3243804",  
  "chr4:3263138", "chr4:3265130", "chr4:3265710", "chr4:3314646",  
  "chr4:3380088", "chr4:3409359", "chr4:3411110", "chr4:3415336",  
  "chr4:3415378", "chr4:3438643", "chr4:3446091", "chr4:3449886",  
  "chr4:3473066", "chr4:3476809", "chr4:3480439", "chr4:3487151",  
  "chr4:3496058", "chr4:3496110", "chr4:3506933", "chr4:3508752",  
  "chr4:3510957", "chr4:3512690", "chr4:3517746", "chr4:3518190",  
  "chr4:3529671", "chr4:3532327", "chr4:3533066", "chr4:3746133",  
  "chr4:3747842", "chr4:3748134", "chr4:3765305", "chr4:3765336",
```

```

"chr4:3944253", "chr4:3944752", "chr4:3944888", "chr4:3946166",
"chr4:3946175", "chr4:3969218", "chr4:4051294", "chr4:4076788",
"chr4:4103104", "chr4:4103105", "chr4:4109198", "chr4:4109210",
"chr4:4240627", "chr4:4242705", "chr4:4243668", "chr4:4245210",
"chr4:4245510", "chr4:4245513", "chr4:4245591", "chr4:4245926",
"chr4:4245929", "chr4:4246109", "chr4:4246433", "chr4:4246453",
"chr4:4246457", "chr4:4246497", "chr4:4249414", "chr4:4249415",
"chr4:4249484", "chr4:4271623", "chr4:4275306", "chr4:4304749",
"chr4:4318931", "chr4:4318970", "chr4:4319564", "chr4:4319728",
"chr4:4319750", "chr4:4322078", "chr4:4709657", "chr4:4732282",
"chr4:4789635", "chr4:4822960", "chr4:4824890", "chr4:4825092",
"chr4:4825180", "chr4:4865316", "chr4:4865321", "chr4:5018702",
"chr4:5812778", "chr4:5814082", "chr4:5833660", "chr4:5833899",
"chr4:5835541", "chr4:5851205", "chr4:5862752", "chr4:5862938",
"chr4:5862943", "chr4:5901873", "chr4:5905499", "chr4:5906287",
"chr4:6018891", "chr4:6019046", "chr4:6020190", "chr4:6020367",
"chr4:6025638", "chr4:6025656", "chr4:6025766", "chr4:6026058",
"chr4:6083488", "chr4:6204935", "chr4:6235553", "chr4:6237142",
"chr4:6238466", "chr4:6239906", "chr4:6240929", "chr4:6245022",
"chr4:6245618", "chr4:6245732", "chr4:6245915", "chr4:6246075",
"chr4:6246373", "chr4:6246959", "chr4:6290594", "chr4:6292020",
"chr4:6294095", "chr4:6298375", "chr4:6316092", "chr4:6321396",
"chr4:6324647", "chr4:6324785", "chr4:6327669", "chr4:6328354",
"chr4:6328507", "chr4:6333130", "chr4:6333559", "chr4:6333669",
"chr4:6335966", "chr4:6435341", "chr4:6435486", "chr4:6435926",
"chr4:6437191", "chr4:6437197", "chr4:6457121", "chr4:6457131",
"chr4:6457132", "chr4:6568390", "chr4:6570032", "chr4:6570768",
"chr4:6596360", "chr4:6613252", "chr4:6613462", "chr4:6620991",
"chr4:6624771", "chr4:6626154", "chr4:6641969", "chr4:6642090",
"chr4:6644466", "chr4:6644467", "chr4:6644468", "chr4:6647889",
"chr4:6648300", "chr4:6662665", "chr4:6663319", "chr4:6663715",
"chr4:6674554", "chr4:6678553", "chr4:6678599", "chr4:6690535",
"chr4:6698664", "chr4:6698667", "chr4:6698706", "chr4:6720572",
"chr4:6911679", "chr4:6985889", "chr4:6987394", "chr4:7002344",
"chr4:7004495", "chr4:7004506", "chr4:7005196", "chr4:7005199",
"chr4:7024077", "chr4:7024398", "chr4:7029430", "chr4:7031064",
"chr4:7044357", "chr4:7044380", "chr4:7048842", "chr4:7052115",
"chr4:7055253", "chr4:7064243", "chr4:7067765", "chr4:7073187",
"chr4:7074027", "chr4:7677967", "chr4:7701947", "chr4:7702795",
"chr4:7703505", "chr4:7703807", "chr4:7704795", "chr4:7704818",
"chr4:7709703", "chr4:7712150", "chr4:7714490", "chr4:7733843",
"chr4:7735162", "chr4:7735164", "chr4:7736103", "chr4:7736112")

```

5.7) Biological Association Visualization: Manhattan Plot

- Finally, we plot the Manhattan plot graph

```

manhattan(GWAS_TABLE_Ommit,
          highlight = SNP_HIGHLIGHT,
          annotateTop = T,
          annotatePval = 0.20,
          genomewideline = -log10(0.0001))

```

