

Learning, Teaching
and Student Engagement



Cairns
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Basics of R Studio

The module covers concepts such as:

- Setting up R Studio
- Getting Data into R
- Tidying Data
- Basic Analysis
- Data Visualization with ggplot2

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1. Setting Up R-Studio

The R Studio Interface

When opening R Studio, you will be presented with the following screen. The colours and fonts may vary depending on your Operating System but the layout will be the same.

This tab provides a list of commands that have been previously run

① The Console
Commands will be run and the results output here
(R Scripts and dataframes will also be displayed in the top half of this box)

② The Environment
An organised list of your created Variables will appear here

③ Your Plots
Your graphs and plots will be displayed here

④ The Files
This tab shows the computer's file system

This tab shows R packages installed or available to install

This tab provides help and documentation for all commands

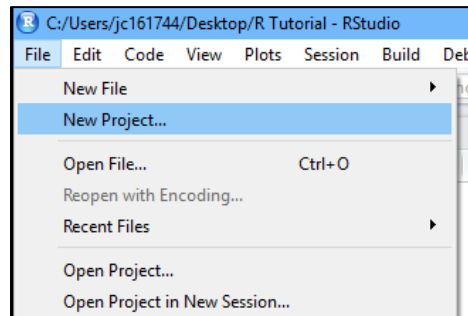
On creating a new R script (see next section), the script panel will open. You will write your R code/script in here and it will be run in the console.

④ Your Script
When starting a new R script, this pane will open. You write your code here and it will run in the console.

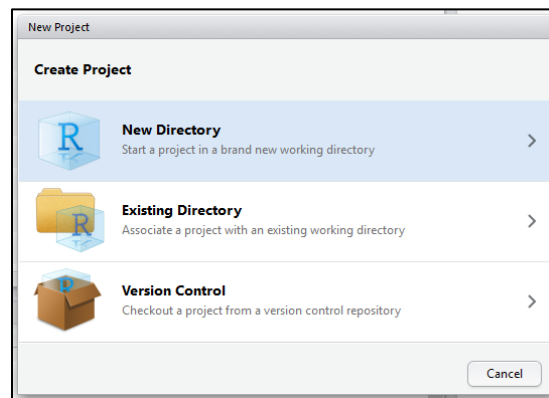
① The Console
Commands will be run and the results output here.

Start a New Project in R

When starting to work with a new dataset, a New Project should be created.



Creating a New Directory makes a default working directory and a logical place to store all associated files such as raw data spreadsheets.



Any associated excel documents or text files can be saved into this new folder and easily accessed from within R. You can then perform data analysis or produce visualisations with your imported data.

Directions:

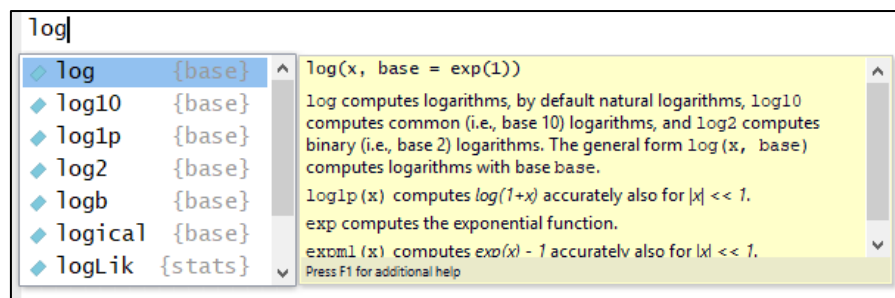
1. Open R Studio
2. Create a New Project using a New Directory in a location of your choosing

2. Basic Commands in R Studio

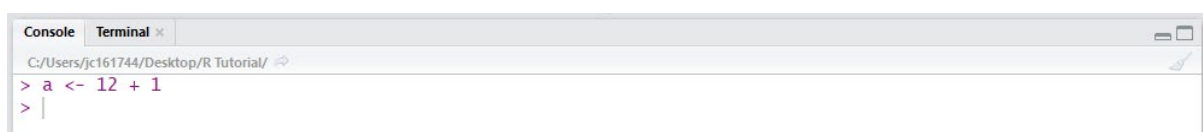
Run a Command

Base R Cheat Sheet: <https://www.rstudio.com/resources/cheatsheets/>

Commands in R can be entered directly into the console at the bottom left of the screen. Entering 3 or more characters of a command into the console or a script will open the suggested command menu. This menu suggests commands or the names of variables you have intended to type, alongside a description and suggested use. Entering `?` followed by any R command will open a help page in the help tab found in the bottom right hand corner of the screen (eg. `?log10` opens the log10 help page). This help page will offer settings and formatting for each command, as well as an example.



On completing a command and pressing `enter`, R will immediately run the code, print the output and move to a new line. Using the `↑` key will repeat the last command entered into the console.



At its heart, R is a calculator and can accept any mathematical calculation directly into the console. The following table represents just a few of the available mathematical operators:

R Command	Mathematical Operator	Example
<code>*</code>	x (multiply)	<code>10 * 2 = 20</code>
<code>/</code>	÷ (divide)	<code>50 / 2 = 25</code>
<code>^</code>	(exponent/power)	<code>10^2 = 10² = 100</code>
<code>log10(x)</code>	<code>log₁₀x</code>	<code>log10(100) = 2</code>
<code>log(x, base)</code>	<code>log_{base}x</code>	<code>log(25,5) = 2</code>
<code>sum(a,b,c)</code>	<code>a + b + c</code>	<code>sum(1,2,3,4) = 10</code>

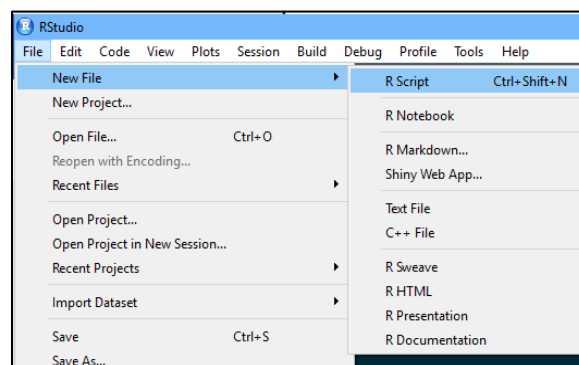
Directions:

Enter the following commands into the console, pressing enter after every line:

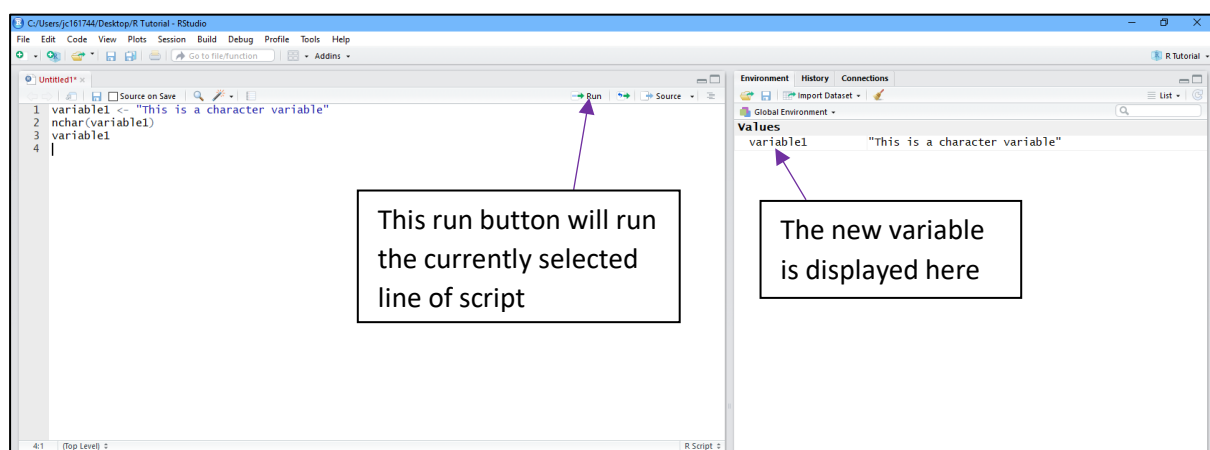
1. $(5^2+5)/3$
2. $\log_{10}(90+5*2)$
3. `sum(50, 3, 5)`
4. `sum(log(32,2), 8^4, 4+5, 12/3)`

Using R Scripts

Commands can be run directly from the console, but creating an R Script allows you to edit and reuse previous commands and to create more complicated lists of commands. A script also allows you to save your commands to be reopened later.

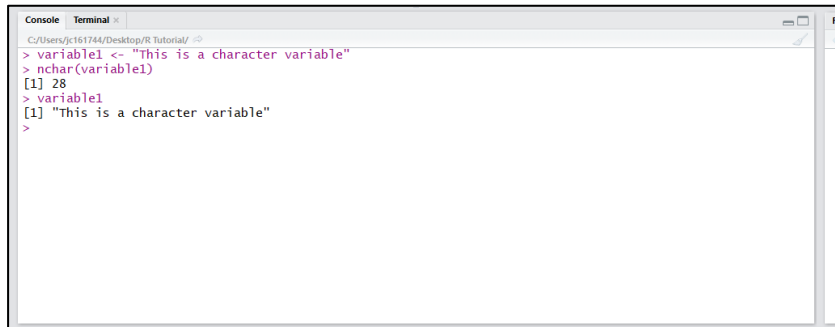


Multiple commands can be entered into a script, one after the other across multiple lines.



The script above creates a new variable called `variable1` with the value "This is a character variable". The next command counts the number of characters in the variable. The final command returns the value of `variable1`.

To run the script one line at a time, navigate the cursor to the appropriate line and press **CTRL + Enter**. To run all commands from the start, press **CTRL + Shift + Enter**.

A screenshot of an R console window. The window has a title bar with 'Console' and 'Terminal' tabs. The path 'C:/Users/jc161744/Desktop/R Tutorial/' is visible. The console shows the following commands and output:

```
> variable1 <- "This is a character variable"
> nchar(variable1)
[1] 28
> variable1
[1] "This is a character variable"
>
```

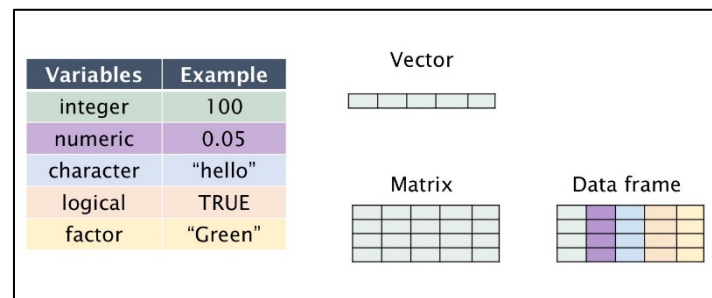
Directions:

1. Create a new script
2. Enter the following code into your script:
variable2 <- c(12,1,15,3,20,6,11)
variable2
mean(variable2)
variable2 + 2
3. Run your code (Ctrl + Shift + Enter)
4. Save your script

3. Getting Data into R-Studio

Getting Data into R

Variables can be thought of as a labelled container used to store information. Variables allow us to recall saved information to later use in calculations. Variables can store many different things in R studio, from single values to tables of information, images and graphs.



(Source: https://sydney-informatics-hub.github.io/lessonbmc/02-BMC_R_Day1_B/index.html)

Assigning a Value to a Variable:

Storing a value or “assigning” it to a variable is completed using either `<-` or `=` function. The name given to a variable should describe the information or data being stored. This helps when revisiting old code or when sharing it with others.

A screenshot of the R Studio code editor window titled 'Untitled1*'. The code contains four lines of assignments:

```
1 first_number <- 1
2 a_character <- "a"
3 some_logic <- TRUE
4 a_factor <- "Red"
5 |
```

Annotations include a box labeled 'Variable Name' with an arrow pointing to 'first_number' in line 1, and a box labeled 'Value' with an arrow pointing to 'Red' in line 4.

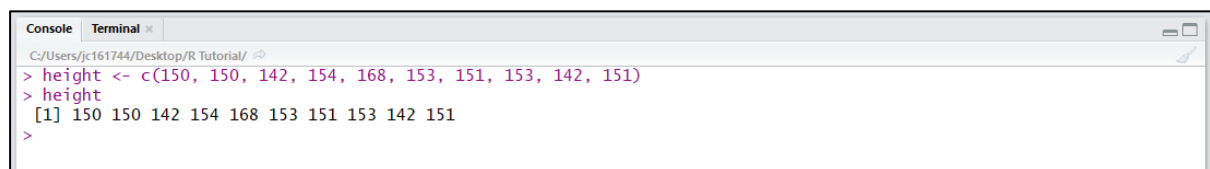
Creating a Vector

A variable can hold one value or many values. A vector is used to store more than one value of the same type. The *combine* or *c()* function (type `?c` in the console for the further information) allows us to combine them into a single list of values.

Example:

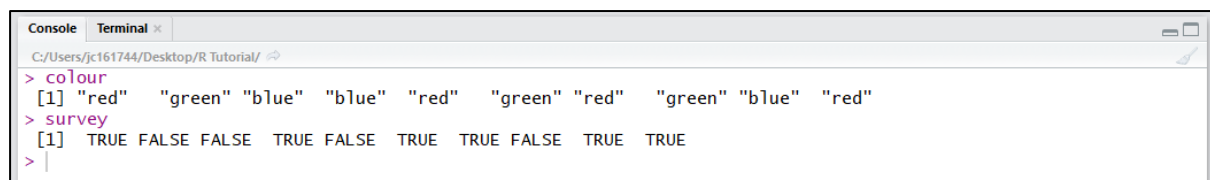
A class of 10 students have been surveyed and their heights recorded:
150cm, 150cm, 142cm, 154cm, 168cm, 153cm, 151cm, 153cm, 142cm and 151cm

To begin analysing this data in R, the values must be stored in a variable. In the following, the variable *height* has been created to contain our values:



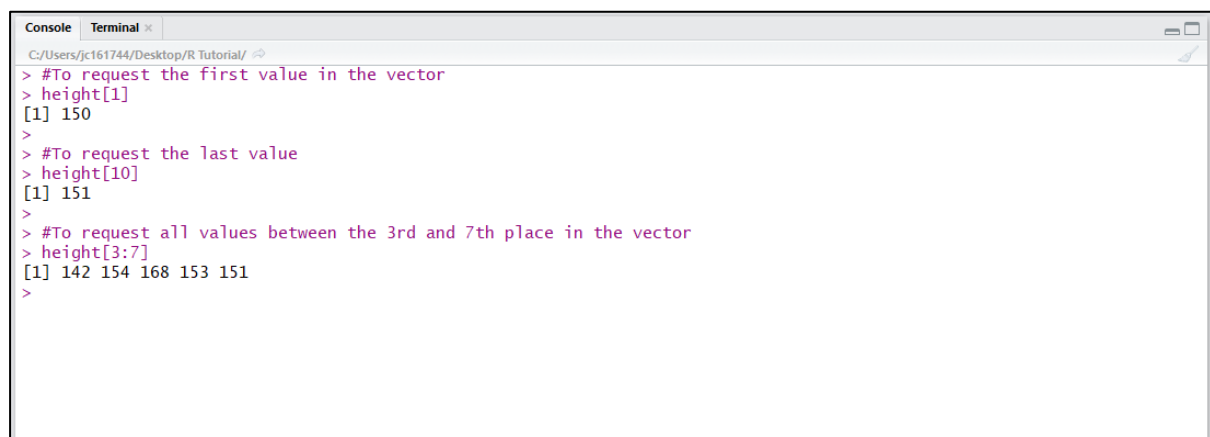
```
Console Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> height <- c(150, 150, 142, 154, 168, 153, 151, 153, 142, 151)
> height
[1] 150 150 142 154 168 153 151 153 142 151
>
```

The vector can then be recalled using the variable name *height*. Vectors for colour (text strings) and survey (logical values) have also created.



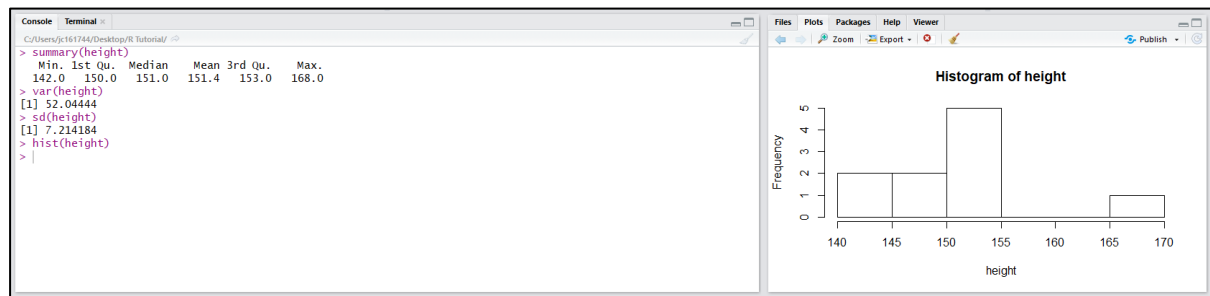
```
Console Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> colour
[1] "red" "green" "blue" "blue" "red" "green" "red" "green" "blue" "red"
> survey
[1] TRUE FALSE FALSE TRUE FALSE TRUE TRUE FALSE TRUE TRUE
>
```

To recall a single value from the vector, use the variable name followed by the position of the value in the list and surrounded by `[]` brackets.



```
Console Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> #To request the first value in the vector
> height[1]
[1] 150
>
> #To request the last value
> height[10]
[1] 151
>
> #To request all values between the 3rd and 7th place in the vector
> height[3:7]
[1] 142 154 168 153 151
>
```

Useful statistical analysis can be performed on single set of values using vectors:



Combining Vectors into a Dataframe

A dataset will often contain more than 1 variable of interest. To combine vectors of the same length together into a table or “dataframe” (similar to an excel table), we use the `data.frame()` command. Below we have combined 3 vectors (colour, height and survey), containing 10 values each, together into a dataframe. The table has been assigned to the variable `table`.

```
> table <- data.frame(colour, height, survey)
> table
  colour height survey
1    red    150   TRUE
2  green    150  FALSE
3   blue    142  FALSE
4   blue    154   TRUE
5    red    168  FALSE
6  green    153   TRUE
7    red    151   TRUE
8  green    153  FALSE
9   blue    142   TRUE
10   red    151   TRUE
```

Columns

Header row

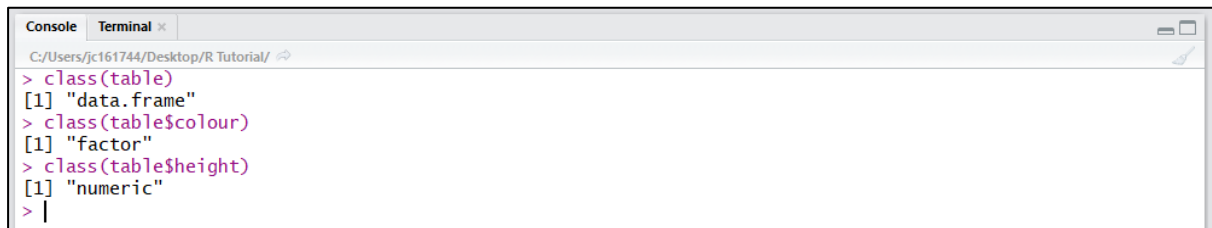
Values

The top line of the dataframe is called the header row and contains a descriptive name for the values in each column.

Below the header row, values can be referred to individually or in whole rows and columns. To retrieve a single value from a dataframe assigned to a variable, the variable name is used then followed by the coordinates of the value within [row, column] square brackets (eg. `table[2,1]` returns green and `table[3,2]` returns 142). Whole rows can be returned individually using coordinates (eg. `table[3,]` returns all values for row 3). Single columns can be returned by either referring to them using a coordinate with the row blank (eg. `table[,3]` returns all values in 3rd column), or by using the variable name followed by a `$` and the column header (eg. `table$height` returns all “height” values from the dataframe “table”).

```
> table[2,1]
[1] green
Levels: blue green red
> table[3,2]
[1] 142
> table[,3]
[1] TRUE FALSE FALSE TRUE FALSE TRUE TRUE FALSE TRUE TRUE
> table$height
[1] 150 150 142 154 168 153 151 153 142 151
> |
```

Note: You can find out what type of data is stored within a variable or a column in a dataframe using the `class()` function.

A screenshot of an R console window. The window has a title bar with 'Console' and 'Terminal' tabs. The address bar shows the path 'C:/Users/jc161744/Desktop/R Tutorial/'. The console contains the following text:

```
> class(table)
[1] "data.frame"
> class(table$colour)
[1] "factor"
> class(table$height)
[1] "numeric"
> |
```

Some examples of classes are: “matrix”, “data.frame”, “array”, “factor”, “numeric”, “logic”

Directions:

1. Create vectors
2. Create a dataframe
3. Use coordinates to find cells
4. Use coordinates to find rows/columns
5. Use variable names
6. Use coordinates to produce a table WITHOUT a row or column

Importing an Excel File into R

In Excel, simplify your table to basic column titles and no unnecessary data as R will attempt to manipulate the structure into columns. Save your excel file in *.csv (MS-DOS) into your R Project folder. In R Studio use the `read.csv` function with your file name in "" to read:

```
> new_dataframe <- read.csv("example.csv")
> new_dataframe
  Colour Taste weight size eaten
1    red  sweet    1.2   5.6 FALSE
2    blue   sour    1.4   6.2 FALSE
3   green   sour    1.1   5.3  TRUE
4 orange  salty    1.3   5.9  TRUE
5 purple  salty    1.6   6.8  TRUE
6 orange  salty    1.3   5.9 FALSE
7 purple  salty    1.6   6.8 FALSE
8    blue   sour    1.4   6.2  TRUE
9   green   sour    1.1   5.3  TRUE
10   red  sweet    1.2   5.6 FALSE
11 green   sour    1.1   5.3 FALSE
12 orange  salty    1.7   7.1 FALSE
13 purple  salty    1.6   6.8 FALSE
14 orange  salty    1.6   6.8  TRUE
15 purple  salty    1.6   6.8 FALSE
16   blue   sour    1.3   5.9  TRUE
```

① Read the *.csv file in R
(this will not be saved unless you assign it to a variable)

② Assign the data from the file to a variable

③ Open the variable to confirm the data

The `read.csv` function can include settings or parameters that may need to be set for the file to be read correctly (see `?read.csv` for more info). Parameters are entered after the file name and separated by a comma. Some of the more useful parameters are shown below:

```
> read.csv("example.csv", sep = ",", header = TRUE, dec = ".")
  Colour Taste weight size eaten
1    red  sweet    1.2   5.6 FALSE
2    blue   sour    1.4   6.2 FALSE
3   green   sour    1.1   5.3  TRUE
4 orange  salty    1.3   5.9  TRUE
5 purple  salty    1.6   6.8  TRUE
6 orange  salty    1.3   5.9 FALSE
7 purple  salty    1.6   6.8 FALSE
8    blue   sour    1.4   6.2  TRUE
9   green   sour    1.1   5.3  TRUE
10   red  sweet    1.2   5.6 FALSE
11 green   sour    1.1   5.3 FALSE
12 orange  salty    1.7   7.1 FALSE
13 purple  salty    1.6   6.8 FALSE
14 orange  salty    1.6   6.8  TRUE
15 purple  salty    1.6   6.8 FALSE
16   blue   sour    1.3   5.9  TRUE
```

The file you want to import

How is each value in the *.csv file separated (normally with ",")?

Does the first row of your table contain the header row?

Does your data use a "." or a "," for decimals?
i.e. 12.1 vs 12,1

Note: Other read functions exist such as `readxl` to directly read xls files, but functionality and options vary. Help documentation can be found within R using the appropriate help command (eg. `?readxl` command for `readxl`).

4. Basic Tidying of your Data

Clean Up Your Data

As with all statistical software, your data must be in the correct format for visualisation and analysis to function correctly.

To check the type of each variable in a dataframe, the `class()` function could be used separately. A quicker way to check the variables in a dataframe is the structure or `str()` function, which displays all variables at once.

Variables	Example
integer	100
numeric	0.05
character	"hello"
logical	TRUE
factor	"Green"

```
Console Terminal
C:/Users/jc161744/Desktop/R Tutorial/
> str(new_dataframe)
'data.frame': 16 obs. of 5 variables:
 $ Colour: Factor w/ 5 levels "blue","green",...: 5 1 2 3 4 3 4 1 2 5 ...
 $ Taste : Factor w/ 3 levels "salty","sour",...: 3 2 2 1 1 1 1 2 2 3 ...
 $ weight: num 1.2 1.4 1.1 1.3 1.6 1.3 1.6 1.4 1.1 1.2 ...
 $ size : num 5.6 6.2 5.3 5.9 6.8 5.9 6.8 6.2 5.3 5.6 ...
 $ eaten : logi FALSE FALSE TRUE TRUE TRUE FALSE ...
>
```

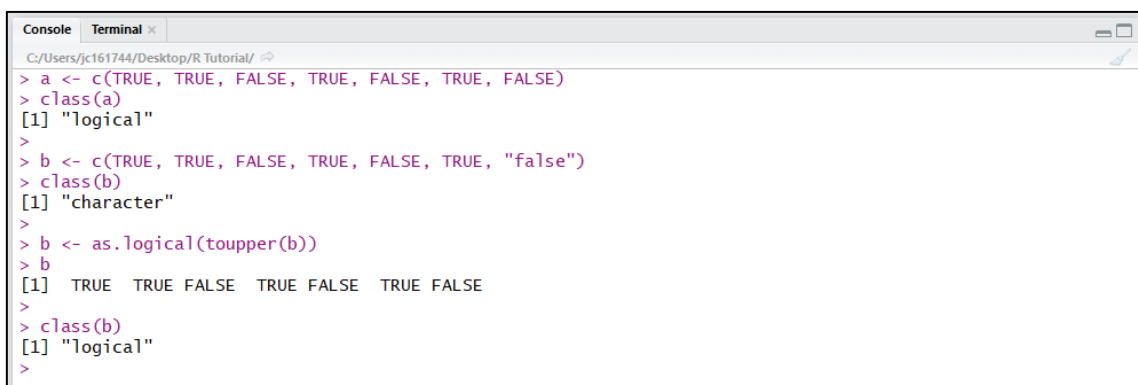
The first and second variables are categories or “factors”
The third variable is a number or “numeric”
The fourth is True/False or “logical”

While numeric variables generally cause few problems, logical and factor variables often do have issues due to R interpreting the variable type when importing from an Excel file.

- **Problem:** One of the logical values is in lower case (eg. TRUE, TRUE, false, FALSE), so all values are interpreted as a character type variable (“TRUE”, “TRUE”, “false”, “FALSE”). R interprets logical variables only if

all values are in CAPITAL letters. This prevents any analysis that relies on a comparison between the TRUE and FALSE values.

Solution: The problem is most easily fixed in Excel before the data is imported. Converting the variables in R can be achieved using the `toupper()` function.



```
Console | Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> a <- c(TRUE, TRUE, FALSE, TRUE, FALSE, TRUE, FALSE)
> class(a)
[1] "logical"
>
> b <- c(TRUE, TRUE, FALSE, TRUE, FALSE, TRUE, "false")
> class(b)
[1] "character"
>
> b <- as.logical(toupper(b))
> b
[1] TRUE TRUE FALSE TRUE FALSE TRUE FALSE
>
> class(b)
[1] "logical"
>
```

- **Problem:** R automatically converted categories into groups or “levels” but there were mixed upper and lower case letters (e.g “Green”, “GREEN” and “green” will all become different levels).

Solution: These are easily converted in Excel before importing to R-Studio, by converting all letters to either upper or lower case. Converting values between upper and lower case in R is achieved using the `toupper()` or `tolower()` functions which converts all values to the same case. This command also converts factors to character type variables. The `factor()` function is then used to convert the variable back into a factor, and determining new levels.

```
Console Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> a
[1] Red   Green Blue   Orange red
Levels: Blue Green Orange red Red
>
> a <- factor(toupper(a))
> a
[1] RED    GREEN  BLUE   ORANGE RED
Levels: BLUE GREEN ORANGE RED
> |
```

Note: There are methods of manually declaring levels in R and this information can be found in the help documentation (ie. `?factor`, `?gl`, `?levels`). If there is an order to the levels (high, medium and low these can also be declared – see help documentation)

- **Problem:** R has interpreted strings of text as factors

Solution: To convert a factor into text or “character” type variable the `as.character()` function is used.

```
Console Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> foodreviews
[1] Good      Great      Food was OK Excellent
Levels: Excellent Food was OK Good Great
>
> foodreviews <- as.character(foodreviews)
>
> foodreviews
[1] "Good"      "Great"      "Food was OK" "Excellent"
> class(foodreviews)
[1] "character"
>
```

- **Problem:** R has interpreted numeric data as factors

Solution: To convert a factor into a number is a 2 step process. The factor must be converted to a character first using `as.character()`, then converted to a number using `as.numeric()`.

```
Console Terminal x
C:/Users/jc161744/Desktop/R Tutorial/
> numbers
[1] 12.4 124.3 161.2 189.2
Levels: 12.4 124.3 161.2 189.2
> numbers <- as.numeric(as.character(numbers))
> numbers
[1] 12.4 124.3 161.2 189.2
>
```


5. Graphing in ggplot2

Graphing with ggplot2

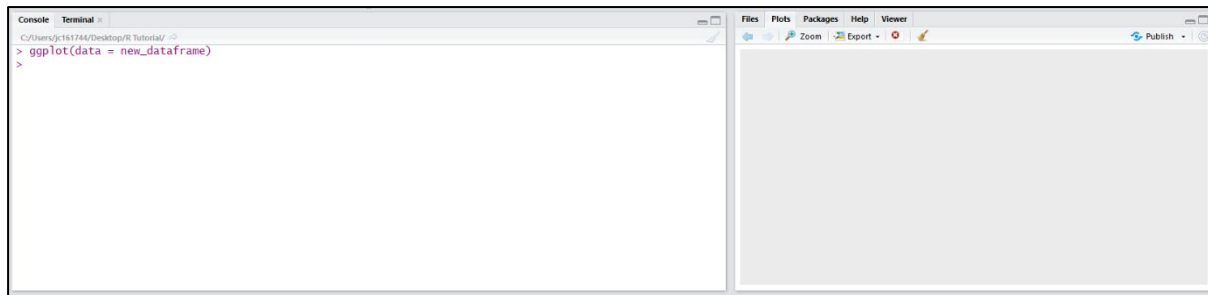
ggplot2 Cheatsheet: <https://raw.githubusercontent.com/rstudio/cheatsheets/main/gganimate.pdf>

While R comes with many useful functions built in, other plugins or “packages” can be downloaded and added to bring extra functionality. One of the more useful packages is ggplot2 (based on The Grammar of Graphics by Leland Wilkinson), which introduces a variety of powerful visualisation and graphing options.

The ggplot2 package must first be downloaded and installed into R Studio using the command `install.packages("ggplot2")`. This command will only need to be run once, as the package will then be available to load in the future. Once installed, the package must be loaded into your current R session using `library(ggplot2)`. The package will need to be loaded for every new R session/project.

```
99 install.packages("ggplot2")
100 library(ggplot2)
```

The package ggplot2 simplifies data visualisation. You provide the data, how the variables should be interpreted, and graphical options if required, while ggplot2 handles the details. To load the data that you would like to visualise, the `ggplot(data = yourdata)` function is used.



The next step is choosing a visualisation type or “geom”. This option comes after the ggplot function and they are separated by a `+`. There are many different types of graph and the choice of which to use depends on your data. The most common types are `geom_histogram` for a histogram, `geom_bar` for a bar chart, `geom_boxplot` for a box and whisker plot, `geom_point` for a scatterplot, and `geom_smooth` for a line of best fit or fitted curve. Many of these different graphs can be overlaid with other visualisations, with each requiring you to define the variable/s to display. Many also require extra parameters, all of which can be found in help documentation.

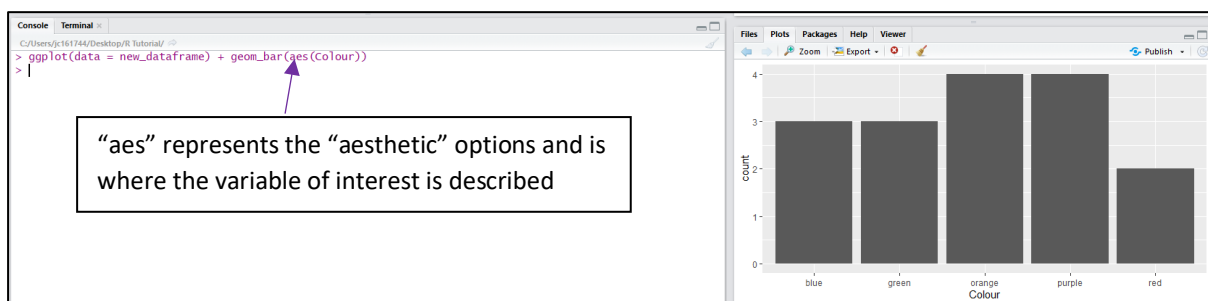
The following visualisation examples will use the following dataframe:

```

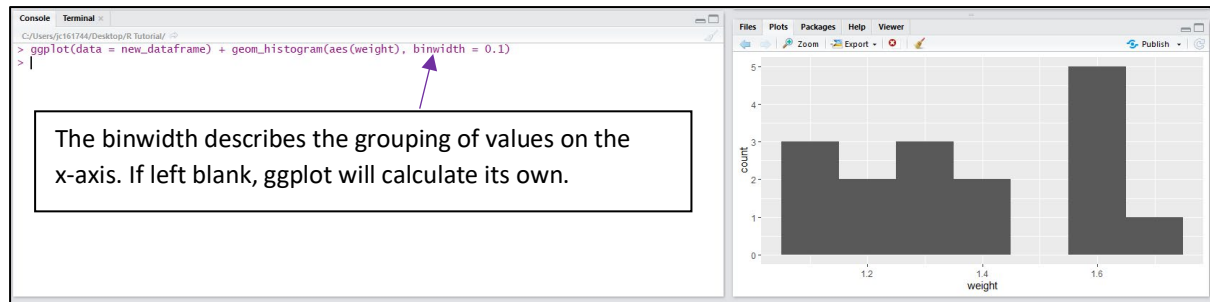
> new_dataframe
  Colour Taste weight size eaten
1    red sweet   1.2  5.6 FALSE
2    blue sour   1.4  6.2 FALSE
3   green sour   1.1  5.3  TRUE
4  orange salty   1.3  5.9  TRUE
5  purple salty   1.6  6.8  TRUE
6  orange salty   1.3  5.9 FALSE
7  purple salty   1.6  6.8 FALSE
8    blue sour   1.4  6.2  TRUE
9   green sour   1.1  5.3  TRUE
10   red sweet   1.2  5.6 FALSE
11  green sour   1.1  5.3 FALSE
12  orange salty   1.7  7.1 FALSE
13  purple salty   1.6  6.8 FALSE
14  orange salty   1.6  6.8  TRUE
15  purple salty   1.6  6.8 FALSE
16   blue sour   1.3  5.9  TRUE

```

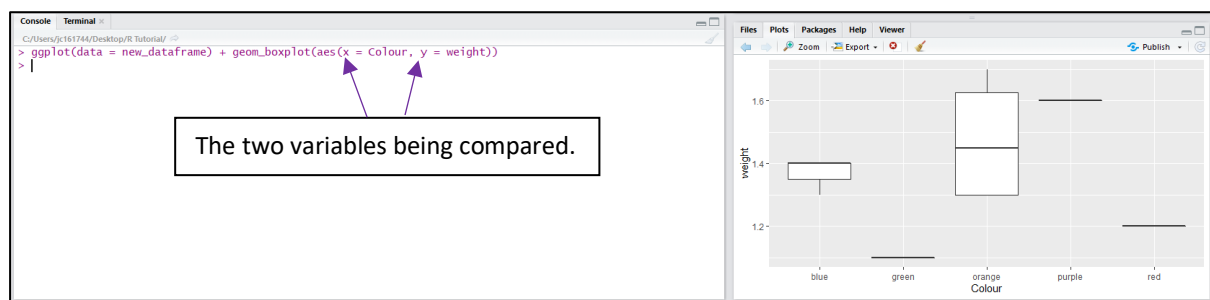
A bar chart representing the frequency for each “colour”:



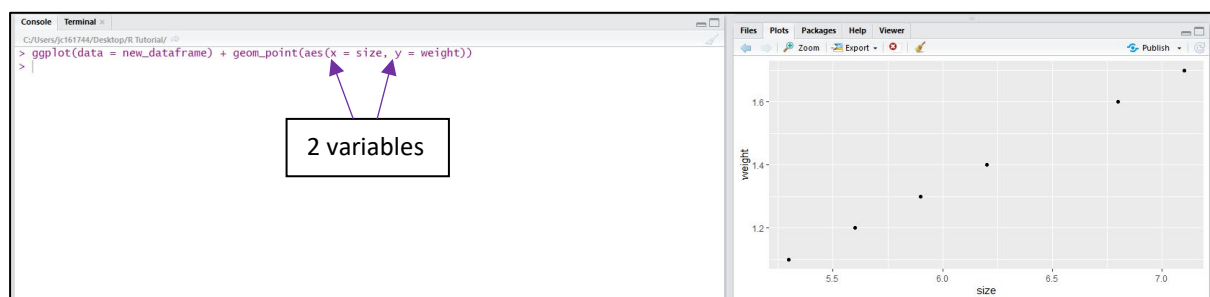
A histogram representing the range of “weight”:



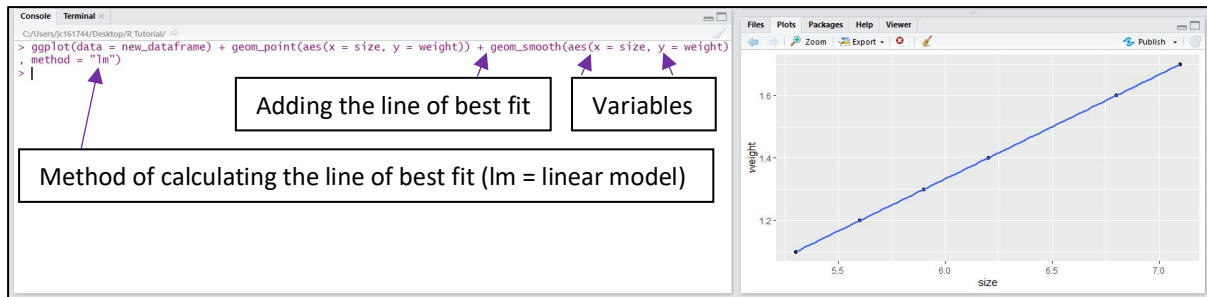
A box and whisker plot representing the “weight” for each “colour”:



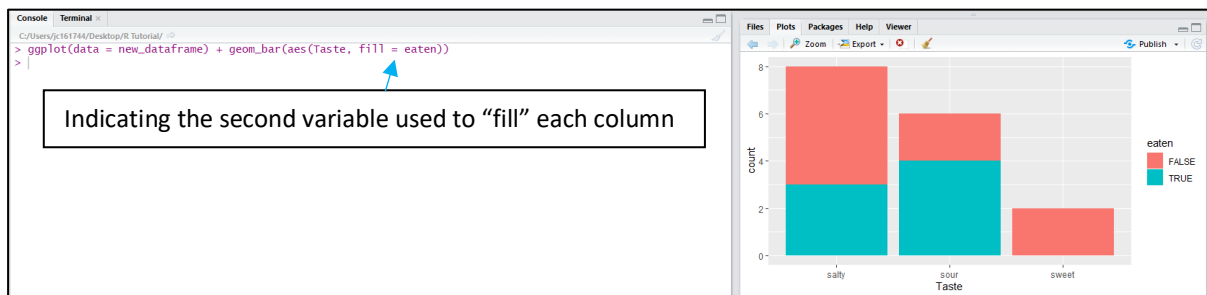
A scatterplot representing “size” compared to “weight”:



The above scatterplot but with a fitted line using a linear model:



A bar chart representing the frequency of “taste” and the ratio of “eaten” for each:



Basic R Studio Tutorials

- <https://data-flair.training/blogs/rstudio-tutorial/>

More ggplot2 graphing ideas can be found at:

- <https://ggplot2.tidyverse.org/>
- <https://www.r-graph-gallery.com/>
- <http://r-statistics.co/Top50-Ggplot2-Visualizations-MasterList-R-Code.html>
- <https://datacarpentry.org/R-ecology-lesson/04-visualization-ggplot2.html>

Official R Cheat Sheets can be found at:

- <https://rstudio.com/resources/cheatsheets/>



[**www.jcu.edu.au/students/learning-centre**](http://www.jcu.edu.au/students/learning-centre)