Getting Started in R

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Are you curious to learn what R can do for you? Do you want to see how it works? Yes, then this "Getting Started" guide is for you. It uses realistic examples and a real life dataset to manipulate, visualise and summarise data. By the end of it you will have an overview of the key concepts of R and the "tidyverse" package.

R | Tiyverse | Statistics | Data Science

1. Preface

This "Getting Started" guide will give you a flavour of what R[1] and the tidyverse can do for you. To get the most out of this guide, read it whilst doing the examples and exercises using RStudio[2]^.

Experiment Safely. Be brave and experiment with commands and options as it is an essential part of the learning process. Things can (and will) go "wrong", like, getting error messages or deleting things that you create by using this guide. You can recover from most situations (e.g. by restarting R). To do this "safely" start with a *fresh* R session without any other data loaded (otherwise you could lose it).

2. Introduction

Before Starting. Make sure that:

1. R and RStudio are installed.
2. http://ilustat.com/shared/Getting-Started-in-R.zip has been downloaded and unzipped
3. Double click `"Getting-Started-in-R.Rproj"` to open RStudio with the setup for this guide.

Starting R & RStudio. R starts automatically when you open RStudio (see Figure 1). The console starts with information about the version number, license and contributors. The last line is a standard prompt ">" that indicates R is ready and expecting instructions to do something.

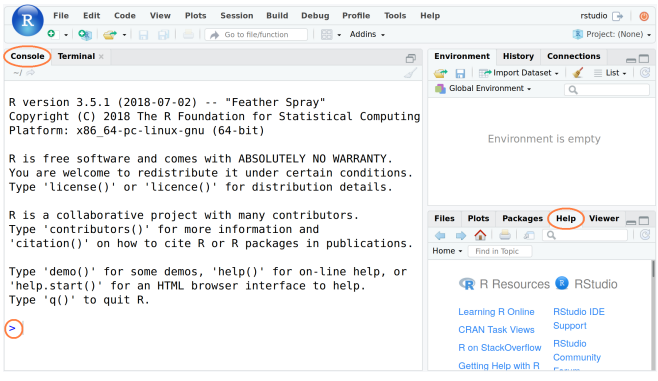


Fig. 1. RStudio Screenshot with Console on the left and Help tab in the bottom right

Quitting R & RStudio. When you quit RStudio you will be asked whether to `Save workspace` with two options:

- "Yes" – Your current R workspace (containing the work that you have done) will be restored next time you open RStudio.
- "No" – You will start with a fresh R session next time you open RStudio. For now select "*No*" to prevent errors being carried over from previous sessions).

3. R Help

I strongly recommend that you learn how to use R's useful and extensive built-in help system which is an essential part of finding solutions to your R programming problems.

`help()` function. From the R "Console" you can use the `help()` function or `?`. For example, try the following two commands (which give the same result):

```
help(mean)
?mean
```

Keyword search. To do a keyword search use the function `apropos()` with the keyword in double quotes (`"keyword"`) or single quote (`'keyword'`). For example:

```
apropos("mean")
#   [1] ".colMeans"       ".rowMeans"
#   [3] "colMeans"        "cummean"
#   [5] "kmeans"          "mean"
#   [7] "mean_cl_boot"    "mean_cl_normal"
#   [9] "mean_sdl"        "mean_se"
#  [11] "mean.Date"       "mean.default"
#  [13] "mean.difftime"   "mean.POSIXct"
#  [15] "mean.POSIXlt"    "rowMeans"
#  [17] "weighted.mean"
```

Help Examples. Use the `example()` function to run the examples at the end of the help for a function:

```
example(mean)
#
#  mean> x <- c(0:10, 50)
#
#  mean> xm <- mean(x)
#
#  mean> c(xm, mean(x, trim = 0.10))
#  [1] 8.75 5.50
```

RStudio Help. Rstudio provides search box in the "Help" tab to make your life easier (see Figure 1).

Searching On-line For R Help. There are a lot of on-line resources that can help. However you must understand that blindly copying and pasting could be harmful and further it won't help you to learn and develop. When you search on-line use `[R]` in your search term (e.g. "[R] summary statistics by group"). Note that often there is more than one solution to your problem. It is good to investigate the different options.

Exercise. Try the following:

1. `help(median)`
2. `?sd`
3. `?max`

[1] R project: https://www.r-project.org/
[2] RStudio IDE: https://www.rstudio.com/products/RStudio/

Warning. If an R command is not complete then R will show a plus sign (+) prompt on second and subsequent lines until the command syntax is correct.

```
+
```

To break out this, press the escape key (ESC).

Hint. To recall a previously typed commands use the up arrow key (↑). To go between previously typed commands use the up and down arrow (↓) keys. To modify or correct a command use the left (←) and right arrow (→) keys.

4. Some R Concepts

In R speak, scalars, vectors/variables and datasets are called ***objects***. To create objects (things) we have to use the assignment operator `<-`. For example, below, object `height` is assigned a value of 173 (typing `height` shows its value):

```
height <- 173
height
#  [1] 173
```

Warning: R is case sensitive. `age` and `AgE` are different:

```
age <- 10
AgE <- 50
```

```
age
#  [1] 10
AgE
#  [1] 50
```

New lines. R commands are usually separated by a new line but they can also be separated by a semicolon (`;`).

```
Name <- "Leo"; Age <- 25; City <- "Lisbon"
Name; Age; City
#  [1] "Leo"
#  [1] 25
#  [1] "Lisbon"
```

Comments. It is useful to put human readable comments in your programs. These comments could help the future you when you go back to your program. R comments start with a hash sign (`#`). Everything after the hash to the end of the line will be ignored by R.

```
# This comment line will be ignored when run.
City     # Text after "#" is ignored.
#  [1] "Lisbon"
```

5. R as a Calculator

You can use R as a calculator. Try the following:

```
2 + 3
#  [1] 5
(5*11)/4 - 7
#  [1] 6.75
# ^ = "to the power of"
7^3
#  [1] 343
```

Other math functions. You can also use standard mathematical functions that are typically found on a scientific calculator.

- Trigonometric: `sin()`, `cos()`, `tan()`, `acos()`, `asin()`, `atan()`
- Rounding: `abs()`, `ceiling()`, `floor()`, `round()`, `sign()`, `signif()`, `sqrt()`, `trunc()`
- Logarithms & Exponentials: `exp()`, `log()`, `log10()`, `log2()`

```
# Square root
sqrt(2)
#  [1] 1.414214
# Round down to nearest integer
floor(8.6178)
#  [1] 8
# Round to 2 decimal places
round(8.6178, 2)
#  [1] 8.62
```

Exercise. What do the following pairs of examples do?

1. `ceiling(18.33)` and `signif(9488, 2)`
2. `exp(1)` and `log10(1000)`
3. `sign(-2.9)` and `sign(32)`
4. `abs(-27.9)` and `abs(11.9)`

6. Some More R Concepts

You can do some clever and useful things with using the assignment operator `<-`:

```
roomLength <- 7.8
roomWidth <- 6.4
roomArea <- roomLength * roomWidth
roomArea
#  [1] 49.92
```

Text objects. You can also assign text to an object.

```
Greeting <- "Hello World!"
Greeting
#  [1] "Hello World!"
```

Vectors. The objects presented so far have all been scalars (single values). Working with vectors is where R shines best as they are the basic building blocks of datasets. To create a vector we can use the `c()` (combine values into a vector) function.

```
# A "numeric" vector
x1 <- c(26, 10, 4, 7, 41, 19)
x1
#  [1] 26 10  4  7 41 19
# A "character" vector of country names
x2 <- c("Peru", "Italy", "Cuba", "Ghana")
x2
#  [1] "Peru"  "Italy" "Cuba"  "Ghana"
```

There are many other ways to create vectors, for example, `rep()` (replicate elements) and `seq()` (create sequences):

```
# Repeat vector (2, 6, 7, 4) three times
r1 <- rep(c(2, 6, 7, 4), times=3)
r1
#   [1] 2 6 7 4 2 6 7 4 2 6 7 4
# Vector from -2 to 3 incremented by half
s1 <- seq(from=-2, to=3, by=0.5)
s1
```

```
#   [1] -2.0 -1.5 -1.0 -0.5  0.0  0.5  1.0  1.5
#   [9]  2.0  2.5  3.0
```

Vector operations. You can also do calculations on vectors, for example using `x1` from above:

```
x1 * 2
#  [1] 52 20  8 14 82 38
round(sqrt(x1*2.6), 2)
#  [1]  8.22  5.10  3.22  4.27 10.32  7.03
```

Missing Values. Missing values are coded as `NA` in R. For example,

```
x2 <- c(3, -7, NA, 5, 1, 1)
x2
#  [1]  3 -7 NA  5  1  1
x3 <- c("Rat", NA, "Mouse", "Hamster")
x3
#  [1] "Rat"     NA        "Mouse"   "Hamster"
```

Managing Objects. Use function `ls()` to list the objects in your workspace. The `rm()` function removes (deletes) them.

```
ls()
#   [1] "age"        "Age"        "AgE"
#   [4] "City"       "Greeting"   "height"
#   [7] "Name"       "r1"         "roomArea"
#  [10] "roomLength" "roomWidth"  "s1"
#  [13] "x"          "x1"         "x2"
#  [16] "x3"         "xm"
rm(x, x1, x2, x3, xm, r1, s1, AGE, age)
```

```
#  Warning in rm(x, x1, x2, x3, xm, r1, s1, AGE,
#  age): object 'AGE' not found
```

```
ls()
#  [1] "Age"        "AgE"        "City"
#  [4] "Greeting"   "height"     "Name"
#  [7] "roomArea"   "roomLength" "roomWidth"
```

Exercise. Calculate the `gross` by adding the `tax` to `net` amount.

```
net <- c(108.99, 291.42, 16.28, 62.29, 31.77)
tax <- c(22.89, 17.49, 0.98, 13.08, 6.67)
```

7. R Functions and Packages

R Functions. We have already used some R functions (e.g. `c()`, `mean()`, `rep()`, `sqrt()`, `round()`). Most of the computations in R involves using functions. A function essentially has a name and a list of arguments separated by a comma. Let's have look at an example:

```
seq(from = 5, to = 8, by = 0.4)
#  [1] 5.0 5.4 5.8 6.2 6.6 7.0 7.4 7.8
```

The function name is `seq` and it has three arguments `from`, `to` and `by`. The arguments `from` and `to` are the start and end values of a sequence that you want to create, and `by` is the increment of the sequence. The `seq()` functions has other arguments that you could use which are documented in the help page. For example, we could use the argument `length.out` (instead of `by`) to fix the length of the sequence as follows:

```
seq(from = 5, to = 8, length.out = 16)
#   [1] 5.0 5.2 5.4 5.6 5.8 6.0 6.2 6.4 6.6 6.8
#  [11] 7.0 7.2 7.4 7.6 7.8 8.0
```

Custom Functions. You can create your own functions (using the `function()` function) which is a very powerful way to extend R. Writing your own functions is outside the scope of this guide. As you get more and more familiar with R it is very likely that you will eventually need to learn about them but for now you don't need to.

R Packages. You can do many things with a standard R installation and it can be extended using contributed packages. Packages are like apps for R. They can contain functions, data and documentation.

`tidyverse`. The `tidyverse` package[3] is a collection of packages to import, manipulate, explore, visualise and model data in a harmonised and consistent way which helps you to be more productive. We will use the `tidyverse` to visualise and summarise data.

MUST DO: Ensure that the `tidyverse` package is installed.

```
install.packages("tidyverse")
```

Loading packages. To use the `tidyverse` package load it using the `library()` function:

```
library(tidyverse)
```

8. Chick Weight Data

R comes with many datasets installed[4]. We will use the `ChickWeight` dataset to learn about the tidyverse. The help system gives a basic summary of the experiment from which the data was collect:

> *"The body weights of the chicks were measured at birth and every second day thereafter until day 20. They were also measured on day 21. There were four groups of chicks on different protein diets."*

You can get more information, including references by typing:

```
help("ChickWeight")
```

The Data. There are 578 observations (rows) and 4 variables:

- `Chick` – unique ID for each chick.
- `Diet` – one of four protein diets.
- `Time` – number of days since birth.
- `weight` – body weight of chick in grams.

Note. `weight` has a lower case `w` (recall R is case sensitive).

Objective. Investigate the *effect of diet on the weight over time*.

9. Importing The Data

First we will import the data from a file called `ChickWeight.csv` using the `read_csv()` function from the `readr` package (part of the `tidyverse`). The first thing to do, outside of R, is to open the file `ChickWeight.csv` to check what it contains and that it makes sense. Now we can import the data as follows:

[3] Tidyverse: https://www.tidyverse.org/

[4] Type `data()` in the R console to see a list of the datasets.

```
CW <- read_csv("ChickWeight.csv")
```

```
#  Parsed with column specification:
#  cols(
#    Chick = col_double(),
#    Diet = col_double(),
#    Time = col_double(),
#    weight = col_double()
#  )
```

All columns (variables) have been read in as numeric values (i.e. `col_double()`) but you may see that they are read in a integer (i.e. `col_int()`) due to operating system differences.

Important Note. If all goes well then the data is now stored in an R object called `CW`. If you get the following error message then you need to change the working directory to where the data is stored.

```
Error: 'ChickWeight.csv' does not exist in current
working directory ...
```

Change the working directory in RStudio. From the menu bar select "Session - Set Working Directory - Choose Directory..." then go to the directory where the data is stored. Alternatively, within in R, you could use the function `setwd()`[5].

10. Looking at the Dataset

To look at the data type just type the object (dataset) name:

```
CW
#  # A tibble: 578 x 4
#     Chick  Diet  Time weight
#     <dbl> <dbl> <dbl>  <dbl>
#   1    18     1     0     39
#   2    18     1     2     35
#   3    16     1     0     41
#   4    16     1     2     45
#   5    16     1     4     49
#   6    16     1     6     51
#   7    16     1     8     57
#   8    16     1    10     51
#   9    16     1    12     54
#  10    15     1     0     41
#  # ... with 568 more rows
```

`glimpse()` function. If there are too many variables then not all them may be printed. To overcome this issue we can use the `glimpse()` function which makes it possible to see every column in your dataset (called a "data frame" in R speak).

```
glimpse(CW)
#  Observations: 578
#  Variables: 4
#  $ Chick  <dbl> 18, 18, 16, 16, 16, 16, 1...
#  $ Diet   <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1...
#  $ Time   <dbl> 0, 2, 0, 2, 4, 6, 8, 10, ...
#  $ weight <dbl> 39, 35, 41, 45, 49, 51, 5...
```

Interpretation. Both of these show that the dataset has 578 observations and 4 variables as we would expect and as compared to the original data file `ChicWeight.csv`. So a good start.

[5] Use `getwd()` to see the current working directory and `setwd("/to/data/path/data.csv")` to change it (important to use / even for Microsoft Windows).

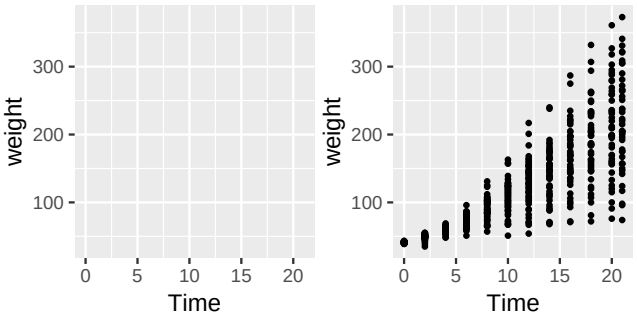
Exercise. It is important to look at the last observations of the dataset as it could reveal potential data issues. Use the `tail()` function to do this. Is it consistent with the original data file `ChickWeight.csv`?

11. Chick Weight: Data Visualisation

`ggplot2` Package. To visualise the chick weight data, we will use the `ggplot2` package (part of the `tidyverse`). Our interest is in seeing how the *weight changes over time for the chicks by diet*. For the moment don't worry too much about the details just try to build your own understanding and logic. To learn more try different things even if you get an error messages.

First plot. Let's plot the weight data (vertical axis) over time (horizontal axis).

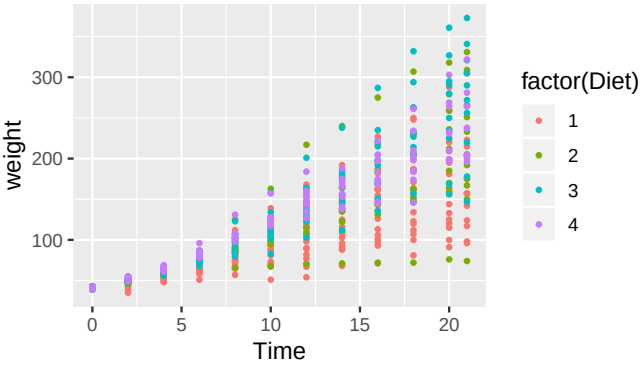
```
# An empty plot (the plot on the left)
ggplot(CW, aes(Time, weight))
# With data (the plot on the right)
ggplot(CW, aes(Time, weight)) + geom_point()
```



Exercise. Switch the variables `Time` and `weight` in code used for the plot on the right? What do you think of this new plot compared to the original?

Add colour for `Diet`. The graph above does not differentiate between the diets. Let's use a different colour for each diet.

```
# Adding colour for diet
ggplot(CW,aes(Time,weight,colour=factor(Diet))) +
  geom_point()
```



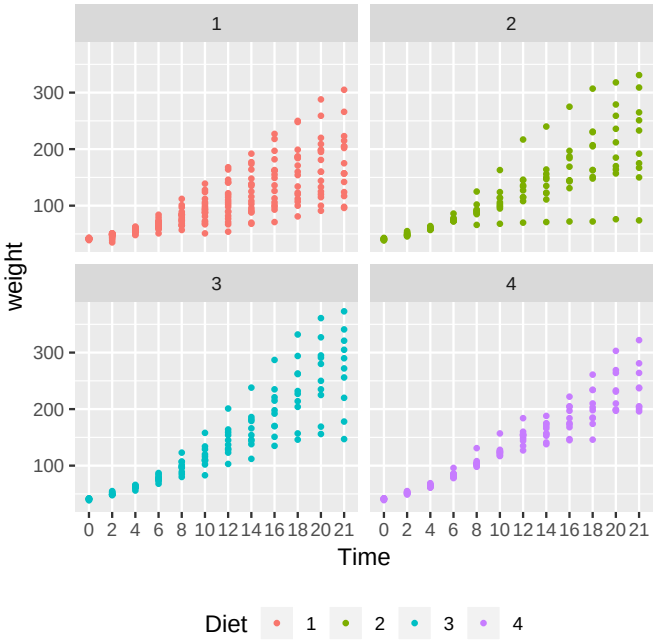
Interpretation. It is difficult to conclude anything from this graph as the points are printed on top of one another (with diet 1 underneath and diet 4 at the top).

Factor Variables. Before we continue, we have to make an important change to the `CW` dataset by making `Diet` and `Time` *factor variables*. This means that R will treat them as categorical variables (see the `<fct>` variables below) instead of continuous variables. It will simplify our coding. The next section will explain the `mutate()` function.

```
CW <- mutate(CW, Diet = factor(Diet))
CW <- mutate(CW, Time = factor(Time))
glimpse(CW)
#  Observations: 578
#  Variables: 4
#  $ Chick  <dbl> 18, 18, 16, 16, 16, 16, 1...
#  $ Diet   <fct> 1, 1, 1, 1, 1, 1, 1, 1, 1...
#  $ Time   <fct> 0, 2, 0, 2, 4, 6, 8, 10, ...
#  $ weight <dbl> 39, 35, 41, 45, 49, 51, 5...
```

`facet_wrap()` function. To plot each diet separately in a grid using `facet_wrap()`:

```
# Adding jitter to the points
ggplot(CW, aes(Time, weight, colour=Diet)) +
  geom_point() +
  facet_wrap(~Diet) +
  theme(legend.position = "bottom")
```



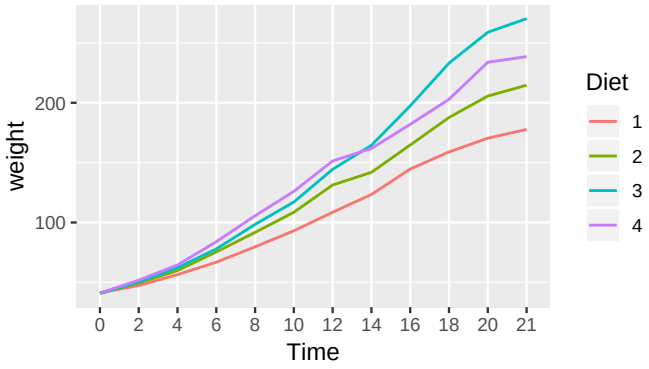
Exercise. To overcome the issue of overlapping points we can ***jitter*** the points using `geom_jitter()`. Replace the `geom_point()` above with `geom_jitter()`. What do you observe?

Interpretation. Diet 4 has the least variability but we can't really say anything about the mean effect of each diet although diet 3 seems to have the highest.

Exercise. For the `legend.position` try using "top", "left" and "none". Do we really need a legend for this plot?

Mean line plot. Next we will plot the mean changes over time for each diet using the `stat_summary()` function:

```
ggplot(CW, aes(Time, weight,
               group=Diet, colour=Diet)) +
  stat_summary(fun.y="mean", geom="line")
```

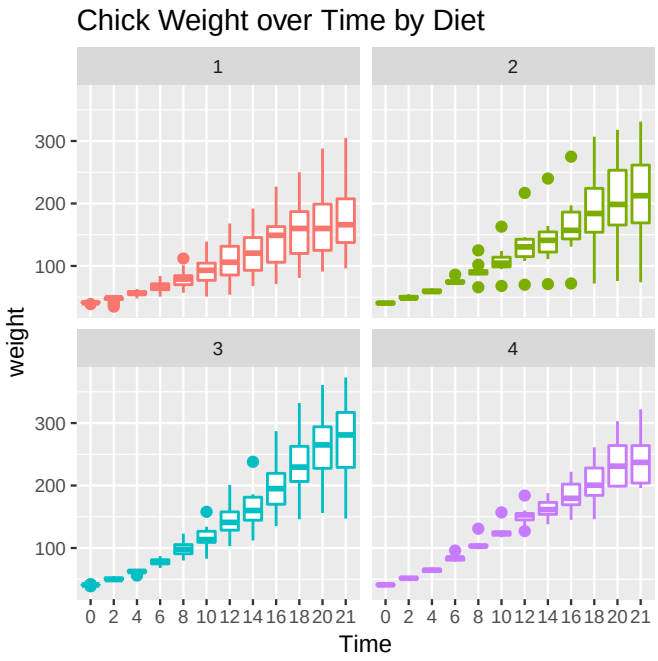


Interpretation. We can see that diet 3 has the highest mean weight gain by the end of the experiment but we don't have any information about the variation (uncertainty) in the data.

Exercise. What happens when you add `geom_point()` to the plot above? Don't forget the `+`. Does it make a difference if you put it before or after the `stat_summary(...)` line? Hint: Look very carefully at how the graph is plotted.

Box-whisker plot. To see variation between the different diets we use `geom_boxplot` to plot a box-whisker plot. A note of caution is that the number of chicks per diet is relatively low to produce this plot.

```
ggplot(CW, aes(Time, weight, colour=Diet)) +
  facet_wrap(~Diet) +
  geom_boxplot() +
  theme(legend.position = "none") +
  ggtitle("Chick Weight over Time by Diet")
```



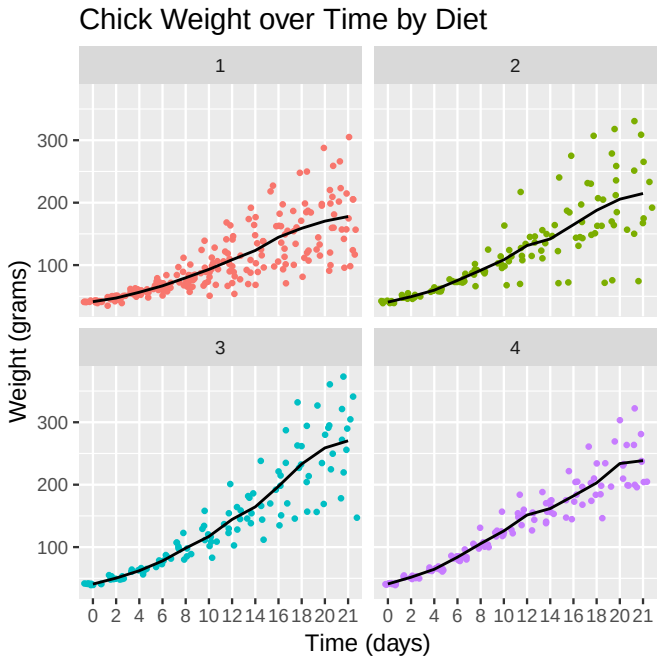
Interpretation. Diet 3 seems to have the highest "average" weight gain but it has more variation than diet 4 which is consistent with our findings so far.

Exercise. Add the following information to the above plot:

- x-axis label (use `xlab()`): "Time (days)"
- y-axis label (use `ylab()`): "Weight (grams)"

Final Plot. Let's finish with a plot that you might include in a publication.

```
ggplot(CW, aes(Time, weight, group=Diet,
                            colour=Diet)) +
  facet_wrap(~Diet) +
  geom_jitter() +
  stat_summary(fun.y="mean", geom="line",
               colour="black") +
  theme(legend.position = "none") +
  ggtitle("Chick Weight over Time by Diet") +
  xlab("Time (days)") +
  ylab("Weight (grams)")
```



12. Tidyverse: Data Wrangling Basics

In this section we will learn how to wrangle (manipulate) datasets using the `tidyverse` package. Let's start with the `mutate()`, `select()`, `rename()`, `filter()` and `arrange()` functions.

`mutate()`. Adds a new variable (column) or modifies an existing one. We already used this above to create factor variables.

```
# Added a column
CWm1 <- mutate(CW, weightKg = weight/1000)
CWm1
#  # A tibble: 578 x 5
#    Chick Diet  Time  weight weightKg
#    <dbl> <fct> <fct>  <dbl>    <dbl>
#  1    18 1     0         39    0.039
#  2    18 1     2         35    0.035
#  3    16 1     0         41    0.041
#  4    16 1     2         45    0.045
#  5    16 1     4         49    0.049
#  # ... with 573 more rows

# Modify an existing column
CWm2 <- mutate(CW, Diet = str_c("Diet ", Diet))
CWm2
#  # A tibble: 578 x 4
#    Chick Diet   Time  weight
#    <dbl> <chr>  <fct>  <dbl>
#  1    18 Diet 1 0         39
#  2    18 Diet 1 2         35
#  3    16 Diet 1 0         41
#  4    16 Diet 1 2         45
#  5    16 Diet 1 4         49
#  # ... with 573 more rows
```

`select()`. Keeps, drops or reorders variables.

```
# Drop the weight variable from CWm1 using minus
select(CWm1, -weight)
#  # A tibble: 578 x 4
#    Chick Diet  Time  weightKg
#    <dbl> <fct> <fct>    <dbl>
#  1    18 1     0        0.039
#  2    18 1     2        0.035
#  3    16 1     0        0.041
#  4    16 1     2        0.045
#  5    16 1     4        0.049
#  # ... with 573 more rows

# Keep variables Time, Diet and weightKg
select(CWm1, Chick, Time, Diet, weightKg)
#  # A tibble: 578 x 4
#    Chick Time  Diet  weightKg
#    <dbl> <fct> <fct>    <dbl>
#  1    18 0     1        0.039
#  2    18 2     1        0.035
#  3    16 0     1        0.041
#  4    16 2     1        0.045
#  5    16 4     1        0.049
#  # ... with 573 more rows
```

`rename()`. Renames variables whilst keeping all variables.

```
rename(CW, Group = Diet, Weight = weight)
#  # A tibble: 578 x 4
#    Chick Group Time  Weight
#    <dbl> <fct> <fct>  <dbl>
#  1    18 1     0         39
#  2    18 1     2         35
#  3    16 1     0         41
#  4    16 1     2         45
#  5    16 1     4         49
#  # ... with 573 more rows
```

`filter()`. Keeps or drops observations (rows).

```
filter(CW, Time==21 & weight>300)
#  # A tibble: 8 x 4
#    Chick Diet  Time  weight
#    <dbl> <fct> <fct>  <dbl>
#  1     7 1     21        305
#  2    29 2     21        309
#  3    21 2     21        331
#  4    32 3     21        305
#  5    40 3     21        321
#  # ... with 3 more rows
```

For comparing values in vectors use: < (less than), > (greater than), <= (less than and equal to), >= (greater than and equal to), == (equal to) and != (not equal to). These can be combined logically using & (and) and | (or).

`arrange()`. Changes the order of the observations (rows).

```
arrange(CW, Chick, Time)
#  # A tibble: 578 x 4
#    Chick Diet  Time  weight
#    <dbl> <fct> <fct>  <dbl>
#  1     1 1     0         42
#  2     1 1     2         51
#  3     1 1     4         59
#  4     1 1     6         64
#  5     1 1     8         76
#  # ... with 573 more rows

arrange(CW, desc(weight))
#  # A tibble: 578 x 4
#    Chick Diet  Time  weight
#    <dbl> <fct> <fct>  <dbl>
#  1    35 3     21       373
#  2    35 3     20       361
#  3    34 3     21       341
#  4    35 3     18       332
#  5    21 2     21       331
#  # ... with 573 more rows
```

Exercise. What does the `desc()` do? Try using `desc(Time)`.

13. Tidyverse: Pipe operator %>%

In reality you will end up doing multiple data wrangling steps that you will want to save. This is where the pipe operator, %>%, plays a very useful role. Let's have a look at an example:

```
CW21 <- CW %>%
  filter(Time %in% c(0, 21)) %>%
  rename(Weight = weight) %>%
  mutate(Group = factor(str_c("Diet ", Diet))) %>%
  select(Chick, Group, Time, Weight) %>%
  arrange(Chick, Time)

CW21
#  # A tibble: 95 x 4
#    Chick Group  Time  Weight
#    <dbl> <fct>  <fct>  <dbl>
#  1     1 Diet 1 0         42
#  2     1 Diet 1 21       205
#  3     2 Diet 1 0         40
#  4     2 Diet 1 21       215
#  5     3 Diet 1 0         43
#  # ... with 90 more rows
```

Read %>% as "then". To understand the code above we should read the pipe operator %>% as "then".

> Create a new dataset (object) called `CW21` using dataset `CW` ***then*** keep the data for days 0 and 21 ***then*** rename variable `weight` to `Weight` ***then*** create a variable called `Group` ***then*** keep variables `Chick`, `Group`, `Time` and `Weight` and ***then*** finally arrange the data by variables `Chick` and `Time`.

In practice.

```
CW21 <- CW %>%
  filter(., Time %in% c(0, 21)) %>%
  rename(., Weight = weight) %>%
  mutate(., Group=factor(str_c("Diet ",Diet))) %>%
  select(., Chick, Group, Time, Weight) %>%
  arrange(., Chick, Time)
```

The pipe operator, %>%, replaces the dots `(.)` with whatever is returned from code preceding it. For example, the dot in `filter(., Time %in% c(0, 21))` is replaced by `CW`. The output of the `filter(...)` then replaces the dot in `rename(., Weight = weight)` and so on. Think of it as a data assembly line with each function doing its thing and passing it to the next.

14. Chick Weight: Summary Statistics

From the data visualisations above we concluded that the diet 3 has the highest mean and diet 4 the least variation. In this section, we will quantify the effects of the diets using summary statistics. We start by looking at the number of observations and the mean by **diet** and **time**.

```
mnsdCW <- CW %>%
  group_by(Diet, Time) %>%
  summarise(N = n(), Mean = mean(weight)) %>%
  arrange(Diet, Time)

mnsdCW
#  # A tibble: 48 x 4
#  # Groups:   Diet [4]
#    Diet  Time      N  Mean
#    <fct> <fct> <int> <dbl>
#  1 1     0        20  41.4
#  2 1     2        20  47.2
#  3 1     4        19  56.5
#  4 1     6        19  66.8
#  5 1     8        19  79.7
#  # ... with 43 more rows
```

`group_by()` function. For each distinct combination of `Diet` and `Time`, the chick weight data is summarised into the number of observations (`N`) and the mean (`Mean`) of `weight`.

Other summaries. Let's also calculate the standard deviation, median, minimum and maximum values but only at days 0 and 21.

```
sumCW <-  CW %>%
  filter(Time %in% c(0, 21)) %>%
  group_by(Diet, Time) %>%
  summarise(N = n(),
            Mean = mean(weight),
            SD = sd(weight),
            Median = median(weight),
            Min = min(weight),
            Max = max(weight)) %>%
  arrange(Diet, Time)

sumCW
#  # A tibble: 8 x 8
#  # Groups:   Diet [4]
#    Diet  Time      N  Mean     SD Median   Min
#    <fct> <fct> <int> <dbl>  <dbl>  <dbl> <dbl>
#  1 1     0        20  41.4  0.995   41      39
#  2 1     21       16 178.  58.7    166      96
#  3 2     0        10  40.7  1.49    40.5    39
#  4 2     21       10 215.  78.1    212.     74
#  5 3     0        10  40.8  1.03    41      39
#  # ... with 3 more rows, and 1 more variable:
#  #   Max <dbl>
```

Let's make the summaries "prettier", say, for a report or publication.

```
prettySumCW <- sumCW %>%
 mutate(Mean_SD = str_c(format(Mean, digits=1),
          " (", format(SD, digits=2), ")")) %>%
 mutate(Range = str_c(Min, " - ", Max)) %>%
 select(Diet, Time, N, Mean_SD, Median, Range) %>%
 arrange(Diet, Time)

prettySumCW
#  # A tibble: 8 x 6
#  # Groups:   Diet [4]
#    Diet  Time      N Mean_SD    Median Range
#    <fct> <fct> <int> <chr>       <dbl> <chr>
#  1 1     0        20 " 41 ( 0.~   41   39 - ~
#  2 1     21       16 178 (58.7~  166   96 - ~
#  3 2     0        10 " 41 ( 1.~   40.5 39 - ~
#  4 2     21       10 215 (78.1)  212.  74 - ~
#  5 3     0        10 " 41 ( 1)"   41   39 - ~
#  # ... with 3 more rows
```

Final Table. Eventually you should be able to produce[6] a publication ready version as follows:

Diet	Time	N	Mean_SD	Median	Range
1	0	20	41 (0.99)	41.0	39 - 43
1	21	16	178 (58.70)	166.0	96 - 305
2	0	10	41 (1.5)	40.5	39 - 43
2	21	10	215 (78.1)	212.5	74 - 331
3	0	10	41 (1)	41.0	39 - 42
3	21	10	270 (72)	281.0	147 - 373
4	0	10	41 (1.1)	41.0	39 - 42
4	21	9	239 (43.3)	237.0	196 - 322

Interpretation. This summary table offers the same interpretation as before, namely that diet 3 has the highest mean and median weights at day 21 but a higher variation than group 4. However it should be noted that at day 21, diet 1 lost 4 chicks from 20 that started and diet 4 lost 1 from 10. This could be a sign of some issues (e.g. safety).

Limitations of data. Information on bias reduction measures is not given and is not available either[7]. We don't know if the chicks were fairly and appropriately randomised to the diets and whether the groups are comparable (e.g., same breed of chicks, sex (gender) balance). Hence we should be very cautious with drawing conclusion and taking actions with this data.

15. Conclusion

This "Getting Started in R" guide introduced you to some of the basic concepts underlying R and used a real life dataset to produce some graphs and summary statistics. It is only a flavour of what R can do but hopefully you have seen some of power of R and its potential.

What next. There are plenty of R courses, books and on-line resources that you can learn from. It is hard to recommend any in particular as it depends on how you learn best. Find things that work for you (paying attention to the quality) and don't be afraid to make mistakes or ask questions. Most importantly have fun.

[6] Using the `kable()` function from the `knitr` package with functions from the `kableExtra` package.

[7] I contacted the source authors and kindly received the following reply *"They were mainly undergraduate projects, final-year, rather than theses, so, unfortunately, it's unlikely that any record remains, particularly after so many years."*