20 Things to Know About **R** & a couple of things to know about stats

Alexandre Courtiol

Leibniz Institute of Zoo and Wildlife Research

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and Wildlife Research
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Poll

How would you rate your **R**-language proficiency, from A0 to C2?

- **A0**
  no experience of **R** what-so-ever
- **A1**
  read a well coded **R** script and understand the main ideas
- **A2**
  use RStudio, import data, do simple clean-up tasks & simple plots
  (with heavy help from stackoverflow or chatGPT)
- **B1**
  no longer get stuck with typos, code simple functions, produce rmarkdown or quarto reports, use most core `tidyverse` packages with ease, some knowledge of base **R**
- **B2**
  code complex functions, create simple packages, understand how to use new packages quickly, solid knowledge of base **R**
- **C1**
  write elegant & efficient code, supervise the development of large packages, code functions tackling scoping difficulties, code bottlenecks in other languages...
- **C2**
  able to help C1-level people in a variety of tricky circumstances

20 Things to Know About **R**

1. What are **R** and RStudio?
2. How to best setup **R** & RStudio?
3. How to best organise your work?
4. How to write reproductible code?
5. How to use **R** as a simple calculator?
6. How to store the results of operations?
7. How to do things beyond simple algebra?
8. How to use a new function?
9. How to decipher complex function calls?
10. How to import data in **R**?
11. How to manipulate data frames?
12. How to manipulate lists?
13. How to manipulate vectors?
14. How to use packages?
15. How to use `{dplyr}` for an efficient manipulation of data frames?
16. How to plot things?
17. How to use `{ggplot2}` for an efficient production of plots?
18. When to update what?
19. How to reach the level A2/B1?
20. How to reach levels beyond B1?

1. What are **R** and RStudio?

Why learning **R**?

- among the best software and programming language dedicated to data science
- rich in functionality with close to 100,000 free packages
  (`https://rdrr.io`, `https://r-universe.dev`)
- large friendly community
  (X #rstats, `https://dslcio.slack.com`, `https://forum.posit.co/`, gatherings)
- open source and free

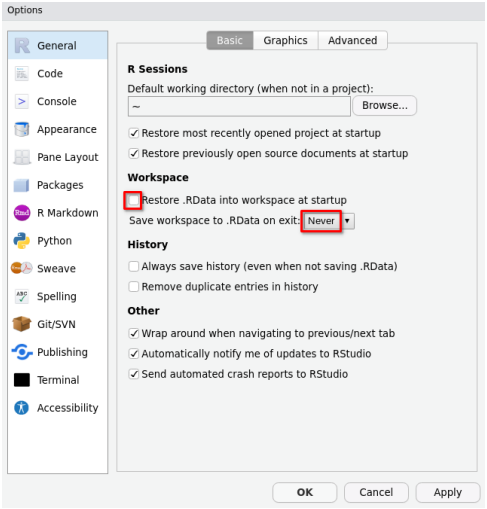
RStudio is a GUI to **R** that is fancier and more modern than the one provided by default

Note: RStudio is currently loosing ground against Visual Studio Code among geeks, but Posit is fighting back by developing Positron

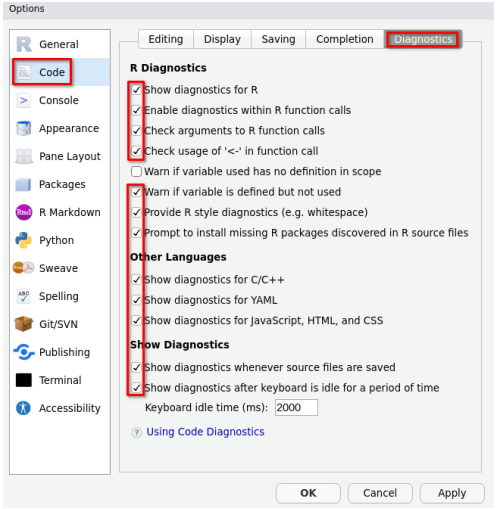
2a. How to best setup **R** & RStudio?

Open: Menu / Tools / Global options and set things as follows:

Never save or restore the workspace!



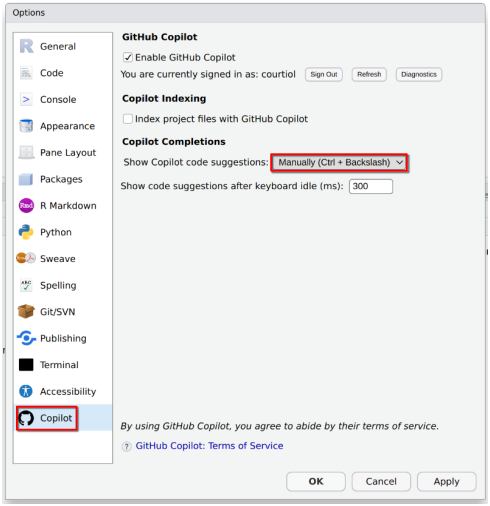
Activate code diagnostics



2b. How to best setup **R** & RStudio?

Want to have a go at Github copilot?

If you must, better not show Copilot suggestions automatically



3. How to best organise your work?

Before you start some new work in **R**,

1. create a new RStudio project (Menu / File / New Project... / ...)
2. create a new **R** script file (Menu / File / New File / R Script)
3. save the created **R** script file into the project folder directory

NB:

- an RStudio project is a folder containing the different files for a given project, including a simple project file that allows you to open RStudio with the correct working directory set
- an **R** script is a (text) file where you can write **R** code

Note: alternatives to **R** scripts exist to implement your work if you need to format text around your code (e.g. Quarto files: `https://quarto.org/docs/computations/r.html`)

Practice

1. create a new project
2. create a new **R** Script file
3. save the created **R** Script file into the project folder directory
4. have a look at the RStudio cheatsheet

NB:

- a project is defined by a simple (text) file. Its main benefit is to open RStudio with the correct working directory set (that is, the one where the project file is)
- an **R** Script file is a (text) file where we can write **R** code

4. How to write reproductible code?

Best (simple) practice:

1. only use the `Console` pane to mess around
2. write proper **R** code in the `Source` pane
3. comment thoroughly your **R** script using # signs
4. re-run frequently your entire script to make sure that it works
   (after restarting the session: Menu / Session / Restart R)
5. avoid relying on too many packages, especially if they are not stable
6. write down the output of `sessionInfo()` as comment to document the version of the packages you use

Note: more efficient methods exist to make your code reproducible. Full reproducibility is hardly ever quite possible in practice, so the best tool for you depends on where you want to stand along the trade-off between light weight less reproducible solutions (e.g. package Renv), or heavier more reproducible solution (e.g. rocker containers). My personal approach is often to create an R package dedicated to the project.

5. How to use **R** as a simple calculator?

R can perform basic arithmetic:

```
1 + 1
## [1] 2
1 - 1
## [1] 0
2 * pi
## [1] 6.283185
3 / 2
## [1] 1.5
5^2
## [1] 25
5^(2 + 1)
## [1] 125
Inf/Inf
## [1] NaN
```

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R can perform logical operations:

```
1 == 1
## [1] TRUE
(1 == 1) & (1 == 2)
## [1] FALSE
(1 == 1) | (1 == 2)
## [1] TRUE
1 != 2
## [1] TRUE
!(1 == 2)
## [1] TRUE
2 >= 1
## [1] TRUE
2 < 1
## [1] FALSE
```

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2 >= 1
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## [1] FALSE
```

As for most other programming languages, avoid equality tests for floating-point numbers!

```
0.8 - 0.3 - 0.5 == 0.8 - 0.5 - 0.3 ## would be TRUE in an ideal world
## [1] FALSE
```

Practice

Compute $\sqrt{\frac{2^{3+1}}{\frac{4}{5 \times 6}} - 20}$

NB: $\sqrt{x} = x^{\frac{1}{2}}$

6. How to store the results of operations?

The results of operations are stored into *objects* that are created using the "arrow" assignment operator:

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one_plus_one <- 1 + 1 ## storing the result
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Objects can then be used through their name (that is the whole point):

```
one_plus_one ## displaying the result
## [1] 2
one_plus_one_plus_one <- one_plus_one + 1
one_plus_one_plus_one
## [1] 3
```

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Tips:

```
(one_times_two <- 1 * 2) ## storing and displaying the result at once
## [1] 2
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## [1] 3
```

Tips:

```
(one_times_two <- 1 * 2) ## storing and displaying the result at once
## [1] 2
```

- -> works too (if you switch the left hand side and the right hand side)
- "_" and "." are OK but avoid spaces & other weird characters in names
- names are CaSe sensITIVE

7. How to do things beyond simple algebra?

For doing more complex things, one has to use *functions*:

```
vector_x <- c(1, 4, 10)
```

```
mean_x <- mean(x = vector_x)
mean_x
## [1] 5
```

```
sd_x <- sd(x = vector_x)
sd_x
## [1] 4.582576
```

```
cv_x <- sd_x/mean_x
cv_x
## [1] 0.9165151
```

```
round(x = cv_x, digits = 2)
## [1] 0.92
```

Note: all the red words are functions

8. How to use a new function?

Before using a new function, it is a good idea to check its documentation:

```
mean()
```

```
?mean()
```

```
Usage:
     mean(x, ...)
     ## Default S3 method:
     mean(x, trim = 0, na.rm = FALSE, ...)

Arguments:
       x: An R object.  Currently there are methods for numeric/logical
          vectors and date, date-time and time interval objects, and
          for data frames all of whose columns have a method.  Complex
          vectors are allowed for 'trim = 0', only.
    trim: the fraction (0 to 0.5) of observations to be trimmed from
          each end of 'x' before the mean is computed.  Values of trim
          outside that range are taken as the nearest endpoint.
   na.rm: a logical value indicating whether 'NA' values should be
          stripped before the computation proceeds.
[...]
```

9. How to decipher complex function calls?

In **R**, it is easy to write synonymous code that *looks* very different:

Example 1:

```
round(sd(c(1, 4, 10))/mean(c(1, 4, 10)), 2)
## [1] 0.92
```

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Example 1:

```
round(sd(c(1, 4, 10))/mean(c(1, 4, 10)), 2)
## [1] 0.92
```

Example 2:

```
c(1, 4, 10) |>
  sd() |>
  prod(1/mean(c(1, 4, 10))) |>
  round(2)
## [1] 0.92
```

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Example 1:

```
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## [1] 0.92
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Example 2:

```
c(1, 4, 10) |>
  sd() |>
  prod(1/mean(c(1, 4, 10))) |>
  round(2)
## [1] 0.92
```

- To decipher the first example, run things from the inside out, step-by-step
- To decipher the second example, run things adding one line at a time (always skipping the final pipe)

Here the implementation from Example 1 is easier to read, but this is not always the most natural way to write

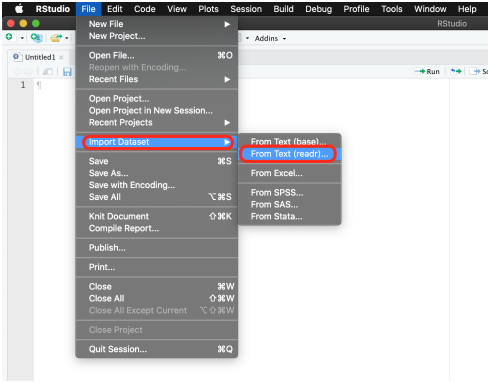
10. How to import data in **R**?

R can read (and write) many formats storing data, such as:

- tabulated text files (`*.csv`, `*.txt`, ...) → no pkg or `{readr}`
- MS Excel files (`*.xlsx`) → `{readxl}`
- binary R files (`*.rda`, `*.RData`, `*.rds`) → no pkg

For importing data you can often simply rely on the GUI:

(but for reproducibility do copy and paste the **R** code automatically generated into your script)



11a. How to manipulate data frames?

The most common class of objects used for storing data in **R** is the data frame!

Example: the `calibration_example1` dataset

```
library(readr)
calibration <- read_csv("data/calibration_example1.csv")
calibration
## # A tibble: 39 x 5
##   site    lat  long y.tissue sd.y.tissue
##   <chr> <dbl> <dbl>    <dbl>       <dbl>
## 1 A      46.2  18.9    -71.8           1
## 2 A      46.2  18.9   -103.            1
## 3 A      46.2  18.9    -68.9           1
## # i 36 more rows
```

- each column is a variable, usually corresponding to a vector
  (a series of elements of 1 type)
- all columns have the same length (rectangular format)
- contains column names (usually informative) and row names (usually not informative)
- a `tibble` is one of the possible formats for data frames, but all formats work similarly

11b. How to manipulate data frames?

```
calibration$y.tissue ## extract vector
##  [1]  -71.8 -103.4  -68.9 -103.3  -92.3 -102.0 -105.3  -93.4  -95.9  -93.2  -93.2  -92.9  -99.8
## [14]  -89.1 -112.9  -99.6 -102.4 -105.2  -97.9  -97.1  -96.0  -88.3  -94.2  -84.3 -112.5 -109.7
## [27] -103.3 -116.2 -107.1 -119.7  -96.7  -71.9 -106.6 -105.5 -105.0  -84.3  -87.9  -91.0  -73.6
```

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```

```
calibration[calibration$site == "B", c("lat", "long", "y.tissue")]  ## filter rows and columns
## # A tibble: 3 x 3
##     lat  long y.tissue
##   <dbl> <dbl>    <dbl>
## 1  48.5  19.1    -92.3
## 2  48.5  19.1   -102
## 3  48.5  19.1   -105.
```

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calibration[calibration$site == "B", c("lat", "long", "y.tissue")]  ## filter rows and columns
## # A tibble: 3 x 3
##     lat  long y.tissue
##   <dbl> <dbl>    <dbl>
## 1  48.5  19.1    -92.3
## 2  48.5  19.1   -102
## 3  48.5  19.1   -105.
```

```
calibration$sd.y.tissue <- NULL ## delete a column
calibration$species <- "my species" ## add a column
calibration
## # A tibble: 39 x 5
##   site    lat  long y.tissue species
##   <chr> <dbl> <dbl>    <dbl> <chr>
## 1 A      46.2  18.9    -71.8 my species
## 2 A      46.2  18.9   -103.  my species
## 3 A      46.2  18.9    -68.9 my species
## # i 36 more rows
```

12. How to manipulate lists?

Most functions doing something more complicated than simple arithmetic produce lists:

```
calib2sp <- calibration[calibration$site %in% c("A", "C"), ]
test_calib2sp <- t.test(y.tissue ~ site, data = calib2sp)
```

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```

```
str(test_calib2sp) ## reveals the (often hidden) structure of the list
## List of 10
##  $ statistic  : Named num 1.06
##   ..- attr(*, "names")= chr "t"
##  $ parameter  : Named num 3.31
##   ..- attr(*, "names")= chr "df"
##  $ p.value    : num 0.36
##  $ conf.int   : num [1:2] -19.2 39.9
##   ..- attr(*, "conf.level")= num 0.95
##  $ estimate   : Named num [1:2] -86.8 -97.2
##   ..- attr(*, "names")= chr [1:2] "mean in group A" "mean in group C"
##  $ null.value : Named num 0
##   ..- attr(*, "names")= chr "difference in means between group A and group C"
##  $ stderr     : num 9.79
##  $ alternative: chr "two.sided"
##  $ method     : chr "Welch Two Sample t-test"
##  $ data.name  : chr "y.tissue by site"
##  - attr(*, "class")= chr "htest"
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```

You can extract named elements from lists as vectors in data frames:

```
test_calib2sp$p.value
## [1] 0.3595509
```

You can extract elements from lists (named or not) using indexes too:

```
test_calib2sp[[3]]
## [1] 0.3595509
```

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You can replace elements:

```
calibration$y.tissue[1] <- NA ## change is saved!
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```

You can select multiple elements:

```
calibration$y.tissue[1:10] ## change is not saved unless you assign it
##  [1]     NA -103.4  -68.9 -103.3  -92.3 -102.0 -105.3  -93.4  -95.9  -93.2
```

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```

You can select multiple using a vector of `logicals`:

```
calibration$site == "A"
##  [1]  TRUE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [17] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [33] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
calibration$y.tissue[calibration$site == "A"]
## [1]     NA -103.4  -68.9 -103.3
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## [33] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
calibration$y.tissue[calibration$site == "A"]
## [1]     NA -103.4  -68.9 -103.3
```

You can remove elements:

```
calibration$y.tissue[-2]
##  [1]     NA  -68.9 -103.3  -92.3 -102.0 -105.3  -93.4  -95.9  -93.2  -93.2  -92.9  -99.8  -89.1
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14. How to use packages?

Packages extend **R** functionalities:

- for most users; e.g. `{dplyr}`, `{ggplot2}`
- for specific users; e.g. `{IsoriX}`, `{MixSIAR}`
- for developers creating packages; e.g. `{devtools}`, `{Rcpp}`

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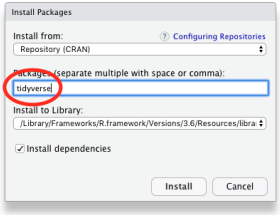

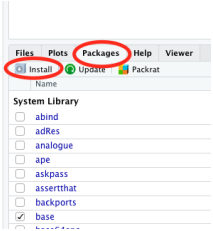

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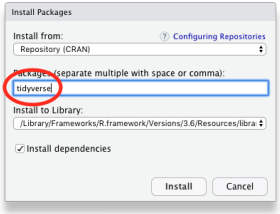
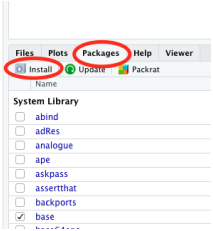
- for developers creating packages; e.g. `{devtools}`, `{Rcpp}`

Simple installation (once per **R** installation):





Loading (once per session):

```
library(dplyr)
```

15. How to use {dplyr} for an efficient manipulation of data frames?

You can all kind of data manipulation by combining 4 simple functions from {dplyr}:

- `select()` to keep or discard columns
- `filter()` to keep or discard rows
- `mutate()` to create new columns
- `summarise()` to compute summary statistics per group (defined using `.by = ...`)

15. How to use {dplyr} for an efficient manipulation of data frames?

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- `filter()` to keep or discard rows
- `mutate()` to create new columns
- `summarise()` to compute summary statistics per group (defined using `.by = ...`)

Example:

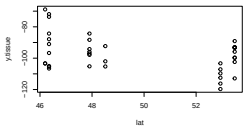
```
calibration |>
  filter(site != "A") |>
  mutate(y.tissue.not.permil = y.tissue / 1000) |>
  summarize(mean_per_site = mean(y.tissue.not.permil), .by = site)
## # A tibble: 5 x 2
##   site  mean_per_site
##   <chr>         <dbl>
## 1 B           -0.0999
## 2 C           -0.0972
## 3 D           -0.0947
## # i 2 more rows
```

16. How to plot things?

There are many plotting systems in **R**, such as:

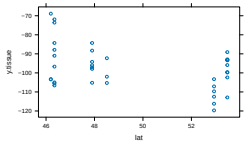
- {graphics} (build-in system): most efficient for small jobs, but difficult for complex tasks
- {lattice}: difficult, but efficient for complex tasks
- {ggplot2}: easy and efficient for most tasks (but quite verbose)

```
plot(y.tissue ~ lat,
     data = calibration)
```



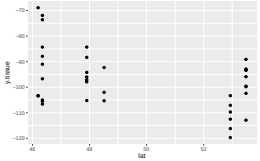

```
library(lattice)

xyplot(y.tissue ~ lat,
       data = calibration)
```




```
library(ggplot2)

ggplot(data = calibration,
  aes(x = lat, y = y.tissue)) +
  geom_point()
```



Notes:

- whatever you are using, plotting your data is very important
- defaults are always quite ugly

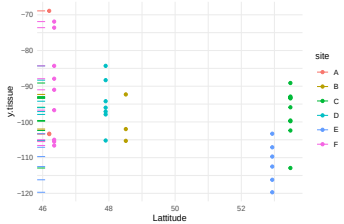
17. How to use {ggplot2} for an efficient production of plots?

All plots are composed of the same elements:

data + **aes**thetic mappings + **geom**etries + **scale**s + a **coord**inate system + a **theme** + a **facet**ing specification
(the first 3 are mandatory, the last 4 are not since they have default presets)

We then build a plot by adding such components together:

```
ggplot(calibration) +
  aes(x = lat, y = y.tissue, colour = site) +
  geom_point() +
  geom_rug(sides = "l") + ## l for left!
  scale_x_continuous("Lattitude") +
  theme_minimal()
```



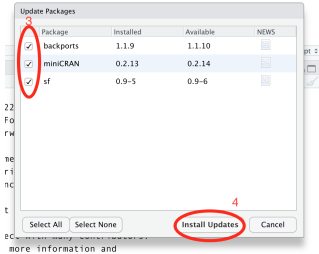
Note: check `https://www.r-graph-gallery.com` for examples

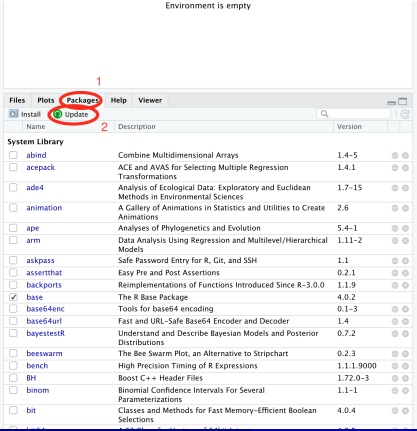
18. When to update what?

Update:

- **R** (at least once a year after the big new release in spring)
- RStudio (at least after each update of **R**)
- packages (at least once a month)

For packages:

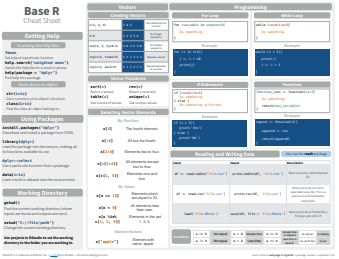


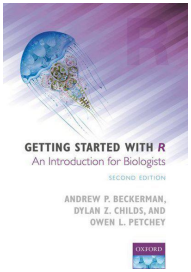


19. How to reach the level A2/B1?

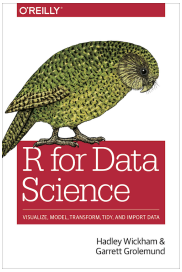
There are many resources available at your disposal:

- tons of online tutorials, videos, forums...
- RStudio cheatsheets
- Official documentation (help files + `https://cran.r-project.org/manuals.html`)
- Books (not always free):

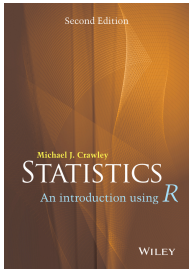




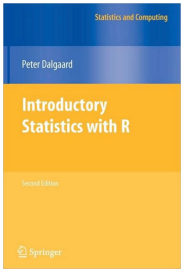
~ 30 €



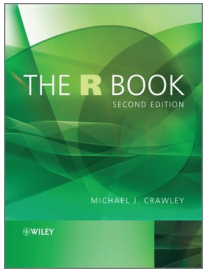
~ 0 or 60 €



~ 35 €



~ 40 €



~ 60 €

20. How to reach levels beyond B1?

This is not beyond your reach!

- give AI and stackoverflow a break (at least no more hopeful copy/pasting)
- try to help less advanced colleagues
- look at the code of more advanced **R** geeks (GitHub is a good source)
- act as a scientist: once you know some basics, if you notice something that does not behave as you thought it should, make hypotheses and test them
- try to contribute to collaborative **R** projects (e.g. on GitHub)

If you persist, you will become very good at **R** no matter how difficult you may find it now!