Introduction to R programming for data science – day 1

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R programming

R is:

- One of the leading programming languages for statistics and data science
- Useful for basic and advanced data analyses
- Prerequisite for job positions in life science and biomedicine

Why?

- Its is free
- It supports reproducibile analyses
- It provides packages for data analysis

In this course…

We will learn the **basics of R programming** through lectures and hands-on computer exercises using Rstudio:

- variables, data types, and data structures
- data manipulation and visualization
- operations
- reading and writing files
- running and repeating tasks using functions and control statements.

Disclaimer: this is **not** a course in statistics or bioinformatics.

Course info

Course material: https://github.com/FFinotello/Rcourse

Note: to download a text file, right-click on Raw and select Save link as.

Exam

- **Written test:** multiple-choice questions on theory and small example codes like those in the slides (at the MUI after the course, without the laptop)
- **Hands-on project:** data analysis project do be described in a short report (at home, to be sent by e-mail)

Installation

Install first R and then Rstudio

To install **R**:

https://www.r-project.org

See “To download R, please choose your preferred CRAN mirror”.

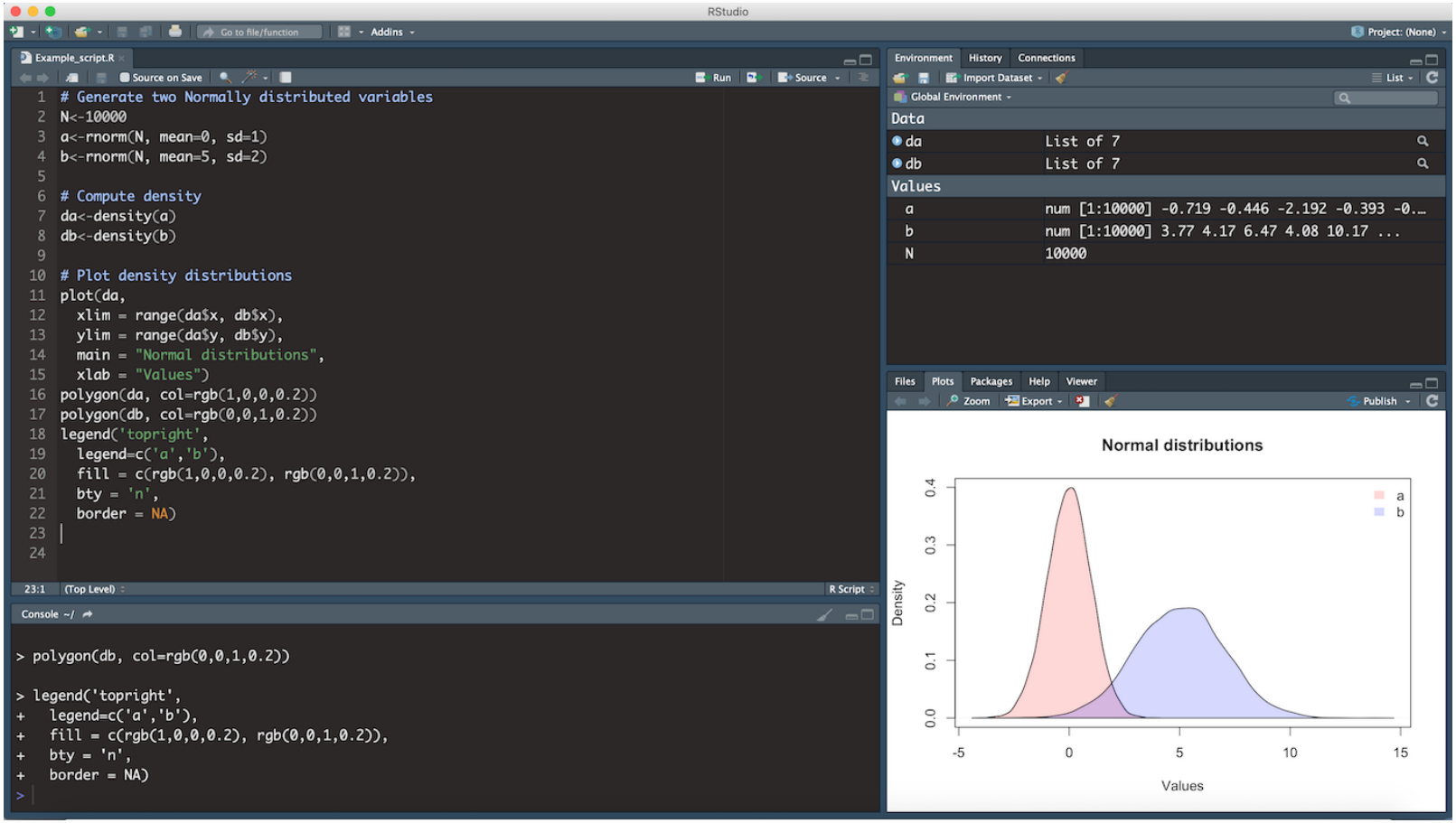
To install **RStudio Desktop**:

https://www.rstudio.com/products/rstudio/download/#download

RStudio

RStudio console

RStudio is an integrated development environment (IDE) for R.
It has four main panels with adjustable sizes:



From the toolbar: View > Panes > Show All Panes

RStudio console

In the console you can type commands and see outputs.

```
( 12^2 - 20 * 2 + 1) / 5
```

```
## [1] 21
```

```
log10(100)
```

```
## [1] 2
```

```
sqrt(9) / 3
```

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

Have a look at the History panel: what do you see?

RStudio scripts

Instead of using the console, you can save your code in a .R file (e.g. *R_script_day1.R*)

Open a **new file**: File > New File > New R Script

Save as R script: File > Save as

Set working directory: Session > Set Working Directory > To Source File Location

Open an R script: File > Open File (e.g. *Example_script.R*)

You can run all the in a script altogether with Source or in chunks using Control+Enter.

Remember to save your code regularly!

Variables and data types

Variables

Vaiables are symbolic names used to store data that can be manipulated in a computer program

In R, variables are assigned with <-

```
height <- 1.90

weight <- 80

# Body mass index
BMI <- weight/height^2
```

Have a look at the Environment panel: what do you see?

Case-sensitive programming

R is case-sensitive

```
BMI
```

```
## [1] 22.16066
```

```
bmi
```

```
## Error in eval(expr, envir, enclos): object 'bmi' not found
```

Variable names

- Short, but descriptive
- Must start with a letter
- Nust not contain special characters
- Cannot be **reserved words** (if, function, NA, TRUE, …)

Try assign the value of 10 to a variable called:

- *myVar*
- *my_var*
- *my.var*
- *my-var*
- *1var*
- *var1*

Operations

Once variables are assigned, they can be used to perform operations

```
x <- 6
y <- 2
x + y
```

```
## [1] 8
```

```
x^y
```

```
## [1] 36
```

```
x == y
```

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

Arithmetic operators

Operator	Description
+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Exponent
%%	Modulus (Remainder from division)
%/%	Integer Division

Relational operators

Operator	Description
<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
==	Equal to
!=	Not equal to

Logical operators

Operator	Description
!	Logical NOT
&	Element-wise logical AND
&&	Logical AND
|	Element-wise logical OR
||	Logical OR

Atomic vector types

In R, there are several types of atomic vectors (also called *classes*):

- Character
- Numeric
- Logical
- Complex
- Integer

Data type examples

```
Name <- "Maria"
class(Name)
```

```
## [1] "character"
```

```
PhD <- TRUE
class(PhD)
```

```
## [1] "logical"
```

```
yearsSincePhD <- 5
class(yearsSincePhD)
```

```
## [1] "numeric"
```

Missing Values

In R, missing values are usually coded with NA

```
Name <- "Michael"
PhD <- FALSE
yearsSincePhD <- NA

is.na(Name)
```

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

```
is.na(yearsSincePhD)
```

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

Note: NA are not strings (no quotation marks)

Other indefinite values

Not a number: NaN

```
( var1 <- 0/0 )
```

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

Infinite: Inf

```
( var2 <- 9/0 )
```

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

```
var3 <- -10/0
```

What is the value of *var3*?

Data conversion/coercion

Class conversion is possible, but it must be handled with care

```
var1 <- 1
( var2 <- as.character(var1) )
```

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

```
class(var2)
```

```
## [1] "character"
```

```
( var3 <- as.logical(var1) )
```

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

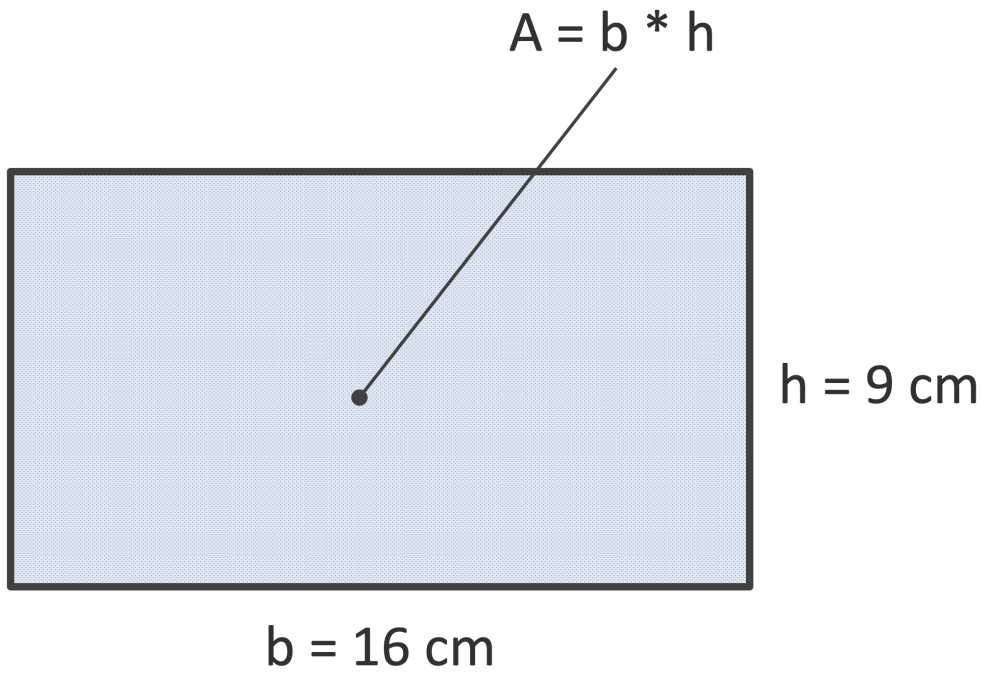
Data type conversion

Conversion to	Function	Rules
numeric	`as.numeric`	`FALSE` → 0
		`TRUE` → 1
		`"1"`, `"2"`, ... → 1, 2, ...
		`"A"`, ... → `NA`
logical	`as.logical`	0 → `FALSE`
		other numbers → `TRUE`
		`"FALSE"`, `"F"` → `FALSE`
		`"TRUE"`, `"T"` → `TRUE`
		other characters → `NA`
character	`as.character`	1, 2, ... → `"1"`, `"2"`, ...
		`FALSE` → `"FALSE"`
		`TRUE` → `"TRUE"`

Source: https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf

Exercises

Ex. 1.1



- Initialize two *numeric variables* called *b* and *h* with the length of the base and heigth of the rectangle depited above, respectively.
- Initialize a *numeric variable* called *A* with the value of the area of the rectangle computed on the fly.
- Check if the area is bigger than 100 cm^2.

Ex. 1.2

```
Name <- "Maria"
Age <- "20"
PhD <- "TRUE"
```

What is the class of the variables above?

1. *Name*: character; *Age*: numeric; *PhD*: character
2. *Name*: character; *Age*: character; *PhD*: character
3. *Name*: character; *Age*: numeric; *PhD*: logical
4. None of the above

Ex. 1.3

```
x <- 5
y <- 0
z <- x/y
```

What is the value of *z*?

1. -Inf
2. NA
3. NaN
4. None of the above

Data structures

Data structures

In R, there are different data structures, including:

Data structure	Can contain different data types?
Vector	No
Matrix	No
Factor	No
List	Yes
Data.frame	Yes

Data structure: vector

Vectors can be build with *c* and their length can be assessed with the function *length*

```
( x <- c(1, 2, 3, 4) )
```

```
## [1] 1 2 3 4
```

```
( y <- c("a", "b", "c") )
```

```
## [1] "a" "b" "c"
```

```
length(y)
```

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

Data structure: vector

Vectors can contain a single data type only, so beware of conversions

```
(z <- c("a", "b", 1, 2))
```

```
## [1] "a" "b" "1" "2"
```

```
(v <- c(x, y))
```

```
## [1] "1" "2" "3" "4" "a" "b" "c"
```

What are the classes of *z* and *v*?

Fast ways to build vectors

```
( j <- 1:4 ) # Seq. of integers
```

```
## [1] 1 2 3 4
```

```
( x <- seq(0, 1, 0.1) ) # Seq. of numbers (from, to, step)
```

```
##  [1] 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
```

```
( y <- rep("A", 5) ) # Seq. of repeated numbers or characters
```

```
## [1] "A" "A" "A" "A" "A"
```

```
( z <- c(rep("A", 3), rep("B", 5)) ) # Vector combination
```

```
## [1] "A" "A" "A" "B" "B" "B" "B" "B"
```

Assign and query vector names

```
( age <- c(19, 30, 20) )
```

```
## [1] 19 30 20
```

```
names(age) <- c("Mary", "John", "Lisa") # Assign

age
```

```
## Mary John Lisa
##   19   30   20
```

```
names(age) # Query
```

```
## [1] "Mary" "John" "Lisa"
```

Data structure: matrix

2-dimensional variable that can be build with the function *matrix*

```
( M <- matrix(1:6, ncol=3, byrow=FALSE) ) # Fill by columns (def.)
```

```
##      [,1] [,2] [,3]
## [1,]    1    3    5
## [2,]    2    4    6
```

```
( N <- matrix(1:6, ncol=3, byrow=TRUE) ) # Fill by rows
```

```
##      [,1] [,2] [,3]
## [1,]    1    2    3
## [2,]    4    5    6
```

Matrix rows and columns

```
M <- matrix(1:6, nrow=2, byrow=FALSE)
dim(N)
```

```
## [1] 2 3
```

```
ncol(M)
```

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

```
nrow(M)
```

```
## [1] 2
```

Matrix row and column names

```
colnames(M) <- c("Sample_A", "Sample_B", "Sample_C") # Assign
rownames(M) <- c("Gene1", "Gene2") # Assign
M
```

```
##       Sample_A Sample_B Sample_C
## Gene1        1        3        5
## Gene2        2        4        6
```

```
colnames(M) # Query
```

```
## [1] "Sample_A" "Sample_B" "Sample_C"
```

```
rownames(M) # Query
```

```
## [1] "Gene1" "Gene2"
```

Data structure: factor

Categorical variable that can build with the function *factor*

```
strain <- factor(c("WildType", "WildType", "Mutant", "Mutant"))
strain
```

```
## [1] WildType WildType Mutant   Mutant
## Levels: Mutant WildType
```

```
length(strain)
```

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

```
levels(strain)
```

```
## [1] "Mutant"   "WildType"
```

Factor conversion

```
( x <- as.factor(c(10, 2, 2, 3)))
```

```
## [1] 10 2  2  3
## Levels: 2 3 10
```

```
( y <- as.numeric(x) ) # This does NOT work
```

```
## [1] 3 1 1 2
```

```
( z <- as.numeric(as.character(x)) ) # This works
```

```
## [1] 10  2  2  3
```

Data structure: list

A list is a structure that can contain different objects (including lists!)

It can be created with the function *list*

```
v <- 1:3
M <- matrix(1:4, ncol=2)
( myList <- list(myVec=v, myMat=M) )
```

```
## $myVec
## [1] 1 2 3
##
## $myMat
##      [,1] [,2]
## [1,]    1    3
## [2,]    2    4
```

List names and length

```
length(myList)
```

```
## [1] 2
```

```
names(myList)
```

```
## [1] "myVec" "myMat"
```

```
nrow(myList)
```

```
## NULL
```

```
ncol(myList)
```

```
## NULL
```

Note: the output of several functions are structured as lists

Data structure: data.frame

A data.frame is a 2-dimensional object ("matrix-like") that can contain different types of data on its colums.

It can be created with the function *data.frame*

```
( DF <- data.frame(name=c("Mary", "John", "Lisa"),
  age=c(19, 30, 20),
  city=c("New York", "Seattle", "New York"),
  stringsAsFactors=FALSE) )
```

```
##   name age     city
## 1 Mary  19 New York
## 2 John  30  Seattle
## 3 Lisa  20 New York
```

Data.frame rows and columns

```
dim(DF)
```

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

```
nrow(DF)
```

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

```
ncol(DF)
```

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

```
colnames(DF)
```

```
## [1] "name" "age"  "city"
```

What are the row names of *DF*?

Exercises

Ex. 1.4

```
x <- c("a", "b", "c")
y <- seq(1,10)
z <- c(x,y)
```

What is the *class* of *z*?

1. Character and numeric
2. Numeric
3. Character
4. NA

Ex. 1.5

Build a *numeric vector* containing all even numbers greater than 0 and that do not exceed 100.

Ex. 1.6

- Build a *vector of factors* storing the information about which mice is wild type ("WT") and or mutant ("MU") in the figure above (try to use *rep*).
- Assign mice identifiers (M1, M2, …) to the same vector (use *names*).

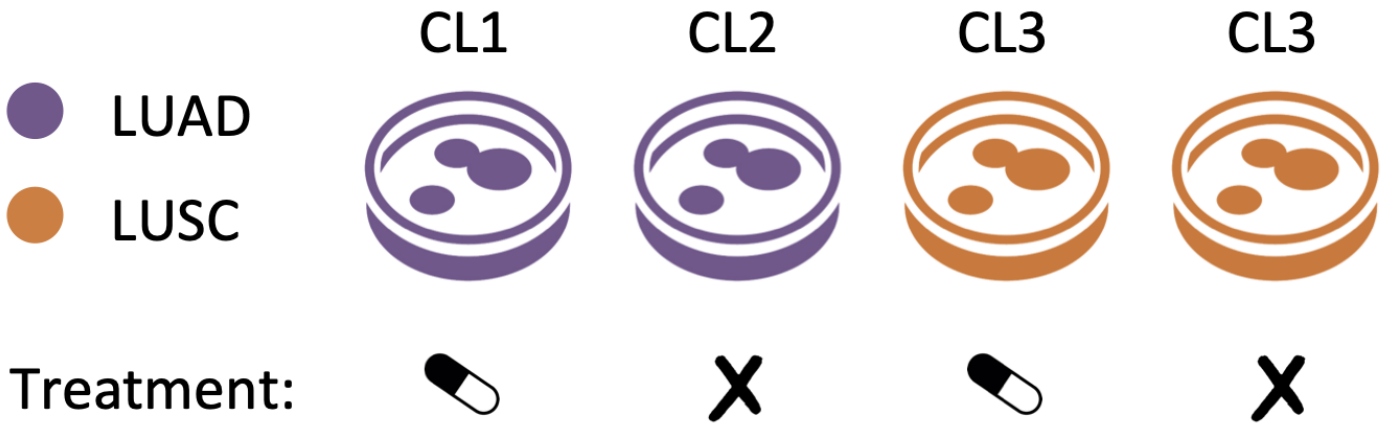
Ex. 1.7

- Initialize a *matrix* with 2 rows and 3 columns that has all “1” on the first row and all “2” on the second row.
- Give it column and row names as you wish.
- Check its dimensions.

Ex. 1.8

- Initialize a *numeric vector* to store the year in which you got your driving licence and the yer you got your first own car (NA values are possible). Set appropriate names.
- Initialize a *character vector* to store the names of your favorite cities in Europe (as many as you like).
- Save both vectors in a *list* using meaningful names (lists can contain different objects with different sizes).

Ex. 1.9



- Imagine you have an experiment with 4 lung cancer cell lines: 2 from adenocarcinomas (LUAD) and 2 from squamous cell carcinoma (LUSC).
- One cell line from each is treated with a drug, the others are untreated, as shown in the figure above
- Save in a *data.frame* the info about the experiment: cell line identifier, lung-cancer subtype, and treatment.
- Check how many rows and columns the data.frame has.

Useful resources

R for beginners: https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf

Stackoverflow (Ask a Question): https://stackoverflow.com

Solutions

Ex. 1.1: A=144 (>100)

Ex. 1.2: 2) Character, character, character

Ex. 1.3: 4) None of the above (Inf)

Ex. 1.4: 3) Character