INTRODUCTION TO R

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Objects in R

R is an **object-based** programming language hence why *objects* are one of the *smallest* and *most important* units anyone attempting to handle R should be aware of. Like words in a sentence they **carry information**.

Objects are characterised by **attributes**:

Attribute	Meaning	Definition
Name	R-internal name which is used to refer to the object in question	User-defined
Type	R-internal class of the object in question	Often user-defined
Mode	R-internal class of values contained within the object in question	Not user-defined
Dimensions	Arrangement of content within the object in question	Often user-defined

Assigning and Removing Objects

An object is **assigned** some content in `R` as follows:

- Name <- Object/Content (this is the way to go)
- Name = Object/Content (avoid this)

This will **add** an object of the chosen name **to** the **working environment.**

> Only one object of the same name can be present in the working environment at any given time.

To **alter**/**remove** a specific object from your `R` working environment do either of the following:

- Name <- Object/Content (simply **overwrite** it)
- `rm(`Name`)` (**remove** the object from your working environment)

Object Modes

Modes refer to the class of object-contained values. Usually, you will only encounter some of the following basic modes:

R-internal object mode	Real-world counterpart
`character`	A letter, word or sentence
`numeric`	A number (can have decimal points)
`logical`	An indicator of `TRUE` or `FALSE`

Within R, the **mode of any objects content** can be **identified** using the `class()` function after having broken down the object into basic `vector` type components.
Additionally, one may want to employ the `str()` function which attempts to automatically perform some of the subsetting for you and give you an overview of the components within your object.

Object Types/Classes

Objects in `R` appear as different **types** (also referred to as *classes*):

`R`-internal object type	Real-world counterpart
`vector`	A list of variable values
`factor`	A list of variable values with pre-defined possible values
`matrix`	A table of variable values
`data frame`	A table of variable values
`function`	A recipe-style functional expression detailing a process
`list`	A list where each element corresponds to a list, table or recipe

Within `R`, the **type of any object** can be **identified** using the `class()` or `str()` function. Note that, for an object of type `vector`, the `class()` function returns the **mode** of the vectors contents.

Vector I (`character`)

`Vectors` are created using the function `c(... , ...)` ("c" stands for *concatenate*; "," separates individual units within the vector) in R:

- A `character` vector:

```
Letters_vec <- c("A", "B", "C")
Letters_vec
```

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

```
class(Letters_vec)
```

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

You can also **convert** object element mode to be of `character` by using the function `as.character()`.

Vector II (`numeric`)

- A `numeric` vector:

```
Numbers_vec <- c(1, 2, 3)
Numbers_vec
```

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

```
class(Numbers_vec)
```

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

You can also **convert** object element mode to be of `numeric` by using the function `as.numeric()`.

Vector III (`logical`)

- A `logical` vector:

```
Logic_vec <- c(TRUE, FALSE)
Logic_vec
```

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

```
class(Logic_vec)
```

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

You can also **convert** object element mode to be of `logical` by using the function `as.logical()` (keep in mind that this will only yield partially desirable results).

Factor

`Factors` are created using the function `factor(x , levels , ...)` ("x" represents the data; "levels" indicates the preconceived levels our data should take and is usually estimated from the data by default) in R.

- A `factor` type object:

```
Letters_fac <- factor(x = c("A", "B", "C"))
Letters_fac
```

```
## [1] A B C
## Levels: A B C
```

```
class(Letters_fac)
```

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

You can also **convert** object types to be of `factor` by using the function `as.factor()`.

Lists

`Lists` are created using the function `list(...)` ("`...`" represents the objects passed to the list) in R.

```
Vectors_ls <- list(Numbers_vec, Letters_vec)
Vectors_ls
```

```
## [[1]]
## [1] 1 2 3
##
## [[2]]
## [1] "A" "B" "C"
```

```
class(Vectors_ls)
```

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

Keep in mind that a list **can contain every conceivable object** of R **within** every list position (yes, even lists of lists are possible).

You can also **convert** object types to be of `list` by using the function `as.list()`.

Matrix

`Matrices` are created using the function `matrix(data, nrow, ncol, byrow, dimnames)` ("data" represents the data; "nrow" and "ncol" indicate the number of rows and columns respectively, "byrow" is a logical argument indicating whether to fill the data into the matrix by row or by column, "dimnames" let's you ascribe names to columns and rows) in R.

```
Combine_mat <- matrix(data = c(Numbers_vec, Letters_vec), ncol = 2)
Combine_mat
```

```
##      [,1] [,2]
## [1,] "1"  "A"
## [2,] "2"  "B"
## [3,] "3"  "C"
```

```
class(Combine_mat)
```

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

You can also **convert** object types to be of `matrix` by using the function `as.matrix()`.

Data Frame I (creating from a `matrix`)

`Data Frames` are created using the function `data.frame(...)` ("..." can stand for a `matrix` or index individual columns) in R.

- Creating a `data.frame` from a `matrix`:

```
Combine_df <- data.frame(Combine_mat)
Combine_df
```

```
##   X1 X2
## 1  1  A
## 2  2  B
## 3  3  C
```

```
class(Combine_df)
```

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

You can also edit the names of columns and rows in a `data.frame` object using the commands `colnames()` and `rownames()` respectively.

Data Frame II (creating with individual columns)

- Creating a `data.frame` from `vectors` as individual columns:

```
Combine2_df <- data.frame(Numbers = Numbers_vec, Letters = Letters_vec)
Combine2_df
```

```
##   Numbers Letters
## 1       1       A
## 2       2       B
## 3       3       C
```

```
class(Combine_df)
```

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

You can also **convert** object types to be of `data.frame` by using the function `as.data.frame()`.

Converting Modes

Target Mode	Function	What Happens
`numeric`	`as.numeric`	`FALSE` −> `0`
		`TRUE` −> `1`
		`"1", "2", "..."` −> `1, 2, ...`
		`"A"` −> `NA`
`character`	`as.character`	`1, 2, ...` −> `"1", "2", "..."`
		`FALSE` −> `"FALSE"`
		`TRUE` −> `"TRUE"`
`logical`	`as.logical`	`0` −> `FALSE`
		any number that isn't `0` −> `TRUE`
		`"FALSE"/"F"` −> `FALSE`
		`"TRUE"/"T"` −> `TRUE`
		any character that isn't any of the above −> `NA`

Converting Types

Target Type	Function	What Happens
`vector`	`as.vector`	factor levels are dropped matrices are made into vectors one column at a time data frames are made into vectors but remain in an array arrangement lists remain as lists
`factor`	`as.factor`	factor levels are established from vector values factors levels drawn from a column-wise vectorisation of matrices does not work on data frames or lists
`matrix`	`as.matrix`	Puts content of vectors or factor into a single column data frames remain unaltered as far as data structure goes lists turn into cells with type and number of items of list positions
`data frame`	`as.data.frame`	each object gets put into a separate column matrices remain unaltered as far as data structure goes every list position is made into a column
`list`	`as.list`	every element gets put into an individual list position columns of data frames occupy list positions

Object Dimensions (`matrices` and `data.frames`)

Object **dimensions** are the last of the essential attributes of objects we will consider. They tell you how data is arranged. They are assessed using the `dim(...)` function in R ("..." stands for any given object name in R):

- Matrices have dimensions of rowcount x columncount

```
dim(Combine_mat)
```

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

- Data Frames also have dimensions of rowcount x columncount

```
dim(Combine_df)
```

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

Object Dimensions (vectors, factors, lists)

- Vectors, Factors and Lists don't have `dimensions`...

```
c(dim(Letters_vec), dim(Letters_fac), dim(Vectors_ls))
```

```
## NULL
```

- ... they only have a `length`

```
c(length(Letters_vec), length(Letters_fac), length(Vectors_ls))
```

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

The Naming System (`data.frames`)

Names can serve as *labels* to elements of an object and are implemented/ assigned using the `names()` function at the most basic level (i.e. "for 'vectors` and `factors`"). Further implementations of *names* come in the form of the following functions:

- `colnames()` (column labels, `data.frames`)
- `rownames()` (row labels, `data.frames`)
- `dimnames()` (dimension labels, `matrices`)

```
colnames(Combine2_df)
```

```
## [1] "Numbers" "Letters"
```

```
rownames(Combine2_df)
```

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

```
Combine2_df$Numbers   # subsetting by column 'Numbers'
```

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

The Naming System (`vectors`)

- Our vectors don’t have names assigned yet:

```
names(Numbers_vec)
```

```
## NULL
```

- Let’s do that:

```
SubNames1 <- Numbers_vec
names(SubNames1) <- Letters_vec
SubNames1
```

```
## A B C
## 1 2 3
```

The Indexing System (`matrices` and `data.frames`)

The **indexing** system is basically the *numerical* **counterpart** to the naming system and called into action by the **use of square brackets** (`[]`):

- `[elementnumber]` for `vectors and factors`
- `[[elementnumber]]` for `lists`
- `[rownumber, columnnumber]` for `data.frames` and `matrices`
  - First element of second column of our matrix:

```
Combine_mat[1, 2]
```

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

  - Entire first column of our data frame:

```
Combine_df[, 1]
```

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

The Indexing System (`vectors`, `factors` and `lists`)

- Third element of our letter vector:

```
Letters_vec[3]
```

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

- First element of our list:

```
Vectors_ls[[1]]
```

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

What is Vectorisation and why should I care?

R is a **vectorised** language.

- **What** does that mean?

  Any mathematical operation is applied to every element in an object:

```
Numbers_vec + 1
```

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

- **Why** care?

  Because it greatly influences how you do calculations in R.

Writing Functions in R

Functions are *special objects* within R as they **carry information for processing objects**. Functions require the following **components**:

- *Name* - each function has a name
- *Argument(s)* - give additional information to the function
- *Call* - a function needs to be called to exert its effect

Users can **create** their own **functions** in R as follows:

```
Plus1 <- function(x) {
    # function has an argument of `x`
    y <- x + 1  # 1 is added to the object `x` and saved as `y`
    return(y)  # object `y` is returned
}
Plus1(Numbers_vec)  # call the function on thes Numbers vector
```

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

indicate **comments in the code** - these are not run but can help explain stuff to the user

What are R packages?

Packages are R's way of supplying the user with a widened **range of functionality** (just like a mod to a computer game or bonus tracks on a CD).

There are **thousands of packges** for R which have been designed by other R users, tested vigorously, and are available freely for you to use.

All packages are available via the Comprehensive R Archive Network (https://cran.r-project.org/) and an overview of available packages can be retrieved here: https://cran.r-project.org/web/packages/available_packages_by_date.html.

What do I do with packages?

You **install** and **load** them into R!

This is done in a **two-step process**:

- `install.packages()` is used to install packages in R

```r
# vegan is a common library of functionality in biostatistics
install.packages("vegan")
```

- `library()` is used to load them into the current working environment

```r
library(vegan)
```

Logical statements

Logical statements are indicators of **whether something is true or not**. We use those frequently in real life (i.e. ‘Is a 10 ECTS course worth more to me than a 5 ECTS course?’). R implements these with the following operators:

Operator	Translation
==	“equals”
!=	“does not equal”
<	“is smaller”
<=	“is equal or smaller”
>	“is bigger”
>=	“is equal or bigger”

These statements return an element of mode `logical` (`TRUE` or `FALSE`).

`if()` statements

`if()` statements *build on logical statements*. They **test whether something is correct** and then act on it:

```
# is 1 smaller than 2?
if (Numbers_vec[1] < Numbers_vec[2]) {
    # if the statement is correct
    print("Is smaller")  # print this to the console
} else {
    # if the statement is not correct
    print("Is not smaller")  # print this to the console
}
```

```
## [1] "Is smaller"
```

`for()` loops

`for()` loops are in **action whilst** an **indiciator** is **within a specified data range**:

```
# loop from one to length of the letter vector in steps of 1
for (i in 1:length(Letters_vec)) {
    # print current itteration element of letters vector
    print(Letters_vec[i])
}
```

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

`while()` loops

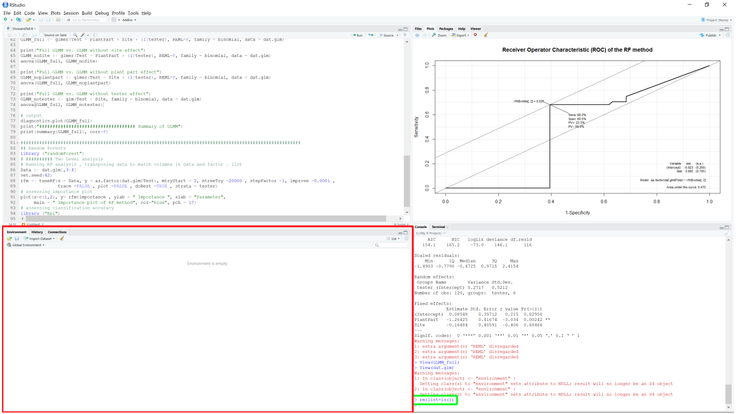
`while()` loops work a lot like `for()` loops and are in **action whilst** an **indiciator statement** is `TRUE`:

```
# while our data frame has equal to or less than 3 columns
while (dim(Combine_df)[2] <= 3) {
    # bind letters factor vector to data frame as column
    Combine_df <- cbind(Combine_df, Letters_fac)
}
Combine_df  # inspect the result
```

```
##   X1 X2 Letters_fac Letters_fac
## 1  1  A           A           A
## 2  2  B           B           B
## 3  3  C           C           C
```

rm(list=ls())

- `rm(list=ls())` clears the entire working environment



rm(list=ls()) II

`rm(list=ls())` is **extremely useful** and one should use this before sourcing (running an entire script) any R document to avoid influence of remnants of previous R sessions on the current analysis.

→ Simply code this to be **your first line**!

`getwd()` and `setwd()`

- `getwd()` returns the current working directory

$\rightarrow$ can identify the project folder if coded into script fairly early (usually second line)

$\rightarrow$ can be used to soft code the working directory

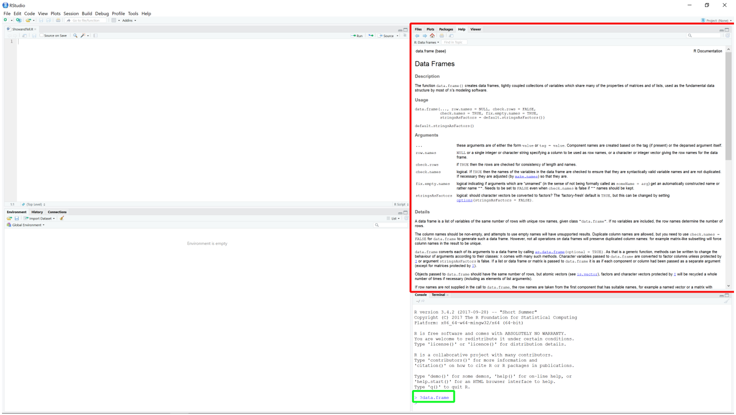
- `setwd()` is used to set specific working directories

$\rightarrow$ can be used to address specific folders on your hard drive as the current working directory

$\rightarrow$ often used to hard code the working directory (please avoid this at all cost!)

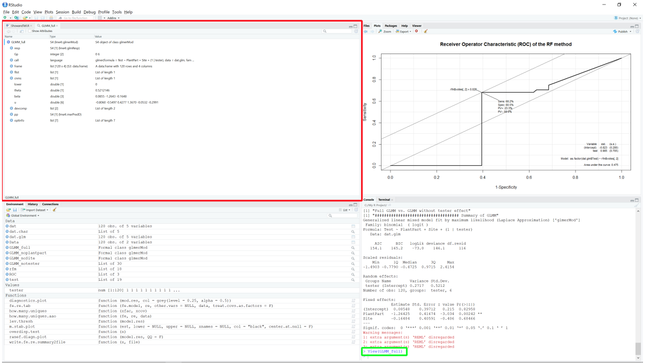
?

- `?` followed by a function name, this will open the help documentation for said function



View()

- `View()` is a very neat command that lets the user inspect any object of their choosing in a separate tab



Creating and Inspecting Objects (`vectors` and `factors`)

Create the following `vectors` or `factors`:

Name	Content
`Letters_vec`	A vector reading "A", "B", "C"
`Numbers_vec`	A vector reading 1, 2, 3
`Logic_vec`	A vector reading `TRUE`, `FALSE`
`Big_vec`	A vector of the elements of the first three vectors
`Seq_vec`	A vector reading as a sequence of full numbers from 1 to 20
`Letters_fac`	A factor reading "A", "B", "C"
`Numbers_fac`	A factor reading 1, 2, 3
`Constrained_fac`	A factor reading 1, 2, 3, levels 1 and 2 are allowed
`Expanded_fac`	A factor reading 1, 2, 3 levels 1 - 4 are allowed

Inspect these objects for their classes and dimensions!

Creating and Inspecting Objects (`matrices`, `data.frames` and `lists`)

Create the following objects:

Name	Content
`Combine_mat`	`Numbers_vec` and `Letters_vec` in columns of a matrix
`Pivot_mat`	First two vectors in distinct rows of a matrix
`Names_mat`	The above matrix with meaningful names
`Combine_df`	The first matrix we established as a data frame
`Names_df`	The previous data frame with meaningful names
`Vectors_ls`	The first two vectors we created as a list

Inspect these objects for their classes and dimensions!

Statements and Loops

Test the following *statements*:

- `Numbers_vec` contains more elements than `Letters_fac`
- The first column of `Combine_df` is shorter than `Vectors_ls`
- The elements of `Letters_vec` are the same as the elements of `Letters_fac`

Write the following *loops*:

- Print each element of `Vectors_ls`
- Print each element of `Numbers_vec` + 1
- Subtract 1 from each element of the first column of `Combine_mat` and print each element separately

Using the Useful Commands

Do the following:

- Read out your current working directory
- Inspect the `Vectors_ls` object using the `View()` function
- Inspect the `Combine_df` object using the `View()` function
- Get the help documentation for the `as.matrix()` function
- Install and load the `dplyr` package
- Remove the `Logic_vec` object from your working environment
- Clear your entire working environment