Introduction to R

Slides adapted from Jean Monlong with permission

Department of Medical Biophysics

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Why R ?

Why R ?

Simple

- Interpreted language (no compilation needed)
- No manual memory management
- Vectorized

Free

- Widely used, vast community of R users
- Good life expectancy

Flexible

- Open-source: anyone can see/create/modify code.
- Multiplatform: Windows, Mac, Unix, it works everywhere

Trendy

- More and more packages
- More and more popular among (big) data scientists

Easy installation

- Install R from
  `http://cran.r-project.org/`

- Additionally, you can get a nice interface through Rstudio Desktop from
  `http://www.rstudio.com/ide/download/desktop`

Workshop setup

Open Rstudio

- Click on the bottom-left corner (Ubuntu/Windows)
- Type *rstudio*, click on Rstudio icon.

In Rstudio

- On the bottom-right panel, go to *Documents* folder.
- Create o folder for your data and scripts. E.g. *Rworkshop*.
- Set this folder as working directory (*More* button).
- Create an empty script for today's session (*File* $\rightarrow$ *New File* $\rightarrow$ *R Script*).

Download today's slides and data

1. Download all the files attached to the workshop instruction email
2. Put it in your *Rworkshop* folder.

Console ? Script ?

Console

- Where R is running.
- You could write and run the commands directly there.

Script

- A text file with commands. *Extension: .R.*
- To keep a trace of your analysis.
- Recommended.
- Easy to send commands from a script to the console.

When you get an error

1. Read the command, look for typos.
2. Read the error message.
3. 1. and 2. again.
4. Raise your hand, someone will assist you.

Solving errors is an important skill to learn.

Data structure

Data structure - Overview

Unit type

numeric Numbers, e.g. 0, 1, 42, −66.6.

character (string) Words, e.g. “male”, “ENSG0007”.

logical (boolean) Binary, i.e. two possible values: *TRUE* or *FALSE*.

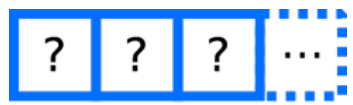
Structure

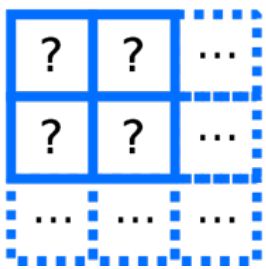
vector Ordered collection of elements of the **same type**.

matrix 2-D vector of elements of the **same type**.

list Flexible **mixed type** container of other objects.

dataframe Progeny of matrix and list





Assign a value to an object

Choose an object name

- **Starts with a letter** or the dot not followed by a number.
- **Letters**, **numbers**, **dot** or **underline** characters.
- Correct: “valid.name”, ”valid_name”, ”valid2name3”.
- Incorrect: ”valid name”, ”valid-name”, ”1valid2name3”.

Assign a value

The name of the object followed by the assignment symbol and the value.

```
valid.name_123 = 1
valid.name_123 <- 1

valid.name_123
```

Use a function

- **Parenthesis** are for **functions only**.
- The rest will be for data manipulation.
- Read help manual to know more about a function (help, ? or F1 in Rstudio).

```
print(1)
myFunction(valid.name_123)

help(print)
?print
```

Vectors

Vectors

vector construction

c	Concatenate function.
1:10	vector with numbers from 1 to 10.

Example

```
luckyNumbers = c(4,8,15,16,23,42)
luckyNumbers
oneToTen = 1:10
tenOnes = rep(1,10)
samples = c("sampA","sampB")
samples
```

Extra

seq	Create a sequence of numbers.
rep	Repeat element several times.
runif	Simulate random numbers from Uniform distribution. Same for rnorm, rpois, ...

Exercise - Create some vectors

Instructions

- Create a vector with 7 *numeric* values.
- Create a vector with 7 *character* values.
- Be creative !

Vectors

Manipulation

Using index/position between [ ].

Characterization

length Number of element in the vector.
names Get or set the names of the vector's values.

Example

```
luckyNumbers[3]
luckyNumbers[2:4]
luckyNumbers[2:4] = c(14,3,9)

length(luckyNumbers)

names(luckyNumbers)
names(luckyNumbers) = c("frank","henry","philip",
                        "steve","tom","francis")
luckyNumbers["philip"]
```

Vectors

Manipulation

sort	Sort a vector.
sample	Shuffle a vector.

Example

```
sort(luckyNumbers)

sort(c(luckyNumbers,1:10,tenOnes))

rev(1:10)

sample(1:10)
```

Extra

sort/sample	Explore extra parameters.
order	Get the index of the sorted elements.

Vectors

Exploration

head/tail Print the first/last values.

On *numeric* vectors:

summary Summary statistics: minimum, mean, maximum, ...

min/max/mean/var Minimum, maximum, average, variance.

sum Sum of the vector's values.

Example

```
head(samples)
summary(luckyNumbers)
mean(luckyNumbers)
min(luckyNumbers)
```

Extra

log/log2/log10 Logarithm functions.

sqrt Square-root function.

Vectors

Arithmetic operators

- Simple arithmetic operations over all the values of the vector.
- Or values by values when using vectors of same length.
- Arithmetic operation: +, -, *, /.
- Others exist but let's forget about them for now.

Example

```
luckyNumbers * 4
luckyNumbers - luckyNumbers
luckyNumbers / 1:length(luckyNumbers)
luckyNumbers + 2
```

Exercise - Guess my favorite number

Instructions

1. Create a vector with 5 *numeric* values
2. Multiply it by 6.
3. Add 21.
4. Divide it by 3
5. Subtract 1.
6. Halve it.
7. Subtract its original values.

Naming elements of a vector

Retrieving elements by non-repeated strings

- Instead of retrieving a specific element of a vector by its location, you can retrieve by its name.
- You can use the function names and provide a vector of same length as names
- You can then retrieve each element by its name

Example

```
eng_fr_dict = c("bonjour", "stationment", "chien")
names(eng_fr_dict) = c("hello", "parking", "dog")
eng_fr_dict["dog"]
[1] "chien"
```

Matrix

Matrix

Specific to matrices

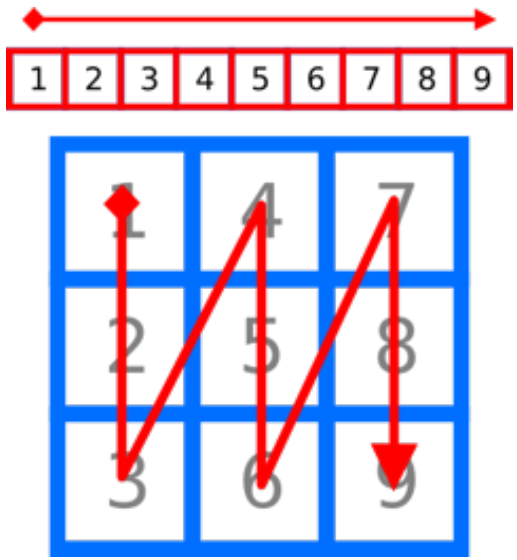
matrix Create a matrix from a vector.
2^{nd} and 3^{rd} parameters define the number of rows and columns.

mat[i,j] Element at row i and column j. If blank, the entire row/column is used.

Example

```
neo = matrix(1:12,3,4)
neo

neo[1,1] = 0
neo[1:2,1:3]
neo[1:2,1:3] = matrix(rep(1,6),2,3)
neo[1,]
```



Exercise

1. Create a matrix with 10 rows and 4 columns with numbers from 1 to 40.
2. Change the element in row 6 column 1 into the value 666.
3. Fill the 3rd row with ones.

Matrix

Specific to matrices

dim Dimension of the matrix: number of rows and columns.

rownames/colnames Get or set the names of the rows/columns.

Example

```
dim(neo)
dim(rbind(neo,neo))

colnames(neo) = c("gene1","gene2","gene3","gene4")
rownames(neo) = c("sample1","sample2","sample3")
neo
neo["sample2","gene3"]
```

Matrix

Same as vector

- length, head, tail.
- For *numeric* matrix: min, max, sum, mean.
- Arithmetic operations: +, -, *, /.

Example

```
head(mat)
mean(mat)
sum(mat) / length(mat)

mat * 2
mat + mat
```

Extra

log/log2/log10 Logarithm functions.

sqrt Square-root function.

Exercise

1. Create a matrix with 100 rows and 4 columns with random numbers inside. *Tip:* runif *function for random numbers.*
2. Name the columns. E.g. *sampleA*, *sampleB*, ...
3. Add 2 to the first column.
4. Multiply the second column by 4.
5. Find which column has the largest mean value.
6. Find which column has the largest value.

Functions - apply

New best friend

- Apply a function to each row (or column) of a matrix.
- No manual iteration, the loop is implicit.
- Second parameter: 1 means rows, 2 means columns.

Example

```
apply(mat,1,mean)
```

Apply - Exercise

1. Create a matrix with 100 rows and 100 columns with random numbers inside.
2. Compute the median value of each column.
3. What is the minimal median value ? Maximal ?

Import/export data

Import/export data - Text files

Easy but important

- What data structure is the more appropriate ? vector, matrix ?
- Does R read/write the file the way you want ?
- The extra parameters of the functions are your allies.

read.csv

To read a data.frame from a multi-column file.

file=	the file name.
header=	*TRUE* use the first line for the column names. Default: *TRUE*.
sep=	the *character* that separate each column. Use '\t' for tabulation. Default: ','.
row.names=	the column number to use as row names.

Example

```
mice_df = read.csv("mice.csv")
```

Exercice

Instructions

Read dataForBasicPlots.tsv into an object called mat.ge.

mice.csv

- Columns separated by comma.
- First line represent the column names.

Questions

1. How many time points are there?
2. How many genotypes?
3. Print the first 5 row and columns.

Import/export data - Text files

write.table

To write a data.frame in a multi-column file.

df	the matrix or data.frame to write.
file=	the file name.
col.names=	*TRUE* print the column names in the first line. Default: *TRUE*.
row.names=	*TRUE* print the rows names in the first columns. Default: *TRUE*.
quote=	*TRUE* surround character by quotes(″). Default: *TRUE* → messy.
sep=	the *character* that separate each column. By default, a white-space.

Example

```
write.table(mice_df, file="mice.tsv", col.names=TRUE,
            row.names=FALSE, quote=FALSE, sep="\t")
```

Import/export data

R objects

save Save R objects into a file. Usual extension: *.RData*. file= parameter to specify file name.

save.image Save the entire R environment.

load Load R objects from a (*.RData*) file. verbose to print the names of the objects loaded.

Example

```
save(luckyNumbers, tenOnes, mat, file="uselessData.RData")
load(file="uselessData.RData")
```

Conditions

Logical values

Logical type

TRUE / FALSE values

Example

```
hgssRules = TRUE
dwight = FALSE
male = c(TRUE, FALSE, TRUE)
```

Conditions

Logical tests

==	both values equal ?
> or >=	left value greater (greater or equal) than right value ?
< or <=	left value smaller (smaller or equal) than left value ?
!	NOT operator : negates the value.
|	OR operator : returns TRUE if either are TRUE.
&	AND operator : returns TRUE if both are TRUE.

Example

```
test <- 2 + 2 == 4    ## (TRUE)
!test                 ## (FALSE)
test & !test          ## (FALSE)
test | !test          ## (TRUE)
```

Conditions

Vectorized operations

Any logical tests can be vectorized (compare 2 vectors).

|	Is a OR operator for vectorized application.
&	Is an AND operator for vectorized application.
which	Returns the index of the vectors with *TRUE* values.

Example

```
c(TRUE, TRUE) & c(TRUE, FALSE) -> TRUE, FALSE

which(5:10 == 6)
which(luckyNumbers > 2)

luckyNumbers[which(luckyNumbers>2 & luckyNumbers<10)]
```

Conditions - Exercise

1. Create a vector of random integer numbers between 0 and 10.

   Tips:

   - 2nd and 3rd parameters of sample function.
   - OR 2nd and 3rd parameters of runif function and round.
2. Remove values below 3.
3. Change to 8 any value higher than 8.

On mice dataframe

Remove any male mice younger than 9 days.

Testing conditions

if else

Test a condition, if *TRUE* run some instruction, if *FALSE* something else (or nothing).

```
if( Condition ){
...   Instructions
}
```

Example

```
luck = "none"
if(length(luckyNumbers)>3){
  luck = "a lot"
} else if(length(luckyNumbers)==3){
  luck = "some"
} else {
  luck = "not enough"
}
```

Conditions - Exercise

Write an if block that classified mice as 'Young' and 'Old':

- 'Young' if age is less than 9
- 'Old' if age is greater or equal to 9.

Functions

Functions

- Name of the function with parameters between parenthesis.
- Takes input(s) and return something. E.g. mean(luckyNumbers).

Do your own

- function To define functions.
- All the object created within the function are temporary.
- return Specify what will be returned by the function.

Structure

```
myFunctionName = function(input.obj1,second.input.obj ) {
...
... Instructions on 'input.obj1' and 'second.input.obj'
...
return(my.output.obj)
}

myFunctionName(1,c(2,4,5))
```

Functions - Example

Function takes a vector as input and :

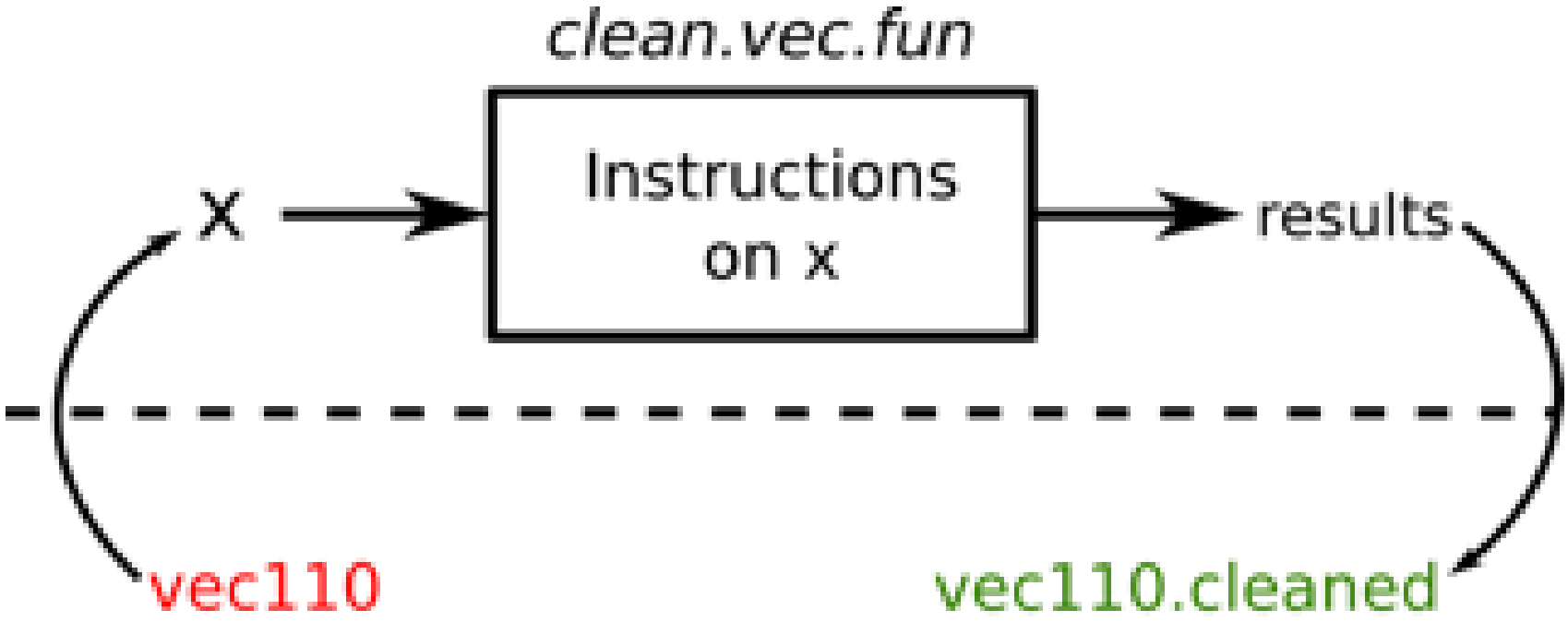
- removes values lower than 3.
- changes to 8 values higher than 8.

Example

```
clean.vec.fun = function(x){
  x = x[which(x>=3)]
  x[which(x>8)] = 8
  return(x)
}

vec110 = 1:10
vec110.cleaned = clean.vec.fun(vec110)
```

Functions - Concept



vec110.cleaned = clean.vec.fun(vec110)

Functions - Exercise

Create a function that classify the average value of a vector. It returns:

- *low* if the average if below 3.
- *medium* if the average if between 3 and 7.
- *high* if the average if above 7.

Create a function that:

1. returns the average of the minimum and maximum value of a vector.
2. returns how many values are higher than 3 in a vector.

- Test your functions on vectors with random number from 0 to 10.
- How would you run them on all mat.gene genes ?

Final exercise

Most variant brain region

1. Load volumes.csv as a dataframe. The last two columns represent ID and Timepoint similar to mice.csv
2. Other columns represent one region in the brain and MRI readouts
3. create volume$_m at, which contains all but the last two columns in volume_d f set rown$ usepaste$function$.
4. Write a function that identifies the column with the highest variation among all samples

Online resources

R basics

- `http://www.twotorials.com/` : small video-tutorials.
- `www.youtube.com/user/rdpeng/` : Coursera *Computing for Data Analysis* videos. Other interesting videos, e.g. *ggplot2*.

- `https://www.datacamp.com/` or `http://tryr.codeschool.com/` : Interactive tutorial of R basics.

- `http://www.r-tutor.com/` : R and statistics small web-tutorials.
- `http://www.computerworld.com/s/article/9239625/Beginner_s_guide_to_R_Introduction` : Beginner's guide with screenshots.
- `http://cran.r-project.org/manuals.html` : R manual.

Bioinformatics

- `http://stephenturner.us/p/edu` List of online resources for Bioinformatics.
- `http://bioinformatics.ca/workshops/2013/` : Bioinformatics workshop material.
- `http://manuals.bioinformatics.ucr.edu/home/R_BioCondManual` : Pieces of code for bioinformatics analysis, plots. Including Bioconductor.
- `http://bioconductor.org/help/course-materials/2013/` : Bioinformatics tutorials material: pdf and R scripts.

Extra

Loops

for loops

Iterate over the element of a container and run instructions.

```
for(v in vec){
...  Instruction
}
```

while loops

Run instructions as long as a condition is *TRUE*.

```
while( CONDITION ){
...  Instruction
}
```

Example

```
facto = 1
for(n in 1:10){
   facto = facto * n
}
```

Tidyverse

for loops

A set of packages which make R more efficient and easier to work with.

- ggplot2, for data visualisation.
- dplyr, for data manipulation.
- tidyr, for data tidying.
- readr, for data import.
- purrr, for functional programming.
- tibble, for tibbles, a modern re-imagining of data frames.
- stringr, for strings.
- forcats, for factors.

Tidyverse

Summarise

```
mice_df %>% summarise(MeanOfAge=mean(Age))
```

group by

```
mice_df %>% group_by(Sex) %>%
    summarise(MeanOfAge=mean(Age))
```

filter

```
mice_df %>% filter(ID==901)
```

Loops - Exercise

Write a function that computes the mean values of the columns:

1. using the apply function.
2. using a for loop.
3. (using a while loop.)

Basic plotting

boxplot

Plot the distribution (quantiles/median/outliers) of variables.

x The matrix (or list) of distributions

Example

```
boxplot(volume_mat)
```

Save your plot into a *pdf/png*

Open a connection to a output file, plot as usual, close the connection.

pdf	Open the connection to a *pdf* output.
png	Open the connection to a *png* output.
dev.off()	Close the connection

Example

```
pdf("myNicePlot.pdf")
plot(...)
dev.off()
```

Type coercion.

- Automatic conversion of an object to another type, e.g numeric→character, logical→numeric.
- Awareness for debugging.
- Useful sometimes.

Example

```
is.numeric( c(1:10,"eleven") )

logical.vector = c(TRUE,TRUE,FALSE,TRUE,FALSE)
sum(logical.vector)
mean(logical.vector)
```

character operations

paste	Paste several *character* into one.
grep	Search a pattern in a vector and return the index when matched.
grepl	Search a pattern in a vector and return *TRUE* if found.
strsplit	Split *character* into several.

Example

```
sample.name = "Ob5cU8eN4mE"
file.name = paste("pathToYourDirectory/greatAnalysis-",
                                    sample.name,".txt",sep="")

which(sample.names=="controlA" & sample.names=="controlB")
grep("control",sample.names)
```

One-liner quiz

Instructions

Write R command to address each question. Only one-line command allowed. The shorter the better.

Questions

1. From a matrix of *numeric*, compute the proportion of columns with average value higher than 0.
2. From a matrix of *numeric*, print the name of the column with the highest value.
3. From a matrix of *numeric*, print the rows with only positive values.