Workshop: Introduction to R

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McGill

Welcome blabla,
Who's a complete beginner ?
Give me a R, give me a ... well that's it
Potential addition: matrix fill up scheme, Rstudio use guide/slide, Tips
box, Question box
Exercises/data to prepare:
nice/funny plots
useful function
debugging
one-liner quiz.

Why learning R ?

Useful for your research

- ► To explore your results. Curiosity and safety !
- ► To do/understand your analysis. Independence and control !
- ► To apply the latest Bioinformatics analyzes. Bioconductor !
- ► To keep track of your analysis. Reproducibility and automation !

- ► You do it, not some busy bioinformatician.

It's a good time investment

Simple: interpretative language(no compilation needed), no memory management, +++

Free: widely used, vast community of R users, good life expectancy.

Multiplatform: Windows, Mac, Unix, it works everywhere.

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Workshop: Introduction to R

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It's a good time investment
- Simple: interpretative language(no compilation needed), no memory management, +++
- Free: widely used, vast community of R users, good life expectancy.
- Multiplatform: Windows, Mac, Unix, it works everywhere.

671 packages in Bioconductor. Bioconductor provides tools for the analysis and comprehension of high-throughput genomic data.

vs other languages

Let's create an array, shuffle it and find where is 5.

In C. . .

```c
#include <stdlib.h>
#include <time.h>
int main() {
    int size = 10;
    int *elements = malloc(sizeof(int)*size);
    int i = 0;
    srand(time(NULL));
    for (i = 0; i < size; ++i)
        elements[i] = i;
    for (i = size - 1; i > 0; --i) {
        int w = rand()%i;
        int t = elements[i];
        elements[i] = elements[w];
        elements[w] = t;
    }
    for(i = 0; i < size; ++i) {
        if(elements[i] == 5)
            printf("%d\n", i);
    }
    free(elements);
}
```

In R. . .

```r
which(sample(0:9) == 5)
```

vs other languages

Let's create an array, shuffle it and find where is 5.

In C...

```
#include <stdlib.h>
#include <time.h>
int main() {
    int size = 10;
    int *sequence = malloc(sizeof(int)*size);
    int i = 0;
    srand(time(0));
    for (i = 0; i < size; i++)
        sequence[i] = i;
    for (i = size - 1; i > 0; --i) {
        int j = rand()%i;
        int t = sequence[j];
        sequence[j] = sequence[i];
        sequence[i] = t;
    }
    for(i = 0; i < size; i++) {
        if(sequence[i] == 5)
            printf("%d\n", i);
    }
    free(sequence);
}
```

In R...

```
which(sample(0:9) == 5)
```

The shuffle array example is good

R and Rstudio

Easy installation

- ► Install R from
  `http://cran.r-project.org/`
- ► Install Rstudio Desktop from
  `http://www.rstudio.com/ide/download/desktop`

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Emacs+ESS on Linux, R console on Mac

Data structure - Overview

Unit type

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

character   Words, e.g. "male", "ENSG0007", "Vive la France".
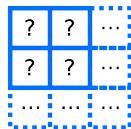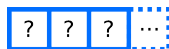
logical   Binary, i.e. two possible values: *TRUE* or *FALSE*.

Structure

vector   Ordered collection of elements of the same type.

matrix   Matrix of element of the same type.

list   Flexible container, mixed type possible. Recursive.

Workshop: Introduction to R

└─ Data structures

  └─ Data structure - Overview

Unit type	
numeric	Numbers, e.g. 0, 1, 42, −66.6.
character	Words, e.g. "male", "ENSG0007", "Vive la France".
logical	Binary, i.e. two possible values: *TRUE* or *FALSE*.

Structure	
vector	Ordered collection of elements of the same type.
matrix	Matrix of element of the same type.
list	Flexible container, mixed type possible. Recursive.

Other type but more complex and less useful, e.g. factors

a value to an object

Choose an object name

- **Letters**, **numbers**, **dot** or **underline** characters.
- **Starts with a letter** or the dot not followed by a number.
- 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
```

Vector construction

c	Concatenate function.
1:10	Vector with numbers from 1 to 10.
rep	Repeat element several times.

Example

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

Vector construction
- c Concatenate function.
- 1:10 Vector with numbers from 1 to 10.
- rep Repeat element several times.

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

Questions: Create your own numbers and favorite group of friends/hockey player/star/genes.
create a vector with 10:20 and three 3
Be creative: different names, values, sizes

Manipulation

Using an index between [ ].

vec[i:j]   Get or set a vector from i^{th} to j^{th} values.

Characterization

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

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"]
```

Manipulation

Using an index between [ ].
vec[i:j] Get or set a vector from i^{th} to j^{th} values.

Characterization
length Number of element in the vector.
names Get or set the names of the vector.

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"]

Square-brackets
Questions:
Show me your third number
change it
Create a new vector with the first three numbers
Show me the first and last values of it
add 3 at the end of the vector
Name the values one two three four

Manipulation

sort	Sort a vector.
order	Get the index of the sorted elements.
rev	Reverse a vector.
sample	Shuffle a vector.

Example

```
sort(luckyNumbers)
luckyNumbers[order(luckyNumbers)]

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

rev(1:10)

sample(1:10)
```

Manipulation

sort	Sort a vector.
order	Get the index of the sorted elements.
rev	Reverse a vector.
sample	Shuffle a vector.

Example

```
sort(luckyNumbers)
luckyNumbers[order(luckyNumbers)]

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

rev(1:10)

sample(1:10)
```

Questions: print a shuffle version of the vector
add "Jean" at the end of the character vector,
reverse it,
make the reverse the new value.

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)
```

Tips: na.rm
Questions:
Show me the beginning of your numbers
average value of this beginning
the sum of the minimum and maximum value.

Operations

- Simple arithmetic operations over all the values of the vector.
- Or values by values when using vectors of same length.
- Arithmetic operation: +, -, *, /.

Example

```
luckyNumbers * 4 - 2
luckyNumber s* 1:length(luckyNumbers) -
                        rev(1:length(luckyNumbers))
```

Operations
  ▶ Simple arithmetic operations over all the values of the vector.
  ▶ Or values by values when using vectors of same length.
  ▶ Arithmetic operation: +, -, *, /.

Example
luckyNumbers * 4 - 2
luckyNumber =* 1:length(luckyNumbers) -
                        rev(1:length(luckyNumbers))

Let's apply it to the Exercise

Exercise - Guess my favorite number

Instructions

1. Create a vector of *numeric* values. At least two values.
2. Multiply it by 6.
3. Add 21.
4. Divide it by 3
5. Remove 1.
6. Halve it.
7. Remove its original values.

Workshop: Introduction to R

└─Data structures

└─Exercise - Guess my favorite number

Instructions
1. Create a vector of numeric values. At least two values.
2. Multiply it by 6.
3. Add 21.
4. Divide it by 3
5. Remove 1.
6. Halve it.
7. Remove its original values.

Tips: save the original values somewhere or change the values of a new vector.
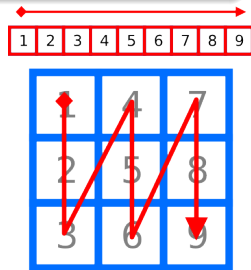
Specific to matrices

matrix	Create a matrix from a vector. 2nd and 3rd parameters define the number of rows and columns.
mat[i:j,k:l]	Subset from the i to j row and k to l column.

Example

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

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

Specific to matrices

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

mat[i:j,k:l] Subset from the i to j row and k to l column.

Example

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

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

Questions:

create 4x4 matrix with number from 1 to 16

the same but shuffled

print the first column

the three first columns

Specific to matrices

rbind/cbind Concatenate vectors or matrix by row or column.

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

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

Example

```
rbind(neo, neo)
cbind(neo, neo)

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

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

Workshop: Introduction to R

└─Data structures

Specific to matrices

rbind/cbind Concatenate vectors or matrix by row or column.
dim Dimension of the matrix: number of rows and columns.
rownames/colnames Get or set the names of the rows/columns.

Example
```
rbind(meo, meo)
cbind(meo, meo)

dim(meo)
dim(rbind(meo,meo))

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

Questions: Add an extra line to the matrix
Print the new dimension

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
```

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
```

Questions:
Average of the matrix
Average of the first two columns
multiply by 2 and remove the matrix

Exercise

1. Create a matrix of 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. Print the name of the column with the largest mean value.
4. Print the name of the column with the largest value.

1. Create a matrix of 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. Print the name of the column with the largest mean value.
4. Print the name of the column with the largest value.

What if it had 100 rows...

- apply

New best friend

- ▶ Apply a function to row or columns of a 2 dimension data structure (matrix or data frame).
- ▶ No manual iteration, the loop is implicit.
- ▶ Second argument: 1 means rows, 2 means columns.

Example

```
apply(mat,1,mean)
apply(mat,2,function(x){
  x.mean = mean(x)
  return(x.mean+1)
})
```

– apply

New best friend

▶ Apply a function to row or columns of a 2 dimension data structure (matrix or data frame).
▶ No manual iteration, the loop is implicit.
▶ Second argument: 1 means rows, 2 means columns.

Example

```
apply(mat,1,mean)
apply(mat,2,function(x){
  x.mean = mean(x)
  return(x.mean+1)
})
```

Same for list, etc
output

Flexible container

A list can contain any element type. It does not require elements to be of the same type.

list	Create a list.
l[[i]]	Get or set the ith object of the list.
l$toto	Get or set the element labeled as *toto*.
names	Get or set the names of the list elements.
length	Get the number of element in the list.
str	Output the structure of a R object.

Example

```
l = list(vec=1:10,mat=matrix(runif(25),5))
str(l)
l
l$vec = 1
l
```

Flexible container

A list can contain any element type. It does not require elements to
be of the same type.

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[[i]]   Get or set the ith object of the list.
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length   Get the number of element in the list.
str   Output the structure of a R object.

Example

l = list(vec=1:10,mat=matrix(runif(25),5))
str(l)

l$vec = 1
1

Questions:
Make a phonebook: A list of 3 elements (vectors): names, phone number
and address

- lapply

apply for lists

▶ Useful way to iterate through lists.

Example

```
file_list <- read.files('.')
files_content <- lapply(file_list, function(file) \{
data <- read.csv(file)
#Do something with the data
return(data)
\})
```

- ▶ Name of the function with arguments between parenthesis.
- ▶ E.g. `mean(x)`.

Do your own

function To define functions.

- ▶ All the object created within the function are temporary.

return Define what will be returned by the function.

Example

```
almostMean = function(x){
  x.mean = mean(x)
  return(x.mean+1)
}
almostMean(0:10)
x.mean
```

- Name of the function with arguments between parenthesis.
- E.g. mean(x).

Do your own

function To define functions.
- All the object created within the function are temporary.

return Define what will be returned by the function.

Example

```
almostMean = function(x){
  x.mean = mean(x)
  return(x.mean+1)
}
almostMean(0:10)
x.mean
```

Question:create a function that returns the power: pow <- function(base, exp) ...

Boolean

logical Binary data: *TRUE* or *FALSE*.

Numeric comparison ==, !=, >, <, >=, <=.

Boolean operation AND: &, OR: |, NOT: !

which Returns the index of the vectors with *TRUE* values.

any Take a vector of *logical* and return *TRUE* if at least one value is *TRUE*.

%in% Vectorized any. See example/supp material.

Example

```
2 + 2 == 4
(2 < 3) & (3 != 1+2)
which(5:10 == 6)
any(9>1:10)
any(9>1:10 & 8<=1:10)
luckyNumbers[which(luckyNumbers %in% c(16,42,-66.6))]
```

Boolean
  logical Binary data: *TRUE* or *FALSE*.
Numeric comparison ==, !=, >, <, >=, <=.
Boolean operation AND: &, OR: |, NOT: !
  which Returns the index of the vectors with *TRUE* values.
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      value is *TRUE*.
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Example
```
2 + 2 == 4
(2 < 3) & (3 != 1+2)
which(5:10 == 6)
any(9>1:10)
any(9>1:10 & 8<=1:10)
luckyNumbers[which(luckyNumbers %in% c(16,42,-66.6))]
```

Is more details on logical rules necessary ?
Question: write a function that filters out numbers: largerThan ¡-
function(data, threshold) {...}

conditions

if else

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

Example

```
if(length(luckyNumbers)>3){
  cat("Too many lucky numbers.\n")
  luckyNumbers = luckyNumbers[1:3]
} else if(length(luckyNumbers)==3){
  cat("Just enough lucky numbers.\n")
} else {
  cat("You need more lucky numbers.\n")
}
```

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└─Conditions and loops

conditions

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

Example
```
if(length(luckyNumbers)>3){
  cat("Too many lucky numbers.\n")
  luckyNumbers = luckyNumbers[1:3]
} else if(length(luckyNumbers)==3){
  cat("Just enough lucky numbers.\n")
} else {
  cat("You need more lucky numbers.\n")
}
```

Maybe more theoretical structure
Question: write a function that filter number higher than 10

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
}
```

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
}
```

Question:

Import/export data

Easy but important

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

scan

To read a vector from a file with, for example, one value per line.

    file= the file name.

  what= the type of the argument gives the type of the values, e.g 1, $''a''$.

    sep= the character that separate each value. By default, a white-space or end of line.

write

To write a vector from a file with one value per line.

    vec the vector to write.

  file= the file name.

  sep= the character that separate each value.

Questions: try to write on vector
Then re-read it.

Import/export data

read.data

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: *FALSE*.

as.is= *TRUE* read the values as simple type, no complex type inference, **recommended**. Default: *FALSE*.

sep= the character that separate each column. By default, a white-space or end of line.

write.data

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* $\rightarrow$ messy.

sep= the character that separate each column. By default, a white-space.

Import/export data

read.data
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: *FALSE*
as.is: *TRUE* read the values as simple type, no complex type inference, **recommended**. Default: *FALSE*
sep: the character that separate each column. By default, a white-space or end of line.

write.data
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 column. Default: *TRUE*
quotes: *TRUE* surround character by quotes("). Default: *TRUE* → messy.
sep: the character that separate each column. By default, a white-space.

Questions: try to write a matrix with the different arguments
Then re-read it.

/export data

R objects

save	Save R objects into a file. Usual extension: *.RData*. file= argument 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")
load(file="dataForBasicPlots.RData",verbose=TRUE)
```

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R objects
    save Save R objects into a file. Usual extension: .RData.
        file= argument 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, tenDoss, mat, file="uselessData.RData")
load(file="uselessData.RData")
load(file="dataForBasicPlots.RData",verbose=TRUE)
```

Rstudio tips
Questions: load data for next exercise.
Save your objects if you want to...

Basic plotting

hist	Plot the value distribution of a vector.
plot	Plot one vector against the other.
line	Same as plot but super-imposed to the existent one.
abline	Draw vertical/horizontal lines.

Common arguments

main=	A title for the plot.
xlim=/ylim	A vector of size two defining the desired limit on the x/y axis.
xlab=/ylab=	A name for the x/y axis.

Questions: plot the prepared data(some funny shaped plots ?)
Histogram with vertical line on the mean

Debugging

Instructions
1. Open **scriptToDebug.R** document.
2. Run and debug it !

Debugging

Instructions
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2. Run and debug it !

Bugs: header load table, type read.table, parenthesis/brackets, infinite loop, NA in mean etc, operation different length, type coercion numeric character, non-unique (col)names, (global variable within function), apply rows returning matrix

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 columns with the highest value.
3. From a matrix of numeric, print the rows with only positive values.
4.

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└─Extra exercises

└─One-liner quiz

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 columns with the highest value.
3. From a matrix of numeric, print the rows with only positive values.
4.

Find more questions.

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)
```

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└─Miscellaneous

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)
```

Questions: How would you do it

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)
```

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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 = "DbdcU8aN4mE"
file.name = paste("pathToYourDirectory/greatAnalysis-",
                                sample.name,".txt",sep="")

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

More details

object name

- **Letters**, **numbers**, **dot** or **underline** characters.
- **Starts with a letter** or the dot not followed by a number.
- make.names convert character into valid object names.

Example

```
make.names(c("valid name","valid_name","valid.name",
             "valid-name","2.valid.name","x2.valid-name"))
```

object name

▸ **Letters**, **numbers**, **dot** or **underline** characters.
▸ **Starts with a letter** or the dot not followed by a number.
▸ **make.names** convert character into valid object names.

Example

```
make.names(c("valid name","valid_name","valid.name",
             "valid-name","2.valid_name","x2.valid-name"))
```

Should it be present in the beginning ?