Workshop: Introduction to R

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Human Genetics department

October 21, 2013

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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, vectorized.

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

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

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

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 *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...

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

The shuffle array example is good

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 *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...

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

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`

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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”.

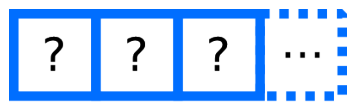
logical Binary, i.e. two possible values: *TRUE* or *FALSE*.

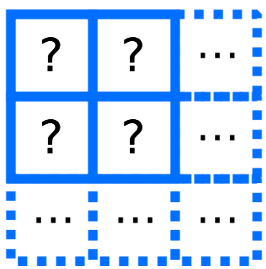
Structure

vector Ordered collection of elements of the same type.

matrix Matrix of element of the same type.

list Flexible container, mixed type possible. Recursive.





Data structure - Overview

Unit type

numeric	Numbers, e.g. 0, 1, 42, −66.6.
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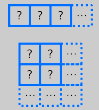
logical	Binary, i.e. two possible values: *TRUE* or *FALSE*.

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.
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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'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"]
```

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'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"]
```

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)
```

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 s* 1:length(luckyNumbers) -
                          rev(1:length(luckyNumbers))
```

Let's apply it to the Exercise

Exercise - Guess my favorite number

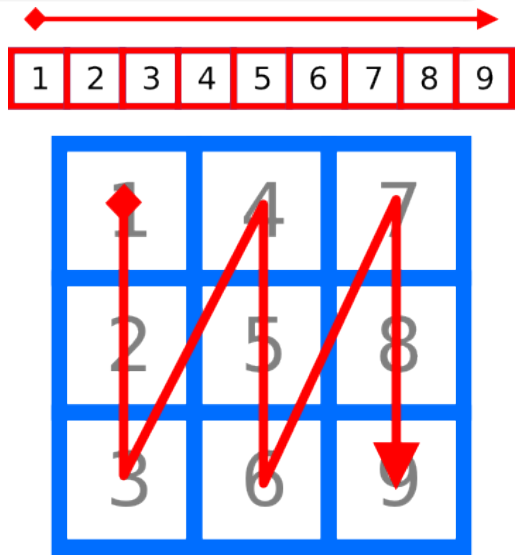
Instructions

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.

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,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.
2^{nd} and 3^{rd} 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

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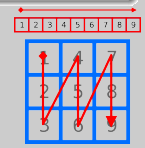

Questions:
create 4x4 matrix with number from 1 to 16
the same but shuffled
print the first column
the three first columns

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
```

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
```

Questions: Add an extra line to the matrix
Add an extra line to the matrix then the matrix square 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.

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.

What if it had 100 rows...

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 i^{th} 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

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l[[i]]	Get or set the i^{th} object of the list.
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Example

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

Questions:

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

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 :
return the average of the minimum and maximum of a vector
returns the power: pow <- function(base, exp)

Functions - Exercise

Create a function that:

1. returns the average of the minimum and maximum value of a vector.
2. returns the power of a number.
   Two arguments: base and exponent.
   Returns: $base^{exponent}$.

   Tips: $base^{exponent} = e^{exponent \times ln(base)} =$ exp(exponent * log(base))

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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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 smaller than 3
The same with the threshold as a parameter: largerThan <- function(data, threshold) {...}

Conditions - Exercise

Create a function that:

1. remove values below 3 from a vector.
2. remove values below a specified threshold from a vector.

if else

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

```
if( CONDITION ){
  INSTRUCTIONS
}
```

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")
}
```

conditions

if else

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

```
if( CONDITION ){
  INSTRUCTIONS
}
```

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")
}
```

Question: write a function that classify the average expression of a vector into “low” for lower than 3, “medium” between 3 and 7, “high” greater than 7.

if else - 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.

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
}
```

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
}
```

Apply versus loop speech then vote if they want to do the exercice?

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.)

/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)
```

/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)
```

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

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.

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.

Example

```
input.data = read.table("fileToRead.txt", as.is=TRUE,
                                          header=TRUE, sep="\t")
```

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

Example

```
write.table(resToWrite, file="fileToRead.txt", col.names=TRUE,
                            row.names=FALSE, quote=FALSE, sep="\t")
```

/export data - Text files

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

Example

```
write.table(resToWrite, file="fileToRead.txt", col.names=TRUE,
                        row.names=FALSE, quote=FALSE, sep="\t")
```

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

hist

Plot the value distribution of a vector.

x The vector with the values to plot.

plot

Plot one vector against the other.

x The first vector to plot. *x-axis.*

y The second vector to plot. *y-axis.*

type How the points are plotted. "p" as points, "l" joined by lines.

Example

```
hist(mat.ge[,1])
plot(mat.ge[,1],mat.ge[,2])
```

Common arguments

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

Example

```
hist(mat.ge[,1],main="A basic graph",
                xlab="first column values")

plot(mat.ge[,1],mat.ge[,2],main="Another basic graph",
  xlab="first column values",ylab="second column values")
```

Extra parameters

col	the colour of the points/lines. 1:black, 2:red, ...
pch	Shape of the points. 1:circle, 2:triangle, ...
lty	Shape of the lines. 1:plain, 2:dotted, ...

Extra functions

lines	Same as plot but super-imposed to the existent one.
abline	Draw vertical/horizontal lines.

Example

```
plot(mat.ge[,1],mat.ge[,2],main="Another basic graph",
  xlab="first column values",ylab="second column values")
lines(mat.ge[,1],mat.ge[,3],type="p",col=2,pch=2)
abline(h=0,lty=2)
```

Debugging

Instructions

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

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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.

Find more questions.

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coercion.

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

Example

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

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

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

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

More details

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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()
```