R: An Introduction

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  2. S can be used for data exploration (tabulating, sorting data, drawing plots to look for trends, etc.
  3. It can be used as a sophisticated calculator to evaluate complex arithmetic expressions, and a very flexible and general object-oriented programming language to perform more extensive data manipulation.
- Later on, S evolved into S-PLUS, however, S-PLUS was very expensive.
- **R**oss Ihaka and **R**obert Gentleman from the University of Auckland, decided to write a stripped-down version of S, which was R. Five years later, version 1.0.0 of R was released on 29 Feb 2000.

What is R?

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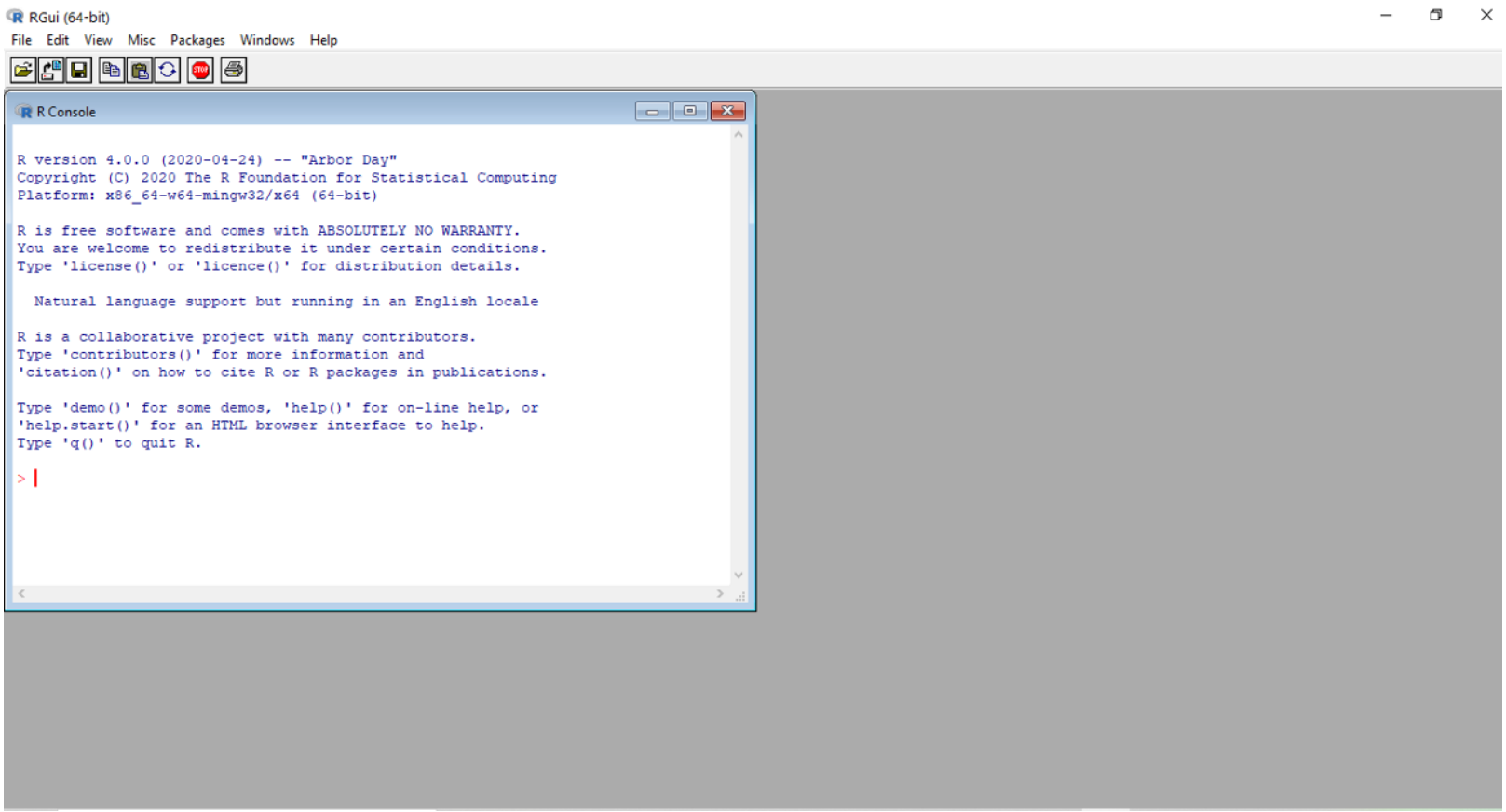
- An effective data handling and storage facility.
- A suite of operators for calculations on array, in particular, matrices.
- A large, coherent, integrated collection of intermediate tools for data analysis.
- Graphical facilities for data analysis.
- A well developed, simple and effective programming language.

How To Start R?

- Downloading R from `https://www.r-project.org/`
- Double click the R's icon in the desktop to activate R (at least version 4.0.0).
- After R is started, the R console is open in the RGui window.



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- Dataframe:
  -Similar to the Matrix object but columns can have different modes.

  -The rows contain different observations from your study or measurements from your experiment;

  -The columns contain the values of different variables which may be of different modes.

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  -The rows contain different observations from your study or measurements from your experiment;

  -The columns contain the values of different variables which may be of different modes.
- List: generalization of a vector – represents a collection of data objects.

Creating a Vector in R: "c" function

- To create a vector, the simplest way is using the concatenation "c" function.

```
> #creating a vector of numbers:
> number<-c(2,4,6,8,10)
> number
[1]  2  4  6  8 10
> # creating a vector of strings/characters:
> string<-c("weight", "height", "gender")
> string
[1] "weight" "height" "gender"
> #creating a Boolean vector (T/F):
> logic<- c(T, T, F, F, T)
> logic
[1]  TRUE  TRUE FALSE FALSE  TRUE
```

Appending item(s) to the existing vector:

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- What is c(number,12,14)? A vector of numbers.

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> logic
[1]  TRUE  TRUE FALSE FALSE  TRUE
```

Appending item(s) to the existing vector:

- What is c(number,12,14)? A vector of numbers.
- What is c(string, 12,14)? A vector of strings where "12" and "14" are treated as strings.

Creating a Vector in R: "numeric" function

The "numeric" function creates a vector with all its elements being 0.

```
> number.2<-numeric(3)
> number.2
[1] 0 0 0
> c(number, number.2)
[1]  2  4  6  8 10  0  0  0
> c(string, number.2)
[1] "weight" "height" "gender" "0"      "0"      "0"
```

Creating a Vector in R: "rep" function

The "rep" function replicates elements of vectors.
rep(a,b): replicate the item *a* by *b* times.

```
> #rep(a,b): replicate the item a by b times.
> number.3<-rep(2,3)
> number.3
[1] 2 2 2
> number.3<-rep(c(1,2),3)
> number.3
[1] 1 2 1 2 1 2
> rep(c(6,3),c(2,4))#6 and 3 are replicated 2, 4 times, respectively
[1] 6 6 3 3 3 3
> rep(string,2)
[1] "weight" "height" "gender" "weight" "height" "gender"
```

What is the length of the vector: rep(c(6,3,2),c(2,1,2))?

Creating a Vector in R: "seq" function

seq(from = a, to = b, by = c): from the number *a* to number *b*, create a sequence of numbers evenly spread by a distance of *c*.

```
> seq(from=2, to=10, by=2)
[1]  2  4  6  8 10
> seq(from=2, to=10, length = 5)
[1]  2  4  6  8 10
> 1:5
[1] 1 2 3 4 5
> 1:5*2
[1]  2  4  6  8 10
> seq(2,10,2)
[1]  2  4  6  8 10
> seq(10)
 [1]  1  2  3  4  5  6  7  8  9 10
> c(10,8,4, rep(2,3), rep(1:2,2), rep(c(5,7),2:3), seq(6,10,2))
 [1] 10  8  4  2  2  2  1  2  1  2  5  5  7  7  7  6  8 10
```

Creating a Matrix: "dim" function

```
> v <- c(1:6)
> dim(v) <- c(2,3) # 2 rows, 3 columns
> v
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```

- The dim(v) command will take the values of the vector v to fill the matrix by column.

```
> dim(v)=NULL
> v
[1] 1 2 3 4 5 6
```

Creating a Matrix: "dim" function

```
> v <- c(1:6)
> dim(v) <- c(2,3) # 2 rows, 3 columns
> v
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```

- The dim(v) command will take the values of the vector v to fill the matrix by column.

- To convert back to a vector, we simply use the dim function again.

```
> dim(v)=NULL
> v
[1] 1 2 3 4 5 6
```

Creating a Matrix: "matrix" function

- *matrix(v,r,c)*: take the values from vector *v* to create a matrix with *r* rows and *c* columns.

```
> v <- c(1:6)
> m <- matrix(v, nrow=2, ncol=3)
> m
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
> # to fill the matrix by rows:
> m <- matrix(v, nrow=2, ncol=3, byrow=T)
> m
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
```

Creating a Matrix: "matrix" function

- *matrix(v,r,c)*: take the values from vector *v* to create a matrix with *r* rows and *c* columns.
- By default, matrix is filled by column.

```
> v <- c(1:6)
> m <- matrix(v, nrow=2, ncol=3)
> m
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
> # to fill the matrix by rows:
> m <- matrix(v, nrow=2, ncol=3, byrow=T)
> m
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
```

Creating a Matrix: "rbind" and "cbind" functions

- To bind a row (or many rows) onto a matrix, the command *rbind* can be used.

```
> a <- c(1,2,3,4)
> b <- c(5,6,7,8)
> ab_row <- rbind(a,b)
> ab_row
  [,1] [,2] [,3] [,4]
a    1    2    3    4
b    5    6    7    8
```

Creating a Matrix: "rbind" and "cbind" functions

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> a <- c(1,2,3,4)
> b <- c(5,6,7,8)
> ab_row <- rbind(a,b)
> ab_row
```

```
  [,1] [,2] [,3] [,4]
a    1    2    3    4
b    5    6    7    8
```

- To bind a column (or many columns) onto a matrix, the command *cbind* can be used.

```
> ab_col <- cbind(ab_row, c(9,10))
> ab_col
```

```
  [,1] [,2] [,3] [,4] [,5]
a    1    2    3    4    9
b    5    6    7    8   10
```

Form of a Dataframe in R (1)

- R handles data in objects known as dataframes.

Example: an experiment with three treatments (control, pre-heated and pre-chilled), and four measurements per treatment. A dataframe is created based on the given measurements.

This is a wrong dataframe.

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- A dataframe is an object with rows and columns:
  - The rows contain different **observations or measurements**;
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Form of a Dataframe in R (1)

- R handles data in objects known as dataframes.
- A dataframe is an object with rows and columns:
  - The rows contain different **observations or measurements**;
  - The columns contain the values of different **variables**.
- **All the values of the same variable must go in the same column**.

Example: an experiment with three treatments (control, pre-heated and pre-chilled), and four measurements per treatment. A dataframe is created based on the given measurements.

This is a wrong dataframe.

Form of a Dataframe in R (2)

The correct dataframe should be

Response	Treatment
6.1	Control
5.9	Control
5.8	Control
5.4	Control
6.3	Pre-heated
6.2	Pre-heated
5.8	Pre-heated
6.3	Pre-heated
7.1	Pre-chilled
8.2	Pre-chilled
7.3	Pre-chilled
6.9	Pre-chilled

- This has 2 variables: measurements as the response variable and another variable (called "treatment") for three levels of experimental factor.

Creating Dataframes in R: "data.frame" command (1)

data.frame converts a matrix or a collection of vectors into a dataframe.

- Example

```
> v <- c(1:6)*2
> v
[1]  2  4  6  8 10 12
> m <- matrix(v, 2, 3) #matrix of 2 rows, 3 columns
> df1 <- data.frame(m)
> df1
  X1 X2 X3
1  2  6 10
2  4  8 12
> names(df1)
[1] "X1" "X2" "X3"
```

Creating Dataframes in R: "data.frame" command (2)

- Another example

```
> a<- c(11,12)
> b <- c(13,14)
> df2 <- data.frame(a,b)
> df2
   a  b
1 11 13
2 12 14
> names(df2)
[1] "a" "b"
```

In this example, *a* and *b* (the vectors' name) are used for the column names in the dataframe instead of the default *X1* and *X2*.

Specifying Column/Row names

- The columns are automatically labeled.

```
> names(df1)
[1] "X1" "X2" "X3"
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> names(df1)
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```

- Column names can be re-named.

```
> names(df1)=c("Column 1","Column 2","Column 3")
> names(df1)
[1] "Column 1" "Column 2" "Column 3"
```

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```

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> names(df1)
[1] "Column 1" "Column 2" "Column 3"
```

- Row names are automatically assigned and are labeled as "1", "2", and so on:

```
> row.names(df1)
[1] "1" "2"
```

Specifying Column/Row names

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```
> names(df1)
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```

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```
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> names(df1)
[1] "Column 1" "Column 2" "Column 3"
```

- Row names are automatically assigned and are labeled as "1", "2", and so on:

```
> row.names(df1)
[1] "1" "2"
```

- Row names can be re-named if desired:

```
> row.names(df1)=c("Row1","Row2")
> row.names(df1)
[1] "Row1" "Row2"
```

Reading Data Files: A Quick Overview

There are several ways of reading/importing data files into R:

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- *read.csv(...)* can be used to read dataframes from files using comma to separate values (.csv files).
- *read.fwf(...)* can be used to read files that have a fixed width format.

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- *read.csv(...)* can be used to read dataframes from files using comma to separate values (.csv files).
- *read.fwf(...)* can be used to read files that have a fixed width format.
- When reading from Excel files, a simple method is to save each worksheet separately as a csv file and use *read.csv(....)* on each saved csv file.

Importing a Dataset to R: "scan" function

scan() function read data into a vector or list from the console or file.

```
> v<-scan()
1: 1 2 3 4 5
6: 4 3 2 1
10: 1 1 1 1
14:
Read 13 items
> v
 [1] 1 2 3 4 5 4 3 2 1 1 1 1 1
>
```

Import a Free Format Data File (1)

- The first line contains the names of variables, then we use: *header* = *TRUE*. Without *header* = *TRUE*:

```
> data1<-read.table("C:/Data/crab.txt")
> data1
```

	V1	V2	V3	V4	V5
1	color	spine	width	satell	weight
2	3	3	28.3	8	3.050
3	4	3	22.5	0	1.550
4	2	1	26.0	9	2.300
5	4	3	24.8	0	2.100
6	4	3	26.0	4	2.600
7	3	3	23.8	0	2.100
8	2	1	26.5	0	2.350
9	4	2	24.7	0	1.900
10	3	1	23.7	0	1.950
11	4	3	25.6	0	2.150
12	4	3	24.3	0	2.150
13	3	3	25.8	0	2.650
14	3	3	28.2	11	3.050
15	5	2	21.0	0	1.850

Import a Free Format Data File (2)

- With *header* = *TRUE*.

```
> data1<-read.table("C:/Data/crab.txt", header = TRUE)
> data1
    color spine width satell weight
1       3     3  28.3      8  3.050
2       4     3  22.5      0  1.550
3       2     1  26.0      9  2.300
4       4     3  24.8      0  2.100
5       4     3  26.0      4  2.600
6       3     3  23.8      0  2.100
7       2     1  26.5      0  2.350
8       4     2  24.7      0  1.900
9       3     1  23.7      0  1.950
10      4     3  25.6      0  2.150
11      4     3  24.3      0  2.150
12      3     3  25.8      0  2.650
13      3     3  28.2     11  3.050
14      5     2  21.0      0  1.850
15      3     1  26.0     14  2.300
16      2     1  27.1      8  2.950
```

Import a Free Format Data File (2)

- If the first line of the data file does not contain the names of the variables, we can create a vector to store the variable names:

```
> varnames <- c("Subject", "Gender", "CA1", "CA2", "HW")
> data2<-read.table("C:/Data/ex_1.txt", header = FALSE,
+                   col.names = varnames)
> data2
```

```
  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
2       7      M  85  89  A
3       4      F  90  86  B
4      20      M  82  85  B
5      25      F  94  94  A
6      14      F  88  84  C
```

Missing values are denoted by NA.

Importing a Comma Separated Data

- The most convenient way to read in comma-separated data files is using *read.table* function.

```
> data3<-read.table("C:/Data/ex_1_comma.txt",
+                   header = FALSE, sep = ",")
> data3
```

```
  V1 V2 V3 V4 V5
1 10  M 80 84  A
2  7  M 85 89  A
3  4  F 90 86  B
4 20  M 82 85  B
5 25  F 94 94  A
6 14  F 88 84  C
```

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```

```
  V1 V2 V3 V4 V5
1 10  M 80 84  A
2  7  M 85 89  A
3  4  F 90 86  B
4 20  M 82 85  B
5 25  F 94 94  A
6 14  F 88 84  C
```

- Equivalently, we can use *read.csv* function:

```
> data3<-read.csv("C:/Data/ex_1_comma.txt", header = FALSE)
```

Importing a Fixed Width Format File

The fixed format data file: `R_example_1_fixed.txt` has the following fixed format: subject(2), gender(1), CA1(3), CA2(3), HW(1).

```
1 10M 80 84A
2 7 M 85 89A
3 4 F 90 86B
4 20M 82 85B
5 25F 94 94A
6 14F 88 84C
```

- Use the function read.fwf - the widths of variables are specified in a vector.

```
> data3 <-read.fwf("C:/Data/ex_1_fixed.txt", width=c(2,1,3,3,1))
> data3
  V1 V2 V3 V4 V5
1 10  M 80 84  A
2  7  M 85 89  A
3  4  F 90 86  B
4 20  M 82 85  B
5 25  F 94 94  A
6 14  F 88 84  C
```

Importing Binary Files

- Binary data generated from other statistical software can be read into R (but it should be avoided).
- The R package *foreign* provides import facilities for some other statistical software.
- Activate the package by typing *library(foreign)*.

1. *read.spss(...)* reads in SPSS files.
2. *read.mtp(...)* imports Minitab worksheets.
3. *read.xport(...)* reads in SAS files in TRANSPORT format.
4. *read.S(...)* reads in binary objects produced by S-Plus.

To Assess a Dataframe

- Use *attach* command to make the variables in a dataframe accessible by their name within the R session, and use *names* command to get the list of the variable names.

```
> data3<-read.table("C:/Data/ex_1_name.txt", header = TRUE)
> data3
  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
2       7      M  85  89  A
3       4      F  90  86  B
4      20      M  82  85  B
5      25      F  94  94  A
6      14      F  88  84  C
> names(data3)
[1] "Subject" "Gender"  "CA1"     "CA2"     "HW"
> CA1
Error: object 'CA1' not found
>
```

To Assess a Dataframe

- Use *attach* command to make the variables in a dataframe accessible by their name within the R session, and use *names* command to get the list of the variable names.

```
> data3<-read.table("C:/Data/ex_1_name.txt", header = TRUE)
> data3
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3       4      F  90  86  B
4      20      M  82  85  B
5      25      F  94  94  A
6      14      F  88  84  C
> names(data3)
[1] "Subject" "Gender"  "CA1"     "CA2"     "HW"
> CA1
Error: object 'CA1' not found
>
```

- Need to use *attach* command:

```
> data3<-read.table("C:/Data/ex_1_name.txt", header = TRUE)
> attach(data3)
> CA1
[1] 80 85 90 82 94 88
```

Assessing Parts of a Dataframe: Column Subscript

Selecting some specified variables (columns):

```
> data3[,1]
[1] 10  7  4 20 25 14
> data3[,2:4]
  Gender CA1 CA2
1      M  80  84
2      M  85  89
3      F  90  86
4      M  82  85
5      F  94  94
6      F  88  84
```

Assessing Parts of a Dataframe: Row Subscript

Selecting some specified observations (rows):

```
> data3[1,]
  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
```

```
> data3[1:3,]
  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
2       7      M  85  89  A
3       4      F  90  86  B
```

Selecting some specific values in the data

```
> data3[3,3]
[1] 90
```

```
> data3[3,4]
[1] 86
```

Assessing Parts of a Dataframe: Logical Tests

```
> # all the rows (observations) whose gender = M:
> data3[Gender == "M",]

  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
2       7      M  85  89  A
4      20      M  82  85  B

> #all the rows (observations) whose gender = M and CA2>85
> data3[Gender == "M" & CA2 > 85,]

  Subject Gender CA1 CA2 HW
2       7      M  85  89  A
```

Assessing Parts of a Dataframe: Logical Tests (2)

Some logical operators in R:

Operator	Description
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
==	exactly equal to
!=	not equal to
!x	Not x
x | y	x OR y
x & y	x AND y
isTRUE(x)	test if X is TRUE

Combining Dataframes by Rows (Observations)

```
> #create a dataframe from first 3 rows of data3:
> data1<-data.frame(data3[1:3,])
> #create a dataframe from last 3 rows of data3:
> data2<-data.frame(data3[4:6,])
> data<-rbind(data1,data2)
> #Combining two dataframes above:
> data
```

	Subject	Gender	CA1	CA2	HW
1	10	M	80	84	A
2	7	M	85	89	A
3	4	F	90	86	B
4	20	M	82	85	B
5	25	F	94	94	A
6	14	F	88	84	C

If the variables (name of columns) are not the same in both dataframes, an error message will be displayed.

Combining Dataframes by Variables (Columns)

```
> #create a dataframe from first 3 columns of data3:
> data1<-data.frame(data3[,1:3])
> #create a dataframe from the last two columns of data3:
> data2<-data.frame(data3[,4:5])
> #Combining two dataframes above:
> data<-cbind(data1,data2)
> data
```

```
  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
2       7      M  85  89  A
3       4      F  90  86  B
4      20      M  82  85  B
5      25      F  94  94  A
6      14      F  88  84  C
```

```
> #If data2<-data.frame(data3[,4]) then how the data looks like?
```

If the variables (name of columns) do not have the same length in in both dataframes, an error message will be displayed.

Combining Dataframes by Variables (1)

- Using *merge* command to merge 2 dataframes by a common variable.

```
> data1<-read.table("C:/Data/ex_1_IQ.txt", header = TRUE)
> data1
  Subject  IQ
1      10 106
2       7 112
3       4 119
4      20 102
5      25 125
6      14 101
> data<-merge(data3,data1 ,by="Subject", all=TRUE)
> data
  Subject Gender CA1 CA2 HW  IQ
1       4      F  90  86  B 119
2       7      M  85  89  A 112
3      10      M  80  84  A 106
4      14      F  88  84  C 101
5      20      M  82  85  B 102
6      25      F  94  94  A 125
```

Combining Dataframes by Variables (2)

- Equivalently, we can use:

```
> attach(data1)

The following object is masked from data3:

    Subject

> data<-data.frame(data3, IQ)
> data
  Subject Gender CA1 CA2 HW  IQ
1      10      M  80  84  A 106
2       7      M  85  89  A 112
3       4      F  90  86  B 119
4      20      M  82  85  B 102
5      25      F  94  94  A 125
6      14      F  88  84  C 101
```

Sorting a Dataframe

- Sort data3 by CA1 in ascending order:

```
> data3[order(CA1),]
  Subject Gender CA1 CA2 HW
1      10      M  80  84  A
4      20      M  82  85  B
2       7      M  85  89  A
6      14      F  88  84  C
3       4      F  90  86  B
5      25      F  94  94  A
```

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> data3[order(CA1),]
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1      10      M  80  84  A
4      20      M  82  85  B
2       7      M  85  89  A
6      14      F  88  84  C
3       4      F  90  86  B
5      25      F  94  94  A
```

- Sort data3 by CA2 in descending order and only variables Subject, CA1 and CA2 are selected:

```
> data3[rev(order(CA2)), c(1,3:4)]
  Subject CA1 CA2
5      25  94  94
2       7  85  89
3       4  90  86
4      20  82  85
6      14  88  84
1      10  80  84
> #data3[rev(order(CA2)), c("Subject","CA1","CA2")]
```

while Loop

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  1. `(condition)` must evaluate to a TRUE or a FALSE.
  2. If `(condition)` is TRUE, do all the steps inside the while code block
  3. Check `(condition)` again
  4. Repeat until `(condition)` is a FALSE.

while Loop: Examples

- Find the sum of first 10 integers:

```
> x<-0; S<-0
> while(x<=10) {S<- S+ x
+                  x<-x+1}
> S
[1] 55
```

while Loop: Examples

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```
> x<-0; S<-0
> while(x<=10) {S<- S+ x
+                  x<-x+1}
> S
[1] 55
```

- To print all the squares of integers from 1 to 5:

```
> x <- 0
> test <- TRUE  # or: test <- 1
> while(test>0){x <- x+1
+ test <- isTRUE(x<6) # or (x<6)
+ cat(x^2,test,"\n") }
1 TRUE
4 TRUE
9 TRUE
16 TRUE
25 TRUE
36 FALSE
```

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  2. First time, `<variable>` starts at the smallest value in the range and do all the steps inside the `{expression}`.

`for` Loop (1)

- The `for` loop is in the form of:
  `for (<variable> in <range>) {expression}`

- How this loop works:
  1. Each time through the loop, `<variable>` takes a value
  2. First time, `<variable>` starts at the smallest value in the range and do all the steps inside the `{expression}`.
  3. Next time, `<variable>` gets the previous value + 1, until the last value in the range.

for Loop (2)

Example: find the sum of first 10 integers:

- ```
  > S<-0; for(i in 1:10){S <-S+i}
  > S
  [1] 55
  ```
  ```

for Loop (2)

Example: find the sum of first 10 integers:

- ```
  > S<-0; for(i in 1:10){S <-S+i}
  > S
  [1] 55
  ```
- A more advanced way:

```
> x <- numeric(10)
> for (i in 1:10){s <- 0
+                 for (j in 1:i){s <- s+j}; x[i] <- s
+ cat("The sum of the first ", i, "numbers = ", x[i], "\n")}
The sum of the first  1 numbers =  1
The sum of the first  2 numbers =  3
The sum of the first  3 numbers =  6
The sum of the first  4 numbers =  10
The sum of the first  5 numbers =  15
The sum of the first  6 numbers =  21
The sum of the first  7 numbers =  28
The sum of the first  8 numbers =  36
The sum of the first  9 numbers =  45
The sum of the first  10 numbers =  55
```
```

Output: *sink* Function

```
>
> sink("C:/Data/datasink_ex1.txt")
> x <- numeric(15)
> for (i in 1:15)
+ { s <- 0
+ for (j in 1:i) {s <- s+j}
+ x[i] <- s
+ cat("The sum of the first ", i, "numbers = ",x[i], "\n")
+ }
> sink()
> cat("The sum of the first ", i, "numbers = ",x[i], "\n")
The sum of the first  15 numbers =  120
>
```

All the output are stored in a text file named `datasink_ex1` under directory "C:/Data".

- The *sink* function is used to send objects and text to a file.
- This is useful when we want to keep a copy of the output in a file or when the contents of an object or function that may be too big to display on screen.

Output: *cat* Function

- The *cat* functions prints the output shown in the console unless redirected by sink.

```
> cat("The sum of the first ", i, "numbers = ",x[i], "\n")
The sum of the first  10 numbers =  55
```

Output: *cat* Function

- The *cat* functions prints the output shown in the console unless redirected by sink.

```
> cat("The sum of the first ", i, "numbers = ",x[i], "\n")
The sum of the first  10 numbers =  55
```

- "\n" is used to tell R to start a new line after this point.

write.table and *write.csv* Function

- The function *write.table* or *write.csv* can be used to write dataframes to a file.

```
> data
  Subject Gender CA1 CA2 HW  IQ
1      10      M  80  84  A 106
2       7      M  85  89  A 112
3       4      F  90  86  B 119
4      20      M  82  85  B 102
5      25      F  94  94  A 125
6      14      F  88  84  C 101
> write.table(data,"C:/Data/ex_1_with_IQ.txt")
```

- Dataframe "data" will be written to a text file (.txt) named "ex_1_with_IQ" in the directory `C:/Data`.

Built-in or Existing Functions in R

x and y are vectors. Some functions on vector in R:

- max(x): maximum value of x
- min(x): minimum value of x
- sum(x): total of all the values in x
- mean(x): arithmetic average values in x
- median(x): median value of x
- range(x): min(x), max(x)
- var(x): sample variance of x, with degrees of freedom = length(x) - 1
- cor(x,y): correlation between vectors x and y
- sort(x): a sorted version of x
- rank(x): vector of the ranks containing the permutation to sort x into ascending order

User-define Functions

- Characteristics of a function:
  -has a name
  -has parameters (0 or more)
  -has a body
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  -has a name
  -has parameters (0 or more)
  -has a body
  -returns something

- How to write/define:
  `name <-` function`(parameters) { function body }`

- At the end of the `function body`, some command to ask for evaluation and return should be included.

User-define Functions: Examples

- A function to find sum of all the values in a vector:

```
> int<-c(1:10)
> s=function(x)sum(x)
> s(int)
[1] 55
```

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```

- A function to find the standard error of the mean of a vector (SE of $\bar{x}$):

```
> se<-function(x){sqrt(var(x)/length(x))}
> # the command inside {} asks for a return
> se(CA1)
[1] 2.125245
```

User-define Functions: Examples

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```

- *if () else* in R: *if* statement can be followed by an optional *else* statement which executes when the boolean expression is false.

```
> x<-0
> for (i in 1:7){if (i<=5){x<-x+i}else{print("STOP")}}
[1] "STOP"
[1] "STOP"
> x
[1] 15
```

User-define Functions: Examples

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[1] "STOP"
> x
[1] 15
```

- Question: write a function to find the median of a given dataset.

Further Reading

- A good source for reading more details about building functions in R: `https://datasciencebeginners.com/2018/11/02/10-user-defined-functions-in-r/`