R – Basic Syntax

R Command Prompt

Once you have R environment setup, then it's easy to start your R command prompt by just typing the following command at your command prompt:

```
$ R
```

This will launch R interpreter and you will get a prompt > where you can start typing your program as follows:

```
> myString <- "Hello, World!"
> print ( myString)
[1] "Hello, World!"
```

Here first statement defines a string variable myString, where we assign a string "Hello, World!" and then next statement print() is being used to print the value stored in variable myString.

R Script File

Usually, you will do your programming by writing your programs in script files and then you execute those scripts at your command prompt with the help of R interpreter called **Rscript**. So let's start with writing following code in a text file called test.R as under:

```
# My first program in R Programming
myString <- "Hello, World!"

print ( myString)
```

Save the above code in a file test.R and execute it at Linux command prompt as given below. Even if you are using Windows or other system, syntax will remain same.

```
$ Rscript test.R
```

When we run the above program, it produces the following result.

```
[1] "Hello, World!"
```

Comments

Comments are like helping text in your R program and they are ignored by the interpreter while executing your actual program. Single comment is written using # in the beginning of the statement as follows:

```
# My first program in R Programming
```

R does not support multi-line comments but you can perform a trick which is something as follows:

```
if(FALSE){
   "This is a demo for multi-line comments and it should be put
   inside either a single of double quote"
}

myString <- "Hello, World!"
print ( myString)
```

Though above comments will be executed by R interpreter, they will not interfere with your actual program. You should put such comments inside, either single or double quote.

R – Data Types

Generally, while doing programming in any programming language, you need to use various variables to store various information. Variables are nothing but reserved memory locations to store values. This means that, when you create a variable you reserve some space in memory.

You may like to store information of various data types like character, wide character, integer, floating point, double floating point, Boolean etc. Based on the data type of a variable, the operating system allocates memory and decides what can be stored in the reserved memory.

In contrast to other programming languages like C and java in R, the variables are not declared as some data type. The variables are assigned with R-Objects and the data type of the R-object becomes the data type of the variable. There are many types of R-objects. The frequently used ones are:

- **Vectors**
- **Lists**
- **Matrices**
- **Arrays**
- **Factors**
- **Data Frames**

The simplest of these objects is the **vector object** and there are six data types of these atomic vectors, also termed as six classes of vectors. The other R-Objects are built upon the atomic vectors.

Data Type	Example	Verify

Logical	TRUE , FALSE	`v <- TRUE`
		`print(class(v))`
		it produces the following result:
		`[1] "logical"`

Numeric	12.3, 5, 999	`v <- 23.5`
		`print(class(v))`
		it produces the following result:
		`[1] "numeric"`

<table>
<tr><td>Integer</td><td>2L, 34L, 0L</td><td>
<pre>v <- 2L
print(class(v))</pre>
it produces the following result:
<pre>[1] "integer"</pre>
</td></tr>
<tr><td>Complex</td><td>3 + 2i</td><td>
<pre>v <- 2+5i
print(class(v))</pre>
it produces the following result:
<pre>[1] "complex"</pre>
</td></tr>
<tr><td>Character</td><td>'a' , '"good", "TRUE", '23.4'</td><td>
<pre>v <- "TRUE"
print(class(v))</pre>
it produces the following result:
<pre>[1] "character"</pre>
</td></tr>
<tr><td>Raw</td><td>"Hello" is stored as 48 65 6c 6c 6f</td><td>
<pre>v <- charToRaw("Hello")
print(class(v))</pre>
it produces the following result:
<pre>[1] "raw"</pre>
</td></tr>
</table>

In R programming, the very basic data types are the R-objects called **vectors** which hold elements of different classes as shown above. Please note in R the number of classes is not confined to only the above six types. For example, we can use many atomic vectors and create an array whose class will become array.

Vectors

When you want to create vector with more than one element, you should use **c()** function which means to combine the elements into a vector.

```
# Create a vector.
apple <- c('red','green',"yellow")
print(apple)
```

```
# Get the class of the vector.
print(class(apple))
```

When we execute the above code, it produces the following result:

```
[1] "red"    "green"  "yellow"
[1] "character"
```

Lists

A list is an R-object which can contain many different types of elements inside it like vectors, functions and even another list inside it.

```
# Create a list.
list1 <- list(c(2,5,3),21.3,sin)

# Print the list.
print(list1)
```

When we execute the above code, it produces the following result:

```
[[1]]
[1] 2 5 3

[[2]]
[1] 21.3

[[3]]
function (x)  .Primitive("sin")
```

Matrices

A matrix is a two-dimensional rectangular data set. It can be created using a vector input to the matrix function.

```
# Create a matrix.
M = matrix( c('a','a','b','c','b','a'), nrow=2,ncol=3,byrow = TRUE)
print(M)
```

When we execute the above code, it produces the following result:

```
     [,1] [,2] [,3]
```

```
[1,] "a"  "a"  "b"
[2,] "c"  "b"  "a"
```

Arrays

While matrices are confined to two dimensions, arrays can be of any number of dimensions. The array function takes a dim attribute which creates the required number of dimension. In the below example we create an array with two elements which are 3x3 matrices each.

```
# Create an array.
a <- array(c('green','yellow'),dim=c(3,3,2))
print(a)
```

When we execute the above code, it produces the following result:

```
, , 1

     [,1]     [,2]     [,3]
[1,] "green"  "yellow" "green"
[2,] "yellow" "green"  "yellow"
[3,] "green"  "yellow" "green"

, , 2

     [,1]     [,2]     [,3]
[1,] "yellow" "green"  "yellow"
[2,] "green"  "yellow" "green"
[3,] "yellow" "green"  "yellow"
```

Factors

Factors are the r-objects which are created using a vector. It stores the vector along with the distinct values of the elements in the vector as labels. The labels are always character irrespective of whether it is numeric or character or Boolean etc. in the input vector. They are useful in statistical modeling.

Factors are created using the **factor()** function.The **nlevels** functions gives the count of levels.

```
# Create a vector.
apple_colors <- c('green','green','yellow','red','red','red','green')
```

```
# Create a factor object.
factor_apple <- factor(apple_colors)


# Print the factor.
print(factor_apple)
print(nlevels(factor_apple))
```

When we execute the above code, it produces the following result:

```
[1] green  green  yellow red    red    red    yellow green
Levels: green red yellow
# applying the nlevels function we can know the number of distinct values
[1] 3
```

Data Frames

Data frames are tabular data objects. Unlike a matrix in data frame each column can contain different modes of data. The first column can be numeric while the second column can be character and third column can be logical. It is a list of vectors of equal length.

Data Frames are created using the **data.frame()** function.

```
# Create the data frame.
BMI <-      data.frame(
                  gender = c("Male", "Male","Female"),
                  height = c(152, 171.5, 165),
                  weight = c(81,93, 78),
                  Age =c(42,38,26)
                  )
print(BMI)
```

When we execute the above code, it produces the following result:

```
  gender height weight Age
1   Male  152.0     81  42
2   Male  171.5     93  38
3 Female  165.0     78  26
```

R–Variables

A variable provides us with named storage that our programs can manipulate. A variable in R can store an atomic vector, group of atomic vectors or a combination of many R-objects. A valid variable name consists of letters, numbers and the dot or underline characters. The variable name starts with a letter or the dot not followed by a number.

Variable Name	Validity	Reason
var_name2.	valid	Has letters, numbers, dot and underscore
var_name%	Invalid	Has the character '%'. Only dot(.) and underscore allowed.
2var_name	invalid	Starts with a number
.var_name , var.name	valid	Can start with a dot(.) but the dot(.)should not be followed by a number.
.2var_name	invalid	The starting dot is followed by a number making it invalid
_var_name	invalid	Starts with _ which is not valid

Variable Assignment

The variables can be assigned values using leftward, rightward and equal to operator. The values of the variables can be printed using **print()** or **cat()**function. The **cat()** function combines multiple items into a continuous print output.

```
# Assignment using equal operator.
var.1 = c(0,1,2,3)

# Assignment using leftward operator.
var.2 <- c("learn","R")

# Assignment using rightward operator.
c(TRUE,1) -> var.3

print(var.1)
```

```
cat ("var.1 is ", var.1 ,"\n")
cat ("var.2 is ", var.2 ,"\n")
cat ("var.3 is ", var.3 ,"\n")
```

When we execute the above code, it produces the following result:

```
[1] 0 1 2 3
var.1 is  0 1 2 3
var.2 is  learn R
var.3 is  1 1
```

Note: The vector c(TRUE,1) has a mix of logical and numeric class. So logical class is coerced to numeric class making TRUE as 1.

Data Type of a Variable

In R, a variable itself is not declared of any data type, rather it gets the data type of the R -object assigned to it. So R is called a dynamically typed language, which means that we can change a variable's data type of the same variable again and again when using it in a program.

```
var_x <- "Hello"
cat("The class of var_x is ",class(var_x),"\n")

var_x <- 34.5
cat("  Now the class of var_x is ",class(var_x),"\n")

var_x <- 27L
cat("   Next the class of var_x becomes ",class(var_x),"\n")
```

When we execute the above code, it produces the following result:

```
The class of var_x is  character
  Now the class of var_x is  numeric
    Next the class of var_x becomes  integer
```

Finding Variables

To know all the variables currently available in the workspace we use the **ls()** function. Also the ls() function can use patterns to match the variable names.

```
print(ls())
```

When we execute the above code, it produces the following result:

```
[1] "my var"     "my_new_var" "my_var"     "var.1"
[5] "var.2"      "var.3"      "var.name"   "var_name2."
[9] "var_x"      "varname"
```

Note: It is a sample output depending on what variables are declared in your environment.

The ls() function can use patterns to match the variable names.

```
# List the variables starting with the pattern "var".
print(ls(pattern="var"))
```

When we execute the above code, it produces the following result:

```
[1] "my var"     "my_new_var" "my_var"     "var.1"
[5] "var.2"      "var.3"      "var.name"   "var_name2."
[9] "var_x"      "varname"
```

The variables starting with **dot(.)** are hidden, they can be listed using "all.names=TRUE" argument to ls() function.

```
print(ls(all.name=TRUE))
```

When we execute the above code, it produces the following result:

```
[1] ".cars"        ".Random.seed" ".var_name"    ".varname"     ".varname2"
[6] "my var"       "my_new_var"   "my_var"       "var.1"        "var.2"
[11]"var.3"        "var.name"     "var_name2."   "var_x"
```

Deleting Variables

Variables can be deleted by using the **rm()** function. Below we delete the variable var.3. On printing the value of the variable error is thrown.

```
rm(var.3)
print(var.3)
```

When we execute the above code, it produces the following result:

```
[1] "var.3"
Error in print(var.3) : object 'var.3' not found
```

All the variables can be deleted by using the **rm()** and **ls()** function together.

```
rm(list=ls())
print(ls())
```

When we execute the above code, it produces the following result:

```
character(0)
```

R–Operators

An operator is a symbol that tells the compiler to perform specific mathematical or logical manipulations. R language is rich in built-in operators and provides following types of operators.

Types of Operators

We have the following types of operators in R programming:

- Arithmetic Operators
- Relational Operators
- Logical Operators
- Assignment Operators
- Miscellaneous Operators

Arithmetic Operators

Following table shows the arithmetic operators supported by R language. The operators act on each element of the vector.

Operator	Description	Example

+	Adds two vectors	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v+t)`
		it produces the following result:
		`[1] 10.0  8.5  10.0`

−	Subtracts second vector from the first	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v-t)`
		it produces the following result:
		`[1] -6.0  2.5  2.0`

*	Multiplies both vectors	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v*t)`
		it produces the following result:
		`[1] 16.0 16.5 24.0`

/	Divide the first vector with the second	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v/t)`
		When we execute the above code, it produces the following result:
		`[1] 0.250000 1.833333 1.500000`

%%	Give the remainder of the first vector with the second	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v%%t)`
		it produces the following result:
		`[1] 2.0 2.5 2.0`

%/%	The result of division of first vector with second (quotient)	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v%/%t)`
		it produces the following result:
		`[1] 0 1 1`

^	The first vector raised to the exponent of second vector	`v <- c( 2,5.5,6)`
		`t <- c(8, 3, 4)`
		`print(v^t)`

		it produces the following result: `[1]  256.000  166.375 1296.000`

Relational Operators

Following table shows the relational operators supported by R language. Each element of the first vector is compared with the corresponding element of the second vector. The result of comparison is a Boolean value.

Operator	Description	Example

>	Checks if each element of the first vector is greater than the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v>t)`
		it produces the following result:
		`[1] FALSE  TRUE FALSE FALSE`

<	Checks if each element of the first vector is less than the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v < t)`
		it produces the following result:
		`[1]  TRUE FALSE  TRUE FALSE`

==	Checks if each element of the first vector is equal to the corresponding element of the second vector.	`v <- c(2,5.5,6,9)`
		`t <- c(8,2.5,14,9)`
		`print(v==t)`
		it produces the following result:
		`[1] FALSE FALSE FALSE  TRUE`

<table>
<tr>
<td><=</td>
<td>Checks if each element of the first vector is less than or equal to the corresponding element of the second vector.</td>
<td><pre><code>v <- c(2,5.5,6,9)
t <- c(8,2.5,14,9)
print(v<=t)</code></pre>
it produces the following result:
<pre><code>[1] TRUE FALSE TRUE TRUE</code></pre></td>
</tr>
<tr>
<td>>=</td>
<td>Checks if each element of the first vector is greater than or equal to the corresponding element of the second vector.</td>
<td><pre><code>v <- c(2,5.5,6,9)
t <- c(8,2.5,14,9)
print(v>=t)</code></pre>
it produces the following result:
<pre><code>[1] FALSE TRUE FALSE TRUE</code></pre></td>
</tr>
<tr>
<td>!=</td>
<td>Checks if each element of the first vector is unequal to the corresponding element of the second vector.</td>
<td><pre><code>v <- c(2,5.5,6,9)
t <- c(8,2.5,14,9)
print(v!=t)</code></pre>
it produces the following result:
<pre><code>[1] TRUE TRUE TRUE FALSE</code></pre></td>
</tr>
</table>

Logical Operators

Following table shows the logical operators supported by R language. It is applicable only to vectors of type logical, numeric or complex. All numbers greater than 1 are considered as logical value TRUE.

Each element of the first vector is compared with the corresponding element of the second vector. The result of comparison is a Boolean value.

<table>
<tr><th>Operator</th><th>Description</th><th>Example</th></tr>
<tr><td>&</td><td>It is called Element-wise Logical AND operator. It combines each element of the first vector with the corresponding element of the second vector and gives a output TRUE if both the elements are TRUE.</td><td>v <- c(3,1,TRUE,2+3i)
t <- c(4,1,FALSE,2+3i)
print(v&t)
it produces the following result:
[1] TRUE TRUE FALSE TRUE</td></tr>
<tr><td>|</td><td>It is called Element-wise Logical OR operator. It combines each element of the first vector with the corresponding element of the second vector and gives a output TRUE if one the elements is TRUE.</td><td>v <- c(3,0,TRUE,2+2i)
t <- c(4,0,FALSE,2+3i)
print(v|t)
it produces the following result:
[1] TRUE FALSE TRUE TRUE</td></tr>
<tr><td>!</td><td>It is called Logical NOT operator. Takes each element of the vector and gives the opposite logical value.</td><td>v <- c(3,0,TRUE,2+2i)
print(!v)
it produces the following result:
[1] FALSE TRUE FALSE FALSE</td></tr>
</table>

The logical operator && and || considers only the first element of the vectors and give a vector of single element as output.

<table>
<tr><th>Operator</th><th>Description</th><th>Example</th></tr>
<tr><td>&&</td><td>Called Logical AND operator. Takes first element of both the vectors and gives the TRUE only if both are TRUE.</td><td><pre>v <- c(3,0,TRUE,2+2i)
t <- c(1,3,TRUE,2+3i)
print(v&&t)</pre>it produces the following result:<pre>[1] TRUE</pre></td></tr>
<tr><td>||</td><td>Called Logical OR operator. Takes first element of both the vectors and gives the TRUE only if both are TRUE.</td><td><pre>v <- c(0,0,TRUE,2+2i)
t <- c(0,3,TRUE,2+3i)
print(v||t)</pre>it produces the following result:<pre>[1] FALSE</pre></td></tr>
</table>

Assignment Operators

These operators are used to assign values to vectors.

<table>
<tr><th>Operator</th><th>Description</th><th>Example</th></tr>
<tr><td><-
or
=
or
<<-</td><td>Called Left Assignment</td><td><pre>v1 <- c(3,1,TRUE,2+3i)
v2 <<- c(3,1,TRUE,2+3i)
v3 = c(3,1,TRUE,2+3i)
print(v1)
print(v2)
print(v3)
it produces the following result:
[1] 3+0i 1+0i 1+0i 2+3i
[1] 3+0i 1+0i 1+0i 2+3i</pre></td></tr>
</table>

		`[1] 3+0i 1+0i 1+0i 2+3i`

-> or **->>**	Called Right Assignment	`c(3,1,TRUE,2+3i) -> v1`
		`c(3,1,TRUE,2+3i) ->> v2`
		`print(v1)`
		`print(v2)`
		`it produces the following result:`
		`[1] 3+0i 1+0i 1+0i 2+3i`
		`[1] 3+0i 1+0i 1+0i 2+3i`

Miscellaneous Operators

These operators are used to for specific purpose and not general mathematical or logical computation.

Operator	Description	Example

:	Colon operator. It creates the series of numbers in sequence for a vector.	`v <- 2:8`
		`print(v)`
		it produces the following result:
		`[1] 2 3 4 5 6 7 8`

%in%	This operator is used to identify if an element belongs to a vector.	`v1 <- 8`
		`v2 <- 12`
		`t <- 1:10`
		`print(v1 %in% t)`
		`print(v2 %in% t)`
		it produces the following result:
		`[1] TRUE`
		`[1] FALSE`

<table>
<tr>
<td>%*%</td>
<td>This operator is used to multiply a matrix with its transpose.</td>
<td>

```
M = matrix( c(2,6,5,1,10,4), nrow=2,ncol=3,byrow =
TRUE)

t = M %*% t(M)

print(t)
```

it produces the following result:

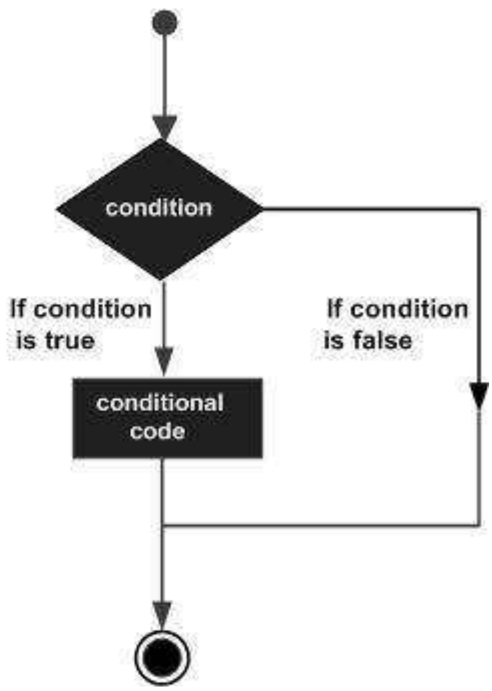
```
     [,1] [,2]

[1,]   65   82

[2,]   82  117
```

</td>
</tr>
</table>

R – Decision making

Decision making structures require the programmer to specify one or more conditions to be evaluated or tested by the program, along with a statement or statements to be executed if the condition is determined to be **true**, and optionally, other statements to be executed if the condition is determined to be **false**.

Following is the general form of a typical decision making structure found in most of the programming languages:



R provides the following types of decision making statements. Click the following links to check their detail.

Statement	Description
if statement	An **if** statement consists of a Boolean expression followed by one or more statements.
if...else statement	An if statement can be followed by an optional else statement, which executes when the Boolean expression is false.
switch statement	A switch statement allows a variable to be tested for equality against a list of values.

R - If Statement

An **if** statement consists of a Boolean expression followed by one or more statements.

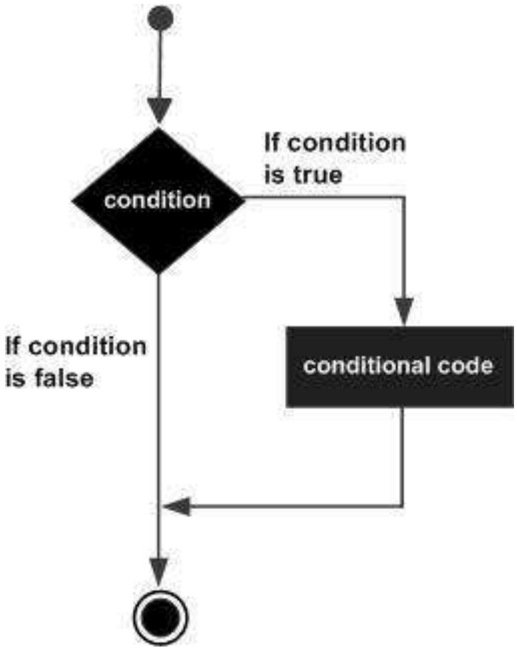
Syntax

The basic syntax for creating an **if** statement in R is:

```
if(boolean_expression) {
   // statement(s) will execute if the boolean expression is true.
}
```

If the Boolean expression evaluates to be **true**, then the block of code inside the if statement will be executed. If Boolean expression evaluates to be **false**, then the first set of code after the end of the if statement (after the closing curly brace) will be executed.

Flow Diagram



Example

```
x <- 30L
if(is.integer(x)){
   print("X is an Integer")
}
```

When the above code is compiled and executed, it produces the following result:

```
[1] "X is an Integer"
```

R – If...Else Statement

An **if** statement can be followed by an optional **else** statement which executes when the boolean expression is false.

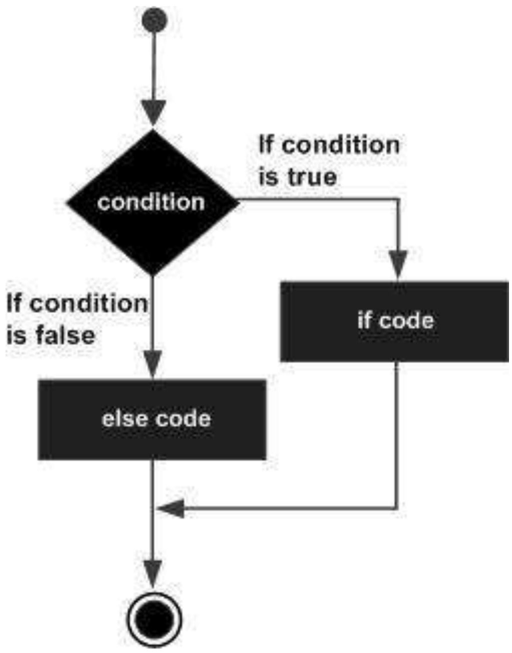
Syntax

The basic syntax for creating an **if...else** statement in R is:

```
if(boolean_expression) {
   // statement(s) will execute if the boolean expression is true.
} else {
  // statement(s) will execute if the boolean expression is false.
}
```

If the Boolean expression evaluates to be **true**, then the **if block** of code will be executed, otherwise **else block** of code will be executed.

Flow Diagram



Example

```
x <- c("what","is","truth")
if("Truth" %in% x){
   print("Truth is found")
} else {
   print("Truth is not found")
}
```

When the above code is compiled and executed, it produces the following result:

```
[1] "Truth is not found"
```

Here "Truth" and "truth" are two different strings.

The if...else if...else Statement

An **if** statement can be followed by an optional **else if...else** statement, which is very useful to test various conditions using single if...else if statement.

When using **if**, **else if**, **else** statements there are few points to keep in mind.

- An **if** can have zero or one **else** and it must come after any **else if**'s.
- An **if** can have zero to many **else if**'s and they must come before the else.
- Once an **else if** succeeds, none of the remaining **else if**'s or **else**'s will be tested.

Syntax

The basic syntax for creating an **if...else if...else** statement in R is:

```
if(boolean_expression 1) {
   // Executes when the boolean expression 1 is true.
}else if( boolean_expression 2) {
   // Executes when the boolean expression 2 is true.
}else if( boolean_expression 3) {
   // Executes when the boolean expression 3 is true.
}else {
   // executes when none of the above condition is true.
}
```

Example

```
x <- c("what","is","truth")
if("Truth" %in% x){
   print("Truth is found the first time")
} else if ("truth" %in% x) {
   print("truth is found the second time")
} else {
   print("No truth found")
}
```

When the above code is compiled and executed, it produces the following result:

```
[1] "truth is found the second time"
```

R – Switch Statement

A switch statement allows a variable to be tested for equality against a list of values. Each value is called a case, and the variable being switched on is checked for each case.

Syntax

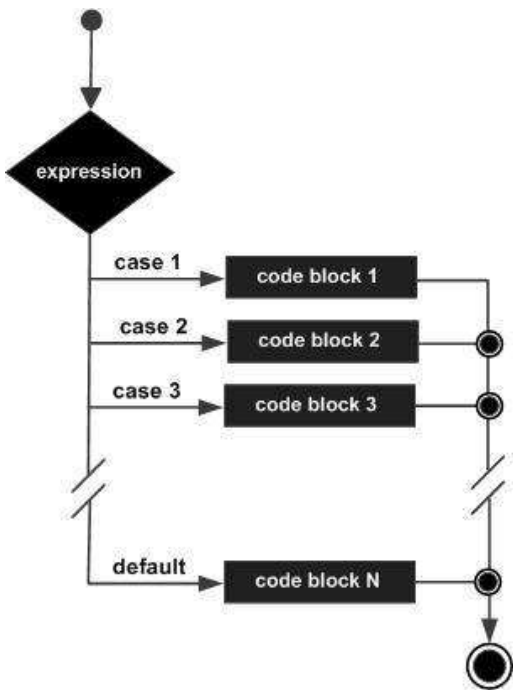
The basic syntax for creating a switch statement in R is :

```
switch(expression, case1, case2, case3....)
```

The following rules apply to a switch statement:

- If the value of expression is not a character string it is coerced to integer.
- You can have any number of case statements within a switch. Each case is followed by the value to be compared to and a colon.
- If the value of the integer is between 1 and nargs()-1 (The max number of arguments)then the corresponding element of case condition is evaluated and the result returned.
- If expression evaluates to a character string then that string is matched (exactly) to the names of the elements.
- If there is more than one match, the first matching element is returned.
- No Default argument is available.
- In the case of no match, if there is a unnamed element of ... its value is returned. (If there is more than one such argument an error is returned.)

Flow Diagram



Example

```
x <- switch(
  3,
  "first",
  "second",
  "third",
  "fourth"
)
print(x)
```

When the above code is compiled and executed, it produces the following result:

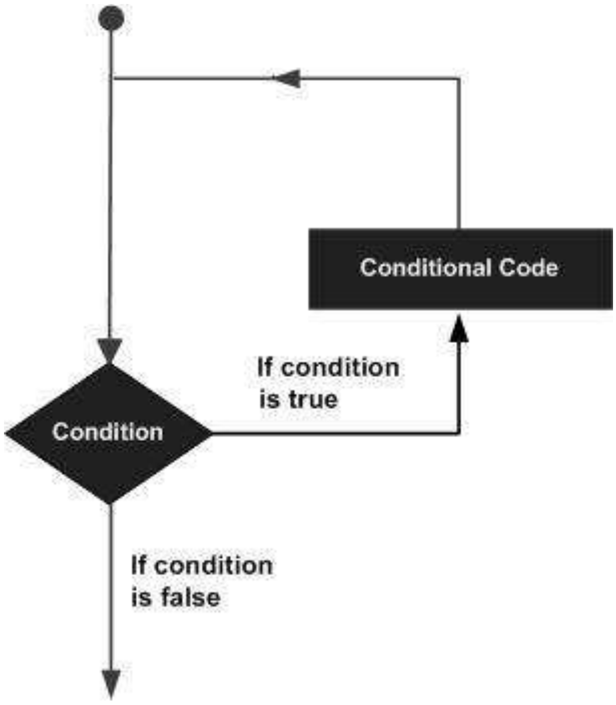
```
[1] "third"
```

R – Loops

There may be a situation when you need to execute a block of code several number of times. In general, statements are executed sequentially. The first statement in a function is executed first, followed by the second, and so on.

Programming languages provide various control structures that allow for more complicated execution paths.

A loop statement allows us to execute a statement or group of statements multiple times and the following is the general form of a loop statement in most of the programming languages:



R programming language provides the following kinds of loop to handle looping requirements. Click the following links to check their detail.

Loop Type	Description
repeat loop	Executes a sequence of statements multiple times and abbreviates the code that manages the loop variable.
while loop	Repeats a statement or group of statements while a given condition is true. It tests the condition before executing the loop body.
for loop	Like a while statement, except that it tests the condition at the end of the loop body.

R - Repeat Loop

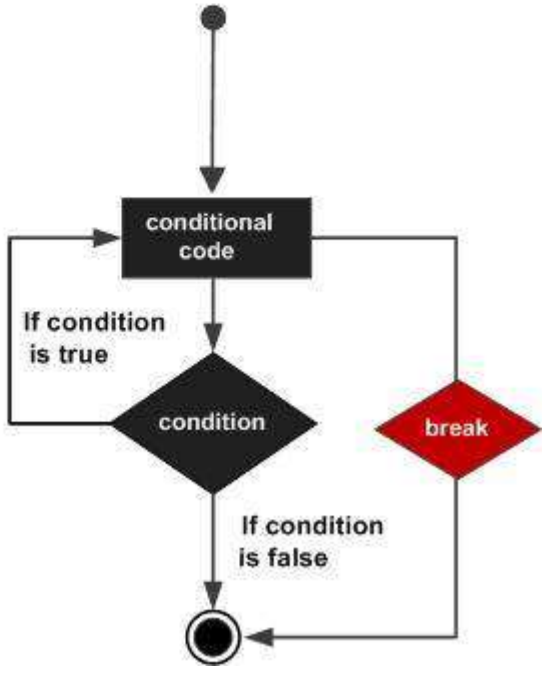
The Repeat loop executes the same code again and again until a stop condition is met.

Syntax

The basic syntax for creating a repeat loop in R is:

```
repeat {
   commands
   if(condition){
        break
   }
}
```

Flow Diagram



Example

```
v <- c("Hello","loop")
cnt <- 2
repeat{
   print(v)
   cnt <- cnt+1
   if(cnt > 5){
      break
   }
```

```
}
```

When the above code is compiled and executed, it produces the following result:

```
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
```

R - While Loop

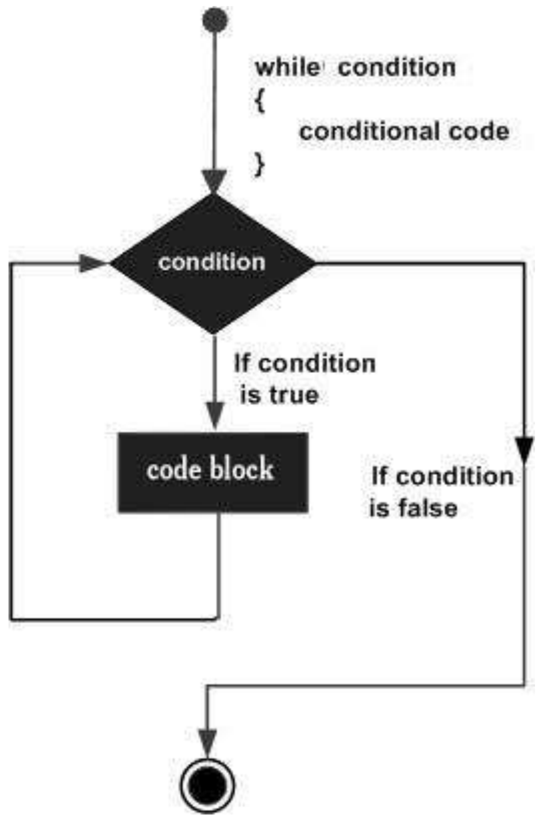
The While loop executes the same code again and again until a stop condition is met.

Syntax

The basic syntax for creating a while loop in R is :

```
while (test_expression) {
   statement
}
```

Flow Diagram



Here key point of the **while** loop is that the loop might not ever run. When the condition is tested and the result is false, the loop body will be skipped and the first statement after the while loop will be executed.

Example

```
v <- c("Hello","while loop")
cnt <- 2
while (cnt < 7){
   print(v)
   cnt = cnt + 1
}
```

When the above code is compiled and executed, it produces the following result :

```
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
[1] "Hello"  "while loop"
```

R – For Loop

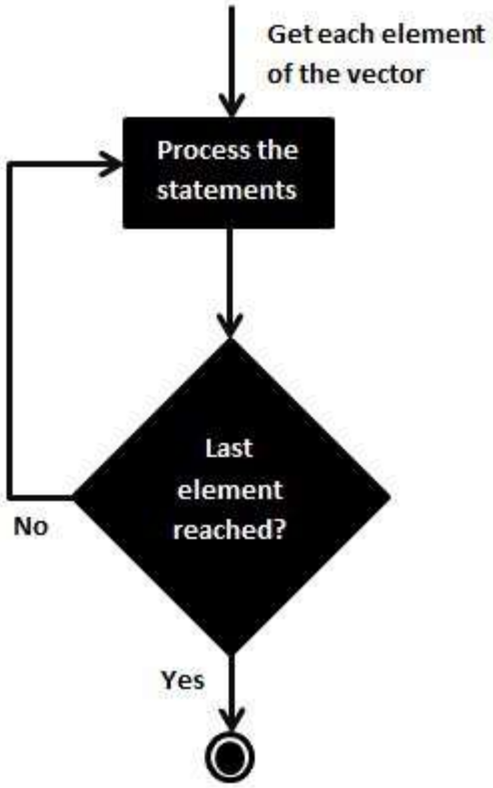
A for loop is a repetition control structure that allows you to efficiently write a loop that needs to execute a specific number of times.

Syntax

The basic syntax for creating a **for** loop statement in R is:

```
for (value in vector) {
    statements
}
```

Flow Diagram



R's for loops are particularly flexible in that they are not limited to integers, or even numbers in the input. We can pass character vectors, logical vectors, lists or expressions.

Example

```
v <- LETTERS[1:4]
for ( i in v) {
   print(i)
}
```

When the above code is compiled and executed, it produces the following result:

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

Loop Control Statements

Loop control statements change execution from its normal sequence. When execution leaves a scope, all automatic objects that were created in that scope are destroyed.

R supports the following control statements. Click the following links to check their detail.

Control Statement	Description
break statement	Terminates the loop statement and transfers execution to the statement immediately following the loop.
Next statement	The next statement simulates the behavior of R switch.

R – Break Statement

The break statement in R programming language has the following two usages:

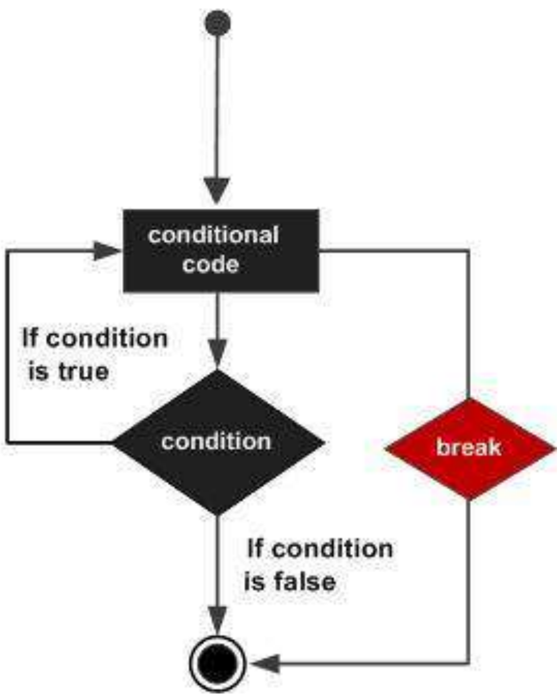
- When the break statement is encountered inside a loop, the loop is immediately terminated and program control resumes at the next statement following the loop.
- It can be used to terminate a case in the switch statement (covered in the next chapter).

Syntax

The basic syntax for creating a break statement in R is:

```
break
```

Flow Diagram



Example

```
v <- c("Hello","loop")
cnt <- 2
repeat{
   print(v)
   cnt <- cnt+1
   if(cnt > 5){
      break
   }
}
```

When the above code is compiled and executed, it produces the following result:

```
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
[1] "Hello" "loop"
```

R – Next Statement

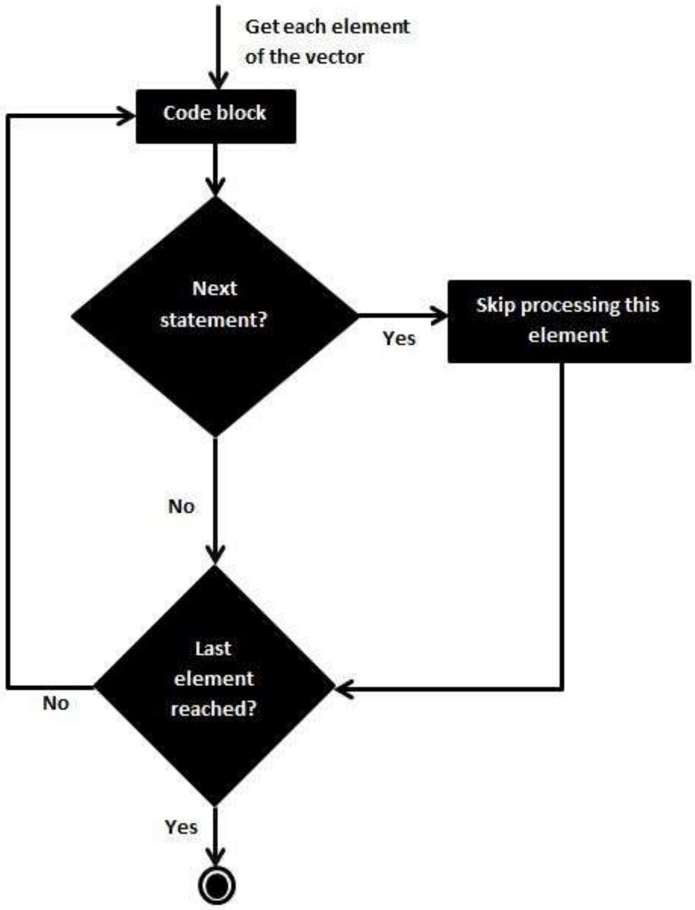
The **next** statement in R programming language is useful when we want to skip the current iteration of a loop without terminating it. On encountering next, the R parser skips further evaluation and starts next iteration of the loop.

Syntax

The basic syntax for creating a next statement in R is:

```
next
```

Flow Diagram



Example

```
v <- LETTERS[1:6]
for ( i in v){
   if (i == "D"){
      next
   }
   print(i)
}
```

When the above code is compiled and executed, it produces the following result:

```
[1] "A"
[1] "B"
[1] "C"
[1] "E"
[1] "F"
```

R–Function

A function is a set of statements organized together to perform a specific task. R has a large number of in-built functions and the user can create their own functions.

In R, a function is an object so the R interpreter is able to pass control to the function, along with arguments that may be necessary for the function to accomplish the actions.

The function in turn performs its task and returns control to the interpreter as well as any result which may be stored in other objects.

Function Definition

An R function is created by using the keyword **function**. The basic syntax of an R function definition is as follows:

```
function_name <- function(arg_1, arg_2, ...) {
    Function body
}
```

Function Components

The different parts of a function are:

- **Function Name:** This is the actual name of the function. It is stored in R environment as an object with this name.

- **Arguments:** An argument is a placeholder. When a function is invoked, you pass a value to the argument. Arguments are optional; that is, a function may contain no arguments. Also arguments can have default values.

- **Function Body:** The function body contains a collection of statements that defines what the function does.

- **Return Value:** The return value of a function is the last expression in the function body to be evaluated.

R has many **in-built** functions which can be directly called in the program without defining them first. We can also create and use our own functions referred as **user defined** functions.

Built-in Function

Simple examples of in-built functions are seq(), mean(), max(), sum(x)and paste(...) etc. They are directly called by user written programs.

```
# Create a sequence of numbers from 32 to 44.
print(seq(32,44))

# Find mean of numbers from 25 to 82.
print(mean(25:82))

# Find sum of numbers frm 41 to 68.
print(sum(41:68))
```

When we execute the above code, it produces the following result:

```
[1] 32 33 34 35 36 37 38 39 40 41 42 43 44
[1] 53.5
[1] 1526
```

User-defined Function

We can create user-defined functions in R. They are specific to what a user wants and once created they can be used like the built-in functions. Below is an example of how a function is created and used.

```
# Create a function to print squares of numbers in sequence.
new.function <- function(a) {
  for(i in 1:a) {
            b <- i^2
            print(b)
            }
                     }
```

Calling a Function

```
 # Create a function to print squares of numbers in sequence.
new.function <- function(a) {
  for(i in 1:a) {
            b <- i^2
            print(b)
            }
                     }

# Call the function new.function supplying 6 as an argument.
```

```
new.function(6)
```

When we execute the above code, it produces the following result:

```
[1] 1
[1] 4
[1] 9
[1] 16
[1] 25
[1] 36
```

Calling a Function without an Argument

```
# Create a function without an argument.
new.function <- function() {
            for(i in 1:5) {
            print(i^2)
            }
                     }

# Call the function without supplying an argument.
new.function()
```

When we execute the above code, it produces the following result:

```
[1] 1
[1] 4
[1] 9
[1] 16
[1] 25
```

Calling a Function with Argument Values (by position and by name)

The arguments to a function call can be supplied in the same sequence as defined in the function or they can be supplied in a different sequence but assigned to the names of the arguments.

```
# Create a function with arguments.
new.function <- function(a,b,c) {
            result <- a*b+c
            print(result)
                          }
```

```
# Call the function by position of arguments.
new.function(5,3,11)

# Call the function by names of the arguments.
new.function(a=11,b=5,c=3)
```

When we execute the above code, it produces the following result:

```
[1] 26
[1] 58
```

Calling a Function with Default Argument

We can define the value of the arguments in the function definition and call the function without supplying any argument to get the default result. But we can also call such functions by supplying new values of the argument and get non default result.

```
# Create a function with arguments.
new.function <- function(a = 3,b =6) {
            result <- a*b
            print(result)
                              }

# Call the function without giving any argument.
new.function()

# Call the function with giving new values of the argument.
new.function(9,5)
```

When we execute the above code, it produces the following result:

```
[1] 18
[1] 45
```

Lazy Evaluation of Function

Arguments to functions are evaluated lazily, which means so they are evaluated only when needed by the function body.

```
# Create a function with arguments.
new.function <- function(a, b) {
```

```
        print(a^2)
        print(a)
        print(b)
                        }

# Evaluate the function without supplying one of the arguments.
new.function(6)
```

When we execute the above code, it produces the following result:

```
[1] 36
[1] 6
Error in print(b) : argument "b" is missing, with no default
```

R – Strings

Any value written within a pair of single quote or double quotes in R is treated as a string. Internally R stores every string within double quotes, even when you create them with single quote.

Rules Applied in String Construction

- The quotes at the beginning and end of a string should be both double quotes or both single quote. They can not be mixed.
- Double quotes can be inserted into a string starting and ending with single quote.
- Single quote can be inserted into a string starting and ending with double quotes.
- Double quotes can not be inserted into a string starting and ending with double quotes.
- Single quote can not be inserted into a string starting and ending with single quote.

Examples of Valid Strings

Following examples clarify the rules about creating a string in R.

```
a <- 'Start and end with single quote'
print(a)

b <- "Start and end with double quotes"
print(b)

c <- "single quote ' in between double quotes"
print(c)

d <- 'Double quotes " in between single quote'
print(d)
```

When the above code is run we get the following output:

```
[1] "Start and end with single quote"
[1] "Start and end with double quotes"
[1] "single quote ' in between double quote"
[1] "Double quote \" in between single quote"
```

Examples of Invalid Strings

```
e <- 'Mixed quotes"
print(e)

f <- 'Single quote ' inside single quote'
print(f)

g <- "Double quotes " inside double quotes"
print(g)
```

When we run the script it fails giving below results.

```
...: unexpected INCOMPLETE_STRING

.... unexpected symbol
1: f <- 'Single quote ' inside

unexpected symbol
1: g <- "Double quotes " inside
```

String Manipulation

Concatenating Strings - paste() function

Many strings in R are combined using the **paste()** function. It can take any number of arguments to be combined together.

Syntax

The basic syntax for paste function is :

```
paste(..., sep = " ", collapse = NULL)
```

Following is the description of the parameters used:

- **...** represents any number of arguments to be combined.
- **sep** represents any separator between the arguments. It is optional.
- **collapse** is used to eliminate the space in between two strings. But not the space within two words of one string.

Example

```
a <- "Hello"
b <- 'How'
c <- "are you? "

print(paste(a,b,c))

print(paste(a,b,c, sep = "-"))

print(paste(a,b,c, sep = "", collapse = ""))
```

When we execute the above code, it produces the following result:

```
[1] "Hello How are you? "
[1] "Hello-How-are you? "
[1] "HelloHoware you? "
```

Formatting numbers & strings - format() function

Numbers and strings can be formatted to a specific style using **format()**function.

Syntax

The basic syntax for format function is :

```
format(x, digits, nsmall,scientific,width,justify = c("left", "right",
"centre", "none"))
```

Following is the description of the parameters used:

- **x** is the vector input.
- **digits** is the total number of digits displayed.
- **nsmall** is the minimum number of digits to the right of the decimal point.
- **scientific** is set to TRUE to display scientific notation.
- **width** indicates the minimum width to be displayed by padding blanks in the beginning.
- **justify** is the display of the string to left, right or center.

Example

```
# Total number of digits displayed. Last digit rounded off.
result <- format(23.123456789, digits = 9)
print(result)

# Display numbers in scientific notation.
result <- format(c(6, 13.14521), scientific = TRUE)
print(result)

# The minimum number of digits to the right of the decimal point.
result <- format(23.47, nsmall = 5)
print(result)

# Format treats everything as a string.
result <- format(6)
print(result)

# Numbers are padded with blank in the beginning for width.
result <- format(13.7, width = 6)
print(result)

# Left justify strings.
result <- format("Hello",width = 8, justify = "l")
print(result)

# Justfy string with center.
result <- format("Hello",width = 8, justify = "c")
print(result)
```

When we execute the above code, it produces the following result:

```
[1] "23.1234568"
[1] "6.000000e+00" "1.314521e+01"
[1] "23.47000"
[1] "6"
[1] "  13.7"
[1] "Hello   "
```

```
[1] " Hello  "
```

Counting number of characters in a string - nchar() function

This function counts the number of characters including spaces in a string.

Syntax

The basic syntax for nchar() function is :

```
nchar(x)
```

Following is the description of the parameters used:

- **x** is the vector input.

Example

```
result <- nchar("Count the number of characters")
print(result)
```

When we execute the above code, it produces the following result:

```
[1] 30
```

Changing the case - toupper() & tolower() functions

These functions change the case of characters of a string.

Syntax

The basic syntax for toupper() & tolower() function is :

```
toupper(x)
tolower(x)
```

Following is the description of the parameters used:

- **x** is the vector input.

Example

```
# Changing to Upper case.
result <- toupper("Changing To Upper")
print(result)

# Changing to lower case.
```

```
result <- tolower("Changing To Lower")
print(result)
```

When we execute the above code, it produces the following result:

```
[1] "CHANGING TO UPPER"
[1] "changing to lower"
```

Extracting parts of a string - substring() function

This function extracts parts of a String.

Syntax

The basic syntax for substring() function is :

```
substring(x,first,last)
```

Following is the description of the parameters used:

- **x** is the character vector input.
- **first** is the position of the first character to be extracted.
- **last** is the position of the last character to be extracted.

Example

```
# Extract characters from 5th to 7th position.
result <- substring("Extract", 5, 7)
print(result)
```

When we execute the above code, it produces the following result:

```
[1] "act"
```

R–Vectors

Vectors are the most basic R data objects and there are six types of atomic vectors. They are logical, integer, double, complex, character and raw.

Vector Creation

Single Element Vector

Even when you write just one value in R, it becomes a vector of length 1 and belongs to one of the above vector types.

```
# Atomic vector of type character.
print("abc");

# Atomic vector of type double.
print(12.5)

# Atomic vector of type integer.
print(63L)

# Atomic vector of type logical.
print(TRUE)

# Atomic vector of type complex.
print(2+3i)

# Atomic vector of type raw.
print(charToRaw('hello'))
```

When we execute the above code, it produces the following result:

```
[1] "abc"
[1] 12.5
[1] 63
[1] TRUE
[1] 2+3i
[1] 68 65 6c 6c 6f
```

Multiple Elements Vector

Using colon operator with numeric data

```
# Creating a sequence from 5 to 13.
v <- 5:13
print(v)

# Creating a sequence from 6.6 to 12.6.
v <- 6.6:12.6
print(v)

# If the final element specified does not belong to the sequence then it is discarded.
v <- 3.8:11.4
print(v)
```

When we execute the above code, it produces the following result:

```
[1]  5  6  7  8  9 10 11 12 13
[1]  6.6  7.6  8.6  9.6 10.6 11.6 12.6
[1]  3.8  4.8  5.8  6.8  7.8  8.8  9.8 10.8
```

Using sequence (Seq.) operator

```
# Create vector with elements from 5 to 9 incrementing by 0.4.
print(seq(5, 9, by=0.4))
```

When we execute the above code, it produces the following result:

```
 [1] 5.0 5.4 5.8 6.2 6.6 7.0 7.4 7.8 8.2 8.6 9.0
```

Using the c() function

The non-character values are coerced to character type if one of the elements is a character.

```
# The logical and numeric values are converted to characters.
s <- c('apple','red',5,TRUE)
print(s)
```

When we execute the above code, it produces the following result:

```
[1] "apple" "red"   "5"     "TRUE"
```

Accessing Vector Elements

Elements of a Vector are accessed using indexing. The **[ ] brackets** are used for indexing. Indexing starts with position 1. Giving a negative value in the index drops that element from result. **TRUE**, **FALSE** or **0** and **1** can also be used for indexing.

```
# Accessing vector elements using position.
t <- c("Sun","Mon","Tue","Wed","Thurs","Fri","Sat")
u <- t[c(2,3,6)]
print(u)

# Accessing vector elements using logical indexing.
v <- t[c(TRUE,FALSE,FALSE,FALSE,FALSE,TRUE,FALSE)]
print(v)

# Accessing vector elements using negative indexing.
x <- t[c(-2,-5)]
print(x)

# Accessing vector elements using 0/1 indexing.
y <- t[c(0,0,0,0,0,0,1)]
print(y)
```

When we execute the above code, it produces the following result:

```
[1] "Mon" "Tue" "Fri"
[1] "Sun" "Fri"
[1] "Sun" "Tue" "Wed" "Fri" "Sat"
[1] "Sun"
```

Vector Manipulation

Vector Arithmetic

Two vectors of same length can be added, subtracted, multiplied or divided giving the result as a vector output.

```
# Create two vectors.
v1 <- c(3,8,4,5,0,11)
v2 <- c(4,11,0,8,1,2)

# Vector addition.
```

```
add.result <- v1+v2
print(add.result)

# Vector substraction.
sub.result <- v1-v2
print(sub.result)

# Vector multiplication.
multi.result <- v1*v2
print(multi.result)

# Vector division.
divi.result <- v1/v2
print(divi.result)
```

When we execute the above code, it produces the following result:

```
[1]  7 19  4 13  1 13
[1] -1 -3  4 -3 -1  9
[1] 12 88  0 40  0 22
[1] 0.7500000 0.7272727       Inf 0.6250000 0.0000000 5.5000000
```

Vector Element Recycling

If we apply arithmetic operations to two vectors of unequal length, then the elements of the shorter vector are recycled to complete the operations.

```
v1 <- c(3,8,4,5,0,11)
v2 <- c(4,11)
# V2 becomes c(4,11,4,11,4,11)

add.result <- v1+v2
print(add.result)

sub.result <- v1-v2
print(sub.result)
```

When we execute the above code, it produces the following result:

```
[1]  7 19  8 16  4 22
[1] -1 -3  0 -6 -4  0
```

Vector Element Sorting

Elements in a vector can be sorted using the **sort()** function.

```
v <- c(3,8,4,5,0,11, -9, 304)

# Sort the elements of the vector.
sort.result <- sort(v)
print(sort.result)

# Sort the elements in the reverse order.
revsort.result <- sort(v, decreasing = TRUE)
print(revsort.result)

# Sorting character vectors.
v <- c("Red","Blue","yellow","violet")
sort.result <- sort(v)
print(sort.result)

# Sorting character vectors in reverse order.
revsort.result <- sort(v, decreasing = TRUE)
print(revsort.result)
```

When we execute the above code, it produces the following result:

```
[1]  -9   0   3   4   5   8  11 304
[1] 304  11   8   5   4   3   0  -9
[1] "Blue"   "Red"    "violet" "yellow"
[1] "yellow" "violet" "Red"    "Blue"
```

R – Lists

Lists are the R objects which contain elements of different types like - numbers, strings, vectors and another list inside it. A list can also contain a matrix or a function as its elements. List is created using **list()** function.

Creating a List

Following is an example to create a list containing strings, numbers, vectors and a logical values

```
# Create a list containing strings, numbers, vectors and a logical values.
list_data <- list("Red", "Green", c(21,32,11), TRUE, 51.23, 119.1)
print(list_data)
```

When we execute the above code, it produces the following result:

```
[[1]]
[1] "Red"

[[2]]
[1] "Green"

[[3]]
[1] 21 32 11

[[4]]
[1] TRUE

[[5]]
[1] 51.23

[[6]]
[1] 119.1
```

Naming List Elements

The list elements can be given names and they can be accessed using these names.

```
# Create a list containing a vector, a matrix and a list.
list_data <- list(c("Jan","Feb","Mar"), matrix(c(3,9,5,1,-2,8), nrow=2),
list("green",12.3))


# Give names to the elements in the list.
names(list_data) <- c("1st Quarter", "A_Matrix", "A Inner list")


# Show the list.
print(list_data)
```

When we execute the above code, it produces the following result:

```
$`1st_Quarter`
[1] "Jan" "Feb" "Mar"


$A_Matrix
     [,1] [,2] [,3]
[1,]    3    5   -2
[2,]    9    1    8


$A_Inner_list
$A_Inner_list[[1]]
[1] "green"


$A_Inner_list[[2]]
[1] 12.3
```

Accessing List Elements

Elements of the list can be accessed by the index of the element in the list. In case of named lists it can also be accessed using the names.

We continue to use the list in the above example:

```
# Create a list containing a vector, a matrix and a list.
list_data <- list(c("Jan","Feb","Mar"), matrix(c(3,9,5,1,-2,8), nrow=2),
list("green",12.3))
```

```
# Give names to the elements in the list.
names(list_data) <- c("1st Quarter", "A_Matrix", "A Inner list")

# Access the first element of the list.
print(list_data[1])

# Access the thrid element. As it is also a list, all its elements will be
printed.
print(list_data[3])

# Access the list element using the name of the element.
print(list_data$A_Matrix)
```

When we execute the above code, it produces the following result:

```
$`1st_Quarter`
[1] "Jan" "Feb" "Mar"

$A_Inner_list
$A_Inner_list[[1]]
[1] "green"

$A_Inner_list[[2]]
[1] 12.3

     [,1] [,2] [,3]
[1,]    3    5   -2
[2,]    9    1    8
```

Manipulating List Elements

We can add, delete and update list elements as shown below. We can add and delete elements only at the end of a list. But we can update any element.

```
# Create a list containing a vector, a matrix and a list.
list_data <- list(c("Jan","Feb","Mar"), matrix(c(3,9,5,1,-2,8), nrow=2),
list("green",12.3))

# Give names to the elements in the list.
names(list_data) <- c("1st Quarter", "A_Matrix", "A Inner list")
```

```
# Add element at the end of the list.
list_data[4] <- "New element"
print(list_data[4])

# Remove the last element.
list_data[4] <- NULL

# Print the 4th Element.
print(list_data[4])

# Update the 3rd Element.
list_data[3] <- "updated element"
print(list_data[3])
```

When we execute the above code, it produces the following result:

```
[[1]]
[1] "New element"

$
NULL

$`A Inner list`
[1] "updated element"
```

Merging Lists

You can merge many lists into one list by placing all the lists inside one list() function.

```
# Create two lists.
list1 <- list(1,2,3)
list2 <- list("Sun","Mon","Tue")

# Merge the two lists.
merged.list <- c(list1,list2)



# Print the merged list.
```

```
print(merged.list)
```

When we execute the above code, it produces the following result :

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

[[2]]
[1] 2

[[3]]
[1] 3

[[4]]
[1] "Sun"

[[5]]
[1] "Mon"

[[6]]
[1] "Tue"
```

Converting List to Vector

A list can be converted to a vector so that the elements of the vector can be used for further manipulation. All the arithmetic operations on vectors can be applied after the list is converted into vectors. To do this conversion, we use the **unlist()** function. It takes the list as input and produces a vector.

```
# Create lists.
list1 <- list(1:5)
print(list1)

list2 <-list(10:14)
print(list2)

# Convert the lists to vectors.
v1 <- unlist(list1)
v2 <- unlist(list2)
```

```
print(v1)
print(v2)

# Now add the vectors
result <- v1+v2
print(result)
```

When we execute the above code, it produces the following result :

```
[[1]]
[1] 1 2 3 4 5

[[1]]
[1] 10 11 12 13 14

[1] 1 2 3 4 5
[1] 10 11 12 13 14
[1] 11 13 15 17 19
```

R–Matrices

Matrices are the R objects in which the elements are arranged in a two-dimensional rectangular layout. They contain elements of the same atomic types. Though we can create a matrix containing only characters or only logical values, they are not of much use. We use matrices containing numeric elements to be used in mathematical calculations.

A Matrix is created using the **matrix()** function.

Syntax

The basic syntax for creating a matrix in R is:

```
matrix(data, nrow, ncol, byrow, dimnames)
```

Following is the description of the parameters used:

- **data** is the input vector which becomes the data elements of the matrix.
- **nrow** is the number of rows to be created.
- **ncol** is the number of columns to be created.
- **byrow** is a logical clue. If TRUE then the input vector elements are arranged by row.
- **dimname** is the names assigned to the rows and columns.

Example

Create a matrix taking a vector of numbers as input

```
# Elements are arranged sequentially by row.
M <- matrix(c(3:14), nrow=4, byrow=TRUE)
print(M)

# Elements are arranged sequentially by column.
N <- matrix(c(3:14), nrow=4, byrow=FALSE)
print(N)

# Define the column and row names.
rownames = c("row1", "row2", "row3", "row4")
colnames = c("col1", "col2", "col3")
```

```
P <- matrix(c(3:14), nrow=4, byrow=TRUE, dimnames=list(rownames, colnames))
print(P)
```

When we execute the above code, it produces the following result:

```
     [,1] [,2] [,3]
[1,]    3    4    5
[2,]    6    7    8
[3,]    9   10   11
[4,]   12   13   14
     [,1] [,2] [,3]
[1,]    3    7   11
[2,]    4    8   12
[3,]    5    9   13
[4,]    6   10   14
     col1 col2 col3
row1    3    4    5
row2    6    7    8
row3    9   10   11
row4   12   13   14
```

Accessing Elements of a Matrix

Elements of a matrix can be accessed by using the column and row index of the element. We consider the matrix P above to find the specific elements below.

```
# Define the column and row names.
rownames = c("row1", "row2", "row3", "row4")
colnames = c("col1", "col2", "col3")

# Create the matrix.
P <- matrix(c(3:14), nrow=4, byrow=TRUE, dimnames=list(rownames, colnames))

# Access the element at 3rd column and 1st row.
print(P[1,3])

# Access the element at 2nd column and 4th row.
print(P[4,2])
```

```
# Access only the  2nd row.
print(P[2,])

# Access only the 3rd column.
print(P[,3])
```

When we execute the above code, it produces the following result:

```
[1] 5
[1] 13
col1 col2 col3
   6    7    8
row1 row2 row3 row4
   5    8   11   14
```

Matrix Computations

Various mathematical operations are performed on the matrices using the R operators. The result of the operation is also a matrix.

The dimensions (number of rows and columns) should be same for the matrices involved in the operation.

Matrix Addition & Subtraction

```
# Create two 2x3 matrices.
matrix1 <- matrix(c(3, 9, -1, 4, 2, 6), nrow=2)
print(matrix1)

matrix2 <- matrix(c(5, 2, 0, 9, 3, 4), nrow=2)
print(matrix2)

# Add the matrices.
result <- matrix1 + matrix2
cat("Result of addition","\n")
print(result)

# Subtract the matrices
result <- matrix1 - matrix2
cat("Result of subtraction","\n")
```

```
print(result)
```

When we execute the above code, it produces the following result:

```
     [,1] [,2] [,3]
[1,]    3   -1    2
[2,]    9    4    6
     [,1] [,2] [,3]
[1,]    5    0    3
[2,]    2    9    4
Result of addition
     [,1] [,2] [,3]
[1,]    8   -1    5
[2,]   11   13   10
Result of subtraction
     [,1] [,2] [,3]
[1,]   -2   -1   -1
[2,]    7   -5    2
```

Matrix Multiplication & Division

```
# Create two 2x3 matrices.
matrix1 <- matrix(c(3, 9, -1, 4, 2, 6), nrow=2)
print(matrix1)

matrix2 <- matrix(c(5, 2, 0, 9, 3, 4), nrow=2)
print(matrix2)

# Multiply the matrices.
result <- matrix1 * matrix2
cat("Result of multiplication","\n")
print(result)

# Divide the matrices
result <- matrix1 / matrix2
cat("Result of division","\n")
print(result)
```

When we execute the above code, it produces the following result:

```
     [,1] [,2] [,3]
[1,]    3   -1    2
[2,]    9    4    6
     [,1] [,2] [,3]
[1,]    5    0    3
[2,]    2    9    4
Result of multiplication
     [,1] [,2] [,3]
[1,]   15    0    6
[2,]   18   36   24
Result of division
     [,1]      [,2]      [,3]
[1,]  0.6      -Inf 0.6666667
[2,]  4.5 0.4444444 1.5000000
```

R–Arrays

Arrays are the R data objects which can store data in more than two dimensions. For example - If we create an array of dimension (2, 3, 4) then it creates 4 rectangular matrices each with 2 rows and 3 columns. Arrays can store only data type.

An array is created using the **array()** function. It takes vectors as input and uses the values in the **dim** parameter to create an array.

Example

The following example creates an array of two 3x3 matrices each with 3 rows and 3 columns.

```
# Create two vectors of different lengths.
vector1 <- c(5,9,3)
vector2 <- c(10,11,12,13,14,15)

# Take these vectors as input to the array.
result <- array(c(vector1,vector2),dim=c(3,3,2))
print(result)
```

When we execute the above code, it produces the following result:

```
, , 1

     [,1] [,2] [,3]
[1,]    5   10   13
[2,]    9   11   14
[3,]    3   12   15

, , 2

     [,1] [,2] [,3]
[1,]    5   10   13
[2,]    9   11   14
[3,]    3   12   15
```

Naming Columns and Rows

We can give names to the rows, columns and matrices in the array by using the **dimnames** parameter.

```
# Create two vectors of different lengths.
vector1 <- c(5,9,3)
vector2 <- c(10,11,12,13,14,15)
column.names <- c("COL1","COL2","COL3")
row.names <- c("ROW1","ROW2","ROW3")
matrix.names <- c("Matrix1","Matrix2")

# Take these vectors as input to the array.
result <- array(c(vector1,vector2),dim=c(3,3,2),dimnames =
list(column.names,row.names,matrix.names))
print(result)
```

When we execute the above code, it produces the following result:

```
, , Matrix1

     ROW1 ROW2 ROW3
COL1    5   10   13
COL2    9   11   14
COL3    3   12   15

, , Matrix2

     ROW1 ROW2 ROW3
COL1    5   10   13
COL2    9   11   14
COL3    3   12   15
```

Accessing Array Elements

```
# Create two vectors of different lengths.
vector1 <- c(5,9,3)
vector2 <- c(10,11,12,13,14,15)
column.names <- c("COL1","COL2","COL3")
row.names <- c("ROW1","ROW2","ROW3")
```

```
matrix.names <- c("Matrix1","Matrix2")


# Take these vectors as input to the array.
result <- array(c(vector1,vector2),dim=c(3,3,2),dimnames =
list(column.names,row.names,matrix.names))


# Print the third row of the second matrix of the array.
print(result[3,,2])


# Print the element in the 1st row and 3rd column of the 1st matrix.
print(result[1,3,1])


# Print the 2nd Matrix.
print(result[,,2])
```

When we execute the above code, it produces the following result:

```
ROW1 ROW2 ROW3
   3   12   15
[1] 13
     ROW1 ROW2 ROW3
COL1    5   10   13
COL2    9   11   14
COL3    3   12   15
```

Manipulating Array Elements

As array is made up matrices in multiple dimensions, the operations on elements of array are carried out by accessing elements of the matrices.

```
# Create two vectors of different lengths.
vector1 <- c(5,9,3)
vector2 <- c(10,11,12,13,14,15)


# Take these vectors as input to the array.
array1 <- array(c(vector1,vector2),dim=c(3,3,2))


# Create two vectors of different lengths.
vector3 <- c(9,1,0)
```

```
vector4 <- c(6,0,11,3,14,1,2,6,9)
array2 <- array(c(vector1,vector2),dim=c(3,3,2))
```

```

# create matrices from these arrays.
matrix1 <- array1[,,2]
matrix2 <- array2[,,2]

# Add the matrices.
result <- matrix1+matrix2
print(result)
```

When we execute the above code, it produces the following result:

```
     [,1] [,2] [,3]
[1,]   10   20   26
[2,]   18   22   28
[3,]    6   24   30
```

Calculations Across Array Elements

We can do calculations across the elements in an array using the **apply()**function.

Syntax

```
apply(x, margin, fun)
```

Following is the description of the parameters used:

- **x** is an array.
- **margin** is the name of the data set used.
- **fun** is the function to be applied across the elements of the array.

Example

We use the apply() function below to calculate the sum of the elements in the rows of an array across all the matrices.

```
# Create two vectors of different lengths.
vector1 <- c(5,9,3)
vector2 <- c(10,11,12,13,14,15)

# Take these vectors as input to the array.
new.array <- array(c(vector1,vector2),dim=c(3,3,2))
```

```
print(new.array)

# Use apply to calculate the sum of the rows across all the matrices.
result <- apply(new.array, c(1), sum)
print(result)
```

When we execute the above code, it produces the following result:

```
, , 1

     [,1] [,2] [,3]
[1,]    5   10   13
[2,]    9   11   14
[3,]    3   12   15

, , 2

     [,1] [,2] [,3]
[1,]    5   10   13
[2,]    9   11   14
[3,]    3   12   15

[1] 56 68 60
```

Factors are the data objects which are used to categorize the data and store it as levels. They can store both strings and integers. They are useful in the columns which have a limited number of unique values. Like "Male, "Female" and True, False etc. They are useful in data analysis for statistical modeling.

Factors are created using the factor () function by taking a vector as input.

Example

```
# Create a vector as input.
data <-
c("East","West","East","North","North","East","West","West","West","East","North")
print(data)
print(is.factor(data))

# Apply the factor function.
factor_data <- factor(data)
print(factor_data)
print(is.factor(factor_data))
```

When we execute the above code, it produces the following result:

```
 [1] "East"  "West"  "East"  "North" "North" "East"  "West"  "West"  "West"
"East"  "North"
[1] FALSE
 [1] East  West  East  North North East  West  West  West  East  North
Levels: East North West
[1] TRUE
```

Factors in Data Frame

On creating any data frame with a column of text data, R treats the text column as categorical data and creates factors on it.

```
# Create the vectors for data frame.
height <- c(132,151,162,139,166,147,122)
weight <- c(48,49,66,53,67,52,40)
gender <- c("male","male","female","female","male","female","male")
```

```
# Create the data frame.
input_data <- data.frame(height,weight,gender)
print(input_data)

# Test if the gender column is a factor.
print(is.factor(input_data$gender))

# Print the gender column so see the levels.
print(input_data$gender)
```

When we execute the above code, it produces the following result:

```
  height weight gender
1    132     48   male
2    151     49   male
3    162     66 female
4    139     53 female
5    166     67   male
6    147     52 female
7    122     40   male
[1] TRUE
[1] male   male   female female male   female male
Levels: female male
```

Changing the Order of Levels

The order of the levels in a factor can be changed by applying the factor function again with new order of the levels.

```
data <-
c("East","West","East","North","North","East","West","West","West","East","North")
# Create the factors
factor_data <- factor(data)
print(factor_data)

# Apply the factor function with required order of the level.
new_order_data <- factor(factor_data,levels = c("East","West","North"))
print(new_order_data)
```

When we execute the above code, it produces the following result:

```
 [1] East  West  East  North North East  West  West  West  East  North
Levels: East North West
 [1] East  West  East  North North East  West  West  West  East  North
Levels: East West North
```

Generating Factor Levels

We can generate factor levels by using the **gl()** function. It takes two integers as input which indicates how many levels and how many times each level.

Syntax

```
gl(n, k, labels)
```

Following is the description of the parameters used:

- **n** is a integer giving the number of levels.
- **k** is a integer giving the number of replications.
- **labels** is a vector of labels for the resulting factor levels.

Example

```
v <- gl(3, 4, labels = c("Tampa", "Seattle","Boston"))
print(v)
```

When we execute the above code, it produces the following result:

```
Tampa   Tampa   Tampa   Tampa   Seattle Seattle Seattle Seattle Boston
[10] Boston  Boston  Boston
Levels: Tampa Seattle Boston
```

A data frame is a table or a two-dimensional array-like structure in which each column contains values of one variable and each row contains one set of values from each column.

Following are the characteristics of a data frame.

- The column names should be non-empty.
- The row names should be unique.
- The data stored in a data frame can be of numeric, factor or character type.
- Each column should contain same number of data items.

Create Data Frame

```
# Create the data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
     salary = c(623.3,515.2,611.0,729.0,843.25),
     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-11","2015-03-27")),
     stringsAsFactors=FALSE
                 )
# Print the data frame.
print(emp.data)
```

When we execute the above code, it produces the following result:

```
  emp_id emp_name salary start_date
1      1     Rick 623.30 2012-01-01
2      2      Dan 515.20 2013-09-23
3      3 Michelle 611.00 2014-11-15
4      4     Ryan 729.00 2014-05-11
5      5     Gary 843.25 2015-03-27
```

Get the Structure of the Data Frame

The structure of the data frame can be seen by using **str()** function.

```
# Create the data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
     salary = c(623.3,515.2,611.0,729.0,843.25),
     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-11","2015-03-27")),
     stringsAsFactors=FALSE
                  )
# Get the structure of the data frame.
str(emp.data)
```

When we execute the above code, it produces the following result:

```
'data.frame':   5 obs. of  4 variables:
 $ emp_id    : int  1 2 3 4 5
 $ emp_name  : chr  "Rick" "Dan" "Michelle" "Ryan" ...
 $ salary    : num  623 515 611 729 843
 $ start_date: Date, format: "2012-01-01" "2013-09-23" "2014-11-15" "2014-05-11" ...
```

Summary of Data in Data Frame

The statistical summary and nature of the data can be obtained by applying **summary()** function.

```
# Create the data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
     salary = c(623.3,515.2,611.0,729.0,843.25),
     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-11","2015-03-27")),
     stringsAsFactors=FALSE
                  )
# Print the summary.
print(summary(emp.data))
```

When we execute the above code, it produces the following result:

```
     emp_id    emp_name             salary        start_date
 Min.   :1   Length:5           Min.   :515.2   Min.   :2012-01-01
 1st Qu.:2   Class :character   1st Qu.:611.0   1st Qu.:2013-09-23
 Median :3   Mode  :character   Median :623.3   Median :2014-05-11
 Mean   :3                      Mean   :664.4   Mean   :2014-01-14
 3rd Qu.:4                      3rd Qu.:729.0   3rd Qu.:2014-11-15
 Max.   :5                      Max.   :843.2   Max.   :2015-03-27
```

Extract Data from Data Frame

Extract specific column from a data frame using column name.

```
# Create the data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
     salary = c(623.3,515.2,611.0,729.0,843.25),
     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-
11","2015-03-27")),
     stringsAsFactors=FALSE
                  )
# Extract Specific columns.
result <- data.frame(emp.data$emp_name,emp.data$salary)
print(result)
```

When we execute the above code, it produces the following result:

```
  emp.data.emp_name emp.data.salary
1              Rick          623.30
2               Dan          515.20
3          Michelle          611.00
4              Ryan          729.00
5              Gary          843.25
```

Extract the first two rows and then all columns

```
# Create the data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
```

```
     salary = c(623.3,515.2,611.0,729.0,843.25),

     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-
11","2015-03-27")),

     stringsAsFactors=FALSE

                  )

# Extract first two rows.

result <- emp.data[1:2,]

print(result)
```

When we execute the above code, it produces the following result:

```
emp_id emp_name salary start_date

1      1     Rick  623.3 2012-01-01

2      2      Dan  515.2 2013-09-23
```

Extract 3rd and 5th row with 2nd and 4th column

```
# Create the data frame.

emp.data <- data.frame(

     emp_id = c (1:5),

     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),

     salary = c(623.3,515.2,611.0,729.0,843.25),

     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-
11","2015-03-27")),

     stringsAsFactors=FALSE

                  )


# Extract 3rd and 5th row with 2nd and 4th column.

result <- emp.data[c(3,5),c(2,4)]

print(result)
```

When we execute the above code, it produces the following result:

```
  emp_name start_date

3 Michelle 2014-11-15

5     Gary 2015-03-27
```

Expand Data Frame

A data frame can be expanded by adding columns and rows.

Add Column

Just add the column vector using a new column name.

```
# Create the data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
     salary = c(623.3,515.2,611.0,729.0,843.25),
     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-11","2015-03-27")),
     stringsAsFactors=FALSE
                   )

# Add the "dept" coulmn.
emp.data$dept <- c("IT","Operations","IT","HR","Finance")
v <- emp.data
print(v)
```

When we execute the above code, it produces the following result:

```
emp_id emp_name salary start_date       dept
1      1     Rick 623.30 2012-01-01         IT
2      2      Dan 515.20 2013-09-23 Operations
3      3 Michelle 611.00 2014-11-15         IT
4      4     Ryan 729.00 2014-05-11         HR
5      5     Gary 843.25 2015-03-27    Finance
```

Add Row

To add more rows permanently to an existing data frame, we need to bring in the new rows in the same structure as the existing data frame and use the **rbind()** function.

In the example below we create a data frame with new rows and merge it with the existing data frame to create the final data frame.

```
# Create the first data frame.
emp.data <- data.frame(
     emp_id = c (1:5),
     emp_name = c("Rick","Dan","Michelle","Ryan","Gary"),
     salary = c(623.3,515.2,611.0,729.0,843.25),
     start_date = as.Date(c("2012-01-01","2013-09-23","2014-11-15","2014-05-11","2015-03-27")),
     dept=c("IT","Operations","IT","HR","Finance"),
```

```
     stringsAsFactors=FALSE
                  )
# Create the second data frame
emp.newdata <-    data.frame(
     emp_id = c (6:8),
     emp_name = c("Rasmi","Pranab","Tusar"),
     salary = c(578.0,722.5,632.8),
     start_date = as.Date(c("2013-05-21","2013-07-30","2014-06-17")),
     dept = c("IT","Operations","Fianance"),
     stringsAsFactors=FALSE
                        )

# Bind the two data frames.
emp.finaldata <- rbind(emp.data,emp.newdata)
print(emp.finaldata)
```

When we execute the above code, it produces the following result:

```
  emp_id emp_name salary start_date       dept
1      1     Rick 623.30 2012-01-01         IT
2      2      Dan 515.20 2013-09-23 Operations
3      3 Michelle 611.00 2014-11-15         IT
4      4     Ryan 729.00 2014-05-11         HR
5      5     Gary 843.25 2015-03-27    Finance
6      6    Rasmi 578.00 2013-05-21         IT
7      7   Pranab 722.50 2013-07-30 Operations
8      8    Tusar 632.80 2014-06-17   Fianance
```

R–Packages

R packages are a collection of R functions, complied code and sample data. They are stored under a directory called **"library"** in the R environment. By default, R installs a set of packages during installation. More packages are added later, when they are needed for some specific purpose. When we start the R console, only the default packages are available by default. Other packages which are already installed have to be loaded explicitly to be used by the R program that is going to use them.

All the packages available in R language are listed at R Packages.

Below is a list of commands to be used to check, verify and use the R packages.

Check Available R Packages

Get library locations containing R packages

```
.libPaths()
```

When we execute the above code, it produces the following result. It may vary depending on the local settings of your pc.

```
[2] "C:/Program Files/R/R-3.2.2/library"
```

Get the list of all the packages installed

```
library()
```

When we execute the above code, it produces the following result. It may vary depending on the local settings of your pc.

```
Packages in library 'C:/Program Files/R/R-3.2.2/library':


base                    The R Base Package
boot                    Bootstrap Functions (Originally by Angelo Canty
                        for S)
class                   Functions for Classification
cluster                 "Finding Groups in Data": Cluster Analysis
                        Extended Rousseeuw et al.
codetools               Code Analysis Tools for R
compiler                The R Compiler Package
```

Get all packages currently loaded in the R environment

```
search()
```

When we execute the above code, it produces the following result. It may vary depending on the local settings of your pc.

```
[1] ".GlobalEnv"        "package:stats"     "package:graphics"
[4] "package:grDevices" "package:utils"     "package:datasets"
[7] "package:methods"   "Autoloads"         "package:base"
```

Install a New Package

There are two ways to add new R packages. One is installing directly from the CRAN directory and another is downloading the package to your local system and installing it manually.

Install directly from CRAN

The following command gets the packages directly from CRAN webpage and installs the package in the R environment. You may be prompted to choose a nearest mirror. Choose the one appropriate to your location.

```
 install.packages("Package Name")


# Install the package named "XML".
 install.packages("XML")
```

Install package manually

Go to the link R Packages to download the package needed. Save the package as a **.zip** file in a suitable location in the local system.

Now you can run the following command to install this package in the R environment.

```
install.packages(file_name_with_path, repos = NULL, type="source")


# Install the package named "XML"
install.packages("E:/XML_3.98-1.3.zip", repos = NULL, type="source")
```

Load Package to Library

Before a package can be used in the code, it must be loaded to the current R environment. You also need to load a package that is already installed previously but not available in the current environment.

A package is loaded using the following command:

```
library("package Name", lib.loc="path to library")


# Load the package named "XML"
install.packages("E:/XML_3.98-1.3.zip", repos = NULL, type="source")
```

R – Data Reshaping

Data Reshaping in R is about changing the way data is organized into rows and columns. Most of the time data processing in R is done by taking the input data as a data frame. It is easy to extract data from the rows and columns of a data frame but there are situations when we need the data frame in a format that is different from format in which we received it. R has many functions to split, merge and change the rows to columns and vice-versa in a data frame.

Joining Columns and Rows in a Data Frame

We can join multiple vectors to create a data frame using the **cbind()**function. Also we can merge two data frames using **rbind()** function.

```
# Create vector objects.
city <- c("Tampa","Seattle","Hartford","Denver")
state <- c("FL","WA","CT","CO")
zipcode <- c(33602,98104,06161,80294)

# Combine above three vectors into one data frame.
addresses <- cbind(city,state,zipcode)

# Print a header.
cat("# # # # The First data frame\n")

# Print the data frame.
print(addresses)

# Create another data frame with similar columns
new.address <- data.frame(
   city = c("Lowry","Charlotte"),
   state = c("CO","FL"),
   zipcode = c("80230","33949"),
   stringsAsFactors=FALSE
)

# Print a header.
cat("# # # The Second data frame\n")
```

```
# Print the data frame.
print(new.address)

# Combine rows form both the data frames.
all.addresses <- rbind(addresses,new.address)

# Print a header.
cat("# # # The combined data frame\n")

# Print the result.
print(all.addresses)
```

When we execute the above code, it produces the following result:

```
# # # # The First data frame
     city       state zipcode
[1,] "Tampa"    "FL"  "33602"
[2,] "Seattle"  "WA"  "98104"
[3,] "Hartford" "CT"  "6161"
[4,] "Denver"   "CO"  "80294"
# # # The Second data frame
       city state zipcode
1     Lowry    CO   80230
2 Charlotte    FL   33949
# # # The combined data frame
       city state zipcode
1     Tampa    FL   33602
2   Seattle    WA   98104
3  Hartford    CT    6161
4    Denver    CO   80294
5     Lowry    CO   80230
6 Charlotte    FL   33949
```

Merging Data Frames

We can merge two data frames by using the **merge()** function. The data frames must have same column names on which the merging happens.

In the example below, we consider the data sets about Diabetes in Pima Indian Women available in the library names "MASS". we merge the two data sets based on the values of blood pressure("bp") and body mass index("bmi"). On choosing these two columns for merging, the records where values of these two variables match in both data sets are combined together to form a single data frame.

```
library(MASS)
merged.Pima <- merge(x=Pima.te, y=Pima.tr,
                    by.x=c("bp", "bmi"),
                    by.y=c("bp", "bmi")
)
print(merged.Pima)
nrow(merged.Pima)
```

When we execute the above code, it produces the following result:

```
   bp  bmi npreg.x glu.x skin.x ped.x age.x type.x npreg.y glu.y skin.y ped.y
1  60 33.8       1   117     23 0.466    27     No       2   125     20 0.088
2  64 29.7       2    75     24 0.370    33     No       2   100     23 0.368
3  64 31.2       5   189     33 0.583    29    Yes       3   158     13 0.295
4  64 33.2       4   117     27 0.230    24     No       1    96     27 0.289
5  66 38.1       3   115     39 0.150    28     No       1   114     36 0.289
6  68 38.5       2   100     25 0.324    26     No       7   129     49 0.439
7  70 27.4       1   116     28 0.204    21     No       0   124     20 0.254
8  70 33.1       4    91     32 0.446    22     No       9   123     44 0.374
9  70 35.4       9   124     33 0.282    34     No       6   134     23 0.542
10 72 25.6       1   157     21 0.123    24     No       4    99     17 0.294
11 72 37.7       5    95     33 0.370    27     No       6   103     32 0.324
12 74 25.9       9   134     33 0.460    81     No       8   126     38 0.162
13 74 25.9       1    95     21 0.673    36     No       8   126     38 0.162
14 78 27.6       5    88     30 0.258    37     No       6   125     31 0.565
15 78 27.6      10   122     31 0.512    45     No       6   125     31 0.565
16 78 39.4       2   112     50 0.175    24     No       4   112     40 0.236
17 88 34.5       1   117     24 0.403    40    Yes       4   127     11 0.598
   age.y type.y
1     31     No
2     21     No
3     24     No
4     21     No
5     21     No
```

```
6     43    Yes
7     36    Yes
8     40     No
9     29    Yes
10    28     No
11    55     No
12    39     No
13    39     No
14    49    Yes
15    49    Yes
16    38     No
17    28     No
[1] 17
```

Melting and Casting

One of the most interesting aspects of R programming is about changing the shape of the data in multiple steps to get a desired shape. The functions used to do this are called **melt()** and **cast()**.

We consider the dataset called ships present in the library called "MASS".

```
library(MASS)
print(ships)
```

When we execute the above code, it produces the following result:

```
   type year period service incidents
1     A   60     60     127         0
2     A   60     75      63         0
3     A   65     60    1095         3
4     A   65     75    1095         4
5     A   70     60    1512         6
.............
.............
8     A   75     75    2244        11
9     B   60     60   44882        39
10    B   60     75   17176        29
11    B   65     60   28609        58
............
............
```

```
17    C   60     60    1179         1
18    C   60     75     552         1
19    C   65     60     781         0
............
............
```

Melt the Data

Now we melt the data to organize it, converting all columns other than type and year into multiple rows.

```
molten.ships <- melt(ships, id = c("type","year"))
print(molten.ships)
```

When we execute the above code, it produces the following result:

```
    type year  variable value
1      A   60    period    60
2      A   60    period    75
3      A   65    period    60
4      A   65    period    75
............
............
9      B   60    period    60
10     B   60    period    75
11     B   65    period    60
12     B   65    period    75
13     B   70    period    60
...........
...........
41     A   60   service   127
42     A   60   service    63
43     A   65   service  1095
...........
...........
70     D   70   service  1208
71     D   75   service     0
72     D   75   service  2051
73     E   60   service    45
```

```
74     E   60   service     0
75     E   65   service   789
...........
...........
101    C   70 incidents     6
102    C   70 incidents     2
103    C   75 incidents     0
104    C   75 incidents     1
105    D   60 incidents     0
106    D   60 incidents     0
...........
...........
```

Cast the Molten Data

We can cast the molten data into a new form where the aggregate of each type of ship for each year is created. It is done using the **cast()** function.

```
recasted.ship <- cast(molten.ships, type+year~variable,sum)
print(recasted.ship)
```

When we execute the above code, it produces the following result:

```
   type year period service incidents
1     A   60    135     190         0
2     A   65    135    2190         7
3     A   70    135    4865        24
4     A   75    135    2244        11
5     B   60    135   62058        68
6     B   65    135   48979       111
7     B   70    135   20163        56
8     B   75    135    7117        18
9     C   60    135    1731         2
10    C   65    135    1457         1
11    C   70    135    2731         8
12    C   75    135     274         1
13    D   60    135     356         0
14    D   65    135     480         0
15    D   70    135    1557        13
```

```
16    D   75    135    2051         4
17    E   60    135      45         0
18    E   65    135    1226        14
19    E   70    135    3318        17
20    E   75    135     542         1
```