Programming for Data Analytics

1. Introduction to R and Atomic Vectors

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Instructor – Dr. Jim Duggan

- Senior Lecturer @ NUI Galway
- Research interests:
  - System Dynamics
  - Computational Epidemiology
  - Data Science & Artificial Intelligence
- Industry Experience as Programmer, Software Design, Business Analytics
- Application areas: Public Health Systems

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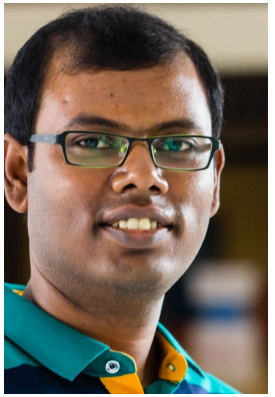
Lab Tutors

Joana Barros

- PhD student at the Biomedical Data Analytics group in the Insight Centre for Data Analytics – NUIG
- Data Analytics experience from Master in Bioinformatics and PhD
- Current research focuses on the public health domain, in particular, disease surveillance



Jaynal Abedin

- PhD Student @Insight Centre for Data Analytics, NUI Galway
- Six years of experience in leading a team of statisticians at a public health research organization prior to start PhD
- About 10 years of experience in R programming
  - Data Manipulation with R, PACKT
  - R Graphs Cookbook 2nd Edition, PACKT
- Research interests:
  - Anomaly detection
  - Machine learning
- Application area: Sports analytics, healthcare

Timetable

- Lectures:
  - Thursdays 9-10 IT204
  - Thursdays 12-1 AUC G002 Aras Ui Chathail
- Labs
  - Thursday 4-6 Finnegan Suite
  - R Studio Available on College Suites, local package installations
- Assignments (40% of Grade)
  - Weekly
  - Due Lab Day + 10 , 23.59

Time/Day	Thursday
9:00 am	CT5102 Programming for Data Analytics: TBC (J Duggan)
10:00 am	CT422 Modern Information Management: IT125G (C O'Riordan)
11:00 am	CT422 Modern Information Management: IT125G (C O'Riordan)
12:00 pm	CT5102 Programming for Data Analytics: TBC (J Duggan)
1:00 pm	ST255 Probability: Dillon Theatre (J Hinde)
2:00 pm	
3:00 pm	CT475 Machine Learning and Data Mining: AUC G002 Theatre Aras Ui Chathail (T Charlin/B Bray)
4:00 pm	CT5102 Programming for Data Analytics Lab: Finnegan Computer Suite
5:00 pm	CT5102 Programming for Data Analytics Lab: Finnegan Computer Suite

Prerequisites

Required…

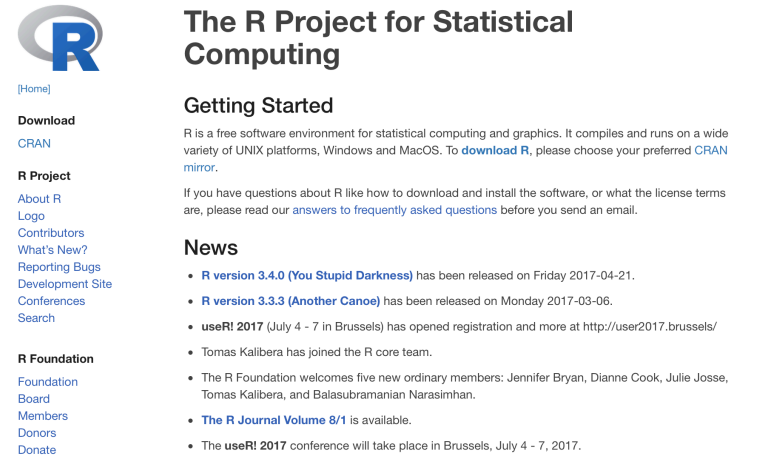
- Programming language
  - Variables
  - Arrays, Loops
  - Functions
  - Libraries
  - Data structures

Useful to have…

- Object oriented programming
  - Objects and Classes
  - Inheritance
- Relational databases
  - Tables
  - Queries
  - Summarising data

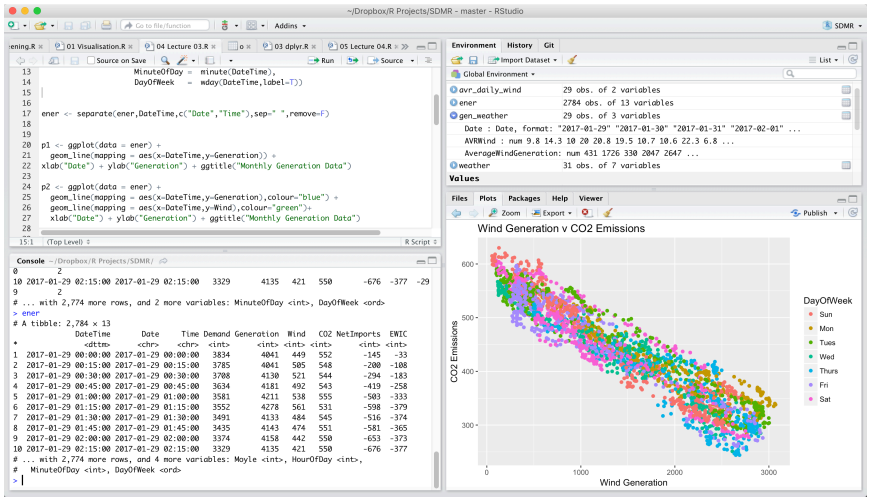
R...

https://www.r-project.org

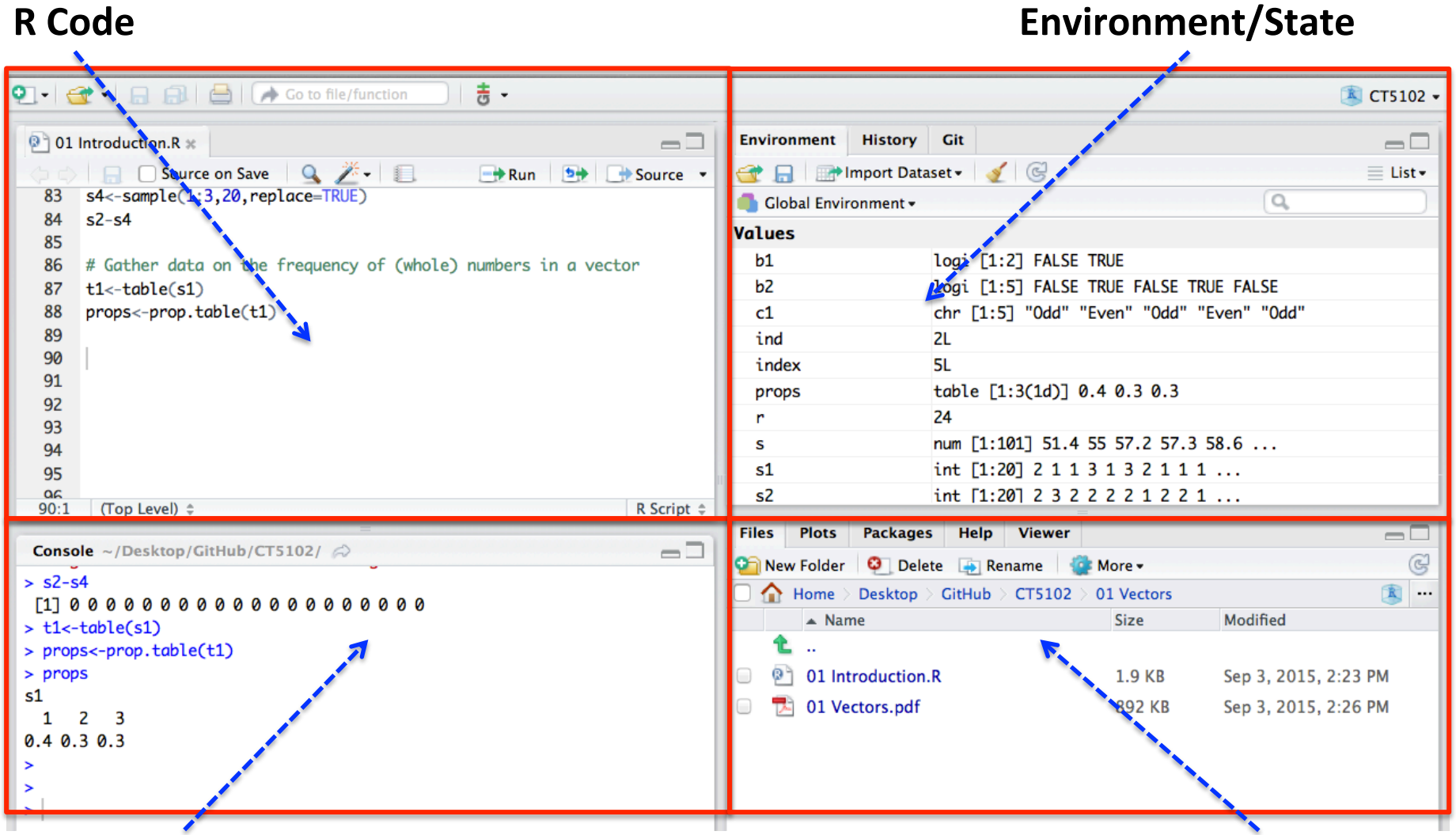


- R's *mission* is to enable the best and most thorough exploration of data possible (Chambers 2008).
- It is a dialect of the S language, developed at Bell Laboratories
- ACM noted that *S "will forever alter the way people analyze, visualize, and manipulate data"*

https://www.rstudio.com

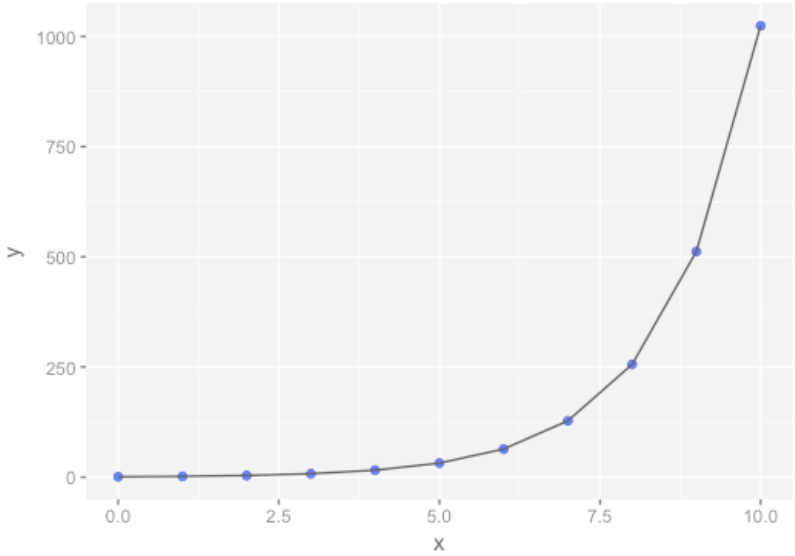


IDE Used: R Studio

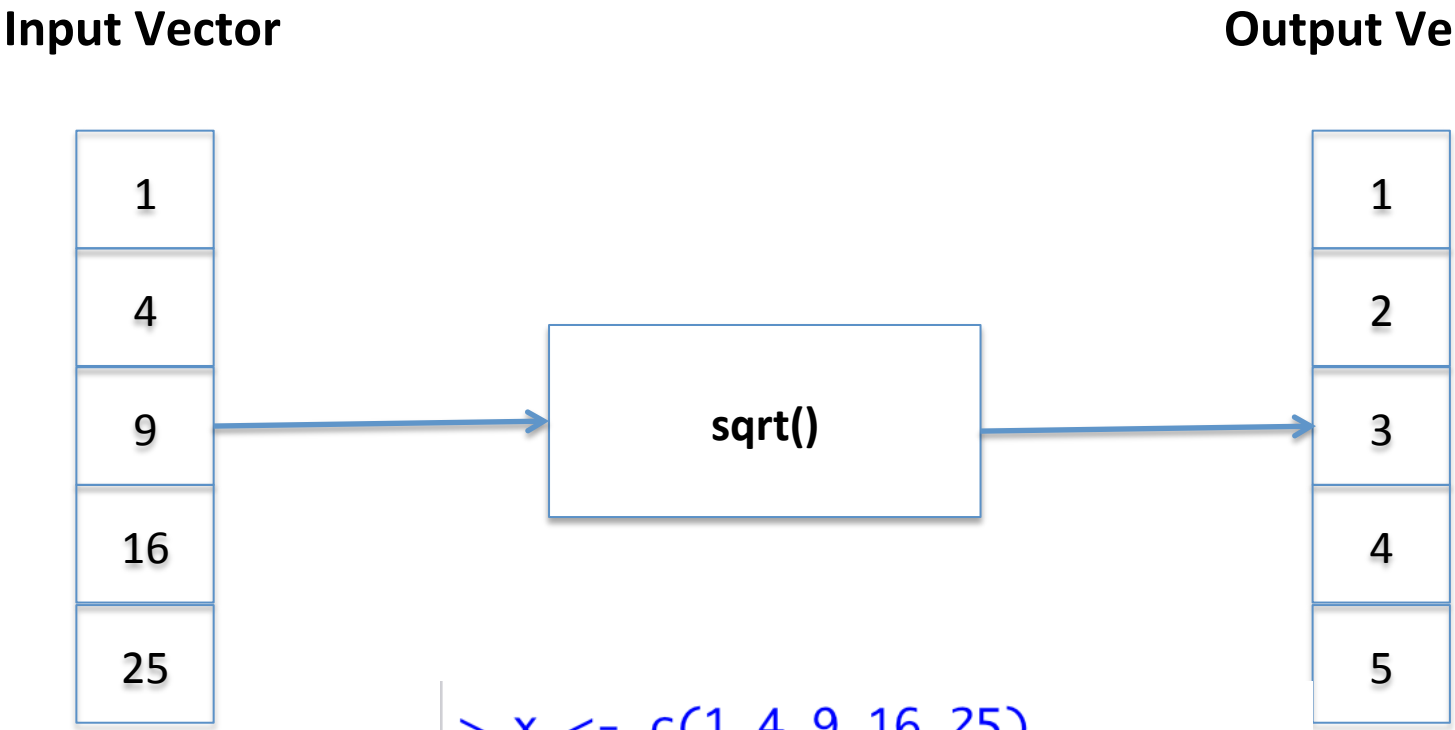


Sample R Script

```
>
> x <- 0:10
>
> x
 [1]  0  1  2  3  4  5  6  7  8  9 10
>
> y <- 2 ^ x
>
> y
 [1]    1    2    4    8   16   32   64  128  256  512
[11] 1024
>
> qplot(x,y)+geom_point(colour="blue")+geom_line()
```



** Note qplot requires the library ggplot2*



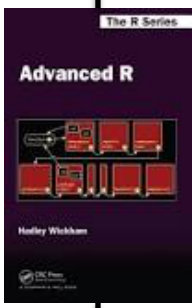

```
> x <- c(1,4,9,16,25)
> x
[1]  1  4  9 16 25
>
> y<- sqrt(x)
>
> y
[1] 1 2 3 4 5
```

Course Overview

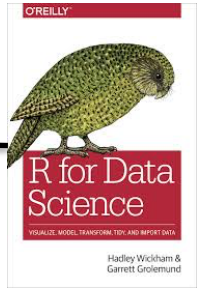
Lectures I-3	**R Fundamentals** ***Atomic Vectors*** *– Functions – Lists – Matrices – Data Frames*
Lectures 4-9	**Data Science with R** *ggplot2 – dplyr – tidyr – stringr – lubridate - purrr*
Lectures 10-11	**Advanced Programming with R** *Environments – Closures – S3 Object System*
Lectures 12	**Machine Learning with R – Case Studies** *Electricity Generation, Health*

Text Books

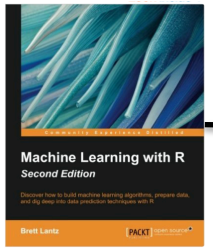
R Fundamentals
Atomic Vectors *– Functions – Lists – Matrices – Data Frames*



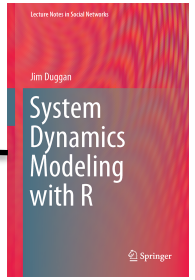
Data Science with R
ggplot2 – dplyr – tidyr – stringr – lubridate - purrr



Advanced Programming with R
Environments – Closures – S3 Object System



Machine Learning with R – Case Studies
Electricity Generation, Marketing, Health



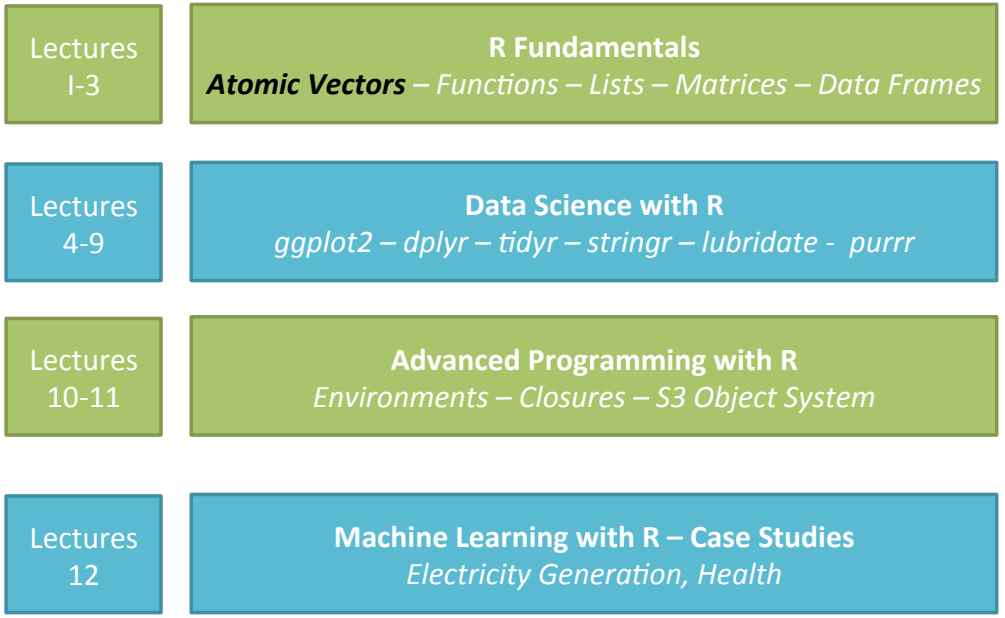
R – Data Types

	Homogenous	Heterogenous
1d	**Atomic Vector**	List
2d	Matrix	Data Frame
nd	Array	

- The basic data structure in R is the Vector
- Vectors come in two flavours
  - Atomic vectors
  - Lists
- With atomic vectors, all elements have the same type

Lecture Overview

- Atomic Vectors
- Subsetting Vectors
- Vectorisation
- Programming Constructs in R



1.1 Atomic Vectors

- Four common types
  - logical
  - integer
  - double (or numeric)
  - character
- Usually created with c() – short for combine

```
> dbl_var <- c(2.2, 2.5, 2.9)
> str(dbl_var)
 num [1:3] 2.2 2.5 2.9
>
> int_var <- c(0L, 1L, 2L)
> str(int_var)
 int [1:3] 0 1 2
>
> log_var<- c(TRUE, TRUE, F, FALSE)
> str(log_var)
 logi [1:4] TRUE TRUE FALSE FALSE
>
> chr_var<- c("CT5102","CT561")
> str(chr_var)
 chr [1:2] "CT5102" "CT561"
```

Atomic vector types

```
> dbl_var
[1] 2.2 2.5 2.9
> typeof(dbl_var)
[1] "double"
>
> int_var
[1] 0 1 2
> typeof(int_var)
[1] "integer"
```

```
> log_var
[1]  TRUE  TRUE FALSE FALSE
> typeof(log_var)
[1] "logical"
>
> chr_var
[1] "CT5102" "CT561"
> typeof(chr_var)
[1] "character"
```

Creating atomic vectors using sequences

The colon operator (:) generates regular sequences (atomic vectors) within a specified range.

```
> v1<-1:10
> v1
 [1]  1  2  3  4  5  6  7  8  9 10

> v2<-3:13
> v2
 [1]  3  4  5  6  7  8  9 10 11 12 13
```

Creating vectors of fixed size

- Useful when using loops to generate results

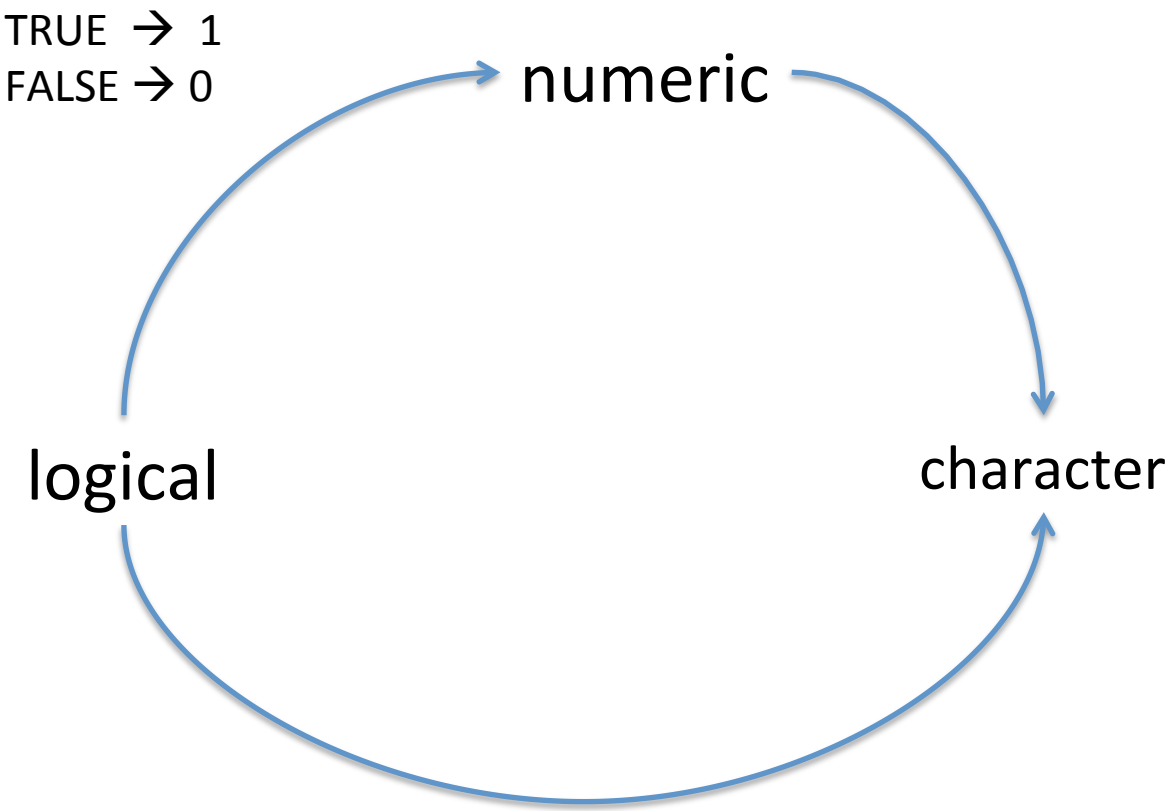
```
> v1 <- vector (mode="numeric", length=20)
>
> v1
 [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
>
> v2 <- vector (mode="character", length=20)
>
> v2
 [1] "" "" "" "" "" "" "" "" "" "" "" "" "" "" "" "" "" "" "" ""
>
> v3 <- vector (mode="logical", length=20)
>
> v3
 [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
[12] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

Coercion of atomic vectors

- All elements of an atomic vector MUST be of the same type
- When different type are combined, they will be coerced into the most flexible types
- What will be the type and values of
  - c(1L, T, F)
  - c(1,T,F)

Coercion Rules
Least to most flexible

- logical
- integer
- double
- character



Grolemund (2014) p 52

Challenge 1.1

- Determine the types for each of the following (coerced) vectors

```
v1<- c(1L, T, FALSE)

v2<- c(1L, T, FALSE, 2)

v3<- c(T, FALSE, 2, "FALSE")

v4<- c(2L, "FALSE")

v5<- c(0L, 1L, 2.11)
```

Missing Values - NA

- In a project of any size, data is likely to be incomplete due to
  - Missed survey questions
  - Faulty equipment
  - Improperly coded data
- In R, missing data is represented by the symbol NA

```
> x <- 1:10
>
> x
 [1]  1  2  3  4  5  6  7  8  9 10
>
> x[7] <- NA
>
> x
 [1]  1  2  3  4  5  6 NA  8  9 10
>
> sum(x)
[1] NA
>
> sum(x, na.rm=T)
[1] 48
```

is.na() function

- The function is.na() indicates which elements are missing
- Returns a logical vector, the same size as the input vector

```
> x
 [1]  1  2  3  4  5  6 NA  8  9 10
>
> is.na(x)
 [1] FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE
>
> x[!is.na(x)]
[1]  1  2  3  4  5  6  8  9 10
```

Challenge 1.2

- Create a vector of 100 numbers
- Set 10 of these to NA (random)
- Print the locations of the missing values
- Hint: Check out the R function *which*

1.2 Subsetting Atomic Vectors

- Subsetting data is a key activity in data science
- R's subsetting operators are powerful and fast
- For atomic vectors, the operator [is used
- In R, the index for a vector starts at 1

```
> x<-c(2.1, 4.2, 3.3, 5.4)
>
> x
[1] 2.1 4.2 3.3 5.4
>
>
> x[1]
[1] 2.1
> x[c(1,3)]
[1] 2.1 3.3
```

(1) Positive integers

Positive integers return elements at the specified position


```
> x<-1:5
>
> x
[1] 1 2 3 4 5
>
> x[1:2]
[1] 1 2
>
> x[5]
[1] 5
>
> x[5:1]
[1] 5 4 3 2 1
```

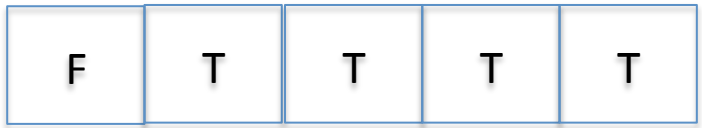
(2) Negative integers

Negative integers omit elements at specified positions

```
> x
[1] 1 2 3 4 5
>
> x[-1]
[1] 2 3 4 5
>
> x[-(3:4)]
[1] 1 2 5
```

(3) Logical Vectors

Select elements where the corresponding logical value is TRUE. This approach supports ***recycling***




```
> x
[1] 1 2 3 4 5
> x[c(F,T,T,T,T)]
[1] 2 3 4 5
```

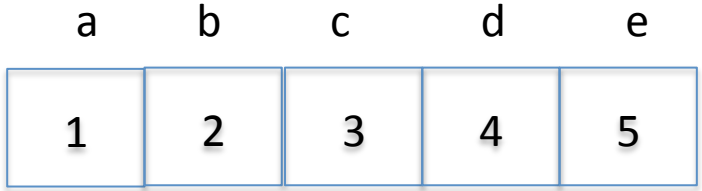
```
> x
[1] 1 2 3 4 5
>
> x[c(T,F)]
[1] 1 3 5
```

Logical Vectors - Advantages

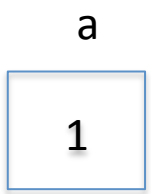
Expressions can be used to create a logical vector

```
> x
[1] 1 2 3 4 5
> b <- x < median(x)
>
> b
[1]  TRUE  TRUE FALSE FALSE FALSE
> x[b]
[1] 1 2
> x[x<median(x)]
[1] 1 2
```

(4) Character vectors



Return elements with matching names




```
> x<-1:5
> x
[1] 1 2 3 4 5
> letters[x]
[1] "a" "b" "c" "d" "e"
>
> names(x)<-letters[x]
>
> x
a b c d e
1 2 3 4 5
>
> x["a"]
a
1
```

Logical Expressions in R

Operators	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

```
> x
[1] 1 2 3 4 5
>
> b<- x<median(x) | x > median(x)
>
> b
[1]  TRUE  TRUE FALSE  TRUE  TRUE
>
> x[b]
[1] 1 2 4 5
```

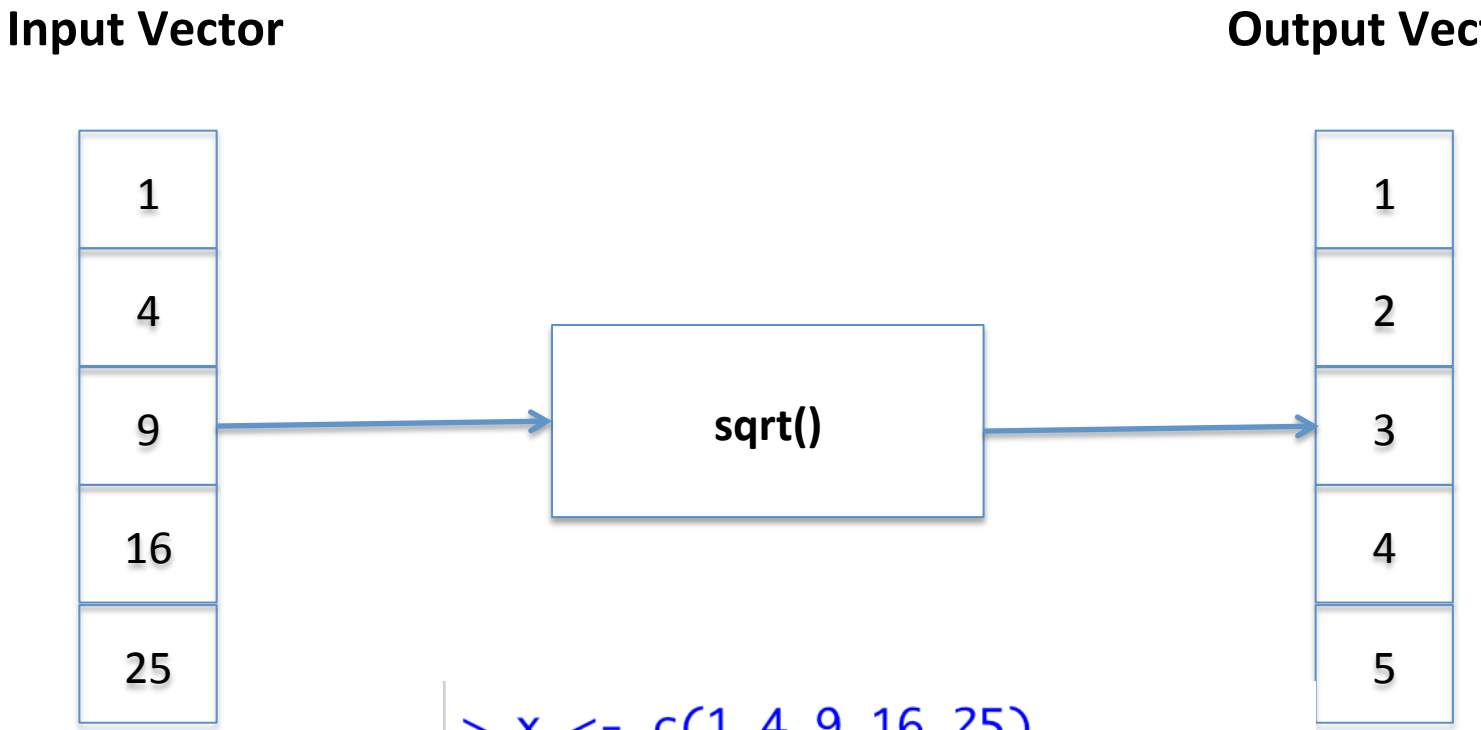
Challenge 1.3

- Create an R vector of squares of 1 to 10
- Find the minimum
- Find the maximum
- Find the average
- Subset all those values greater than the average

1.3 Vectorisation

- A powerful feature of R is that it supports *vectorisation*
- Functions can operate on every element of a vector, and return the results of each individual operation in a new vector.

```
> x <- c(1,4,9,16,25)
> x
[1]  1  4  9 16 25
>
> y<- sqrt(x)
>
> y
[1] 1 2 3 4 5
```




```
> x <- c(1,4,9,16,25)
> x
[1]  1  4  9 16 25
>
> y<- sqrt(x)
>
> y
[1] 1 2 3 4 5
```

Arithmetic Operators

- Arithmetic operations can also be applied to vectors in an element-wise manner

```
> v1 <- 1:5
>
> v1
[1] 1 2 3 4 5
>
> v1 + 10
[1] 11 12 13 14 15
>
> v1 * 20
[1]  20  40  60  80 100
```

Vectorized if/else

- Vectors can also be processed using the vectorized **ifelse(b,u,v)** function, which accepts a boolean vector **b** and allocates the element-wise results to be either **u** or **v**.

```
> v1 <- 1:10
>
> v1
 [1]  1  2  3  4  5  6  7  8  9 10
>
> ifelse(v1 %% 2 == 0, "Even" , "Odd")
 [1] "Odd"  "Even" "Odd"  "Even" "Odd"  "Even" "Odd"  "Even"
 [9] "Odd"  "Even"
>
```

sample() function

`sample` takes a sample of the specified size from the elements of `x` using either with or without replacement.

Usage

```
sample(x, size, replace = FALSE, prob = NULL)

sample.int(n, size = n, replace = FALSE, prob = NULL)
```

Arguments

`x`	Either a vector of one or more elements from which to choose, or a positive integer. See 'Details.'
`n`	a positive number, the number of items to choose from. See 'Details.'
`size`	a non-negative integer giving the number of items to choose.
`replace`	Should sampling be with replacement?
`prob`	A vector of probability weights for obtaining the elements of the vector being sampled.

Example – Generate Data

- A population has 55% Female and 45% Male. Generate a vector of 50 elements to simulate this.

```
> pop<-sample(c("M","F"),50,prob = c(.45,.55),replace = T)
>
> pop
 [1] "M" "F" "F" "F" "M" "M" "F" "F" "M" "M" "F" "M" "F" "F" "M"
[16] "F" "F" "F" "F" "M" "F" "M" "F" "F" "F" "M" "F" "F" "M" "F"
[31] "F" "F" "F" "M" "F" "M" "M" "M" "M" "F" "M" "F" "F" "M" "F"
[46] "F" "M" "M" "F" "M"
>
> length(pop[pop=="M"])/50
[1] 0.42
```

Challenge 1.4

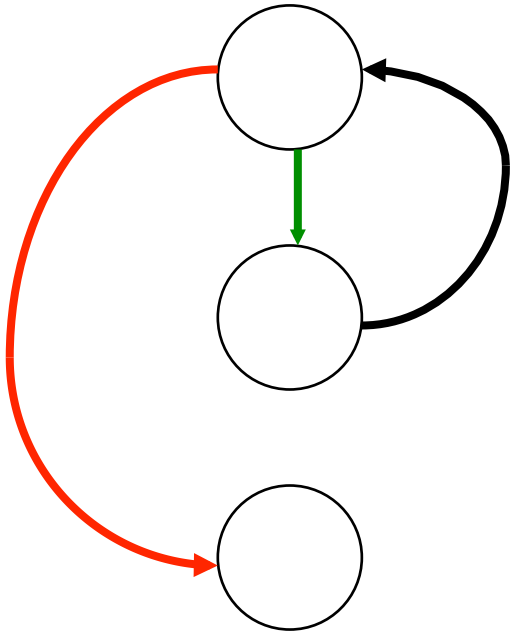
- Create a vector of random numbers between 30 and 90 (random grades for an test)
- Create a new (parallel) vector that categorises results as follows:
  - Greater or equal to 60 – Honours
  - Between 40 and 59 – Pass
  - Less than 40 – Fail
- Use the ifelse() (vectorised) function

1.4 Programming in R

- R is a block-structured language, where blocks are delineated by {}
- Statements separated by newline characters, or with semicolon
- Variable types are not declared (similar to JavaScript)

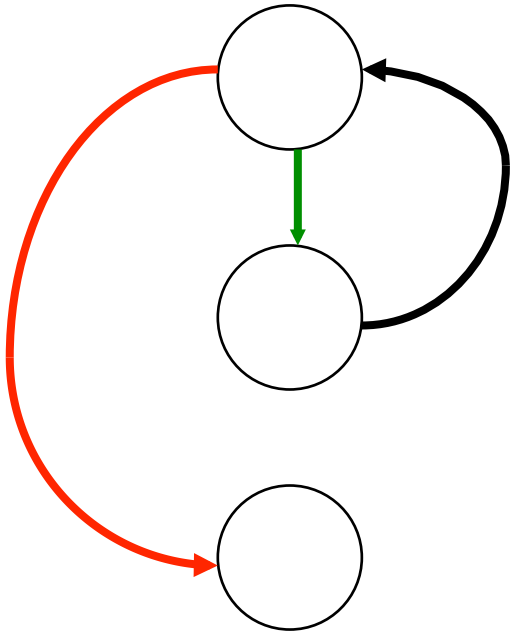
Loops - for

```
>
> x <- 1:3
>
> for(n in x){
+     print(n)
+ }
[1] 1
[1] 2
[1] 3
```



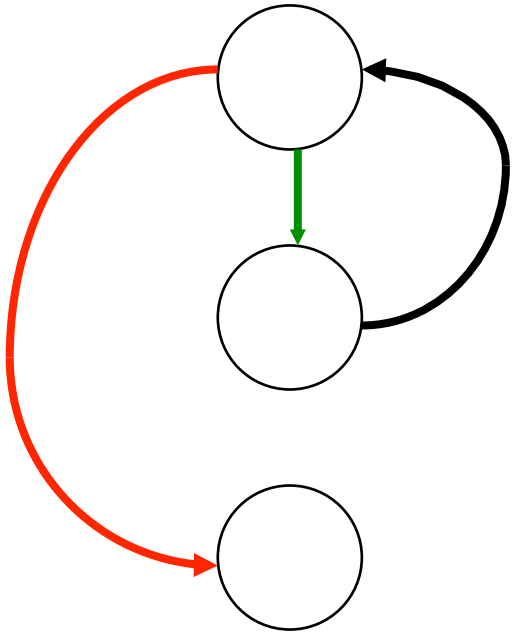
Loops - for

```
> x <- 1:3
>
> for(i in 1:length(x)){
+     print(x[i])
+ }
[1] 1
[1] 2
[1] 3
```



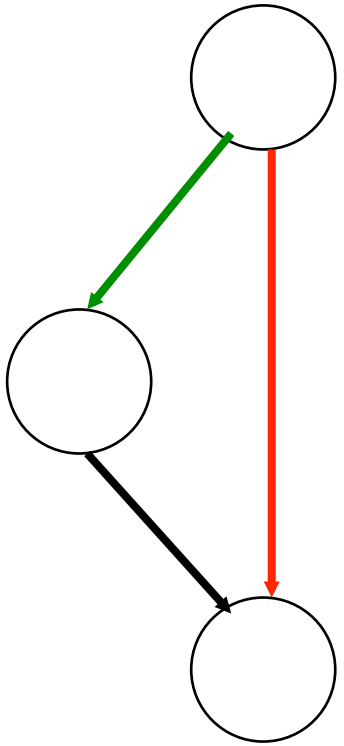
Loops - while

```
> x <- 1:3
>
> count <- 1
> while(count <= length(x)){
+     print(x[count])
+     count <- count + 1
+ }
[1] 1
[1] 2
[1] 3
```



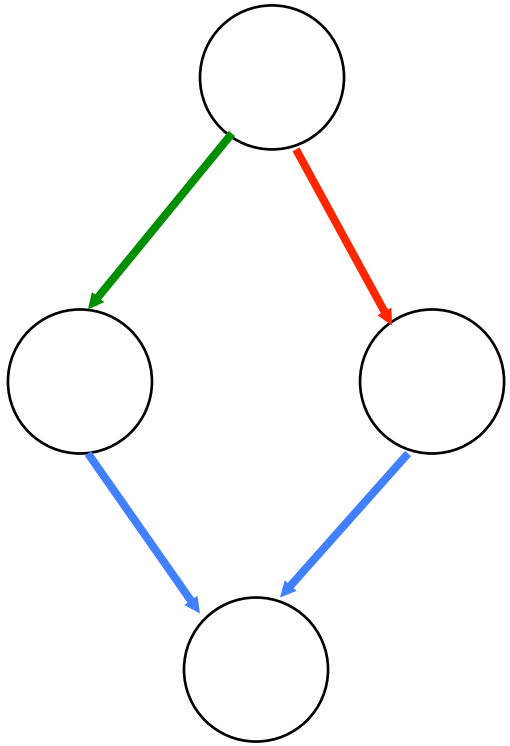
if

```
> x<-10
>
> if(x %% 2 == 0){
+    print("Even number...")
+ }
[1] "Even number..."
```



if else

```
> x<-11
> if(x %% 2 == 0){
+   print("Even number...")
+ } else
+   {
+   print("Odd number...")
+ }
[1] "Odd number..."
```



It is important to note that else must be in the same line as the closing braces of the if statements.

http://www.programiz.com/r-programming/if-else-statement

if else if

```
> x<-0
> if(x<0){
+    print("Negative number")
+ } else if (x > 0){
+    print("Positive number")
+ } else {
+    print("Zero!")
+ }
[1] "Zero!"
```

Lecture 1 Summary

- Introduction to R
- Atomic Vectors
  - Creation
  - Subsetting
  - Vectorisation
- Overview of Programming Structures (loops & ifs)

CT5102: Programing for Data Analytics

Assignment 1: Atomic Vectors

The aim of this assignment is to gain familiarity with creating and processing atomic vectors in R.

There are three tasks:

(1) Simulate the roll of two dice (N=1000), and count the number of outcomes that are odd and even. Produce the following vector as output (results should be the same as this, given that the set.seed(99) function is called.

```
> ans
 Number Odd Number Even
        523          477
```

(2) For the data generated, calculate the frequency of each outcome (i.e. the sum of the two dice values for each roll). The following vector should be generated, and the R function table() cannot be used:

```
> ans1
  2   3   4   5   6   7   8   9  10  11  12
 28  72  84 108 128 162 123 127  86  54  28
```

(3) Generate 5 random passwords of length 10, where a password can have any digit, or letter (upper and lower case). The vector to sample from should be:

```
> both
"a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q"
"r" "s" "t" "u" "v" "w" "x" "y" "z" "A" "B" "C" "D" "E" "F" "G" "H"
"I" "J" "K" "L" "M" "N" "O" "P" "Q" "R" "S" "T" "U" "V" "W" "X" "Y"
"Z" "0" "1" "2" "3" "4" "5" "6" "7" "8" "9"
```

The test output (using the seed value of 99) should be:

```
> ans2
[1] "wyyEexjOjZ" "rsqvWEOIMU" "BLWZ3MNLdR" "G1Xp7ZimvO" "yUHUrgR57Y"
```

The R Functions to be used include:

- **`set.seed(99)`**, to ensure that the results shown below are replicated.
- **`sample()`** – to generate the random samples
- **`paste()`** – for collapsing a vector of characters into a single string.
- The R constants **LETTERS** and **letters**.

References

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