

# Introduction to R 2025

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# **Part I**

# **Introduction**



# **Chapter 1**

## **Workshop Info**

Welcome to the 2025 Introduction to R Canadian Bioinformatics Workshop webpage!

### **1.1 Pre-work**

You can find your pre-work here.

### **1.2 Class Photo**

### **1.3 Schedule**



## Chapter 2

# Meet Your Faculty

### **2.0.0.1 Mohamed Helmy**

Principal Scientist and Adjunct Professor Vaccine and Infectious Disease Organization (VIDO), University of Saskatchewan Saskatoon, Saskatchewan, Canada

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Mohamed is a Computational Systems Biologist and Principal Scientist leading the Bioinformatics and Systems Biology Lab (BSBL) at the Vaccine and Infectious Disease Organization (VIDO), University of Saskatchewan. He received his MSc and PhD in Computational Systems Biology from Keio University (Tokyo, Japan) and completed his postdoctoral training in bioinformatics at Kyoto University and the University of Toronto. Mohamed's interdisciplinary research profile bridges biology, computer science, and public health.

### **2.0.0.2 Sylvia Li**

Graduate student Vaccine and Infectious Disease Organization (VIDO), University of Saskatchewan Saskatoon, Saskatchewan, Canada

Sylvia is a Computer science MSc student at the University of Saskatchewan, supervised by Dr. Helmy. She holds dual BSc degrees in Bioinformatics and Computer science. Currently her work focuses on bacterial genomic data.

Data and Compute Setup

### **2.0.0.3 Course data downloads**

Coming soon!

**2.0.0.4 Compute setup**

Coming soon!

## **Part II**

# **Modules**



# Chapter 3

## Module 1

### 3.1 Lecture

#### 3.1.1 1A

#### 3.1.2 1B

### 3.2 Lab 1A

#### 3.2.1 Variables

Create 2 numeric variables and assign values for each

```
x = 10  
y = 6
```

Calculate the sum of them

```
total = x + y  
total
```

```
## [1] 16
```

Calculate the square root of the total

```
sr = sqrt(total)
sr
```

```
## [1] 4
```

### 3.2.2 Data Structures

Vector

```
v <- c(1,2,3,4)
v
```

```
## [1] 1 2 3 4
```

Matrix

```
m <- matrix(1:6, nrow = 2)
m
```

```
##      [,1] [,2] [,3]
## [1,]     1     3     5
## [2,]     2     4     6
```

Dataframe

```
df <- data.frame(age=c(25,30), name=c("Mo","Tom"), group=c("A", "B"))
df
```

```
##   age name group
## 1  25   Mo     A
## 2  30  Tom     B
```

List

```
lst <- list(numbers=v, info=df)
lst
```

```
## $numbers
## [1] 1 2 3 4
##
## $info
##   age name group
## 1  25   Mo     A
## 2  30   Tom    B
```

### 3.3 Lab 1B

#### 3.3.1 Install BioconductoR packages

```
install.packages("BiocManager")
BiocManager::install("ALL")
```

#### 3.3.2 View patient metadata

```
library(BiocManager)
library(ALL)
data(ALL)
df2 <- pData(ALL)
```

#### 3.3.3 Quick summary

```
#summary(pData(ALL)[, c("age", "sex", "BT", "relapse")])
summary(df2[, c("age", "sex", "BT", "relapse")])
```

```
##      age       sex       BT      relapse
##  Min. : 5.00  F :42   B2    :36  Mode :logical
##  1st Qu.:19.00 M :83   B3    :23  FALSE:35
##  Median :29.00 NA's: 3   B1    :19  TRUE :65
##  Mean   :32.37          T2    :15  NA's :28
##  3rd Qu.:45.50          B4    :12
##  Max.   :58.00          T3    :10
##  NA's   :5            (Other):13
```

### 3.3.4 str() and dim() functions

```
dim(df2)
```

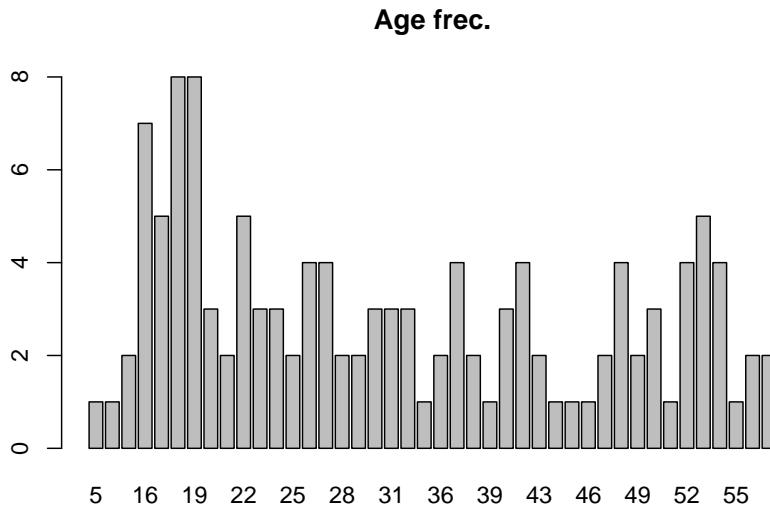
```
## [1] 128 21
```

```
str(df2)
```

```
## 'data.frame': 128 obs. of 21 variables:
## $ cod : chr "1005" "1010" "3002" "4006" ...
## $ diagnosis : chr "5/21/1997" "3/29/2000" "6/24/1998" "7/17/1997" ...
## $ sex : Factor w/ 2 levels "F","M": 2 2 1 2 2 2 1 2 2 2 ...
## $ age : int 53 19 52 38 57 17 18 16 15 40 ...
## $ BT : Factor w/ 10 levels "B","B1","B2",...: 3 3 5 2 3 2 2 2 3 3 ...
## $ remission : Factor w/ 2 levels "CR","REF": 1 1 1 1 1 1 1 1 1 1 ...
## $ CR : chr "CR" "CR" "CR" "CR" ...
## $ date.cr : chr "8/6/1997" "6/27/2000" "8/17/1998" "9/8/1997" ...
## $ t(4;11) : logi FALSE FALSE NA TRUE FALSE FALSE ...
## $ t(9;22) : logi TRUE FALSE NA FALSE FALSE FALSE ...
## $ cyto.normal : logi FALSE FALSE NA FALSE FALSE FALSE ...
## $ citog : chr "t(9;22)" "simple alt." NA "t(4;11)" ...
## $ mol.biol : Factor w/ 6 levels "ALL1/AF4","BCR/ABL",...: 2 4 2 1 4 4 4 4 4 2
## $ fusion protein: Factor w/ 3 levels "p190","p190/p210",...: 3 NA 1 NA NA NA NA NA ...
## $ mdr : Factor w/ 2 levels "NEG","POS": 1 2 1 1 1 1 2 1 1 1 ...
## $ kinet : Factor w/ 2 levels "dyploid","hyperd.": 1 1 1 1 1 2 2 1 1 NA ...
## $ ccr : logi FALSE FALSE FALSE FALSE FALSE FALSE ...
## $ relapse : logi FALSE TRUE TRUE TRUE TRUE TRUE ...
## $ transplant : logi TRUE FALSE FALSE FALSE FALSE FALSE ...
## $ f.u : chr "BMT / DEATH IN CR" "REL" "REL" "REL" ...
## $ date last seen: chr NA "8/28/2000" "10/15/1999" "1/23/1998" ...
```

### 3.3.5 the table() function

```
af <- table(df2$age)
barplot(af, main = "Age freq.")
```



```
### mean and median age
```

```
mn <- mean(df2$age) # this will return NA
md <- median(df2$age) # this will return NA

mn <- mean(df2$age, na.rm = TRUE) # this will work
md <- median(df2$age, na.rm = TRUE) # this will work
```

### 3.3.6 standard deviation and variance

```
std <- sd(df2$age, na.rm = TRUE)
vr <- var(df2$age, na.rm = TRUE)
```

### 3.3.7 Extremes

```
mxx <- max(df2$age, na.rm = T)
mnn <- min(df2$age, na.rm = T)
```

### 3.3.8 Table and (Frequency)

```
age_dit <- table(df2$age)
```

### 3.3.9 Quick summary

```
summary(df2[, c("age", "sex", "BT", "relapse")])
```

```
##      age          sex          BT       relapse 
## Min.   : 5.00   F    :42   B2    :36   Mode :logical
## 1st Qu.:19.00  M    :83   B3    :23   FALSE:35  
## Median :29.00  NA's: 3   B1    :19   TRUE :65   
## Mean   :32.37                T2    :15   NA's :28  
## 3rd Qu.:45.50                B4    :12                
## Max.   :58.00                T3    :10                
## NA's   :5                  (Other):13
```

### 3.3.10 Patients older than 40

```
older_patients <- subset(df2, age > 40)
```

### 3.3.11 Patients who relapsed

```
relapsed_patients <- subset(df2, relapse == TRUE)
```

## 3.3.12 Subsetting and Filtering

### 3.3.12.1 subset()

```
subset(df2, age > 40 & relapse == TRUE)
```

```

##      cod diagnosis sex age BT remission CR      date.cr t(4;11) t(9;22)
## 03002 3002 6/24/1998 F 52 B4      CR CR 8/17/1998 NA NA
## 04007 4007 7/22/1997 M 57 B2      CR CR 9/17/1997 FALSE FALSE
## 08012 8012 10/22/1998 M 55 B3      CR CR 1/9/1999 FALSE FALSE
## 15004 15004 2/10/2000 M 44 B1      CR CR 4/3/2000 TRUE FALSE
## 16004 16004 4/19/1997 F 58 B1      CR CR 7/15/1997 TRUE FALSE
## 19005 19005 11/15/1997 F 48 B1      CR CR 2/3/1998 FALSE FALSE
## 20002 20002 5/9/1997 F 58 B2      CR CR 8/19/1997 FALSE TRUE
## 24005 24005 1/3/1997 F 45 B1      CR CR 4/8/1997 TRUE FALSE
## 24017 24017 9/15/1998 M 57 B2      CR CR 12/7/1998 FALSE TRUE
## 26003 26003 2/18/1998 F 49 B4      CR CR 4/21/1998 FALSE FALSE
## 28028 28028 7/8/1998 M 47 B1      CR CR 9/3/1998 TRUE FALSE
## 28036 28036 12/23/1998 M 52 B3      CR CR 3/8/1999 FALSE TRUE
## 43001 43001 11/14/1996 M 41 B1      CR CR 1/30/1997 FALSE TRUE
## 49006 49006 8/12/1998 F 43 B2      CR CR 11/19/1998 NA NA
## 62003 62003 12/4/1998 M 53 B4      CR CR 1/28/1999 FALSE TRUE
## 63001 63001 7/8/1997 M 49 B1      CR CR 9/2/1997 NA NA
## 84004 84004 9/25/1998 M 50 B      CR CR 12/1/1998 NA NA
## 16002 16002 4/10/1997 M 50 T3      CR CR 6/10/1997 NA NA
## 43015 43015 2/29/2000 M 52 T2      CR CR 6/8/2000 FALSE FALSE
##      cyto.normal      citog mol.biol fusion protein mdr kinet ccr
## 03002      NA      <NA> BCR/ABL      p190 NEG diploid FALSE
## 04007      FALSE     del(6q)      NEG      <NA> NEG diploid FALSE
## 08012      FALSE    simple alt.      NEG      <NA> NEG diploid FALSE
## 15004      FALSE    t(4;11) ALL1/AF4      <NA> NEG diploid FALSE
## 16004      FALSE    t(4;11) ALL1/AF4      <NA> NEG diploid FALSE
## 19005      TRUE     normal ALL1/AF4      <NA> NEG diploid FALSE
## 20002      FALSE t(9;22)+other BCR/ABL      p190 NEG diploid FALSE
## 24005      FALSE    t(4;11) ALL1/AF4      <NA> NEG diploid FALSE
## 24017      FALSE t(9;22)+other BCR/ABL      p190 NEG hyperd. FALSE
## 26003      FALSE     del(p15/p16) BCR/ABL      p210 NEG diploid FALSE
## 28028      FALSE    t(4;11) ALL1/AF4      <NA> NEG diploid FALSE
## 28036      FALSE    t(9;22) BCR/ABL      p190 NEG diploid FALSE
## 43001      FALSE    t(9;22) BCR/ABL      p190/p210 POS diploid FALSE
## 49006      NA      <NA> BCR/ABL      p210 NEG diploid FALSE
## 62003      FALSE t(9;22)+other BCR/ABL      p210 NEG hyperd. FALSE
## 63001      NA      <NA> ALL1/AF4      <NA> NEG diploid FALSE
## 84004      NA      <NA> BCR/ABL      p190 NEG diploid FALSE
## 16002      NA      <NA>      NEG      <NA> NEG hyperd. FALSE
## 43015      TRUE     normal      NEG      <NA> NEG diploid FALSE
##      relapse transplant f.u date last seen
## 03002      TRUE      FALSE REL 10/15/1999
## 04007      TRUE      FALSE REL 11/4/1997
## 08012      TRUE      FALSE REL 4/9/1999
## 15004      TRUE      FALSE REL 12/19/2000
## 16004      TRUE      FALSE REL 12/9/1997

```

```

## 19005    TRUE    FALSE REL    2/4/1998
## 20002    TRUE    FALSE REL   12/15/1997
## 24005    TRUE    FALSE REL   8/28/1997
## 24017    TRUE    FALSE REL   2/22/2000
## 26003    TRUE    FALSE REL   7/1/1998
## 28028    TRUE    FALSE REL  10/20/1999
## 28036    TRUE    FALSE REL  3/15/1999
## 43001    TRUE    FALSE REL  6/28/1998
## 49006    TRUE    FALSE REL  4/26/1999
## 62003    TRUE    FALSE REL  8/8/2000
## 63001    TRUE    FALSE REL  6/10/1998
## 84004    TRUE    FALSE REL  1/25/1999
## 16002    TRUE    FALSE REL 12/7/1999
## 43015    TRUE    FALSE REL 3/15/2002

```

### 3.3.13 Indexing with

```
df2[df2$age > 40, ]      # filter rows
```

```

##      cod diagnosis sex age BT remission CR date.cr
## 01005 1005 5/21/1997 M 53 B2 CR          CR 8/6/1997
## 03002 3002 6/24/1998 F 52 B4 CR          CR 8/17/1998
## 04007 4007 7/22/1997 M 57 B2 CR          CR 9/17/1997
## 08012 8012 10/22/1998 M 55 B3 CR          CR 1/9/1999
## 09008 9008 12/17/1999 M 41 B3 CR          CR 2/15/2000
## 12006 12006 2/20/1997 M 46 B3 REF         REF <NA>
## 12019 12019 9/4/1997 M 53 B2 CR          CR 11/11/1997
## 14016 14016 5/27/1999 M 53 B2 <NA>       <NA> <NA>
## 15004 15004 2/10/2000 M 44 B1 CR          CR 4/3/2000
## 16004 16004 4/19/1997 F 58 B1 CR          CR 7/15/1997
## 16009 16009 7/11/2000 F 43 B2 <NA>       <NA> <NA>
## 19005 19005 11/15/1997 F 48 B1 CR          CR 2/3/1998
## 20002 20002 5/9/1997 F 58 B2 CR          CR 8/19/1997
## 24005 24005 1/3/1997 F 45 B1 CR          CR 4/8/1997
## 24011 24011 8/5/1997 F 51 B2 <NA> DEATH IN INDUCTION <NA>
## 24017 24017 9/15/1998 M 57 B2 CR          CR 12/7/1998
## NA <NA> <NA> <NA> NA <NA> <NA> <NA> <NA>
## 26003 26003 2/18/1998 F 49 B4 CR          CR 4/21/1998
## 27004 27004 10/20/1998 F 48 B2 REF         REF <NA>
## 28007 28007 2/21/1997 F 47 B3 CR          CR 4/7/1997
## 28021 28021 3/18/1998 F 54 B3 CR          CR DEATH IN CR 5/22/1998
## 28028 28028 7/8/1998 M 47 B1 CR          CR 9/3/1998

```

```

## 28032 28032 9/26/1998   F  52   B1      CR          CR 10/30/1998
## 28036 28036 12/23/1998   M  52   B3      CR          CR  3/8/1999
## NA.1 <NA>      <NA> <NA>  NA <NA>    <NA>      <NA> <NA>
## 30001 30001 1/16/1997   F  54   B3      <NA> DEATH IN INDUCTION <NA>
## NA.2 <NA>      <NA> <NA>  NA <NA>    <NA>      <NA> <NA>
## 43001 43001 11/14/1996  M  41   B1      CR          CR 1/30/1997
## 43007 43007 10/14/1997  M  54   B4      CR          CR 12/30/1997
## 49006 49006 8/12/1998   F  43   B2      CR          CR 11/19/1998
## 57001 57001 1/29/1997   F  53   B3      <NA> DEATH IN INDUCTION <NA>
## 62001 62001 11/11/1997  F  50   B4      REF         REF <NA>
## 62002 62002 1/15/1998   M  54   B4      <NA> DEATH IN INDUCTION <NA>
## 62003 62003 12/4/1998   M  53   B4      CR          CR 1/28/1999
## 63001 63001 7/8/1997   M  49   B1      CR          CR  9/2/1997
## 84004 84004 9/25/1998   M  50   B       CR          CR 12/1/1998
## NA.3 <NA>      <NA> <NA>  NA <NA>    <NA>      <NA> <NA>
## 02020 2020 3/23/2000   F  48   T2      <NA> DEATH IN INDUCTION <NA>
## 16002 16002 4/10/1997  M  50   T3      CR          CR  6/10/1997
## 16007 16007 11/1/1998  M  41   T3      CR          CR 11/5/1998
## 31015 31015 12/3/1998  M  48   T2      <NA> DEATH IN INDUCTION <NA>
## 43006 43006 6/17/1997  M  41   T2      REF         REF <NA>
## 43015 43015 2/29/2000  M  52   T2      CR          CR  6/8/2000
## NA.4 <NA>      <NA> <NA>  NA <NA>    <NA>      <NA> <NA>
##           t(4;11) t(9;22) cyto.normal      citog mol.biol fusion protein mdr
## 01005 FALSE   TRUE    FALSE      t(9;22) BCR/ABL      p210 NEG
## 03002 NA      NA     NA      <NA> BCR/ABL      p190 NEG
## 04007 FALSE   FALSE   FALSE      del(6q) NEG      <NA> NEG
## 08012 FALSE   FALSE   FALSE      simple alt. NEG      <NA> NEG
## 09008 FALSE   TRUE    FALSE      t(9;22)+other BCR/ABL      p190 NEG
## 12006 FALSE   TRUE    FALSE      t(9;22) BCR/ABL      p210 NEG
## 12019 FALSE   FALSE   TRUE      normal NEG      <NA> POS
## 14016 FALSE   TRUE    FALSE      t(9;22) BCR/ABL      p210 NEG
## 15004 TRUE    FALSE   FALSE      t(4;11) ALL1/AF4    <NA> NEG
## 16004 TRUE    FALSE   FALSE      t(4;11) ALL1/AF4    <NA> NEG
## 16009 NA      NA     NA      <NA> NEG      <NA> POS
## 19005 FALSE   FALSE   TRUE      normal ALL1/AF4    <NA> NEG
## 20002 FALSE   TRUE    FALSE      t(9;22)+other BCR/ABL      p190 NEG
## 24005 TRUE    FALSE   FALSE      t(4;11) ALL1/AF4    <NA> NEG
## 24011 FALSE   TRUE    FALSE      t(9;22) BCR/ABL      p210 POS
## 24017 FALSE   TRUE    FALSE      t(9;22)+other BCR/ABL      p190 NEG
## NA      NA     NA      <NA> <NA> <NA> <NA>
## 26003 FALSE   FALSE   FALSE      del(p15/p16) BCR/ABL      p210 NEG
## 27004 FALSE   TRUE    FALSE      t(9;22)+del(p15) BCR/ABL      p190 NEG
## 28007 FALSE   FALSE   TRUE      normal NEG      <NA> NEG
## 28021 FALSE   TRUE    FALSE      t(9;22)+other BCR/ABL      p190/p210 NEG
## 28028 TRUE    FALSE   FALSE      t(4;11) ALL1/AF4    <NA> NEG
## 28032 TRUE    FALSE   FALSE      t(4;11) ALL1/AF4    <NA> NEG

```

## 28036	FALSE	TRUE	FALSE	t(9;22)	BCR/ABL	p190	NEG
## NA.1	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 30001	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	p190	NEG
## NA.2	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 43001	FALSE	TRUE	FALSE	t(9;22)	BCR/ABL	p190/p210	POS
## 43007	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## 49006	NA	NA	NA	<NA>	BCR/ABL	p210	NEG
## 57001	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## 62001	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	<NA>	NEG
## 62002	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	<NA>	NEG
## 62003	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	p210	NEG
## 63001	NA	NA	NA	<NA>	ALL1/AF4	<NA>	NEG
## 84004	NA	NA	NA	<NA>	BCR/ABL	p190	NEG
## NA.3	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 02020	FALSE	FALSE	FALSE	complex alt.	NEG	<NA>	NEG
## 16002	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 16007	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 31015	NA	NA	NA	<NA>	NEG	<NA>	POS
## 43006	FALSE	FALSE	FALSE	simple alt.	NEG	<NA>	POS
## 43015	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## NA.4	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
				f.u	date	last	seen
## 01005	dyploid	FALSE	FALSE	TRUE	BMT / DEATH	IN CR	<NA>
## 03002	dyploid	FALSE	TRUE	FALSE	REL	10/15/1999	
## 04007	dyploid	FALSE	TRUE	FALSE	REL	11/4/1997	
## 08012	dyploid	FALSE	TRUE	FALSE	REL	4/9/1999	
## 09008	hyperd.	TRUE	FALSE	TRUE	BMT / CCR	00/09/01	
## 12006	dyploid	NA	NA	NA	<NA>	<NA>	
## 12019	dyploid	TRUE	FALSE	FALSE	CCR	6/6/2002	
## 14016	<NA>	NA	NA	NA	<NA>	<NA>	
## 15004	dyploid	FALSE	TRUE	FALSE	REL	12/19/2000	
## 16004	dyploid	FALSE	TRUE	FALSE	REL	12/9/1997	
## 16009	dyploid	TRUE	FALSE	FALSE	CCR / OFF	5/23/2002	
## 19005	dyploid	FALSE	TRUE	FALSE	REL	2/4/1998	
## 20002	dyploid	FALSE	TRUE	FALSE	REL	12/15/1997	
## 24005	dyploid	FALSE	TRUE	FALSE	REL	8/28/1997	
## 24011	dyploid	NA	NA	NA	<NA>	<NA>	
## 24017	hyperd.	FALSE	TRUE	FALSE	REL	2/22/2000	
## NA	<NA>	NA	NA	NA	<NA>	<NA>	
## 26003	dyploid	FALSE	TRUE	FALSE	REL	7/1/1998	
## 27004	dyploid	NA	NA	NA	<NA>	<NA>	
## 28007	dyploid	TRUE	FALSE	FALSE	CCR	3/22/2002	
## 28021	hyperd.	FALSE	FALSE	DEATH IN CR (ICR)		<NA>	
## 28028	dyploid	FALSE	TRUE	FALSE	REL	10/20/1999	
## 28032	dyploid	TRUE	FALSE	FALSE	CCR	5/16/2002	
## 28036	dyploid	FALSE	TRUE	FALSE	REL	3/15/1999	

```

## NA.1      <NA>    NA     NA     NA      <NA>      <NA>
## 30001 hyperd.    NA     NA     NA      <NA>      <NA>
## NA.2      <NA>    NA     NA     NA      <NA>      <NA>
## 43001 diploid FALSE   TRUE    FALSE    REL    6/28/1998
## 43007 hyperd.  TRUE    FALSE    FALSE   CCR    5/29/2002
## 49006 diploid FALSE   TRUE    FALSE    REL    4/26/1999
## 57001 hyperd.    NA     NA     NA      <NA>      <NA>
## 62001 hyperd.    NA     NA     NA      <NA>      <NA>
## 62002 hyperd.    NA     NA     NA      <NA>      <NA>
## 62003 hyperd. FALSE   TRUE    FALSE    REL    8/8/2000
## 63001 diploid FALSE   TRUE    FALSE    REL    6/10/1998
## 84004 diploid FALSE   TRUE    FALSE    REL    1/25/1999
## NA.3      <NA>    NA     NA      <NA>      <NA>
## 02020 diploid    NA     NA     NA      <NA>      <NA>
## 16002 hyperd. FALSE   TRUE    FALSE    REL    12/7/1999
## 16007 diploid  TRUE    FALSE    FALSE   CCR    1/8/2002
## 31015 diploid    NA     NA     NA      <NA>      <NA>
## 43006 diploid    NA     NA     NA      <NA>      <NA>
## 43015 diploid FALSE   TRUE    FALSE    REL    3/15/2002
## NA.4      <NA>    NA     NA      NA      <NA>      <NA>

```

```
df2[df2$age > 40 & df2$relapse, ]  # multiple conditions (same as df$Relapse == T)
```

```

##      cod diagnosis sex age   BT remission CR date.cr t(4;11) t(9;22)
## 03002 3002 6/24/1998 F 52   B4    CR CR 8/17/1998 NA NA
## 04007 4007 7/22/1997 M 57   B2    CR CR 9/17/1997 FALSE FALSE
## 08012 8012 10/22/1998 M 55   B3    CR CR 1/9/1999 FALSE FALSE
## NA      <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.1    <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 15004 15004 2/10/2000 M 44   B1    CR CR 4/3/2000 TRUE FALSE
## 16004 16004 4/19/1997 F 58   B1    CR CR 7/15/1997 TRUE FALSE
## 19005 19005 11/15/1997 F 48   B1    CR CR 2/3/1998 FALSE FALSE
## 20002 20002 5/9/1997 F 58   B2    CR CR 8/19/1997 FALSE TRUE
## 24005 24005 1/3/1997 F 45   B1    CR CR 4/8/1997 TRUE FALSE
## NA.2    <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 24017 24017 9/15/1998 M 57   B2    CR CR 12/7/1998 FALSE TRUE
## 26003 26003 2/18/1998 F 49   B4    CR CR 4/21/1998 FALSE FALSE
## NA.3    <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 28028 28028 7/8/1998 M 47   B1    CR CR 9/3/1998 TRUE FALSE
## 28036 28036 12/23/1998 M 52   B3    CR CR 3/8/1999 FALSE TRUE
## NA.4    <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.5    <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.6    <NA>      <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 43001 43001 11/14/1996 M 41   B1    CR CR 1/30/1997 FALSE TRUE

```

```

## 49006 49006 8/12/1998 F 43 B2 CR CR 11/19/1998 NA NA
## NA.7 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.8 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.9 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 62003 62003 12/4/1998 M 53 B4 CR CR 1/28/1999 FALSE TRUE
## 63001 63001 7/8/1997 M 49 B1 CR CR 9/2/1997 NA NA
## 84004 84004 9/25/1998 M 50 B CR CR 12/1/1998 NA NA
## NA.10 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.11 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 16002 16002 4/10/1997 M 50 T3 CR CR 6/10/1997 NA NA
## NA.12 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## NA.13 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## 43015 43015 2/29/2000 M 52 T2 CR CR 6/8/2000 FALSE FALSE
## NA.14 <NA> <NA> NA <NA> <NA> <NA> <NA> NA NA
## cyto.normal citog mol.biol fusion protein mdr kinet ccr
## 03002 NA <NA> BCR/ABL p190 NEG diploid FALSE
## 04007 FALSE del(6q) NEG <NA> NEG diploid FALSE
## 08012 FALSE simple alt. NEG <NA> NEG diploid FALSE
## NA NA <NA> <NA> <NA> <NA> <NA> NA
## NA.1 NA <NA> <NA> <NA> <NA> <NA> NA
## 15004 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 16004 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 19005 TRUE normal ALL1/AF4 <NA> NEG diploid FALSE
## 20002 FALSE t(9;22)+other BCR/ABL p190 NEG diploid FALSE
## 24005 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## NA.2 NA <NA> <NA> <NA> <NA> <NA> NA
## 24017 FALSE t(9;22)+other BCR/ABL p190 NEG hyperd. FALSE
## 26003 FALSE del(p15/p16) BCR/ABL p210 NEG diploid FALSE
## NA.3 NA <NA> <NA> <NA> <NA> <NA> NA
## 28028 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 28036 FALSE t(9;22) BCR/ABL p190 NEG diploid FALSE
## NA.4 NA <NA> <NA> <NA> <NA> <NA> NA
## NA.5 NA <NA> <NA> <NA> <NA> <NA> NA
## NA.6 NA <NA> <NA> <NA> <NA> <NA> NA
## 43001 FALSE t(9;22) BCR/ABL p190/p210 POS diploid FALSE
## 49006 NA <NA> BCR/ABL p210 NEG diploid FALSE
## NA.7 NA <NA> <NA> <NA> <NA> <NA> NA
## NA.8 NA <NA> <NA> <NA> <NA> <NA> NA
## NA.9 NA <NA> <NA> <NA> <NA> <NA> NA
## 62003 FALSE t(9;22)+other BCR/ABL p210 NEG hyperd. FALSE
## 63001 NA <NA> ALL1/AF4 <NA> NEG diploid FALSE
## 84004 NA <NA> BCR/ABL p190 NEG diploid FALSE
## NA.10 NA <NA> <NA> <NA> <NA> <NA> NA
## NA.11 NA <NA> <NA> <NA> <NA> <NA> NA
## 16002 NA <NA> NEG <NA> NEG hyperd. FALSE
## NA.12 NA <NA> <NA> <NA> <NA> <NA> NA

```

```

## NA.13      NA      <NA>      <NA>      <NA> <NA> <NA>      NA
## 43015     TRUE    normal     NEG       <NA>  NEG diploid FALSE
## NA.14      NA      <NA>      <NA>      <NA> <NA> <NA>      NA
##      relapse transplant f.u date last seen
## 03002     TRUE    FALSE   REL 10/15/1999
## 04007     TRUE    FALSE   REL 11/4/1997
## 08012     TRUE    FALSE   REL 4/9/1999
## NA        NA      NA <NA>      <NA>
## NA.1       NA      NA <NA>      <NA>
## 15004     TRUE    FALSE   REL 12/19/2000
## 16004     TRUE    FALSE   REL 12/9/1997
## 19005     TRUE    FALSE   REL 2/4/1998
## 20002     TRUE    FALSE   REL 12/15/1997
## 24005     TRUE    FALSE   REL 8/28/1997
## NA.2       NA      NA <NA>      <NA>
## 24017     TRUE    FALSE   REL 2/22/2000
## 26003     TRUE    FALSE   REL 7/1/1998
## NA.3       NA      NA <NA>      <NA>
## 28028     TRUE    FALSE   REL 10/20/1999
## 28036     TRUE    FALSE   REL 3/15/1999
## NA.4       NA      NA <NA>      <NA>
## NA.5       NA      NA <NA>      <NA>
## NA.6       NA      NA <NA>      <NA>
## 43001     TRUE    FALSE   REL 6/28/1998
## 49006     TRUE    FALSE   REL 4/26/1999
## NA.7       NA      NA <NA>      <NA>
## NA.8       NA      NA <NA>      <NA>
## NA.9       NA      NA <NA>      <NA>
## 62003     TRUE    FALSE   REL 8/8/2000
## 63001     TRUE    FALSE   REL 6/10/1998
## 84004     TRUE    FALSE   REL 1/25/1999
## NA.10      NA      NA <NA>      <NA>
## NA.11      NA      NA <NA>      <NA>
## 16002     TRUE    FALSE   REL 12/7/1999
## NA.12      NA      NA <NA>      <NA>
## NA.13      NA      NA <NA>      <NA>
## 43015     TRUE    FALSE   REL 3/15/2002
## NA.14      NA      NA <NA>      <NA>

```

```
df2[, c("age", "BT")]           # select columns
```

```

##      age BT
## 01005  53 B2
## 01010  19 B2

```

```
## 03002 52 B4
## 04006 38 B1
## 04007 57 B2
## 04008 17 B1
## 04010 18 B1
## 04016 16 B1
## 06002 15 B2
## 08001 40 B2
## 08011 33 B3
## 08012 55 B3
## 08018 5 B3
## 08024 18 B2
## 09008 41 B3
## 09017 27 B
## 11005 27 B2
## 12006 46 B3
## 12007 37 B2
## 12012 36 B3
## 12019 53 B2
## 12026 39 B2
## 14016 53 B2
## 15001 20 B1
## 15004 44 B1
## 15005 28 B2
## 16004 58 B1
## 16009 43 B2
## 19005 48 B1
## 20002 58 B2
## 22009 19 B
## 22010 26 B
## 22011 19 B2
## 22013 32 B2
## 24001 17 B2
## 24005 45 B1
## 24008 20 B2
## 24010 16 B2
## 24011 51 B2
## 24017 57 B2
## 24018 29 B2
## 24019 16 B4
## 24022 32 B4
## 25003 15 B2
## 25006 NA B2
## 26001 21 B2
## 26003 49 B4
## 26005 38 B2
```

```
## 26008 17 B1
## 27003 26 B2
## 27004 48 B2
## 28001 16 B3
## 28003 18 B4
## 28005 17 B3
## 28006 22 B3
## 28007 47 B3
## 28019 21 B4
## 28021 54 B3
## 28023 26 B3
## 28024 19 B1
## 28028 47 B1
## 28031 18 B1
## 28032 52 B1
## 28035 27 B3
## 28036 52 B3
## 28037 18 B3
## 28042 18 B3
## 28043 23 B3
## 28044 16 B3
## 28047 NA B3
## 30001 54 B3
## 31007 25 B1
## 31011 31 B3
## 33005 19 B1
## 36001 24 B4
## 36002 23 B2
## 37013 NA B2
## 43001 41 B1
## 43004 37 B3
## 43007 54 B4
## 43012 18 B4
## 48001 19 B2
## 49006 43 B2
## 57001 53 B3
## 62001 50 B4
## 62002 54 B4
## 62003 53 B4
## 63001 49 B1
## 64001 20 B2
## 64002 26 B2
## 65005 22 B2
## 68001 36 B1
## 68003 27 B2
## 84004 50 B
```

```

## LAL5    NA  B
## 01003   31  T
## 01007   16  T3
## 02020   48  T2
## 04018   17  T2
## 09002   40  T3
## 10005   22  T2
## 11002   30  T
## 12008   18  T4
## 15006   22  T2
## 16002   50  T3
## 16007   41  T3
## 17003   40  T
## 18001   28  T2
## 19002   25  T3
## 19008   16  T2
## 19014   31  T2
## 19017   14  T2
## 20005   24  T1
## 24006   19  T4
## 26009   37  T
## 28008   23  T2
## 28009   30  T3
## 31015   48  T2
## 37001   22  T2
## 43006   41  T2
## 43015   52  T2
## 44001   32  T3
## 49004   24  T3
## 56007   37  T3
## 64005   19  T2
## 65003   30  T3
## 83001   29  T2
## LAL4    NA  T

```

```
df <- df2[df2$sex == "F", ] # female patients only (#Assignment with condition)
```

### 3.3.14 with()

```
dfrt2 <- with(df2, df2[age > 40 & relapse == TRUE, ]) #for cleaner syntax
df2[which(df2$age > 40 & df2$relapse == TRUE), ] # more cleanr syntax
```

```

##      cod diagnosis sex age BT remission CR      date.cr t(4;11) t(9;22)
## 03002 3002 6/24/1998 F 52 B4      CR CR 8/17/1998 NA NA
## 04007 4007 7/22/1997 M 57 B2      CR CR 9/17/1997 FALSE FALSE
## 08012 8012 10/22/1998 M 55 B3      CR CR 1/9/1999 FALSE FALSE
## 15004 15004 2/10/2000 M 44 B1      CR CR 4/3/2000 TRUE FALSE
## 16004 16004 4/19/1997 F 58 B1      CR CR 7/15/1997 TRUE FALSE
## 19005 19005 11/15/1997 F 48 B1      CR CR 2/3/1998 FALSE FALSE
## 20002 20002 5/9/1997 F 58 B2      CR CR 8/19/1997 FALSE TRUE
## 24005 24005 1/3/1997 F 45 B1      CR CR 4/8/1997 TRUE FALSE
## 24017 24017 9/15/1998 M 57 B2      CR CR 12/7/1998 FALSE TRUE
## 26003 26003 2/18/1998 F 49 B4      CR CR 4/21/1998 FALSE FALSE
## 28028 28028 7/8/1998 M 47 B1      CR CR 9/3/1998 TRUE FALSE
## 28036 28036 12/23/1998 M 52 B3      CR CR 3/8/1999 FALSE TRUE
## 43001 43001 11/14/1996 M 41 B1      CR CR 1/30/1997 FALSE TRUE
## 49006 49006 8/12/1998 F 43 B2      CR CR 11/19/1998 NA NA
## 62003 62003 12/4/1998 M 53 B4      CR CR 1/28/1999 FALSE TRUE
## 63001 63001 7/8/1997 M 49 B1      CR CR 9/2/1997 NA NA
## 84004 84004 9/25/1998 M 50 B      CR CR 12/1/1998 NA NA
## 16002 16002 4/10/1997 M 50 T3      CR CR 6/10/1997 NA NA
## 43015 43015 2/29/2000 M 52 T2      CR CR 6/8/2000 FALSE FALSE
##      cyto.normal citog mol.biol fusion protein mdr kinet ccr
## 03002 NA <NA> BCR/ABL p190 NEG diploid FALSE
## 04007 FALSE del(6q) NEG <NA> NEG diploid FALSE
## 08012 FALSE simple alt. NEG <NA> NEG diploid FALSE
## 15004 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 16004 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 19005 TRUE normal ALL1/AF4 <NA> NEG diploid FALSE
## 20002 FALSE t(9;22)+other BCR/ABL p190 NEG diploid FALSE
## 24005 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 24017 FALSE t(9;22)+other BCR/ABL p190 NEG hyperd. FALSE
## 26003 FALSE del(p15/p16) BCR/ABL p210 NEG diploid FALSE
## 28028 FALSE t(4;11) ALL1/AF4 <NA> NEG diploid FALSE
## 28036 FALSE t(9;22) BCR/ABL p190 NEG diploid FALSE
## 43001 FALSE t(9;22) BCR/ABL p190/p210 POS diploid FALSE
## 49006 NA <NA> BCR/ABL p210 NEG diploid FALSE
## 62003 FALSE t(9;22)+other BCR/ABL p210 NEG hyperd. FALSE
## 63001 NA <NA> ALL1/AF4 <NA> NEG diploid FALSE
## 84004 NA <NA> BCR/ABL p190 NEG diploid FALSE
## 16002 NA <NA> NEG <NA> NEG hyperd. FALSE
## 43015 TRUE normal <NA> NEG <NA> NEG diploid FALSE
##      relapse transplant f.u date last seen
## 03002 TRUE FALSE REL 10/15/1999
## 04007 TRUE FALSE REL 11/4/1997
## 08012 TRUE FALSE REL 4/9/1999
## 15004 TRUE FALSE REL 12/19/2000
## 16004 TRUE FALSE REL 12/9/1997

```

```

## 19005    TRUE    FALSE REL    2/4/1998
## 20002    TRUE    FALSE REL   12/15/1997
## 24005    TRUE    FALSE REL   8/28/1997
## 24017    TRUE    FALSE REL   2/22/2000
## 26003    TRUE    FALSE REL   7/1/1998
## 28028    TRUE    FALSE REL  10/20/1999
## 28036    TRUE    FALSE REL  3/15/1999
## 43001    TRUE    FALSE REL  6/28/1998
## 49006    TRUE    FALSE REL  4/26/1999
## 62003    TRUE    FALSE REL  8/8/2000
## 63001    TRUE    FALSE REL  6/10/1998
## 84004    TRUE    FALSE REL  1/25/1999
## 16002    TRUE    FALSE REL 12/7/1999
## 43015    TRUE    FALSE REL  3/15/2002

```

### 3.3.15 match() / %in% (matching values)

```
dfrt <- df2[df2$BT %in% c("B2", "B3"), ]
```

### 3.3.16 Logical indexing directly

```
df2[df2$relapse == F | df2$sex == "F", ]
```

	cod	diagnosis	sex	age	BT	remission	CR	date.cr
## 01005	1005	5/21/1997	M	53	B2	CR	CR	8/6/1997
## 03002	3002	6/24/1998	F	52	B4	CR	CR	8/17/1998
## 04010	4010	10/30/1997	F	18	B1	CR	CR	1/7/1998
## 08011	8011	8/21/1998	M	33	B3	CR	CR	10/8/1998
## NA	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 09008	9008	12/17/1999	M	41	B3	CR	CR	2/15/2000
## 09017	9017	2/3/2000	F	27	B	CR	CR	3/23/2000
## 11005	11005	6/1/1998	M	27	B2	CR	DEATH	IN CR 8/3/1998
## NA.1	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 12012	12012	5/21/1997	F	36	B3	REF	REF	<NA>
## 12019	12019	9/4/1997	M	53	B2	CR	CR	11/11/1997
## 12026	12026	5/29/1998	M	39	B2	REF	REF	<NA>
## NA.2	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 15001	15001	9/3/1997	M	20	B1	CR	CR	11/11/1997
## 16004	16004	4/19/1997	F	58	B1	CR	CR	7/15/1997

## 16009	16009	7/11/2000	F	43	B2	<NA>	<NA>	<NA>
## 19005	19005	11/15/1997	F	48	B1	CR	CR	2/3/1998
## 20002	20002	5/9/1997	F	58	B2	CR	CR	8/19/1997
## 22009	22009	8/10/1999	F	19	B	<NA>	<NA>	<NA>
## 22010	22010	12/31/1999	F	26	B	<NA>	<NA>	<NA>
## 22011	22011	4/7/2000	M	19	B2	CR	CR	5/19/2000
## NA.3	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 24001	24001	10/4/1996	F	17	B2	CR	CR	12/20/1996
## 24005	24005	1/3/1997	F	45	B1	CR	CR	4/8/1997
## 24008	24008	5/14/1997	F	20	B2	CR	CR	7/31/1997
## 24010	24010	6/3/1997	F	16	B2	CR	CR	8/11/1997
## 24011	24011	8/5/1997	F	51	B2	<NA> DEATH IN INDUCTION	<NA>	
## 24018	24018	2/18/1999	F	29	B2	CR	CR	5/4/1999
## 24022	24022	12/21/1999	F	32	B4	REF	REF	<NA>
## 25003	25003	5/22/1998	M	15	B2	CR	CR	8/4/1998
## 25006	25006	3/18/2000	<NA>	NA	B2	CR	CR	5/8/2000
## 26001	26001	9/27/1997	M	21	B2	CR	CR	12/11/1997
## 26003	26003	2/18/1998	F	49	B4	CR	CR	4/21/1998
## 26008	26008	8/25/1999	F	17	B1	CR	CR	10/14/1999
## 27003	27003	1/17/1998	F	26	B2	CR	CR	3/16/1998
## 27004	27004	10/20/1998	F	48	B2	REF	REF	<NA>
## NA.4	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 28003	28003	11/28/1996	M	18	B4	CR	CR	1/17/1997
## 28007	28007	2/21/1997	F	47	B3	CR	CR	4/7/1997
## 28019	28019	2/10/1998	M	21	B4	CR	CR	4/2/1998
## 28021	28021	3/18/1998	F	54	B3	CR	DEATH IN CR	5/22/1998
## 28024	28024	4/19/1998	F	19	B1	CR	CR	6/17/1998
## 28032	28032	9/26/1998	F	52	B1	CR	CR	10/30/1998
## 28035	28035	12/21/1998	M	27	B3	CR	CR	2/12/1999
## 30001	30001	1/16/1997	F	54	B3	<NA> DEATH IN INDUCTION	<NA>	
## 33005	33005	2/10/1998	F	19	B1	CR	CR	4/29/1998
## 36001	36001	9/29/1997	F	24	B4	CR	CR	12/5/1997
## NA.5	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 43004	43004	2/4/1997	F	37	B3	CR	CR	4/1/1997
## 43007	43007	10/14/1997	M	54	B4	CR	CR	12/30/1997
## 48001	48001	3/22/1997	M	19	B2	CR	CR	5/20/1997
## 49006	49006	8/12/1998	F	43	B2	CR	CR	11/19/1998
## 57001	57001	1/29/1997	F	53	B3	<NA> DEATH IN INDUCTION	<NA>	
## 62001	62001	11/11/1997	F	50	B4	REF	REF	<NA>
## NA.6	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 64002	64002	10/21/1997	F	26	B2	CR	CR	1/21/1998
## NA.7	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 68001	68001	5/15/1997	M	36	B1	CR	CR	7/22/1997
## 68003	68003	4/11/2000	F	27	B2	<NA> DEATH IN INDUCTION	<NA>	
## NA.8	<NA>	<NA>	<NA>	NA	<NA>	<NA>	<NA>	<NA>
## 01007	1007	9/30/1998	F	16	T3	CR	CR	11/30/1998

```

## 02020 2020 3/23/2000 F 48 T2 <NA> DEATH IN INDUCTION <NA>
## 04018 4018 3/24/2000 M 17 T2 CR CR 5/23/2000
## 09002 9002 5/14/1998 F 40 T3 CR CR 7/21/1998
## NA.9 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA>
## 16007 16007 11/1/1998 M 41 T3 CR CR 11/5/1998
## 17003 17003 4/8/1997 F 40 T REF REF <NA>
## 18001 18001 4/23/1997 F 28 T2 REF REF <NA>
## 19008 19008 4/29/1998 F 16 T2 REF REF <NA>
## 20005 20005 3/15/2000 M 24 T1 CR CR 5/5/2000
## 24006 24006 1/14/1997 F 19 T4 CR CR not known
## 28008 28008 3/27/1997 M 23 T2 CR CR 5/27/1997
## 28009 28009 4/19/1997 F 30 T3 CR CR 6/13/1997
## NA.10 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA>
## NA.11 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA>
## 49004 49004 9/18/1997 M 24 T3 CR CR 11/11/1997
## 56007 56007 8/6/1999 M 37 T3 CR CR 9/24/1999
## NA.12 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA>
## 83001 83001 10/23/1998 M 29 T2 CR CR 12/21/1998
## NA.13 <NA> <NA> <NA> NA <NA> <NA> <NA> <NA>
## t(4;11) t(9;22) cyto.normal citog mol.biol fusion protein mdr
## 01005 FALSE TRUE FALSE t(9;22) BCR/ABL p210 NEG
## 03002 NA NA NA <NA> BCR/ABL p190 NEG
## 04010 FALSE FALSE FALSE complex alt. NEG <NA> POS
## 08011 FALSE FALSE FALSE del(p15/p16) BCR/ABL p190/p210 NEG
## NA NA NA NA <NA> <NA> <NA> <NA>
## 09008 FALSE TRUE FALSE t(9;22)+other BCR/ABL p190 NEG
## 09017 FALSE FALSE TRUE normal NEG <NA> NEG
## 11005 FALSE FALSE FALSE del(7q) + altro BCR/ABL p190 NEG
## NA.1 NA NA NA <NA> <NA> <NA> <NA>
## 12012 FALSE TRUE FALSE t(9;22) BCR/ABL p190 NEG
## 12019 FALSE FALSE TRUE normal NEG <NA> POS
## 12026 FALSE TRUE FALSE t(9;22) BCR/ABL p190/p210 <NA>
## NA.2 NA NA NA <NA> <NA> <NA> <NA>
## 15001 FALSE FALSE TRUE normal NEG <NA> NEG
## 16004 TRUE FALSE FALSE t(4;11) ALL1/AF4 <NA> NEG
## 16009 NA NA NA <NA> NEG <NA> POS
## 19005 FALSE FALSE TRUE normal ALL1/AF4 <NA> NEG
## 20002 FALSE TRUE FALSE t(9;22)+other BCR/ABL p190 NEG
## 22009 FALSE FALSE FALSE simple alt. NEG <NA> NEG
## 22010 FALSE TRUE FALSE t(9;22) BCR/ABL p190/p210 NEG
## 22011 FALSE FALSE TRUE normal NEG <NA> NEG
## NA.3 NA NA NA <NA> <NA> <NA> <NA>
## 24001 NA NA NA <NA> BCR/ABL p190 NEG
## 24005 TRUE FALSE FALSE t(4;11) ALL1/AF4 <NA> NEG
## 24008 NA NA NA <NA> NEG <NA> NEG
## 24010 FALSE TRUE FALSE t(9;22) BCR/ABL p190/p210 NEG

```

## 24011	FALSE	TRUE	FALSE	t(9;22)	BCR/ABL	p210	POS
## 24018	NA	NA	NA	<NA>	NEG	<NA>	POS
## 24022	FALSE	TRUE	FALSE	t(9;22)	BCR/ABL	p190	POS
## 25003	FALSE	FALSE	FALSE	simple alt.	NEG	<NA>	POS
## 25006	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 26001	NA	NA	NA	<NA>	NEG	<NA>	POS
## 26003	FALSE	FALSE	FALSE	del(p15/p16)	BCR/ABL	p210	NEG
## 26008	FALSE	FALSE	TRUE	normal	ALL1/AF4	<NA>	NEG
## 27003	NA	NA	NA	<NA>	BCR/ABL	p190/p210	POS
## 27004	FALSE	TRUE	FALSE	t(9;22)+del(p15)	BCR/ABL	p190	NEG
## NA.4	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 28003	NA	NA	NA	<NA>	E2A/PBX1	<NA>	NEG
## 28007	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## 28019	NA	NA	NA	<NA>	BCR/ABL	p190	NEG
## 28021	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	p190/p210	NEG
## 28024	FALSE	FALSE	FALSE	complex alt.	NEG	<NA>	NEG
## 28032	TRUE	FALSE	FALSE	t(4;11)	ALL1/AF4	<NA>	NEG
## 28035	NA	NA	NA	<NA>	NEG	<NA>	POS
## 30001	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	p190	NEG
## 33005	FALSE	FALSE	FALSE	complex alt.	NEG	<NA>	NEG
## 36001	FALSE	FALSE	TRUE	normal	E2A/PBX1	<NA>	NEG
## NA.5	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 43004	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 43007	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## 48001	FALSE	FALSE	FALSE	complex alt.	NEG	<NA>	NEG
## 49006	NA	NA	NA	<NA>	BCR/ABL	p210	NEG
## 57001	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## 62001	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	<NA>	NEG
## NA.6	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 64002	NA	NA	NA	<NA>	NEG	<NA>	NEG
## NA.7	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 68001	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG
## 68003	FALSE	TRUE	FALSE	t(9;22)+other	BCR/ABL	p190	NEG
## NA.8	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 01007	FALSE	FALSE	FALSE	simple alt.	NUP-98	<NA>	NEG
## 02020	FALSE	FALSE	FALSE	complex alt.	NEG	<NA>	NEG
## 04018	FALSE	FALSE	FALSE	simple alt.	NEG	<NA>	NEG
## 09002	NA	NA	NA	<NA>	NEG	<NA>	NEG
## NA.9	NA	NA	NA	<NA>	<NA>	<NA>	<NA>
## 16007	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 17003	NA	NA	NA	<NA>	NEG	<NA>	POS
## 18001	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 19008	FALSE	FALSE	TRUE	normal	NEG	<NA>	POS
## 20005	NA	NA	NA	<NA>	NEG	<NA>	NEG
## 24006	FALSE	FALSE	FALSE	simple alt.	NEG	<NA>	NEG
## 28008	FALSE	FALSE	TRUE	normal	NEG	<NA>	NEG

```

## 28009      NA      NA      NA      <NA>      NEG      <NA>      NEG
## NA.10     NA      NA      NA      <NA>      <NA>      <NA>      <NA>
## NA.11     NA      NA      NA      <NA>      <NA>      <NA>      <NA>
## 49004    FALSE   FALSE   FALSE   del(7q)      NEG      <NA>      POS
## 56007     NA      NA      NA      <NA>      NEG      <NA>      NEG
## NA.12     NA      NA      NA      <NA>      <NA>      <NA>      <NA>
## 83001    FALSE   FALSE   FALSE   complex alt.      NEG      <NA>      NEG
## NA.13     NA      NA      NA      <NA>      <NA>      <NA>      <NA>
##      kinet   ccr  relapse transplant          f.u  date last seen
## 01005  diploid FALSE   FALSE   TRUE BMT / DEATH IN CR      <NA>
## 03002  diploid FALSE   TRUE   FALSE      REL 10/15/1999
## 04010 hyperd. FALSE   TRUE   FALSE      REL 3/5/1998
## 08011  diploid FALSE   FALSE   TRUE BMT / DEATH IN CR      <NA>
## NA      <NA>     NA      NA      NA      <NA>      <NA>
## 09008 hyperd.  TRUE   FALSE   TRUE BMT / CCR 00/09/01
## 09017  diploid FALSE   TRUE   FALSE      REL 9/11/2001
## 11005  diploid FALSE   FALSE   FALSE DEATH IN CR      <NA>
## NA.1      <NA>     NA      NA      NA      <NA>      <NA>
## 12012  diploid  NA     NA      NA      <NA>      <NA>
## 12019  diploid  TRUE   FALSE   FALSE      CCR 6/6/2002
## 12026  diploid FALSE   FALSE   FALSE DEATH IN CR      <NA>
## NA.2      <NA>     NA      NA      NA      <NA>      <NA>
## 15001  diploid  TRUE   FALSE   FALSE      CCR 6/21/2002
## 16004  diploid FALSE   TRUE   FALSE      REL 12/9/1997
## 16009  diploid  TRUE   FALSE   FALSE CCR / OFF 5/23/2002
## 19005  diploid FALSE   TRUE   FALSE      REL 2/4/1998
## 20002  diploid FALSE   TRUE   FALSE      REL 12/15/1997
## 22009  diploid  NA     NA      NA      <NA>      <NA>
## 22010  diploid  NA     NA      NA      <NA>      <NA>
## 22011  diploid  TRUE   FALSE   FALSE      CCR 7/31/2002
## NA.3      <NA>     NA      NA      NA      <NA>      <NA>
## 24001  diploid FALSE   TRUE   FALSE      REL 2/10/1997
## 24005  diploid FALSE   TRUE   FALSE      REL 8/28/1997
## 24008  diploid FALSE   FALSE   TRUE BMT / CCR 00/09/20+T12501
## 24010  diploid FALSE   TRUE   TRUE BMT / REL 8/24/1998
## 24011  diploid  NA     NA      NA      <NA>      <NA>
## 24018  diploid FALSE   TRUE   FALSE      REL 7/22/2000
## 24022  diploid  NA     NA      NA      <NA>      <NA>
## 25003  diploid  TRUE   FALSE   FALSE      CCR 6/10/2002
## 25006      <NA>    TRUE   FALSE   FALSE      CCR 3/3/2002
## 26001  diploid  TRUE   FALSE   FALSE      CCR 7/31/2002
## 26003  diploid FALSE   TRUE   FALSE      REL 7/1/1998
## 26008  diploid FALSE   TRUE   FALSE      REL 6/26/2000
## 27003  diploid FALSE   TRUE   FALSE      REL 5/6/1998
## 27004  diploid  NA     NA      NA      <NA>      <NA>
## NA.4      <NA>     NA      NA      NA      <NA>      <NA>

```

```

## 28003 hyperd. TRUE FALSE FALSE CCR 12/31/2002
## 28007 diploid TRUE FALSE FALSE CCR 3/22/2002
## 28019 hyperd. TRUE FALSE TRUE BMT / CCR 3/21/2001
## 28021 hyperd. FALSE FALSE FALSE DEATH IN CR (ICR) <NA>
## 28024 hyperd. TRUE FALSE FALSE CCR 12/31/2002
## 28032 diploid TRUE FALSE FALSE CCR 5/16/2002
## 28035 hyperd. TRUE FALSE FALSE CCR 5/20/2002
## 30001 hyperd. NA NA NA <NA> <NA>
## 33005 diploid TRUE FALSE FALSE CCR 6/28/2002
## 36001 diploid FALSE TRUE FALSE REL 1/7/1998
## NA.5 <NA> NA NA <NA> <NA>
## 43004 diploid TRUE FALSE FALSE CCR 3/20/2001
## 43007 hyperd. TRUE FALSE FALSE CCR 5/29/2002
## 48001 hyperd. FALSE FALSE FALSE MUD / DEATH IN CR 12/18/1998
## 49006 diploid FALSE TRUE FALSE REL 4/26/1999
## 57001 hyperd. NA NA NA <NA> <NA>
## 62001 hyperd. NA NA NA <NA> <NA>
## NA.6 <NA> NA NA <NA> <NA>
## 64002 hyperd. FALSE FALSE TRUE BMT / DEATH IN CR <NA>
## NA.7 <NA> NA NA <NA> <NA>
## 68001 diploid TRUE FALSE FALSE CCR 5/10/2002
## 68003 <NA> NA NA <NA> <NA>
## NA.8 <NA> NA NA <NA> <NA>
## 01007 hyperd. FALSE FALSE TRUE BMT / DEATH IN CR <NA>
## 02020 diploid NA NA NA <NA> <NA>
## 04018 diploid TRUE FALSE FALSE CCR 5/14/2001
## 09002 diploid FALSE TRUE FALSE REL / SNC 9/14/1999
## NA.9 <NA> NA NA <NA> <NA>
## 16007 diploid TRUE FALSE FALSE CCR 1/8/2002
## 17003 diploid NA NA NA <NA> <NA>
## 18001 hyperd. NA NA NA <NA> <NA>
## 19008 diploid NA NA NA <NA> <NA>
## 20005 diploid TRUE FALSE FALSE CCR 3/20/2002
## 24006 diploid TRUE FALSE FALSE CCR 6/5/2002
## 28008 hyperd. TRUE FALSE FALSE CCR 4/9/2002
## 28009 diploid FALSE TRUE FALSE REL 6/30/1998
## NA.10 <NA> NA NA <NA> <NA>
## NA.11 <NA> NA NA <NA> <NA>
## 49004 diploid TRUE FALSE FALSE CCR 6/14/2001
## 56007 diploid TRUE FALSE FALSE CCR 1/26/2001
## NA.12 <NA> NA NA <NA> <NA>
## 83001 hyperd. TRUE FALSE FALSE CCR 5/24/2002
## NA.13 <NA> NA NA <NA> <NA>

```

### 3.4 Lab 1B Tasks

```
# Task 1
# Patients younger than 20
subset(ALL_df, age < 20)

# Task 2
# Age and Sex for patients with BT = "B2"
subset(ALL_df, BT == "B2", select = c(age, sex))

# Task 3
# Male patients older than 40
subset(ALL_df, sex == "M" & age > 40)

# Female OR Relapse = Yes
subset(ALL_df, sex == "F" | relapse == T)

# Mini-Challenge
# Male + Relapse + Age > 30
subset(ALL_df, sex == "M" & relapse == T & age > 30)

#OR
ALL_df[ALL_df$sex == "M" & ALL_df$relapse == T & ALL_df$age > 30, ]
```

# Chapter 4

## Module 2

### 4.1 Lecture

#### 4.1.1 2A

#### 4.1.2 2B

### 4.2 Lab 2A

#### 4.2.1 Read data in to R

read CSV - base functions

```
bp <- read.csv2("Desktop/R/data/BloodPressure_Data.csv") # no separation
# take a quick look at the data
head(bp)
```

```
bp <- read.csv2("Desktop/R/data/BloodPressure_Data.csv", sep = ",") # no separation
# take another look at the data
head(bp)
str(bp)
```

readr functions

```
library(readr)
```

Read the CSV file

```
bp_data <- read_csv("Desktop/R/data/BloodPressure_Data.csv")
```

Take a quick look at the data

```
head(bp_data)
str(bp_data)
```

Work with date

```
library(readr)
library("lubridate")
```

read ALL data

```
bp <- read.csv2("Desktop/R/data/BloodPressure_wDates.csv", sep = ",")
```

Convert date column and extract year

```
bp$date <- ymd(bp$date)
bp$Year <- year(bp$date)
```

Filtering blood pressure patients by year and gender

```
subset(bp, Year == 2003 & Gender == "f")
```

#### 4.2.2 Conditions and loops

If {} else {} statement

```
if (condition) {  
    # code if TRUE  
} else {  
    # code if FALSE  
}
```

```
# If else example  
age <- 55  
if (age > 50) {  
    print("Older patient")  
} else {  
    print("Younger patient")  
}
```

```
# If {} else if {} else statement  
  
if (condition1) {  
    # code if condition1 is TRUE  
} else if (condition2) {  
    # code if condition2 is TRUE  
} else {  
    # code if none are TRUE  
}
```

```
# If else if example  
age <- 35  
  
if (age < 18) {  
    print("Child")  
} else if (age >= 18 & age < 60) {  
    print("Adult")  
} else {  
    print("Senior")  
}
```

```
# for loops  
for (i in 1:5) {  
    print(i)  
}
```

```
# for loop example
patients <- c("P1", "P2", "P3")
for (p in patients) {
  print(paste("Processing:", p))
}
```

```
# the apply () family vs. loops
# Using a for loop
m <- matrix(1:9, nrow=3)
row_sums <- c()
for (i in 1:nrow(m)) {
  row_sums[i] <- sum(m[i, ])
}
```

```
# Using apply()
row_sums2 <- apply(m, 1, sum)
```

```
# the apply() family
# apply()
apply(m, 1, sum)    # row sums
apply(m, 2, mean)   # column means
```

```
# lapply()
lapply(list(1:3, 4:6), mean)
```

```
# sapply()
sapply(list(1:3, 4:6), mean)
```

```
# lapply()
lapply(list(1:3, 4:6), mean)
```

```
# tapply()
ages <- c(21, 25, 30, 40, 35)
gender <- c("M", "M", "F", "F", "M")
tapply(ages, gender, mean)  # mean age by gender
```

```
# mapply()
nums1 <- 1:5
nums2 <- 6:10
mapply(sum, nums1, nums2)    # adds 1+6, 2+7, ... 5+10
```

### 4.3 Lab 2A Tasks

Task 1 – Basic Filtering

```
#Use a for loop with if/else conditions
Go through each row of the dataset and:
Print a message if the patient has High BP (> 140) # Tip: use the paste function,
Print a message if the patient has Low BP (< 90)
Otherwise, mark them as Normal
# read data
bp_data <- read.csv2("Desktop/R/data/BloodPressure_wDates.csv", sep = ",")

# Use for loop
for (i in 1:nrow(bp_data)) {
  if (bp_data$BloodPressure[i] > 140) {
    print(paste("Patient", bp_data$ID[i], "has HIGH blood pressure"))
  } else if (bp_data$BloodPressure[i] < 90) {
    print(paste("Patient", bp_data$ID[i], "has LOW blood pressure"))
  } else {
    print(paste("Patient", bp_data$ID[i], "is NORMAL"))
  }
}

# Use apply() instead of loops
bp_data$BP_Status <- apply(bp_data, 1, function(row) {
  if (as.numeric(row["BloodPressure"]) > 140) {
    "HIGH"
  } else if (as.numeric(row["BloodPressure"]) < 90) {
    "LOW"
  } else {
    "NORMAL"
  }
})
```

## 4.4 Lab 2B

### 4.4.1 Basic plotting in R

Plot multiple panels in one plot

```
par(mfrow = c(3, 1))
layout(matrix(c(1, 1, 2, 3), nrow = 2, byrow = TRUE))
```

Histogram of Blood Pressure

```
hist(bp_data$BloodPressure, main="Blood Pressure Distribution",
      xlab="Blood Pressure", col="lightblue")
```

Boxplot of BP by Gender

```
boxplot(BloodPressure ~ Gender, data=bp_data,
        main="BP by Gender", xlab="Gender", ylab="Blood Pressure")
```

Scatterplot Age vs BP

```
plot(bp_data$Age, bp_data$BloodPressure,
      main="Age vs Blood Pressure", xlab="Age", ylab="BP")
```

### 4.4.2 ggplot2

```
# example syntax
#ggplot(data, aes(x, y)) + geom_*
```

```
library(ggplot2)
# Scatterplot: Age vs Blood Pressure
ggplot(bp_data, aes(x=Age, y=BloodPressure)) +
  geom_point()
```

boxplot

```
ggplot(bp_data, aes(x=Group, y=BloodPressure)) +
  geom_boxplot()
```

Customizing ggplot2

```
ggplot(bp_data, aes(x = Age, y = BloodPressure)) +
  geom_point(color = "blue") +
  labs(
    title = "Age vs Blood Pressure",
    x = "Patient Age",
    y = "BP (mmHg)"
  ) +
  theme_minimal()
```

```
# Save last plot as PNG
ggsave("Age_BP_Scatter.png", width=6, height=4)
```

```
# Save specific plot object
p <- ggplot(bp_data, aes(x=Age, y=BloodPressure)) +
  geom_point()
ggsave("data/scatter_plot.png", plot=p)
```

## 4.5 Lab 2B Tasks

ggplot hands on tasks

```
library(lubridate)
library(ggplot2)
library(patchwork)
```

Load data

```
bp_data <- read.csv2("data/BloodPressure_wDates.csv", sep = ",")
```

Get the year in a new column

```
bp_data$Year <- year(bp_data$Date)
```

1. Bar plot: patient counts per group

```
# ggplot hands on tasks
ggplot(bp_data, aes(x=Group)) +
  geom_bar(fill="steelblue") +
  labs(title="Number of Patients per Group", x="Group", y="Count")
```

2. Histogram: Age distribution

```
ggplot(bp_data, aes(x=as.numeric(Age))) +
  geom_histogram(binwidth=5, fill="lightgreen", color="black") +
  labs(title="Age Distribution of Patients", x="Age", y="Frequency")
```

3. Scatterplot: Age vs BloodPressure, colored by Group

```
ggplot(bp_data, aes(x=Age, y=BloodPressure, color=Group)) +
  geom_point() +
  labs(title="Age vs Blood Pressure by Group",
       x="Age", y="Blood Pressure")
```

Bonus hands on

```
library(ggplot2)
library(patchwork) # install.packages("patchwork") if needed
```

1. Bar plot

```
p1 <- ggplot(bp_data, aes(x = Gender, y = BloodPressure, fill = Gender)) +
  stat_summary(fun = "mean", geom = "bar") +
  labs(title = "Average BP by Gender") +
  theme_minimal()
```

2. Histogram

```
p2 <- ggplot(bp_data, aes(x=as.numeric(Age))) +
  geom_histogram(binwidth=5, fill="lightgreen", color="black") +
  labs(title="Age Distribution of Patients", x="Age", y="Frequency")
```

### 3. Boxplot

```
p3 <- ggplot(bp_data, aes(x = Group, y = BloodPressure, fill = Group)) +
  geom_boxplot() +
  labs(title = "BP by Group") +
  theme_minimal()
```

Combine plots into one figure

```
# horizontal layout
(p1 | p2 | p3)

# vertical layout
(p1 / p2 / p3)

# 2x2 grid
(p1 | p2) / p3
```



# **Chapter 5**

## **Module 3**

### **5.1 Lecture**

#### **5.1.1 3A**

#### **5.1.2 3B**

### **5.2 Lab**



# **Chapter 6**

## **Module 4**

### **6.1 Lecture**

#### **6.1.1 4A**

#### **6.1.2 4B**

### **6.2 Lab**