

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)
```

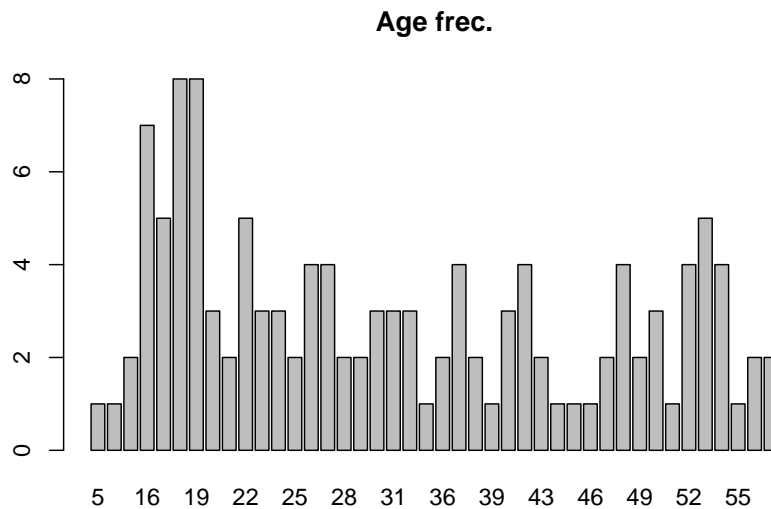
```
## [1] 128 21
```

```
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 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)
```

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##	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	dyploid	FALSE
##	04007	FALSE	del(6q)		NEG		<NA>		NEG	dyploid	FALSE
##	08012	FALSE	simple alt.		NEG		<NA>		NEG	dyploid	FALSE
##	15004	FALSE	t(4;11)		ALL1/AF4		<NA>		NEG	dyploid	FALSE
##	16004	FALSE	t(4;11)		ALL1/AF4		<NA>		NEG	dyploid	FALSE
##	19005	TRUE	normal		ALL1/AF4		<NA>		NEG	dyploid	FALSE
##	20002	FALSE	t(9;22)+other		BCR/ABL		p190		NEG	dyploid	FALSE
##	24005	FALSE	t(4;11)		ALL1/AF4		<NA>		NEG	dyploid	FALSE
##	24017	FALSE	t(9;22)+other		BCR/ABL		p190		NEG	hyperd.	FALSE
##	26003	FALSE	del(p15/p16)		BCR/ABL		p210		NEG	dyploid	FALSE
##	28028	FALSE	t(4;11)		ALL1/AF4		<NA>		NEG	dyploid	FALSE
##	28036	FALSE	t(9;22)		BCR/ABL		p190		NEG	dyploid	FALSE
##	43001	FALSE	t(9;22)		BCR/ABL		p190/p210		POS	dyploid	FALSE
##	49006	NA	<NA>		BCR/ABL		p210		NEG	dyploid	FALSE
##	62003	FALSE	t(9;22)+other		BCR/ABL		p210		NEG	hyperd.	FALSE
##	63001	NA	<NA>		ALL1/AF4						

```
## 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      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>	<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>
##	kinet	ccr	relapse	transplant	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	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 dyploid FALSE    TRUE    FALSE    REL      6/28/1998
## 43007 hyperd.    TRUE    FALSE    FALSE    CCR      5/29/2002
## 49006 dyploid 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 dyploid FALSE    TRUE    FALSE    REL      6/10/1998
## 84004 dyploid FALSE    TRUE    FALSE    REL      1/25/1999
## NA.3      <NA>    NA      NA      NA      <NA>      <NA>
## 02020 dyploid    NA      NA      NA      <NA>      <NA>
## 16002 hyperd. FALSE    TRUE    FALSE    REL      12/7/1999
## 16007 dyploid    TRUE    FALSE    FALSE    CCR      1/8/2002
## 31015 dyploid    NA      NA      NA      <NA>      <NA>
## 43006 dyploid    NA      NA      NA      <NA>      <NA>
## 43015 dyploid 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	NA
##		cyto.normal			citog	mol.biol	fusion	protein	mdr	kinet	ccr
##	03002	NA		<NA>	BCR/ABL			p190	NEG	dyploid	FALSE
##	04007	FALSE		del(6q)	NEG			<NA>	NEG	dyploid	FALSE
##	08012	FALSE		simple alt.	NEG			<NA>	NEG	dyploid	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	dyploid	FALSE
##	16004	FALSE		t(4;11)	ALL1/AF4			<NA>	NEG	dyploid	FALSE
##	19005	TRUE		normal	ALL1/AF4			<NA>	NEG	dyploid	FALSE
##	20002	FALSE		t(9;22)+other	BCR/ABL			p190	NEG	dyploid	FALSE
##	24005	FALSE		t(4;11)	ALL1/AF4			<NA>	NEG	dyploid	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	dyploid	FALSE
##	NA.3	NA		<NA>	<NA>			<NA>	<NA>	<NA>	NA
##	28028	FALSE		t(4;11)	ALL1/AF4			<NA>	NEG	dyploid	FALSE
##	28036	FALSE		t(9;22)	BCR/ABL			p190	NEG	dyploid	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	dyploid	FALSE
##	49006	NA		<NA>	BCR/ABL			p210	NEG	dyploid	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	dyploid	FALSE
##	84004	NA		<NA>	BCR/ABL			p190	NEG	dyploid	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 dyploid 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()

```
df2 <- 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	dyploid	FALSE
##	04007	FALSE		del(6q)		NEG		<NA>	NEG	dyploid	FALSE
##	08012	FALSE		simple alt.		NEG		<NA>	NEG	dyploid	FALSE
##	15004	FALSE		t(4;11)		ALL1/AF4		<NA>	NEG	dyploid	FALSE
##	16004	FALSE		t(4;11)		ALL1/AF4		<NA>	NEG	dyploid	FALSE
##	19005	TRUE		normal		ALL1/AF4		<NA>	NEG	dyploid	FALSE
##	20002	FALSE		t(9;22)+other		BCR/ABL		p190	NEG	dyploid	FALSE
##	24005	FALSE		t(4;11)		ALL1/AF4		<NA>	NEG	dyploid	FALSE
##	24017	FALSE		t(9;22)+other		BCR/ABL		p190	NEG	hyperd.	FALSE
##	26003	FALSE		del(p15/p16)		BCR/ABL		p210	NEG	dyploid	FALSE
##	28028	FALSE		t(4;11)		ALL1/AF4		<NA>	NEG	dyploid	FALSE
##	28036	FALSE		t(9;22)		BCR/ABL		p190	NEG	dyploid	FALSE
##	43001	FALSE		t(9;22)		BCR/ABL		p190/p210	POS	dyploid	FALSE
##	49006	NA		<NA>		BCR/ABL		p210	NEG	dyploid	FALSE
##	62003	FALSE		t(9;22)+other		BCR/ABL		p210	NEG	hyperd.	FALSE
##	63001	NA		<NA>		ALL1/AF4		<NA>	NEG	dyploid	FALSE
##	84004	NA		<NA>		BCR/ABL		p190	NEG	dyploid	FALSE
##	16002	NA		<NA>		NEG		<NA>	NEG	hyperd.	FALSE
##	43015	TRUE		normal		NEG		<NA>	NEG	dyploid	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	dyploid	FALSE	FALSE	TRUE	BMT / DEATH	IN CR	<NA>
## 03002	dyploid	FALSE	TRUE	FALSE		REL	10/15/1999
## 04010	hyperd.	FALSE	TRUE	FALSE		REL	3/5/1998
## 08011	dyploid	FALSE	FALSE	TRUE	BMT / DEATH	IN CR	<NA>
## NA	<NA>	NA	NA	NA	<NA>	<NA>	<NA>
## 09008	hyperd.	TRUE	FALSE	TRUE	BMT / CCR		00/09/01
## 09017	dyploid	FALSE	TRUE	FALSE		REL	9/11/2001
## 11005	dyploid	FALSE	FALSE	FALSE	DEATH	IN CR	<NA>
## NA.1	<NA>	NA	NA	NA	<NA>	<NA>	<NA>
## 12012	dyploid	NA	NA	NA	<NA>	<NA>	<NA>
## 12019	dyploid	TRUE	FALSE	FALSE		CCR	6/6/2002
## 12026	dyploid	FALSE	FALSE	FALSE	DEATH	IN CR	<NA>
## NA.2	<NA>	NA	NA	NA	<NA>	<NA>	<NA>
## 15001	dyploid	TRUE	FALSE	FALSE		CCR	6/21/2002
## 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
## 22009	dyploid	NA	NA	NA	<NA>	<NA>	<NA>
## 22010	dyploid	NA	NA	NA	<NA>	<NA>	<NA>
## 22011	dyploid	TRUE	FALSE	FALSE		CCR	7/31/2002
## NA.3	<NA>	NA	NA	NA	<NA>	<NA>	<NA>
## 24001	dyploid	FALSE	TRUE	FALSE		REL	2/10/1997
## 24005	dyploid	FALSE	TRUE	FALSE		REL	8/28/1997
## 24008	dyploid	FALSE	FALSE	TRUE	BMT / CCR	00/09/20+T12501	
## 24010	dyploid	FALSE	TRUE	TRUE	BMT / REL		8/24/1998
## 24011	dyploid	NA	NA	NA	<NA>	<NA>	<NA>
## 24018	dyploid	FALSE	TRUE	FALSE		REL	7/22/2000
## 24022	dyploid	NA	NA	NA	<NA>	<NA>	<NA>
## 25003	dyploid	TRUE	FALSE	FALSE		CCR	6/10/2002
## 25006	<NA>	TRUE	FALSE	FALSE		CCR	3/3/2002
## 26001	dyploid	TRUE	FALSE	FALSE		CCR	7/31/2002
## 26003	dyploid	FALSE	TRUE	FALSE		REL	7/1/1998
## 26008	dyploid	FALSE	TRUE	FALSE		REL	6/26/2000
## 27003	dyploid	FALSE	TRUE	FALSE		REL	5/6/1998
## 27004	dyploid	NA	NA	NA	<NA>	<NA>	<NA>
## NA.4	<NA>	NA	NA	NA	<NA>	<NA>	<NA>

## 28003	hyperd.	TRUE	FALSE	FALSE	CCR	12/31/2002
## 28007	dyploid	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	dyploid	TRUE	FALSE	FALSE	CCR	5/16/2002
## 28035	hyperd.	TRUE	FALSE	FALSE	CCR	5/20/2002
## 30001	hyperd.	NA	NA	NA	<NA>	<NA>
## 33005	dyploid	TRUE	FALSE	FALSE	CCR	6/28/2002
## 36001	dyploid	FALSE	TRUE	FALSE	REL	1/7/1998
## NA.5	<NA>	NA	NA	NA	<NA>	<NA>
## 43004	dyploid	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	dyploid	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>	<NA>
## 64002	hyperd.	FALSE	FALSE	TRUE	BMT / DEATH IN CR	<NA>
## NA.7	<NA>	NA	NA	NA	<NA>	<NA>
## 68001	dyploid	TRUE	FALSE	FALSE	CCR	5/10/2002
## 68003	<NA>	NA	NA	NA	<NA>	<NA>
## NA.8	<NA>	NA	NA	NA	<NA>	<NA>
## 01007	hyperd.	FALSE	FALSE	TRUE	BMT / DEATH IN CR	<NA>
## 02020	dyploid	NA	NA	NA	<NA>	<NA>
## 04018	dyploid	TRUE	FALSE	FALSE	CCR	5/14/2001
## 09002	dyploid	FALSE	TRUE	FALSE	REL / SNC	9/14/1999
## NA.9	<NA>	NA	NA	NA	<NA>	<NA>
## 16007	dyploid	TRUE	FALSE	FALSE	CCR	1/8/2002
## 17003	dyploid	NA	NA	NA	<NA>	<NA>
## 18001	hyperd.	NA	NA	NA	<NA>	<NA>
## 19008	dyploid	NA	NA	NA	<NA>	<NA>
## 20005	dyploid	TRUE	FALSE	FALSE	CCR	3/20/2002
## 24006	dyploid	TRUE	FALSE	FALSE	CCR	6/5/2002
## 28008	hyperd.	TRUE	FALSE	FALSE	CCR	4/9/2002
## 28009	dyploid	FALSE	TRUE	FALSE	REL	6/30/1998
## NA.10	<NA>	NA	NA	NA	<NA>	<NA>
## NA.11	<NA>	NA	NA	NA	<NA>	<NA>
## 49004	dyploid	TRUE	FALSE	FALSE	CCR	6/14/2001
## 56007	dyploid	TRUE	FALSE	FALSE	CCR	1/26/2001
## NA.12	<NA>	NA	NA	NA	<NA>	<NA>
## 83001	hyperd.	TRUE	FALSE	FALSE	CCR	5/24/2002
## NA.13	<NA>	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 sepgration
# take a quick look at the data
head(bp)
```

```
bp <- read.csv2("Desktop/R/data/BloodPressure_Data.csv", sep = ",") # no sepgration
# 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