

Introduction to R

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Based on slides by Ramiro Logares (ICM-CSIC, Barcelona)

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```
dens <- density(data, n = npts)
dx <- dens$x
dy <- dens$y
if(add == TRUE)
  plot(0., 0., main,
        ylab)
if(orientati == yst)
  dx2 <- (dx - min(dx)) / (max(dx) - min(dx))
  x[1.]
  dy2 <- (dy - min(dy)) / (max(dy) - min(dy))
  y[1.]
seqbelow <- rep(y[1.], length(dx))
if(Fill == T)
  confshade(dx2, seqbelow, dy2)
```



History of R

- Originated from S
 - Statistical programming language developed by John Chambers at Bell Labs in the 70s
 - Developed at the same times as Unix
 - Closed source
- First version of R: developed by Robert Gentleman and Ross Ihaka in the mid-1990s
 - Aimed for better statistics software in their Mac teaching labs
 - Open Source alternative
 - R 1.0.0 released in 2000
- Current version 4.4.1
- Developers: international R-core developing team



John Chambers



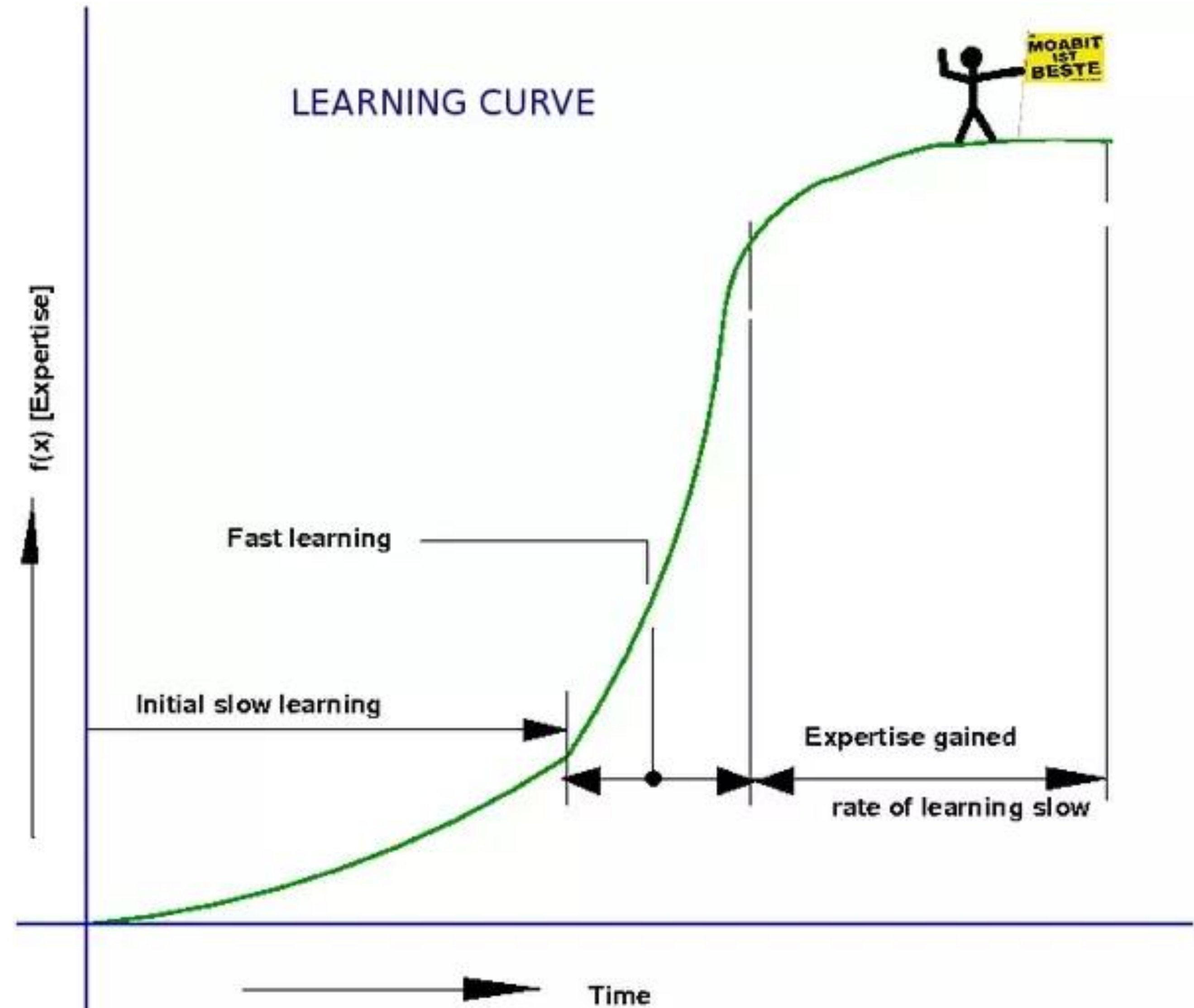
Robert Gentleman



Ross Ihaka

Why learn R?

- Language and environment for statistical computing and graphics
- Open Source (free)
- Cross-platform compatibility
- Community supported
- Great flexibility to do what you want
- Many packages are available: ecology, metabarcoding, networks
- Amazing publication-quality graphs



Installing R

<https://cran.r-project.org/>

Download and Install R

Precompiled binary distributions of the base system and contributed packages, **Windows and Mac** users most likely want one of these versions of R:

- [Download R for Linux](#) ([Debian](#), [Fedora/Redhat](#), [Ubuntu](#))
- [Download R for macOS](#)
- [Download R for Windows](#)

R is part of many Linux distributions, you should check with your Linux package management system in addition to the link above.

Source Code for all Platforms

Windows and Mac users most likely want to download the precompiled binaries listed in the upper box, not the source code. The sources have to be compiled before you can use them. If you do not know what this means, you probably do not want to do it!

- The latest release (2023-06-16, Beagle Scouts) [R-4.3.1.tar.gz](#), read [what's new](#) in the latest version.
- Sources of [R alpha and beta releases](#) (daily snapshots, created only in time periods before a planned release).
- Daily snapshots of current patched and development versions are [available here](#). Please read about [new features and bug fixes](#) before filing corresponding feature requests or bug reports.
- Source code of older versions of R is [available here](#).
- Contributed extension [packages](#)

Questions About R

- If you have questions about R like how to download and install the software, or what the license terms are, please read our [answers to frequently asked questions](#) before you send an email.

Installing R-Studio

- An Integrated Development Environment (IDE): **R-Studio**
 - Set of tools designed to help and be more productive with R
 - Includes a console and syntax-highlighting editor that supports code execution
 - Can have several open sessions (aka. Projects)
 - Includes a Unix terminal
 - Can run other programming languages (python, bash)

DOWNLOAD

RStudio Desktop

Used by millions of people weekly, the RStudio integrated development environment (IDE) is a set of tools built to help you be more productive with R and Python.

Don't want to download or install anything? Get started with RStudio on [Posit Cloud for free](#). If you're a professional data scientist looking to download RStudio and also need common enterprise features, don't hesitate to [book a call with us](#).

1: Install R

RStudio requires R 3.3.0+. Choose a version of R that matches your computer's operating system.

DOWNLOAD AND INSTALL R

2: Install RStudio

DOWNLOAD RSTUDIO DESKTOP FOR MACOS 11+

This version of RStudio is only supported on macOS 11 and higher. For earlier macOS environments, please [download a previous version](#).

Size: 385.88 MB | [SHA-256: 25A2CC51](#) | Version: 2023.09.1+494 | Released: 2023-10-17

<https://posit.co/download/rstudio-desktop/>

1
2 ## BI09905MERG1_V21
3
4 ## Community ecology exercises
5
6 # Install packages
7
8 install.packages("vegan") # Community ecology functions
9
10
11 # Read dada2 output
12
13 otu.tab<-read.table("https://github.com/path/")
14
15
16
17 #Library Vegan
18
19
20

Editor

20:1 (Top Level) R Script

Console Terminal Jobs

~/
en_OTU_00594
en_OTU_00127
bp_OTU_000003
ep_OTU_00353
bn_OTU_000265
en_OTU_00329
en_OTU_01088
> bbmo.core.nw.deg.dist <- degree_distribution(bbmo.core.nw, cumulative=T, mode="all")
> plot(x=0:max(bbmo.core.nw.degree), y=1-bbmo.core.nw.deg.dist , pch=19, cex=1.2, col="orange",
+ xlab="Degree", ylab="Cumulative Frequency")
> plot(bbmo.core.nw)
> plot(x=0:max(bbmo.core.nw.degree), y=1-bbmo.core.nw.deg.dist , pch=19, cex=1.2, col="orange",
+ xlab="Degree", ylab="Cumulative Frequency")
> |

Environment History Connections

Import Dataset

R Global Environment

tara_mine_otu_otu_18S_MIC_mi... 50853 obs. of 8 variables
temp.daylength.merged 371 obs. of 11 variables
temp57 8 obs. of 3 variables
varpart.abiotic.biotic List of 6
winter.vertex.mat int [1:156, 1] 1 2 3 4 5 6 7 8 9 10 ...
world 253 obs. of 52 variables

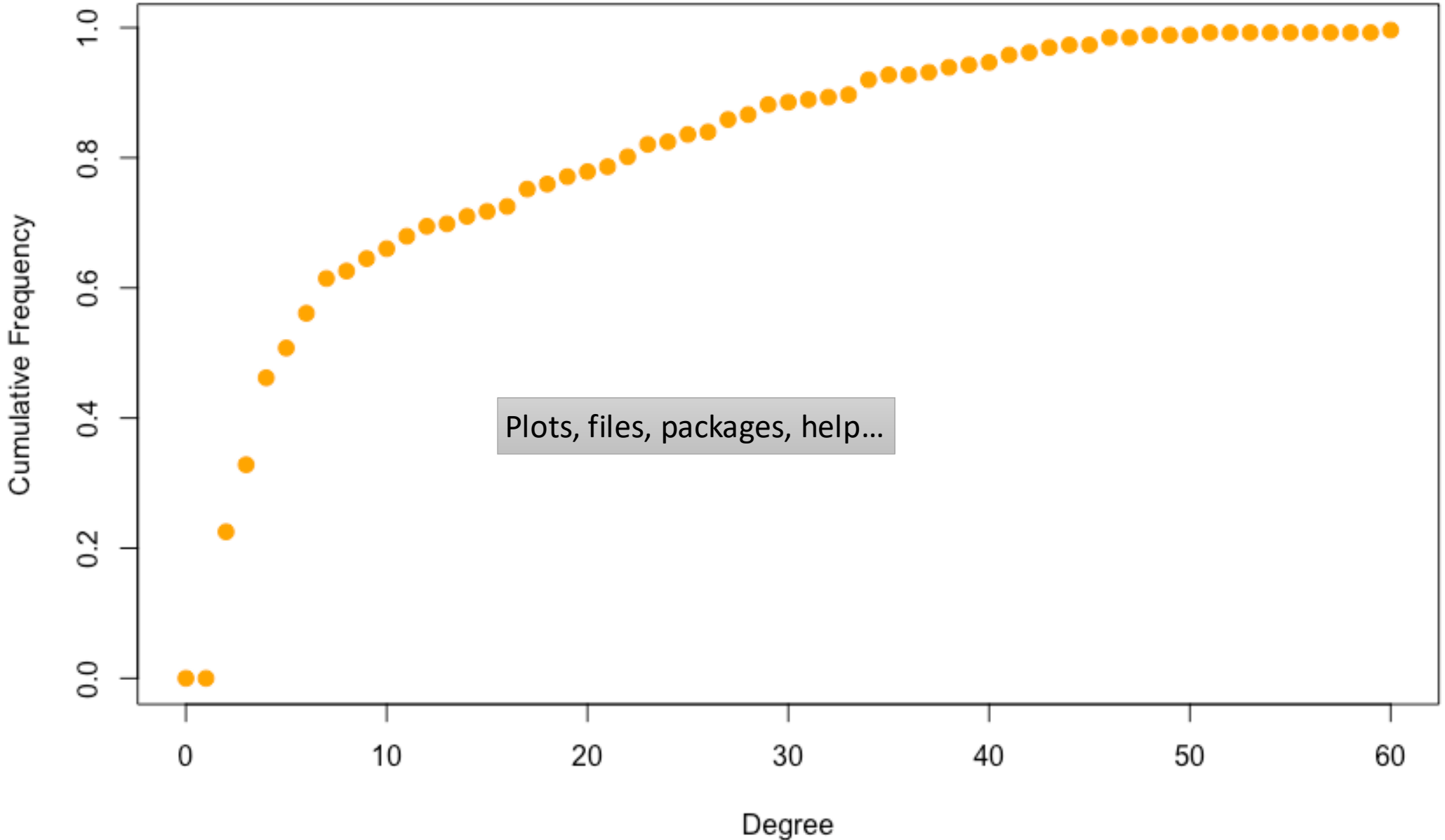
Variables, etc

Values
apl 1.34615384615385
autumn.vertex 'igraph.vs' Named int [1:26] 1 2 3 4 5 6 7 8 9 10 ...
autumn.vertex.tab 'igraph.vs' Named int [1:26] 1 2 3 4 5 6 7 8 9 10 ...
avg.degree 2.11764705882353
bbmo.core.niche.val.signific... chr [1:371] "bn_ASV_000001" "bp_ASV_000001" "ep_ASV_00001" "ep_ASV_00002" "en_ASV...
bbmo.core.nw.deg.dist num [1:61] 1 1 0.775 0.672 0.538 ...

Files Plots Packages Help Viewer

Zoom Export

Publish



Plots, files, packages, help...

Presentation format

- The following slides shows some typical R commands and the important data structures
- The idea is that you become familiar with reading code as you will do when working with R-Studio
- After this introduction, you should be able to follow other sections of the course using R



Intro to R

- Basic operations.

`6+6`

`6-6`

`6*6`

`6/6`

`log(6)`

`log2(6)`

`log10(6)`

`log(6,10)`

`log(6,3)`

`6^6`

`sin(pi/2)`

`cos(pi/2)`

`# ...ETC`

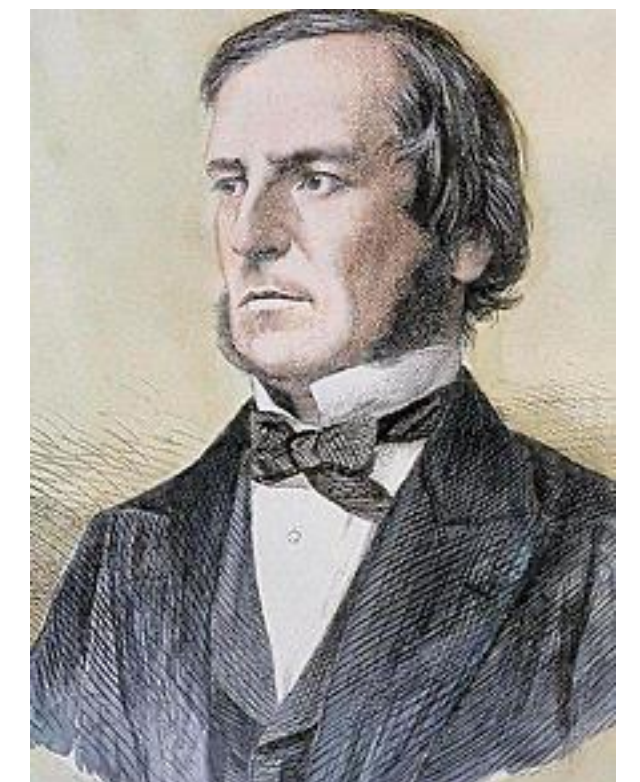
Let's have a look at basic datatypes on which R objects are built

```
#Numeric: numbers with decimals
mynumber <- 66.6
print(mynumber)
# [1] 66.6
class(mynumber) # use it to know what is the data type
# [1] "numeric"
```

```
#Integer: numbers with no decimals
mynumber.int <- as.integer(mynumber)
# [1] 66
class(mynumber.int)
# [1] "integer"
```

```
#Character: can be a letter or a combination of letters enclosed by quotes
mychar <- "bioinfo course"
print(mychar)
# [1] "bioinfo course"
class(mychar)
#[1] "character"
```

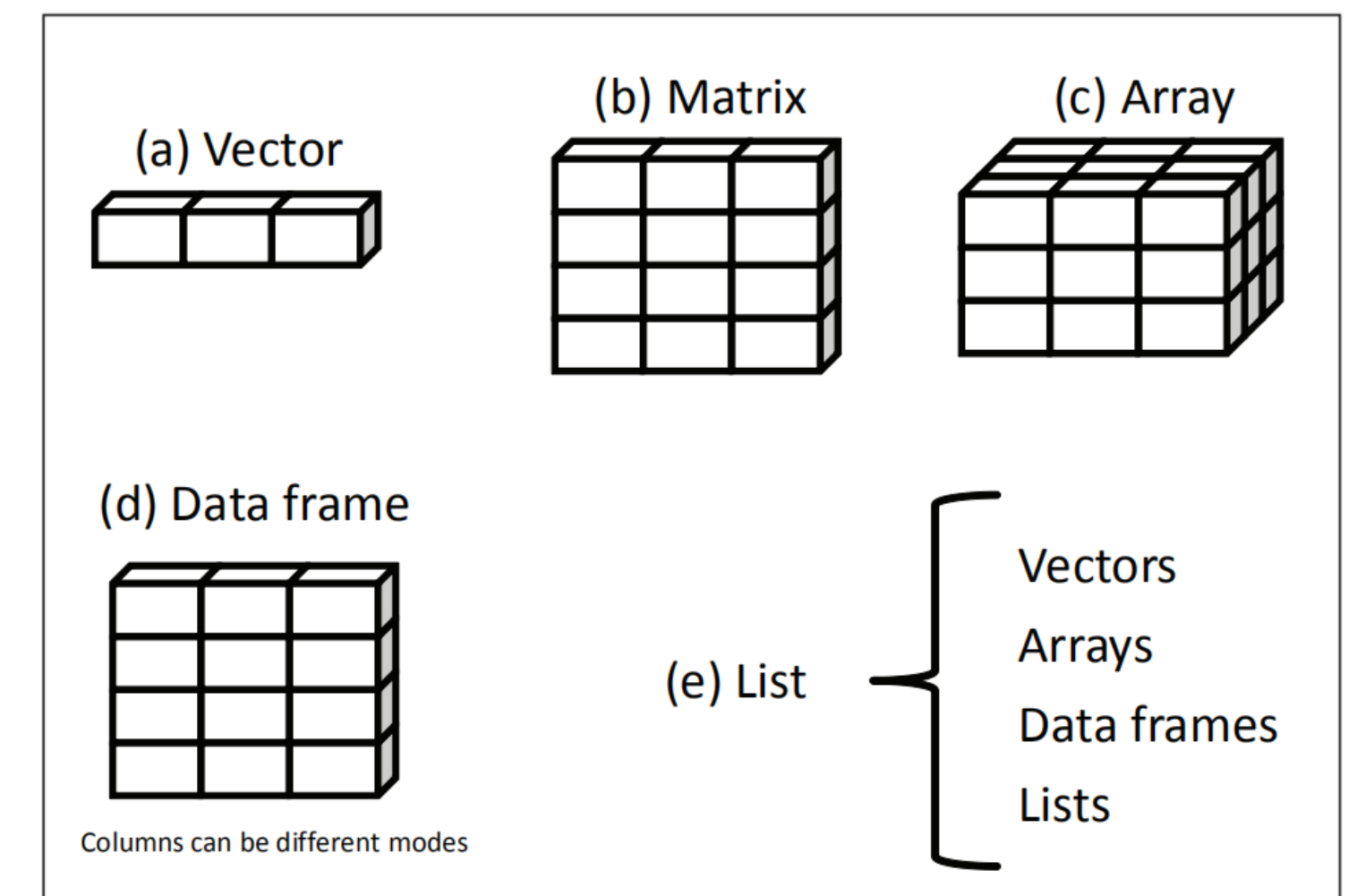
```
#Logical: a variable that can be TRUE or FALSE (boolean)
im.true <- TRUE
print(im.true)
#[1] TRUE
class(im.true)
# [1] "logical"
```



George Boole

Objects and data-types

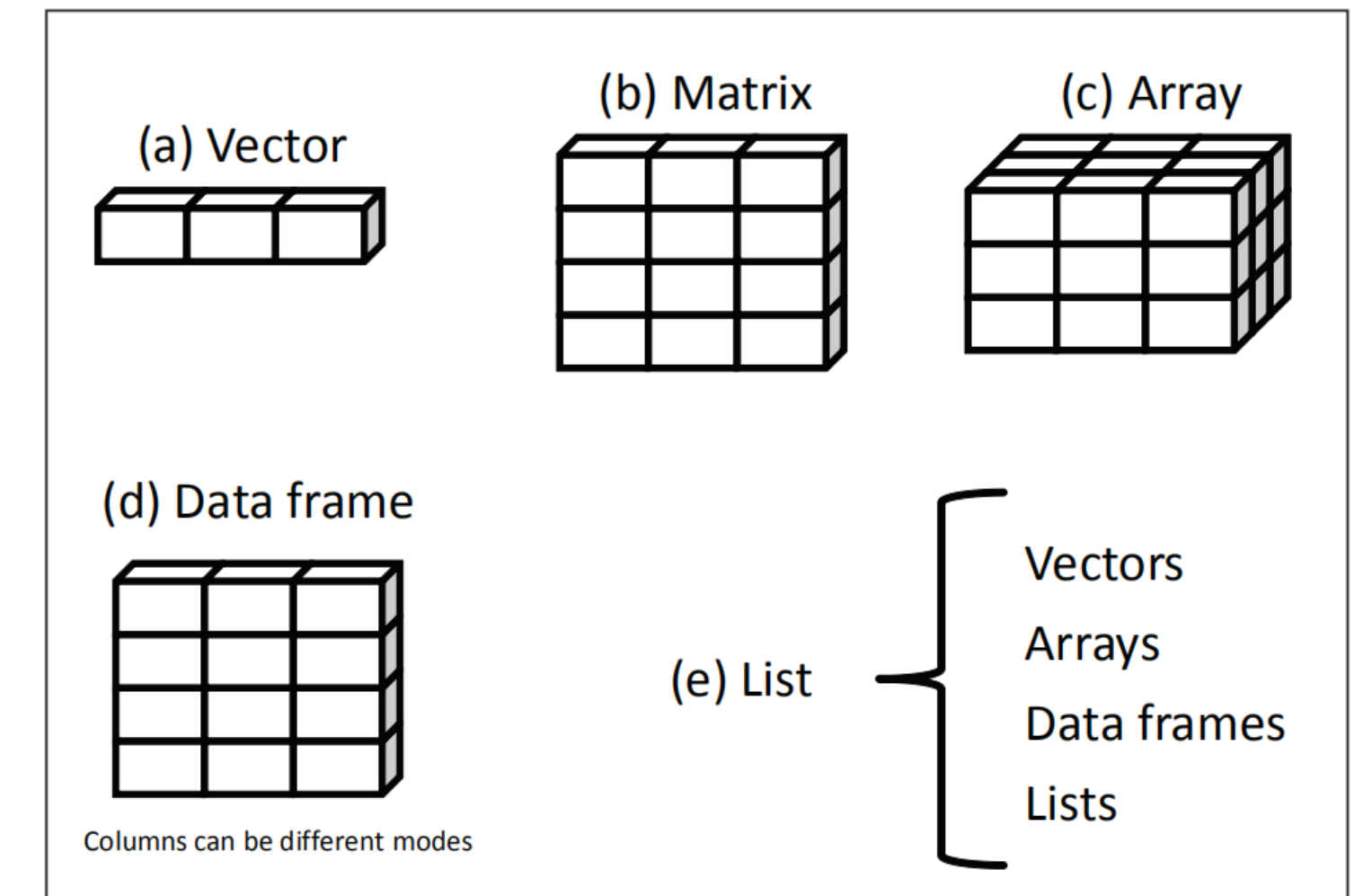
- Fundamental structures in R
- Objects: Vectors, Matrices, Arrays, Data frames, Lists, S4
- Data types: numeric, integer, character, logical, factor



Vectors

Objects that are used to store values or other information of the same data type
They are created with the function "c()" that will generate a 1D array (vector)

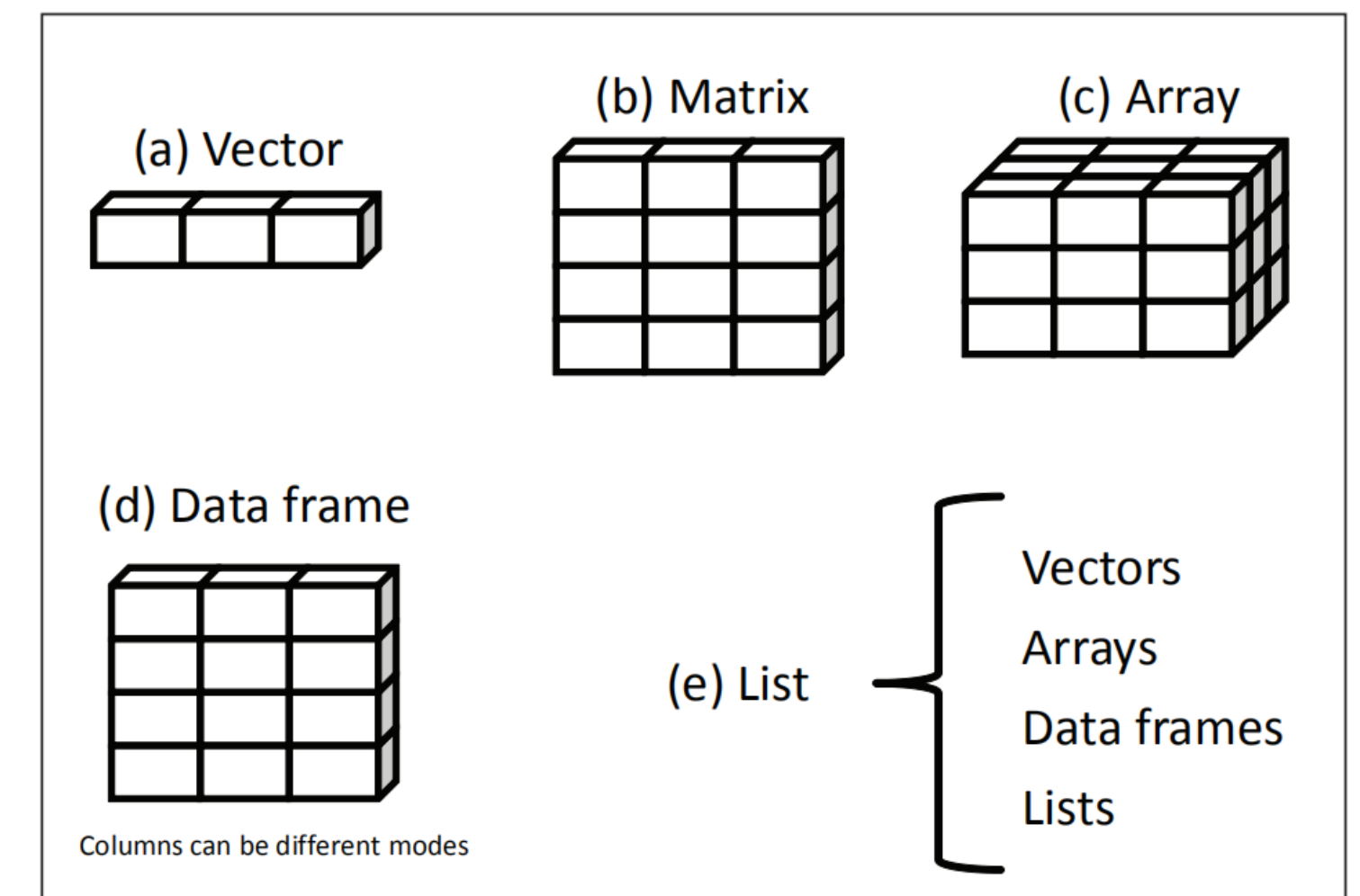
```
species <- c(123, 434, 655, 877, 986) # we create a numeric vector
class(species)
#[1] "numeric"
length(species) # number of elements in the vector
#[1] 5
species[5] # accessing the fifth element in the vector
#[1] 986
species[1:3]
#[1] 123 434 655
species.names <- c("dog", "lion", "human", "pig", "cow")
# we create a character vector
class(species.names)
# [1] "character"
```



Factors

```
#Factor: used to refer to a qualitative relationship.
```

```
# to generate a factor, we'll use a vector defined with the function c()
myfactor <- factor(c("good", "bad", "ugly", "good", "good", "bad", "ugly"))
print(myfactor)
#[1] good bad  ugly good good bad  ugly
#Levels: bad good ugly  <- NB: levels of the factor
class(myfactor)
#[1] "factor"
levels(myfactor) # this can be used to check the levels of a factor
# [1] "bad" "good" "ugly"
nlevels(myfactor)
# [1] 3
class(levels(myfactor))
# [1] "character"
```



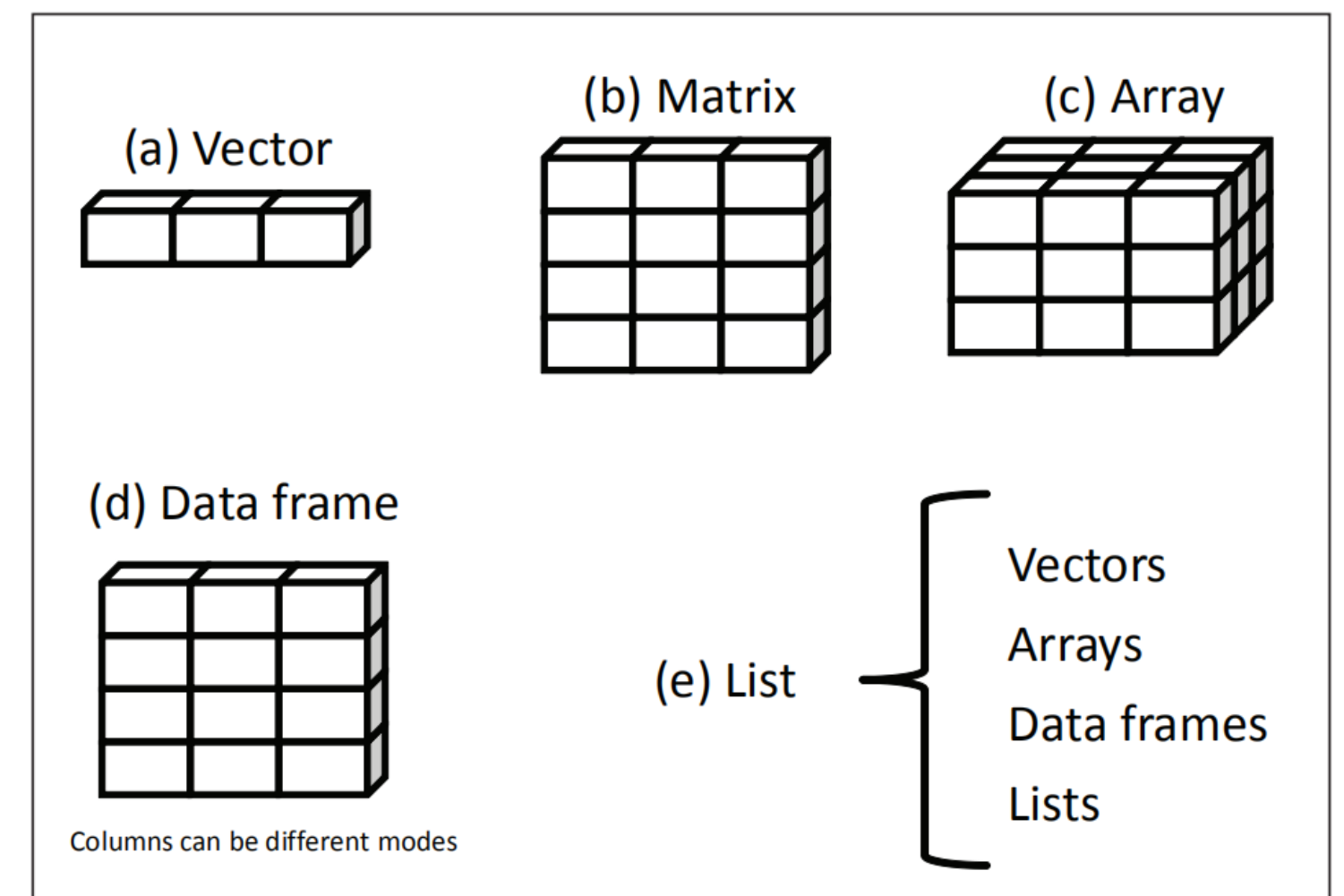
List

```
# List
# It can contain elements of various data types (e.g.vectors,functions,matrices,another list)
# Example of vectors with three different data types in one list
list1 <- c(1:5) # integer vector
#[1] 1 2 3 4 5
list2 <- factor(1:5) # factor vector
# [1] 1 2 3 4 5
# Levels: 1 2 3 4 5
list3 <- letters[1:5]
# [1] "a" "b" "c" "d" "e"
grouped.lists <- list(list1,list2,list3)
#[[1]]
#[1] 1 2 3 4 5

#[[2]]
#[1] 1 2 3 4 5
#Levels: 1 2 3 4 5

#[[3]]
#[1] "a" "b" "c" "d" "e"

#Accessing elements of a list
grouped.lists[[1]] # accessing the first vector
# [1] 1 2 3 4 5
```



#Matrix

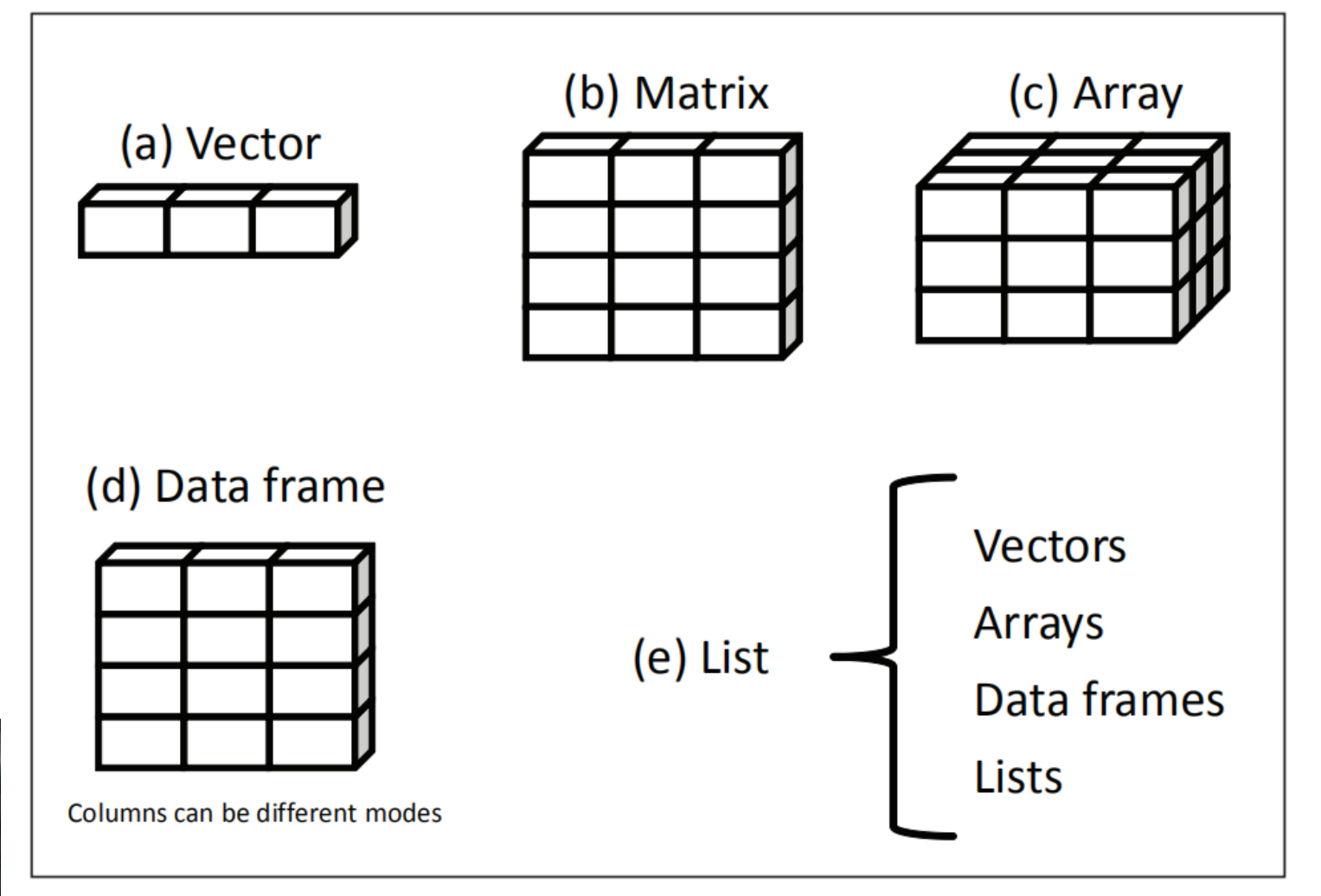
Like a vector, a matrix stores information of the same data type,
but different from a vector, it has 2 dimensions.

#syntax:

```
# mymatrix <- matrix(vector, nrow=r, ncol=c, byrow=FALSE, dimnames=list(vector_rownames, vector_colnames))
# byrow=F indicates that the matrix should be filled by columns
```

```
mymatrix <- matrix(seq(1:100), nrow=10, ncol=10, byrow=FALSE, dimnames=list(c(1:10), letters[1:10]))
print(mymatrix)
```

```
#      a  b  c  d  e  f  g  h  i  j
# 1    1 11 21 31 41 51 61 71 81 91
# 2    2 12 22 32 42 52 62 72 82 92
# 3    3 13 23 33 43 53 63 73 83 93
# 4    4 14 24 34 44 54 64 74 84 94
# 5    5 15 25 35 45 55 65 75 85 95
# 6    6 16 26 36 46 56 66 76 86 96
# 7    7 17 27 37 47 57 67 77 87 97
# 8    8 18 28 38 48 58 68 78 88 98
# 9    9 19 29 39 49 59 69 79 89 99
# 10   10 20 30 40 50 60 70 80 90 100
```



Dataframes

```
#Dataframes
```

```
# More general than a matrix and can contain different data types
```

```
# Variables or features are in columns, while observations are in rows
```

```
# =>NB: this is one of the most common objects in metabarcoding analyses<=
```

```
# Generated with the data.frame() function
```

```
my.data.frame<-data.frame(  
  Name=c("Game of Thrones", "MrRobot", "WestWorld"),  
  Budget=c(344, 59, 122),  
  Seasons=c(8, 4, 3),  
  Audience=c(300, 14, 80),  
  Actors=c(221, 56, 90))
```

```
print(my.data.frame)
```

```
#           Name Budget Seasons Audience Actors  
#1 Game of Thrones    344      8     300    221  
#2      MrRobot      59      4      14     56  
#3    WestWorld    122      3      80     90
```

```
# Assign to the row names the names in the first column
```

```
row.names(my.data.frame) <- my.data.frame[,1]
```

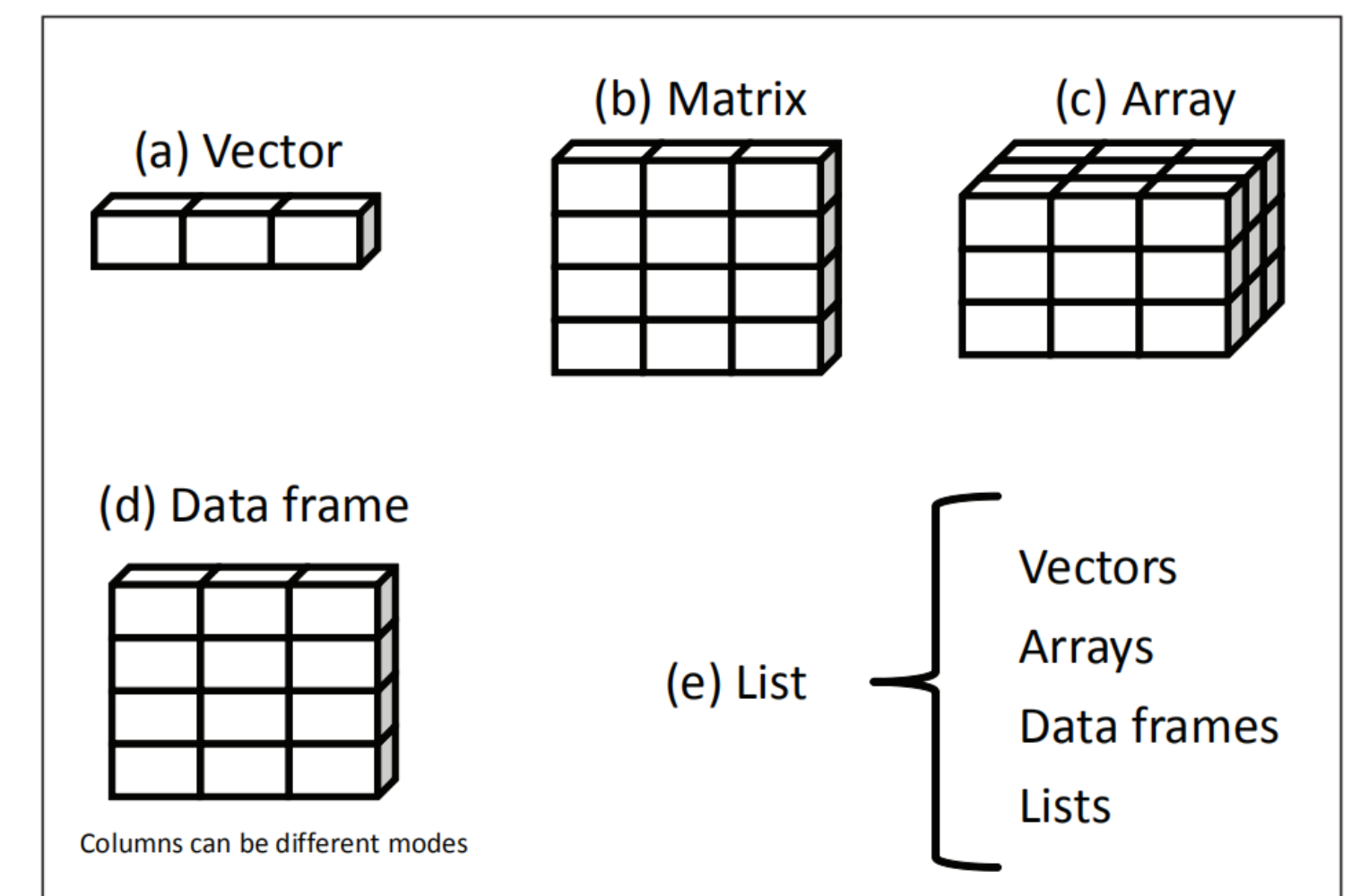
```
# Remove the first column
```

```
my.data.frame <- my.data.frame[, -1]
```

```
print(my.data.frame)
```

```
#           Budget Seasons Audience Actors  
# Game of Thrones    344      8     300    221  
# MrRobot      59      4      14     56  
# WestWorld    122      3      80     90
```

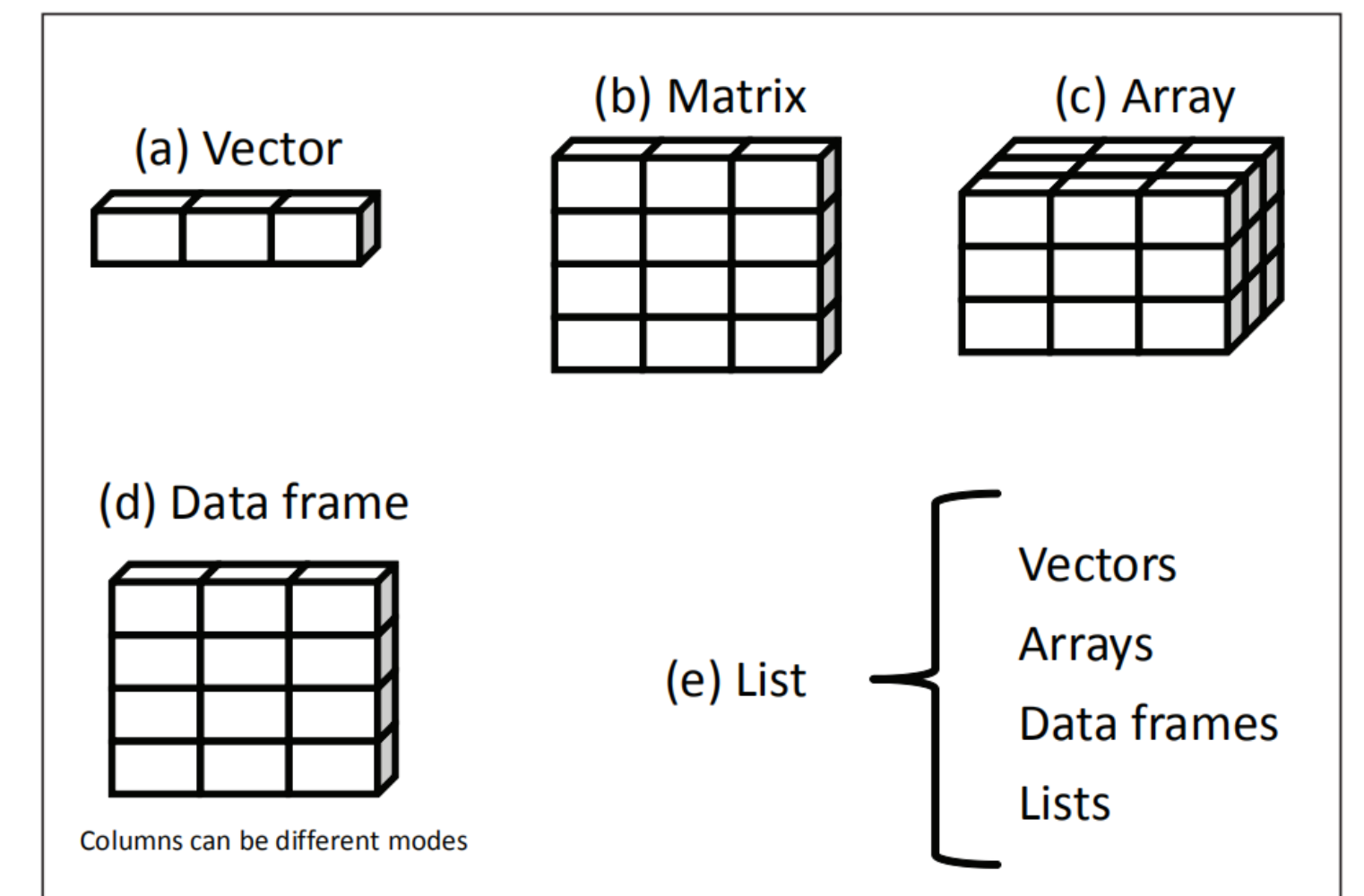
data frame	1	"R"	TRUE
	2	"S"	FALSE
	3	"T"	TRUE
	numeric	character	logical



Dataframes

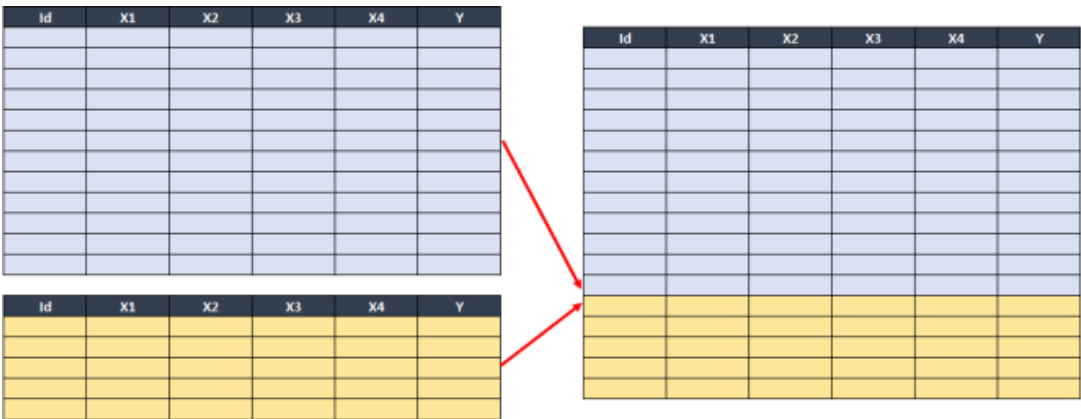
```
class(my.data.frame)
# [1] "data.frame"
ncol(my.data.frame) # Number of columns
# [1] 4
nrow(my.data.frame) # Number of rows
# [1] 3
colnames(my.data.frame) # Column names
# [1] "Budget" "Seasons" "Audience" "Actors"
rownames(my.data.frame) # Name of rows
# "Game of Thrones" "MrRobot" "WestWorld"
colSums(my.data.frame) # Sum values in columns
# Budget Seasons Audience Actors
# 525 15 394 367
rowSums(my.data.frame)
# Game of Thrones MrRobot WestWorld
# 873 133 295
```

data frame	1	"R"	TRUE
	2	"S"	FALSE
	3	"T"	TRUE
	numeric	character	logical

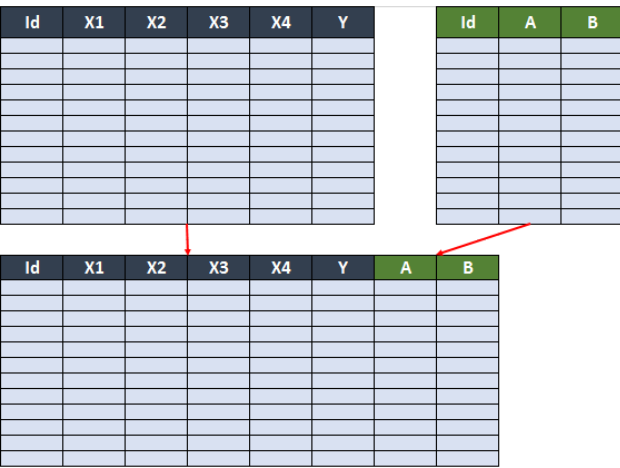


Dataframes

```
rbind(my.data.frame,my.data.frame) # appends dataframes one below the other (column names identical)
#
# Budget Seasons Audience Actors
# Game of Thrones 344 8 300 221
# MrRobot 59 4 14 56
# WestWorld 122 3 80 90
# Game of Thrones1 344 8 300 221
# MrRobot1 59 4 14 56
# WestWorld1 122 3 80 90
```



```
cbind(my.data.frame,my.data.frame) # appends dataframes one next to the other (row names identical)
#
# Budget Seasons Audience Actors Budget Seasons Audience Actors
# Game of Thrones 344 8 300 221 344 8 300 221
# MrRobot 59 4 14 56 59 4 14 56
# WestWorld 122 3 80 90 122 3 80 90
```



```
head(my.data.frame, 2) # Useful to have a look to the beginning of the dataframe (specially useful in big tables)
# Here asking to print only 2 rows
#
# Budget Seasons Audience Actors
# Game of Thrones 344 8 300 221
# MrRobot 59 4 14 56
```

```
my.data.frame[1:2,2:4] # Useful to look at specific sections of the dataframe
#
# Seasons Audience Actors
# Game of Thrones 8 300 221
# MrRobot 4 14 56
```



Dataframes

```
# Let's generate a dataframe with different data types

my.data.frame.2<-data.frame(
  Name=c("Game of Thrones", "MrRobot", "WestWorld", "Chernobyl"),
  Rating=c("Excellent", "Very Good", "Excellent", "Very Good"),
  Audience.Restriction=c(TRUE, FALSE, TRUE, FALSE)

print(my.data.frame.2)
#           Name      Rating Audience.Restriction
# 1 Game of Thrones  Excellent                TRUE
# 2      MrRobot    Very Good                FALSE
# 3   WestWorld    Excellent                TRUE
# 4   Chernobyl    Very Good                FALSE
#Rename row names
row.names(my.data.frame.2) <- my.data.frame.2[,1]
my.data.frame.2<-my.data.frame.2[,-1] # Remove redundant column 1

#           Rating Audience.Restriction
# Game of Thrones  Excellent                TRUE
# MrRobot          Very Good                FALSE
# WestWorld        Excellent                TRUE
# Chernobyl        Very Good                FALSE

str(my.data.frame.2) # Let's look at the data types within this dataframe

# 'data.frame':4 obs. of  2 variables:
#  $ Rating      : chr  "Excellent" "Very Good" "Excellent" "Very Good"
#  $ Audience.Restriction: logi  TRUE FALSE TRUE FALSE

# Variables in this case are characters and logical (TRUE/FALSE)
```


Dataframes

```
#Merge two dataframes based on a pattern
# We will use the series names to merge these dataframes as this is what they have in common

data.frame.large<-merge(my.data.frame, my.data.frame.2, by="row.names") # "by" indicates the column used for merging

#           Row.names Budget Seasons Audience Actors      Rating Audience.Restriction
# 1 Game of Thrones    344         8      300     221 Excellent              TRUE
# 2      MrRobot       59         4       14      56 Very Good              FALSE
# 3    WestWorld    122         3       80      90 Excellent              TRUE
```

NB: “Chernobyl” was not used, as it was only present in one data frame, but this could be modified



Working with tables or data frames

```
#Useful commands to work with tables or dataframes
getwd()          # get working directory
# [1] "/Users/admin"
setwd("path/to/my/directory") # set working directory

my.table<-read.table(file="table.tsv", sep="\t", header=T) # read table; several other options available
dim(my.table)      # Table dimensions
nrow(my.table)     # Number of rows
ncol(my.table)     # Number of columns
colnames(my.table) # Name of columns
rownames(my.table) # Name of rows
colSums(my.table)  # Sum of numeric values in columns
rowSums(my.table)  # Sum of numeric values in rows
head(my.table)     # See table header
t(my.table)        # Transpose table

#Table subsetting
# Format: my.table[row, column]
my.table[1,2]      # Get value from row 1, column 2
my.table[1,]       # Get values from row 1 across all columns
my.table$column.name<-NULL # Remove column
my.table[-5,-2]    # Remove row 5 and column 2
my.table[-(5:10),] # Remove rows 5 to 10, keep all columns
my.table[,-(which(colSums(my.table)==0)) ] # Remove columns that sum 0
```

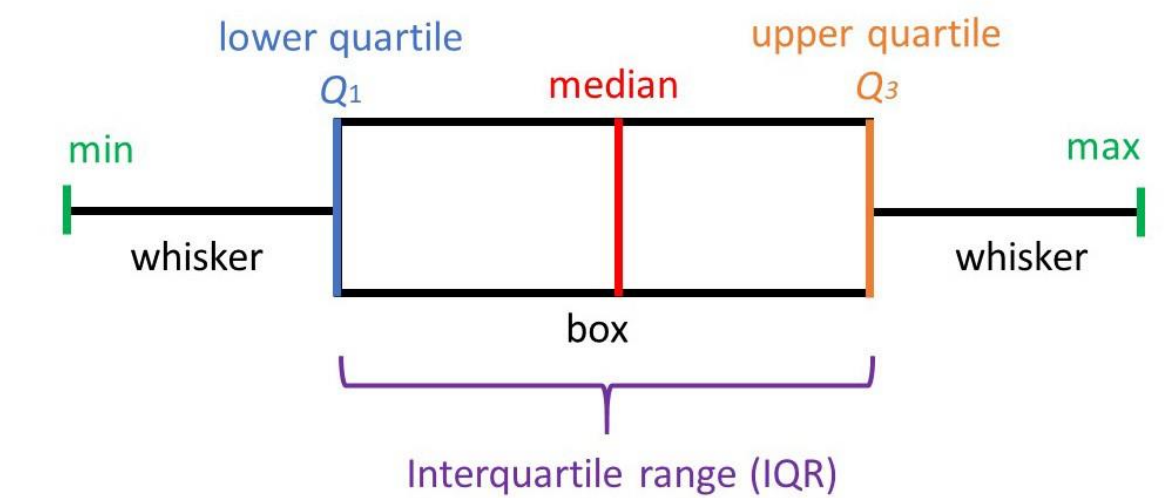
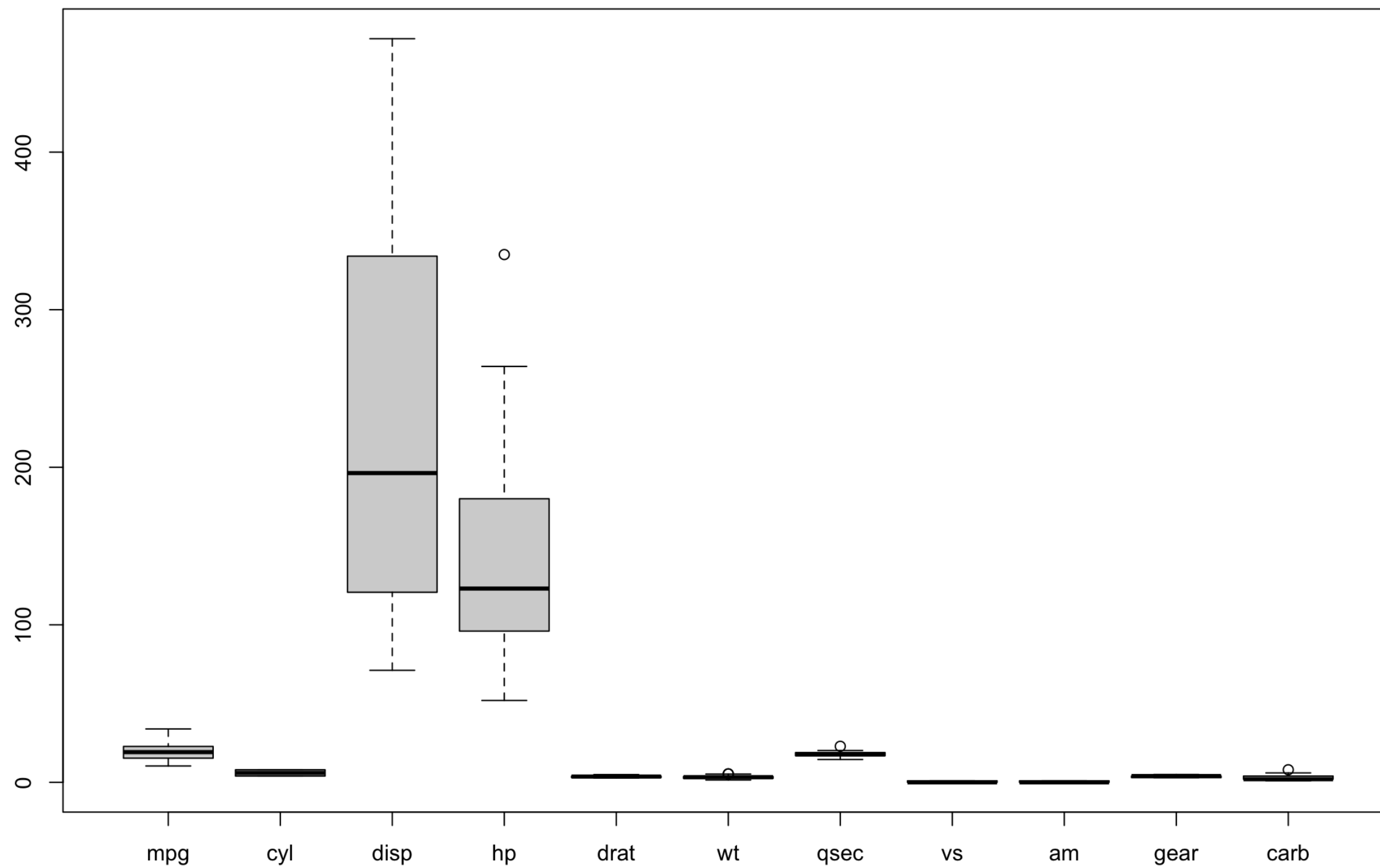
Simple plots

```
#Plotting
data("mtcars") # We load a dataset that comes with R
#The data was extracted from the 1974 Motor Trend US magazine, and comprises fuel consumption and 10 aspects
# of automobile design and performance for 32 automobiles (1973 & 74 models).

#Data structure
#
#      mpg  cyl  disp  hp drat   wt  qsec vs  am  gear carb
# Mazda RX4      21.0   6 160.0 110 3.90 2.620 16.46  0   1     4     4
# Mazda RX4 Wag  21.0   6 160.0 110 3.90 2.875 17.02  0   1     4     4
# Datsun 710      22.8   4 108.0  93 3.85 2.320 18.61  1   1     4     1
# Hornet 4 Drive  21.4   6 258.0 110 3.08 3.215 19.44  1   0     3     1
# ...

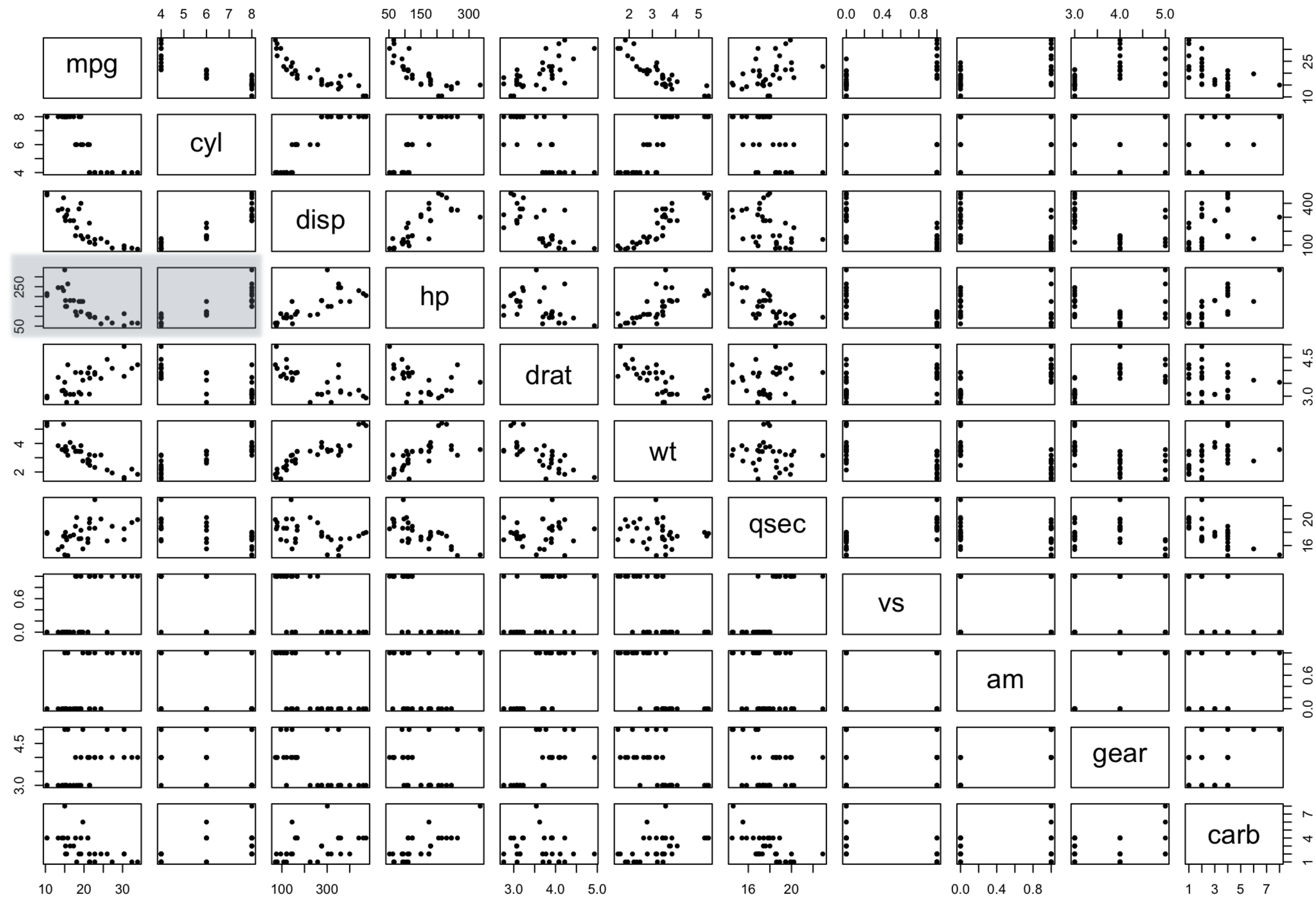
# [, 1] mpg  Miles/(US) gallon
# [, 2] cyl  Number of cylinders
# [, 3] disp Displacement (cu.in.)
# [, 4] hp  Gross horsepower
# [, 5] drat Rear axle ratio
# [, 6] wt  Weight (1000 lbs)
# [, 7] qsec 1/4 mile time
# [, 8] vs  Engine (0 = V-shaped, 1 = straight)
# [, 9] am  Transmission (0 = automatic, 1 = manual)
# [,10] gear Number of forward gears
# [,11] carb Number of carburetors
```





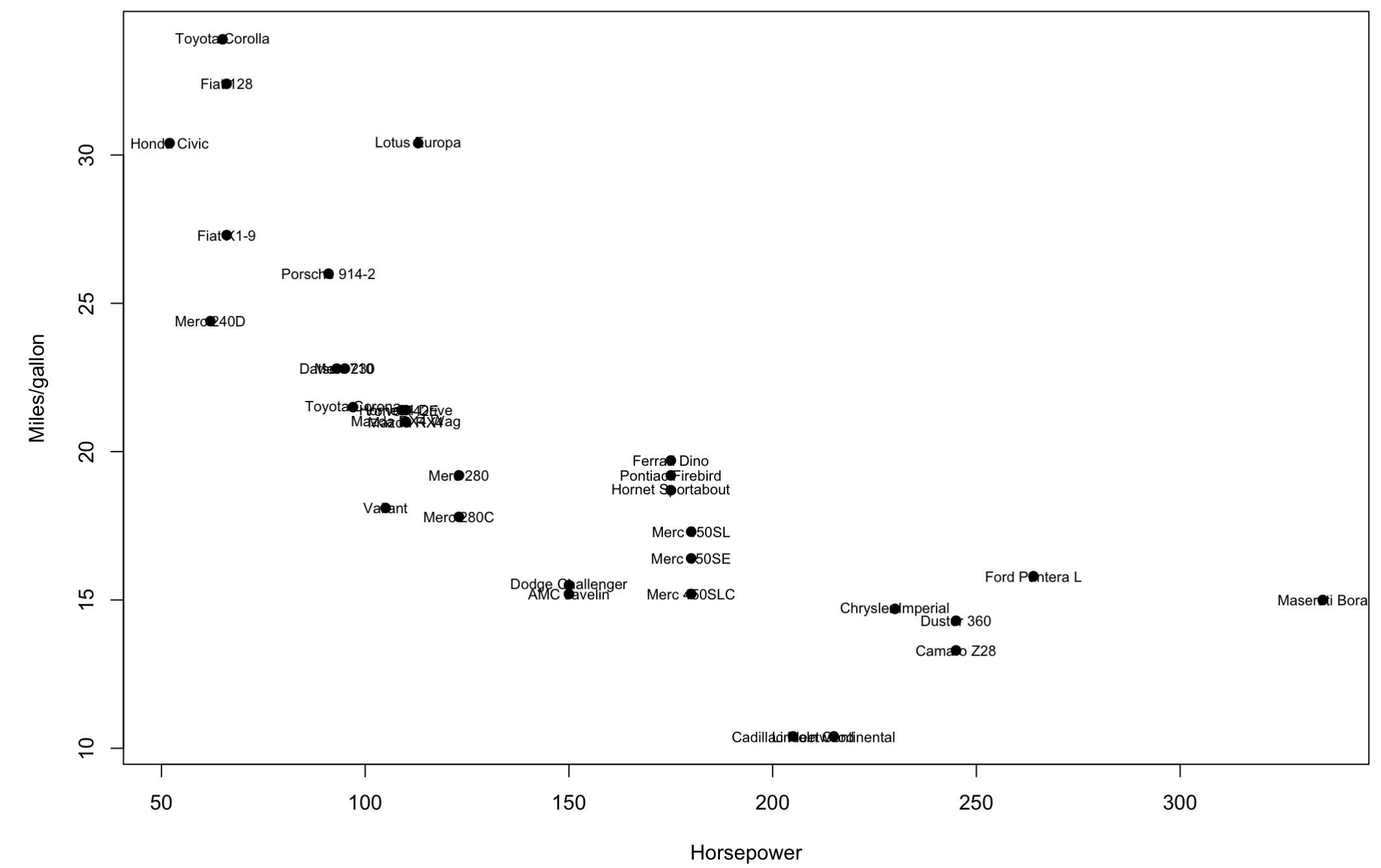
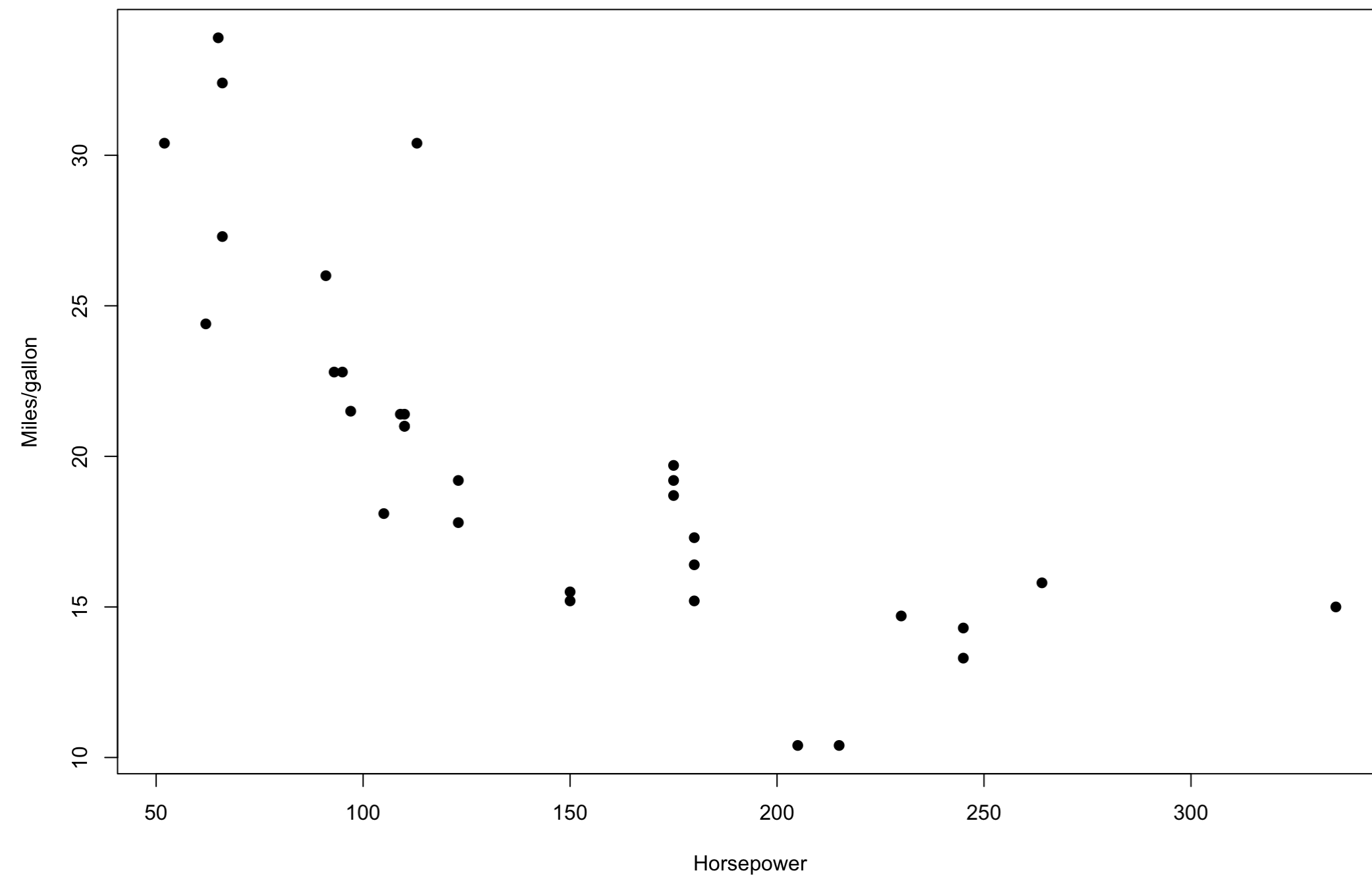
```
boxplot(mtcars) # make a boxplot of variables across car models
```

```
14 # [, 1]   mpg Miles/(US) gallon
15 # [, 2]   cyl Number of cylinders
16 # [, 3]   disp  Displacement (cu.in.)
17 # [, 4]   hp   Gross horsepower
18 # [, 5]   drat  Rear axle ratio
19 # [, 6]   wt   Weight (1000 lbs)
20 # [, 7]   qsec  1/4 mile time
21 # [, 8]   vs   Engine (0 = V-shaped, 1 = straight)
22 # [, 9]   am   Transmission (0 = automatic, 1 = manual)
23 # [,10]   gear  Number of forward gears
24 # [,11]   carb  Number of carburetors
```

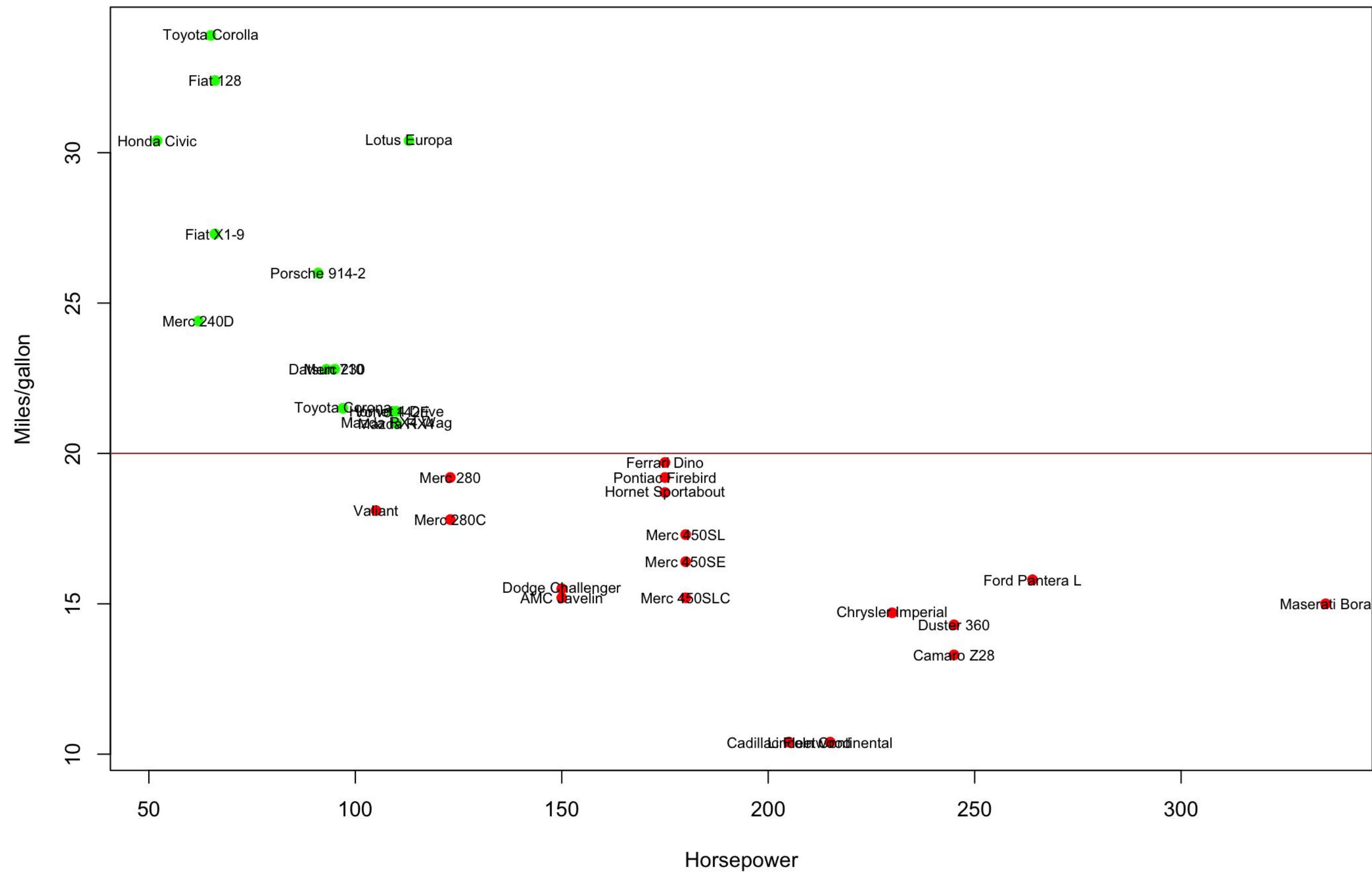



```
plot(mtcars, pch=19, cex=0.6) # make x-y plots for all variables
```

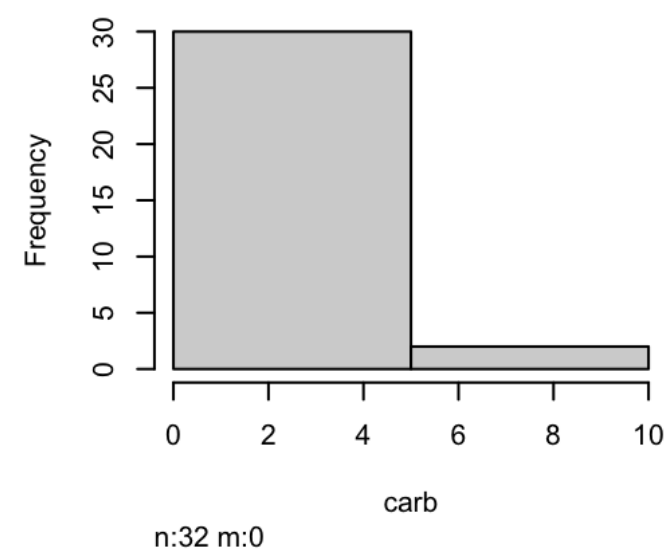
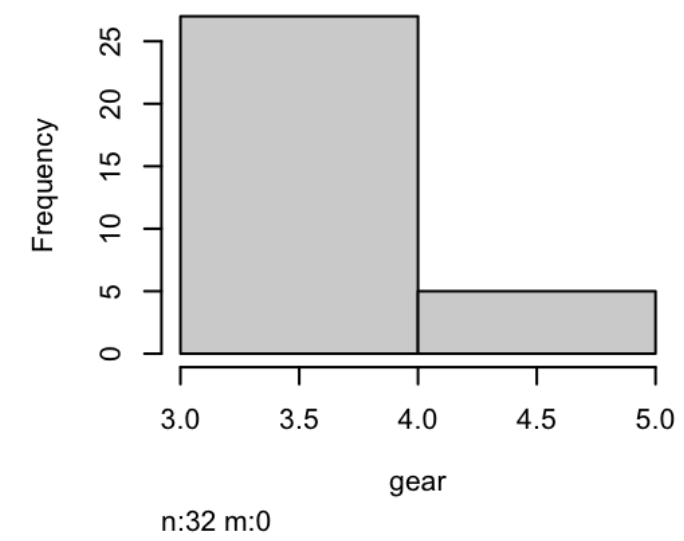
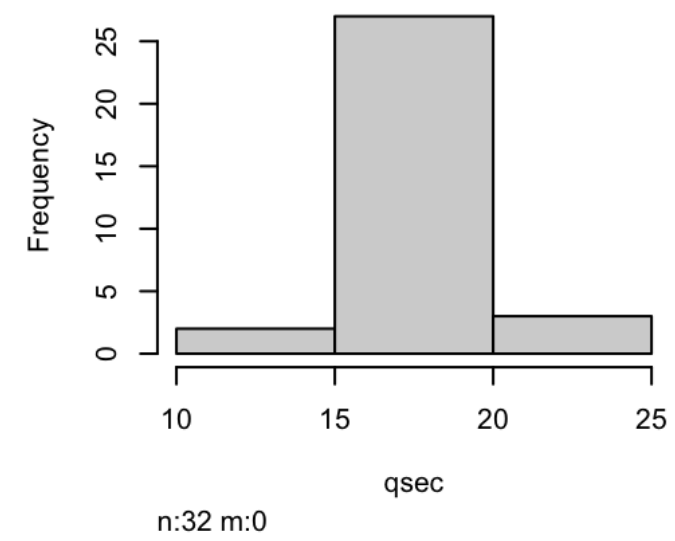
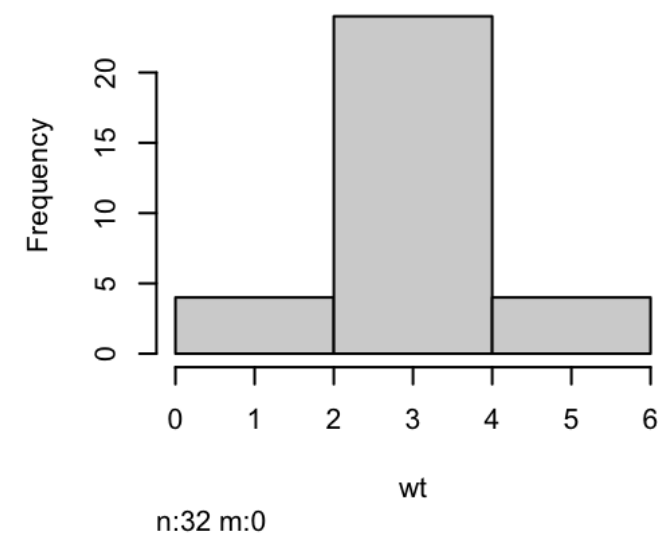
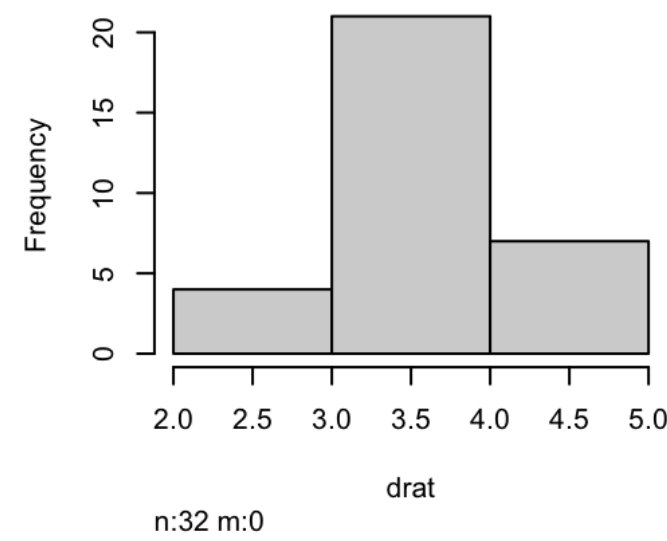
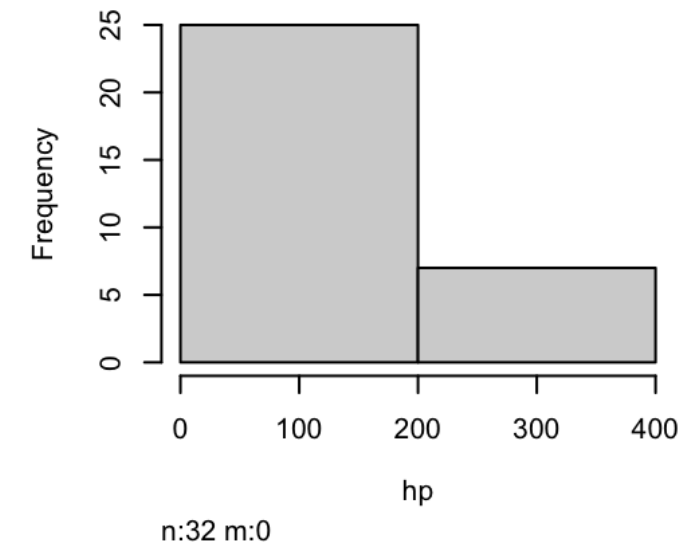
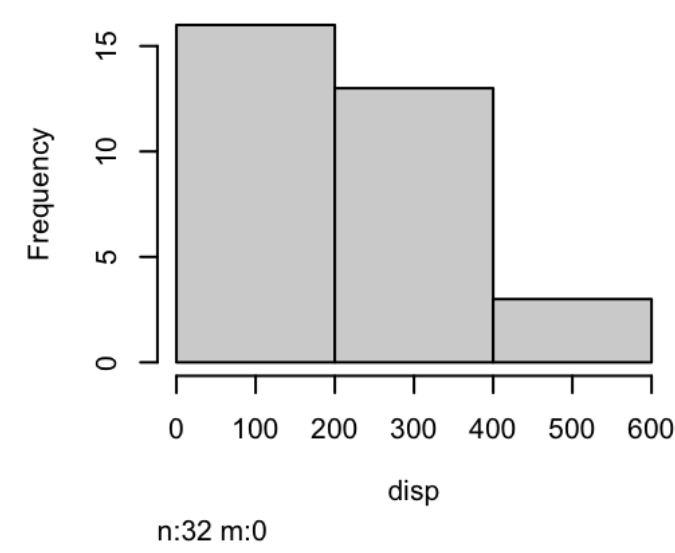
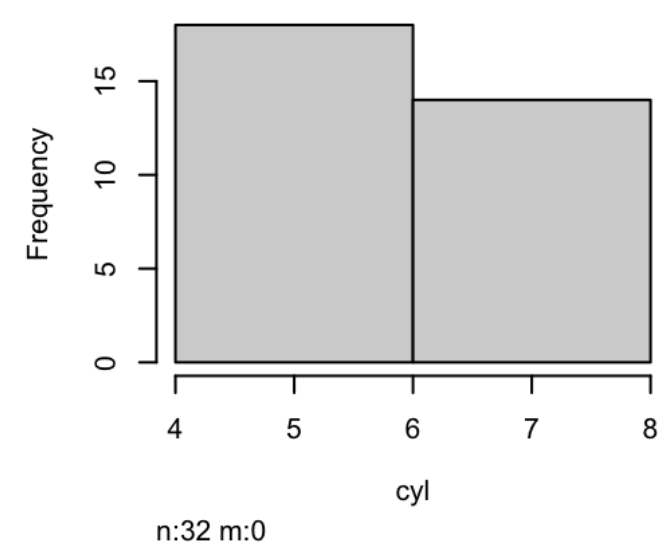
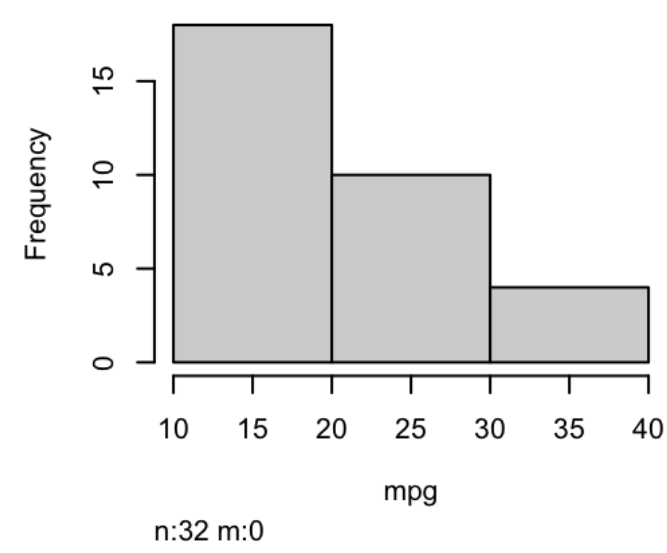
```
14 # [, 1]    mpg Miles/(US) gallon
15 # [, 2]    cyl Number of cylinders
16 # [, 3]    disp  Displacement (cu.in.)
17 # [, 4]    hp   Gross horsepower
18 # [, 5]    drat  Rear axle ratio
19 # [, 6]    wt   Weight (1000 lbs)
20 # [, 7]    qsec  1/4 mile time
21 # [, 8]    vs   Engine (0 = V-shaped, 1 = straight)
22 # [, 9]    am   Transmission (0 = automatic, 1 = manual)
23 # [,10]    gear  Number of forward gears
24 # [,11]    carb  Number of carburetors
```

```
plot(mtcars$hp, mtcars$mpg, xlab="Horsepower", ylab="Miles/gallon", pch=19) # we plot horsepower vs. miles per gallon
text(mtcars$hp, mtcars$mpg, row.names(mtcars), cex=0.7) # we add the car model
```

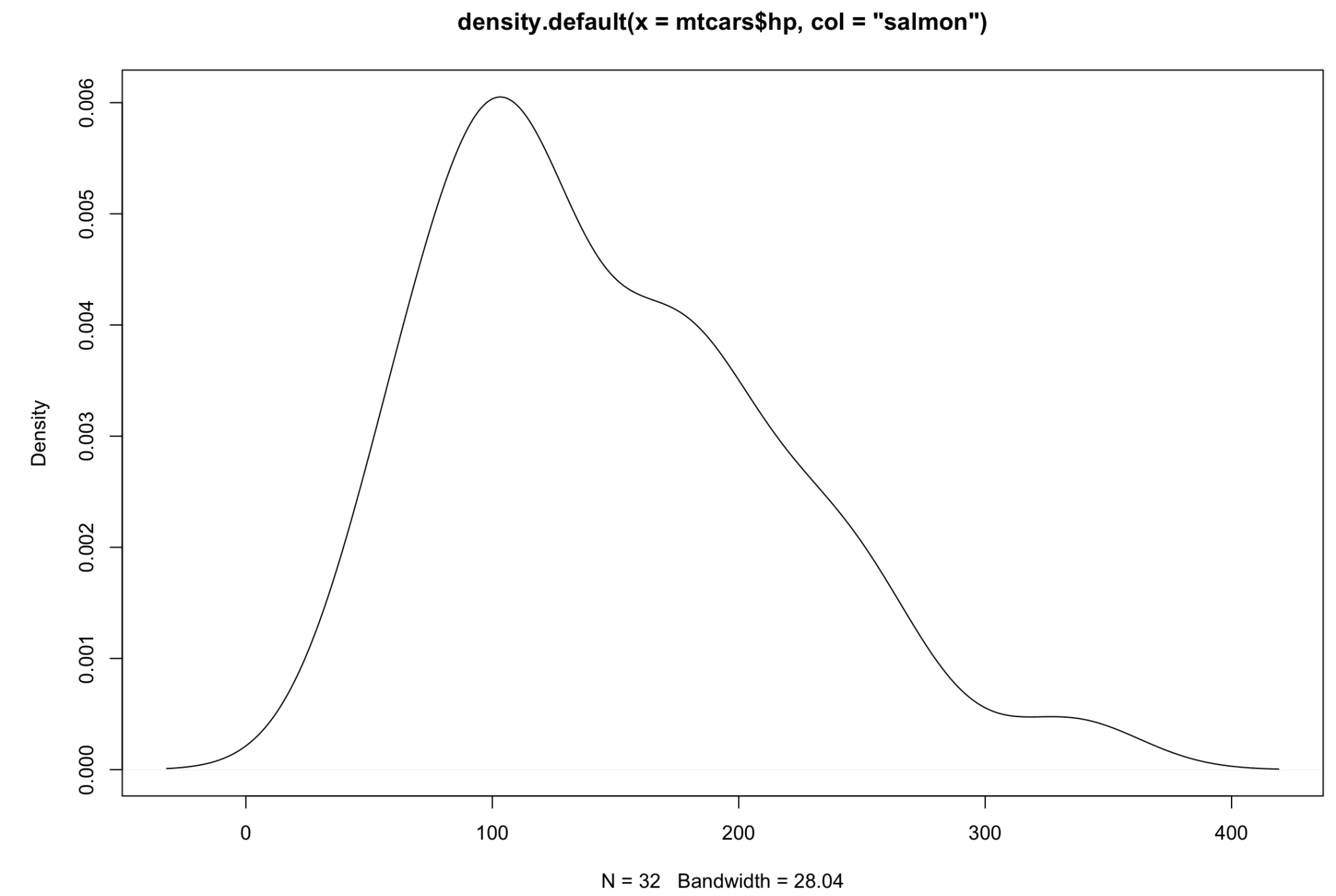
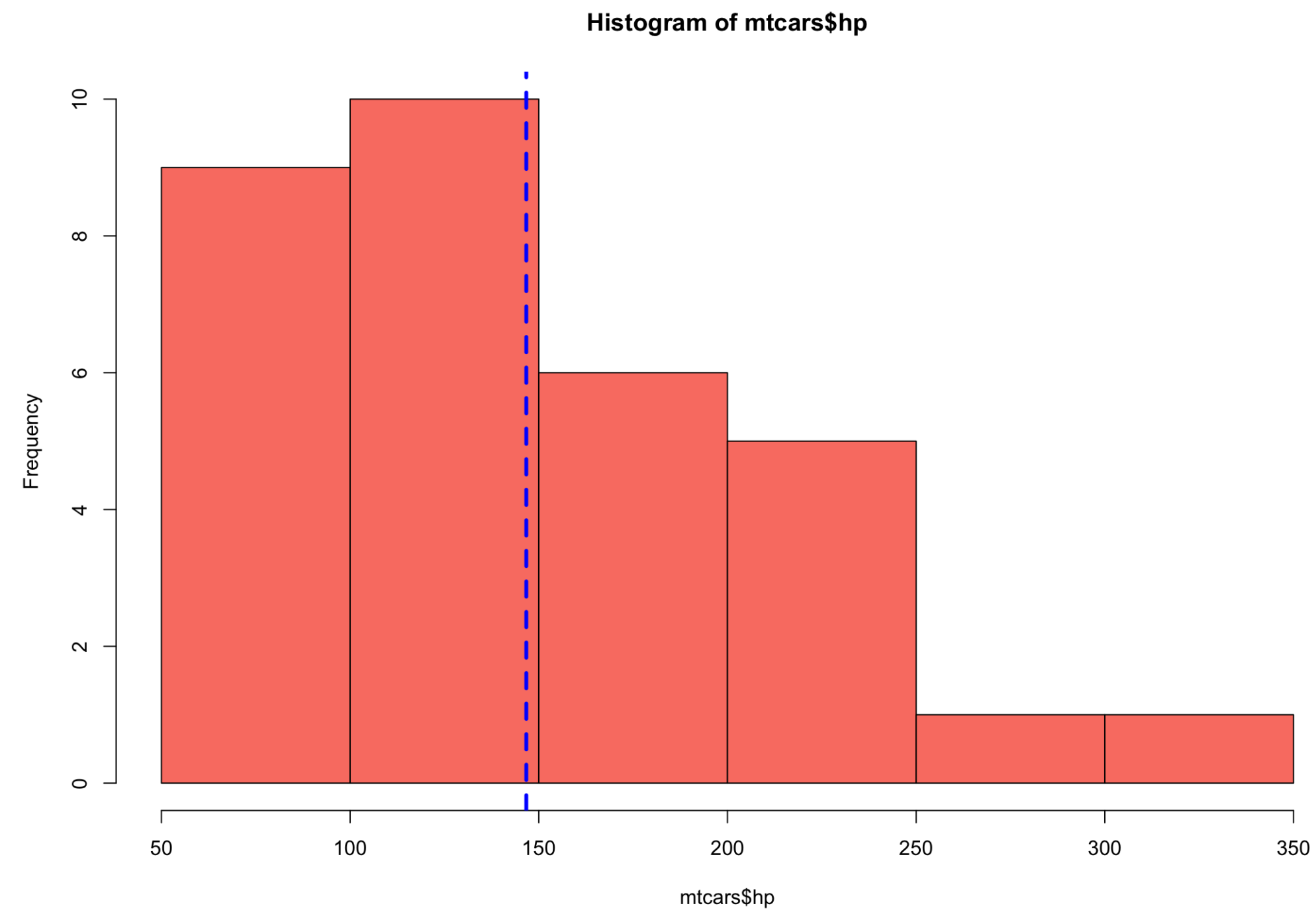


```
plot(mtcars$hp, mtcars$mpg, xlab="Horsepower", ylab="Miles/gallon", pch=19, col=ifelse(mtcars$mpg<20,"red", "green"))
# We color dots according to
# a condition (20<mpg<20 mpg)
text(mtcars$hp, mtcars$mpg, row.names(mtcars), cex=0.7) # we add the car model
abline(h=20, col="brown") # we add an horizontal line at "20"
```



```
hist(mtcars) # we plot an histogram for the different variables
```

```
14 # [, 1]   mpg Miles/(US) gallon
15 # [, 2]   cyl Number of cylinders
16 # [, 3]   disp  Displacement (cu.in.)
17 # [, 4]   hp   Gross horsepower
18 # [, 5]   drat  Rear axle ratio
19 # [, 6]   wt   Weight (1000 lbs)
20 # [, 7]   qsec  1/4 mile time
21 # [, 8]   vs   Engine (0 = V-shaped, 1 = straight)
22 # [, 9]   am   Transmission (0 = automatic, 1 = manual)
23 # [,10]   gear  Number of forward gears
24 # [,11]   carb  Number of carburetors
```

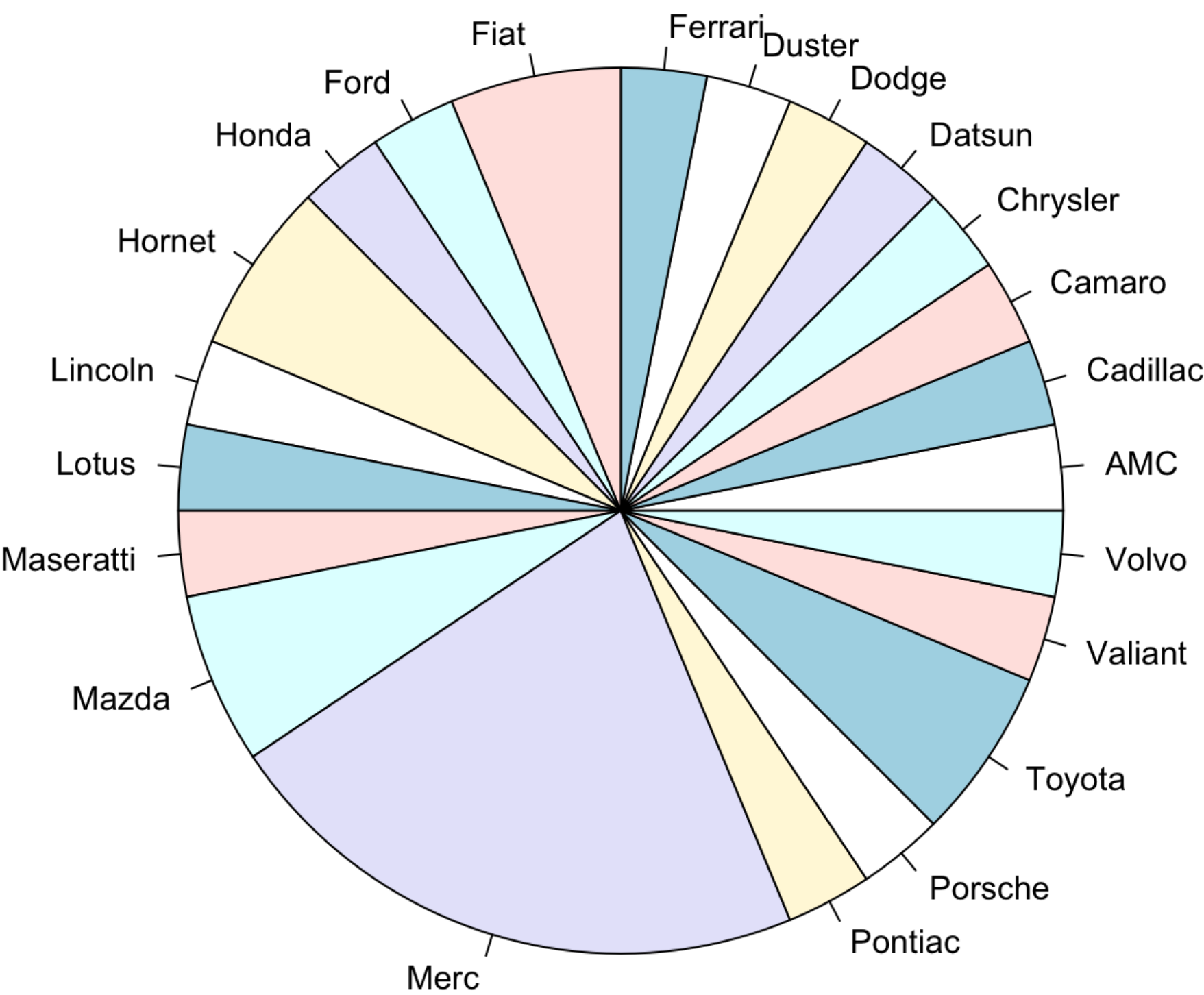


```
hist(mtcars$hp, col="salmon")
abline(v=mean(mtcars$hp), col="blue", lwd=3, lty=2)
plot(density(mtcars$hp))
```

```
brands<-c("Mazda", "Mazda","Datsun", "Hornet", "Hornet", "Valiant", "Duster", "Merc", "Merc", "Merc", "Merc", "Merc","Merc","Merc","Cadillac",
          "Lincoln","Chrysler","Fiat",
          "Honda", "Toyota", "Toyota","Dodge","AMC","Camaro","Pontiac", "Fiat","Porsche", "Lotus", "Ford","Ferrari", "Maseratti","Volvo")
mtcars$brand<-brands # we add an extra column with brands
mtcars[1:5,] # let's double check

#           mpg cyl disp  hp drat   wt  qsec vs am gear carb  brand
# Mazda RX4      21.0   6  160 110 3.90 2.620 16.46  0  1    4    4  Mazda
# Mazda RX4 Wag  21.0   6  160 110 3.90 2.875 17.02  0  1    4    4  Mazda
# Datsun 710      22.8   4  108  93 3.85 2.320 18.61  1  1    4    1 Datsun
# Hornet 4 Drive  21.4   6  258 110 3.08 3.215 19.44  1  0    3    1 Hornet
# Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2 Hornet

pie(table(mtcars$brand)) # we make a piechart of the brands
```



Installing and loading packages

```
1 #Installing packages
2
3 # R has a large repository of packages for different applications
4
5 install.packages("spaa") # Installs the ecological package spaa
6 install.packages("vegan") # Installs the community ecology package Vegan with hundreds of functions
7 library("vegan") # load Vegan
8 #Loading required package: permute
9 # Loading required package: lattice
10 # This is vegan 2.5-7
11
12
13 # Other relevant packages
14
15 install.packages("readr") # To read and write files
16 install.packages("readxl") # To read excel files
17 install.packages("dplyr") # To manipulate dataframes
18 install.packages("tibble") # To work with data frames
19 install.packages("tidyr") # To work with data frames
20 install.packages("stringr") # To manipulate strings
21 install.packages("ggplot2") # To do plots
22 install.packages("kableExtra") # necessary for nice table formatting with knitr
23 install.packages("tidyverse")
24
25 if (!requireNamespace("BiocManager", quietly = TRUE))
26   install.packages("BiocManager")
27 #BiocManager::install(version = "3.10")
28 BiocManager::install(c("dada2", "phyloseq", "Biostrings"))
29
30 install.packages("devtools")
31 devtools::install_github("pr2database/pr2database") # Installs directly from github resources that are not in R repos
32 devtools::install_github("GuillemSalazar/EcolUtils") # Installs other tools for ecological analyses
33
34 #Load libraries
35 ##### Load libraries #####
36
37 library("dada2")
38 library("phyloseq")
39 library("Biostrings")
40 library("ggplot2")
41 library("dplyr")
42 library("tidyr")
43 library("tibble")
44 library("readxl")
45 library("readr")
46 library("stringr")
47 library("kableExtra")
48 library("tidyverse")
49 #library("pr2database")
50
```

TUTORIAL



-The code is available in:

https://github.com/krabberod/UNIS_AB332_2024/