DSCI351-451- ISLR2,3 Intro R, Lin. Regr. Labs

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Contents

11.2.2.1 ISLR R Labs are at the end of each chapter

11.2.2.2 Chapter 2 Lab: Introduction to R

Notice: ISLR was published in 2013

ggplot2 Graphics are not used!

- Since this is before ggplot2 (or even ggplot) were released

And there are no pipes!

- So this was before the tidyverse R packages were released
- not even the dplyr or plyr or magrittr R packages had been released

Also in ISLR, they use = instead of the proper <- assignment operator

- So their code style is different from our Google R style

11.2.2.2.1 Basic Commands

```
x <- c(1, 3, 2, 5) # concatenate a vector
x # dispay the vector
```

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

```
x <-  c(1, 6, 2) # concatenate a vector
x # display a vector
```

```
## [1] 1 6 2
```

```r
y <-  c(1, 4, 3) # concatenate a vector

length(x) # get the length of a vector
```

```
## [1] 3
```

```r
length(y) # get the length of a vector
```

```
## [1] 3
```

```r
x + y # add two vectors
```

```
## [1]  2 10  5
```

```r
ls() # list objects in the work space
```

```
## [1] "x" "y"
```

```r
rm(x, y) # remove objects in the work space
ls() # list objects in the workspace
```

```
## character(0)
```

```r
rm(list = ls()) # remove all objects in the workspace
```

```r
# ?matrix # help on matrix
x <- matrix(data = c(1, 2, 3, 4), nrow = 2, ncol = 2) # make a matrix
x # display a matrix
```

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

```r
x <- matrix(c(1, 2, 3, 4), 2, 2) # make a matrix
matrix(c(1, 2, 3, 4), 2, 2, byrow = TRUE) # matrix filled by row
```

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

```r
sqrt(x) # Square root of each value in the matrix
```

```
##          [,1]     [,2]
## [1,] 1.000000 1.732051
## [2,] 1.414214 2.000000
```

```r
x^2 # Square each value in the matrix
```

```
##      [,1] [,2]
## [1,]    1    9
## [2,]    4   16
```

```r
x <- rnorm(50) # randomly generates 50 values
y <- x + rnorm(50, mean = 50, sd = 0.1) # randomly generates 50 values with
                    # certain criteria and adds the contents of the vector x

cor(x, y) # Finds the correlation between the two vectors
```

```
## [1] 0.9940185
```

```r
set.seed(1303) # sets a new seed
rnorm(50) # makes 50 new random values
```

```
##  [1] -1.1439763145  1.3421293656  2.1853904757  0.5363925179  0.0631929665
##  [6]  0.5022344825 -0.0004167247  0.5658198405 -0.5725226890 -1.1102250073
## [11] -0.0486871234 -0.6956562176  0.8289174803  0.2066528551 -0.2356745091
## [16] -0.5563104914 -0.3647543571  0.8623550343 -0.6307715354  0.3136021252
## [21] -0.9314953177  0.8238676185  0.5233707021  0.7069214120  0.4202043256
## [26] -0.2690521547 -1.5103172999 -0.6902124766 -0.1434719524 -1.0135274099
## [31]  1.5732737361  0.0127465055  0.8726470499  0.4220661905 -0.0188157917
## [36]  2.6157489689 -0.6931401748 -0.2663217810 -0.7206364412  1.3677342065
## [41]  0.2640073322  0.6321868074 -1.3306509858  0.0268888182  1.0406363208
## [46]  1.3120237985 -0.0300020767 -0.2500257125  0.0234144857  1.6598706557
```

```r
set.seed(3) # sets a new seed
y <- rnorm(100) # Makes 100 random variables
```

```r
mean(y) # Calculates the mean of the vector
```

```
## [1] 0.01103557
```

```r
var(y) # calculates the variance of the vector
```

```
## [1] 0.7328675
```

```r
sqrt(var(y)) # calculates the square root of the variance
```

```
## [1] 0.8560768
```

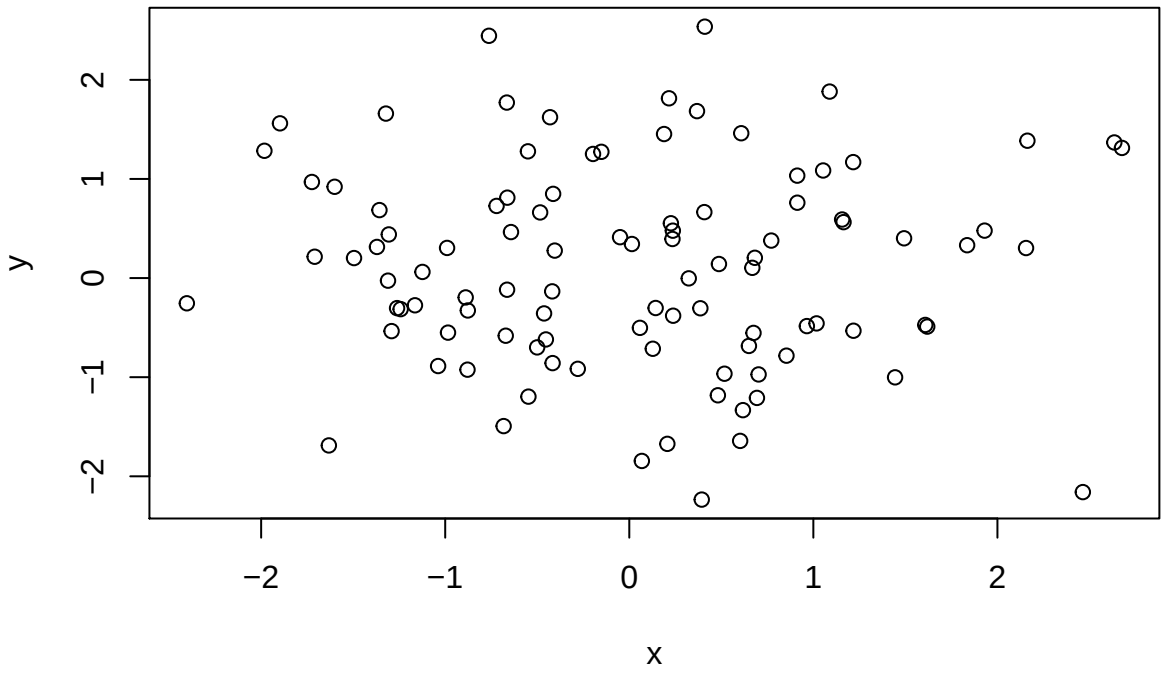
```r
sd(y) # calculates the standard deviation.
```

```
## [1] 0.8560768
```

```r
      # Which is the square root of the variance
```

11.2.2.2.2 Graphics

```r
x <- rnorm(100) # caluculates 100 random values
y <- rnorm(100) # calculates 100 random values

plot(x, y) # plots these two vectors against each other
```




```
plot(x, y, xlab = "this is the x-axis", ylab = "this is the y-axis",
     main = "Plot of X vs Y") # Plots the same data but applies labels to the plot
```


```
pdf("Figure.pdf") # starts the pdf device

plot(x, y, col = "green") # plots the data
dev.off() # turns off the device and prints the pdf to file
```

```
## pdf
```

```
##   2
```

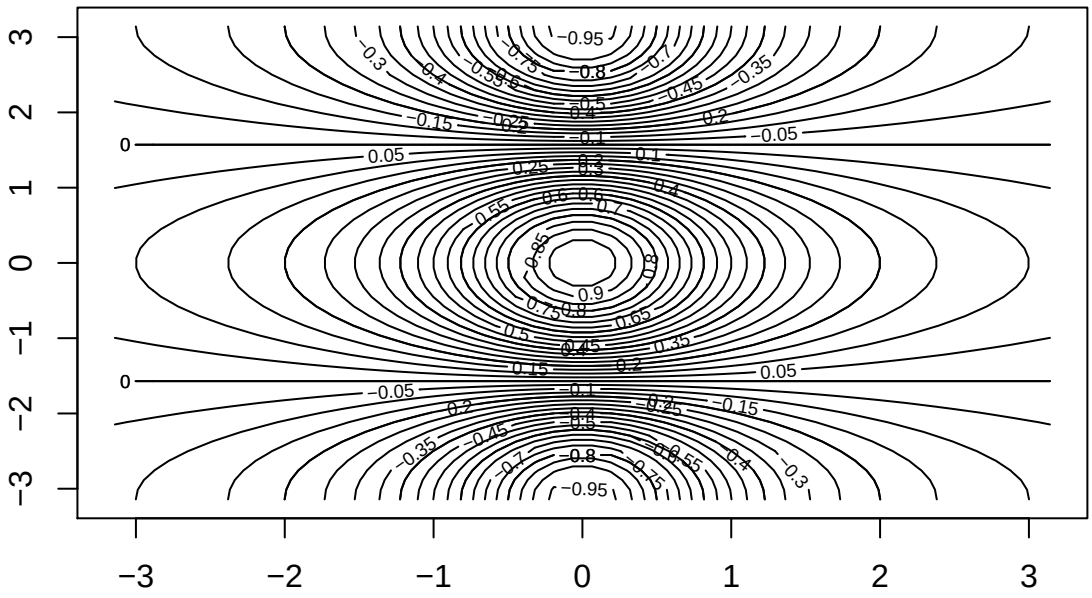
```
x <- seq(1, 10) # generates a sequence of 10 values
x # displays the above values
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

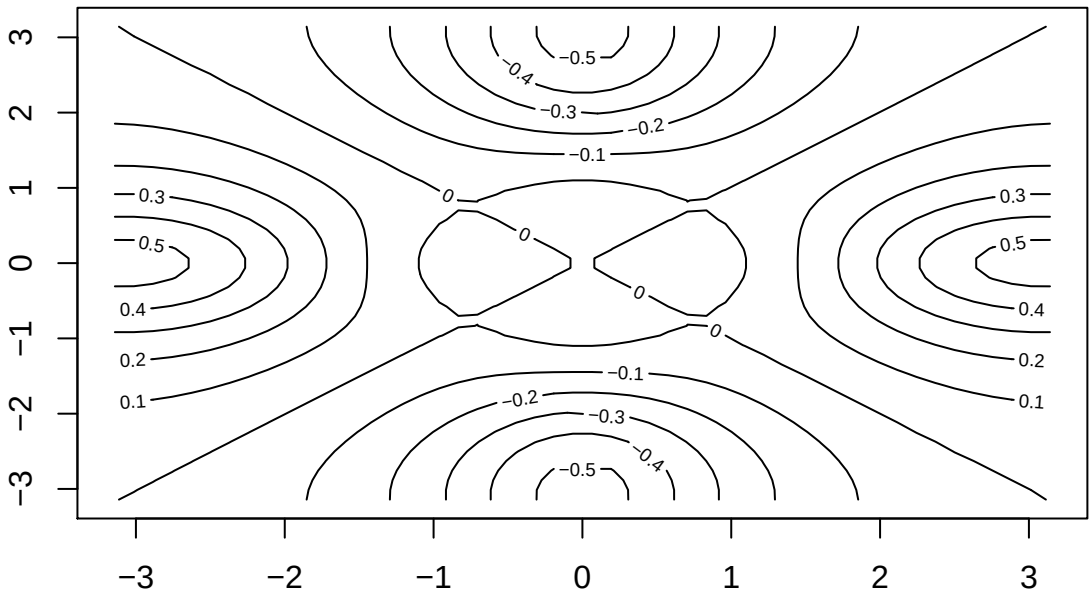
```
x <- 1:10 # this does the exact same thing as the sequence function (for integers)
x # displays the vector
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

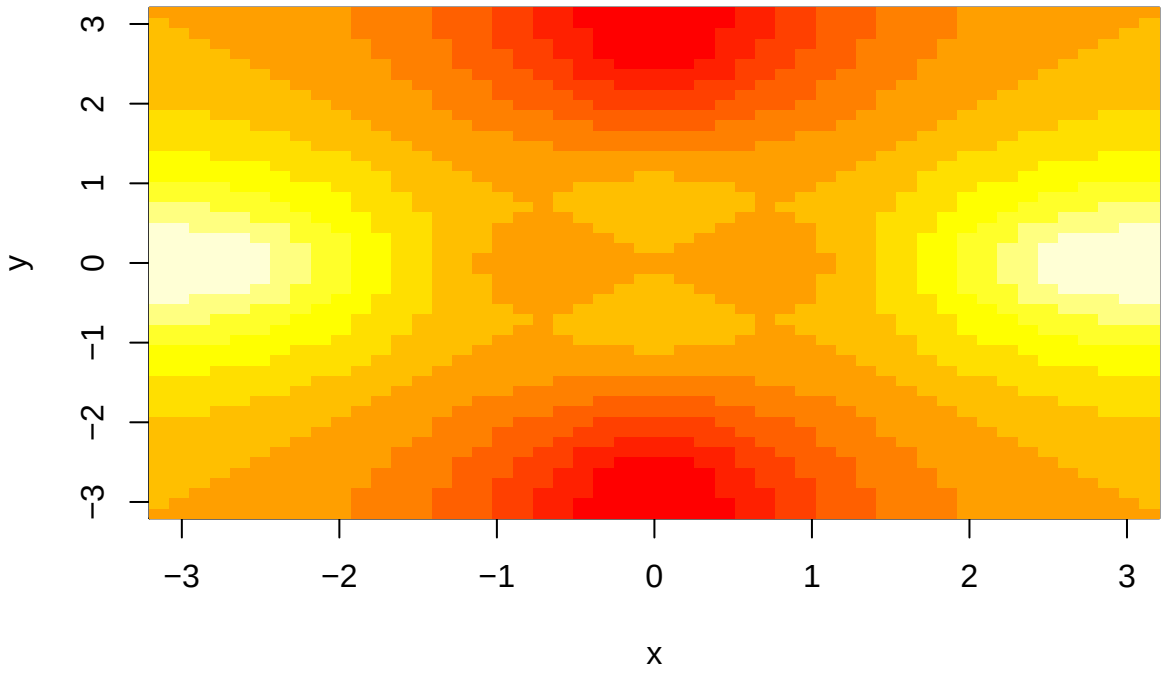
```
x <- seq(-pi, pi, length = 50) # Takes the two end limits and generates 50 numbers that fit inbetween
y <- x # sets x to y
f <- outer(x, y, function(x, y) cos(y)/(1 + x^2)) #x dotted with the transpose of y
contour(x, y, f) # generates a contour
contour(x, y, f, nlevels = 45, add = T) # Generates another contour plot with more contour lines
```



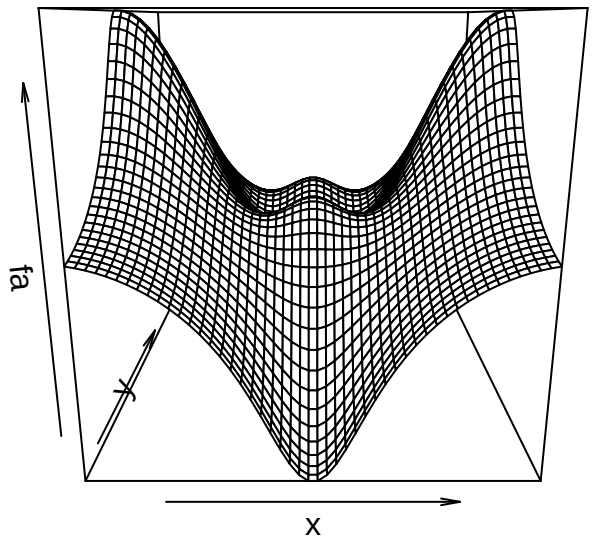

```
fa <- (f - t(f))/2 # a manipulation of the data
contour(x, y, fa, nlevels = 15) # Plots the new contour
```



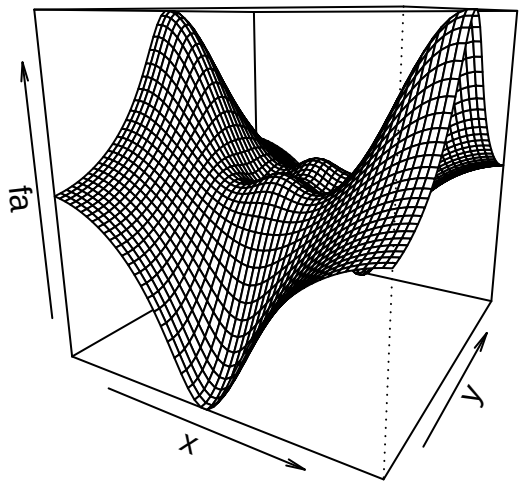

```
image(x, y, fa) # turns the contour into a heatmap image
```



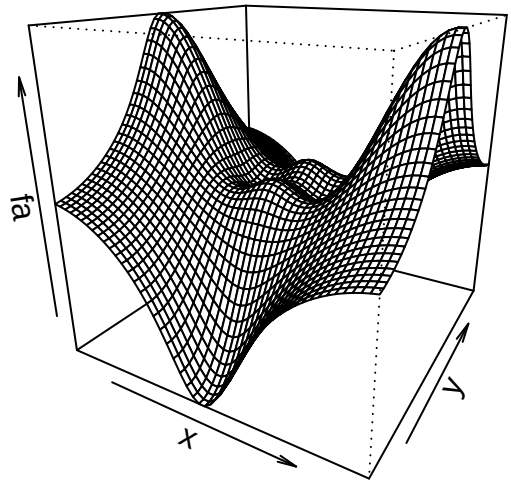

```
persp(x, y, fa) # creates a perspective plot of the data
```



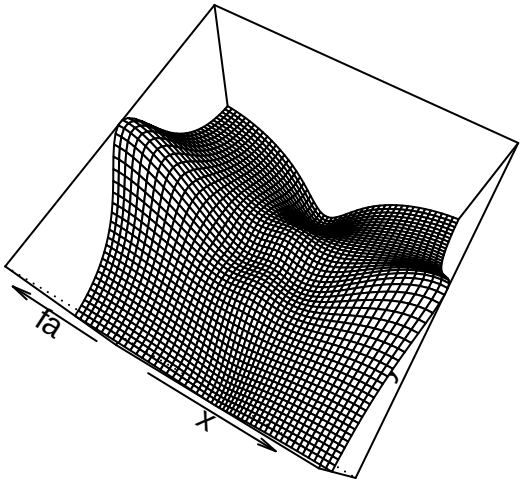

```
persp(x, y, fa, theta = 30) # rotates the perspective plot by 30 degrees
```



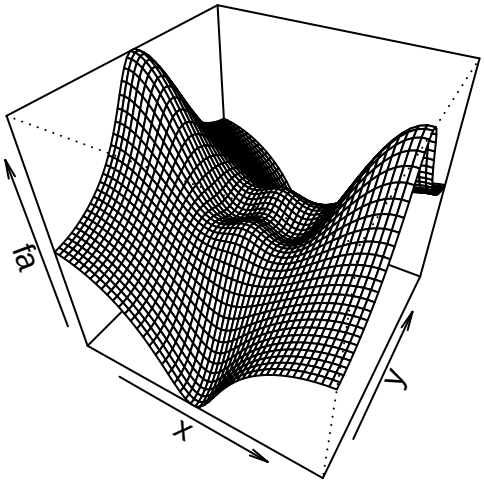

```
persp(x, y, fa, theta = 30, phi = 20) # another rotation
```




```
persp(x, y, fa, theta = 30, phi = 70) # another rotation
```




```
persp(x, y, fa, theta = 30, phi = 40) # another rotation
```



11.2.2.2.3 Indexing Data

```
A <- matrix(1:16, 4, 4) # generates a 4 by 4 matrix
A # displays the matrix
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    5    9   13
## [2,]    2    6   10   14
## [3,]    3    7   11   15
## [4,]    4    8   12   16
```

```
A[2, 3] # gets one value of the matrix
```

```
## [1] 10
```

```
A[c(1, 3), c(2, 4)] # grabs a few points from the matrix
```

```
##      [,1] [,2]
## [1,]    5   13
## [2,]    7   15
```

```r
A[1:3, 2:4] # gets a range of points from the matrix
```

```
##      [,1] [,2] [,3]
## [1,]    5    9   13
## [2,]    6   10   14
## [3,]    7   11   15
```

```r
A[1:2, ] # gets two rows
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    5    9   13
## [2,]    2    6   10   14
```

```r
A[, 1:2] # gets two columns
```

```
##      [,1] [,2]
## [1,]    1    5
## [2,]    2    6
## [3,]    3    7
## [4,]    4    8
```

```r
A[1, ] # gets the first row
```

```
## [1]  1  5  9 13
```

```r
A[-c(1, 3), ] # gets not rows 1 and 3
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    2    6   10   14
## [2,]    4    8   12   16
```

```r
A[-c(1, 3), -c(1, 3, 4)] # gets not those values
```

```
## [1] 6 8
```

```r
dim(A) # gets the dimensions of A
```

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

11.2.2.2.4 Loading Data

```r
library(ISLR)
attach(Auto)
# Auto <- read.table("Auto.data")
# fix(Auto)
# Auto <- read.table("Auto.data",header = T,na.strings = "?")
# fix(Auto)

Auto <- read.csv("data/Auto.csv", header = T, na.strings = "?")
fix(Auto)
dim(Auto)
```

```
## [1] 397   9
```

```r
Auto[1:4, ]
```

```
##   mpg cylinders displacement horsepower weight acceleration year origin
## 1  18         8          307        130   3504         12.0   70      1
## 2  15         8          350        165   3693         11.5   70      1
```

```
## 3  18         8          318        150   3436         11.0   70      1
## 4  16         8          304        150   3433         12.0   70      1
##                       name
## 1 chevrolet chevelle malibu
## 2         buick skylark 320
## 3        plymouth satellite
## 4             amc rebel sst
```

```
Auto = na.omit(Auto)
dim(Auto)
```

```
## [1] 392   9
```

```
names(Auto)
```

```
## [1] "mpg"          "cylinders"    "displacement" "horsepower"
## [5] "weight"       "acceleration" "year"         "origin"
## [9] "name"
```

```
attach(Auto)
```

```
## The following objects are masked from Auto (pos = 3):
##
##     acceleration, cylinders, displacement, horsepower, mpg, name,
##     origin, weight, year
```

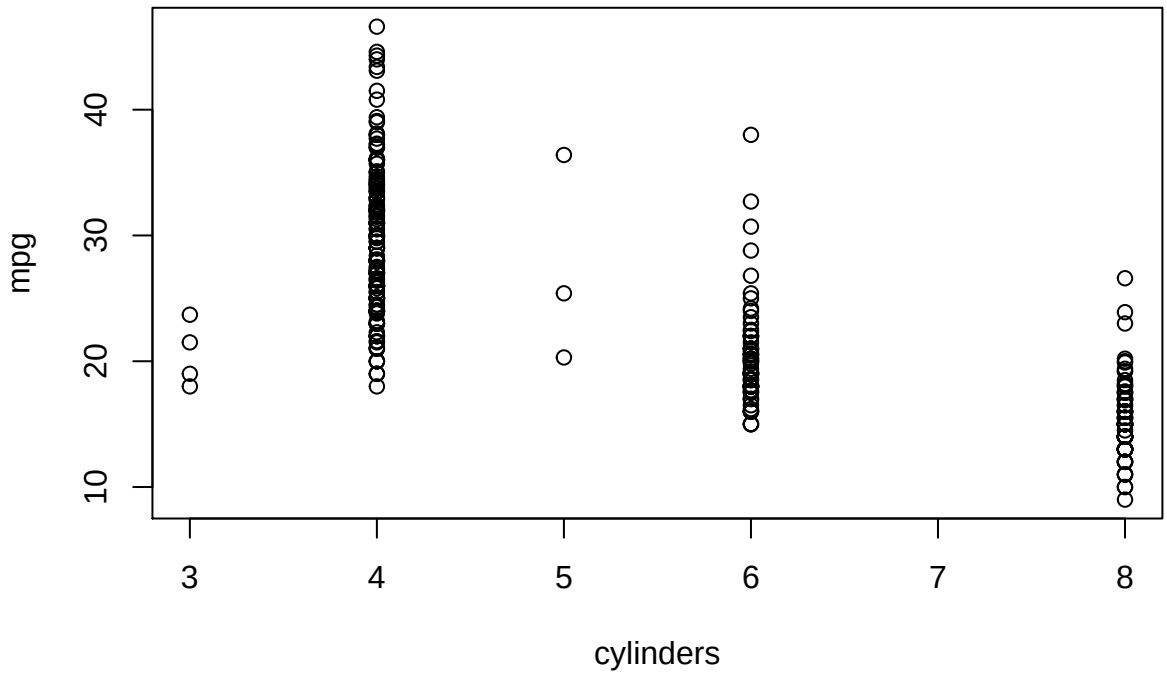
11.2.2.2.5 Additional Graphical and Numerical Summaries

```
library(ISLR)
plot(cylinders, mpg)
# plot(Auto$cylinders, Auto$mpg)
attach(Auto)
```

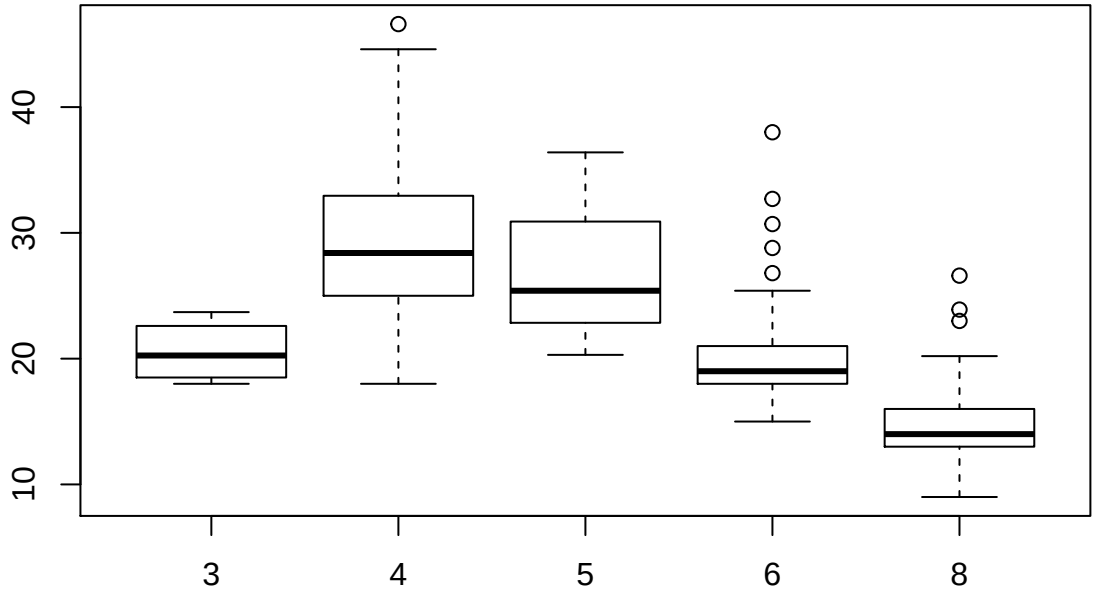
```
## The following objects are masked from Auto (pos = 3):
##
##     acceleration, cylinders, displacement, horsepower, mpg, name,
##     origin, weight, year
```

```
## The following objects are masked from Auto (pos = 4):
##
##     acceleration, cylinders, displacement, horsepower, mpg, name,
##     origin, weight, year
```

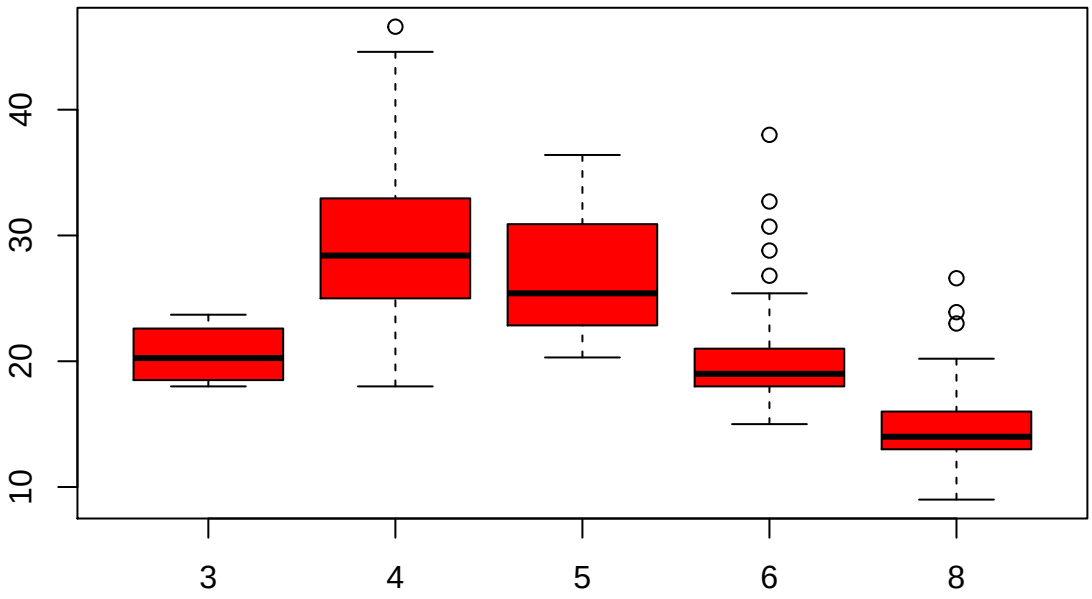
```
plot(cylinders, mpg)
```



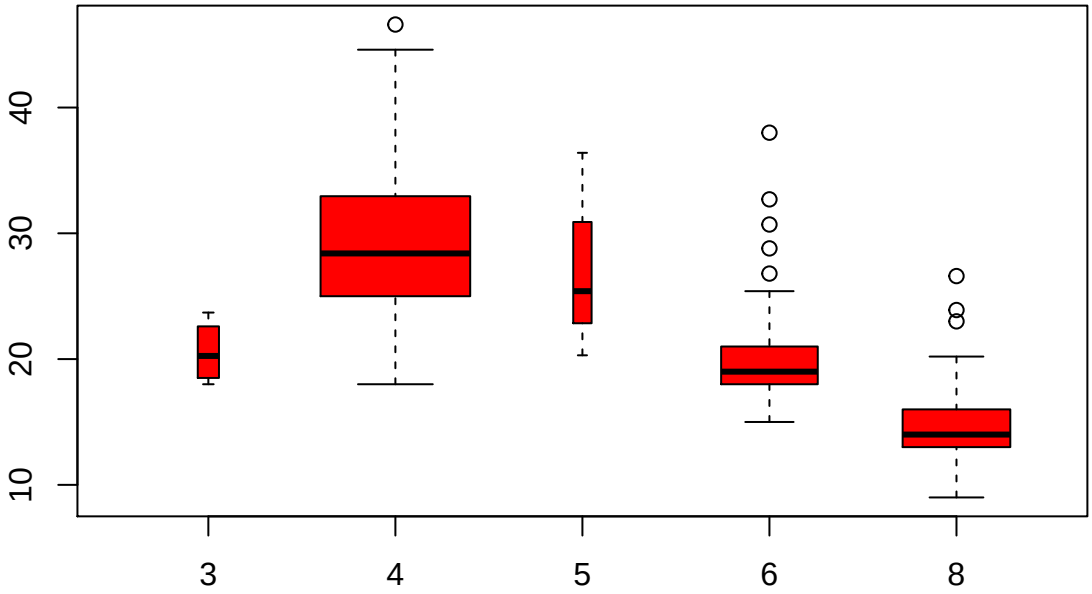

```
cylinders = as.factor(cylinders)
plot(cylinders, mpg)
```



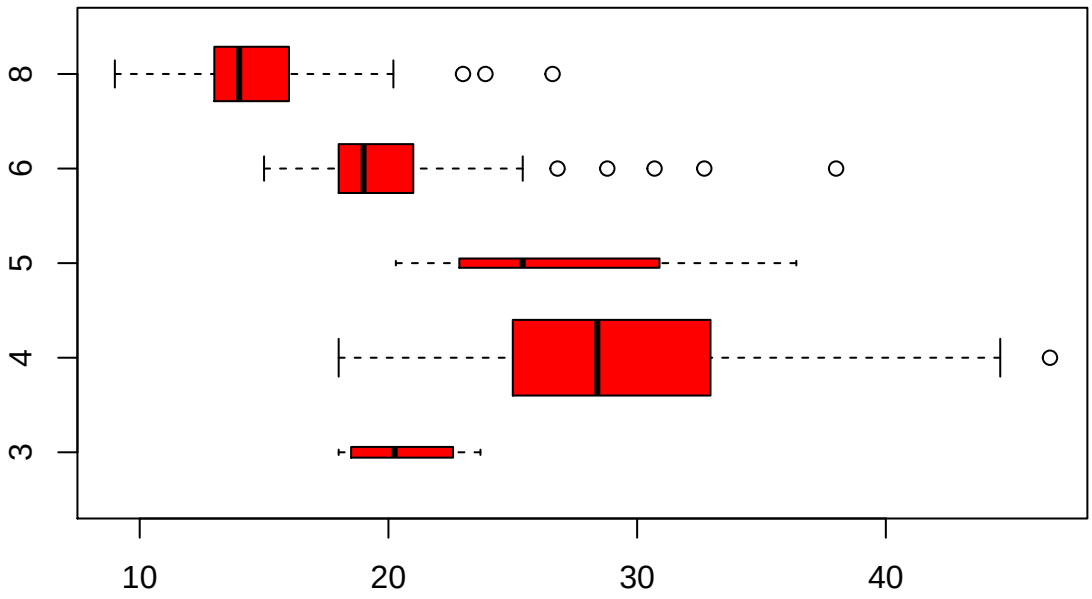

```
plot(cylinders, mpg, col = "red")
```



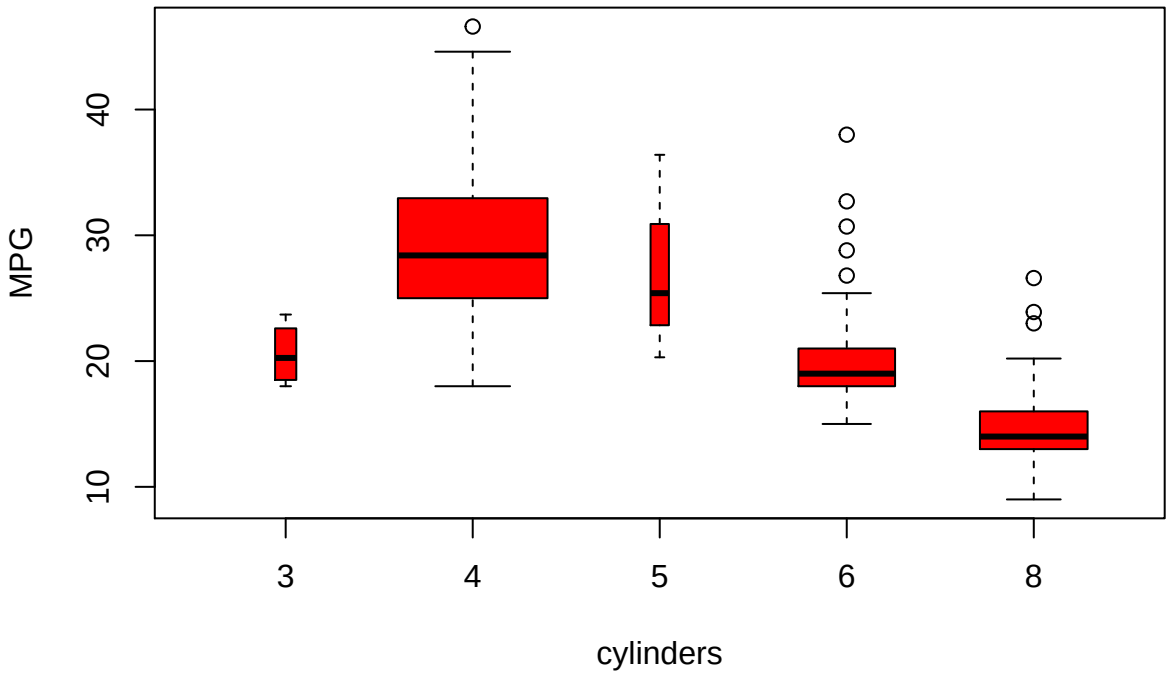

```
plot(cylinders, mpg, col = "red", varwidth = T)
```



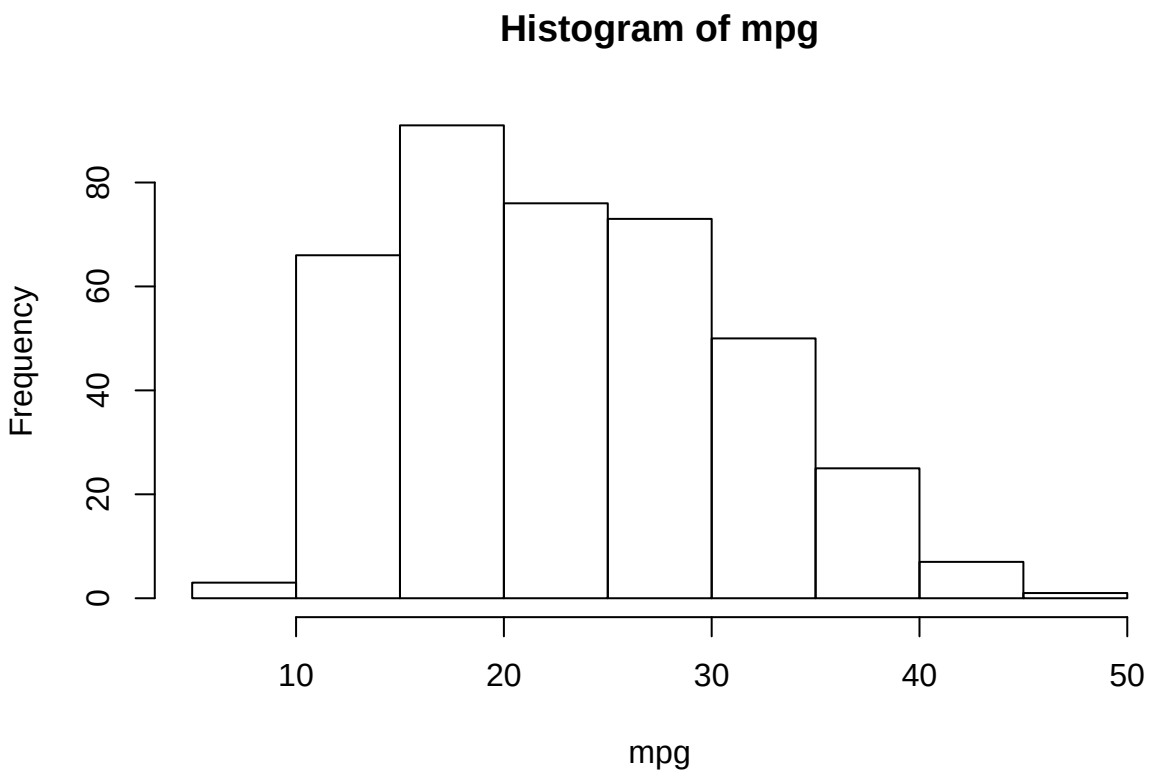

```
plot(cylinders, mpg, col = "red", varwidth = T,horizontal = T)
```



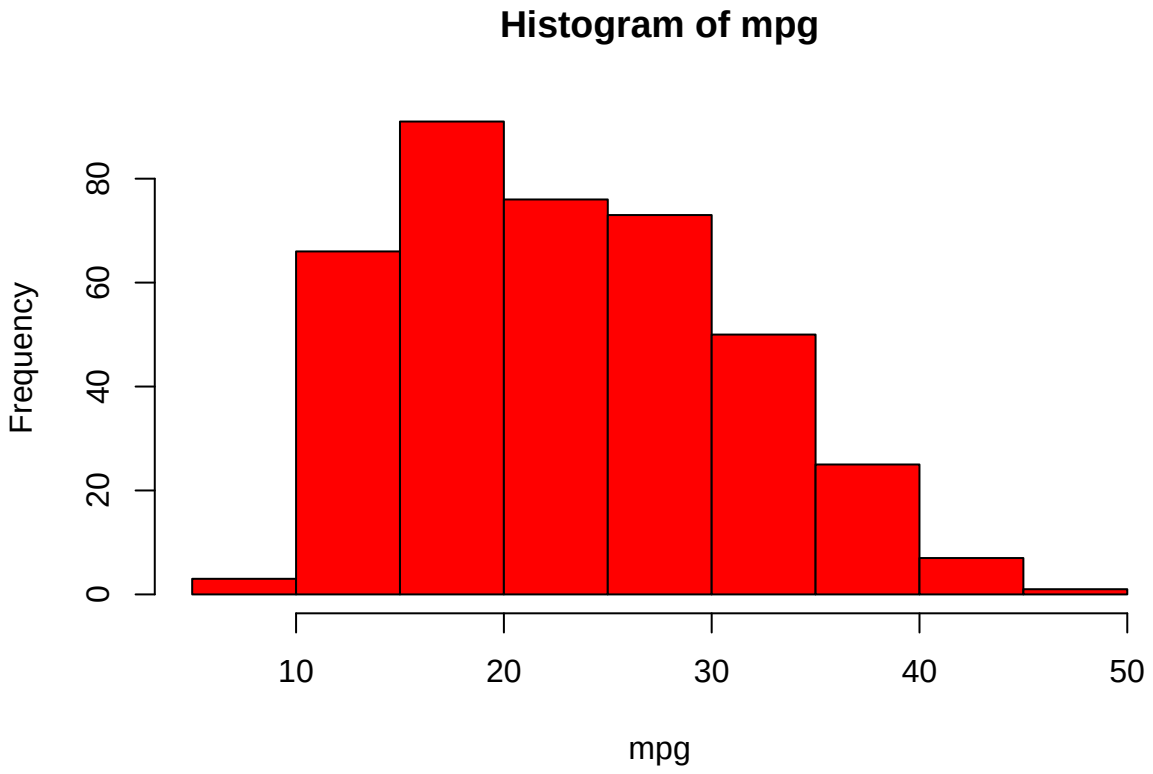

```
plot(cylinders, mpg, col = "red", varwidth = T, xlab = "cylinders", ylab = "MPG")
```



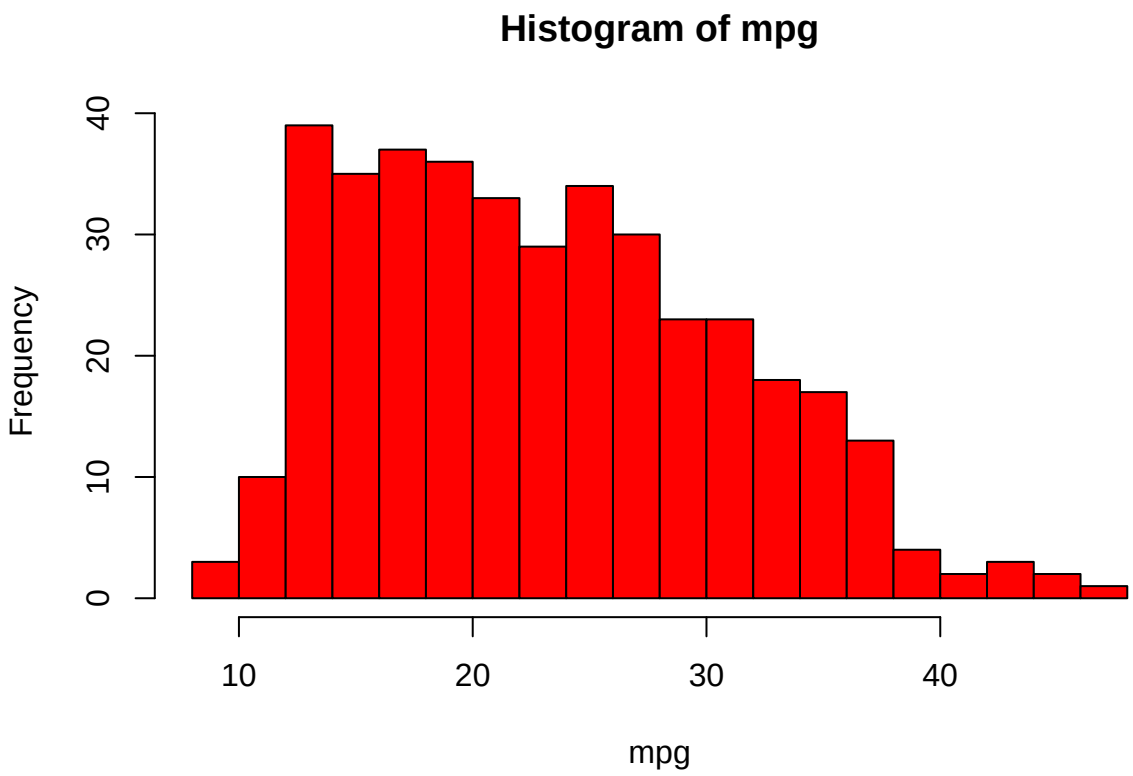

```
hist(mpg)
```



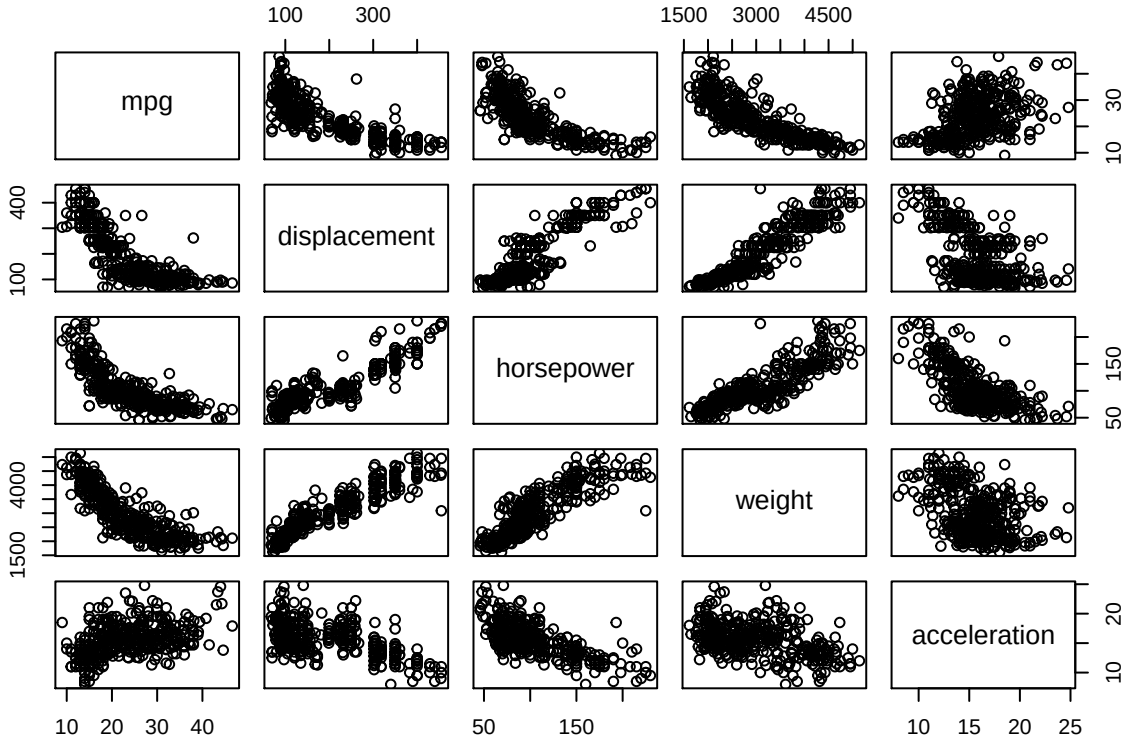

```
hist(mpg, col = 2)
```



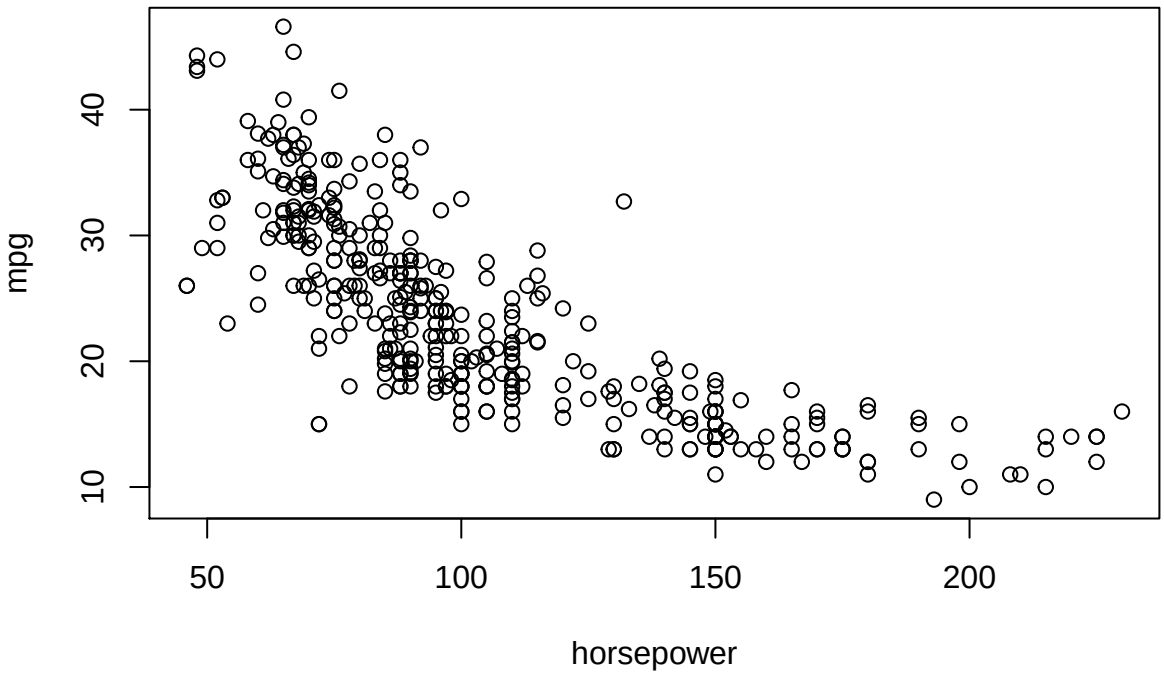

```
hist(mpg, col = 2, breaks = 15)
```




```
# pairs(Auto)
pairs(~ mpg + displacement + horsepower + weight + acceleration, Auto)
```




```
plot(horsepower, mpg)
identify(horsepower, mpg, name)
```




```
## integer(0)
```

```
summary(Auto)
```

```
##       mpg          cylinders      displacement     horsepower
##  Min.   : 9.00   Min.   :3.000   Min.   : 68.0   Min.   : 46.0
##  1st Qu.:17.00   1st Qu.:4.000   1st Qu.:105.0   1st Qu.: 75.0
##  Median :22.75   Median :4.000   Median :151.0   Median : 93.5
##  Mean   :23.45   Mean   :5.472   Mean   :194.4   Mean   :104.5
##  3rd Qu.:29.00   3rd Qu.:8.000   3rd Qu.:275.8   3rd Qu.:126.0
##  Max.   :46.60   Max.   :8.000   Max.   :455.0   Max.   :230.0
##
##      weight      acceleration        year           origin
##  Min.   :1613   Min.   : 8.00   Min.   :70.00   Min.   :1.000
##  1st Qu.:2225   1st Qu.:13.78   1st Qu.:73.00   1st Qu.:1.000
##  Median :2804   Median :15.50   Median :76.00   Median :1.000
##  Mean   :2978   Mean   :15.54   Mean   :75.98   Mean   :1.577
##  3rd Qu.:3615   3rd Qu.:17.02   3rd Qu.:79.00   3rd Qu.:2.000
##  Max.   :5140   Max.   :24.80   Max.   :82.00   Max.   :3.000
##
##                  name
##  amc matador       :  5
##  ford pinto        :  5
##  toyota corolla    :  5
##  amc gremlin       :  4
##  amc hornet        :  4
##  chevrolet chevette:  4
##  (Other)           :365
```

```
summary(mpg)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    9.00   17.00   22.75   23.45   29.00   46.60
```

11.2.2.3 Chapter 3 Lab: Linear Regression

```
library(MASS)
library(ISLR)
```

11.2.2.3.1 Simple Linear Regression

```
# fix(Boston)
names(Boston)
```

```
##  [1] "crim"    "zn"      "indus"   "chas"    "nox"     "rm"      "age"
##  [8] "dis"     "rad"     "tax"     "ptratio" "black"   "lstat"   "medv"
```

```
# lm.fit=lm(medv~lstat) # linear fit (fails)
lm.fit <- lm(medv~lstat, data = Boston) # linear fit (success with data)
attach(Boston) # attaches the dataset
lm.fit <- lm(medv~lstat) # linear model again
lm.fit # shows the lm fit
```

```
##
## Call:
## lm(formula = medv ~ lstat)
##
## Coefficients:
## (Intercept)        lstat
##       34.55        -0.95
```

```
summary(lm.fit) # summary stats of the lm fit
```

```
##
## Call:
## lm(formula = medv ~ lstat)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.168  -3.990  -1.318   2.034  24.500
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 34.55384    0.56263   61.41   <2e-16 ***
## lstat       -0.95005    0.03873  -24.53   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.216 on 504 degrees of freedom
## Multiple R-squared:  0.5441, Adjusted R-squared:  0.5432
## F-statistic: 601.6 on 1 and 504 DF,  p-value: < 2.2e-16
```

```
names(lm.fit) # names of the components in the lm object
```

```
##  [1] "coefficients"  "residuals"     "effects"       "rank"
##  [5] "fitted.values" "assign"        "qr"            "df.residual"
##  [9] "xlevels"       "call"          "terms"         "model"
```

```
coef(lm.fit) # coefs of the model
```

```
## (Intercept)       lstat
```

```
##  34.5538409  -0.9500494
```

```
confint(lm.fit) # 95% interval
```

```
##                 2.5 %     97.5 %
## (Intercept) 33.448457 35.6592247
## lstat       -1.026148 -0.8739505
```

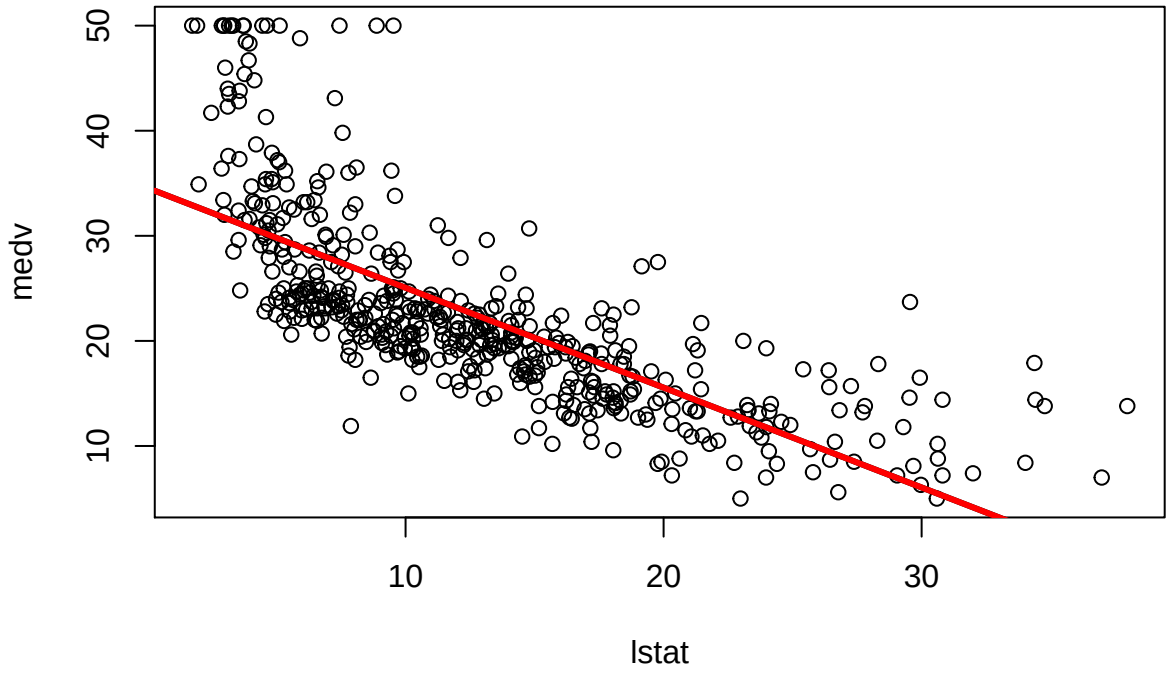
```
predict(lm.fit, data.frame(lstat = (c(5,10,15))), interval = "confidence") # prediction with interval
```

```
##        fit      lwr      upr
## 1 29.80359 29.00741 30.59978
## 2 25.05335 24.47413 25.63256
## 3 20.30310 19.73159 20.87461
```

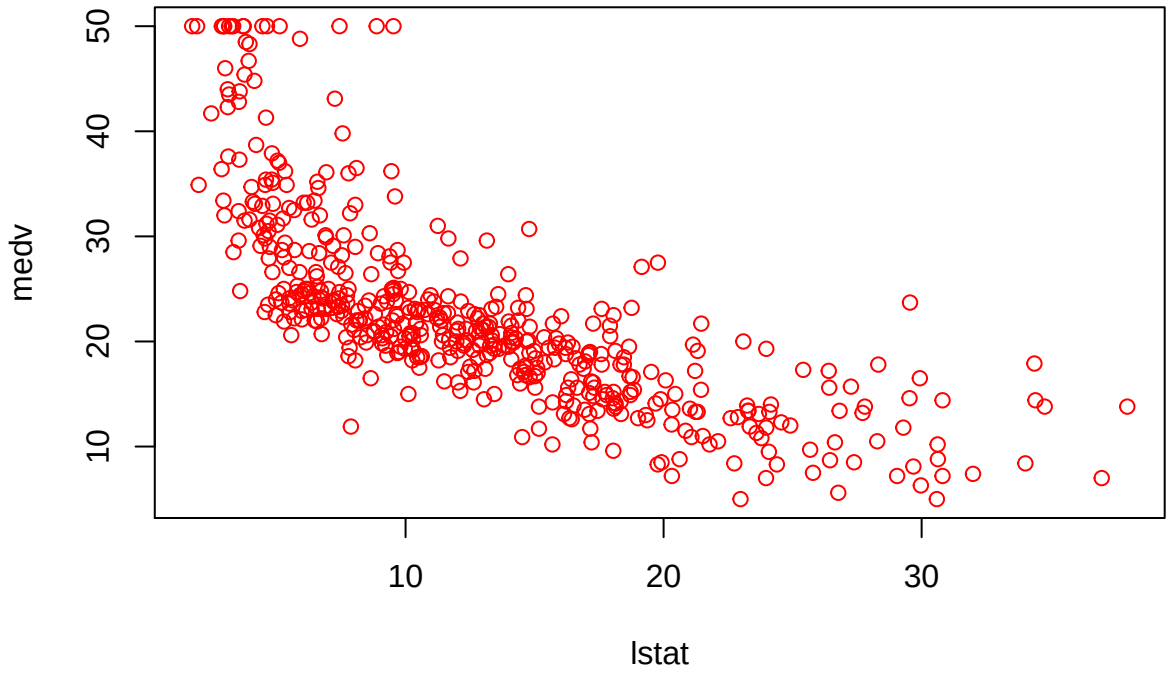
```
predict(lm.fit, data.frame(lstat = (c(5,10,15))), interval = "prediction") # prediction with prediction
```

```
##        fit       lwr      upr
## 1 29.80359 17.565675 42.04151
## 2 25.05335 12.827626 37.27907
## 3 20.30310  8.077742 32.52846
```

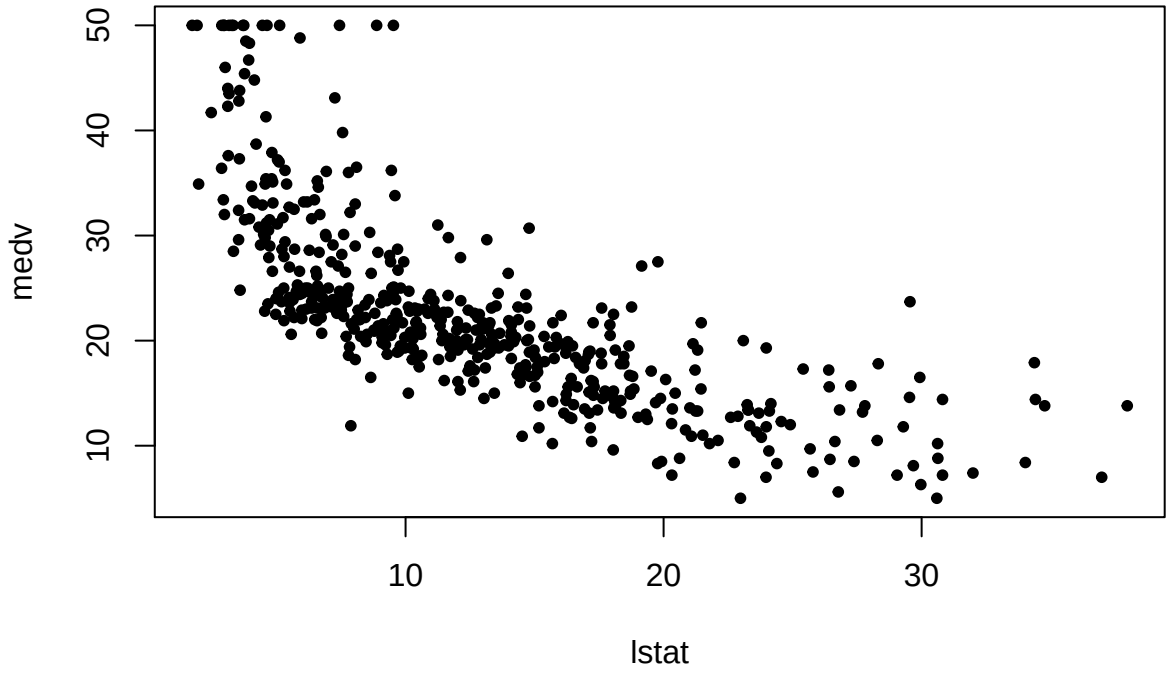
```
plot(lstat, medv) # plots the vars


abline(lm.fit) # plots the fit


abline(lm.fit, lwd = 3) # plots the fit again

abline(lm.fit, lwd = 3, col = "red") # plots the fit and adds a color
```



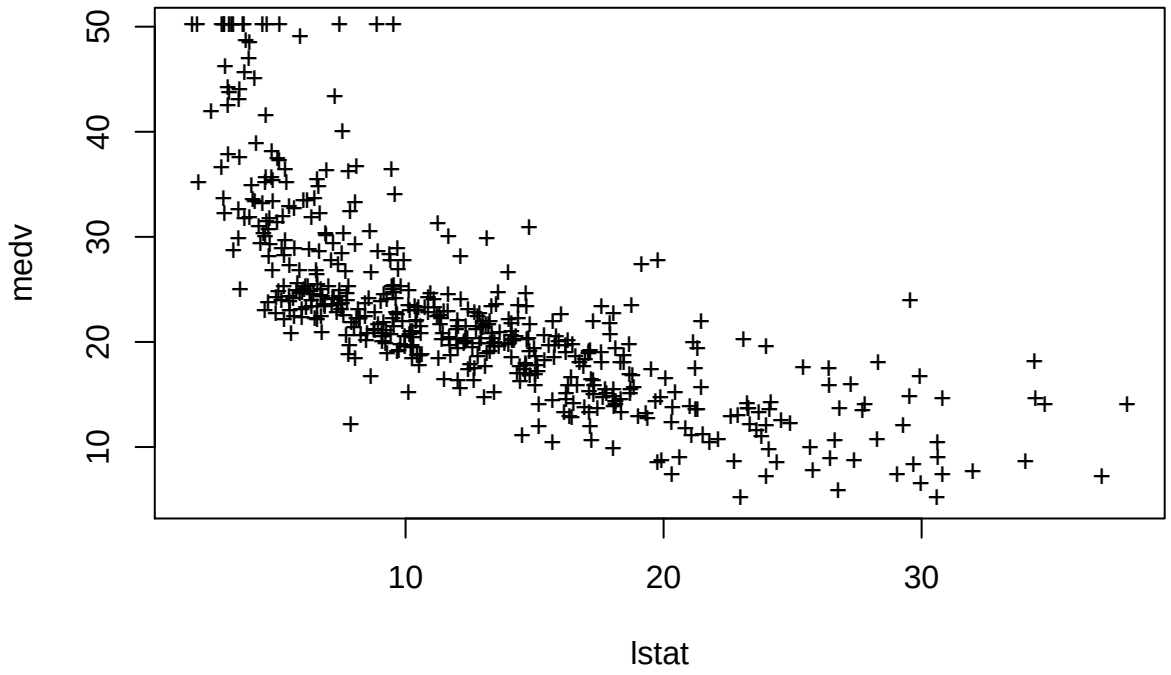
```
plot(lstat, medv, col = "red") # plots the data with a color
```



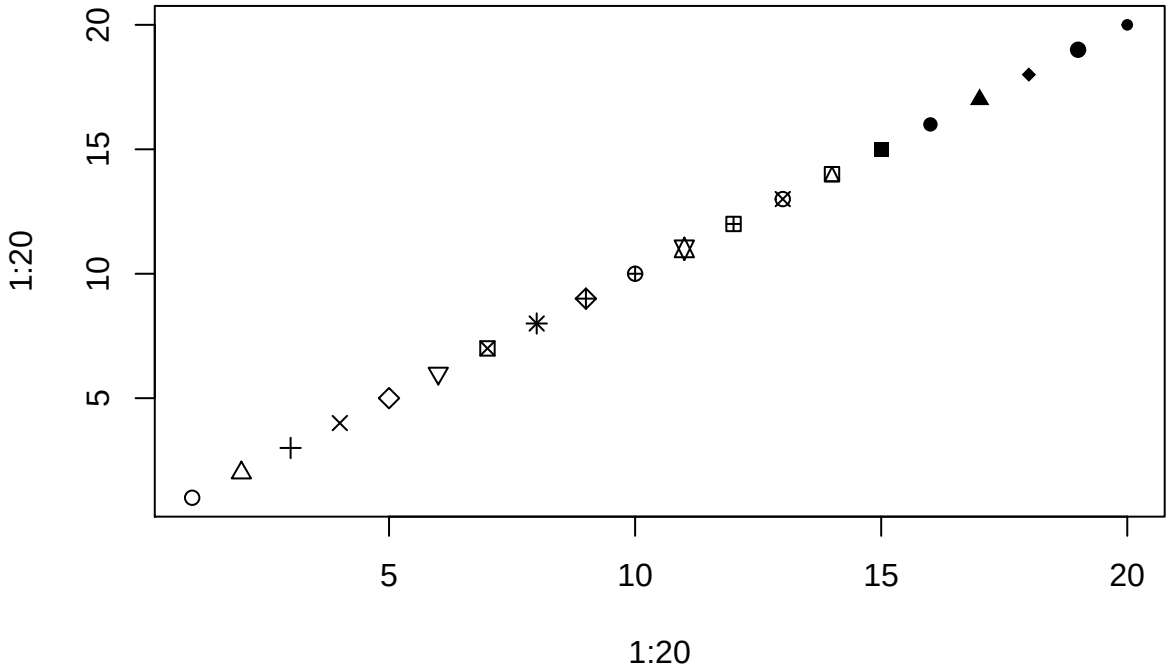

```
plot(lstat, medv, pch = 20) # plots the data with larger points
```



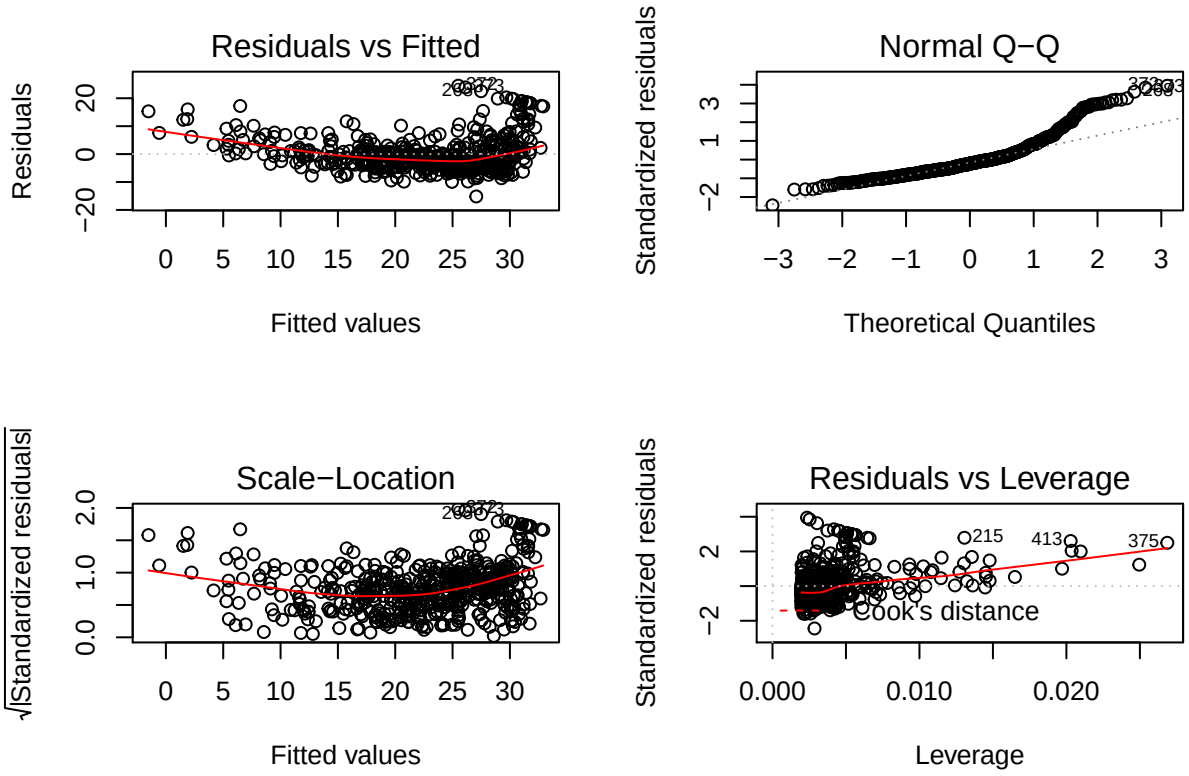

```
plot(lstat, medv, pch = "+") # plots the data with plus signs
```




```
plot(1:20, 1:20, pch = 1:20) # plots a x = y line of various shapes
```

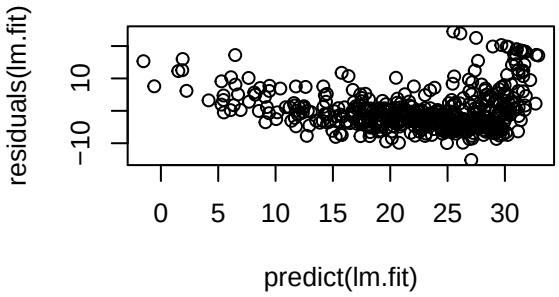


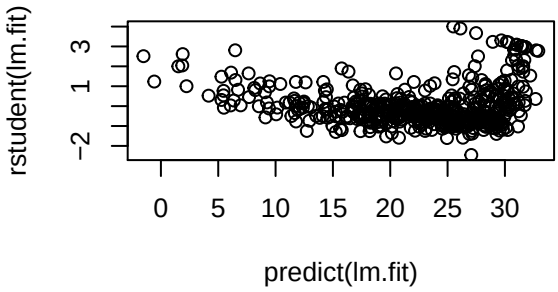

```
par(mfrow = c(2, 2)) # sets of 2 by 2 plot window

plot(lm.fit) # plots various model plots. Residuals etc.
```

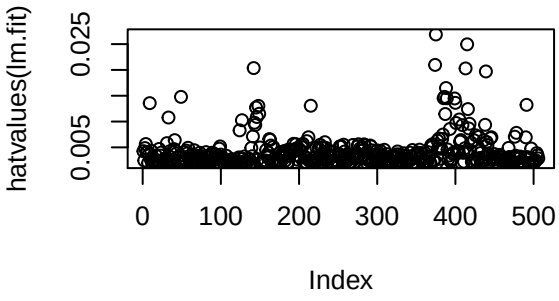



```
plot(predict(lm.fit), residuals(lm.fit)) # computes the residuals

plot(predict(lm.fit), rstudent(lm.fit)) # computes the student

plot(hatvalues(lm.fit)) # shows the leverage statistics

which.max(hatvalues(lm.fit)) # identifies the largest leverage statistic
```

```
## 375
## 375
```







11.2.2.3.2 Multiple Linear Regression

```
lm.fit <- lm(medv~lstat + age, data = Boston) # plus sign adds more predictors
summary(lm.fit) # summary of the fit
```

```
##
## Call:
## lm(formula = medv ~ lstat + age, data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.981  -3.978  -1.283   1.968  23.158
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 33.22276    0.73085  45.458  < 2e-16 ***
## lstat       -1.03207    0.04819 -21.416  < 2e-16 ***
## age          0.03454    0.01223   2.826  0.00491 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.173 on 503 degrees of freedom
## Multiple R-squared:  0.5513, Adjusted R-squared:  0.5495
## F-statistic:   309 on 2 and 503 DF,  p-value: < 2.2e-16
```

```
lm.fit <- lm(medv~., data = Boston) # all predictors in data set used
summary(lm.fit) # summary of that model
```

```
##
## Call:
## lm(formula = medv ~ ., data = Boston)
```

```
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.595  -2.730  -0.518   1.777  26.199
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3.646e+01  5.103e+00   7.144 3.28e-12 ***
## crim        -1.080e-01  3.286e-02  -3.287 0.001087 **
## zn           4.642e-02  1.373e-02   3.382 0.000778 ***
## indus        2.056e-02  6.150e-02   0.334 0.738288
## chas         2.687e+00  8.616e-01   3.118 0.001925 **
## nox         -1.777e+01  3.820e+00  -4.651 4.25e-06 ***
## rm           3.810e+00  4.179e-01   9.116  < 2e-16 ***
## age          6.922e-04  1.321e-02   0.052 0.958229
## dis         -1.476e+00  1.995e-01  -7.398 6.01e-13 ***
## rad          3.060e-01  6.635e-02   4.613 5.07e-06 ***
## tax         -1.233e-02  3.760e-03  -3.280 0.001112 **
## ptratio     -9.527e-01  1.308e-01  -7.283 1.31e-12 ***
## black        9.312e-03  2.686e-03   3.467 0.000573 ***
## lstat       -5.248e-01  5.072e-02 -10.347  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.745 on 492 degrees of freedom
## Multiple R-squared:  0.7406, Adjusted R-squared:  0.7338
## F-statistic: 108.1 on 13 and 492 DF,  p-value: < 2.2e-16
```

```
library(car) # gets the car set which contains vif()
```

```
## Loading required package: carData
```

```
vif(lm.fit) # compute variance inflation factors
```

```
##     crim       zn    indus     chas      nox       rm      age      dis
## 1.792192 2.298758 3.991596 1.073995 4.393720 1.933744 3.100826 3.955945
##      rad      tax  ptratio    black    lstat
## 7.484496 9.008554 1.799084 1.348521 2.941491
```

```
lm.fit1 <- lm(medv~. - age, data = Boston) # remove age because of high p value

summary(lm.fit1) # summary of that model
```

```
##
## Call:
## lm(formula = medv ~ . - age, data = Boston)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -15.6054  -2.7313  -0.5188   1.7601  26.2243
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  36.436927   5.080119   7.172 2.72e-12 ***
## crim         -0.108006   0.032832  -3.290 0.001075 **
## zn            0.046334   0.013613   3.404 0.000719 ***
```

```
## indus         0.020562   0.061433   0.335 0.737989
## chas          2.689026   0.859598   3.128 0.001863 **
## nox         -17.713540   3.679308  -4.814 1.97e-06 ***
## rm            3.814394   0.408480   9.338  < 2e-16 ***
## dis          -1.478612   0.190611  -7.757 5.03e-14 ***
## rad           0.305786   0.066089   4.627 4.75e-06 ***
## tax          -0.012329   0.003755  -3.283 0.001099 **
## ptratio      -0.952211   0.130294  -7.308 1.10e-12 ***
## black         0.009321   0.002678   3.481 0.000544 ***
## lstat        -0.523852   0.047625 -10.999  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.74 on 493 degrees of freedom
## Multiple R-squared:  0.7406, Adjusted R-squared:  0.7343
## F-statistic: 117.3 on 12 and 493 DF,  p-value: < 2.2e-16
```

```
lm.fit1 <- update(lm.fit, ~.-age) # updates the old model as opposed to making a new one
```

11.2.2.3.3 Interaction Terms

```
# lstat:age adds an interaction term
# however, the * adds the interaction terms as well as the individual terms
summary(lm(medv~lstat * age, data = Boston)) # summary of the interation terms and the individual terms
```

```
##
## Call:
## lm(formula = medv ~ lstat * age, data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -15.806  -4.045  -1.333   2.085  27.552
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 36.0885359  1.4698355  24.553  < 2e-16 ***
## lstat       -1.3921168  0.1674555  -8.313 8.78e-16 ***
## age         -0.0007209  0.0198792  -0.036   0.9711
## lstat:age    0.0041560  0.0018518   2.244   0.0252 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.149 on 502 degrees of freedom
## Multiple R-squared:  0.5557, Adjusted R-squared:  0.5531
## F-statistic: 209.3 on 3 and 502 DF,  p-value: < 2.2e-16
```

11.2.2.3.4 Non-linear Transformations of the Predictors

```
lm.fit2 <- lm(medv~lstat + I(lstat^2)) # polynomial fit
summary(lm.fit2) # summary of that fit
```

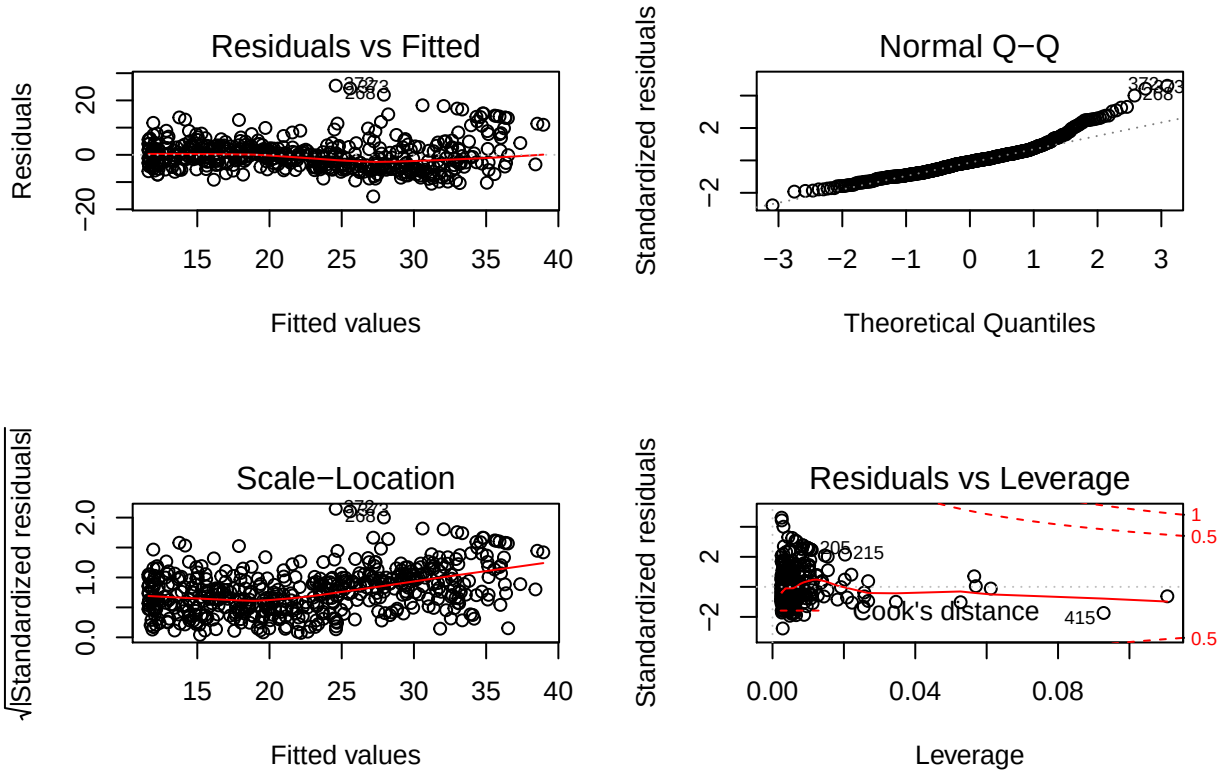
```
##
## Call:
## lm(formula = medv ~ lstat + I(lstat^2))
```

```
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -15.2834  -3.8313  -0.5295   2.3095  25.4148
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 42.862007   0.872084   49.15   <2e-16 ***
## lstat       -2.332821   0.123803  -18.84   <2e-16 ***
## I(lstat^2)   0.043547   0.003745   11.63   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.524 on 503 degrees of freedom
## Multiple R-squared:  0.6407, Adjusted R-squared:  0.6393
## F-statistic: 448.5 on 2 and 503 DF,  p-value: < 2.2e-16
```

```
lm.fit <- lm(medv~lstat) # a linear fit
anova(lm.fit, lm.fit2) # analysis of variance of those 2 fits
```

```
## Analysis of Variance Table
##
## Model 1: medv ~ lstat
## Model 2: medv ~ lstat + I(lstat^2)
##   Res.Df   RSS Df Sum of Sq     F    Pr(>F)
## 1    504 19472
## 2    503 15347  1    4125.1 135.2 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(2, 2)) # a 2 by 2 plot window
plot(lm.fit2) # plots the model plots into the 2 by 2 windows
```




```
lm.fit5 <- lm(medv~poly(lstat, 5)) # computes a fifth order polynomial
summary(lm.fit5) # summary of the fifth order poly
```

```
##
## Call:
## lm(formula = medv ~ poly(lstat, 5))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.5433  -3.1039  -0.7052   2.0844  27.1153
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)       22.5328     0.2318  97.197  < 2e-16 ***
## poly(lstat, 5)1 -152.4595     5.2148 -29.236  < 2e-16 ***
## poly(lstat, 5)2   64.2272     5.2148  12.316  < 2e-16 ***
## poly(lstat, 5)3  -27.0511     5.2148  -5.187 3.10e-07 ***
## poly(lstat, 5)4   25.4517     5.2148   4.881 1.42e-06 ***
## poly(lstat, 5)5  -19.2524     5.2148  -3.692 0.000247 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.215 on 500 degrees of freedom
## Multiple R-squared:  0.6817, Adjusted R-squared:  0.6785
## F-statistic: 214.2 on 5 and 500 DF,  p-value: < 2.2e-16
```

```
summary(lm(medv~log(rm), data = Boston)) # summary of the log of the rm predictor
```

```
##
## Call:
```

```
## lm(formula = medv ~ log(rm), data = Boston)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -19.487  -2.875  -0.104   2.837  39.816
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -76.488      5.028  -15.21   <2e-16 ***
## log(rm)       54.055      2.739   19.73   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.915 on 504 degrees of freedom
## Multiple R-squared:  0.4358, Adjusted R-squared:  0.4347
## F-statistic: 389.3 on 1 and 504 DF,  p-value: < 2.2e-16
```

11.2.2.3.5 Qualitative Predictors

```
# fix(Carseats)
names(Carseats)
```

```
##  [1] "Sales"       "CompPrice"   "Income"      "Advertising" "Population"
##  [6] "Price"       "ShelveLoc"   "Age"         "Education"   "Urban"
## [11] "US"
```

```
lm.fit <- lm(Sales~. + Income:Advertising + Price:Age, data = Carseats)
summary(lm.fit)
```

```
##
## Call:
## lm(formula = Sales ~ . + Income:Advertising + Price:Age, data = Carseats)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.9208 -0.7503  0.0177  0.6754  3.3413
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)          6.5755654  1.0087470   6.519 2.22e-10 ***
## CompPrice            0.0929371  0.0041183  22.567  < 2e-16 ***
## Income               0.0108940  0.0026044   4.183 3.57e-05 ***
## Advertising          0.0702462  0.0226091   3.107 0.002030 **
## Population           0.0001592  0.0003679   0.433 0.665330
## Price               -0.1008064  0.0074399 -13.549  < 2e-16 ***
## ShelveLocGood        4.8486762  0.1528378  31.724  < 2e-16 ***
## ShelveLocMedium      1.9532620  0.1257682  15.531  < 2e-16 ***
## Age                 -0.0579466  0.0159506  -3.633 0.000318 ***
## Education           -0.0208525  0.0196131  -1.063 0.288361
## UrbanYes             0.1401597  0.1124019   1.247 0.213171
## USYes               -0.1575571  0.1489234  -1.058 0.290729
## Income:Advertising   0.0007510  0.0002784   2.698 0.007290 **
## Price:Age            0.0001068  0.0001333   0.801 0.423812
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 1.011 on 386 degrees of freedom
## Multiple R-squared:  0.8761, Adjusted R-squared:  0.8719
## F-statistic:   210 on 13 and 386 DF,  p-value: < 2.2e-16
```

```
attach(Carseats)
contrasts(ShelveLoc)
```

```
##        Good Medium
## Bad       0      0
## Good      1      0
## Medium    0      1
```

11.2.2.3.6 Writing Functions

As we have seen, R comes with many useful functions, and still more func- tions are available by way of R libraries.

However, we will often be interested in performing an operation for which no function is available.

In this setting, we may want to write our own function.

For instance, below we provide a simple function

- that reads in the ISLR and MASS libraries,
- called LoadLibraries().

Before we have created the function, R returns an error if we try to call it.

```
# LoadLibraries
# LoadLibraries()
```

We now create the function.

Note that

- the + symbols are printed by R
- and should not be typed in.

The { symbol informs R that multiple commands are about to be input.

Hitting Enter after typing {

- will cause R to print the + symbol.

We can then input as many commands as we wish, hitting Enter after each one.

Finally the } symbol informs R that no further commands will be entered.

```
LoadLibraries = function(){
  library(ISLR)
  library(MASS)
  print("The libraries have been loaded.")
  }
```

Now if we type in LoadLibraries, R will tell us what is in the function.

```
LoadLibraries
```

```
## function(){
##   library(ISLR)
##   library(MASS)
##   print("The libraries have been loaded.")
```

```
##   }
```

If we call the function,

- the libraries are loaded in
- and the print statement is output.

```
LoadLibraries()
```

```
## [1] "The libraries have been loaded."
```