BIOS 545 Lecture 4

Lists, Data Frames

Steve Pittard, wsp@emory.edu

Lists

Lists provide a way to store information of different types within a single data structure

Remember that vectors and matrices restrict us to only one data type at a time. That is we cannot mix, for example, characters and numbers within a vector or matrix.

Many functions in R return information stored in lists

Consider the following example wherein we store information about a family. Not all this information is of the same type

```
family1 <- list(husband="Fred",
                wife="Wilma",
                numofchildren=3,
                agesofkids=c(8,11,14))

 length(family1)  # Has 4 elements
```

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

```
 family1
```

```
## $husband
## [1] "Fred"
##
## $wife
## [1] "Wilma"
##
## $numofchildren
## [1] 3
##
## $agesofkids
## [1]  8 11 14
```

```
 str(family1)
```

```
## List of 4
##  $ husband      : chr "Fred"
##  $ wife         : chr "Wilma"
##  $ numofchildren: num 3
##  $ agesofkids   : num [1:3] 8 11 14
```

If possible, always create named elements. It is easier for humans to index into a named list

```
family1 <- list(husband="Fred",
                wife="Wilma",
```

```
                numofchildren=3,
                agesofkids=c(8,11,14))
 # If the list elements have names then use "$" to access the element
family1$agesofkids
```

```
## [1]  8 11 14
```

If the list elements have no names then you have to use numeric indexing

```
(family2 <- list("Barney","Betty",2,c(4,6)))
```

```
## [[1]]
## [1] "Barney"
##
## [[2]]
## [1] "Betty"
##
## [[3]]
## [1] 2
##
## [[4]]
## [1] 4 6
```

```
family2 <- list("Barney","Betty",2,c(4,6))

family2[4] # Accesses the 4th index and associated element
```

```
## [[1]]
## [1] 4 6
```

```
family2[[4]] # Accesses the 4th element value only - more direct
```

```
## [1] 4 6
```

```
family2[3:4] # Get 3rd and 4th indices and associate values
```

```
## [[1]]
## [1] 2
##
## [[2]]
## [1] 4 6
```

As newcomers to R we usually doesn't create lists except in two major cases:

1) We are writing a function that does some interesting stuff and we want to return to the user a structure that has information of varying types
2) As a precursor to creating a a data frame, which represents a hybrid object with characteristics of a list and a matrix

As an example of the first case, R has lots of statistical functions that return lists of information.

```
data(mtcars) # Load mtcars into the environment
mylm <- lm(mpg ~ wt + am, data = mtcars)
print(mylm)
```

```
##
## Call:
## lm(formula = mpg ~ wt + am, data = mtcars)
##
```

```
## Coefficients:
## (Intercept)           wt           am
##    37.32155     -5.35281     -0.02362
```

But there is a lot more information

```
str(mylm,attr=FALSE)
```

```
## List of 12
##  $ coefficients : Named num [1:3] 37.3216 -5.3528 -0.0236
##   ..- attr(*, "names")= chr [1:3] "(Intercept)" "wt" "am"
##  $ residuals    : Named num [1:32] -2.274 -0.909 -2.079 1.288 -0.208 ...
##   ..- attr(*, "names")= chr [1:32] "Mazda RX4" "Mazda RX4 Wag" "Datsun 710" "Hornet 4 Drive" ...
##  $ effects      : Named num [1:32] -113.6497 -29.1157 0.0473 1.2698 -0.1748 ...
##   ..- attr(*, "names")= chr [1:32] "(Intercept)" "wt" "am" "" ...
##  $ rank         : int 3
##  $ fitted.values: Named num [1:32] 23.3 21.9 24.9 20.1 18.9 ...
##   ..- attr(*, "names")= chr [1:32] "Mazda RX4" "Mazda RX4 Wag" "Datsun 710" "Hornet 4 Drive" ...
##  $ assign       : int [1:3] 0 1 2
##  $ qr           :List of 5
##   ..$ qr   : num [1:32, 1:3] -5.657 0.177 0.177 0.177 0.177 ...
##   .. ..- attr(*, "dimnames")=List of 2
##   .. .. ..$ : chr [1:32] "Mazda RX4" "Mazda RX4 Wag" "Datsun 710" "Hornet 4 Drive" ...
##   .. .. ..$ : chr [1:3] "(Intercept)" "wt" "am"
##   .. ..- attr(*, "assign")= int [1:3] 0 1 2
##   ..$ qraux: num [1:3] 1.18 1.05 1.08
##   ..$ pivot: int [1:3] 1 2 3
##   ..$ tol  : num 1e-07
##   ..$ rank : int 3
##   ..- attr(*, "class")= chr "qr"
##  $ df.residual  : int 29
##  $ xlevels      : Named list()
##  $ call         : language lm(formula = mpg ~ wt + am, data = mtcars)
##  $ terms        :Classes 'terms', 'formula'  language mpg ~ wt + am
##   .. ..- attr(*, "variables")= language list(mpg, wt, am)
##   .. ..- attr(*, "factors")= int [1:3, 1:2] 0 1 0 0 0 1
##   .. .. ..- attr(*, "dimnames")=List of 2
##   .. .. .. ..$ : chr [1:3] "mpg" "wt" "am"
##   .. .. .. ..$ : chr [1:2] "wt" "am"
##   .. ..- attr(*, "term.labels")= chr [1:2] "wt" "am"
##   .. ..- attr(*, "order")= int [1:2] 1 1
##   .. ..- attr(*, "intercept")= int 1
##   .. ..- attr(*, "response")= int 1
##   .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
##   .. ..- attr(*, "predvars")= language list(mpg, wt, am)
##   .. ..- attr(*, "dataClasses")= Named chr [1:3] "numeric" "numeric" "numeric"
##   .. .. ..- attr(*, "names")= chr [1:3] "mpg" "wt" "am"
##  $ model        :'data.frame':   32 obs. of  3 variables:
##   ..$ mpg: num [1:32] 21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##   ..$ wt : num [1:32] 2.62 2.88 2.32 3.21 3.44 ...
##   ..$ am : num [1:32] 1 1 1 0 0 0 0 0 0 0 ...
##   ..- attr(*, "terms")=Classes 'terms', 'formula'  language mpg ~ wt + am
##   .. .. ..- attr(*, "variables")= language list(mpg, wt, am)
##   .. .. ..- attr(*, "factors")= int [1:3, 1:2] 0 1 0 0 0 1
##   .. .. .. ..- attr(*, "dimnames")=List of 2
```

```
##   .. .. .. .. ..$ : chr [1:3] "mpg" "wt" "am"
##   .. .. .. .. ..$ : chr [1:2] "wt" "am"
##   .. .. ..- attr(*, "term.labels")= chr [1:2] "wt" "am"
##   .. .. ..- attr(*, "order")= int [1:2] 1 1
##   .. .. ..- attr(*, "intercept")= int 1
##   .. .. ..- attr(*, "response")= int 1
##   .. .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
##   .. .. ..- attr(*, "predvars")= language list(mpg, wt, am)
##   .. .. ..- attr(*, "dataClasses")= Named chr [1:3] "numeric" "numeric" "numeric"
##   .. .. .. ..- attr(*, "names")= chr [1:3] "mpg" "wt" "am"
##  - attr(*, "class")= chr "lm"
```

```
names(mylm)
```

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

```
mylm$effects
```

```
##   (Intercept)            wt            am
## -113.64973741  -29.11572170    0.04733203    1.26976047   -0.17484609
##
##   -0.66325556   -3.84950765    4.13027231    2.30709126    0.32515391
##
##   -1.07484609    1.04025555    0.04321657   -1.77780711    1.62409672
##
##    2.59493431    6.45415172    7.39582527    2.13180232    6.85929813
##
##   -2.81488433   -2.92848397   -3.70274372   -3.34303552    2.58486211
##
##    0.81725077    0.66105369    1.56269063   -3.79203411   -2.12384467
##
##   -2.36022355   -0.36804941
```

```
lm(mpg ~ wt, data = mtcars)$coefficients
```

```
## (Intercept)          wt
##   37.285126   -5.344472
```

Some other basic R functions will return a list - such as some of the character functions:

```
mystring <- "This is a test"
mys <- strsplit(mystring, " ")
str(mys)
```

```
## List of 1
##  $ : chr [1:4] "This" "is" "a" "test"
```

```
mys[[1]][1]
```

```
## [1] "This"
```

```
mys[[1]][1:2]
```

```
## [1] "This" "is"
```

```
unlist(mys)
```

```
## [1] "This" "is"   "a"    "test"
```

When we create our own functions we can return a list

```
my.summary <- function(x) {
  return.list <- list()
  return.list$mean <- mean(x)
  return.list$sd <- sd(x)
  return.list$var <- var(x)
  return(return.list)
}
```

```
my.summary(1:10)
```

```
## $mean
## [1] 5.5
##
## $sd
## [1] 3.02765
##
## $var
## [1] 9.166667
```

Remember the sapply command ? We use it to apply a function over each element of a list or a vector. This helps us avoid having to write a "for-loop" every time we want to process a list or a vector.

```
family1 <- list(husband="Fred",
                wife="Wilma",
                numofchildren=3,
                agesofkids=c(8,11,14))

sapply(family1,class)
```

```
##       husband          wife numofchildren    agesofkids
##   "character"   "character"     "numeric"     "numeric"
```

```
sapply(family1,length)
```

```
##       husband          wife numofchildren    agesofkids
##             1             1             1             3
```

sapply tries to return a "simplified" version of the output (either a vector or matrix) hence the "s"in the "sapply". If you don't use something like sapply then the example on the previous slide would look this:

```
family1 <- list(husband="Fred",
                wife="Wilma",
                numofchildren=3,
                agesofkids=c(8,11,14))

 for (ii in 1:length(family1)) {
    cat(names(family1)[ii]," : ",class(family1[[ii]]),"\n")
 }
```

```
## husband  :  character
## wife  :  character
## numofchildren  :  numeric
## agesofkids  :  numeric
```

Similar to sapply, the lapply function let's you "apply" some function over each element of a list or vector. It will return a list version of the output hence the "l" in the lapply. So deciding between sapply and lapply simply is a question of format. What do you want back ? A vector or list ? Most of the time I use sapply.

```r
# lapply( vector_or_list, function_to_apply_to_each element)
family1 <- list(husband="Fred",
                wife="Wilma",
                numofchildren=3,
                agesofkids=c(8,11,14))

lapply(family1,class)
```

```
## $husband
## [1] "character"
##
## $wife
## [1] "character"
##
## $numofchildren
## [1] "numeric"
##
## $agesofkids
## [1] "numeric"
```

check out the following:

```r
lapply(family1,mean)
```

```
## Warning in mean.default(X[[i]], ...): argument is not numeric or logical:
## returning NA

## Warning in mean.default(X[[i]], ...): argument is not numeric or logical:
## returning NA
```

```
## $husband
## [1] NA
##
## $wife
## [1] NA
##
## $numofchildren
## [1] 3
##
## $agesofkids
## [1] 11
```

We can write our own processing function that checks to see if the list element is valid input for the mean function.

```r
my.func <- function(x) {
  if(class(x)=="numeric") {
    return(mean(x))
  }
}
lapply(family1, my.func)
```

```
## $husband
## NULL
##
## $wife
## NULL
```

```
##
## $numofchildren
## [1] 3
##
## $agesofkids
## [1] 11
```

See these videos on the lapply function at:

https://www.youtube.com/playlist?list=PL905DXZOAgwwj16m6C3ioh6aVKDDrEiiO

See this Blog post on lapply

https://rollingyours.wordpress.com/2014/10/20/the-lapply-command-101/

Data Frames

Why should you use Data Frames ?

- A data frame is a special type of list that contains data in a format that allows for easier manipulation, reshaping, and open-ended analysis
- Data frames are tightly coupled collections of variables. It is one of the more important constructs you will encounter when using R so learn all you can about it
- A data frame is an analogue to the Excel spreadsheet but is much more flexible for storing, manipulating, and analyzing data
- Data frames can be constructed from existing vectors, lists, or matrices. Many times they are created by reading in comma delimited files, (CSV files), using the read.table command
- Once you become accustomed to working with data frames, R becomes so much easier to use

Here we have 2 character vectors and 2 numeric vectors. Let's say we want to do some summary on them:

```
names <- c("P1","P2","P3","P4","P5")
temp <-  c(98.2,101.3,97.2,100.2,98.5)
pulse <- c(66,72,83,85,90)
gender <- c("M","F","M","M","F")
```

We could do some summary on this

```
for (ii in 1:length(gender)) {
  print.string = c(names[ii],temp[ii],pulse[ii],gender[ii])
  print(print.string)
}
```

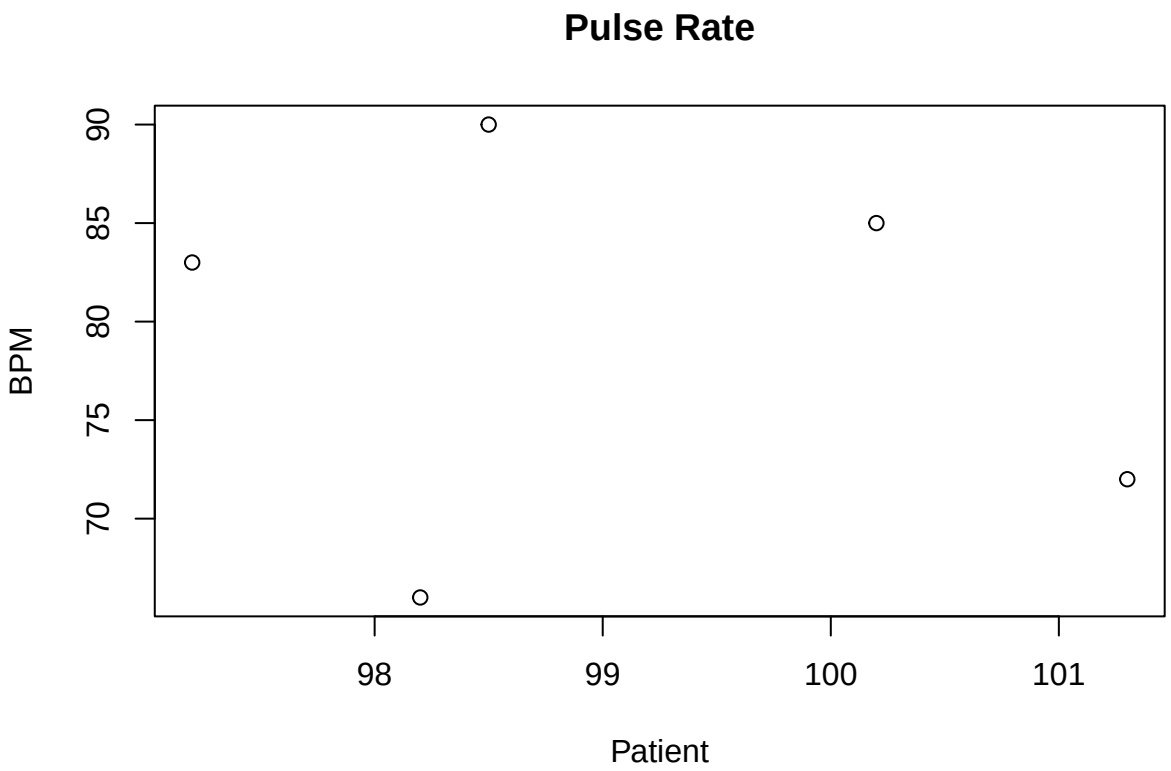
```
## [1] "P1"   "98.2" "66"   "M"
## [1] "P2"    "101.3" "72"    "F"
## [1] "P3"   "97.2" "83"   "M"
## [1] "P4"    "100.2" "85"    "M"
## [1] "P5"   "98.5" "90"   "F"
```

That doesn't generalize at all. Use the dataframe() function to create a data frame. It looks like a matrix but allows for mixed data types

```
names <- c("P1","P2","P3","P4","P5")
temp <- c(98.2,101.3,97.2,100.2,98.5)
pulse <- c(66,72,83,85,90)
gender <- c("M","F","M","M","F")

my_df <- data.frame(names,temp,pulse,gender) # Much more flexible
```

So now what ?

```
plot(my_df$pulse ~ my_df$temp,main="Pulse Rate",xlab="Patient",ylab="BPM")
```




```
mean(my_df[,2:3])
```

```
## Warning in mean.default(my_df[, 2:3]): argument is not numeric or logical:
## returning NA
```

```
## [1] NA
```

Once you have a data frame you could edit it with the Workspace viewer in RStudio although this doesn't generalize. Imagine if your data set had 10,000 lines ?

Builtin Example Data Frames

```
library(help="datasets")
```

```
help(mtcars)
data(mtcars)
str(mtcars)
```

```
## 'data.frame':    32 obs. of  11 variables:
##  $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##  $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
##  $ disp: num  160 160 108 258 360 ...
##  $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
##  $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
##  $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
##  $ qsec: num  16.5 17 18.6 19.4 17 ...
##  $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
```

```
##  $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
##  $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

Get some info on the data frame

```
nrow(mtcars)
```

```
## [1] 32
```

```
ncol(mtcars)
```

```
## [1] 11
```

```
dim(mtcars)
```

```
## [1] 32 11
```

More information is possible

```
rownames(mtcars)
```

```
##  [1] "Mazda RX4"           "Mazda RX4 Wag"       "Datsun 710"
##  [4] "Hornet 4 Drive"      "Hornet Sportabout"   "Valiant"
##  [7] "Duster 360"          "Merc 240D"           "Merc 230"
## [10] "Merc 280"            "Merc 280C"           "Merc 450SE"
## [13] "Merc 450SL"          "Merc 450SLC"         "Cadillac Fleetwood"
## [16] "Lincoln Continental" "Chrysler Imperial"   "Fiat 128"
## [19] "Honda Civic"         "Toyota Corolla"      "Toyota Corona"
## [22] "Dodge Challenger"    "AMC Javelin"         "Camaro Z28"
## [25] "Pontiac Firebird"    "Fiat X1-9"           "Porsche 914-2"
## [28] "Lotus Europa"        "Ford Pantera L"      "Ferrari Dino"
## [31] "Maserati Bora"       "Volvo 142E"
```

We can actually set the rownames using the same function

```
rownames(mtcars) <- 1:32
head(mtcars)
```

```
##    mpg cyl disp  hp drat    wt  qsec vs am gear carb
## 1 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## 2 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## 3 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## 4 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## 5 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## 6 18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

```
rownames(mtcars) <- paste("car",1:32,sep="_")
head(mtcars)
```

```
##        mpg cyl disp  hp drat    wt  qsec vs am gear carb
## car_1 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## car_2 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## car_3 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## car_4 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## car_5 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## car_6 18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

There are many ways to index into or interrogate a data frame. This is where your previous knowledge of the bracket notation will be very useful to you

```
head(mtcars[,-1])    # Get all rows / columns except for column 1
```

```
##       cyl disp  hp drat    wt  qsec vs am gear carb
## car_1   6  160 110 3.90 2.620 16.46  0  1    4    4
## car_2   6  160 110 3.90 2.875 17.02  0  1    4    4
## car_3   4  108  93 3.85 2.320 18.61  1  1    4    1
## car_4   6  258 110 3.08 3.215 19.44  1  0    3    1
## car_5   8  360 175 3.15 3.440 17.02  0  0    3    2
## car_6   6  225 105 2.76 3.460 20.22  1  0    3    1
```

Compare this to:

```
head(mtcars)
```

```
##        mpg cyl disp  hp drat    wt  qsec vs am gear carb
## car_1 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## car_2 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## car_3 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## car_4 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## car_5 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## car_6 18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

What about the following:

```
mtcars[,] # same as
```

```
##         mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## car_1  21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## car_2  21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## car_3  22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## car_4  21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
## car_5  18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
## car_6  18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
## car_7  14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
## car_8  24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## car_9  22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
## car_10 19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
## car_11 17.8   6 167.6 123 3.92 3.440 18.90  1  0    4    4
## car_12 16.4   8 275.8 180 3.07 4.070 17.40  0  0    3    3
## car_13 17.3   8 275.8 180 3.07 3.730 17.60  0  0    3    3
## car_14 15.2   8 275.8 180 3.07 3.780 18.00  0  0    3    3
## car_15 10.4   8 472.0 205 2.93 5.250 17.98  0  0    3    4
## car_16 10.4   8 460.0 215 3.00 5.424 17.82  0  0    3    4
## car_17 14.7   8 440.0 230 3.23 5.345 17.42  0  0    3    4
## car_18 32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
## car_19 30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
## car_20 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
## car_21 21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
## car_22 15.5   8 318.0 150 2.76 3.520 16.87  0  0    3    2
## car_23 15.2   8 304.0 150 3.15 3.435 17.30  0  0    3    2
## car_24 13.3   8 350.0 245 3.73 3.840 15.41  0  0    3    4
## car_25 19.2   8 400.0 175 3.08 3.845 17.05  0  0    3    2
## car_26 27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
## car_27 26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
## car_28 30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
## car_29 15.8   8 351.0 264 4.22 3.170 14.50  0  1    5    4
```

```
## car_30 19.7   6 145.0 175 3.62 2.770 15.50  0  1    5    6
## car_31 15.0   8 301.0 335 3.54 3.570 14.60  0  1    5    8
## car_32 21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

```
mtcars
```

```
##         mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## car_1  21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## car_2  21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## car_3  22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## car_4  21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
## car_5  18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
## car_6  18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
## car_7  14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
## car_8  24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## car_9  22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
## car_10 19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
## car_11 17.8   6 167.6 123 3.92 3.440 18.90  1  0    4    4
## car_12 16.4   8 275.8 180 3.07 4.070 17.40  0  0    3    3
## car_13 17.3   8 275.8 180 3.07 3.730 17.60  0  0    3    3
## car_14 15.2   8 275.8 180 3.07 3.780 18.00  0  0    3    3
## car_15 10.4   8 472.0 205 2.93 5.250 17.98  0  0    3    4
## car_16 10.4   8 460.0 215 3.00 5.424 17.82  0  0    3    4
## car_17 14.7   8 440.0 230 3.23 5.345 17.42  0  0    3    4
## car_18 32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
## car_19 30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
## car_20 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
## car_21 21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
## car_22 15.5   8 318.0 150 2.76 3.520 16.87  0  0    3    2
## car_23 15.2   8 304.0 150 3.15 3.435 17.30  0  0    3    2
## car_24 13.3   8 350.0 245 3.73 3.840 15.41  0  0    3    4
## car_25 19.2   8 400.0 175 3.08 3.845 17.05  0  0    3    2
## car_26 27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
## car_27 26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
## car_28 30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
## car_29 15.8   8 351.0 264 4.22 3.170 14.50  0  1    5    4
## car_30 19.7   6 145.0 175 3.62 2.770 15.50  0  1    5    6
## car_31 15.0   8 301.0 335 3.54 3.570 14.60  0  1    5    8
## car_32 21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

```
# Get first 5 rows and first 3 columns
mtcars[1:5,1:3]
```

```
##        mpg cyl disp
## car_1 21.0   6  160
## car_2 21.0   6  160
## car_3 22.8   4  108
## car_4 21.4   6  258
## car_5 18.7   8  360
```

What about this ?

```
# Get all but the first 5 rows and first 3 columns
mtcars[-1:-5,-1:-3]
```

```
##         hp drat    wt  qsec vs am gear carb
## car_6  105 2.76 3.460 20.22  1  0    3    1
```

```
## car_7  245 3.21 3.570 15.84  0  0    3    4
## car_8   62 3.69 3.190 20.00  1  0    4    2
## car_9   95 3.92 3.150 22.90  1  0    4    2
## car_10 123 3.92 3.440 18.30  1  0    4    4
## car_11 123 3.92 3.440 18.90  1  0    4    4
## car_12 180 3.07 4.070 17.40  0  0    3    3
## car_13 180 3.07 3.730 17.60  0  0    3    3
## car_14 180 3.07 3.780 18.00  0  0    3    3
## car_15 205 2.93 5.250 17.98  0  0    3    4
## car_16 215 3.00 5.424 17.82  0  0    3    4
## car_17 230 3.23 5.345 17.42  0  0    3    4
## car_18  66 4.08 2.200 19.47  1  1    4    1
## car_19  52 4.93 1.615 18.52  1  1    4    2
## car_20  65 4.22 1.835 19.90  1  1    4    1
## car_21  97 3.70 2.465 20.01  1  0    3    1
## car_22 150 2.76 3.520 16.87  0  0    3    2
## car_23 150 3.15 3.435 17.30  0  0    3    2
## car_24 245 3.73 3.840 15.41  0  0    3    4
## car_25 175 3.08 3.845 17.05  0  0    3    2
## car_26  66 4.08 1.935 18.90  1  1    4    1
## car_27  91 4.43 2.140 16.70  0  1    5    2
## car_28 113 3.77 1.513 16.90  1  1    5    2
## car_29 264 4.22 3.170 14.50  0  1    5    4
## car_30 175 3.62 2.770 15.50  0  1    5    6
## car_31 335 3.54 3.570 14.60  0  1    5    8
## car_32 109 4.11 2.780 18.60  1  1    4    2
```

```
# Get first 5 rows and the mpg and am columns
mtcars[1:5,c("mpg","am")]
```

```
##        mpg am
## car_1 21.0  1
## car_2 21.0  1
## car_3 22.8  1
## car_4 21.4  0
## car_5 18.7  0
```

The following is the same as above expcet we index into the columns using numbers instead of names.

```
mtcars[1:5,c(1,9)]
```

```
##        mpg am
## car_1 21.0  1
## car_2 21.0  1
## car_3 22.8  1
## car_4 21.4  0
## car_5 18.7  0
```

To find the names of all the columns

```
names(mtcars)
```

```
##  [1] "mpg"  "cyl"  "disp" "hp"   "drat" "wt"   "qsec" "vs"   "am"   "gear"
## [11] "carb"
```

So this is kind of boring because we can interrogate the data frame to find rows and columns that satisfy certain conditions

```
# find all rows where the MPG >= 30
mtcars[mtcars$mpg >= 30,]
```

```
##         mpg cyl disp  hp drat    wt  qsec vs am gear carb
## car_18 32.4   4 78.7  66 4.08 2.200 19.47  1  1    4    1
## car_19 30.4   4 75.7  52 4.93 1.615 18.52  1  1    4    2
## car_20 33.9   4 71.1  65 4.22 1.835 19.90  1  1    4    1
## car_28 30.4   4 95.1 113 3.77 1.513 16.90  1  1    5    2
```

```
# Find all rows where the mpg >= 30 but return only columns 2-6
mtcars[mtcars$mpg >= 30.0,2:6]
```

```
##        cyl disp  hp drat    wt
## car_18   4 78.7  66 4.08 2.200
## car_19   4 75.7  52 4.93 1.615
## car_20   4 71.1  65 4.22 1.835
## car_28   4 95.1 113 3.77 1.513
```

We can have compound statements. Find all rows where the mpg is >= 30 and the cylinder variable is less than 6.

```
mtcars[mtcars$mpg >= 30.0 & mtcars$cyl < 6,]
```

```
##         mpg cyl disp  hp drat    wt  qsec vs am gear carb
## car_18 32.4   4 78.7  66 4.08 2.200 19.47  1  1    4    1
## car_19 30.4   4 75.7  52 4.93 1.615 18.52  1  1    4    2
## car_20 33.9   4 71.1  65 4.22 1.835 19.90  1  1    4    1
## car_28 30.4   4 95.1 113 3.77 1.513 16.90  1  1    5    2
```

Find all rows that correspond to Automatic and count them. Frequently you just want to know how many rows satisfy as certain condition

```
nrow(mtcars[mtcars$am == 0,])
```

```
## [1] 19
```

```
nrow(mtcars[mtcars$am == 1,])
```

```
## [1] 13
```

Of course there are other ways to do this

```
table(mtcars$am)
```

```
##
##  0  1
## 19 13
```

So we can use other R functions as part of our interrogation query. Let's find all rows in the data frame where the MPG is greater than the mean MPG for the entire data set.

```
mtcars[mtcars$mpg > mean(mtcars$mpg),]
```

```
##         mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## car_1  21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## car_2  21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## car_3  22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## car_4  21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
## car_8  24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## car_9  22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
```

```
## car_18 32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
## car_19 30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
## car_20 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
## car_21 21.5   4 120.1  97 3.70 2.465 20.01  1  0    3    1
## car_26 27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
## car_27 26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
## car_28 30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
## car_32 21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

Here is one which is slightly more involved. Let's find all the rows in the data frame where the MPG is greater than the 75th percentile for all MPG values in the data frame. To work this, you could break this down or do it all on one line.

```
# Looks like the 4th element return represents the 75th percentile
quantile(mtcars$mpg)
```

```
##     0%    25%    50%    75%   100%
## 10.400 15.425 19.200 22.800 33.900
```

```
quantile(mtcars$mpg)[4]
```

```
##  75%
## 22.8
```

```
mtcars[mtcars$mpg > quantile(mtcars$mpg)[4],]
```

```
##         mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## car_8  24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## car_18 32.4   4  78.7  66 4.08 2.200 19.47  1  1    4    1
## car_19 30.4   4  75.7  52 4.93 1.615 18.52  1  1    4    2
## car_20 33.9   4  71.1  65 4.22 1.835 19.90  1  1    4    1
## car_26 27.3   4  79.0  66 4.08 1.935 18.90  1  1    4    1
## car_27 26.0   4 120.3  91 4.43 2.140 16.70  0  1    5    2
## car_28 30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
```

Dealing with Factors

Factors are a special type of variable that we discussed last week. They can be identified by the fact that they ususally assume only a small number of unique values like < 10.

```
str(mtcars)
```

```
## 'data.frame':    32 obs. of  11 variables:
##  $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##  $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
##  $ disp: num  160 160 108 258 360 ...
##  $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
##  $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
##  $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
##  $ qsec: num  16.5 17 18.6 19.4 17 ...
##  $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
##  $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
##  $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

```
unique(mtcars$am)
```

```
## [1] 1 0
```

This begs the question - how many unique values does each column take on ? Is there a way to get that ?

```
sapply(mtcars, function(x) length(unique(x)))
```

```
##  mpg  cyl disp   hp drat   wt qsec   vs   am gear carb
##   25    3   27   22   22   29   30    2    2    3    6
```

If we summarize one of these potential factors right now, R will treat it as being purely numeric which we might not want.

```
summary(mtcars$am)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  0.0000  0.0000  0.0000  0.4062  1.0000  1.0000
```

So this really isn't helpful since we know that the "am" values are transmission types

```
mtcars$am <- factor(mtcars$am, levels = c(0,1), labels = c("Auto","Man") )
summary(mtcars$am)
```

```
## Auto  Man
##   19   13
```

We can add columns to a data frame. Let's say we want to create a new column called"mpgrate"that, based on the output of the quantile command, will have a rating of the that car's MPG in terms of "horrible","bad","good", or "great"

The labels could be more scientific but this is still a good use case. There are a couple of ways to do this:

```
data(mtcars)   # Reload a "pure" copy of mtcars
mpgrate <- cut(mtcars$mpg,
               breaks = quantile(mtcars$mpg),
               labels=c("horrible","Bad","Good","Great"),include.lowest=T)
mtcars <- cbind(mtcars,mpgrate)
head(mtcars[,10:12])
```

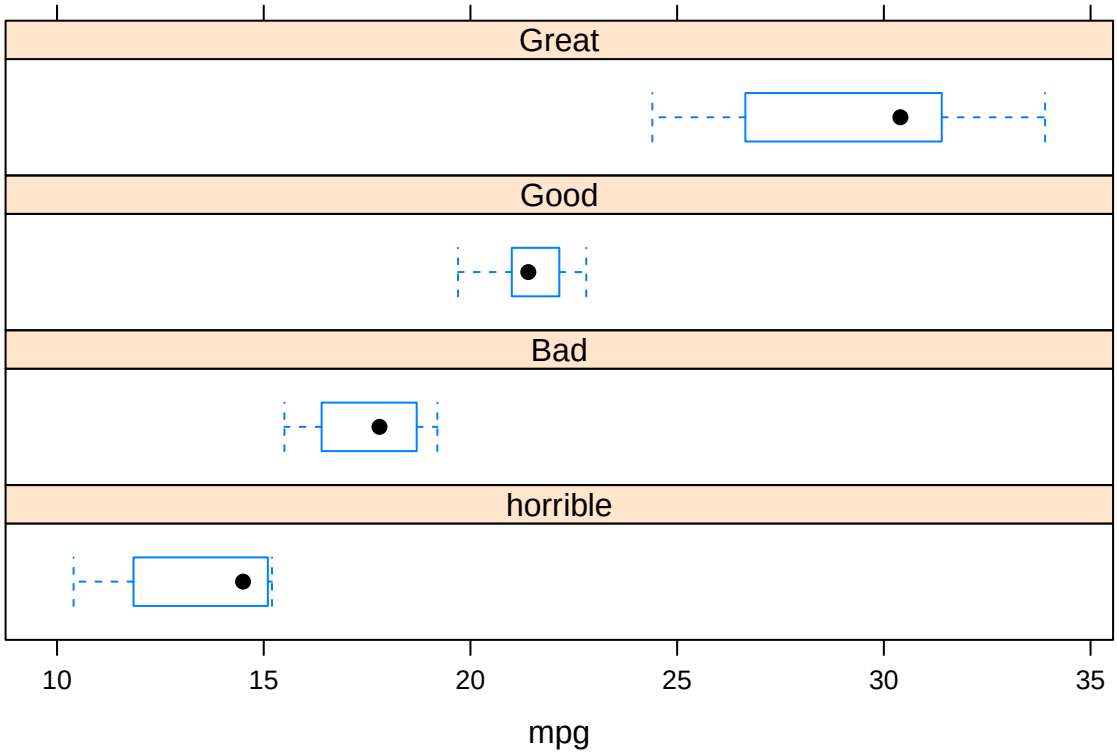
```
##                   gear carb mpgrate
## Mazda RX4            4    4    Good
## Mazda RX4 Wag        4    4    Good
## Datsun 710           4    1    Good
## Hornet 4 Drive       3    1    Good
## Hornet Sportabout    3    2     Bad
## Valiant              3    1     Bad
```

We could also add a new column like:

```
mtcars$mpgrate <- mpgrate
```

Why go to all this trouble ? Because then the plotting functions know how to deal with the data more easily.

```
library(lattice)
bwplot(~mpg|mpgrate,data=mtcars,layout=c(1,4))
```



Transforming columns is a common activity.

```
transform(mtcars,wt = (wt*1000),
                 qsec = round(qsec),
                 am = factor(am,labels=c("A","M")))
```

```
##                    mpg cyl  disp  hp drat   wt qsec vs am gear carb  mpgrate
## Mazda RX4         21.0   6 160.0 110 3.90 2620   16  0  M    4    4     Good
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2875   17  0  M    4    4     Good
## Datsun 710        22.8   4 108.0  93 3.85 2320   19  1  M    4    1     Good
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3215   19  1  A    3    1     Good
## Hornet Sportabout 18.7   8 360.0 175 3.15 3440   17  0  A    3    2      Bad
## Valiant           18.1   6 225.0 105 2.76 3460   20  1  A    3    1      Bad
## Duster 360        14.3   8 360.0 245 3.21 3570   16  0  A    3    4 horrible
## Merc 240D         24.4   4 146.7  62 3.69 3190   20  1  A    4    2    Great
## Merc 230          22.8   4 140.8  95 3.92 3150   23  1  A    4    2     Good
## Merc 280          19.2   6 167.6 123 3.92 3440   18  1  A    4    4      Bad
## Merc 280C         17.8   6 167.6 123 3.92 3440   19  1  A    4    4      Bad
## Merc 450SE        16.4   8 275.8 180 3.07 4070   17  0  A    3    3      Bad
## Merc 450SL        17.3   8 275.8 180 3.07 3730   18  0  A    3    3      Bad
## Merc 450SLC       15.2   8 275.8 180 3.07 3780   18  0  A    3    3 horrible
## Cadillac Fleetwood  10.4   8 472.0 205 2.93 5250   18  0  A    3    4 horrible
## Lincoln Continental 10.4   8 460.0 215 3.00 5424   18  0  A    3    4 horrible
## Chrysler Imperial   14.7   8 440.0 230 3.23 5345   17  0  A    3    4 horrible
## Fiat 128          32.4   4  78.7  66 4.08 2200   19  1  M    4    1    Great
## Honda Civic       30.4   4  75.7  52 4.93 1615   19  1  M    4    2    Great
## Toyota Corolla    33.9   4  71.1  65 4.22 1835   20  1  M    4    1    Great
## Toyota Corona     21.5   4 120.1  97 3.70 2465   20  1  A    3    1     Good
## Dodge Challenger  15.5   8 318.0 150 2.76 3520   17  0  A    3    2      Bad
## AMC Javelin       15.2   8 304.0 150 3.15 3435   17  0  A    3    2 horrible
## Camaro Z28        13.3   8 350.0 245 3.73 3840   15  0  A    3    4 horrible
```

```
## Pontiac Firebird    19.2   8 400.0 175 3.08 3845   17  0  A    3    2      Bad
## Fiat X1-9           27.3   4  79.0  66 4.08 1935   19  1  M    4    1    Great
## Porsche 914-2       26.0   4 120.3  91 4.43 2140   17  0  M    5    2    Great
## Lotus Europa        30.4   4  95.1 113 3.77 1513   17  1  M    5    2    Great
## Ford Pantera L      15.8   8 351.0 264 4.22 3170   14  0  M    5    4      Bad
## Ferrari Dino        19.7   6 145.0 175 3.62 2770   16  0  M    5    6     Good
## Maserati Bora       15.0   8 301.0 335 3.54 3570   15  0  M    5    8 horrible
## Volvo 142E          21.4   4 121.0 109 4.11 2780   19  1  M    4    2     Good
```

Missing Values

The NA (datum Not Available) is R's way of dealing with missing data. NAs can give you trouble unless you explicitly tell functions to ignore them. You can also pass the data through na.omit(), na.exclude(), or complete.cases() to insure that R handles data accordingly.

```
data <- data.frame(x=c(1,2,3,4),
                   y=c(5, NA, 8,3),
                   z=c("F","M","F","M"))

data
```

```
##   x  y z
## 1 1  5 F
## 2 2 NA M
## 3 3  8 F
## 4 4  3 M
```

```
na.omit(data)
```

```
##   x y z
## 1 1 5 F
## 3 3 8 F
## 4 4 3 M
```

```
data <- data.frame(x=c(1,2,3,4),
                   y=c(5, NA, 8,3),
                   z=c("F","M","F","M"))
complete.cases(data)
```

```
## [1]  TRUE FALSE  TRUE  TRUE
```

```
sum(complete.cases(data)) # total number of complete cases
```

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

```
sum(!complete.cases(data)) # total number of incomplete cases
```

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

```
data[complete.cases(data),] # Same as na.omit(data)
```

```
##   x y z
## 1 1 5 F
## 3 3 8 F
## 4 4 3 M
```

```
url <- "https://raw.githubusercontent.com/steviep42/bios545_spring_2021/master/DATA.DIR/hs0.csv"

data1 <- read.table(url,header=F,sep=",")
```

```
names(data1) <- c("gender","id","race","ses","schtyp","prgtype",
                  "read", "write","math","science","socst")
```

```
head(data1)
```

```
##   gender  id race ses schtyp    prgtype read write math science socst
## 1      0  70    4   1      1    general   57    52   41      47    57
## 2      1 121    4   2      1 vocational   68    59   53      63    61
## 3      0  86    4   3      1    general   44    33   54      58    31
## 4      0 141    4   3      1 vocational   63    44   47      53    56
## 5      0 172    4   2      1   academic   47    52   57      53    61
## 6      0 113    4   2      1   academic   44    52   51      63    61
```

```
nrow(data1)
```

```
## [1] 200
```

```
sum(complete.cases(data1))
```

```
## [1] 195
```

```
sum(!complete.cases(data1))
```

```
## [1] 5
```

```
data1[!complete.cases(data1),]
```

```
##    gender  id race ses schtyp  prgtype read write math science socst
## 9       0  84    4   2      1  general   63    57   54      NA    51
## 18      0 195    4   2      2  general   57    57   60      NA    56
## 37      0 200    4   2      2 academic   68    54   75      NA    66
## 55      0 132    4   2      1 academic   73    62   73      NA    66
## 76      0   5    1   1      1 academic   47    40   43      NA    31
```

Many R functions have an argument to exclude missing values

```
data1[!complete.cases(data1),]
```

```
##    gender  id race ses schtyp  prgtype read write math science socst
## 9       0  84    4   2      1  general   63    57   54      NA    51
## 18      0 195    4   2      2  general   57    57   60      NA    56
## 37      0 200    4   2      2 academic   68    54   75      NA    66
## 55      0 132    4   2      1 academic   73    62   73      NA    66
## 76      0   5    1   1      1 academic   47    40   43      NA    31
```

```
mean(data1$science)
```

```
## [1] NA
```

```
mean(data1$science,na.rm=T)
```

```
## [1] 51.66154
```

Many times data will be read in from a comma delimited ,(“CSV”), file exported from Excel. The file can be read from local storage or from the Web.

```
url <- "https://raw.githubusercontent.com/steviep42/bios545_spring_2021/master/DATA.DIR/hsb2.csv"

data1 <- read.table(url,header=T,sep=",")
head(data1)
```

```
##    id female race ses schtyp prog read write math science socst
## 1  70      0    4   1      1    1   57    52   41      47    57
## 2 121      1    4   2      1    3   68    59   53      63    61
## 3  86      0    4   3      1    1   44    33   54      58    31
## 4 141      0    4   3      1    3   63    44   47      53    56
## 5 172      0    4   2      1    2   47    52   57      53    61
## 6 113      0    4   2      1    2   44    52   51      63    61
```

Let's look at a "real" file. I got a file from this site https://data.cityofchicago.org/ and put it on a server if you want to download it and give it a whirl.

Also, my laptop has 8GB of RAM. I suspect if you have 2GB of RAM on your laptop you will be okay but I cannot be sure. On campus it took about 30 seconds to download and read it into R.

I zipped it to make it more manageable. You can download it and read it into R using the following commands

```
url <- "https://github.com/steviep42/bios545_spring_2021/blob/master/DATA.DIR/chi_crimes.csv.zip?raw=tr

download.file(url,destfile="chi_crimes.csv.zip")

chi <- read.csv(unzip("chi_crimes.csv.zip"),
                header=TRUE,sep=",",stringsAsFactors = FALSE)
```

```
names(chi)
```

```
##  [1] "Case.Number"          "ID"                   "Date"
##  [4] "Block"                "IUCR"                 "Primary.Type"
##  [7] "Description"          "Location.Description" "Arrest"
## [10] "Domestic"             "Beat"                 "District"
## [13] "Ward"                 "FBI.Code"             "X.Coordinate"
## [16] "Community.Area"       "Y.Coordinate"         "Year"
## [19] "Latitude"             "Updated.On"           "Longitude"
## [22] "Location"
```

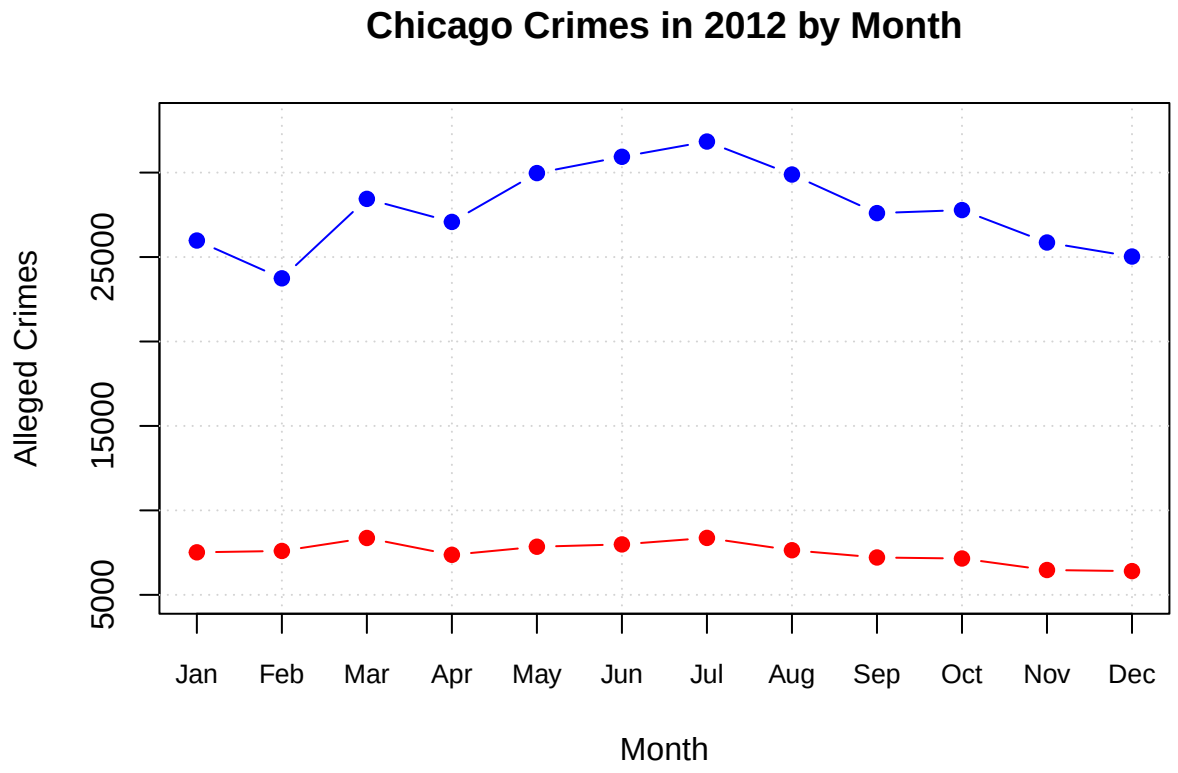
```
sapply(chi, function(x) length(unique(x)))
```

```
##          Case.Number                  ID                Date
##               334114              334139              121484
##                Block                IUCR        Primary.Type
##                28383                 358                  30
##          Description Location.Description              Arrest
##                  296                 120                   2
##             Domestic                Beat            District
##                    2                 302                  25
##                 Ward            FBI.Code        X.Coordinate
##                   51                  30               60704
##       Community.Area        Y.Coordinate                Year
##                   79               89895                   1
##             Latitude          Updated.On           Longitude
##               180396                1311              180393
##             Location
##               178534
```

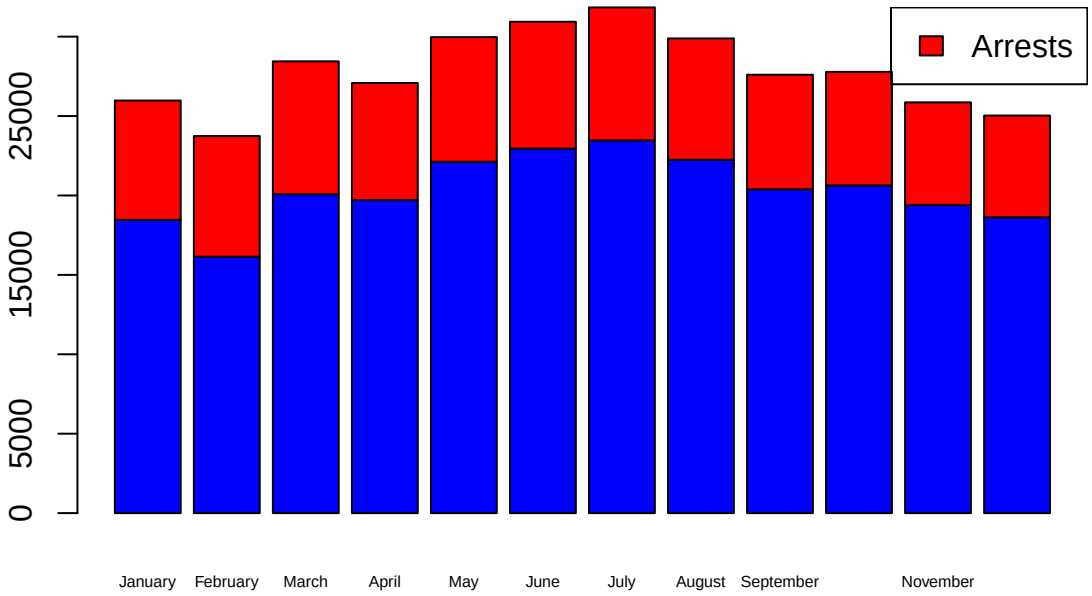
```
# Make the date a "real date"
chi$Date <- strptime(chi$Date,"%m/%d/%Y %r")
chi$month <- months(chi$Date)
chi$month <- factor(chi$month,levels=c("January","February","March",
                    "April","May","June","July","August", "September",
```

```
                    "October","November","December"),ordered=TRUE)
```

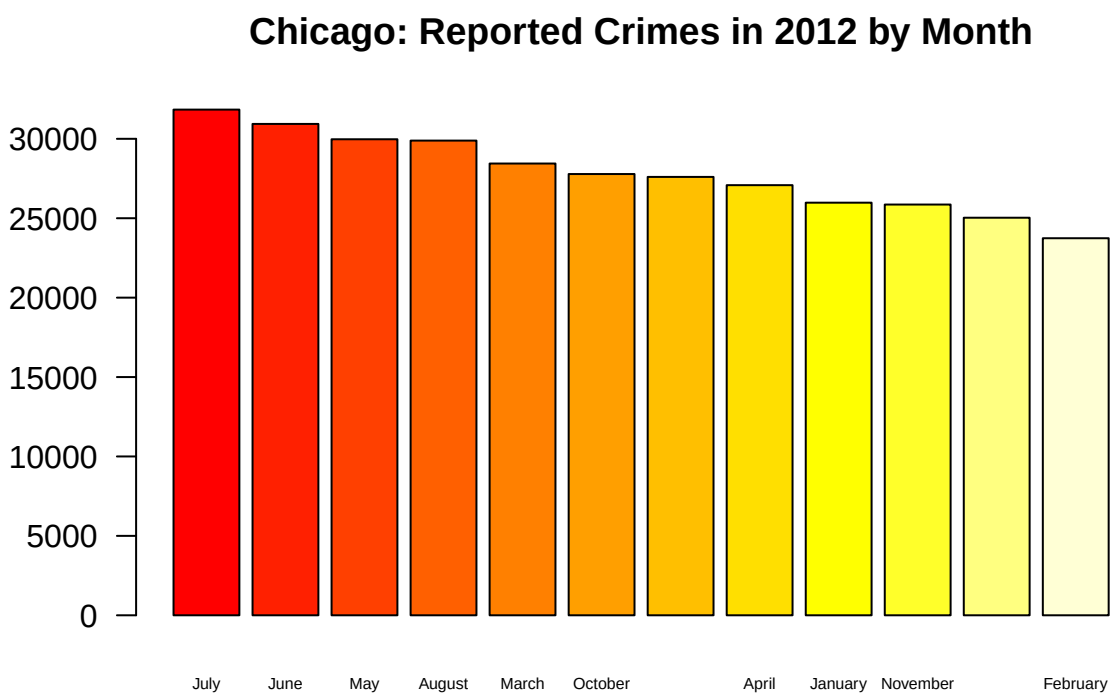
```
# Okay how many crimes were committed in each Month of the year ?
plot(1:12,as.vector(table(chi$month)),
     type="n",xaxt="n", ylab="Alleged Crimes",
     xlab="Month", main="Chicago Crimes in 2012 by Month",ylim=c(5000,33000))
grid()

axis(1,
     at=1:12,
     labels=as.character(sapply(levels(chi$month), function(x) substr(x,1,3))),cex.axis=0.8)

points(1:12,as.vector(table(chi$month)),type="b",pch=19,col="blue")
points(1:12,as.vector(table(chi$month,chi$Arrest)[,2]),
       col="red", pch=19,type="b")
```




```
barplot(table(chi$Arrest,chi$month),
        col=c("blue","red"),
        cex.names=0.5,
        main="Chicago: Reported Crimes vs. Actual Arrests")

legend("topright",c("Arrests"),fill="red")
```

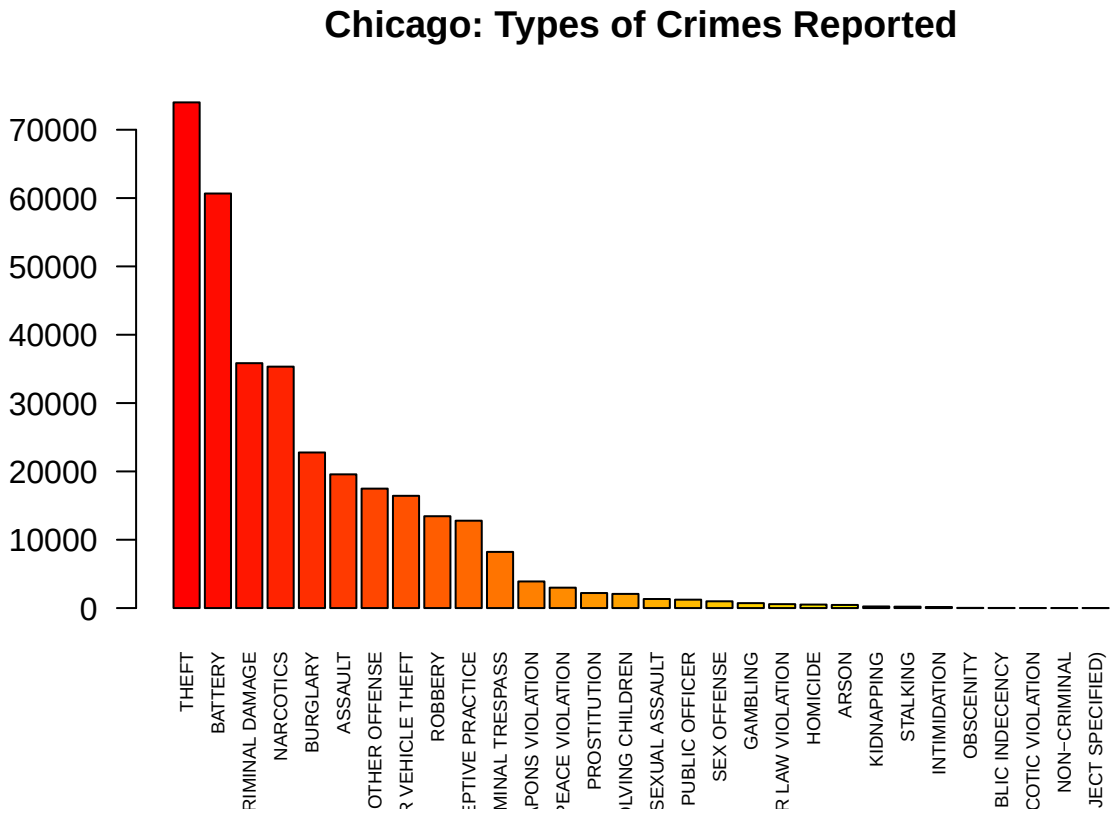



```
 # Even easier to do
hold <- rev(sort(table(chi$month)))
barplot(rev(sort(hold)),horiz=F,
        las=1,cex.names=0.5,col=heat.colors(12),
        main="Chicago: Reported Crimes in 2012 by Month")
```




```
# Find out number of alleged crimes by type
categories <- rev(sort(sapply(unique(as.character(chi$Primary.Type)), function(x) { nrow(chi[chi$Primary

categories <- rev(sort(table(chi$Primary.Type)))
```

```
barplot(categories,horiz=F,las=1,cex.names=0.6,col=heat.colors(30), las=2, main="Chicago: Types of Crime
```




```
hold <- chi[chi$Primary.Type == "GAMBLING",]
hold <- chi[chi$Primary.Type == "GAMBLING" & chi$Description != "GAME/DICE",]
nrow(hold) # How many non-Dice related gambling offenses were there ? # About 26 I think
```

```
## [1] 26
```

```
# Let's plot them on a map
library(googleVis) # This is an addon package you must install
```

```
## Warning: package 'googleVis' was built under R version 4.1.2
```

```
## Creating a generic function for 'toJSON' from package 'jsonlite' in package 'googleVis'
```

```
##
## Welcome to googleVis version 0.6.11
##
## Please read Google's Terms of Use
## before you start using the package:
## https://developers.google.com/terms/
##
## Note, the plot method of googleVis will by default use
## the standard browser to display its output.
##
## See the googleVis package vignettes for more details,
## or visit https://mages.github.io/googleVis/.
##
## To suppress this message use:
## suppressPackageStartupMessages(library(googleVis))
```

```
hold$LatLon <- paste(hold$Latitude,hold$Longitude,sep=":")
hold$Tip <- paste(hold$Description,hold$Locate.Description,hold$Block,
"<BR>",sep=" ")

chi.plot <- gvisMap(hold,"LatLon","Tip")
plot(chi.plot)
```

```
## starting httpd help server ...
```

```
##  done
```

Review apply, sapp,y, and lists

```
set.seed(1)  # Makes the call to rnorm generate the same numbers every time
( mymat <- matrix(round(rnorm(16,10),2),4,4) )
```

```
##       [,1]  [,2]  [,3]  [,4]
## [1,]  9.37 10.33 10.58  9.38
## [2,] 10.18  9.18  9.69  7.79
## [3,]  9.16 10.49 11.51 11.12
## [4,] 11.60 10.74 10.39  9.96
```

Let's say that we want to take the mean of each column. Another way to say this is that we want to apply the mean function to each column in the matrix. This is the way to start thinking about things like this in R. But first, how might we do this if we don't know anything about the apply command ?

```
mean(mymat[,1])
```

```
## [1] 10.0775
```

```
mean(mymat[,2])
```

```
## [1] 10.185
```

```
mean(mymat[,3])
```

```
## [1] 10.5425
```

```
mean(mymat[,4])
```

```
## [1] 9.5625
```

We could put this into a vector

```
( mymatcolmean <- c(mean(mymat[,1]),mean(mymat[,2]),mean(mymat[,3]),mean(mymat[,4])) )
```

```
## [1] 10.0775 10.1850 10.5425  9.5625
```

But we could easily do this outselves using the apply function

```
apply(mymat, 2, mean)
```

```
## [1] 10.0775 10.1850 10.5425  9.5625
```

```
apply(mymat, 1, mean)
```

```
## [1]  9.9150  9.2100 10.5700 10.6725
```

And we could use functions other than **mean** such as getting the sums of the columns

```
apply(mymat,2,sum)    # Get the sum of all the columns
```

```
## [1] 40.31 40.74 42.17 38.25
```

Imagine if the matrix was really big. Here is a matrix with 100,000 elements from a normal distribution

```
set.seed(123)
bigmat <- matrix(rnorm(100000),nrow=1000,ncol=100)
```

Now let's get the means of all the columns

```
apply(bigmat,2,mean)
```

```
##   [1]  0.0161278659  0.0424652533 -0.0201125279 -0.0091603764 -0.0321681836
##   [6]  0.0344790547 -0.0329035141  0.0054608165  0.0199362490 -0.0478416559
##  [11]  0.0260991083  0.0249296523 -0.0630496591  0.0355402168  0.0173350347
##  [16]  0.0036616175 -0.0515827202 -0.0148914815 -0.0274882199 -0.0416180800
##  [21] -0.0190559022  0.0004939275 -0.0174577308  0.0213817922 -0.0334648409
##  [26] -0.0195911041 -0.0349583336  0.0010683705  0.0035989160  0.0269908085
##  [31] -0.0025071086  0.0056892550 -0.0029440338  0.0161870207  0.0128943042
##  [36] -0.0616251256 -0.0115280450  0.0027015691 -0.0094319875 -0.0018834633
##  [41]  0.0195424824 -0.0144738095 -0.0038203591  0.0322663182 -0.0117293734
##  [46] -0.0254981254  0.0699837906  0.0540531702 -0.0080165175  0.0387336883
##  [51]  0.0405523857 -0.0084603524  0.0098630631  0.0006990184 -0.0167948852
##  [56] -0.0129560796  0.0361747069  0.0156466764  0.0320812190  0.0163217647
##  [61] -0.0465319673 -0.0317321353  0.0227199106  0.0242265727  0.0093444154
##  [66]  0.0129220192  0.0225092468 -0.0043516369  0.0036099542  0.0047358985
##  [71] -0.0157537466  0.0256088739 -0.0246586694  0.0312044287  0.0295896845
##  [76]  0.0031180653  0.0075930325 -0.0238613921  0.0475138335 -0.0189951330
##  [81]  0.0072601097  0.0790556048  0.0246173539  0.0174011973 -0.0017227610
##  [86]  0.0148692571  0.0547734413  0.0455918829 -0.0613709908 -0.0695473440
##  [91]  0.0117180640 -0.0768970933  0.0270154389 -0.0140851721  0.0219780381
##  [96] -0.0259417598 -0.0551105458  0.0008382943 -0.0254384898  0.0179135809
```

Check it out to make sure it works. According to this, the mean of column one is 0.0161278659

```
mean(bigmat[,1])
```

```
## [1] 0.01612787
```

Or get the max value from each column

```
apply(bigmat,2,max)
```

```
##   [1] 3.241040 3.390371 3.421095 2.894854 3.445992 3.715721 3.275908 2.856131
##   [9] 3.847768 3.067501 3.035185 2.842996 2.919474 2.801104 3.102420 3.313622
##  [17] 3.274395 2.978586 3.758702 3.268841 3.014451 3.921410 3.672179 4.322815
##  [25] 3.338211 3.502046 2.964529 2.818043 2.850670 3.249978 3.560446 3.048426
##  [33] 3.982778 2.961454 3.068239 3.498277 2.670296 3.013587 3.407816 3.053021
##  [41] 2.562596 3.409307 2.619136 3.079701 3.187999 3.315370 3.598571 2.813426
##  [49] 3.470800 3.262702 3.560689 3.380447 2.842233 3.722831 3.596677 3.826928
##  [57] 3.192798 2.707502 3.691477 3.164501 2.920399 2.998747 3.413671 3.868918
##  [65] 3.133059 3.029871 2.683921 2.608486 3.727903 3.683753 3.008040 3.208739
##  [73] 3.856234 2.907500 3.324857 3.296935 3.197126 3.185820 3.055806 2.642041
##  [81] 2.854507 3.344786 3.726136 3.098896 3.272309 3.100453 3.068710 3.059364
##  [89] 3.311354 3.174059 3.221115 2.913829 3.804633 3.254153 2.926690 2.926363
##  [97] 3.268204 3.093964 2.949278 3.633231
```

We could also pass arguemnts to any R functions we might use. For example, what if we wanted to trim the top and botoom percent of the data before taking the mean?

```
apply(bigmat,2,mean,trim=0.05)
```

```
##   [1]  0.010124729  0.044533560 -0.019411282 -0.006462397 -0.030819549
##   [6]  0.033717292 -0.023613615  0.005274967  0.017642407 -0.056219069
##  [11]  0.027451922  0.033010057 -0.060811086  0.043786958  0.016694742
##  [16] -0.007425057 -0.057162959 -0.024675969 -0.031419105 -0.042494521
##  [21] -0.009673919 -0.001477532 -0.019793191  0.013087891 -0.031507897
##  [26] -0.021735087 -0.029125095 -0.002245781  0.010169435  0.016471393
##  [31] -0.004783183  0.011511935 -0.002665629  0.021474448  0.008128902
##  [36] -0.066836511 -0.004479457 -0.008694218 -0.006656308  0.002096459
##  [41]  0.027225053 -0.015315068 -0.006312255  0.028479939 -0.009297293
##  [46] -0.030737527  0.066635400  0.057058438 -0.003146990  0.041417910
##  [51]  0.034025905 -0.013405727  0.011669530 -0.002207751 -0.012299682
##  [56] -0.016161055  0.034123660  0.017520528  0.033266917  0.013346560
##  [61] -0.042212750 -0.030395950  0.023831216  0.030128865  0.012103036
##  [66]  0.016476108  0.026745756  0.004485525  0.005823565  0.014333697
##  [71] -0.008425933  0.024660540 -0.031098724  0.034487430  0.031345336
##  [76]  0.004307105  0.007206317 -0.025258007  0.051844458 -0.012398481
##  [81]  0.007457985  0.076172058  0.024982899  0.013389702 -0.006060082
##  [86]  0.020392636  0.052406363  0.046222191 -0.062746498 -0.064327546
##  [91]  0.012988233 -0.067480447  0.028435896 -0.011809924  0.019134699
##  [96] -0.019902717 -0.056373122 -0.005365838 -0.030513560  0.025027669
```

This is every efficient. Let's get find the max value of each row of a 1,000,000 element matrix and then from that, get the over all max calue

```
set.seed(234)
biggermat <- matrix(rnorm(1000000),1000,1000)
```

```
# Get the max value of each row
maxrows <- apply(biggermat,1,max)

# Get the max of that
max(maxrows)
```

```
## [1] 4.724117
```

Or maybe just do this.

```
max(apply(biggermat,1,max))
```

```
## [1] 4.724117
```

```
system.time(max(apply(biggermat,1,max)))
```

```
##    user  system elapsed
##   0.017   0.001   0.018
```

Remember we have lists that frequently come back from many R stat functions.

```
x <- 1:10             # x vals
y <- 1:10 + rnorm(10,2,2)   # A y value plus some noise
mylm <- lm(y~x,data.frame(x,y))
```

Let's figure out some things about what we get back

```
str(mylm,0)
```

```
## List of 12
```

```
##  - attr(*, "class")= chr "lm"
```

```
str(mylm,1)
```

```
## List of 12
##  $ coefficients : Named num [1:2] 4.323 0.677
##   ..- attr(*, "names")= chr [1:2] "(Intercept)" "x"
##  $ residuals    : Named num [1:10] 1.444 -1.047 -0.074 -1.907 -0.23 ...
##   ..- attr(*, "names")= chr [1:10] "1" "2" "3" "4" ...
##  $ effects      : Named num [1:10] -25.445 6.149 -0.249 -2.203 -0.647 ...
##   ..- attr(*, "names")= chr [1:10] "(Intercept)" "x" "" "" ...
##  $ rank         : int 2
##  $ fitted.values: Named num [1:10] 5 5.68 6.35 7.03 7.71 ...
##   ..- attr(*, "names")= chr [1:10] "1" "2" "3" "4" ...
##  $ assign       : int [1:2] 0 1
##  $ qr           :List of 5
##   ..- attr(*, "class")= chr "qr"
##  $ df.residual  : int 8
##  $ xlevels      : Named list()
##  $ call         : language lm(formula = y ~ x, data = data.frame(x, y))
##  $ terms        :Classes 'terms', 'formula'  language y ~ x
##   .. ..- attr(*, "variables")= language list(y, x)
##   .. ..- attr(*, "factors")= int [1:2, 1] 0 1
##   .. .. ..- attr(*, "dimnames")=List of 2
##   .. ..- attr(*, "term.labels")= chr "x"
##   .. ..- attr(*, "order")= int 1
##   .. ..- attr(*, "intercept")= int 1
##   .. ..- attr(*, "response")= int 1
##   .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
##   .. ..- attr(*, "predvars")= language list(y, x)
##   .. ..- attr(*, "dataClasses")= Named chr [1:2] "numeric" "numeric"
##   .. .. ..- attr(*, "names")= chr [1:2] "y" "x"
##  $ model        :'data.frame':   10 obs. of  2 variables:
##   ..- attr(*, "terms")=Classes 'terms', 'formula'  language y ~ x
##   .. .. ..- attr(*, "variables")= language list(y, x)
##   .. .. ..- attr(*, "factors")= int [1:2, 1] 0 1
##   .. .. .. ..- attr(*, "dimnames")=List of 2
##   .. .. ..- attr(*, "term.labels")= chr "x"
##   .. .. ..- attr(*, "order")= int 1
##   .. .. ..- attr(*, "intercept")= int 1
##   .. .. ..- attr(*, "response")= int 1
##   .. .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
##   .. .. ..- attr(*, "predvars")= language list(y, x)
##   .. .. ..- attr(*, "dataClasses")= Named chr [1:2] "numeric" "numeric"
##   .. .. .. ..- attr(*, "names")= chr [1:2] "y" "x"
##  - attr(*, "class")= chr "lm"
```

We also encountered lists when using the strsplit function

```
somestring <- "Hello. My name is John. Your name is Mary."

(mys <- strsplit(somestring," "))
```

```
## [[1]]
## [1] "Hello." "My"     "name"   "is"     "John."  "Your"   "name"   "is"
## [9] "Mary."
```

We could reverse this string using the lapply function

```
lapply(mys,rev)
```

```
## [[1]]
## [1] "Mary."  "is"     "name"   "Your"   "John."  "is"     "name"   "My"
## [9] "Hello."
```