Introduction to R Graphics

* R has a powerful environment for visualization of scientific data

• It provides publication quality graphics, which are fully programmable

• Easily reproducible

• Full LaTeX and Sweave support

• Lots of packages and functions with built-in graphics support

• On-screen graphics

• Postscript, PDF, jpeg, png, SVG

http://faculty.ucr.edu/~tgirke/HTML_Presentations/Manuals/Rgraphics/Rgraphics.pdf

Graphics: History

* R Graph Gallery

http://gallery.r-enthusiasts.com/

• R Graphic Manual and Gallery

http://rgm2.lab.nig.ac.jp/RGM2/images.php?show=all&pageID=2087

• Grid Graphics – Paul Murrell

http://www.stat.auckland.ac.nz/~paul/RGraphics/rgraphics.html

* Lattice Graphics

http://lmdvr.r-forge.r-project.org/figures/figures.html

http://faculty.ucr.edu/~tgirke/HTML_Presentations/Manuals/Rgraphics/Rgraphics.pdf

Graphics: History

R graphics can be confusing because there are no less than 4 different systems. Let's list them out here and talk about which one(s) to use.

Low-Level Capability

Base Graphics (Has Low and High Level functions)
Grid Graphics

High-Level Capability

Lattice Graphics
ggplot2

Graphics: History

Base Graphics

* Oldest and most commonly used

• Uses a "pen-on-paper" model. You can only draw on top of the object. Cannot erase, modify, or delete what has already been drawn.

• Has both high and low level plotting routines (unique to Base)

• Base graphics are fast.

• Lots of documentation and "google" support

Graphics: History

Grid Graphics

* Developed in 2000 by Paul Murrell

• Provides a rich set of graphics primitives

• Uses a system of objects and view ports to make complex objects easier.

• You will almost never use this directly unless you want to do in-depth programming

Graphics: History

Lattice package

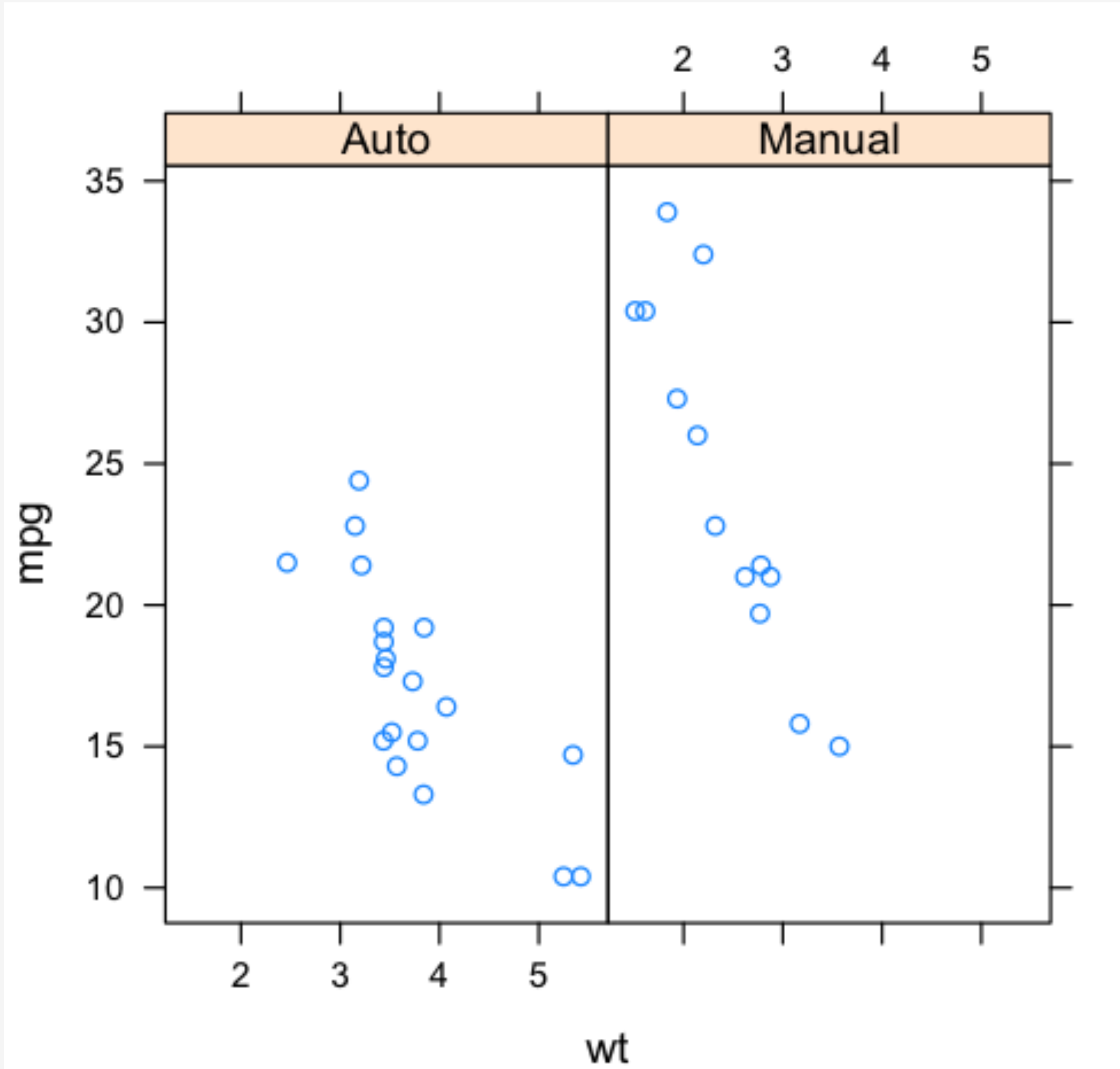
* Developed by Deepayan Sarkar to implement the trellis graphics system described in "Visualizing Data" by Cleveland.

• Easy to create conditioned plots with automatic creation of axes, legends, and other annotations

• Usually considered to be an improvement over Base graphics.

```
library(lattice)
xyplot(mpg~wt | factor(am,labels=c("Auto","Manual")), data=mtcars)
```

Graphics: History



Graphics: History

ggplot2

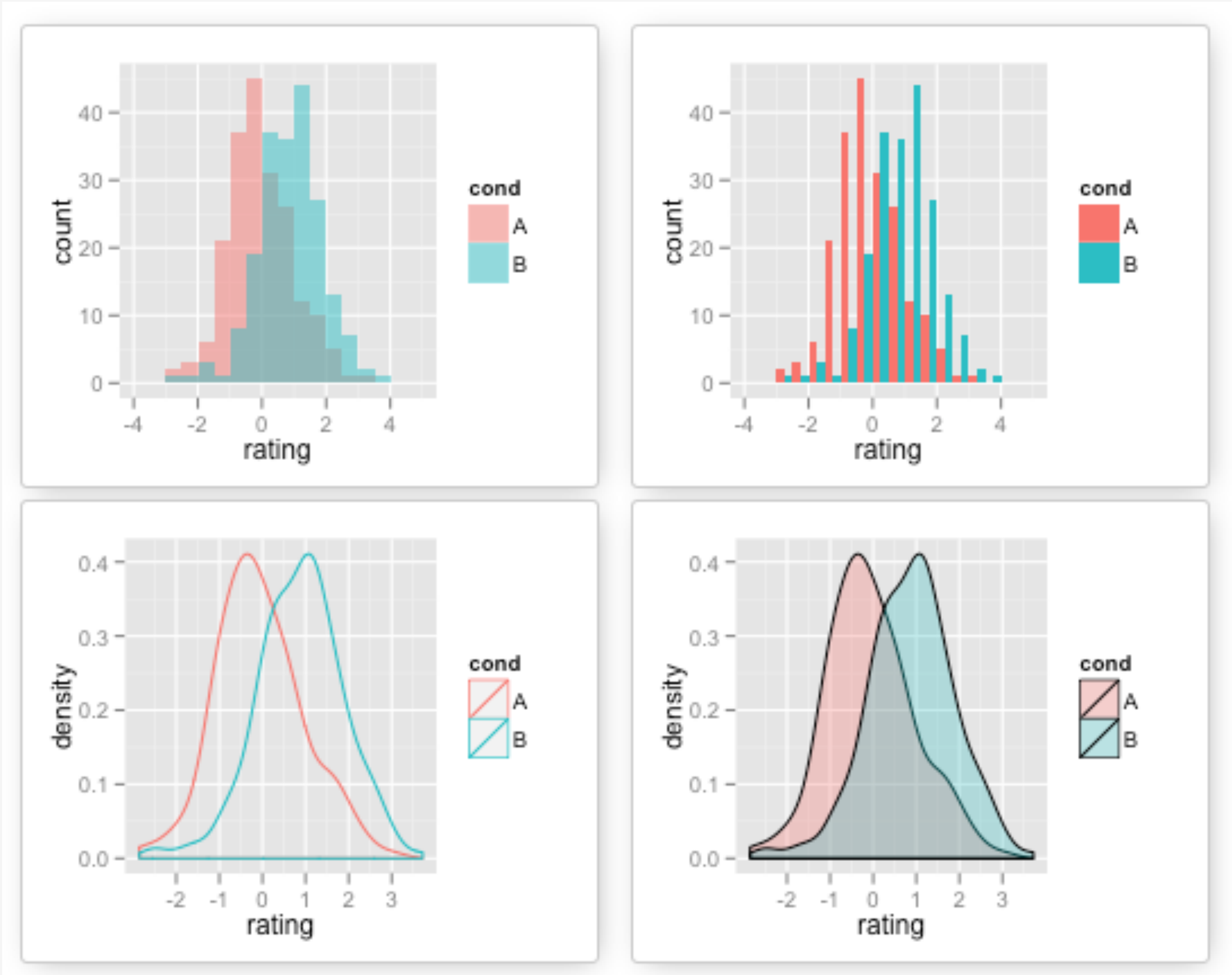
* Developed starting in 2005 by Hadley Wickham

- ggplot2 is an implementation of Leland Wilkinson's *Grammar of Graphics*--a general scheme for data visualization which breaks up graph into semantic components such as scales and layers.

- ggplot2 can serve as a replacement for the base graphics in R and contains a number of defaults for web and print display of common scales.

- Is said to be much slower than Base graphics but this isn't a major thing (in my opinion)

Graphics: History



Graphics: Chart Types

plot(x,y) where x and y are continuous:

X/Y, scatterplot, pairs, sunflower plots

plot(x,[y]) where x and y are categorical. Note that y can be optional:

dotplot, barplot, stacked bar plot, pie chart

plot(x) where x is a single continuous variable:

dotplot, barplot, stripchart, boxplot, density, histogram, QQ Plot

plot(x,y) where one of x and y is continuous and the other is discrete

Side-by-Side dotplot and boxplot, notched boxplot

Graphics

BASE Graphics

Graphics: Base

<u>Base</u> Graphics - Some low level plotting functions (a select list):

FUNCTION NAME	PURPOSE
points(x,y)	Adds points to an existing plot
lines(x,y)	Adds lines to an existing plot
arrows(x,y)	Draws arrows on an existing plot
text(x,y,labels,...)	Adds text to an existing plot
abline(a,b)	Adds a line of slope b and intercept a
polygon(x,y,...)	Draws a polygon
legend(x,y,legend)	Adds a legend to the plot
title("title")	Adds a title to the plot
axis	Adds an axis to the current plot
mtext	Write text in one of the four margins
segments	Draws line segments on an existing plot

Graphics: Base

<u>Base</u> Graphics - Some high level plotting functions (a select list):

FUNCTION NAME	PURPOSE
plot(x,y)	Generic x-y plots
barplot(x)	Creates a barplot of a table object
boxplot(x)	Creates a boxplot of numeric vector
hist(x)	Histogram of numeric data
pie(x)	Pie chart of a table object
dotchart(x)	Dot Plot of a vector or matrix
qqnorm(x)	Normal qqplot of numeric vector
qqline	Draws the qqline
pairs(x)	Scatterplot of matrix or data frame
stripchart	1D Scatterplot
coplot(x ~ y | f)	Conditioned plot by factor

Graphics: Base

<u>Base</u> Graphics – Some arguments to high level functions:

FUNCTION NAME	PURPOSE
add=TRUE	Adds a new plot on top of another (kind of)
axes=FALSE	Suppresses axis creation – you then make your own
xlab="STRING"	Makes the X label
ylab="STRING"	Makes the y-label
main="STRING"	Gives the plot a main title
sub="STRING"	Gives a subtitle
type="p"	Plot individual points
type="l"	Plot lines
type="b"	Plot points connected by lines
type="o"	Plot points overlaid by lines
type="n"	Suppresses plotting but sets up device. Good for

Graphics: Base

<u>Base</u> Graphics – Some arguments to high level functions:

FUNCTION NAME	PURPOSE
mar	Specifies margins around plot area
col	Specify color of plot symbols
pch	Specify type of symbol example(pch)
lwd	Specify size of plot symbols
cex	Control font sizes (see also cex.main, cex.axis, cex.lab)
las	Direction of axis labels in relation to axis
lty	If lines are used this specifies line type (dashed, etc)
type="l"	Plot lines
type="b"	Plot points connected by lines
type="o"	Plot points overlaid by lines
type="n"	Suppresses plotting but sets up device. Good for when you

Graphics: Base

You can save your on-screen graphics to a popular file type for use within a program. You can always do screen grabs too.

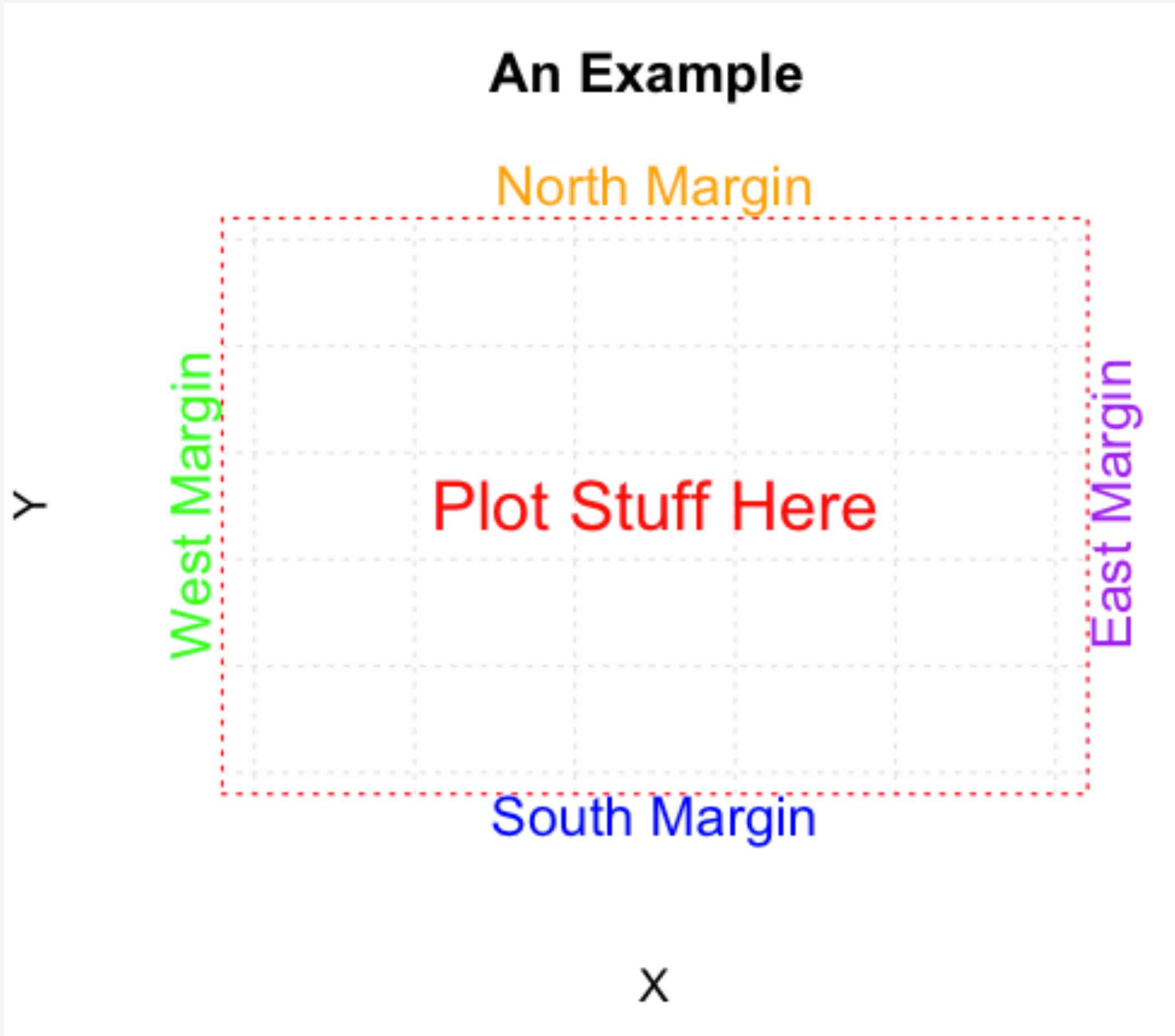
FUNCTION	RESULT OUTPUT
`pdf("file.pdf")`	Creates a PDF file called "file.pdf"
`png("file.png")`	Createa a PNG file
`jpeg("file.jpg")`	Creates a JPG file
`bmp(""file.bmp")`	Creates a BMP file
`postscript("file.ps")`	Creates a Postscript file
`win.meta("file.wmf")`	Creates a Windows meta file

```
> png("mytest.png")

> plot(mtcats$mpg)   # Simple, but you get the point

> dev.off()
```

Graphics: Base: Foundations

```
plot(0:10, 0:10, type="n", xlab="X", ylab="Y", axes=FALSE)

abline(h=seq(0,10,2),lty=3,col="gray90")

abline(v=seq(0,10,2),lty=3,col="gray90")

text(5,5, "Plot Stuff Here", col="red", cex=1.5)

box("plot", col="red", lty = "dotted")

box("inner", col="blue", lty = "dashed")

mtext("South Margin",1,cex=1.2,col="blue")

mtext("West Margin",2,cex=1.2,col="green")

mtext("North Margin",3,cex=1.2,col="orange")

mtext("East Margin",4,cex=1.2,col="purple")

title("An Example Plot")
```

Graphics: Base: Foundations



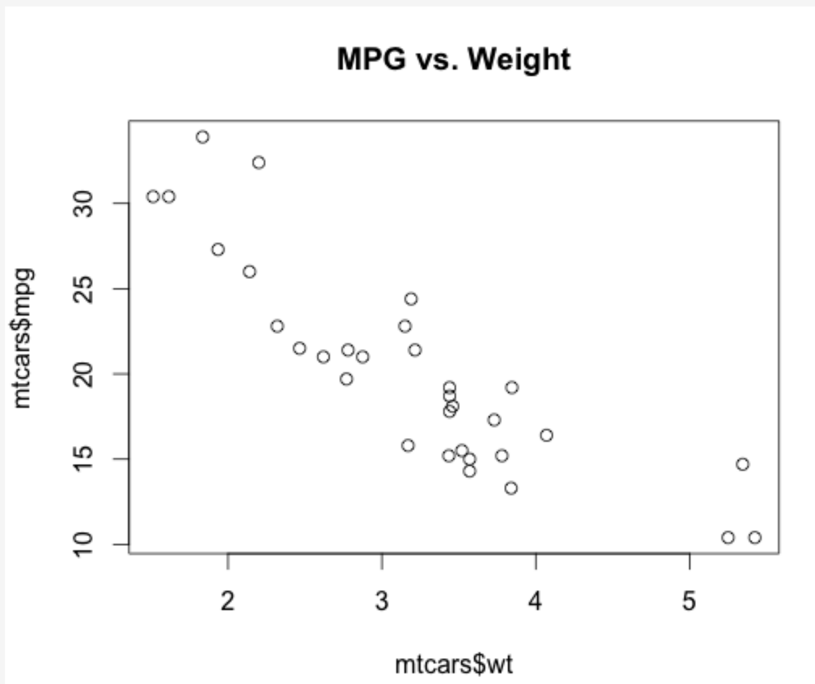
Graphics: Base: Foundations

Let's do some basic plotting. These two commands do the same thing. Given two vectors, x and y (of same length), do a scatterplot:

```
plot(x,y)    # Traditional way
```

Using mtcars:

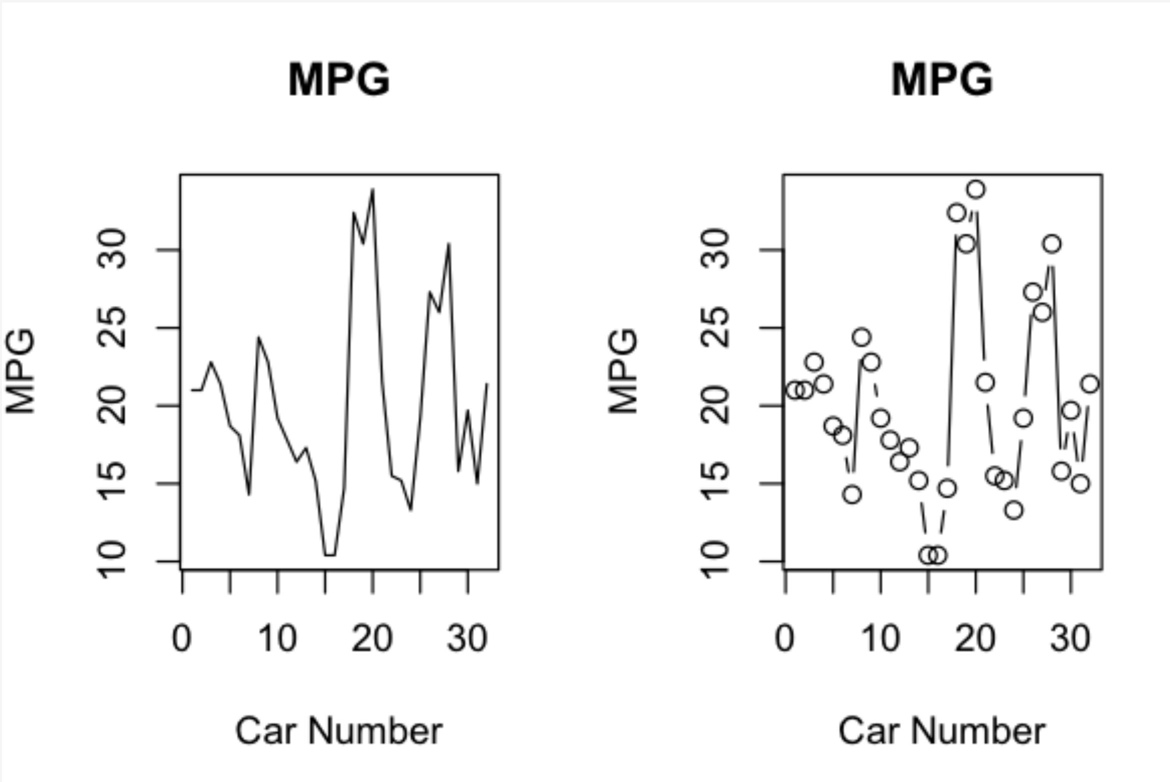
```
plot(mtcars$wt, mtcars$mpg, main="MPG vs. Weight")
```



Graphics: Base: Foundations

We can also plot a single variable:

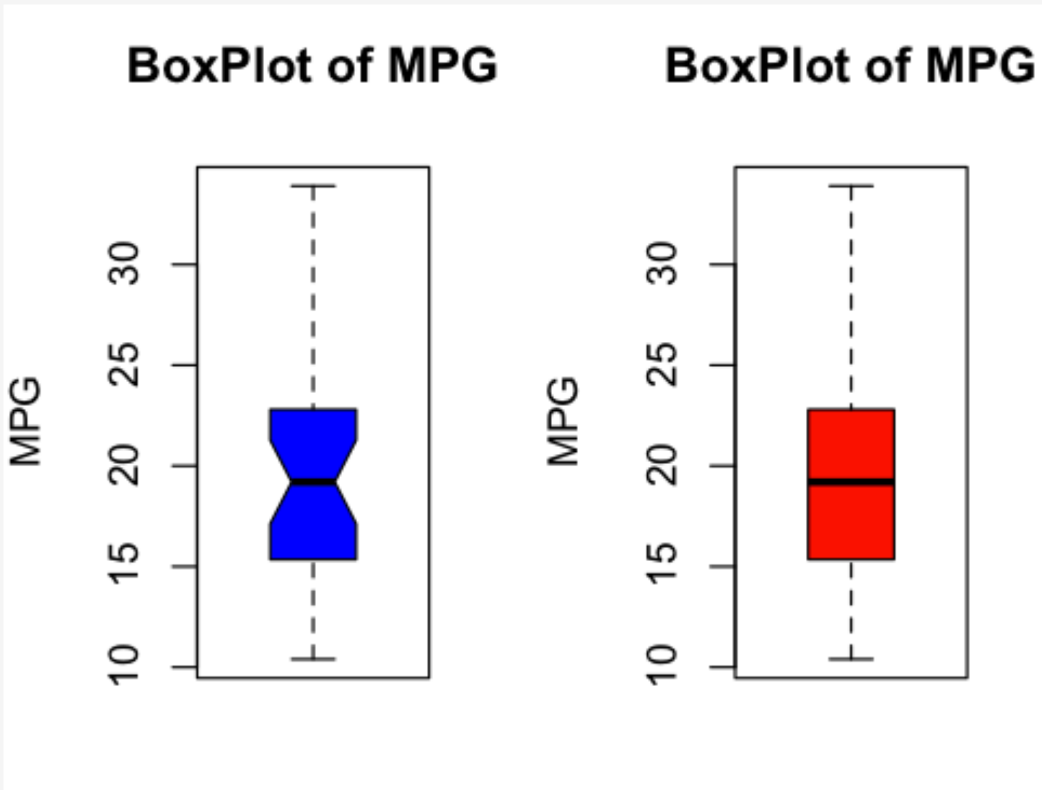
```
plot(mtcars$mpg, main="MPG", type="l",xlab="Car Number",ylab="MPG")

plot(mtcars$mpg, main="MPG", type="b",xlab="Car Number",ylab="MPG")
```



Graphics: Base: Foundations

We can also plot a single variable:

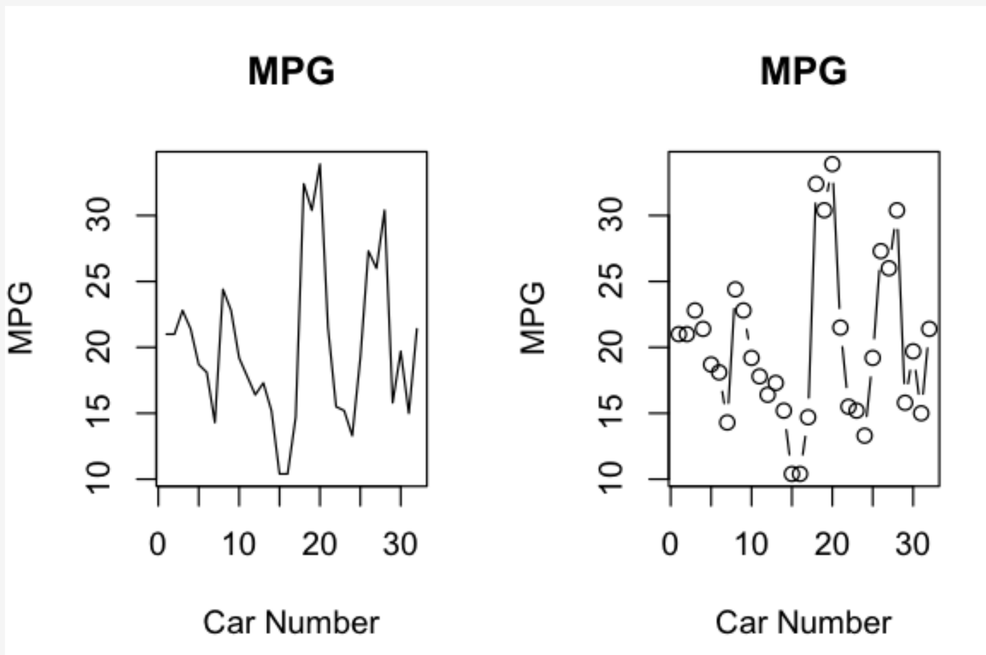
```
boxplot(mtcars$mpg, main="BoxPlot of MPG",
        ylab="MPG",col="blue",notch=TRUE)

boxplot(mtcars$mpg,main="BoxPlot of MPG",ylab="MPG",col="red")
```



Graphics: Base: Panels

How can I get two plots to be on the same page ?

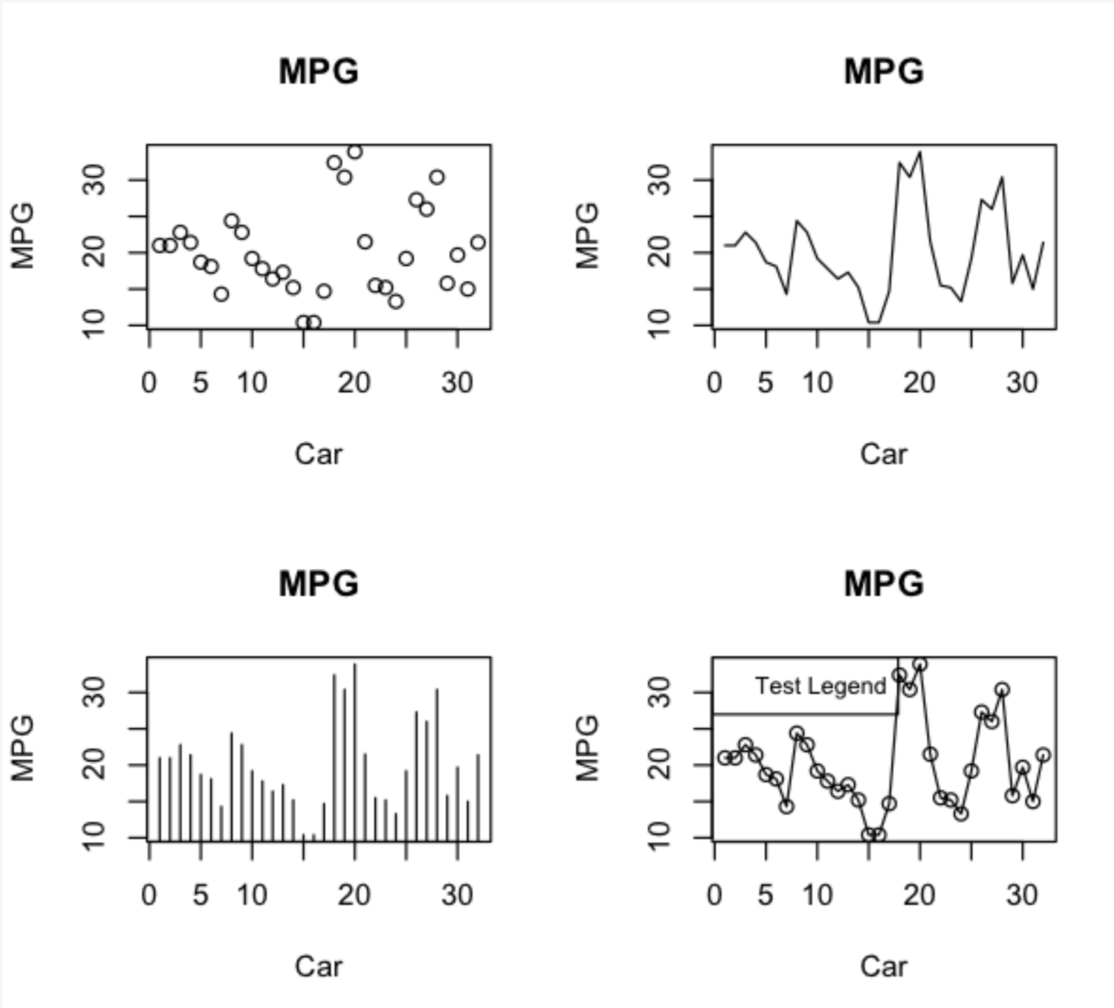
```
par(mfrow=c(1,2)) # One row and two columns

plot(mtcars$mpg, main="MPG", type="l",xlab="Car Number",ylab="MPG")

plot(mtcars$mpg, main="MPG", type="b",xlab="Car Number",ylab="MPG")
```



Graphics: Base: Panels

```
par(mfrow=c(2,2))

plot(mtcars$mpg,main="MPG",xlab="Car",ylab="MPG",type="p")

plot(mtcars$mpg,main="MPG",xlab="Car",ylab="MPG",type="l")

plot(mtcars$mpg,main="MPG",xlab="Car",ylab="MPG",type="h")

plot(mtcars$mpg,main="MPG",xlab="Car",ylab="MPG",type="o")

legend("topleft",legend=c("Test Legend"),cex=0.8)
```

Graphics: Base: Panels

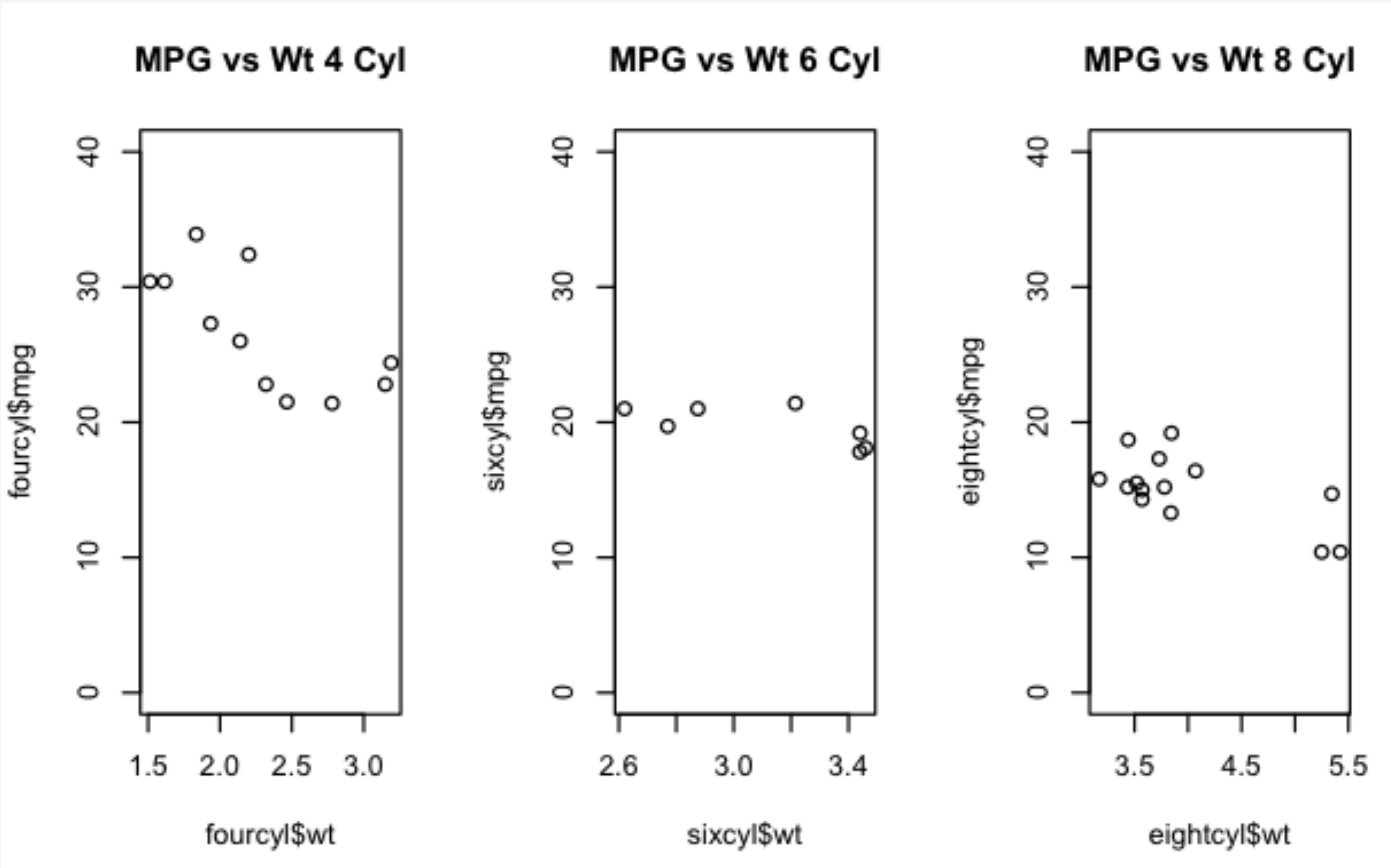


Graphics: Base: MultiPanel

We usually take this approach when we want to plot data across different categories. Like the mpg vs weight across cylinder types. We have three unique cylinder values:

```
unique(mtcars$cyl)   # We have three categories so let's create 3 plots
[1] 6 4 8

par(mfrow=c(1,3))   # One row and three columns

fourcyl   <- mtcars[mtcars$cyl == 4,]
sixcyl    <- mtcars[mtcars$cyl == 6,]
eightcyl  <- mtcars[mtcars$cyl == 8,]

plot(fourcyl$wt, fourcyl$mpg, main = "MPG vs Wt 4 Cyl", ylim=c(0,40))
plot(sixcyl$wt, sixcyl$mpg, main = "MPG vs Wt 6 Cyl", ylim=c(0,40))
plot(eightcyl$wt, eightcyl$mpg, main = "MPG vs Wt 8 Cyl", ylim=c(0,40))

par(mfrow=c(1,1)) # Reset the plot window
```

Graphics: Base: MultiPanel



Graphics: Base: MultiPanel

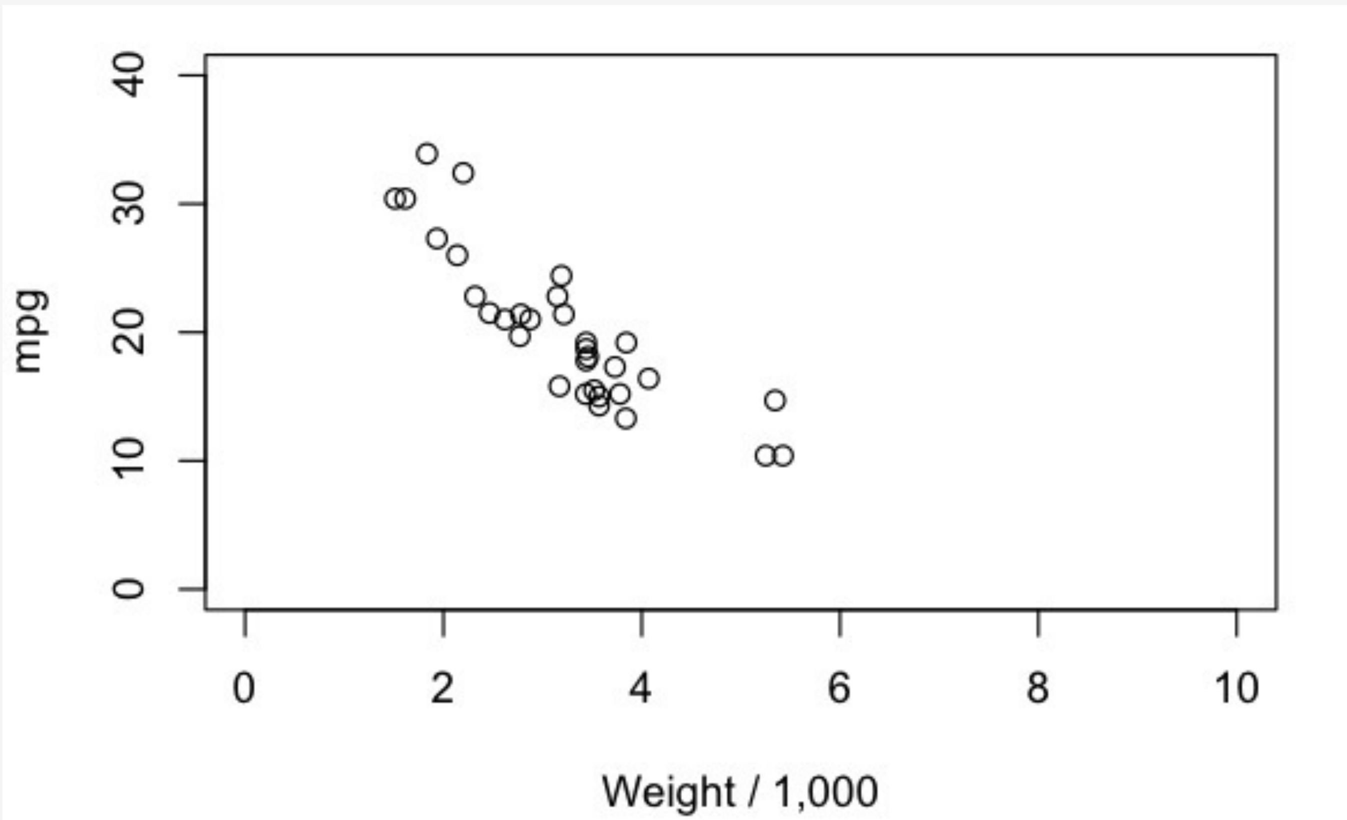
We could automate this using the "split" approach:

```
par(mfrow=c(1,3))   # One row and three columns
mysplits <- split(mtcars, mtcars$cyl)

for (ii in 1:length(mysplits)) {
    plot(mysplits[[ii]]$wt, mysplits[[ii]]$mpg,
    ylim <- c(0,40),
    main=paste("MPG vs weight for",names(mysplits[ii])))
}

# Better yet we could make this into a function

cyl.plot <- function(df, fac, numrows=1, numcols=3) {
  par(mfrow=c(numrows,numcols))
  mysplits <- split(df,fac)
  for (ii in 1:length(mysplits)) {
    plot(mysplits[[ii]]$wt, mysplits[[ii]]$mpg,
         ylim = c(0,40),
         main=paste("MPG vs weight for",names(mysplits[ii])))
  }
}
cyl.plot(mtcars,mtcars$cyl)
```

Graphics: Base: Arguments

We can set plot limits and add annotations

```
plot(mtcars$wt, mtcars$mpg, xlab = "Weight / 1,000", ylab = "MPG",
     xlim = c(0,10), ylim = c(0,40))
```

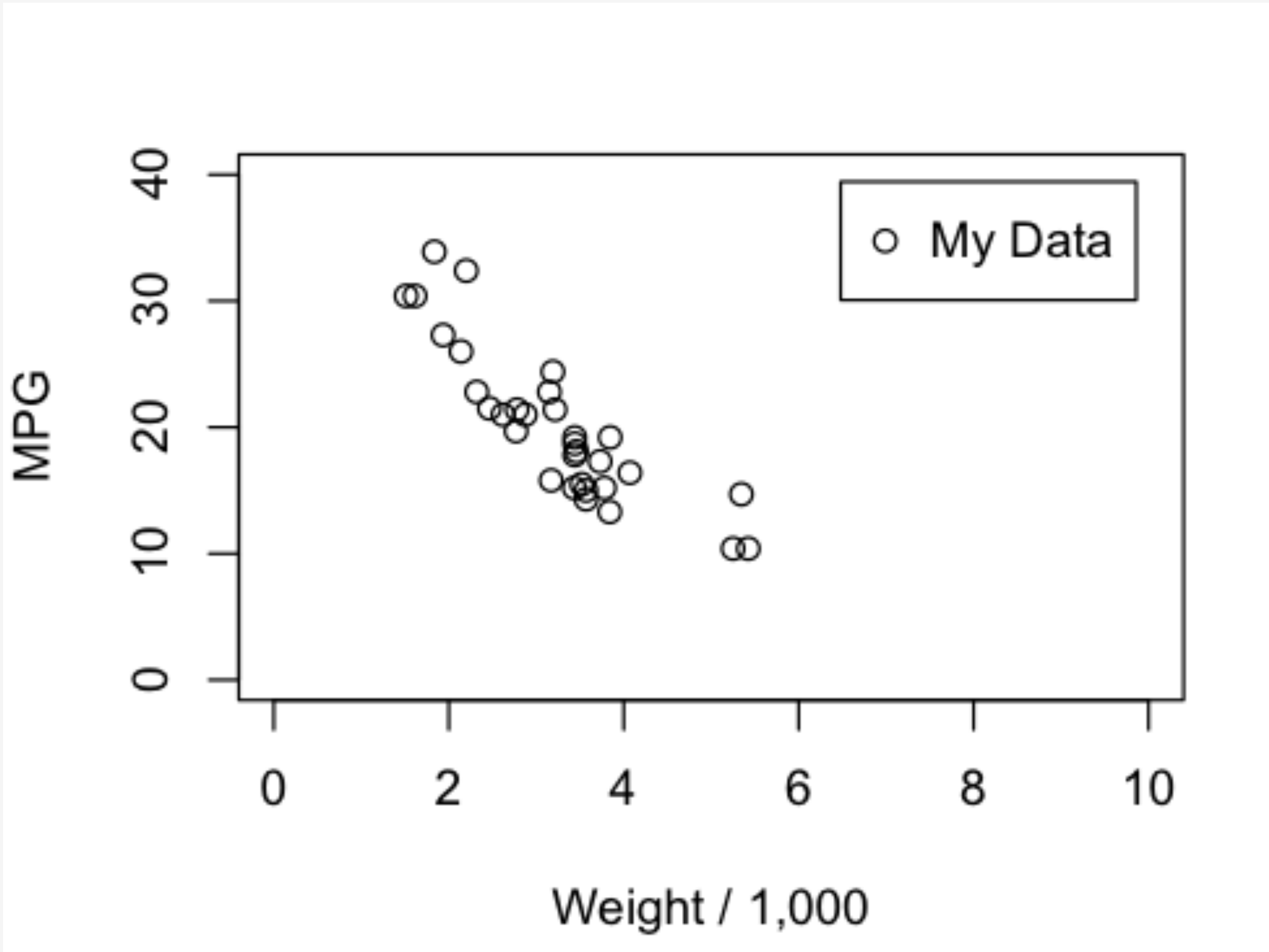


Graphics: Base: Arguments

We can add a legend:

```
plot(mtcars$wt, mtcars$mpg, xlab = "Weight / 1,000", ylab = "MPG",
     xlim = c(0,10), ylim = c(0,40))


legend("topright", inset=0.05, "My Data", pch=1, col="black")

# Could use specific coordinates also

legend(6.5,35, inset=0.05, "My Data", pch=1, col="black")


We specify location of the legend in terms of the data coordinates
```

Graphics: Base: Plotting



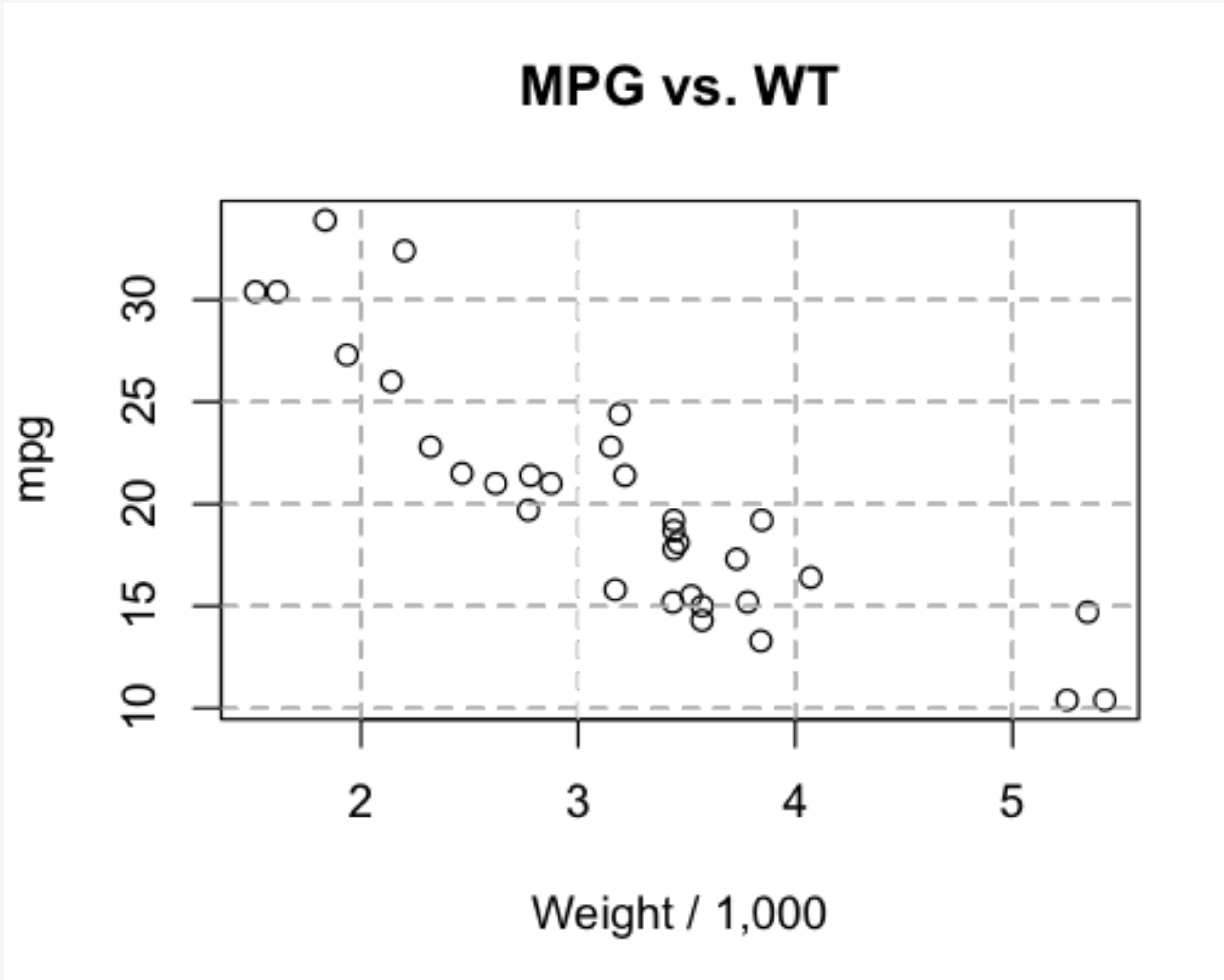
Graphics: Base: Annotation

We could also put up our own grid using some "primitive" graphics functions:

```
plot(mtcars$wt, mtcars$mpg,
               xlab = "Weight / 1,000",
               main = "MPG vs. WT")

abline(v=c(2,3,4,5),lty=2,col="gray90")

# Draws vertical dashed lines at 2,3,4,5

abline(h=c(10,15,20,25,30), lty=2, col="gray90")

# Horizontal lines at 10,15,20,25,30

# Could do:

abline(v=2:5,lty=2,col="gray90")

abline(h=seq(10,30,5),lty=2,col="gray90")
```

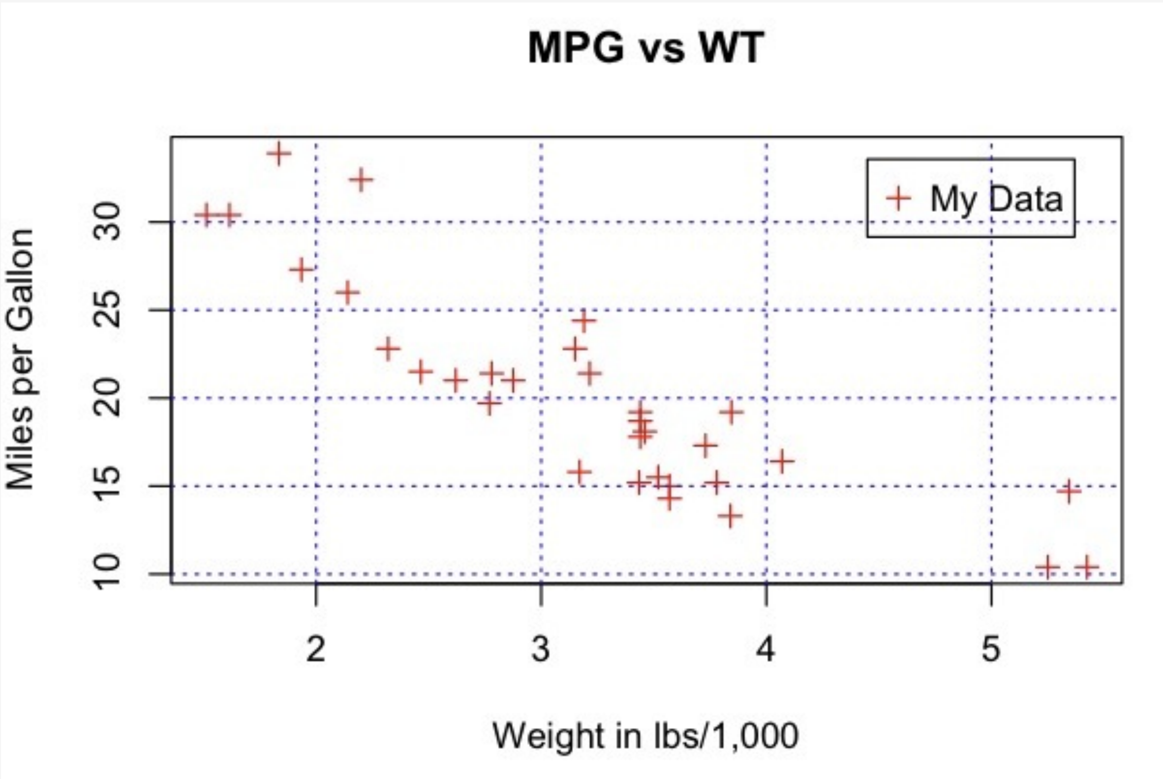
Graphics: Base: Annotation

We could also put up our own grid using some "primitive" graphics functions:



Graphics: Base: Plot Character

```
plot(mtcars$wt, mtcars$mpg,main="MPG vs WT", col="red",
               xlab="Weight in lbs/1,000",
               ylab="Miles per Gallon",
               pch = 3)


legend("topright", inset=0.05, "My Data", pch = 3, col="red")

grid(col="blue")
```



Graphics: Base: Plot Characters

```
example(pch)
```

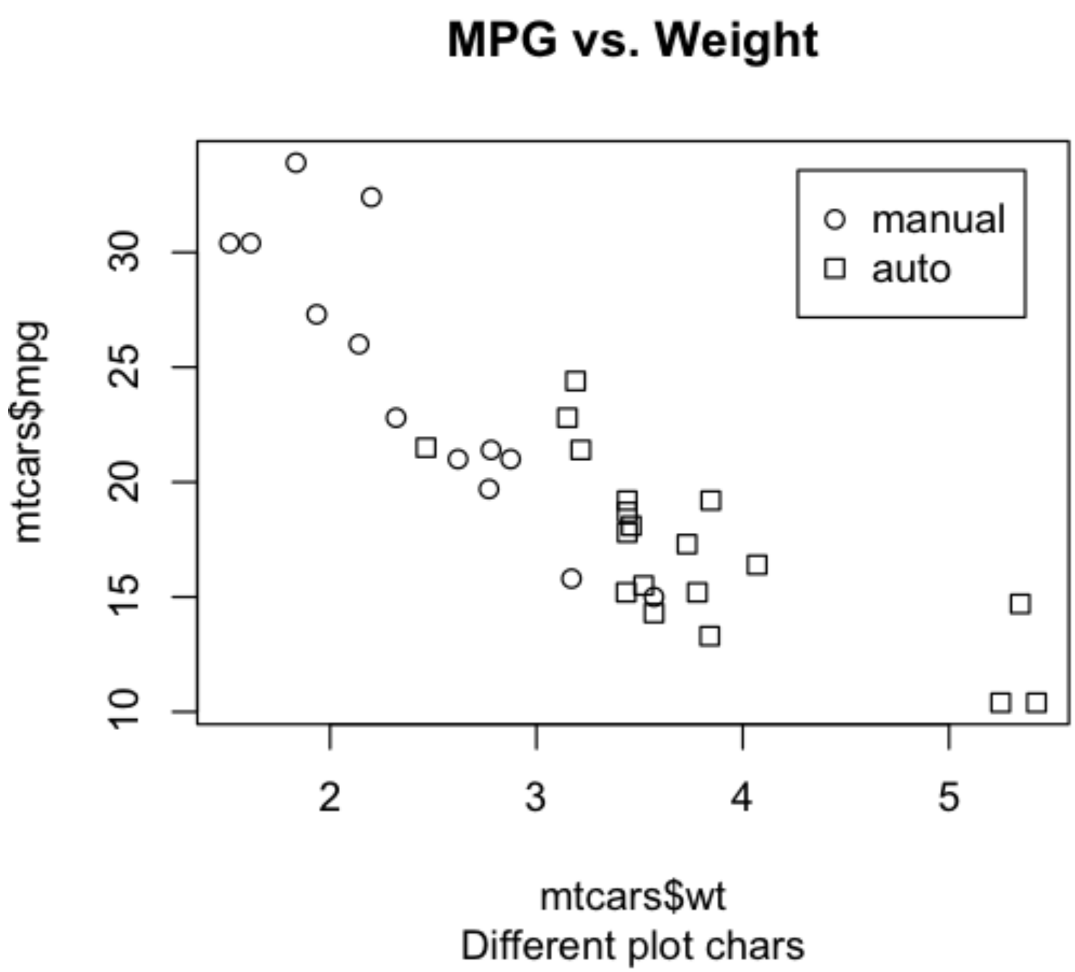
Graphics: Base: Layered Plot

We could also use information from a data frame to help us print different characters based on value. Like in mtcars. Let's plot MPG vs Weight but pick a different plot character based on Transmission Type. Here is one way to do it:

1) Create a blank plot that sets the limits and title
2) Extract records for automatic transmission into a data frame
3) Extract records for manual transmission into a data frame
4) Use the points command to plot these two different groups using a different pch value

```
plot(mtcars$wt, mtcars$mpg, type="n", main="MPG vs. Weight")  # A null plot

auto <- mtcars[mtcars$am == 0,]
manu <- mtcars[mtcars$am == 1,]

points(auto$wt, auto$mpg, pch = 0)
points(manu$wt, manu$mpg, pch = 1)

legend("topright", inset=0.05, c("manual","auto"),
        pch = c(1,0))
```

Graphics: Base: Layered Plot



Graphics: Base: Layered Plot

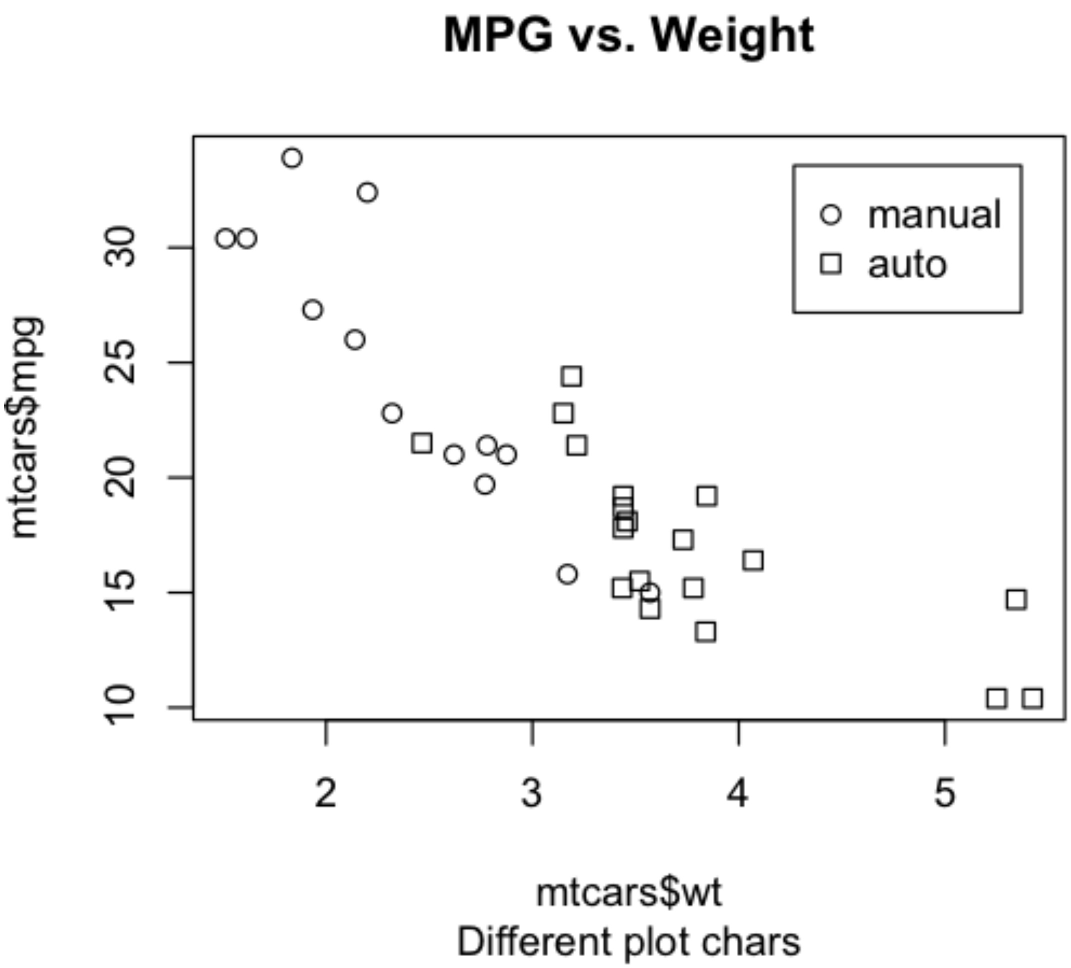
But this would be working too hard. No programming is required. Just recognize that the plot characters are selected by a number from 0 to 25. We can exploit this:

mtcars$am
 [1] 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 1 1 1 1 1 1

We see that am is 0 or 1 which just so happen to also represent valid print characters

```
plot(mtcars$wt, mtcars$mpg, pch=mtcars$am,
     main="MPG vs. Weight", sub="Different plot chars")

legend("topright", inset=0.05, c("manual","auto"),
        pch = unique(mtcars$am))
```

Graphics: Base: Layered Plot



Graphics: Base: Layered

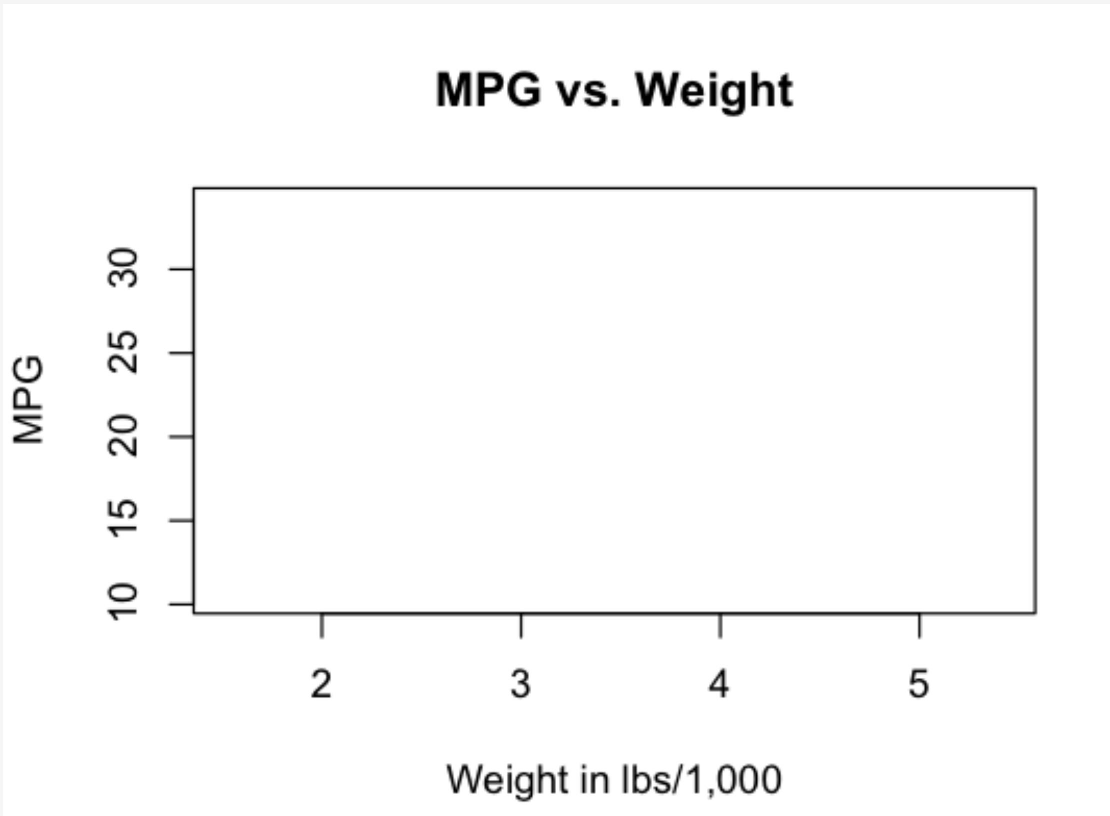
It is also possible to build a plot in layers. We initialize a "blank" plot using the plot command but we specify a type of "n".

Let's plot wt vs MPG and do it such that the records with a weight below the mean weight are in red and those above the mean weight are in blue

Graphics: Base: Layered

It is also possible to build a plot in layers. We initialize a "blank" plot using the plot command but we specify a type of "n".

```
plot(mtcars$wt,mtcars$mpg,type="n",xlab="Weight in lbs/1,000",
     ylab="MPG", main="MPG vs. Weight")
```



Graphics: Base: Layered

How is this useful ? Well we can add points or lines in stages. This allows us to plot things on an existing plot using specific colors or print characters.

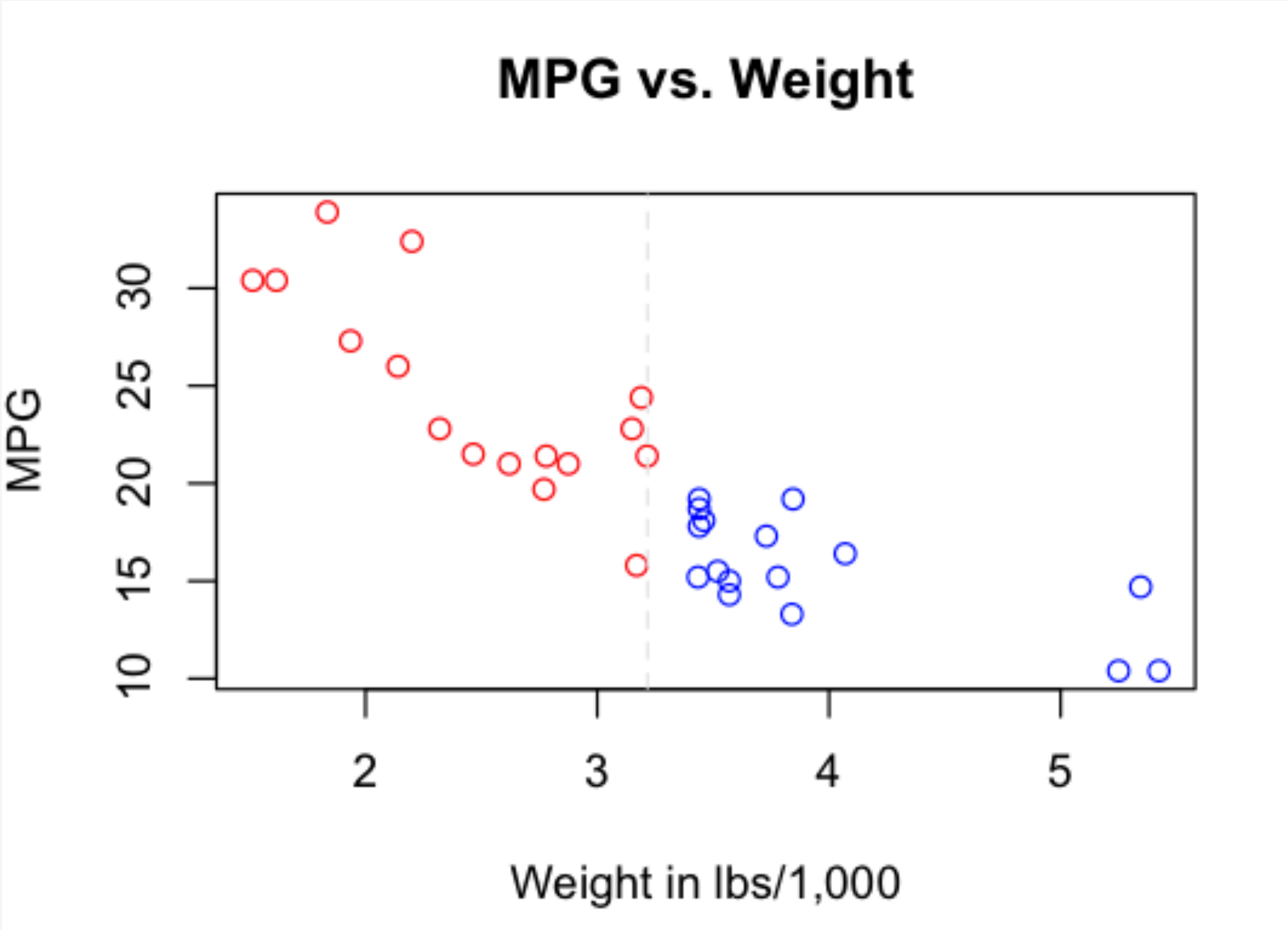
```
plot(mtcars$wt,mtcars$mpg,type="n",xlab="Weight in lbs/1,000",
     ylab="MPG", main="MPG vs. Weight")
```

Let's get records for each category

```
above.mean <- mtcars[mtcars$wt >= mean(mtcars$wt),]

below.mean <- mtcars[mtcars$wt < mean(mtcars$wt),]

# Use the points command to plot each group

points(below.mean$wt,below.mean$mpg,col="red")

points(above.mean$wt,above.mean$mpg,col="blue")

# Draw a vertical line where the mean(wt) is

abline(v=mean(mtcars$wt),lty=2,col="gray90")
```

Graphics: Base: Layered

How is this useful ? Well we can add points or lines in stages. This allows us to plot things on an existing plot using specific colors or print characters.



Graphics: Base: Layered

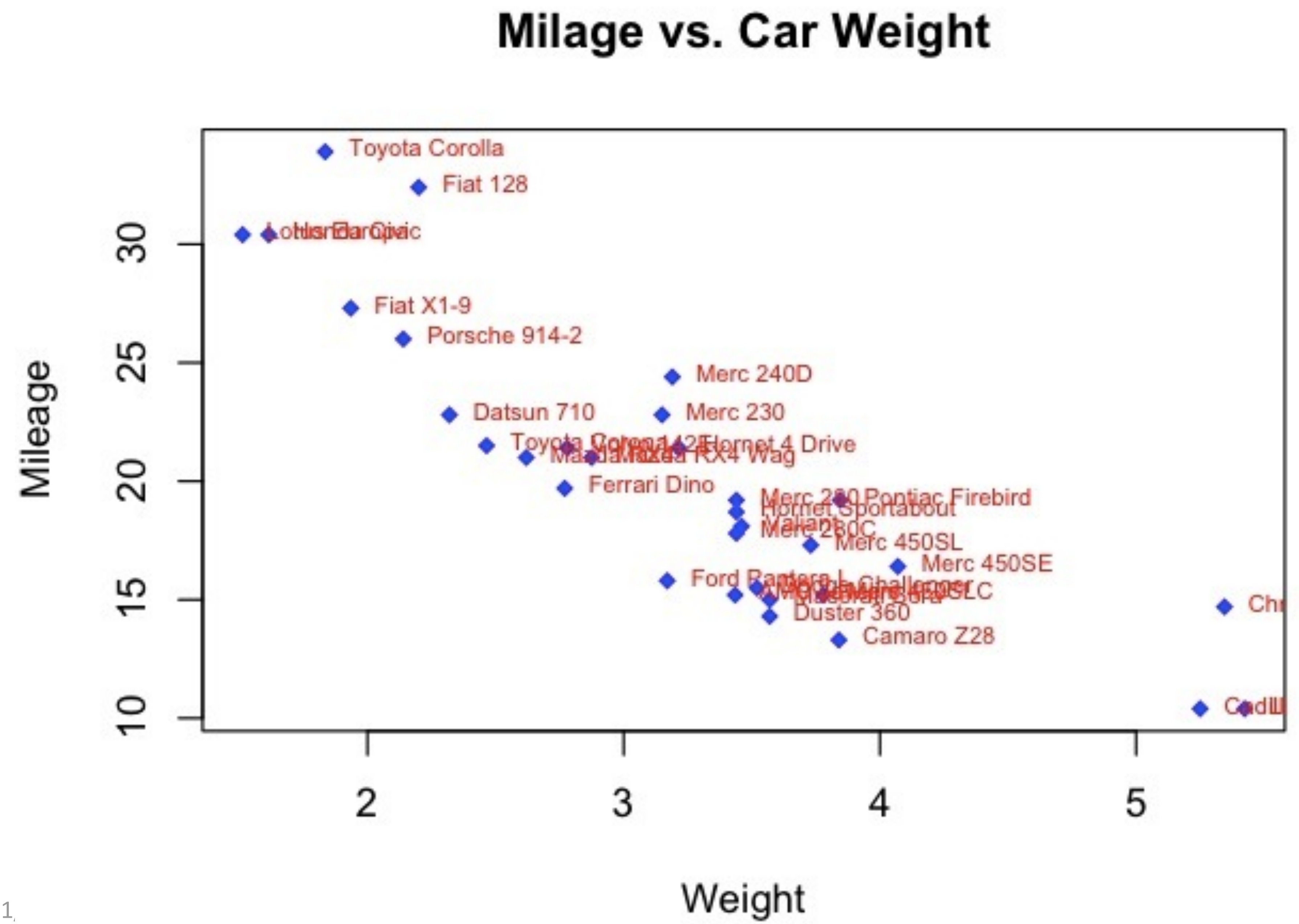
Unfortunately there is nothing in the existing data set that tells us if a given row's weight value is greater than or below the mean weight. We could handle this a couple of ways - one of which is to use our knowledge of for loops.

```
colvec <- ifelse(mtcars$wt >= mean(mtcars$wt),"blue","red")

colvec
 [1] "red"  "red"  "red"  "red"  "blue" "blue" "blue" "red"  "red"  "blue"
[11] "blue" "blue" "blue" "blue" "blue" "blue" "blue" "red"  "red"  "red"
[21] "red"  "blue" "blue" "blue" "blue" "red"  "red"  "red"  "red"  "red"
[31] "blue" "red"

plot(mtcars$wt,mtcars$mpg,col=colvec)
```

Graphics: Base: text

```
We can add text to our plot with no problem.

plot(mtcars$wt, mtcars$mpg, main="Mileage vs. Car Weight",
               xlab="Weight",
               ylab="Mileage",
               pch=18, col="blue")


text(mtcars$wt, mtcars$mpg, # Note we cannot use the formula in text
      row.names(mtcars),    # Get the row names
      cex=0.6,              # Scaling of the font size
      pos=4,                 # 1=below, 2=left, 3=above, 4=right
      col="red")
```

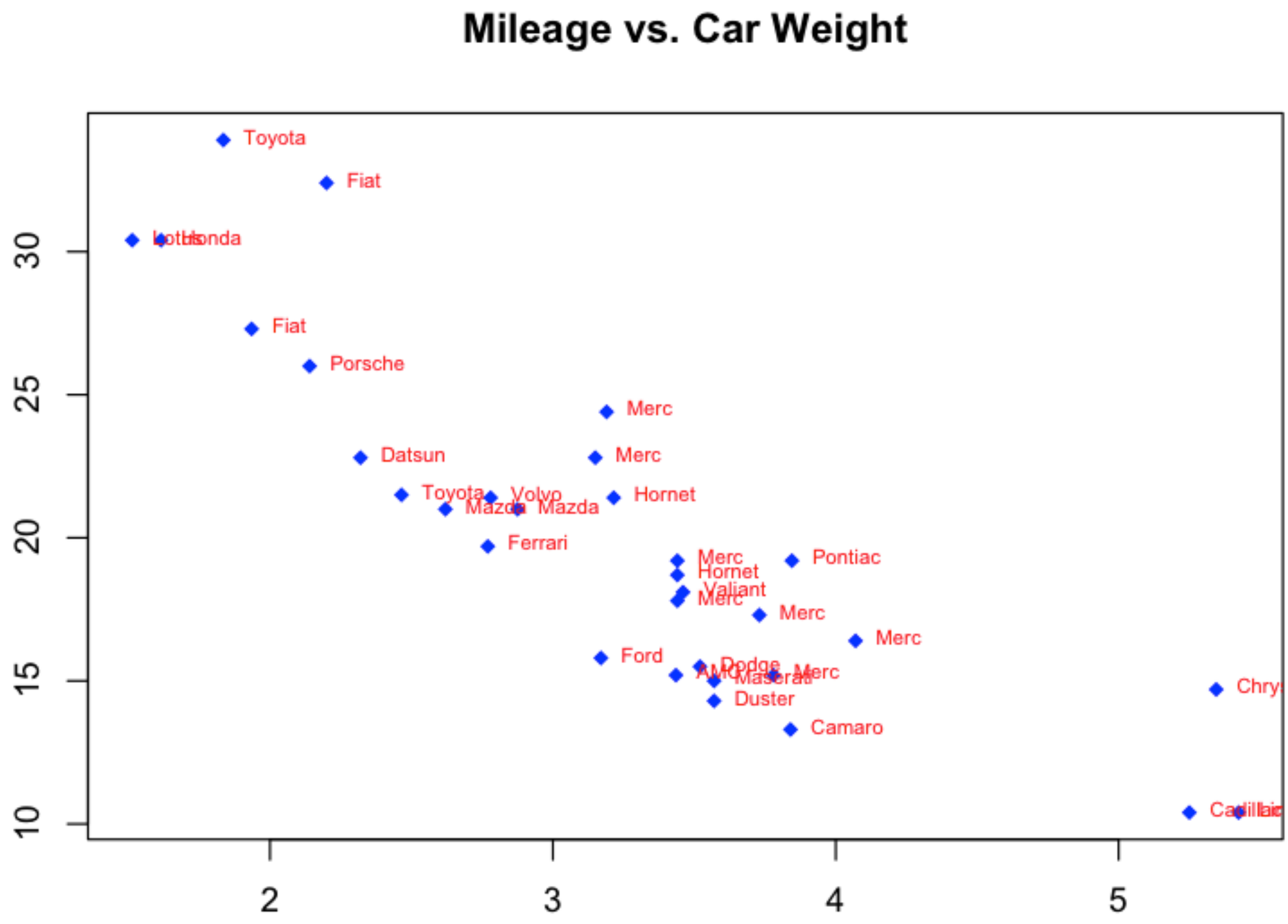
Graphics: Base: text



Graphics: Base: text

```
We can add text to our plot with no problem.

plot(mtcars$wt, mtcars$mpg, main="Mileage vs. Car Weight",
               xlab="Weight",
               ylab="Mileage",
               pch=18, col="blue")


carlabs <- sapply(strsplit(row.names(mtcars)," "),function(x) x[[1]])

 [1] "Mazda" "Mazda" "Datsun" "Hornet" "Hornet" "Valiant" "Duster"
"Merc"     "Mac"      "Merc"      "Merc"
[12] "Merc"     "Merc"     "Merc"     "Cadillac" "Lincoln"  "Chrysler"
"Fiat"     "Honda"    "Toyota"   "Toyota"   "Dodge"
[23] "AMC"      "Camaro"   "Pontiac"  "Fiat"     "Porsche"  "Lotus"
"Ford"     "Ferrari"  "Maserati" "Volvo"

text(mtcars$wt, mtcars$mpg, # Note we cannot use the formula in text
      carlabs,    # Get the row names
      cex=0.6,              # Scaling of the font size
      pos=4,                 # 1=below, 2=left, 3=above, 4=right
      col="red")
```

Graphics: Base: text

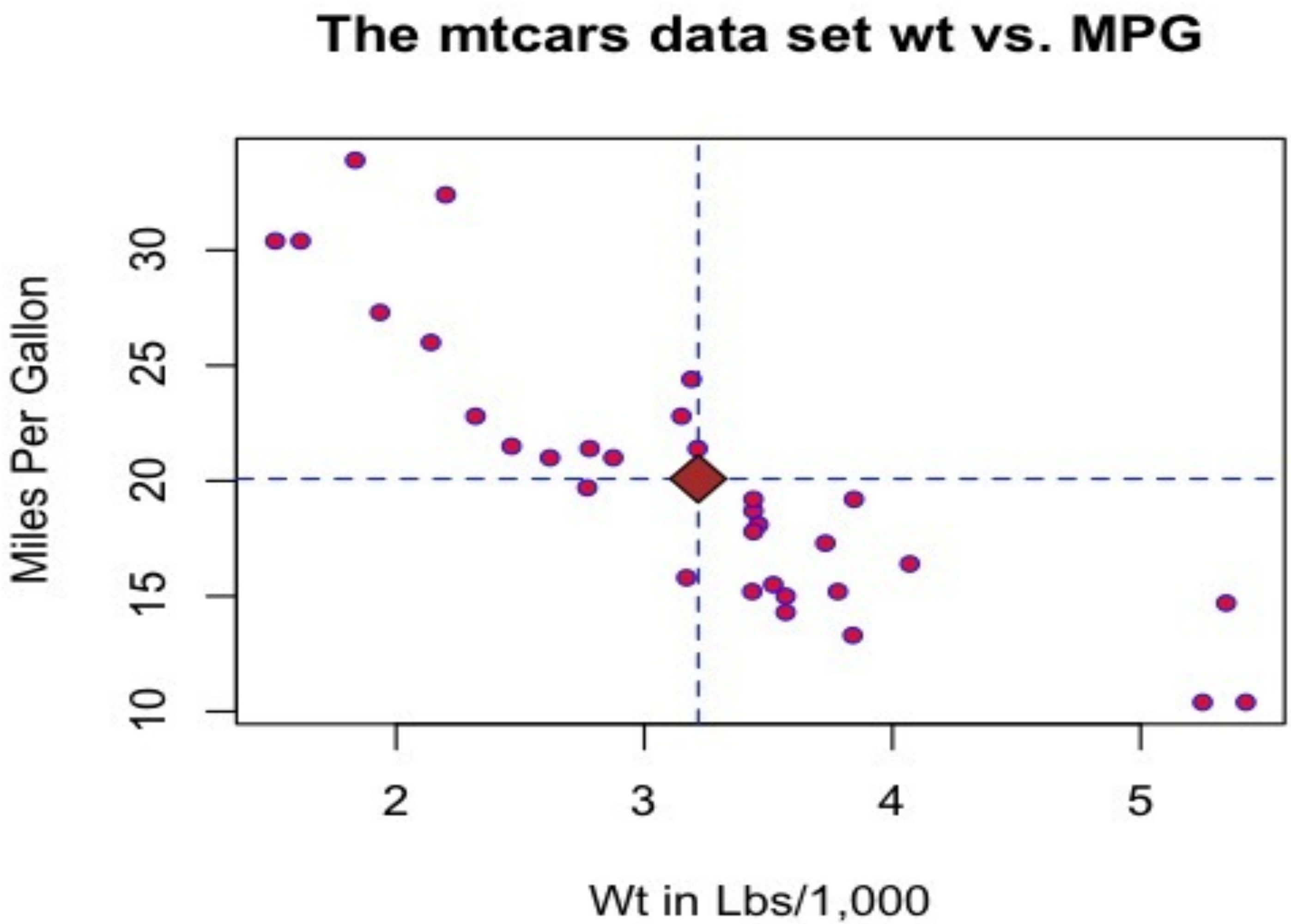


Supplemental: Advanced Annotation

Let's look at a more involved annotation example. We'll use the same data:

```
plot(mtcars$mpg ~ mtcars$wt,cex=0.8,
    pch=21,col="blue",bg="red",
    xlab="Wt in Lbs/1,000",
    ylab="Miles Per Gallon")

title(main="The mtcars data set wt vs. MPG")

# Next draw a vertical line at the mean of the weight

abline(v=mean(mtcars$wt),lty=2,col="blue")

# Next draw a horizontal line at the man of the MPG

abline(h=mean(mtcars$mpg),lty=2,col="blue")

points(mean(mtcars$wt),       # Draws a diamond at the common mean
       mean(mtcars$mpg),
       pch=23,col="black",
       bg="brown",
       cex=2)
```

Supplemental: Advanced Annotation



Supplemental: Advanced Annotation

Let's put some custom text on the graph to indicate the mean.

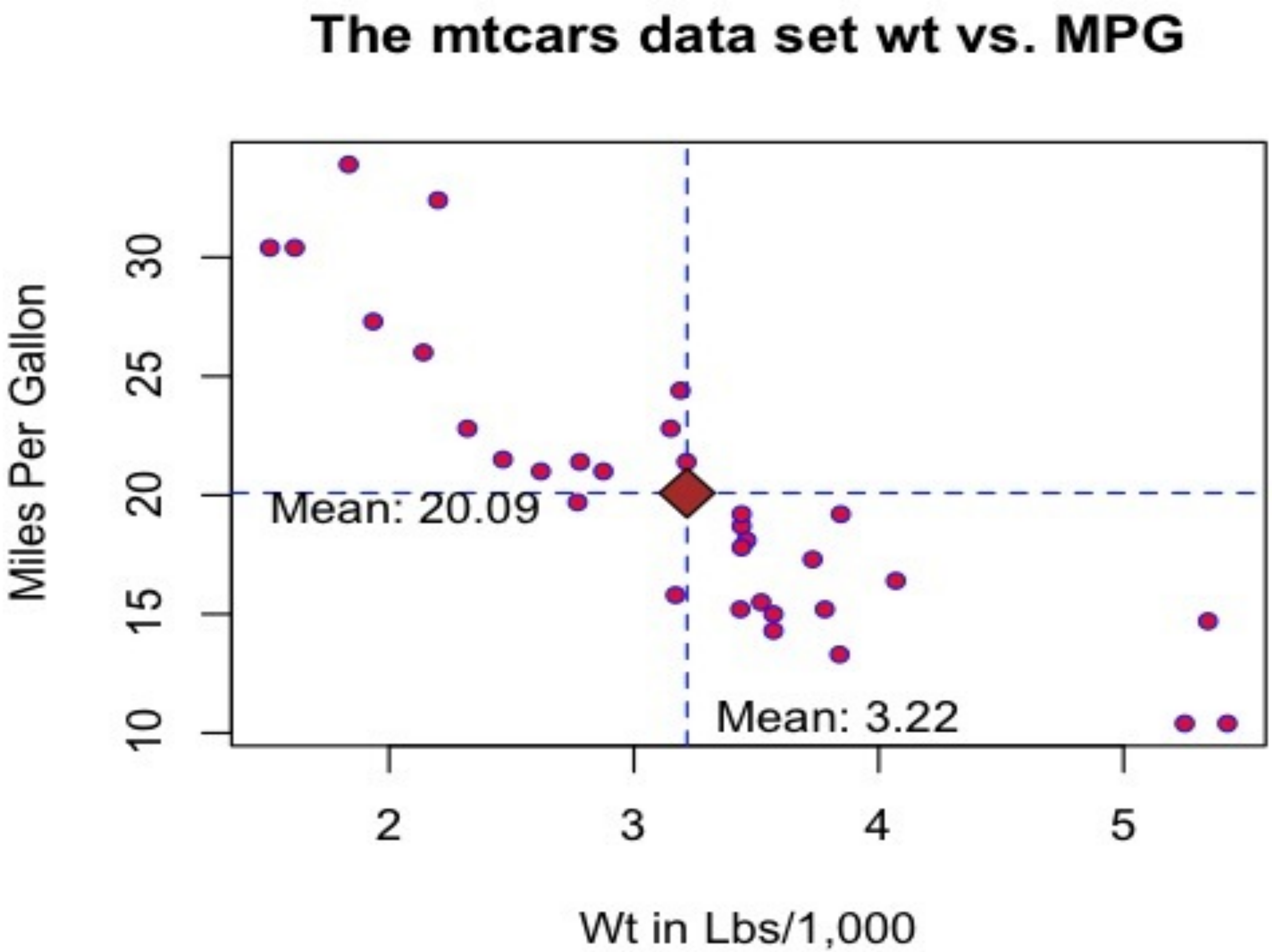
```
text(mean(mtcars$wt),min(mtcars$mpg),
     paste("Mean:",round(mean(mtcars$wt),2)),pos=4)

text(min(mtcars$wt),mean(mtcars$mpg),
    paste("Mean:",round(mean(mtcars$mpg),2)),adj=c(0,1))
```

Note that this is basically equivalent to:

```
text(3.2,10.4,paste("Mean:",round(mean(mtcars$wt),2)),pos=4)

text(2,20.09,paste("Mean:",round(mean(mtcars$mpg),2)))
```

Supplemental: Advanced Annotation

Let's look at a more involved annotation example. We'll use the same data:



Custom Axis

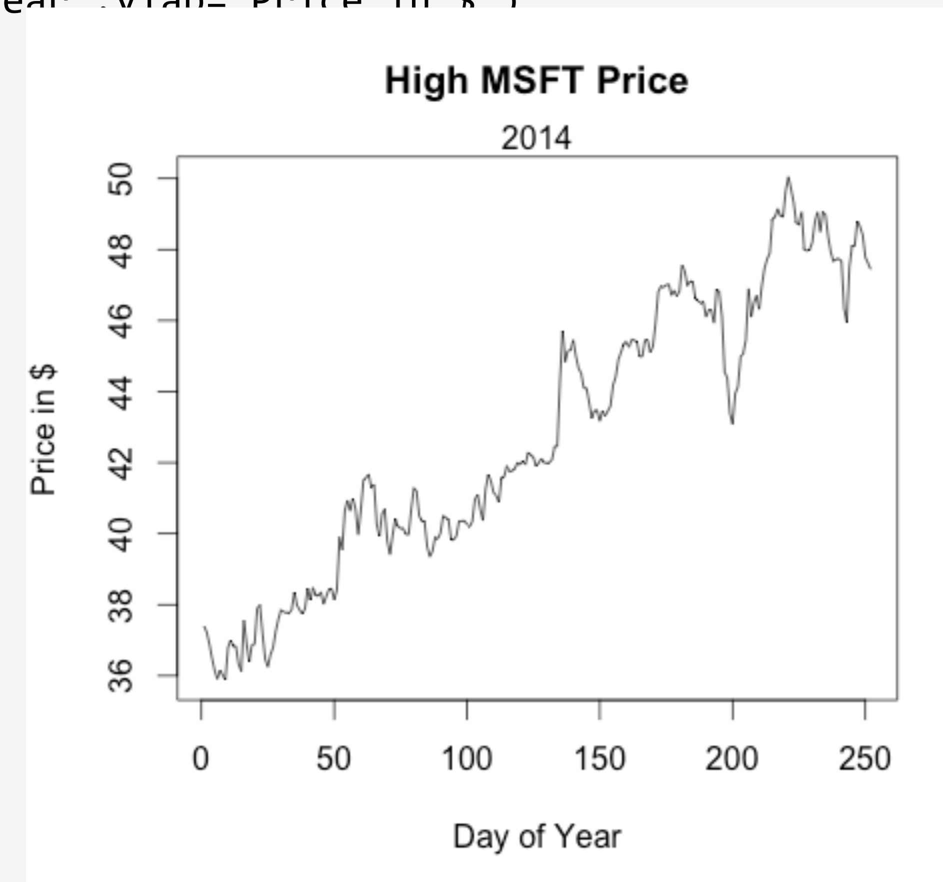
Sometimes we want to draw an axis ourselves because R's defaults aren't what we want. Imagine a set of observations over time such as stock market activity.

Here is a data frame you can read in that tracks actual stock market performance for Microsoft, (MSFT), for each trading day of the year 2014.

```
url <- "https://steviep42.bitbucket.org/bios545r_2017/SUPP.DIR/stock.data.
14.csv"

msft <- read.csv(url)

head(msft)

        Date  Open  High   Low Close   Volume Adj.Close
1 2014-01-02 37.35 37.40 37.10 37.16 30632200     36.17
2 2014-01-03 37.20 37.22 36.60 36.91 31134800     35.93
3 2014-01-06 36.85 36.89 36.11 36.13 43603700     35.17
4 2014-01-07 36.33 36.49 36.21 36.41 35802800     35.44
5 2014-01-08 36.00 36.14 35.58 35.76 59971700     34.81
6 2014-01-09 35.88 35.91 35.40 35.53 36516300     34.58
```

Custom Axis

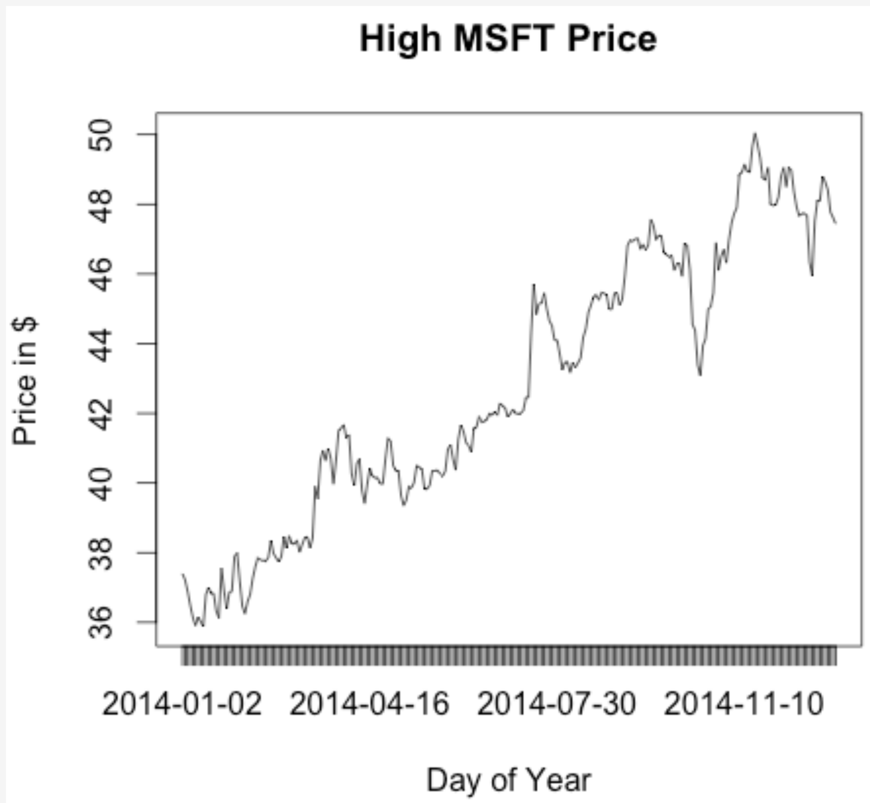
```
url <- "https://steviep42.bitbucket.org/bios545r_2017/SUPP.DIR/stock.data.
14.csv"

msft <- read.csv(url)

plot(msft$High,type="l",main="High MSFT Price",
     xlab="Day of Year",ylab="Price in $")

mtext("2014",3)
```



Custom Axis

The day number is okay but we could also the actual dates as labels. But that could be a problem. First, we use the xaxt argument to suppress the printing of the x-axis

```
plot(msft$High,type="l",main="High MSFT Price",
     xlab="Day of Year",ylab="Price in $", xaxt="n")

axis(1,at=1:nrow(msft),labels=msft$Date)
```



Custom Axis

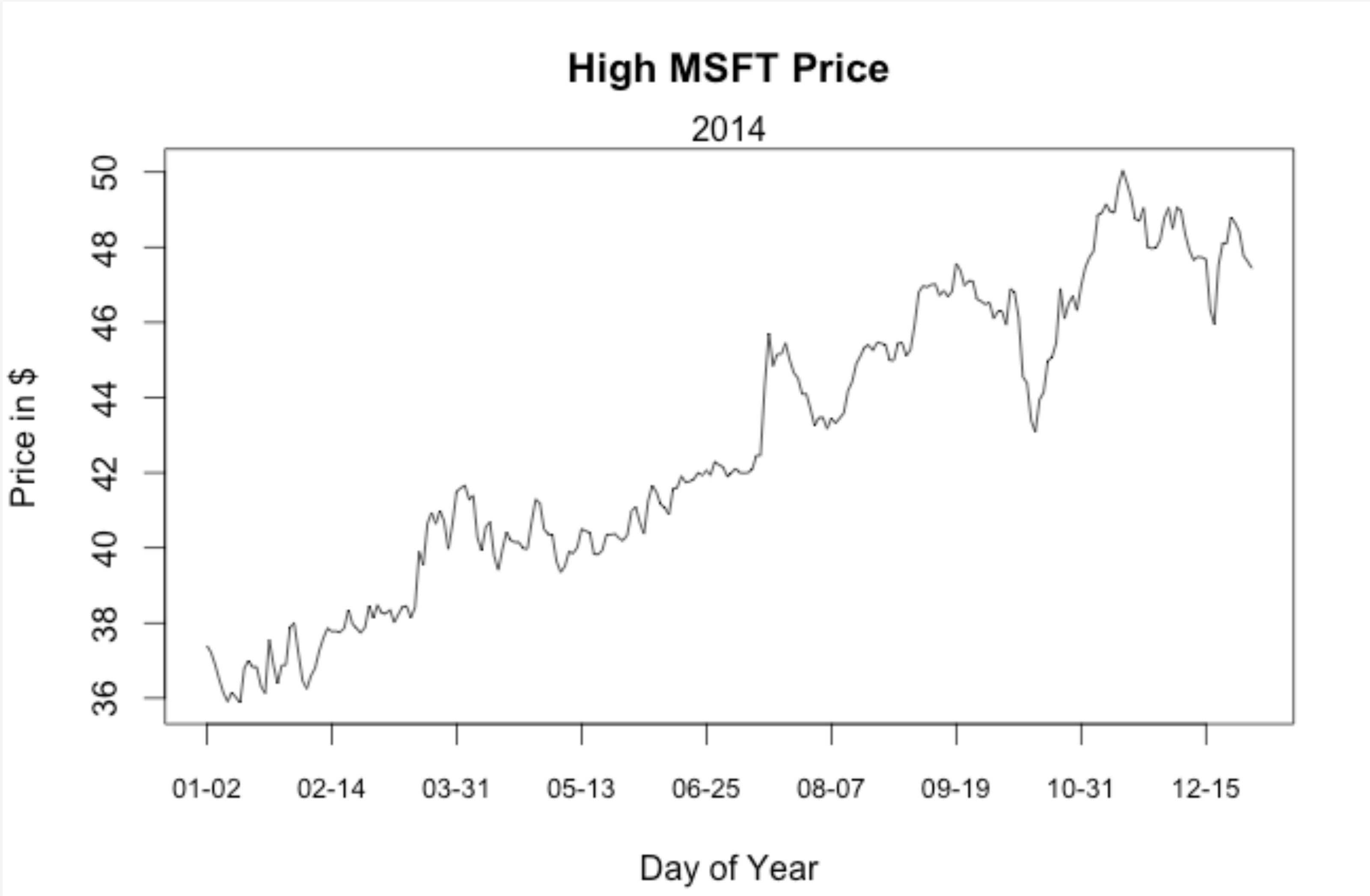
That wasn't so good because the X-axis got really crowded. We can print labels for the x-axis every 30 days or so using this approach.

We could alter this to accommodate an arbitrary number of days and labels.

Notice how we generate sequence that we then use to index into the Dates.

```
plot(msft$High,type="l",main="High MSFT Price",
     xlab="Day of Year",ylab="Price in $", xaxt="n")
mtext("2014",3)

dseq <- seq(1,nrow(msft),30)

axislabs <- substr(msft$Date[dseq],6,10)

axis(1, at=dseq, labels=axislabs, cex.axis=0.8)
```

Custom Axis



High MSFT Price
2014
Price in $
36
38
40
42
44
46
48
50
01-02
02-14
03-31
05-13
06-25
08-07
09-19
10-31
12-15
Day of Year

Graphics: Colors

```
length(colors())  # The colors function returns a vector of colors
[1] 657

colors()[1:5]
[1] "white"         "aliceblue"     "antiquewhite"  "antiquewhite1"
"antiquewhite2"
```

23	bisque4	#8B7D6B	139	125	107
24	black	#000000	0	0	0
25	blanchedalmond	#FFEBCD	255	235	205
26	blue	#0000FF	0	0	255
27	blue1	#0000FF	0	0	255
28	blue2	#0000EE	0	0	238
29	blue3	#0000CD	0	0	205
30	blue4	#00008B	0	0	139
31	blueviolet	#8A2BE2	138	43	226
32	brown	#A52A2A	165	42	42
33	brown1	#FF4040	255	64	64
34	brown2	#EE3B3B	238	59	59
35	brown3	#CD3333	205	51	51

Graphics: Colors

```
grep("yellow",colors(),value=TRUE)

"greenyellow"     "lightgoldenrodyellow" "lightyellow"
"lightyellow1"     "lightyellow2"
"lightyellow3"     "lightyellow4"          "yellow"
"yellow1"          "yellow2"               "yellow3"
"yellow4"          "yellowgreen"

grep("purple",colors(),value=TRUE)
"mediumpurple"  "mediumpurple1" "mediumpurple2" "mediumpurple3"
"mediumpurple4" "purple"        "purple1"
"purple2"       "purple3"       "purple4"
```

Get a copy of the PDF Color Chart from:

http://research.stowers-institute.org/efg/R/Color/Chart/ColorChart.pdf

Graphics: Colors

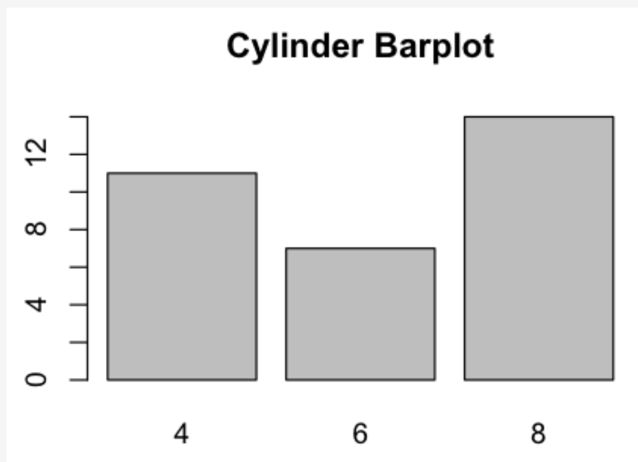
R also has some built in palettes that give you a color scheme from which to choose:

```
Palettes                 package:grDevices                R Documentation

Color Palettes

Description:

     Create a vector of 'n' contiguous colors.

Usage:

     rainbow(n, s = 1, v = 1, start = 0, end = max(1, n - 1)/n, alpha = 1)
     heat.colors(n, alpha = 1)
     terrain.colors(n, alpha = 1)
     topo.colors(n, alpha = 1)
     cm.colors(n, alpha = 1)
```

Graphics: Base: Barplot

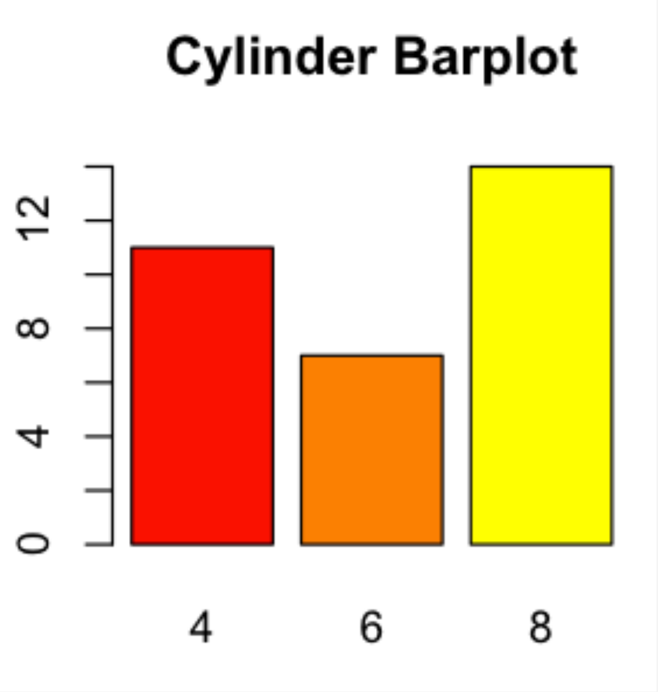
If we have some categories we want to look at we can easily visualize it. Barplots are for plotting tables. Let's count up all the cars by cylinder type from mtcars:

```
table(mtcars$cyl)

 4  6  8
11  7 14

barplot(table(mtcars$cyl), axes=T, main = "Cylinder Barplot")
```



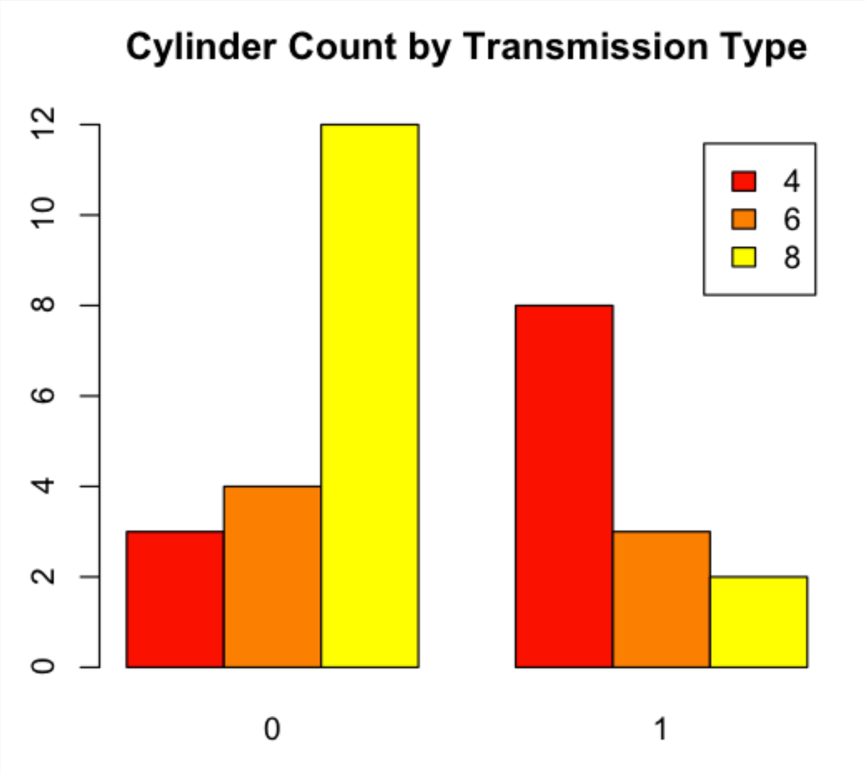
Graphics: Base: Barplot

```
table(mtcars$cyl)

 4  6  8
11  7 14

barplot(table(mtcars$cyl), axes=T,
        main = "Cylinder Barplot", col=heat.colors(3))
```



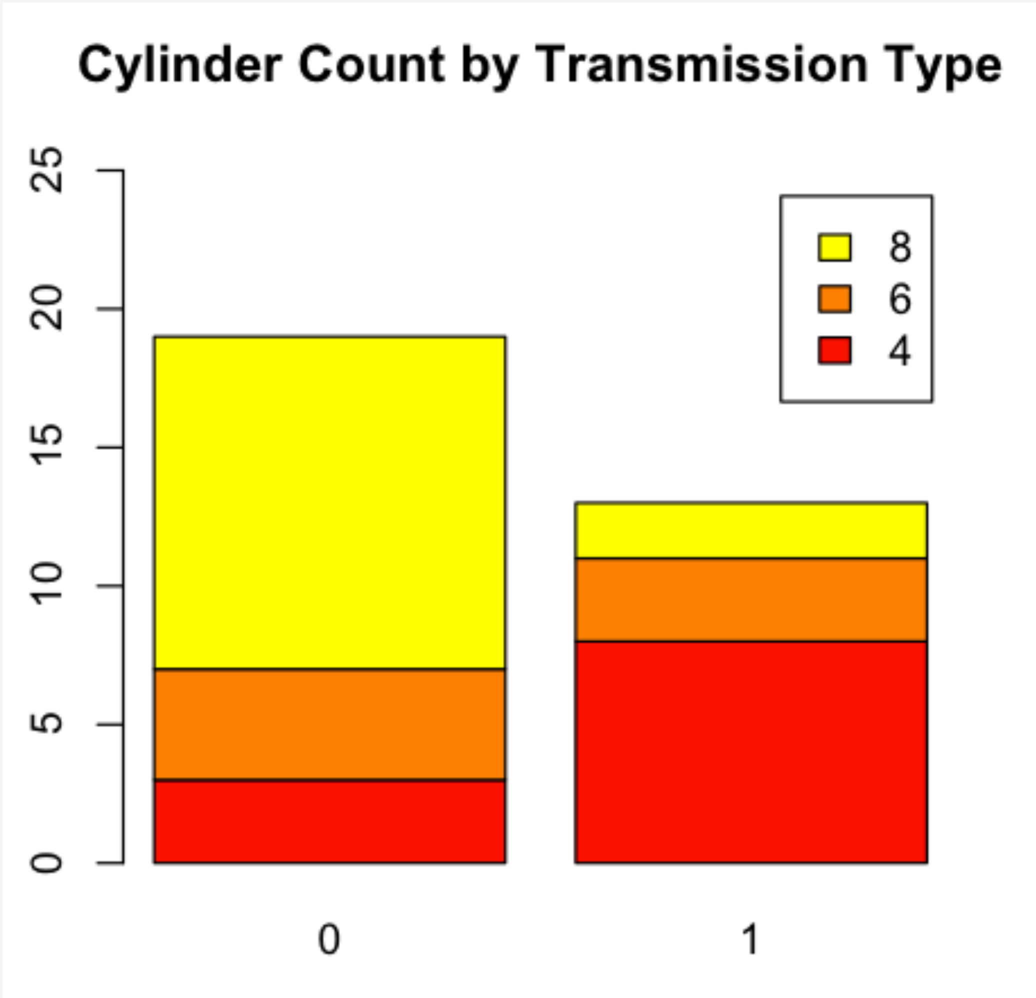
Graphics: Base: Barplot

```
table(mtcars$cyl,mtcars$am)   # A bigger table
     0  1
  4  3  8
  6  4  3
  8 12  2

barplot(table(mtcars$cyl,mtcars$am), legend = T, beside = T,
col=heat.colors(3), main='Cylinder Count by Transmission Type')
```



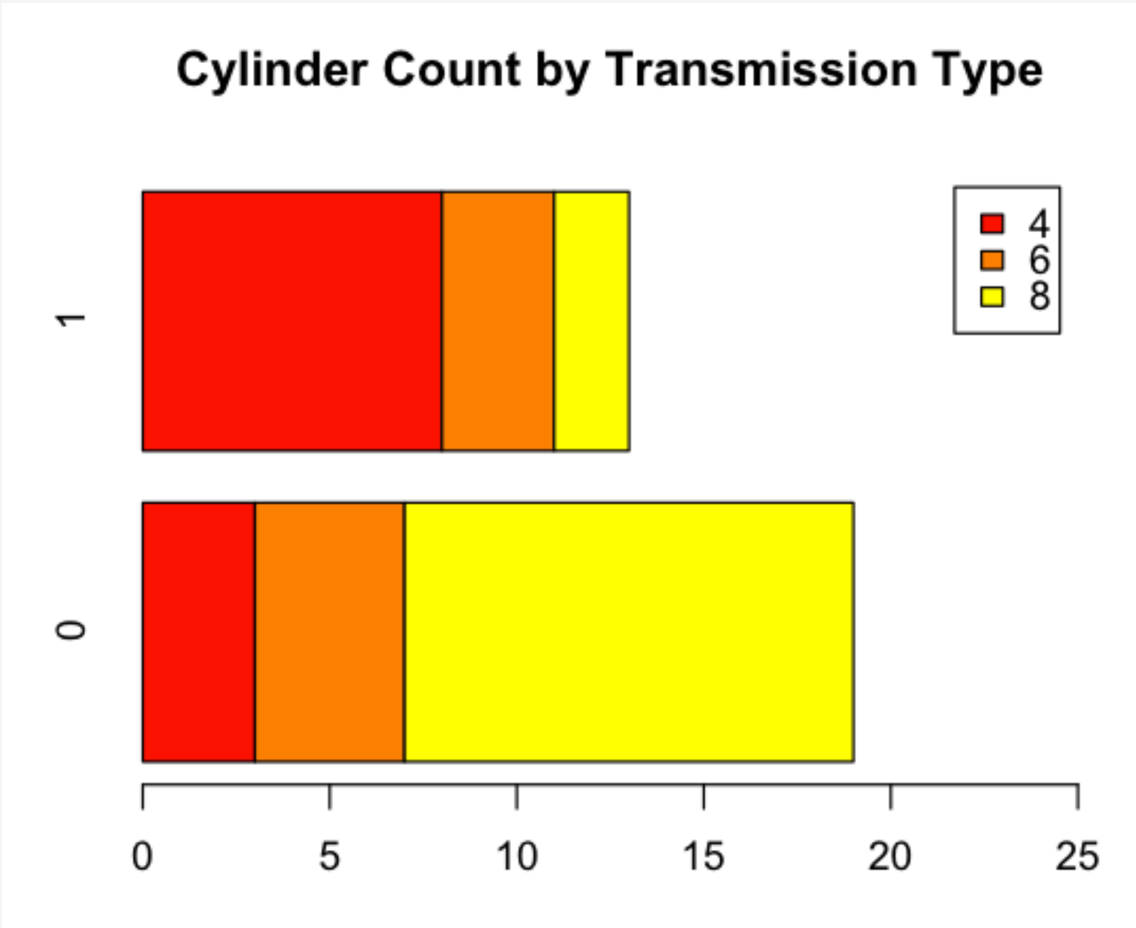
Graphics: Base: Barplot

```
barplot(table(mtcars$cyl,mtcars$am),legend = T,
        beside = F, col=heat.colors(3),
        main='Cylinder Count by Transmission Type',ylim=c(0,25))
```



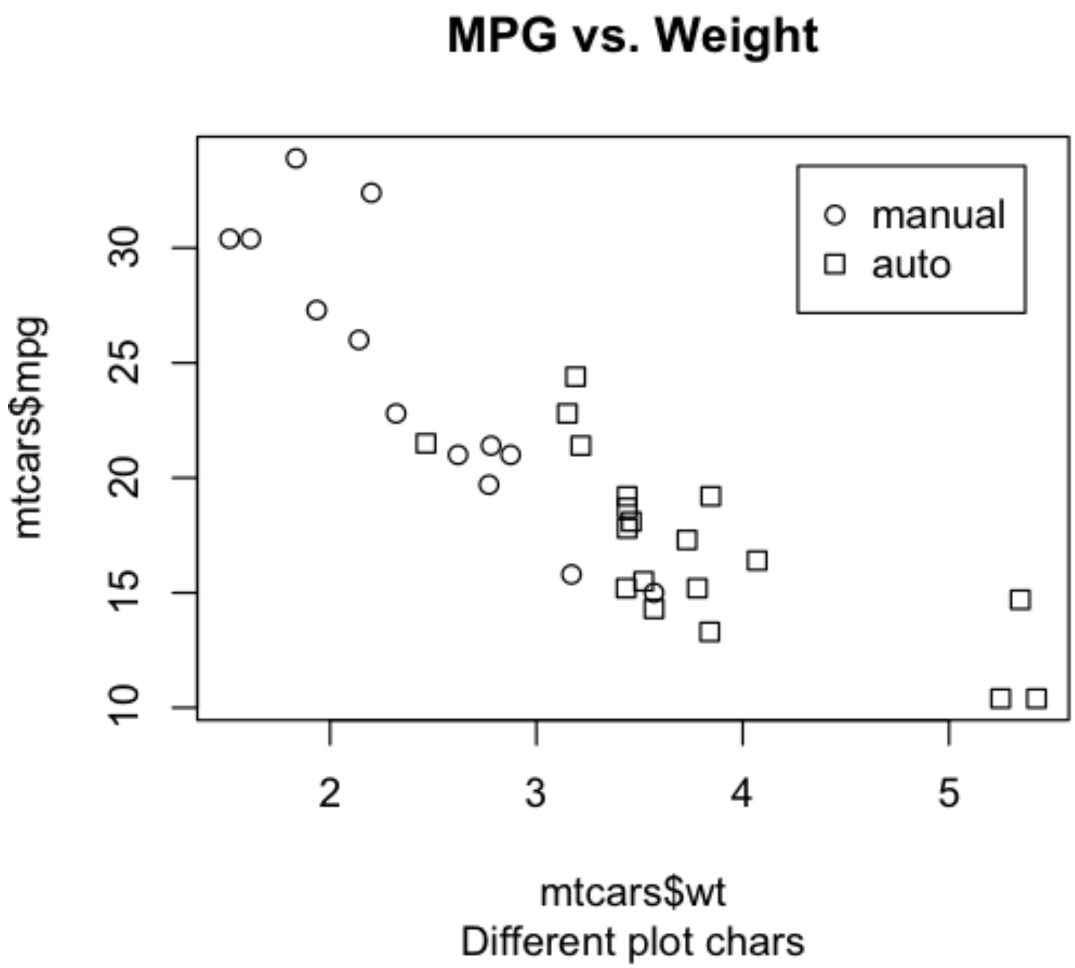
Graphics: Base: Barplot

```
barplot(table(mtcars$cyl,mtcars$am),legend = T,
        beside = F, col=heat.colors(3),
        main='Cylinder Count by Transmission Type',
        xlim=c(0,25),horiz=T)
```



Graphics: Base: Layered Plot

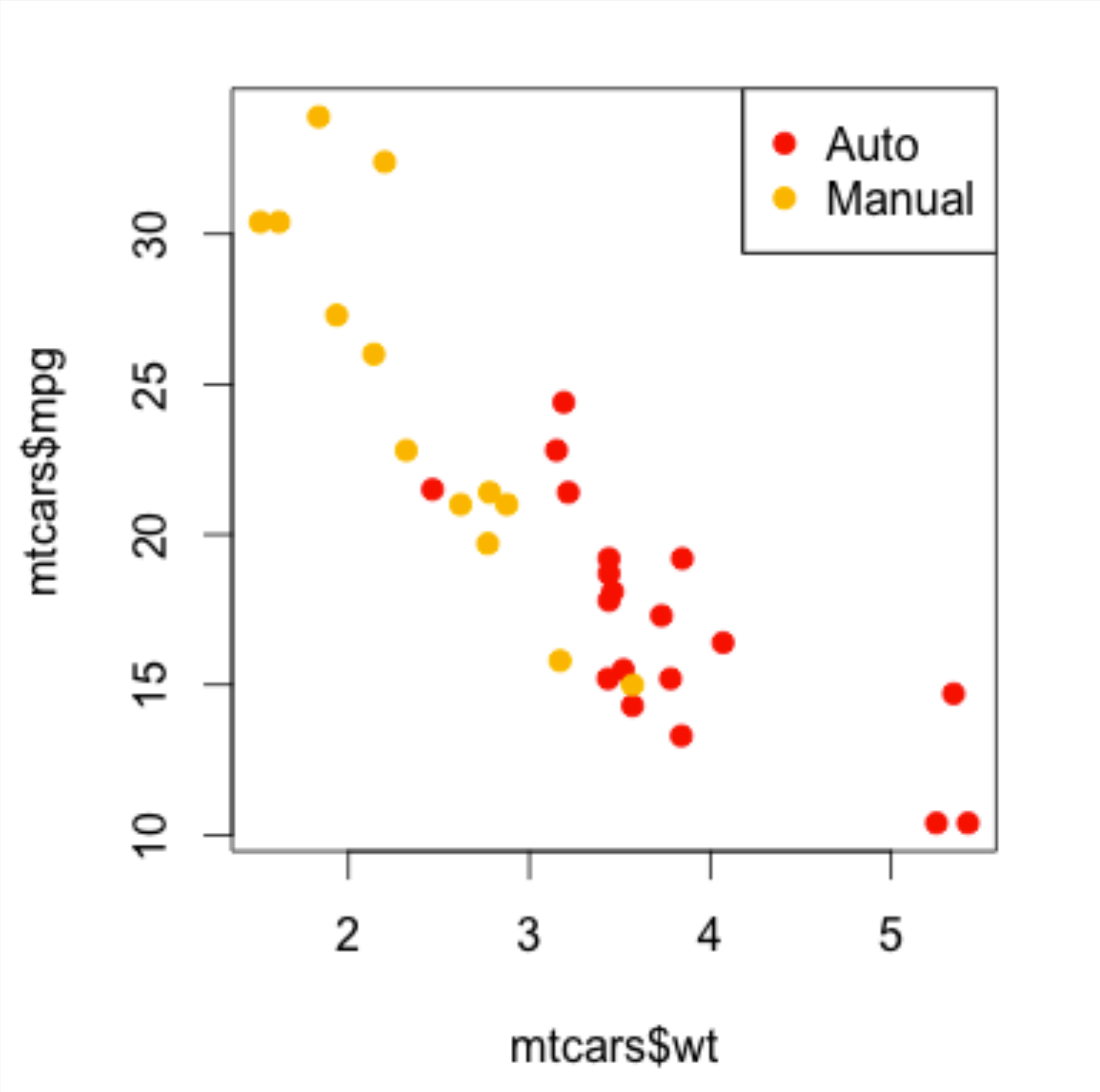
Remember this example ? We used different plot characters to denote manual transmissions vs. automatic. Could we do the same with color ? Of course



Graphics: Colors

```
mycols <- rainbow(2)

mycols
[1] "#FF0000FF" "#00FFFFFF"

# Remember that the transmission types are indicated by a 0 (auto) or
# 1 (manual). We need to take this into account when indexing into the
# mycols vector.

plot(mtcars$wt, mtcars$mpg, col = mycols[mtcars$am+1], pch=19)

legend("topright",c("Auto","Manual"),col=mycols,pch=19)
```

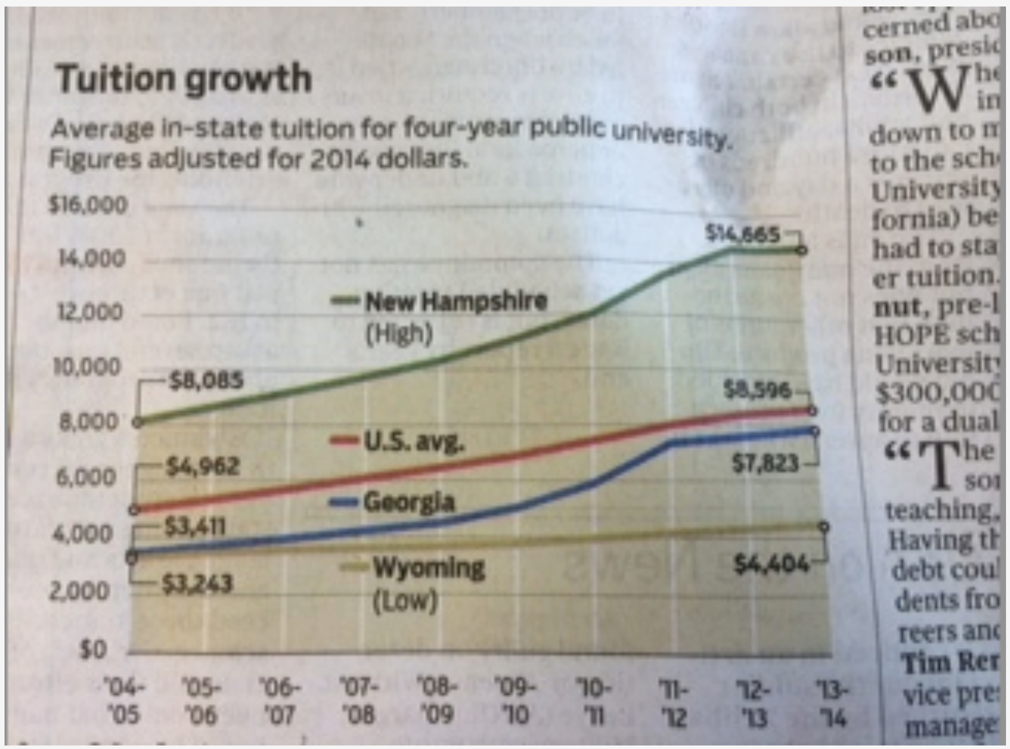
Graphics: Colors



Graphics: Reproducing Consumer Graphics

Consumer graphs, like those found in newspapers or news magazines, have lots of "junk" attached to them, which, for a statistician, is unnecessary.

Here is an example found in a copy of the Atlanta Journal Constitution newspaper from some time last year. You can find these in many magazines and papers.



Graphics: Reproducing Consumer Graphics

I wrote some R code using Base graphics to approximate this.

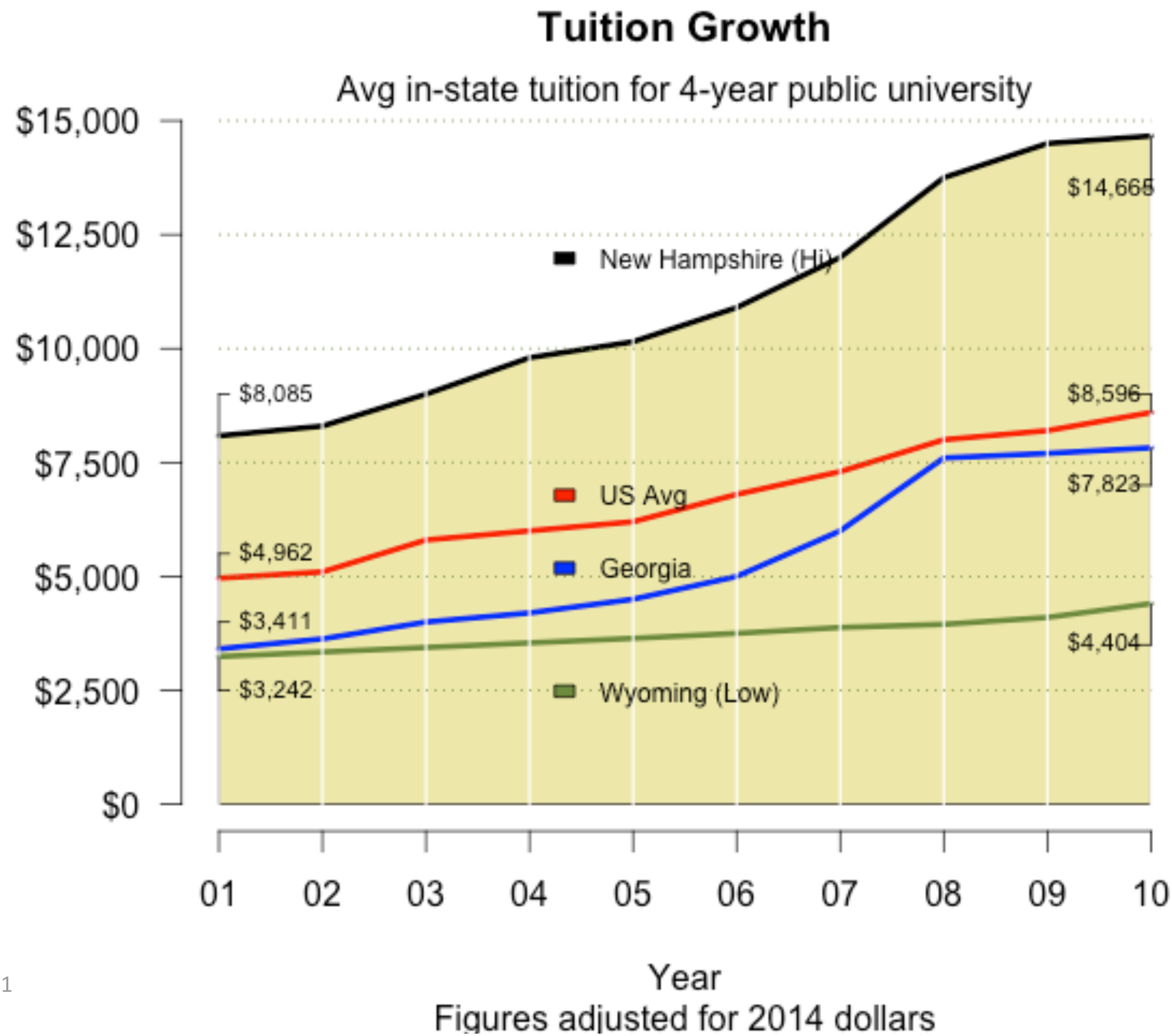
This took a lot of work since the chart relies on intersecting lines, different colors, custom axes, arrows, and text annotations.

I don't enjoy doing things like this at all. A good plot should tell the story without all the extraneous annotations.

But for the public, this type of chart is standard. See the result on the next slide. It's not a perfect match. The x-axis labels need some more work but it's close enough.

The code can be found at:

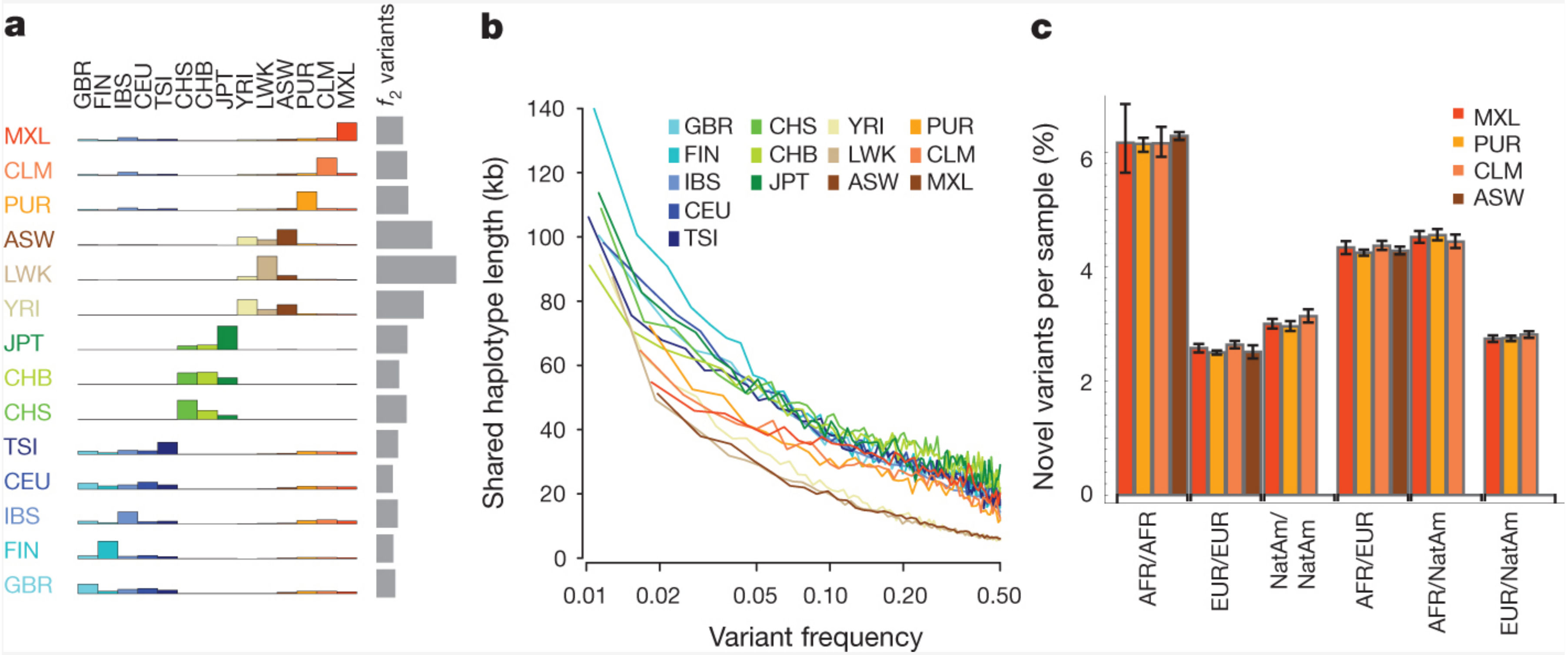
https://steviep42.bitbucket.org/bios545r_2017/SUPP.DIR/ajc.html



Tuition Growth
Avg in-state tuition for 4-year public university
$15,000
$12,500
$10,000
$7,500
$5,000
$2,500
$0
$14,665
New Hampshire (Hi)
$8,085
$8,596
US Avg
$7,823
$4,962
Georgia
$3,411
$4,404
$3,242
Wyoming (Low)
01
02
03
04
05
06
07
08
09
10
Year
Figures adjusted for 2014 dollars

Graphics: Scientific Papers

Allele sharing within and between populations.



The 1000 Genomes Project Consortium *Nature* **491**, 56-65 (2012) doi:10.1038/nature11632

Graphics: Basic Animation

We can do basic animation with Base graphics although there are dedicated packages that make this easier. We use the Central Limit Theorem as an example.

So we want sample repeatedly from some distribution that is not normal.

We then take the mean of the sample and append it to a vector.

We then plot the histogram of the vector containing the averages

We then call the 'Sys.sleep' function to stop briefly which is what gives us the illusion of animation.

We repeat this some number of times, (timestosamp), and what we will see is a histogram of the sampling distribution of the means, which will be normal.

So even though the starting population from which we sampled is NOT normal the distribution of the sampled means is !

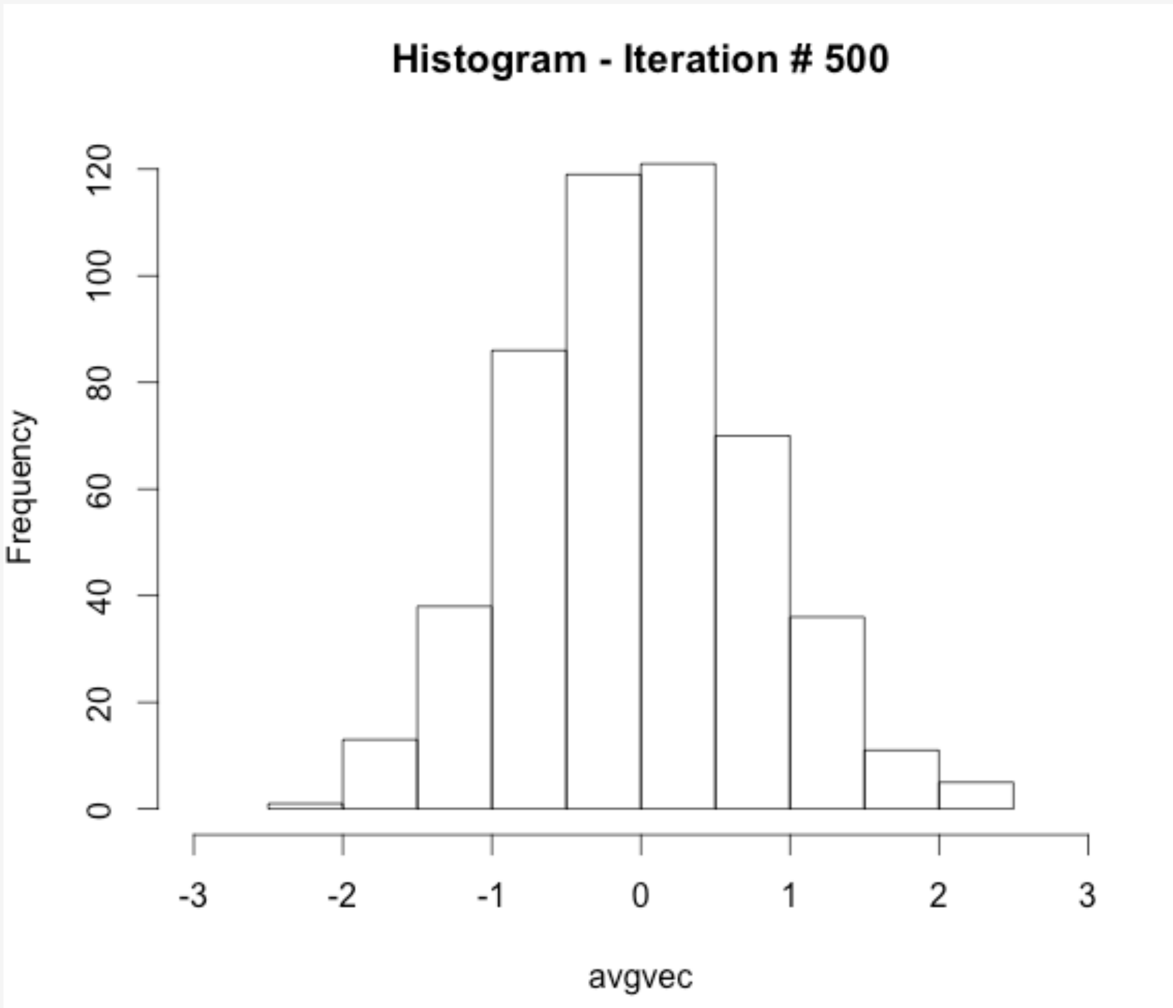
Graphics: Basic Animation

Here is a function that samples from the uniform distribution repeatedly, computes the mean of the sampled values, adds it to a vector, and then creates a histogram

```
x <- runif(1000000,-3,3) # Get one million vals from a uniform distro

myhist <- function(pop,timestosamp, numtosamp, sleep=0.25) {

  avgvec <- vector()
  length(avgvec) <- timestosamp

  for (ii in 1:timestosamp) {
    avgvec <- c(avgvec,mean(sample(pop,numtosamp)))
    hist(avgvec,main=paste("Histogram - Iteration #",ii,sep=" "),
         xlim=c(-3,3))
    Sys.sleep(sleep)
  }
}


myhist(x,500,5,sleep=.10)
```

Graphics: Basic Animation

We can do basic animation with Base graphics although there are dedicated packages that make this easier.



Graphics: Supplemental: Colors

The ‘Indometh’ data frame has 66 rows and 3 columns of data on the pharmacokinetics of indometacin (or, older spelling, ‘indomethacin’).

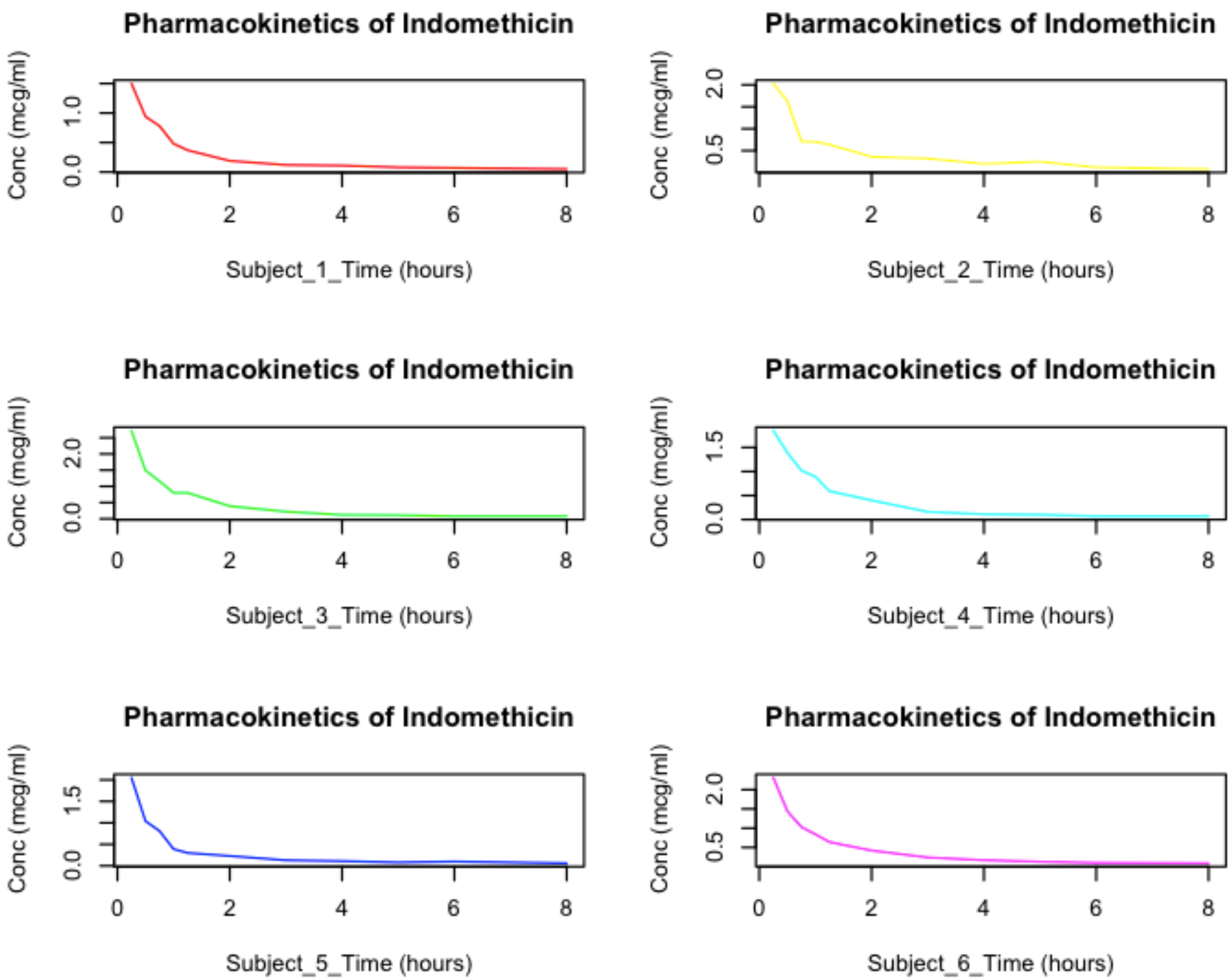
```
head(Indometh)

  Subject time conc
1       1 0.25 1.50
2       1 0.50 0.94
3       1 0.75 0.78
4       1 1.00 0.48
5       1 1.25 0.37
6       1 2.00 0.19

unique(Indometh$Subject)   # We have six Subjects so generate 6 plots
[1] 1 2 3 4 5 6
Levels: 1 < 4 < 2 < 5 < 6 < 3
```

Graphics: Supplemental: Colors

As an aside it might be useful to put all this in a function so you can easily experiment with changing parameters.

```
plot.indometh <- function(mydf, rows=3, cols=2) {

     my.length <- length(levels(Indometh$Subject))

     par(mfrow=c(rows,cols))        # Plot Layout

     col = rainbow(my.length)       # Get some colors

     for (ii in 1:my.length) {
          x.label <- paste("Subject",ii,"Time (hours)",sep="_")
          temp <- subset(mydf,Subject==ii)

          plot(temp$conc ~ temp$time,
            main="Pharmacokinetics of Indomethicin",
             xlab=x.label,
            ylab="Conc (mcg/ml)",type="l",
            col=col[ii])
     }
}

plot.indometh(Indometh)
```

Supplemental: Colors



Supplemental: Colors