Graphics: Base: Barplot

We left off with a discussion on colors and how they can improve a chart or plot.

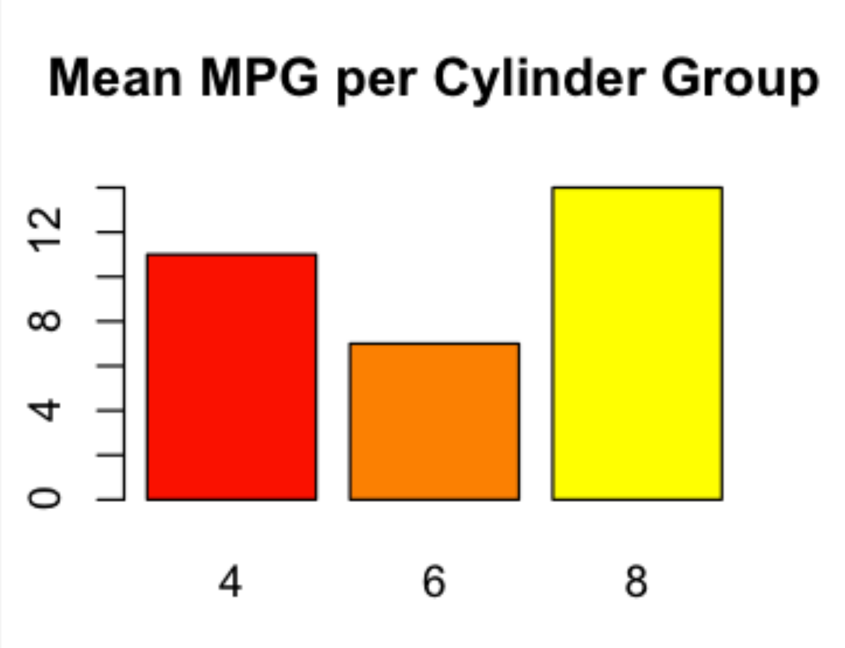
We found that we could use built-in palettes from which we could pick "pre-made" colors. This makes it easy for those of us who can't really pick matching color schemes so easily.

This week we extend this idea some and learn about "color ramps", annotation, as well as some other chart types.

We also explore lattice graphics.

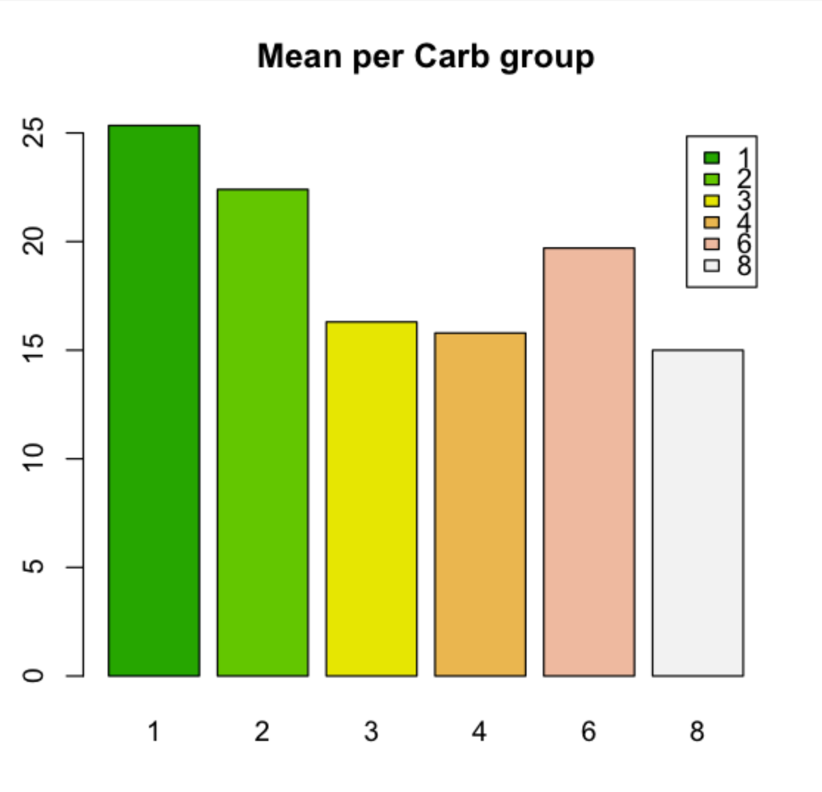
Graphics: Base: Barplot

```
myt <- tapply(mtcars$mpg, mtcars$cyl, mean)

# tapply produces a table

       4        6        8
26.66364 19.74286 15.10000

barplot(myt, main = "Mean MPG per Cylinder Group",
col=heat.colors(3))
```



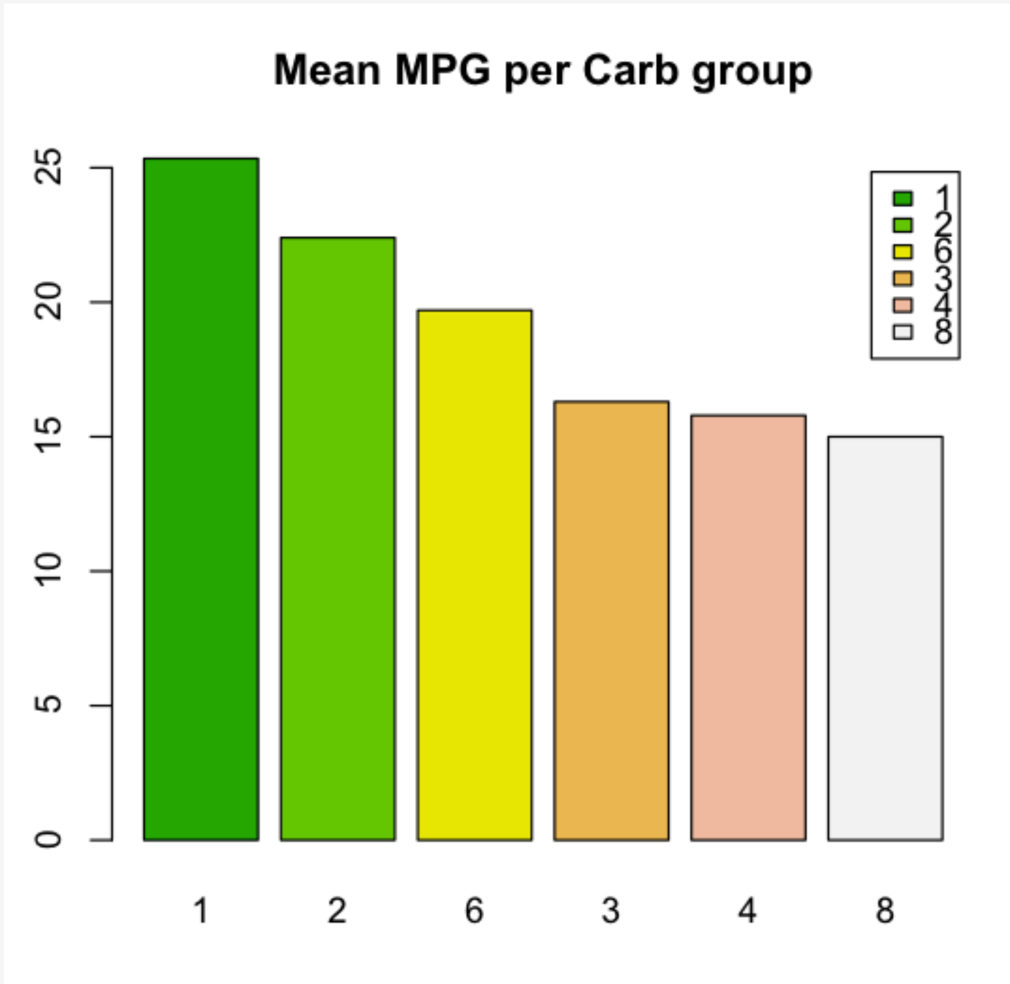
Graphics: Base: Barplot

```
myt <- tapply(mtcars$mpg, mtcars$carb, mean)

       1        2        3        4        6        8
25.34286 22.40000 16.30000 15.79000 19.70000 15.00000

barplot(myt, main = "Mean MPG per Carb group",
             col= terrain.colors(length(myt)),legend=T)
```



Graphics: Base: Barplot

```
barplot(rev(sort(myt)), main = "Mean MPG per Carb group",
            col= terrain.colors(length(myt)),legend=T)
```



Graphics: Base: Barplot

```
barplot(rev(sort(myt)), main = "Mean MPG per Carb group",
            col= terrain.colors(length(myt)),legend=T)


sort(myt)
       8        4        3        6        2        1
15.00000 15.79000 16.30000 19.70000 22.40000 25.34286

rev(sort(myt))
       1        2        6        3        4        8
25.34286 22.40000 19.70000 16.30000 15.79000 15.00000


#  I reverse the sort to make it so the legend doesn't overwrite one of the bars. Try
#  plotting it without doing the rev to see what I mean.

barplot(sort(myt), main = "Mean MPG per Carb group",
            col= terrain.colors(length(myt)),legend=T)
```

Graphics: Base: Barplot

What about making the colors reflect the mean ? If we have an increasing sequence of bars why not make the color for each group a different shade from a graduated color scale.

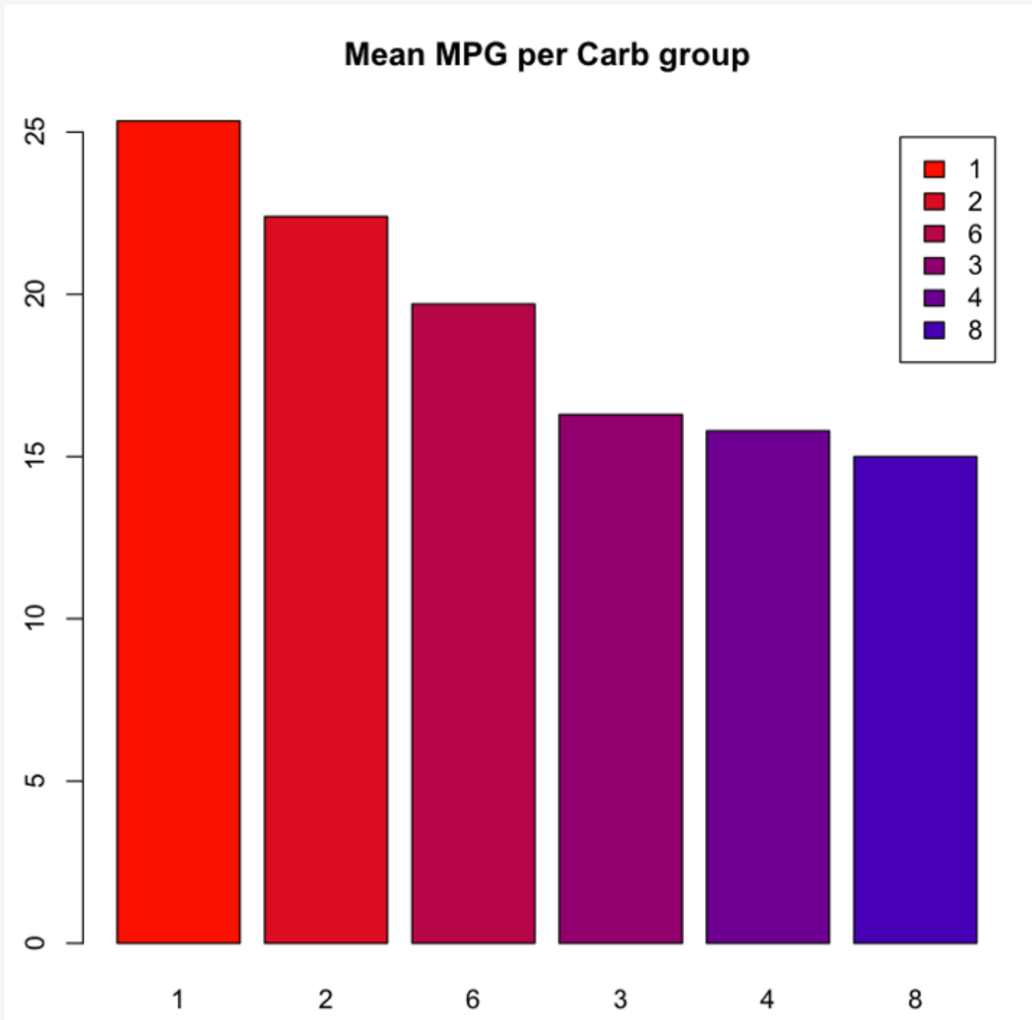
To do this we need a "color ramp" command to generate a palette. Its easier to understand this with an example.

```
mycols <- colorRampPalette(c("red","blue"))( 6 )

[1] "#FF0000" "#DA0024" "#B60048" "#91006D" "#6D0091" "#4800B6"
```

This creates a graduated color scheme between red and blue. Let's apply this to our barplot.

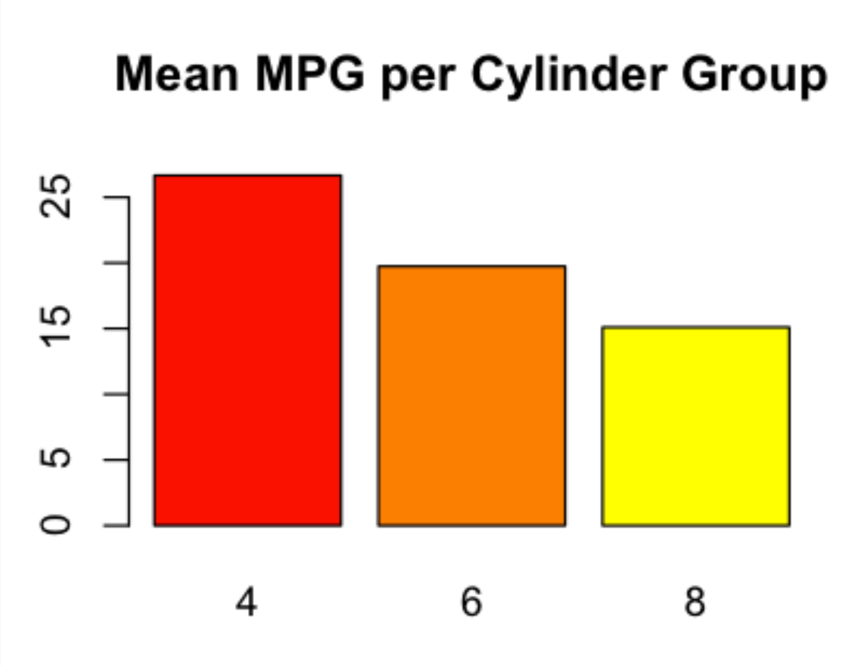
Graphics: Base: Barplot

```
barplot(rev(sort(myt)),
        main = "Mean MPG per Carb group", col=mycols, legend=T)
```



Graphics: Base: Barplot

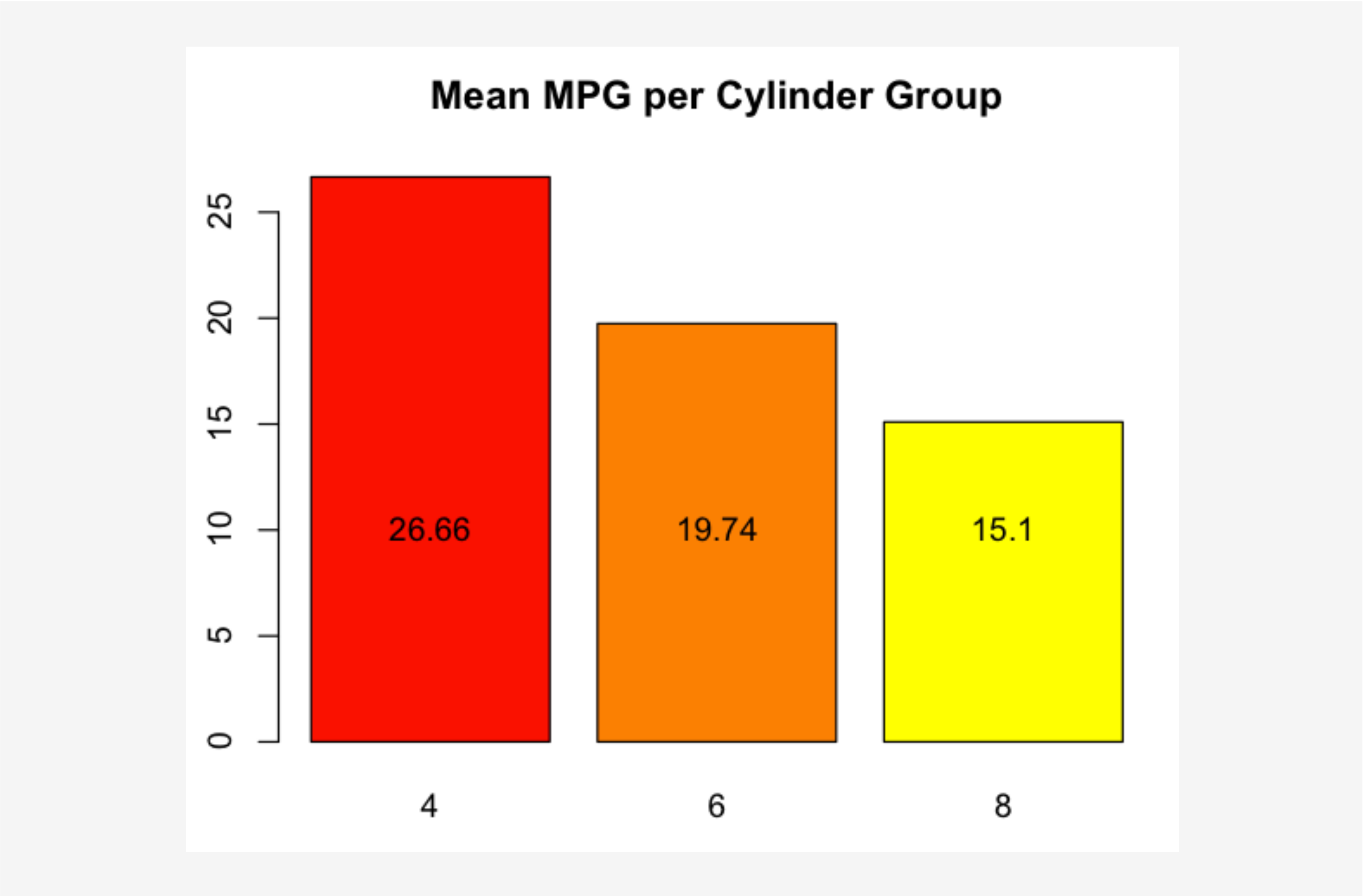
```
myt <- tapply(mtcars$mpg, mtcars$cyl, mean)

# tapply produces a table

       4        6        8
26.66364 19.74286 15.10000

barplot(rev(sort(myt)), main = "Mean MPG per Cylinder Group",
col=heat.colors(3))
```



Graphics: Base: Barplot

```
myt <- tapply(mtcars$mpg, mtcars$cyl, mean)

# tapply produces a table

       4        6        8
26.66364 19.74286 15.10000

temp <- barplot(myt, main = "Mean MPG per Cylinder Group",
                    col=heat.colors(3))

temp        # These represent the X coordinates for each bar
     [,1]
[1,]  0.7
[2,]  1.9
[3,]  3.1

#     x    y   text

text(0.7, 10, 26.66)    # We put up the means one by one

text(1.9, 10, 19.74)

text(3.1, 10, 15.10)
```

Graphics: Base: Barplot



Graphics: Base: Barplot

But there is an easier way. The text function arguments can accept vectors. So an easier way to do this:

```
#     x    y   text

text(0.7, 10, 26.66)    # We put up the means one by one

text(1.9, 10, 19.74)

text(3.1, 10, 15.10)

# is:

text(temp,10,round(myt,2))

temp
     [,1]
[1,]  0.7
[2,]  1.9
[3,]  3.1
```

Graphics: Base: boxplots

If you are doing a X/Y scatterplot and one of them is a categorical variable then the resulting plot will be a boxplot.

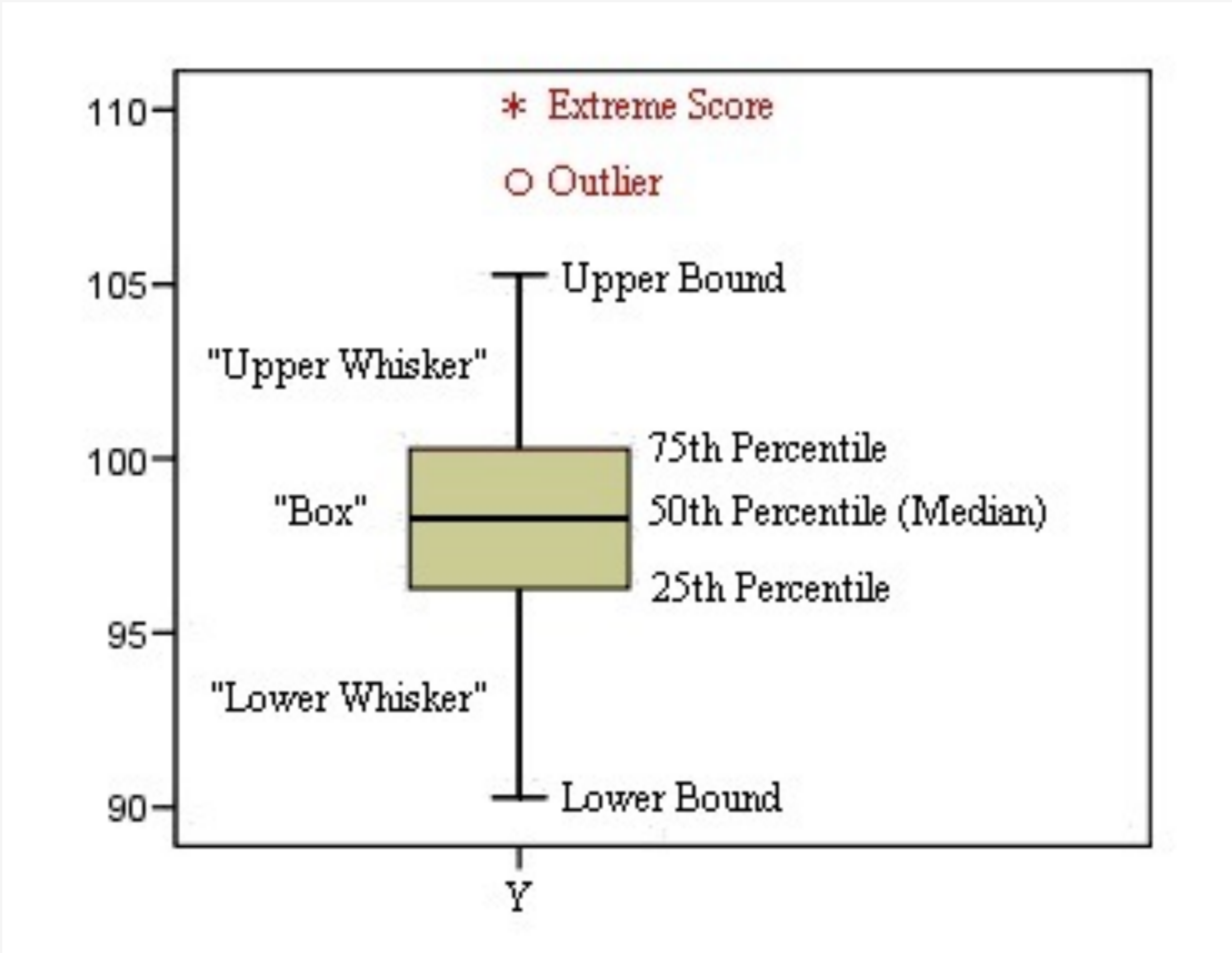
A box plot summarizes a lot of information clearly. It shows the location and spread of data as well as skewness.

The horizontal line shows the median. The bottom and top lines show the 25th and 75th percentiles respectively.

The vertical dashed lines are called "whiskers". The show the maximum of 1) the smaller of the data being plotted or 1.5 times the interquartile range.

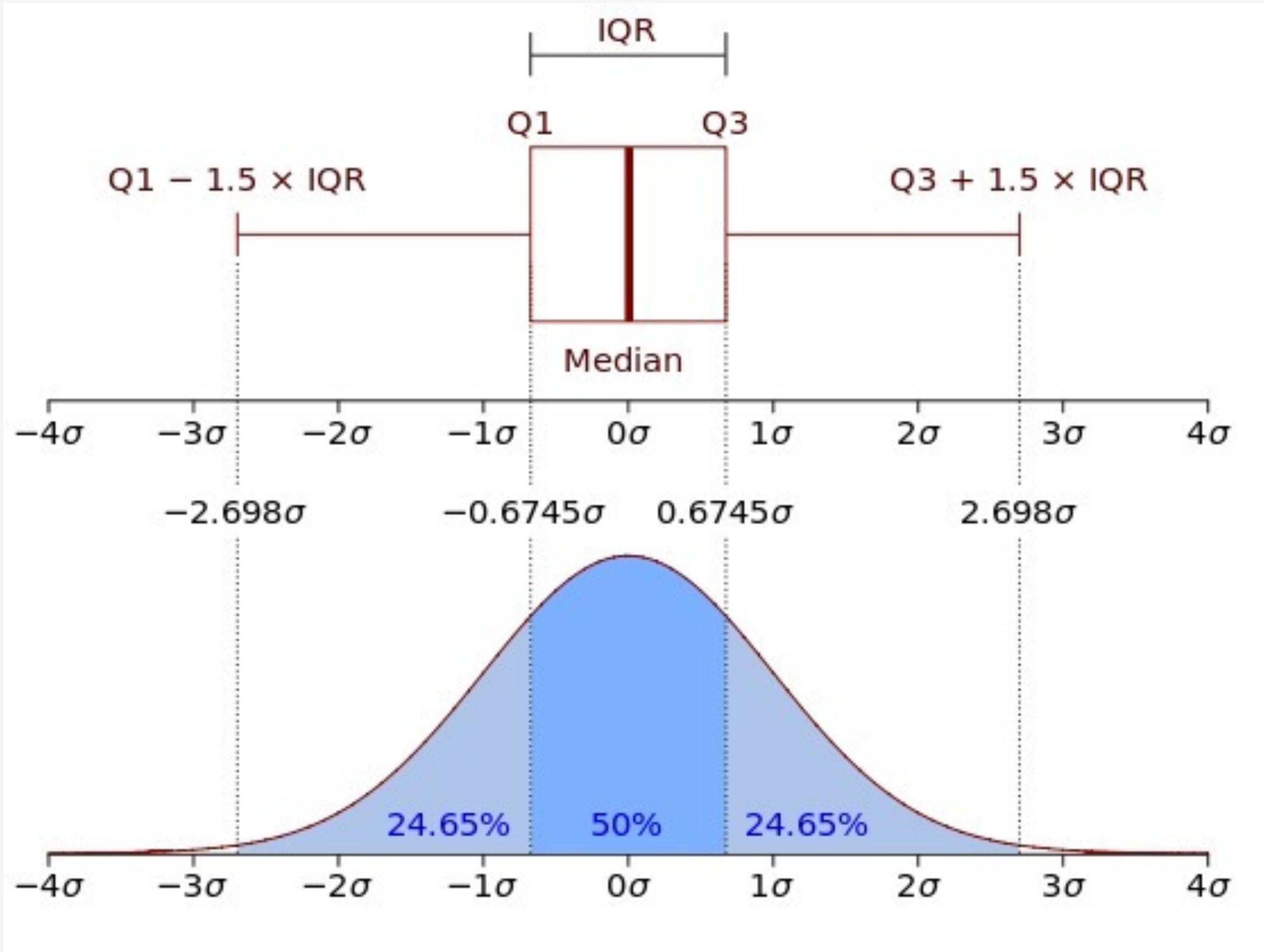
1.5 times the interquartile is roughly two standard deviations. And the IQR is the difference in the response variable between the first and third quartile.

Graphics: Base: boxplots



http://psystats.wikispaces.com/Boxplots

Graphics: Base: boxplots

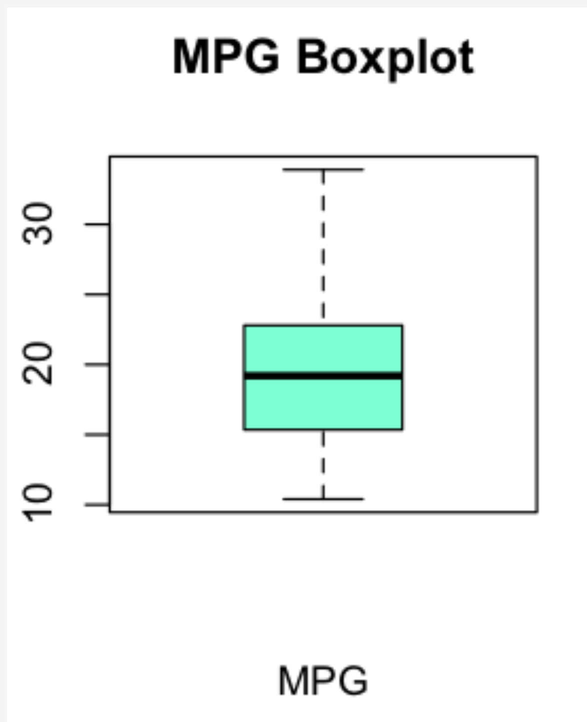


http://en.wikipedia.org/w/index.php?title=File:Boxplot_vs_PDF.svg

Graphics: Base: boxplots

Note that any boxplot output will also match the output from the "fivenum" command:

```
fivenum(mtcars$mpg)
[1] 10.40 15.35 19.20 22.80 33.90

boxplot(mtcars$mpg, main="MPG Boxplot",xlab="MPG",col="aquamarine")
```

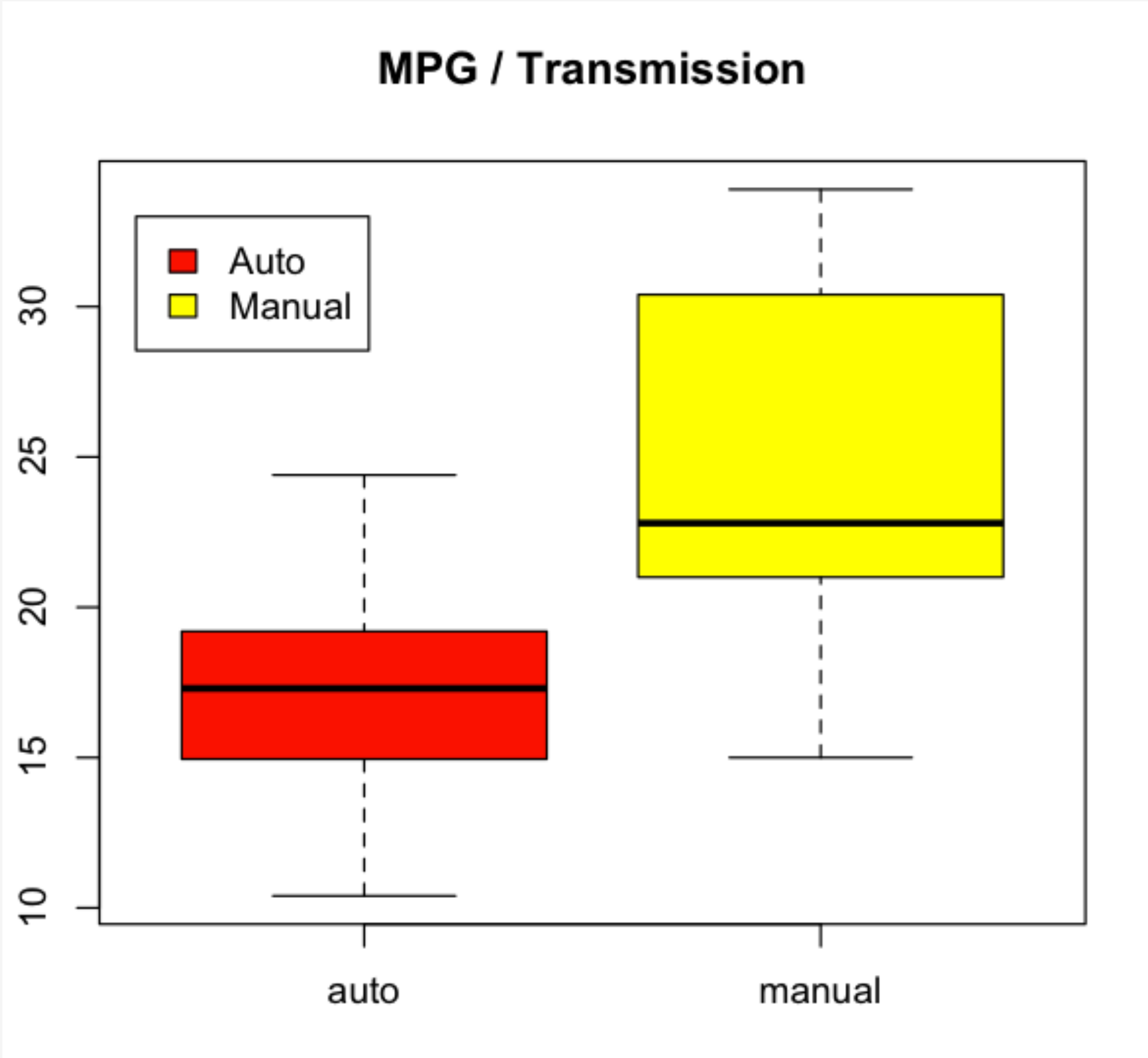


Graphics: Base: boxplots

We can get more than one boxplot within a plot window. If you are doing a X/Y scatterplot and one of them is a categorical variable then the resulting plot will be a boxplot. Let's look at the mtcars dataset now.

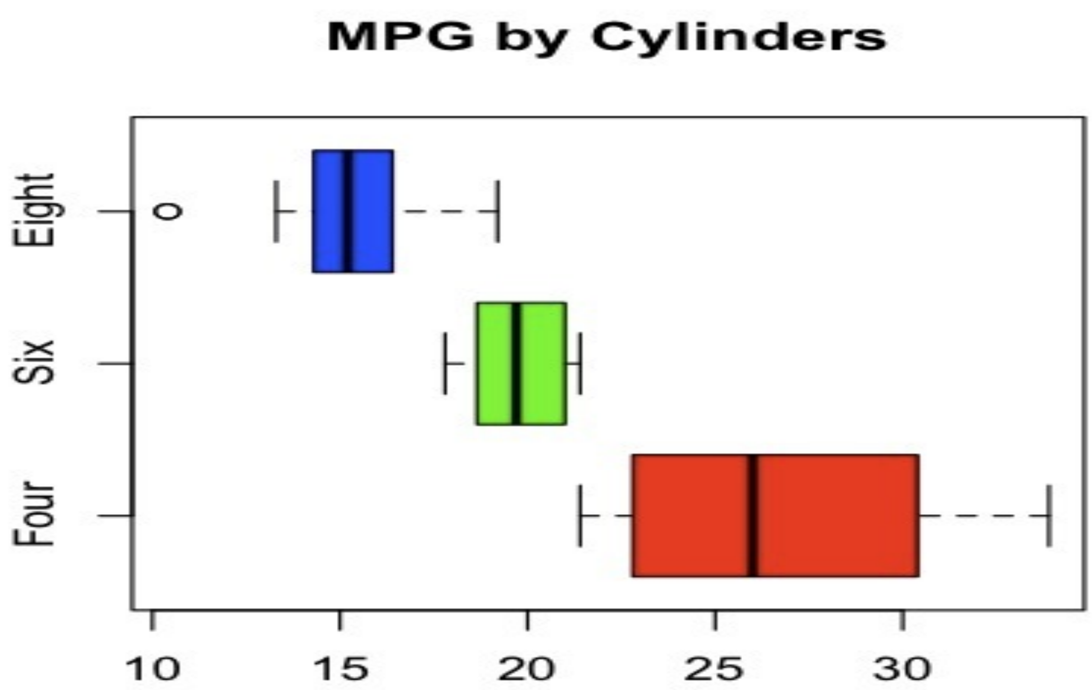
```
boxplot(mpg~am, data = mtcars, main="MPG / Transmission",
                col=heat.colors(2), names=c("auto","manual"))

legend(0.5,33,c("Auto","Manual"),fill=heat.colors(2))
```

Graphics: Base: boxplots



Graphics: Base: boxplots

```
boxplot(mpg~cyl,data=mtcars,main="MPG by Cylinders",
        col=rainbow(3), horizontal=TRUE,
        names=c("Four","Six","Eight"))
```



Graphics: Base: boxplots

Boxplots are generally good at showing distribution of data around the median but not so good at showing the significance of differences between medians. Tukey introduced the idea of "notched" plots to address this problem.

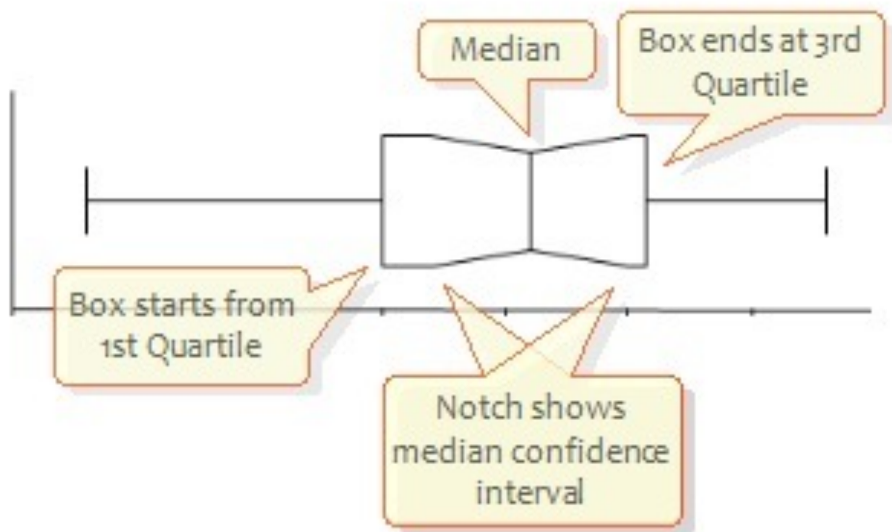
Boxes for which the notches do not overlap are "likely" to have significantly different medians in terms of testing.

The width of the notches is proportional to the interquartile range of the sample and inversely proportional to the square root of the size of the sample.

`http://analyse-it.com/docs/220/standard/summary_paired.htm`

Graphics: Base: boxplots

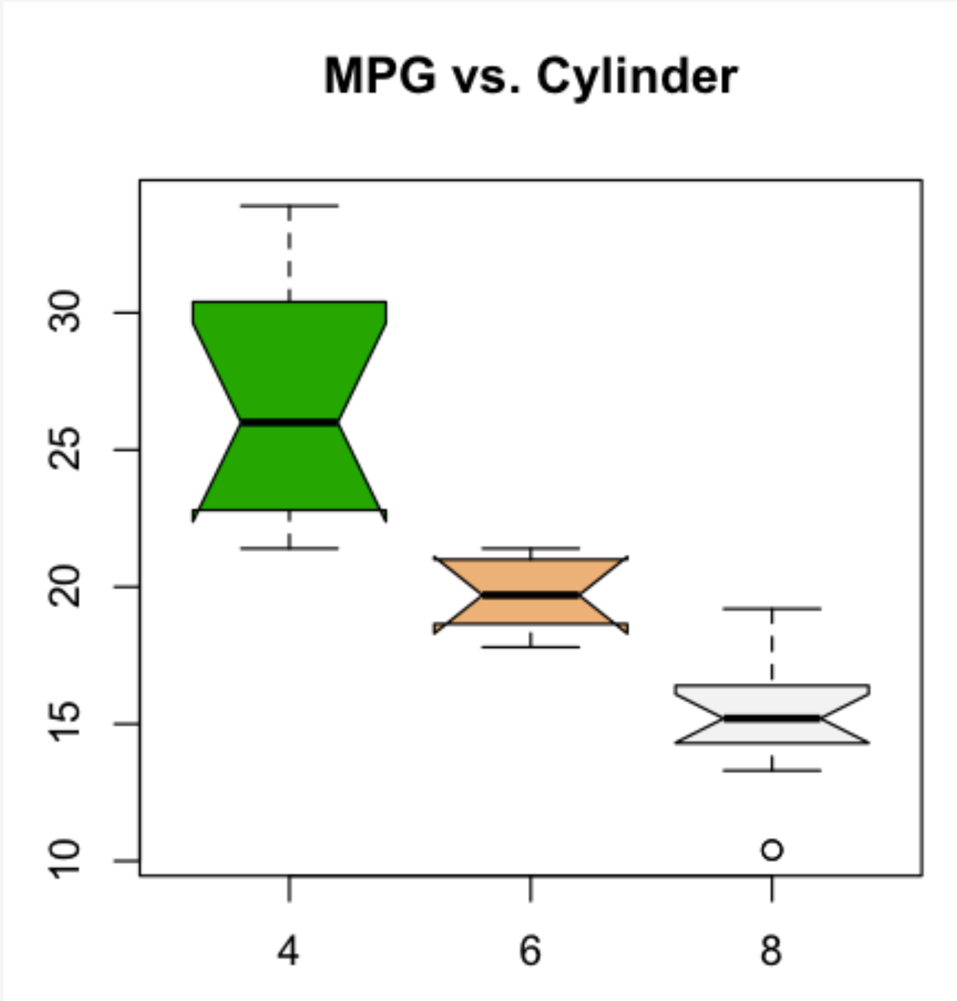
- ***Notched*** box plots show a basic box plot as above, with the addition of a notched (pinched or indented) section for the confidence interval around the median (see below).



http://analyse-it.com/docs/220/standard/summary_paired.htm

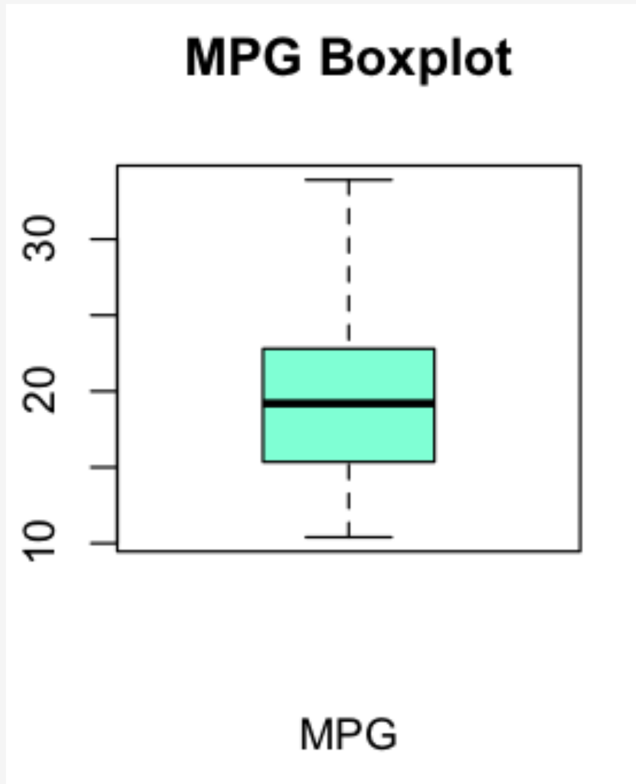
Graphics: Base: boxplots

```
boxplot(mpg~cyl, main="MPG vs. Cylinder", data=mtcars,
          notch=TRUE, col=terrain.colors(3))
```



Graphics: Base: boxplots

```
boxplot(mtcars$mpg, main="MPG Boxplot",xlab="MPG",col="aquamarine")
```



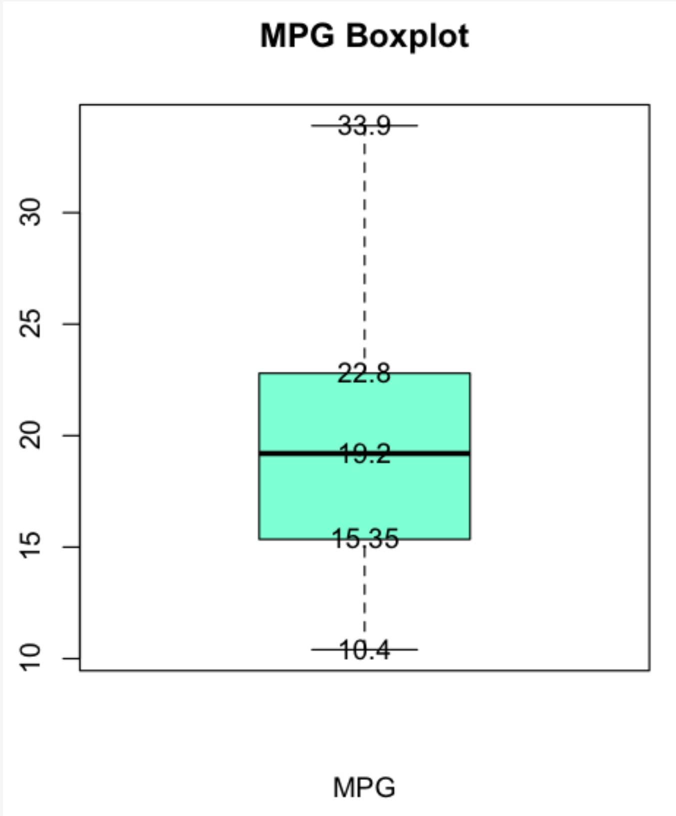
Graphics: Base: boxplots

```
hold <- boxplot(mtcars$mpg, main="MPG Boxplot",
               xlab="MPG",col="aquamarine")
$stats
      [,1]     # This contains the fivenum summary info
[1,] 10.40
[2,] 15.35
[3,] 19.20
[4,] 22.80
[5,] 33.90

$n             # This contains the number of records in the boxplot
[1] 32

$conf
         [,1]
[1,] 17.11916
[2,] 21.28084

$out
numeric(0)

$group
numeric(0)

$names
[1] ""
```

Graphics: Base: boxplots

There is only one boxplot so the X coordinate is "1".

```
text(1,10.4,10.4)
text(1,15.35,15.35)
text(1,19.20,19.20)
text(1,22.8,22.8)
text(1,33.9,33.9)
```



We could do this more simply by recognizing that the text function can handle vectors as well as single values (as in the previous example).

```
text(1,hold$stats[,1],hold$stats[,1])
```

Graphics: Base: boxplots

As with the barchart command, the boxplot command returns some interesting information such as the fivenum value statistics and some other stuff:

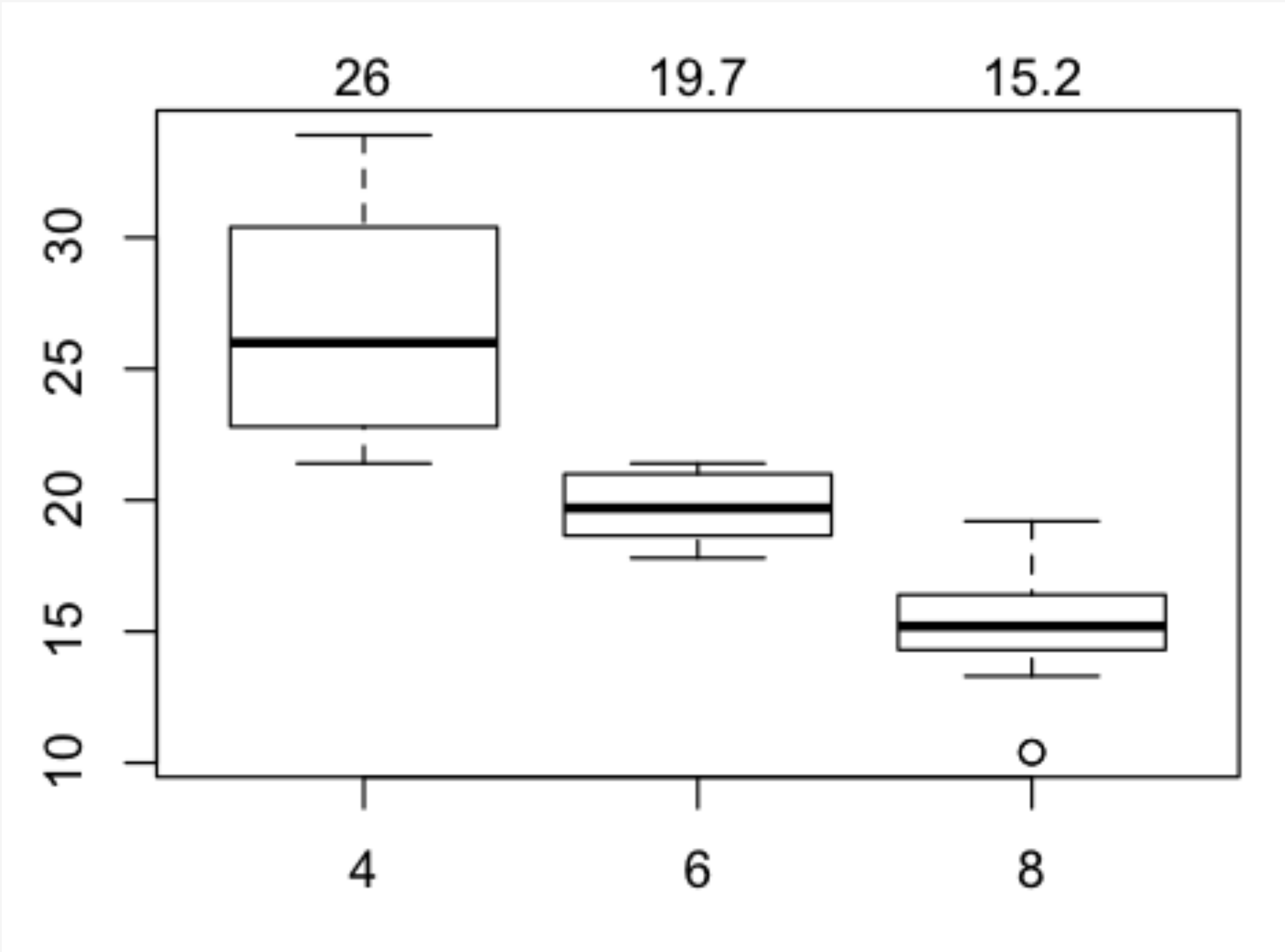
```
tmpvar <- boxplot(mpg~cyl,data=mtcars)

$stats
     [,1]  [,2] [,3]
[1,] 21.4 17.80 13.3
[2,] 22.8 18.65 14.3
[3,] 26.0 19.70 15.2     # This row represents the median across the cylinder groups
[4,] 30.4 21.00 16.4
[5,] 33.9 21.40 19.2

$n                   # This row represents the number of observations in each cyl group
[1] 11  7 14

$conf
         [,1]     [,2]     [,3]
[1,] 22.37945 18.29662 14.31323
[2,] 29.62055 21.10338 16.08677

$out
[1] 10.4 10.4

$group
[1] 3 3

$names
[1] "4" "6" "8"
```

Graphics: Base: boxplots

As with the barchart command, the boxplot command returns some interesting information such as the fivenum value statistics and some other stuff:

```
tmpvar <- boxplot(mpg~cyl,data=mtcars)

tmpvar$stats
     [,1]  [,2] [,3]
[1,] 21.4 17.80 13.3
[2,] 22.8 18.65 14.3
[3,] 26.0 19.70 15.2
[4,] 30.4 21.00 16.4
[5,] 33.9 21.40 19.2

tmpvar$stats[3,]
[1] 26.0 19.7 15.2

mtext(at=1:3, text=tmpvar$stats[3,])

# same as doing the following:

mtext(at=1, text=tmpvar$stats[3,1], side=3) # top margin
mtext(at=2, text=tmpvar$stats[3,2], side=3) # top margin
mtext(at=3, text=tmpvar$stats[3,3], side=3) # top margin
```

Graphics: Base: boxplots

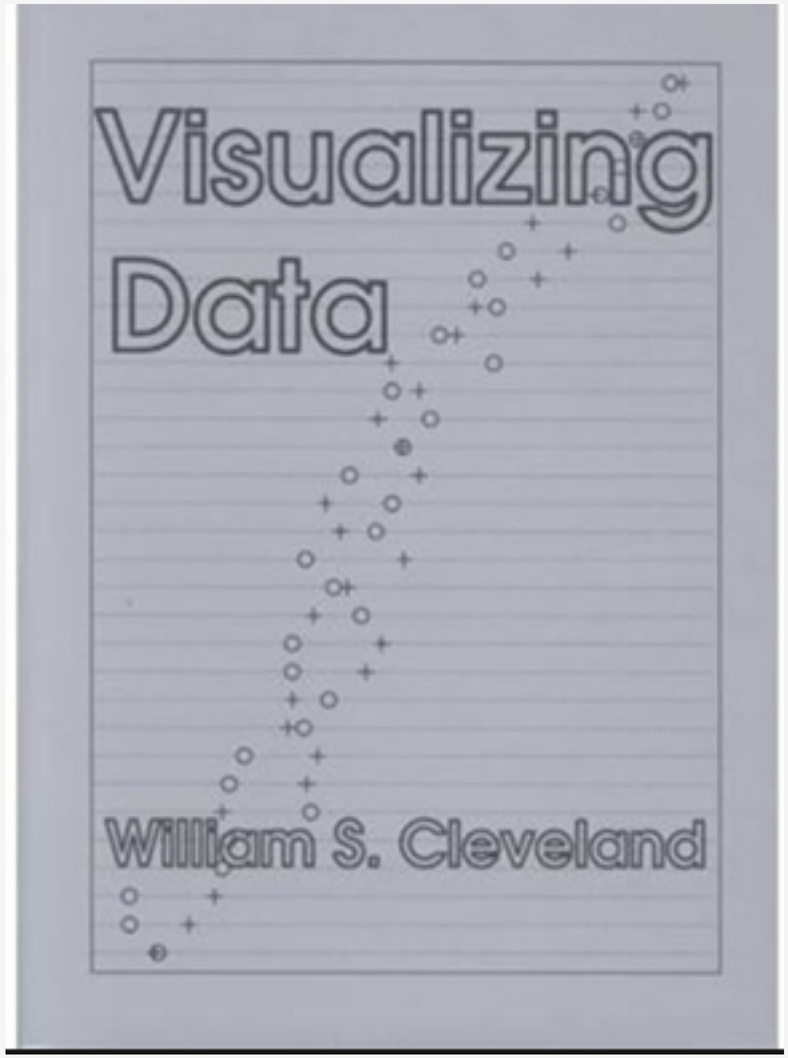


LATTICE Graphics

Note that much of the material in this section is attributable to the Lattice intro available at:

http://lattice.r-forge.r-project.org/Vignettes/src/lattice-intro/lattice-intro.pdf

Graphics: lattice



Graphics: lattice

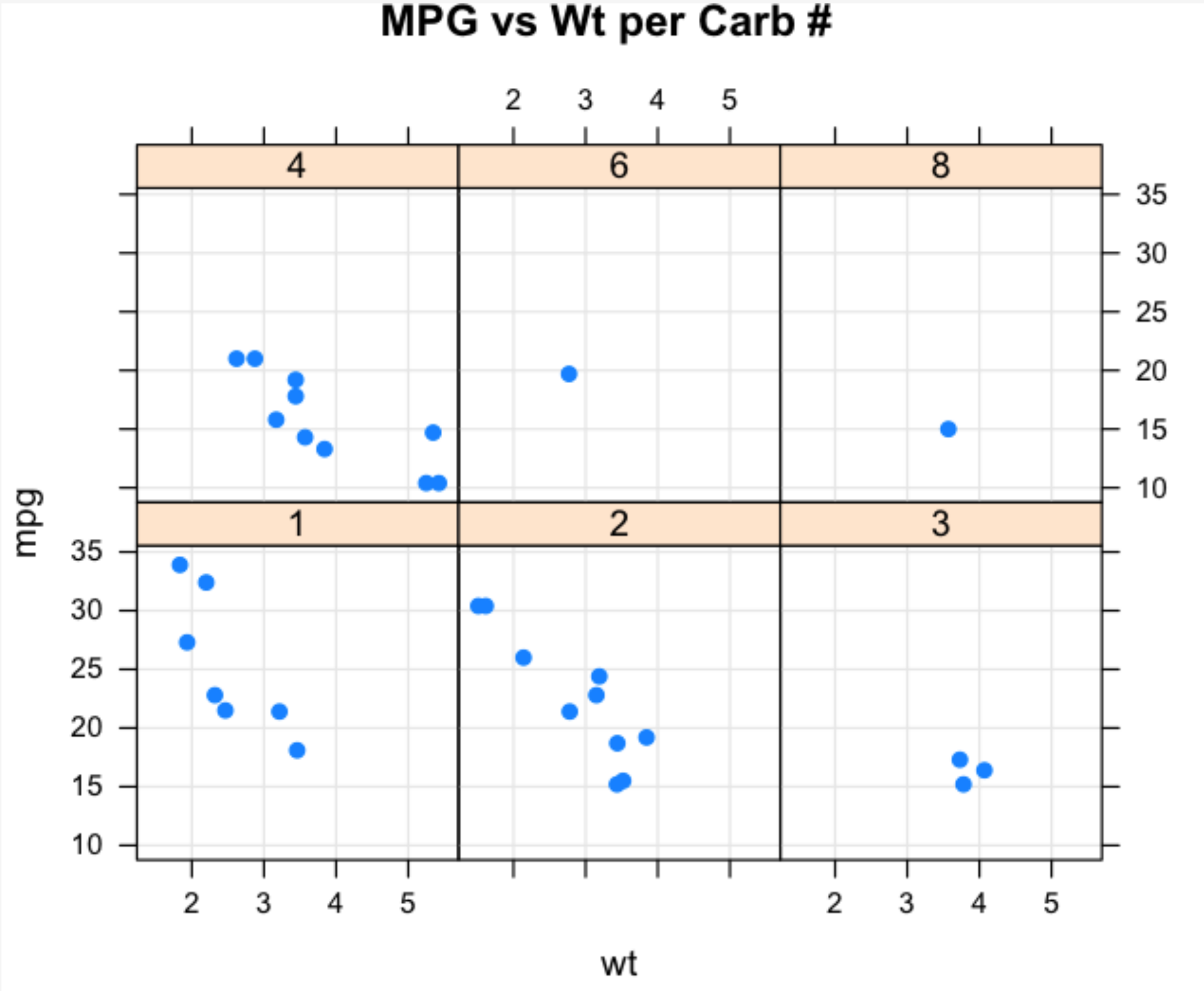
Lattice
Multivariate Data Visualization with R
http://lmdvr.r-forge.r-project.org/figures/figures.html

Graphics: lattice

Why "lattice" ? Note also that "trellis" is a synonym for "lattice"

Graphics: lattice

```
library(lattice)
xyplot(mpg~wt|factor(carb), data=mtcars, pch=19,
       main="MPG vs Wt per Carb #", type=c("p","g"))
```



Graphics: lattice

Design goals

Visualization is an art, but it can benefit greatly from a systematic, scientific approach. In particular, **?** has shown that it is possible to come up with general rules that can be applied to design more effective graphs.

One of the primary goals of Trellis graphics is to provide tools that make it easy to apply these rules, so that the burden of compliance is shifted from the user to the software to the extent possible. Some obvious examples of such rules are:

- Use as much of the available space as possible
- Force direct comparsion by superposition (grouping) when possible
- Encourage comparison when juxtaposing (conditioning): use common axes, add common reference objects such as grids.

Graphics: lattice

The following display types are available in `lattice`.

Function	Default Display
`histogram()`	Histogram
`densityplot()`	Kernel Density Plot
`qqmath()`	Theoretical Quantile Plot
`qq()`	Two-sample Quantile Plot
`stripplot()`	Stripchart (Comparative 1-D Scatter Plots)
`bwplot()`	Comparative Box-and-Whisker Plots
`dotplot()`	Cleveland Dot Plot
`barchart()`	Bar Plot
`xyplot()`	Scatter Plot
`splom()`	Scatter-Plot Matrix
`contourplot()`	Contour Plot of Surfaces
`levelplot()`	False Color Level Plot of Surfaces
`wireframe()`	Three-dimensional Perspective Plot of Surfaces
`cloud()`	Three-dimensional Scatter Plot
`parallel()`	Parallel Coordinates Plot

Graphics: lattice

Lattice Function	Description	Traditional Analogue
barchart()	Barcharts	**barplot()**
bwplot()	Boxplots Box-and-whisker plots	**boxplot()**
densityplot()	Conditional kernel density plots Smoothed density estimate	*none*
dotplot()	Dotplots Continuous versus categorical	**dotchart()**
histogram()	Histograms	**hist()**
qqmath()	Quantile–quantile plots Data set versus theoretical distribution	**qqnorm()**
stripplot()	Stripplots One-dimensional scatterplot	**stripchart()**
qq()	Quantile–quantile plots Data set versus data set	**qqplot()**
xyplot()	Scatterplots	**plot()**
levelplot()	Level plots	**image()**
contourplot()	Contour plots	**contour()**
cloud()	3-dimensional scatterplot	*none*
wireframe()	3-dimensional surfaces	**persp()**
splom()	Scatterplot matrices	**pairs()**
parallel()	Parallel coordinate plots	*none*

Graphics: lattice

Even though lattice graphics is part of R you have to first load the lattice library before using any of the commands:

```
library(lattice)
```

Graphics: lattice

Trellis displays are defined by the type of graphic and the role different variables play in it. Each display type is associated with a corresponding high-level function (histogram, densityplot, etc.). Possible roles depend on the type of display, but typical ones are:

primary variables: those that define the primary display (e.g., usually some continuous variables)

conditioning variables: divides data into subgroups, each of which are presented in a different panel (e.g., a category or factor).

grouping variables: subgroups are contrasted within panels by superposing the corresponding displays (e.g., gender in the last example).

http://lattice.r-forge.r-project.org/Vignettes/src/lattice-intro/lattice-intro.pdf

Graphics: lattice

Lattice/Trellis graphics display a variable,or a relationship between variables, conditioned on one or more other variables. The typical format is:

graph_type(formula,data=some.data) where formula specifies the variable(s) to display and any conditioning variables.

***~x|A** means display numeric variable x for each level of factor A on separate panels.*

```
bwplot(~mpg | factor(am,labels=c("Auto","Manual")), data=mtcars)
```

***x ~ A** means display numeric variable x for each level of A on One panel.*

```
bwplot(mpg ~ factor(am), data=mtcars)
```

***~x** means display numeric variable **x** alone.*

```
histogram(~mpg, data=mtcars)
```

Graphics: lattice

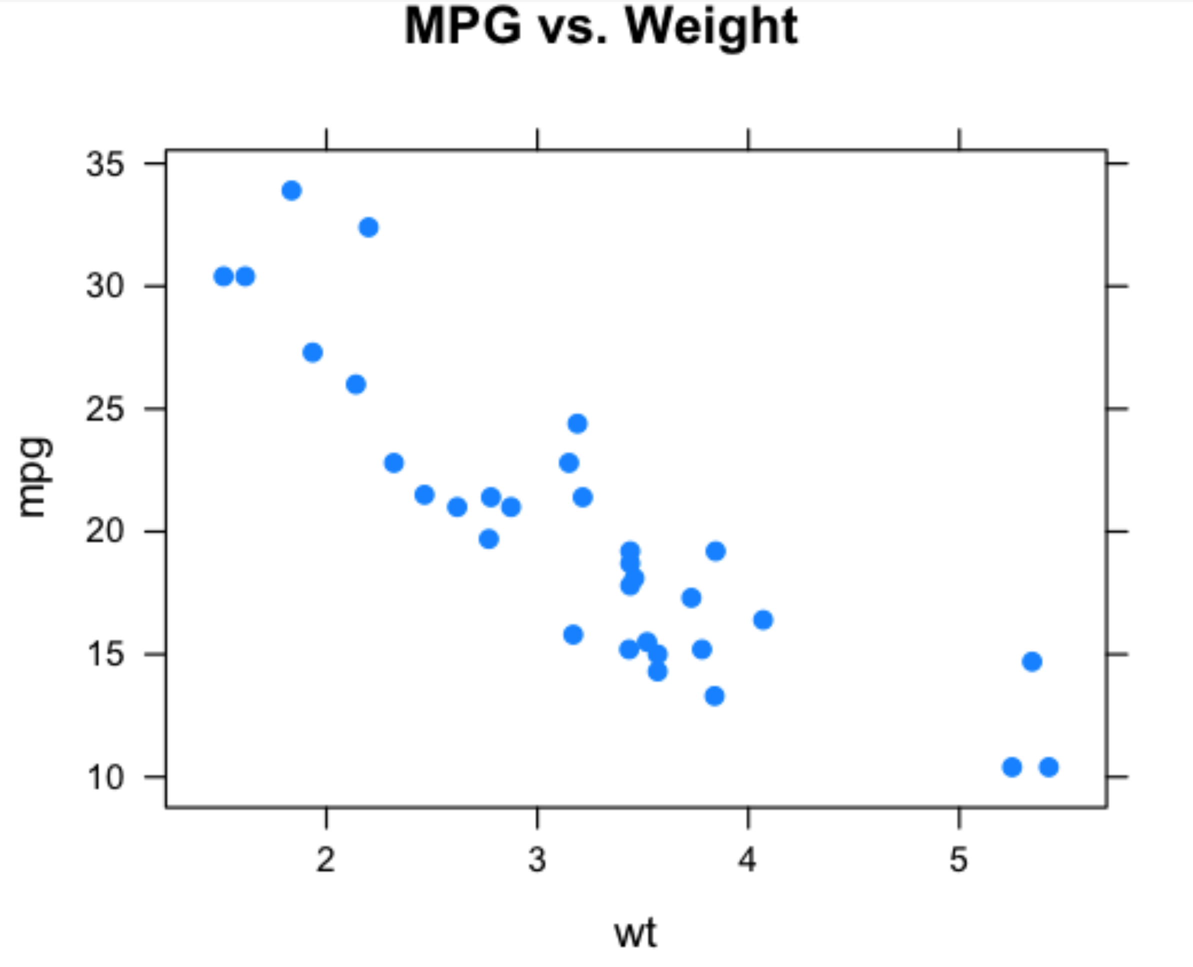
graph_type	description	formula examples
barchart	bar chart	x~A or A~x
bwplot	boxplot	x~A or A~x
cloud	3D scatterplot	z~x*y|A
contourplot	3D contour plot	z~x*y
densityplot	kernal density plot	~x|A*B
dotplot	dotplot	~x|A
histogram	histogram	~x
levelplot	3D level plot	z~y*x
parallel	parallel coordinates plot	dataframe
splom	scatterplot matrix	dataframe
stripplot	strip plots	A~x or x~A
xyplot	scatterplot	y~x|A

Graphics: lattice: xyplot

The typical Basic form when calling a lattice function such as xyplot looks like:

```
vertical.axis.variable ~ horizontal.axis.variable

xyplot(mpg ~ wt, data = mtcars, pch = 19, main = "MPG vs. Weight")
```

Graphics: lattice: xyplot

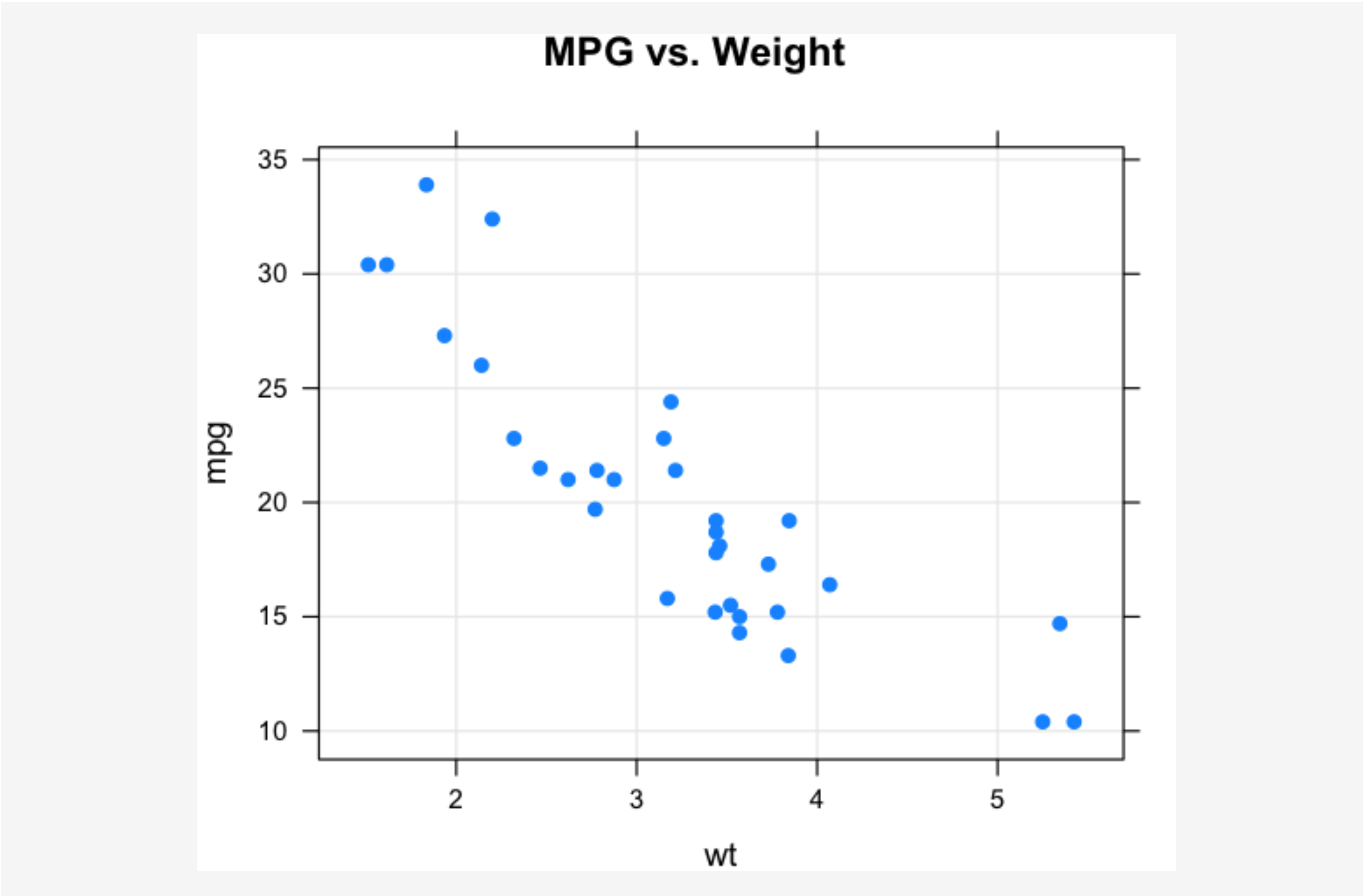


Graphics: lattice: xyplot

* Check out the "type" argument that let's us specify the type of graph we want (e.g. points, lines, grid)

```
 xyplot(mpg ~ wt, data = mtcars, pch = 19,
        main = "MPG vs. Weight", type=c("p","g"))
```

Graphics: lattice: xyplot



Graphics: lattice: Conditioning

* So check out this formula. "mpg" is the y variable and "wt" is the x variable.

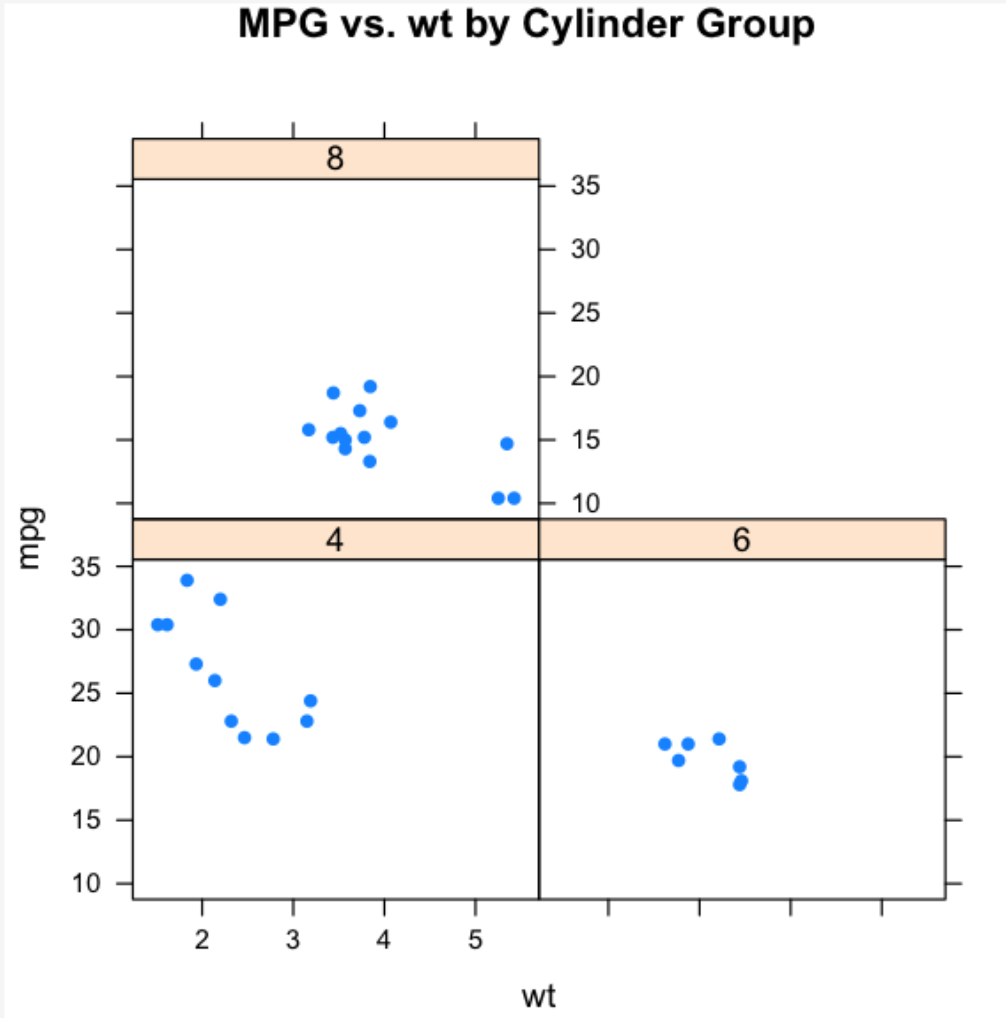
```
xyplot(mpg ~ wt | factor(cyl), data = mtcars, pch=16,
       main = "MPG vs. wt by Cylinder Group"))
```

* "cylinder" is a conditioning variable (preceeded by the | character). The conditioning variable divides the plot into separate panels

* Conditioning variables are usually categorical.

* Note that the "data" argument tells the function what data frame to use.

Graphics: lattice: Conditioning



Graphics: lattice: Conditioning

* So check out this formula. "mpg" is the y variable and "wt" is the x variable.

```
xyplot(mpg ~ wt | factor(cyl), data = mtcars, pch=16, type=c("p","g"),
       main = "MPG vs. wt by Cylinder Group", layout=c(1,3))
```

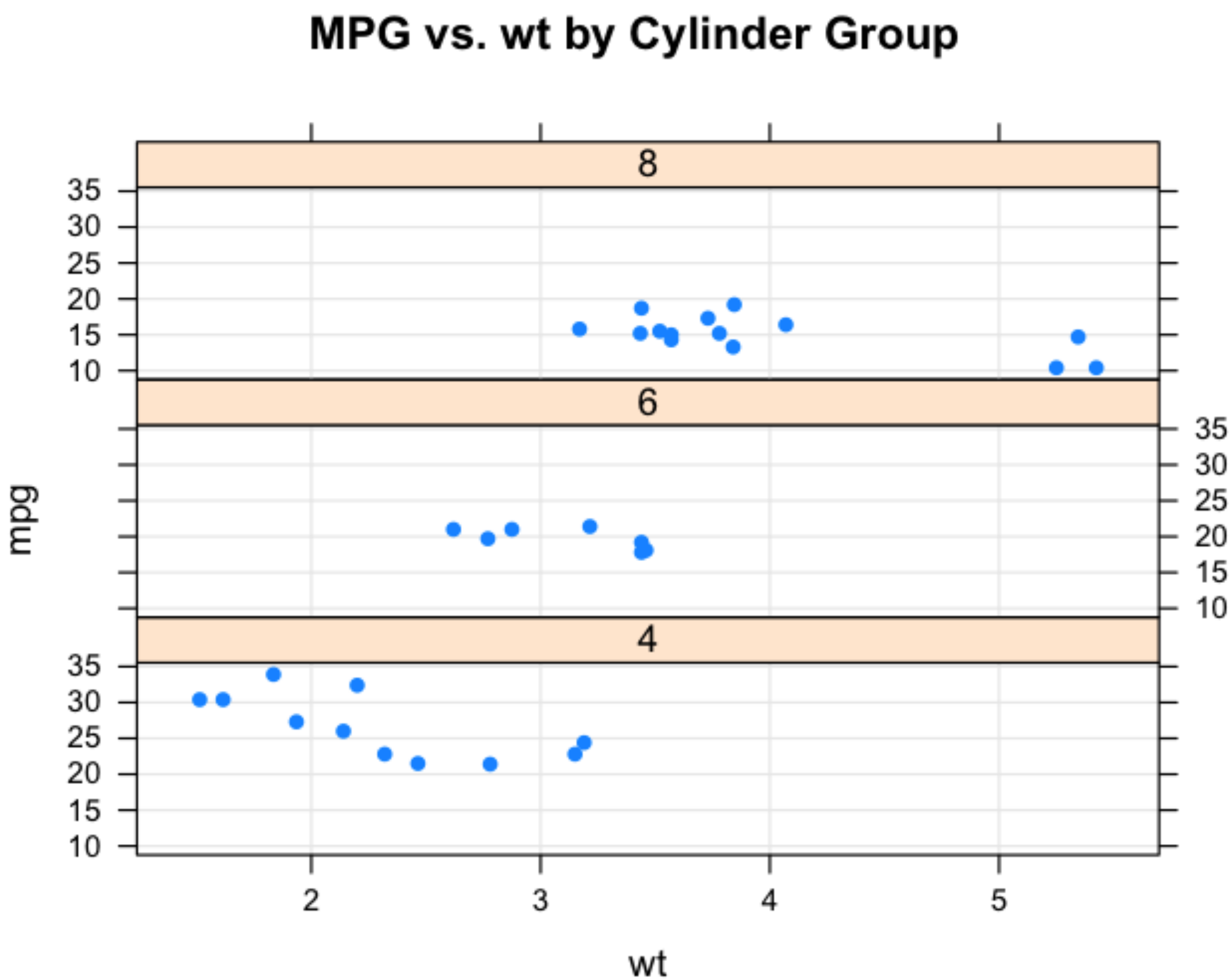
* "cylinder" is a conditioning variable (preceeded by the | character). The conditioning variable divides the plot into separate panels

* Conditioning variables are usually categorical.

* Note that the "data" argument tells the function what data frame to use.

Graphics: lattice: Conditioning

In the Trellis terminology, this plot consists of three panels. Each panel in this case contains a scatterplot and above each panel there is a strip that presents the level of the conditioning variable.



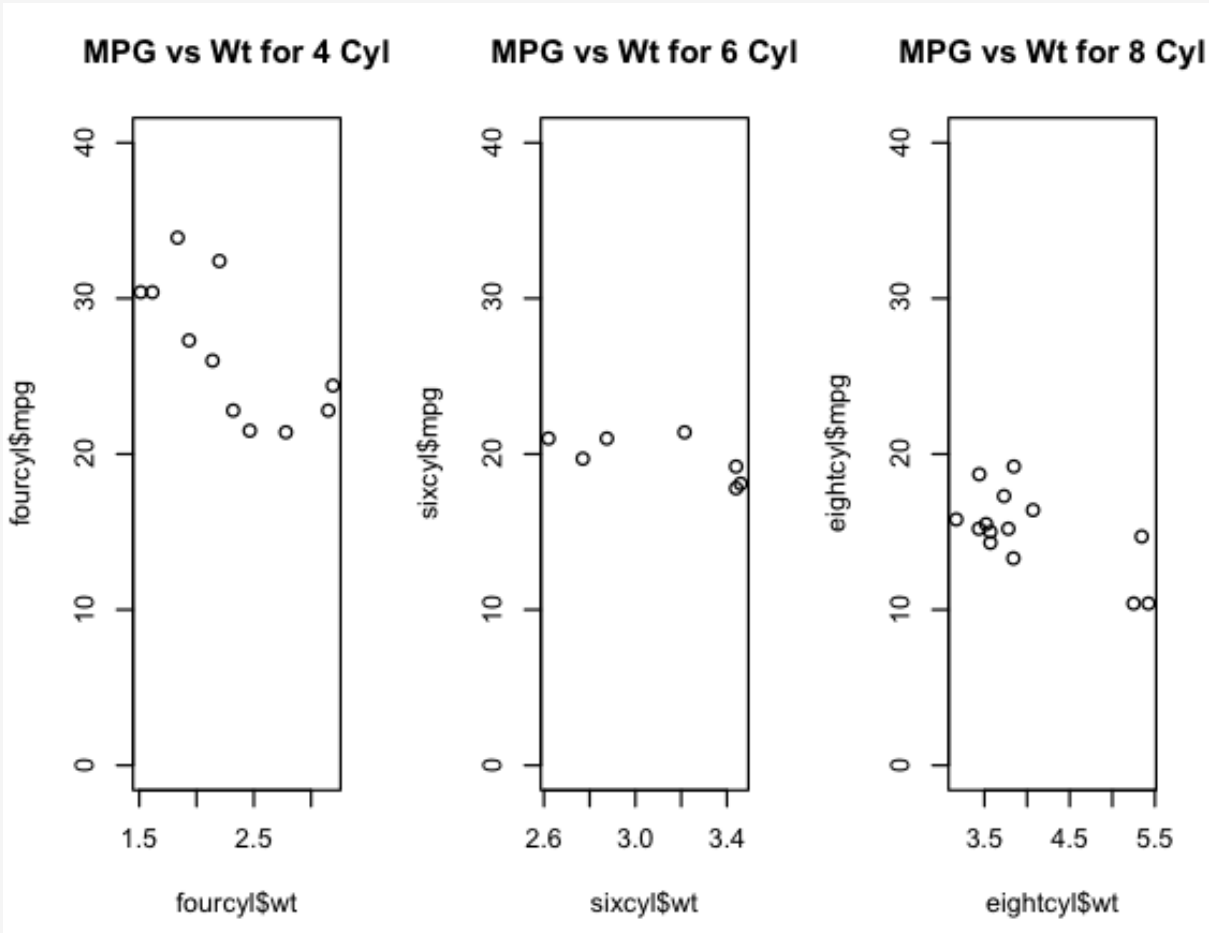
Graphics: lattice: Conditioning

Remember our early X/Y plot with Base graphics where we wanted to plot MPG vs Weight for each cylinder category ? To get a side-by-side panel plot we did something like this:

```
par(mfrow=c(1,3))

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

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

Graphics: lattice: Conditioning

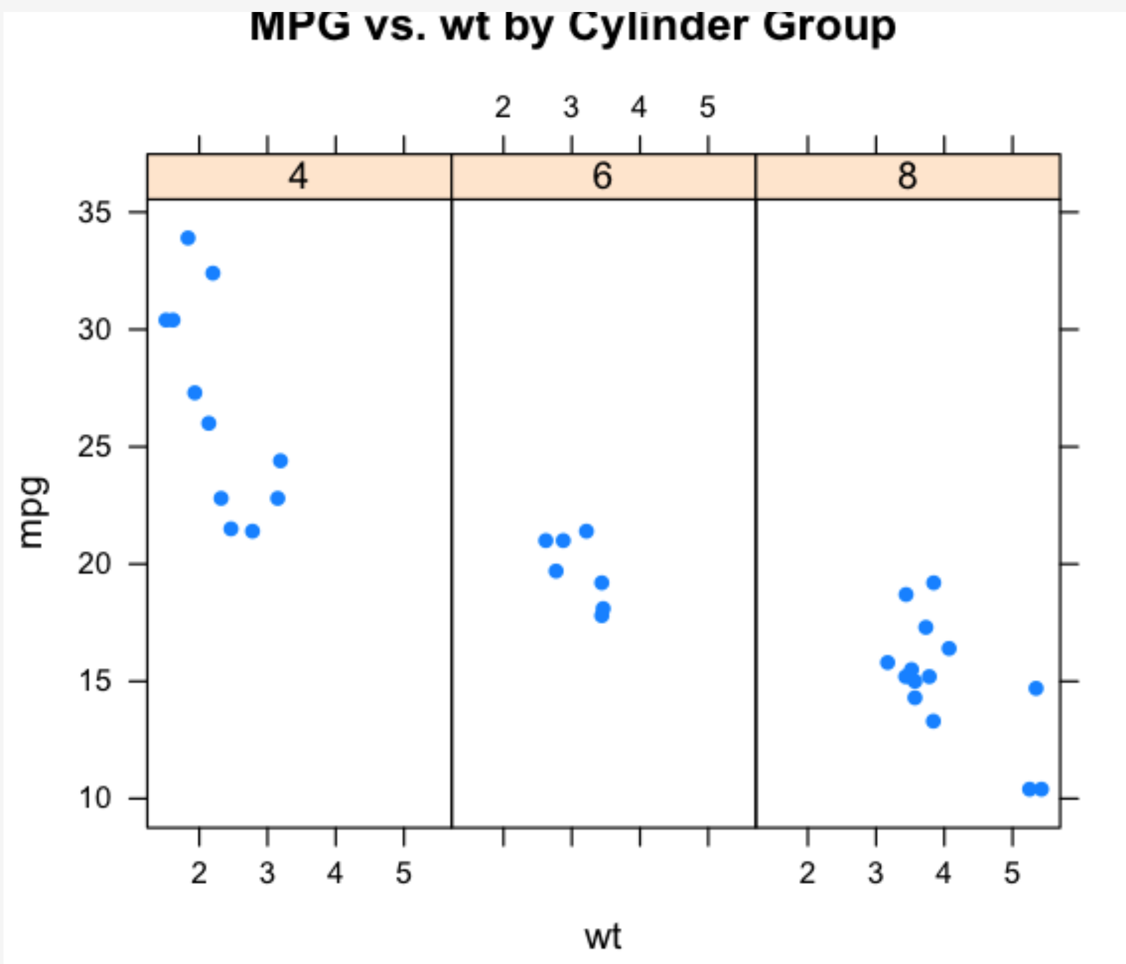
Remember our early X/Y plot with Base graphics where we wanted to plot MPG vs Weight for each cylinder category ? To get a side-by-side panel plot we did something like this:



Graphics: lattice: Conditioning

With lattice plots its much easier:

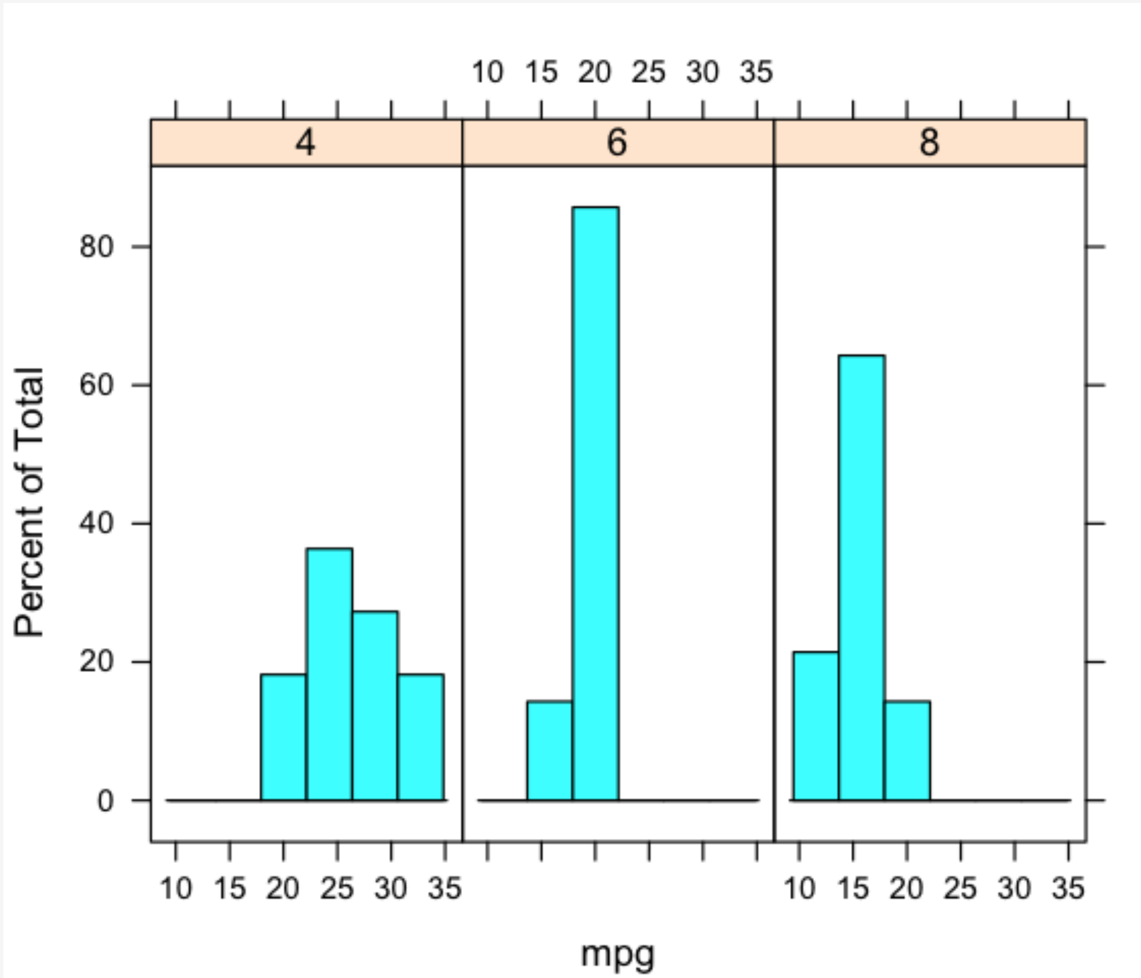
```
library(lattice)
xyplot(mpg~wt|factor(cyl),data = mtcars,layout=c(3,1))
```



Graphics: lattice: Conditioning

This works independently of the chart type:

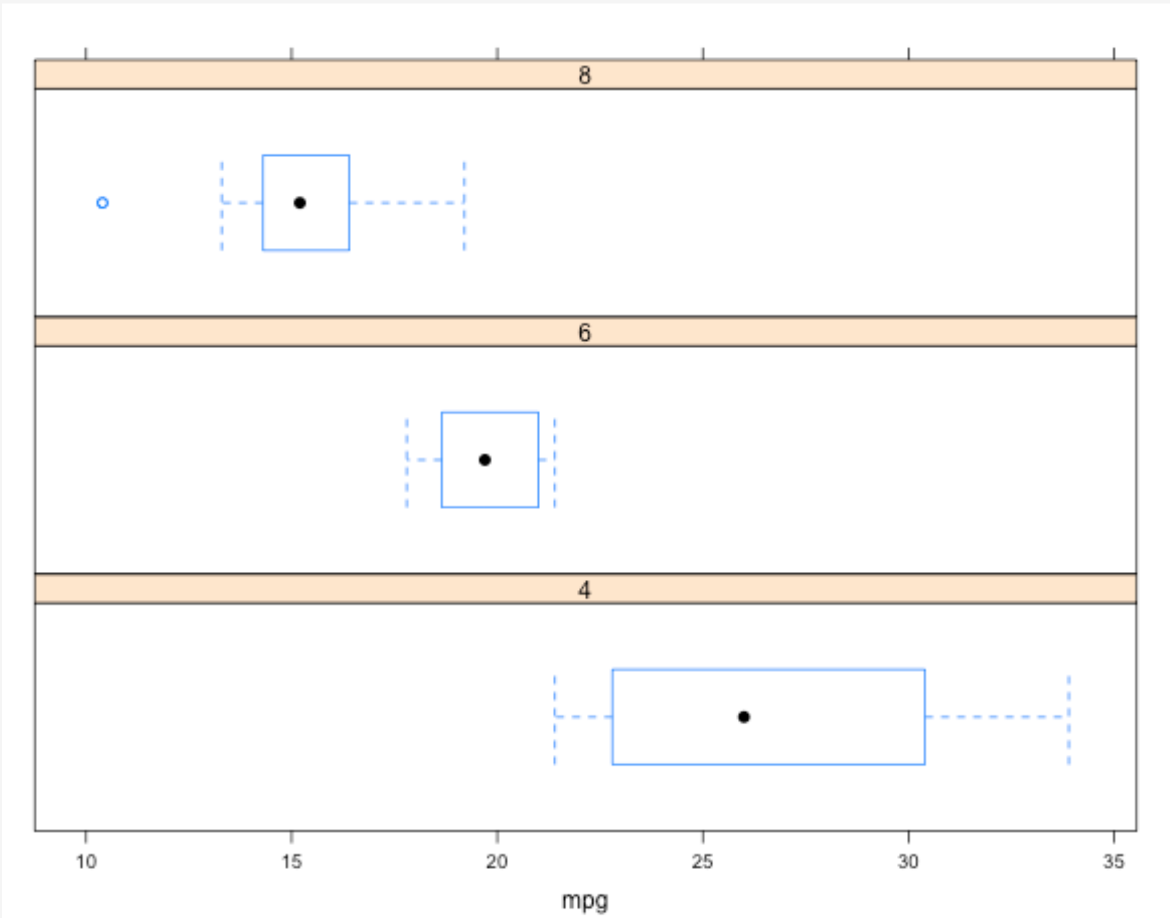
```
histogram(~mpg | factor(cyl), data = mtcars, layout = c(3,1))
```



Graphics: lattice: Conditioning

Since we don't have enough observations to note an obvious distribution let's do a boxplot

```
bwplot(~mpg | factor(cyl), data = mtcars, layout = c(1,3))
```

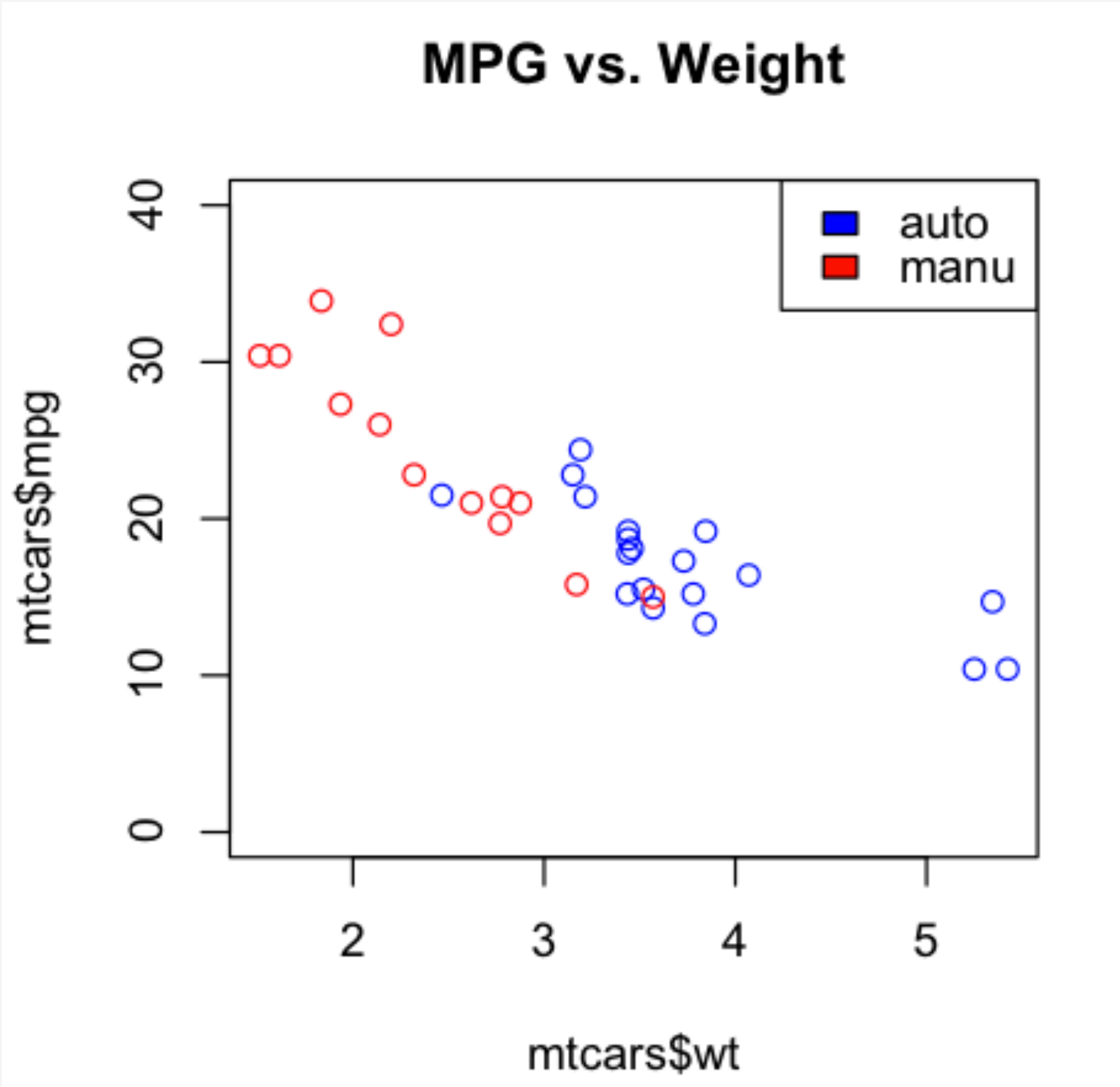


Graphics: lattice: groups

Remember our early X/Y plot with Base graphics where we wanted to plot MPG vs Weight for each transmission type and have it represented by a different color or plot character ? The most basic solution looked like this (although we did improve it somewhat).

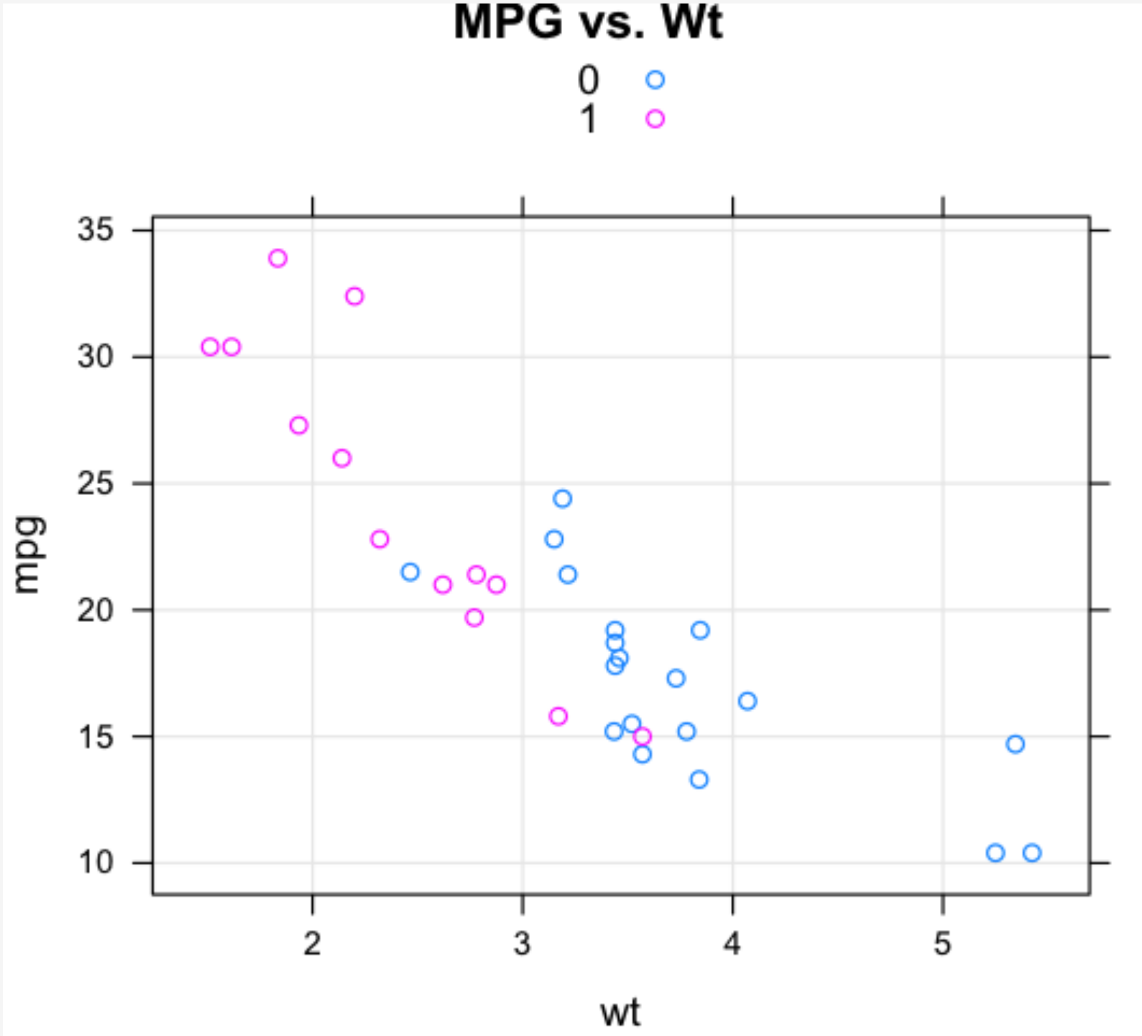
```
plot(mtcars$wt, mtcars$mpg, main="MPG vs. Weight", type="n",
     ylim=c(0,40))

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

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

points(auto$wt, auto$mpg, col="blue")

points(manu$wt, manu$mpg, col="red")

legend("topright",c("auto","manu"),fill=c("blue","red"))
```

Graphics: lattice: groups



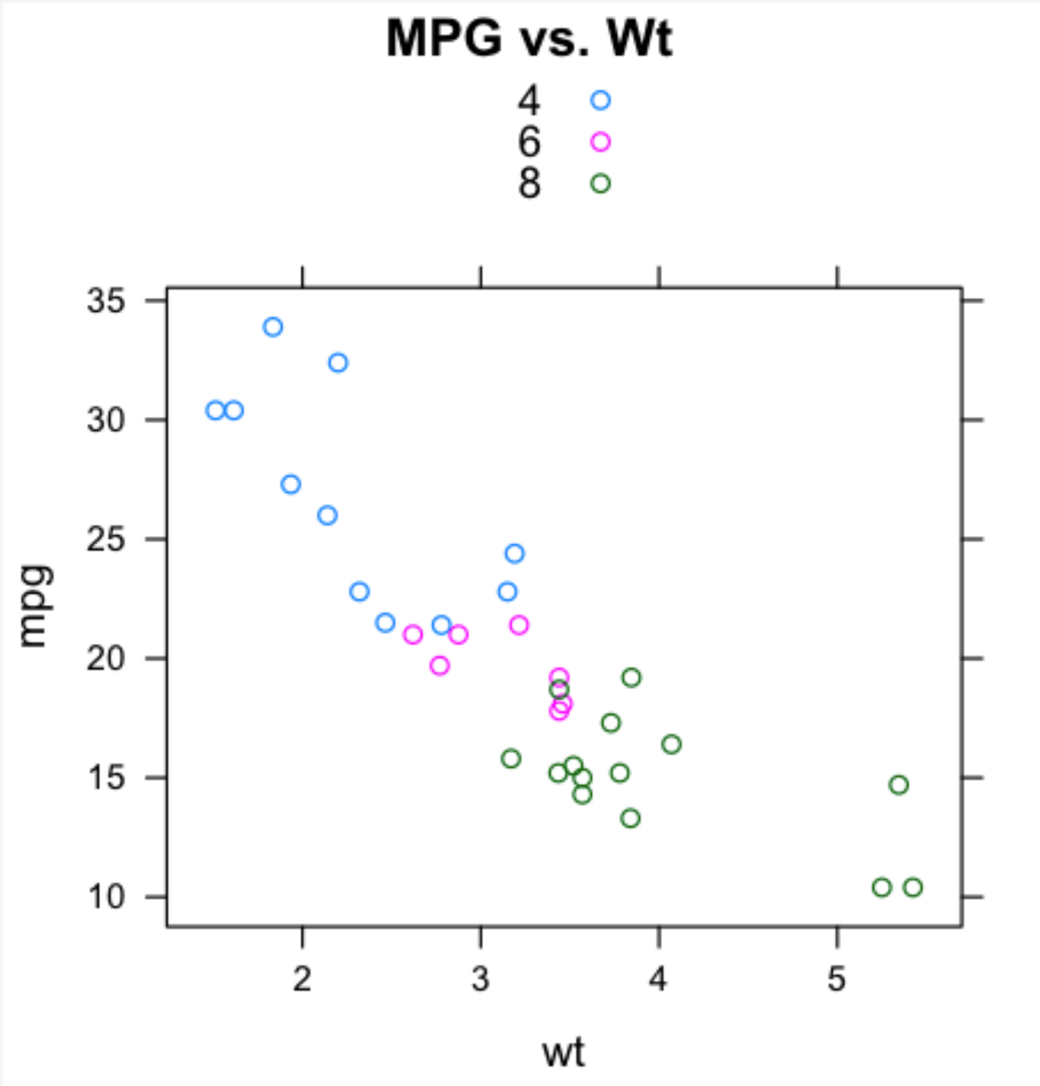
Graphics: lattice: groups

```
xyplot(mpg~wt, data=mtcars, groups=factor(am), type=c("p","g"),
       main="MPG vs. Wt", auto.key=TRUE)
```



Graphics: lattice: groups

```
xyplot(mpg~wt, data=mtcars, groups=cyl, main="MPG vs. Wt", auto.key=TRUE)
```



Graphics: lattice: groups

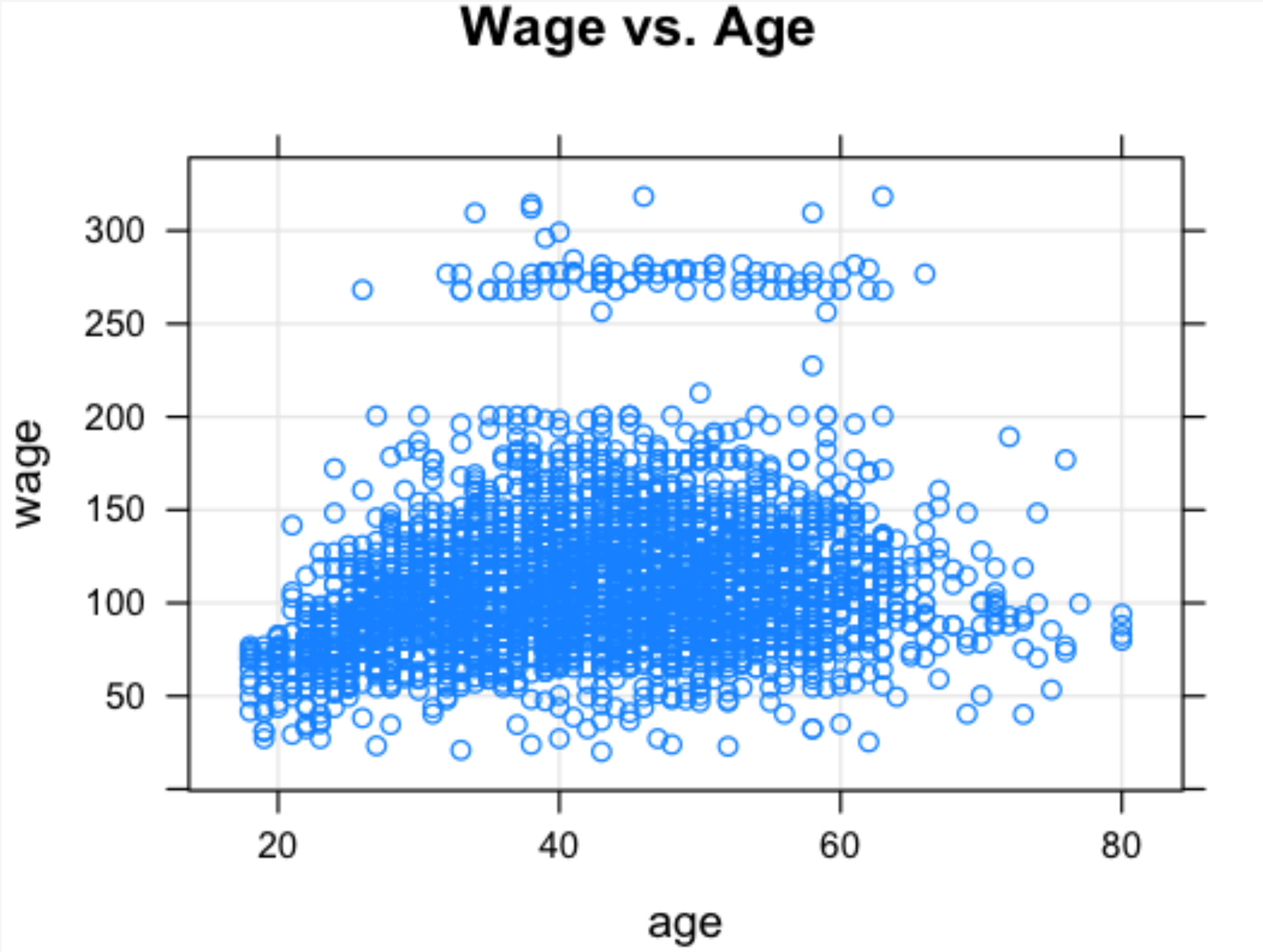
Check this wage data courtesy of the ISLR package. It has wage and other data for a group of 3000 workers in the Mid-Atlantic region.

```
url <- "http://steviep42.bitbucket.org/bios545r/SUPP.DIR/wage.csv"

wage <- read.csv(url)

names(Wage)
 [1] "year"       "age"        "sex"        "maritl"     "race"
 [6] "education"  "region"     "jobclass"   "health"
[10] "health_ins" "logwage"    "wage"
```

Let's look at a plot of Wage vs Data

```
xyplot(wage~age,data=Wage,main="Wage vs. Age",type=c("p","g"))
```

Graphics: lattice: groups



Graphics: lattice: groups

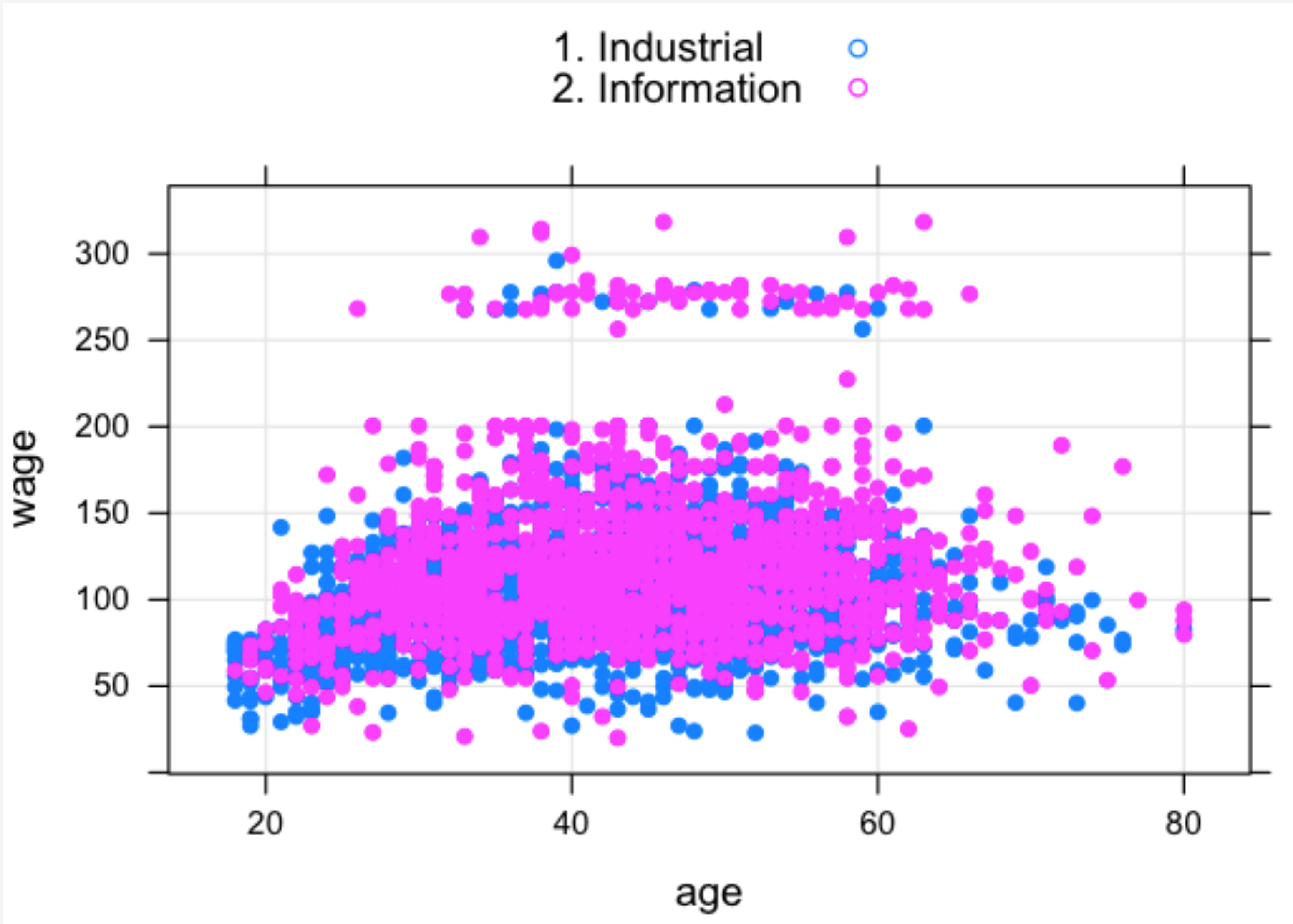
It's not so easy to see what is going on here except maybe that there are some high wage earners that are separate from the larger group.

How might we better understand this ? (Note: Example taken from Leek, Peng, and Caffo) Maybe groups would help ?

```
xyplot(wage~age,data=Wage,groups=jobclass,
       auto.key=TRUE,pch=19,cex=0.7,type=c("p","g"))
```

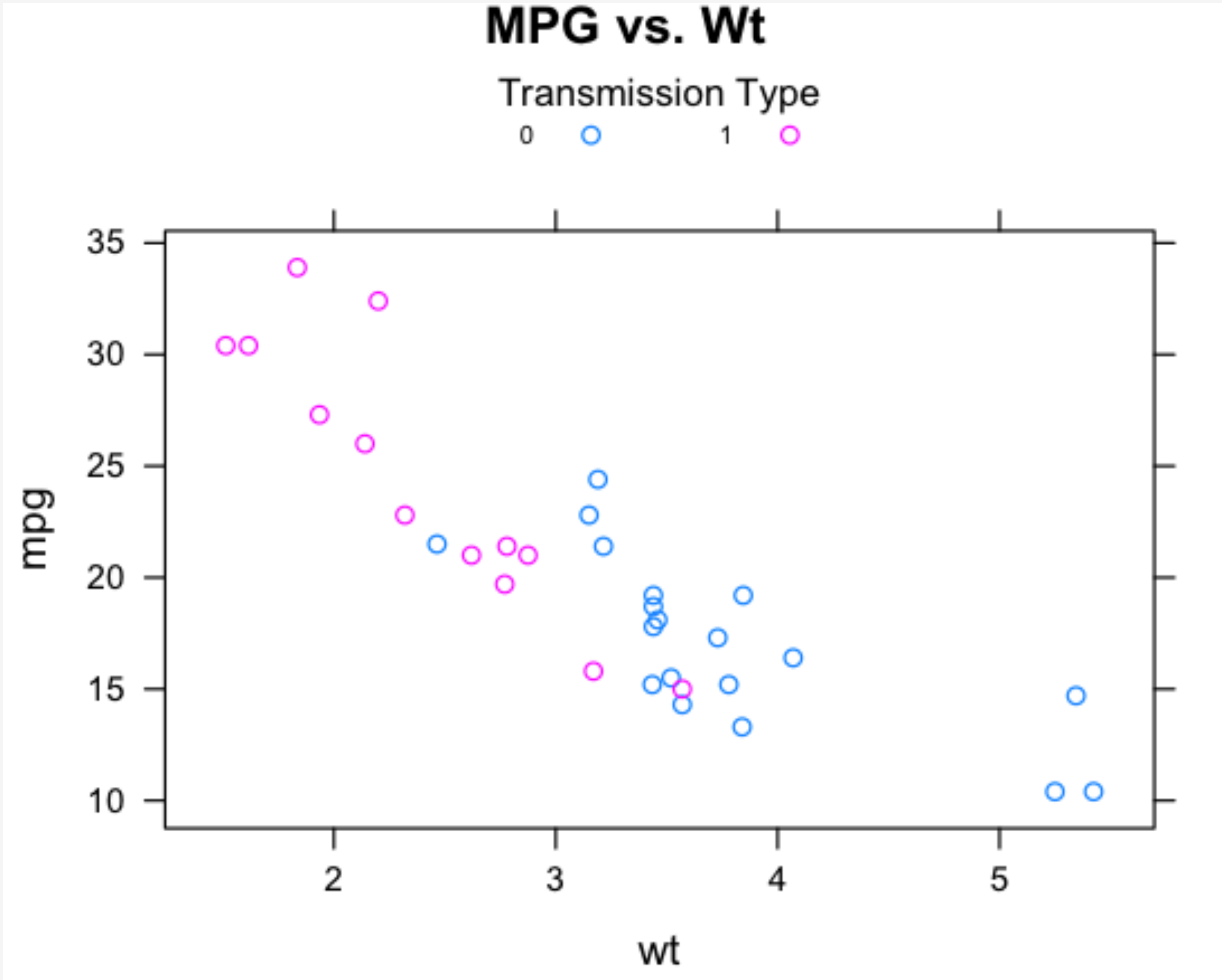
Maybe groups would help ? Yes they would. Let's look at the points grouped by the jobclass variable. If we do this then perhaps the data at the top makes more sense.

Graphics: lattice: groups



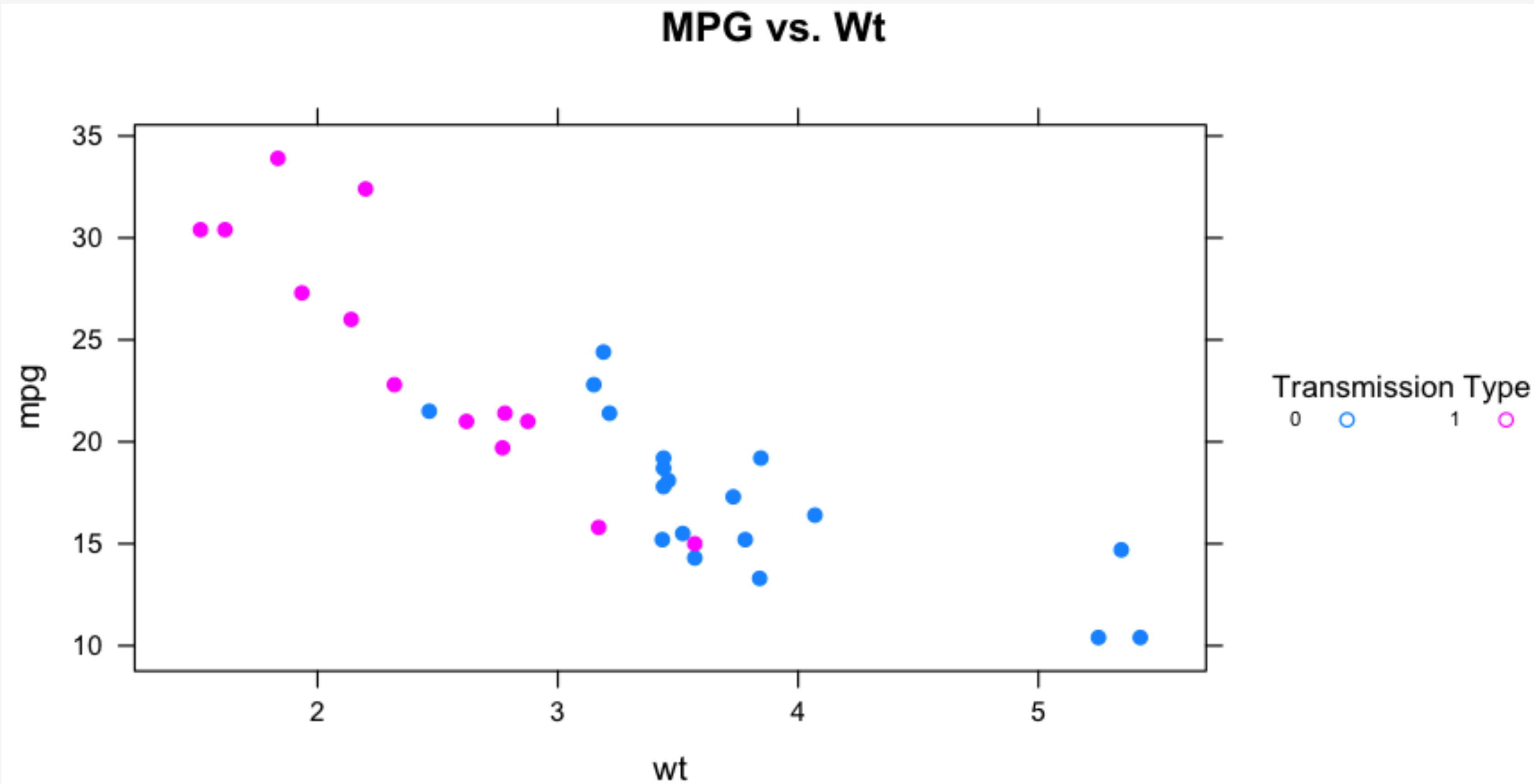
Graphics: lattice: legends

```
xyplot(mpg~wt, data=mtcars, groups=factor(am),
       main="MPG vs. Wt",
       auto.key=list(title="Transmission Type",cex=0.6,columns=2))
```



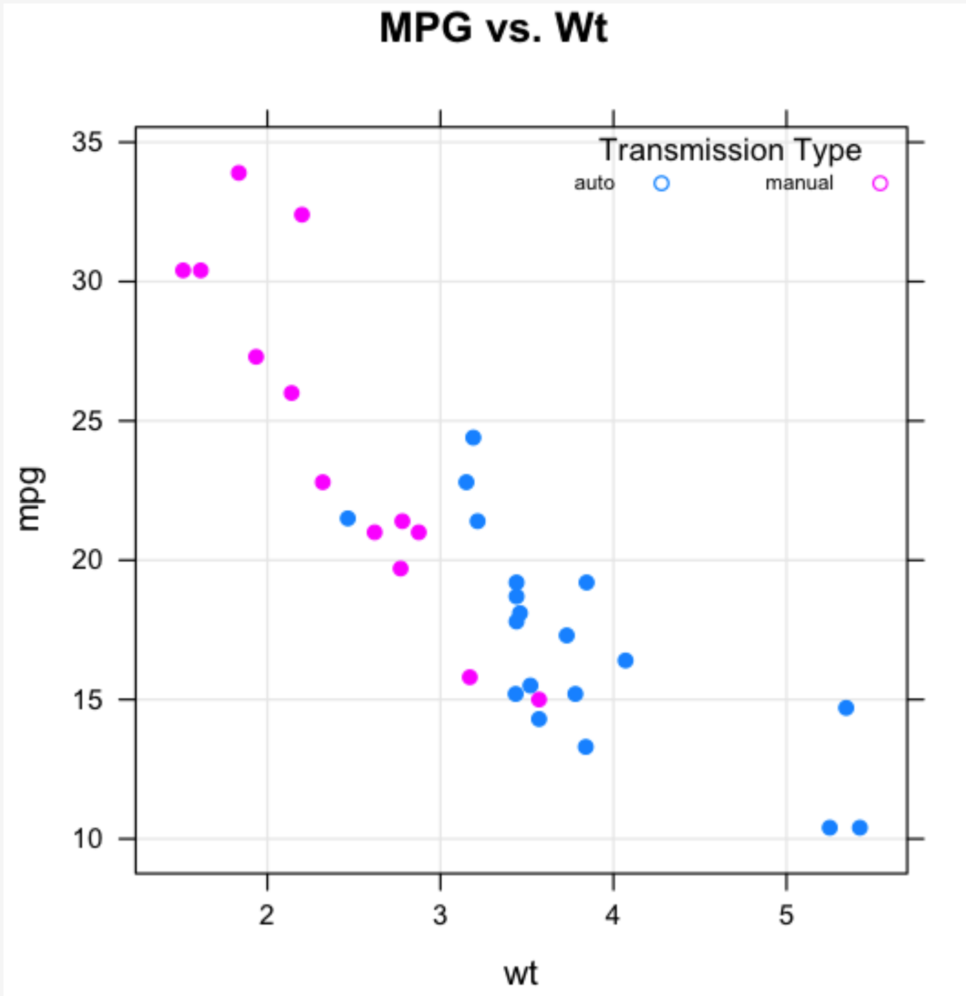
Graphics: lattice: legends

```
xyplot(mpg~wt, data=mtcars, groups=factor(am), main="MPG vs. Wt", pch=19,
       auto.key = list(title="Transmission Type",
                       cex=0.6,columns=2,space="right"))
```



Graphics: lattice: legends

```
xyplot(mpg~wt, data=mtcars, groups=factor(am), main="MPG vs. Wt",
       pch=19, type=c("p","g"),
       auto.key = list(title="Transmission Type", cex=0.6, columns=2,
       corner=c(1,1))
```



Graphics: lattice: legends

Legends can get unwieldy in lattice graphics.

For example, notice that in the previous example the legend plot characters don't match the points that are in the graph.

We can address this two ways:

1) Use a trellis command to set the default pch character

   This is like using the par function with Base graphics to change things
   But you have to remember to change things back !

2) Use the key argument, (instead of auto.key), to create a custom legend

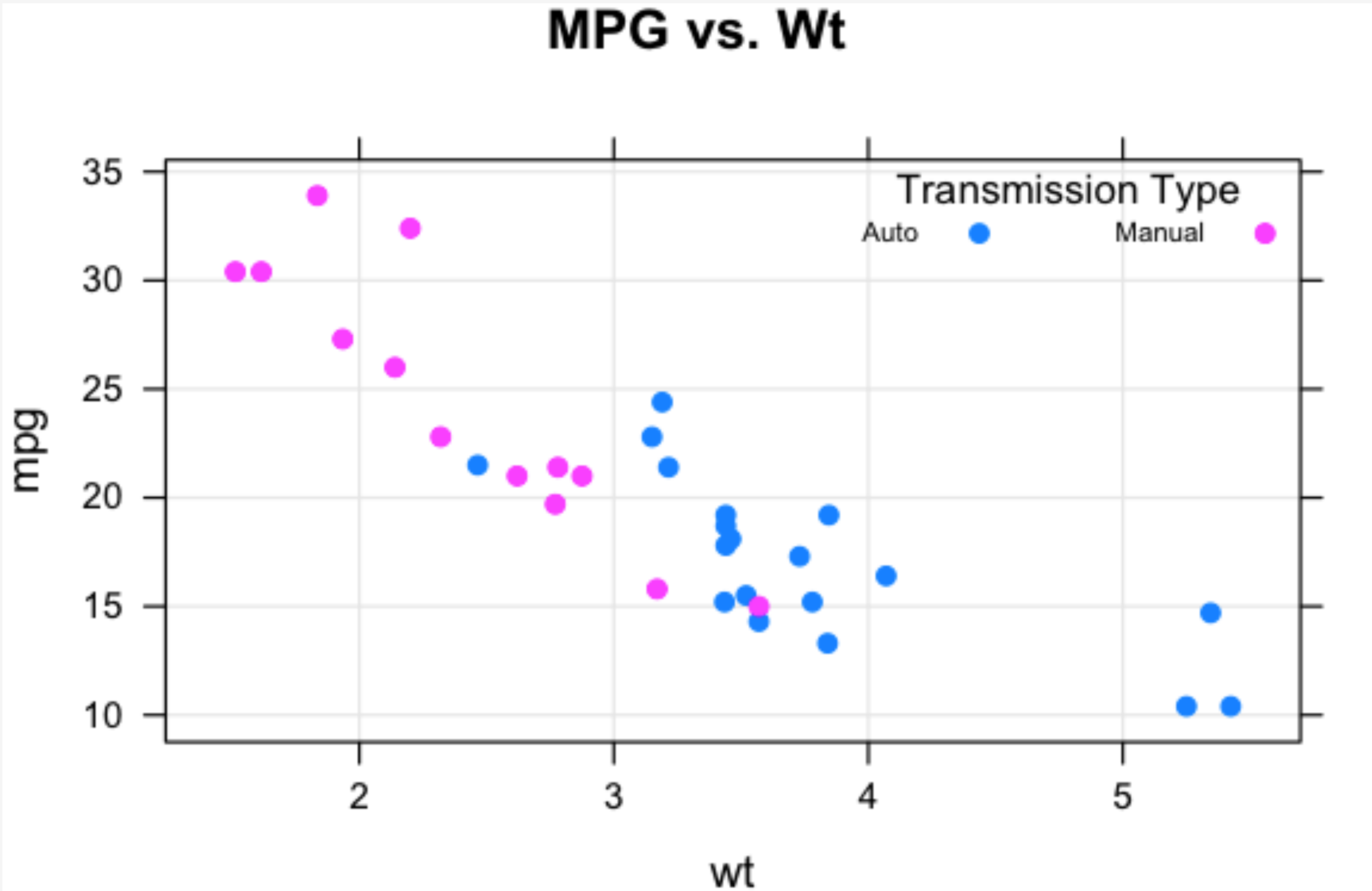
   The key argument lets you specify in great detail how and what you want to appear in the legend but it's hard to find out exactly how to specify it. You have to do some googling to find out.

Graphics: lattice: legends

1) Use a trellis command to set the pch character

```
# First get a copy of the existing trellis meta settings

old.pars <- trellis.par.get()

# Next set the default plot character

trellis.par.set(superpose.symbol=list(pch = 19))

mtcars$am <- factor(mtcars$am,labels=c("Auto","Manual"))

xyplot(mpg~wt, data=mtcars, groups=factor(am),
       main="MPG vs. Wt",
       pch=19, type=c("p","g"),
       auto.key = list(title="Transmission Type", cex=0.6,
                       columns=2, corner=c(1,1)))

# When you are done then set things back to the default

trellis.par.set(old.pars)
```

Graphics: lattice: legends

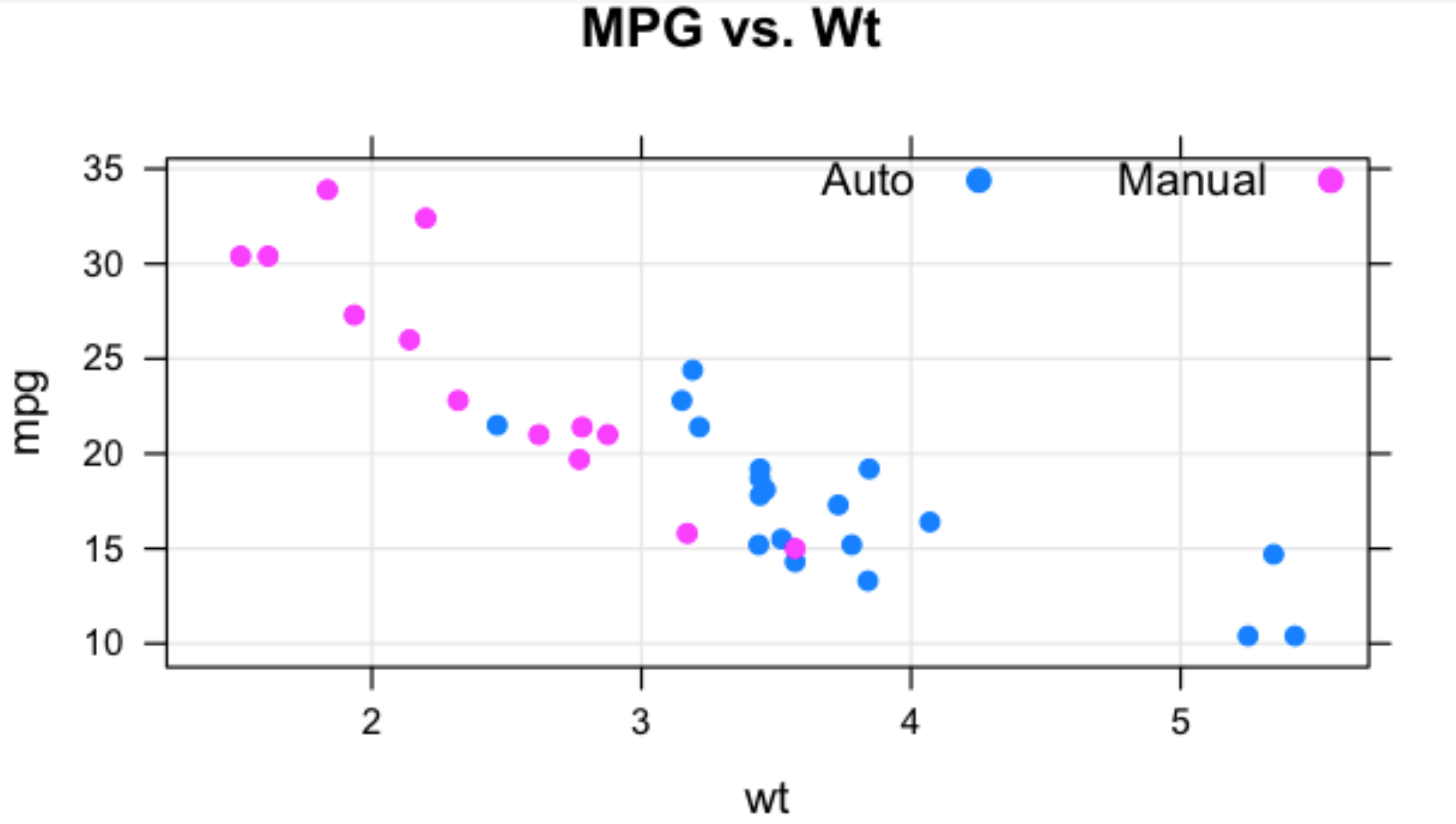


Graphics: lattice: legends

2) Use the key argument, (instead of auto.key), to create a custom legend

```
key <- list(corner=c(1,1),columns=2,
            text=list(levels(mtcars$am)),
            points=list(pch=19,
            col=col[1:nlevels(mtcars$am)]))

mtcars$am <- factor(mtcars$am,labels=c("Auto","Manual"))

xyplot(mpg~wt, data=mtcars, groups=factor(am),
       main="MPG vs. Wt", pch=19, type=c("p","g"),
       key = key)
```

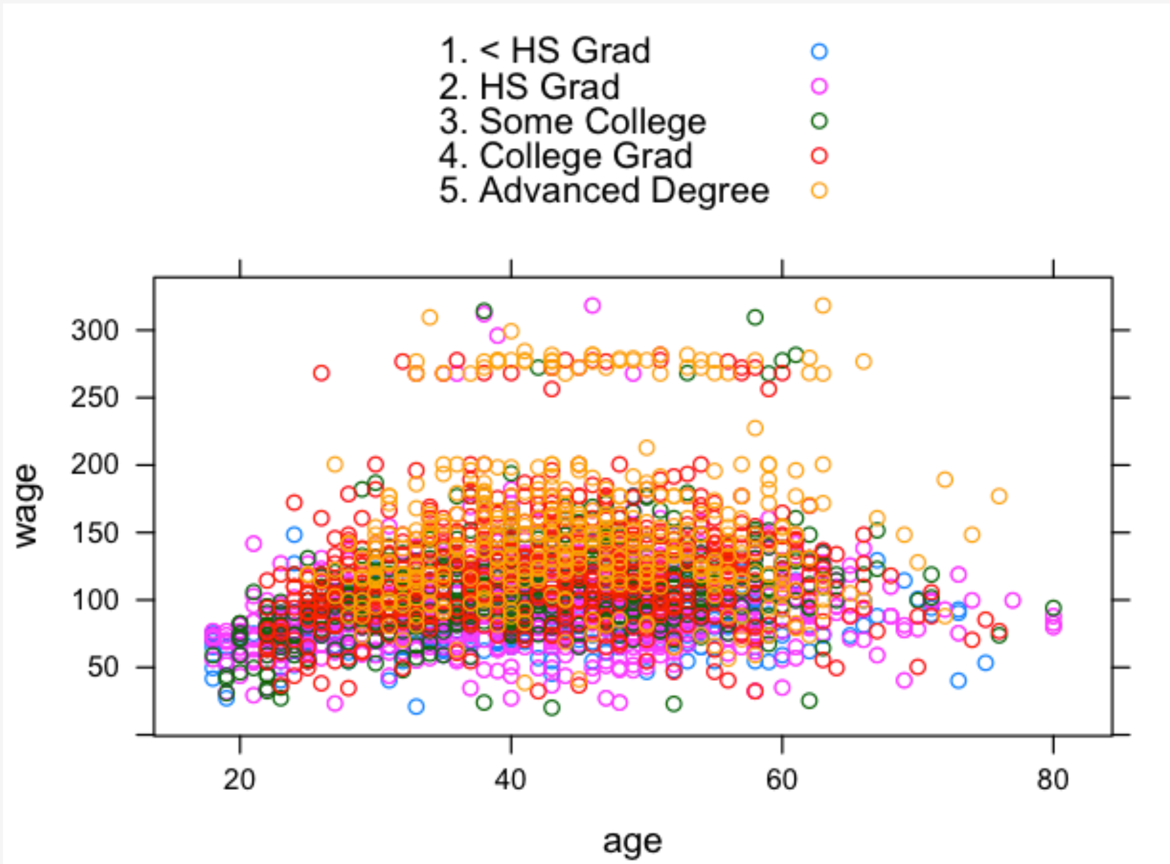
Graphics: lattice: legends



Graphics: lattice: legends

So let's look back at the wage vs. age example except we'll look at education as a grouping variable

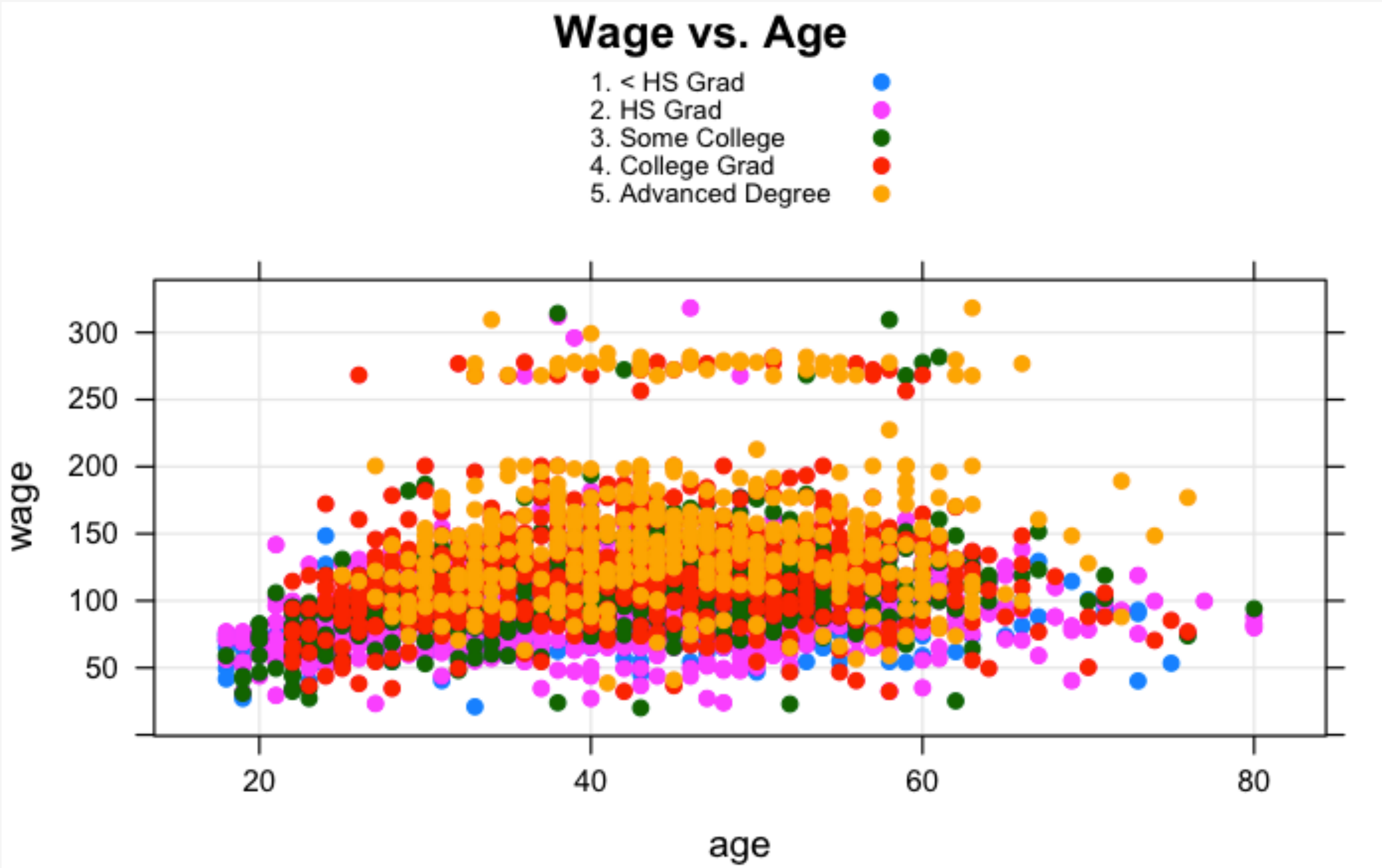
```
url <- "http://steviep42.bitbucket.org/bios545r/SUPP.DIR/wage.csv"
wage <- read.csv(url)
xyplot(wage~age,data=Wage,groups=education,auto.key=TRUE)
```



Graphics: lattice: legends

```
old.pars <- trellis.par.get()

trellis.par.set(superpose.symbol=list(pch = 19))


xyplot(wage~age,data=Wage,groups=education,
       main="Wage vs. Age",type=c("p","g"),
       pch=19, auto.key=list(cex=0.7))

# Optionally put things back how they were

trellis.par.set(old.pars)
```

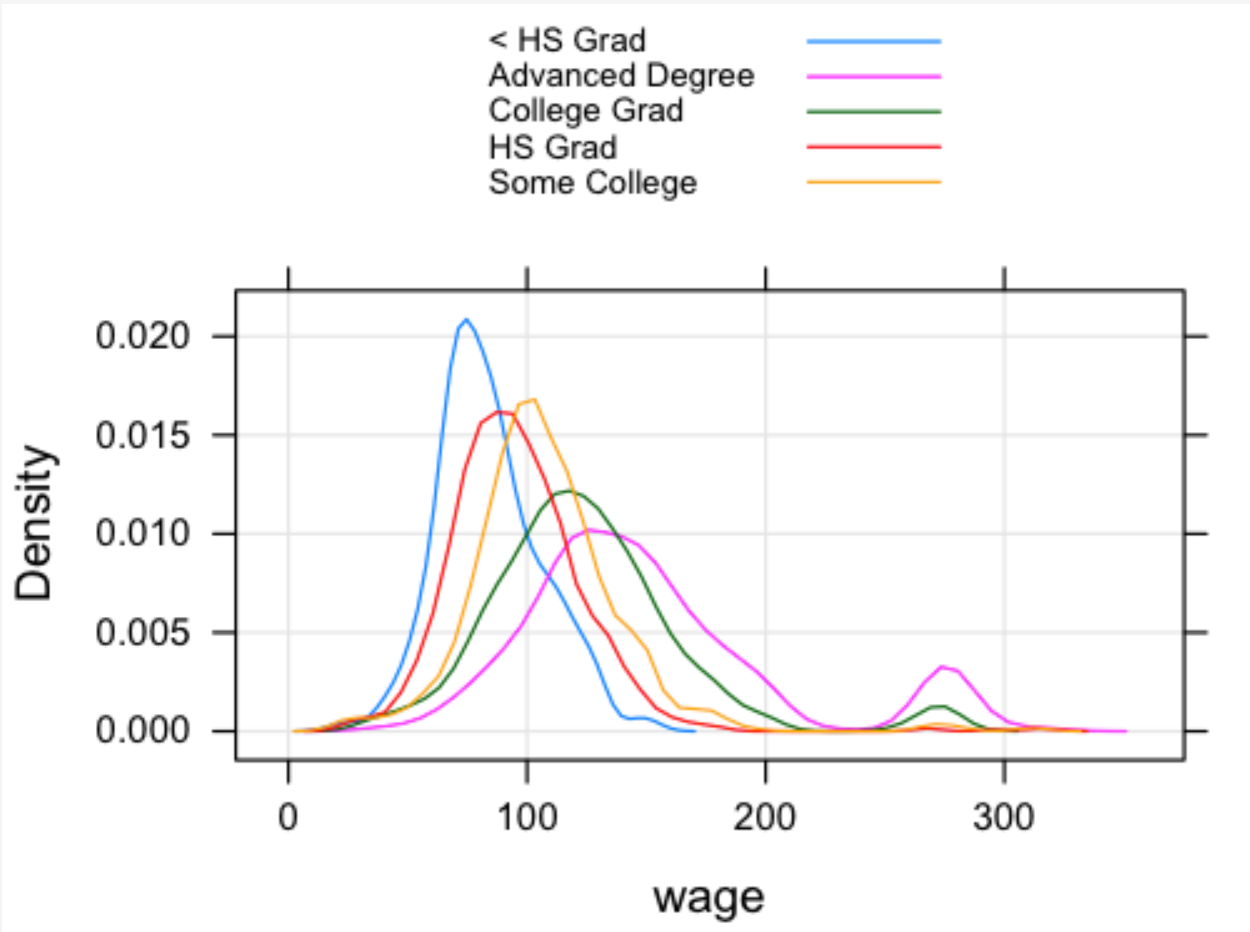
Graphics: lattice: legends



Graphics: lattice: legends

Might be better to look at this as overlaid densities:

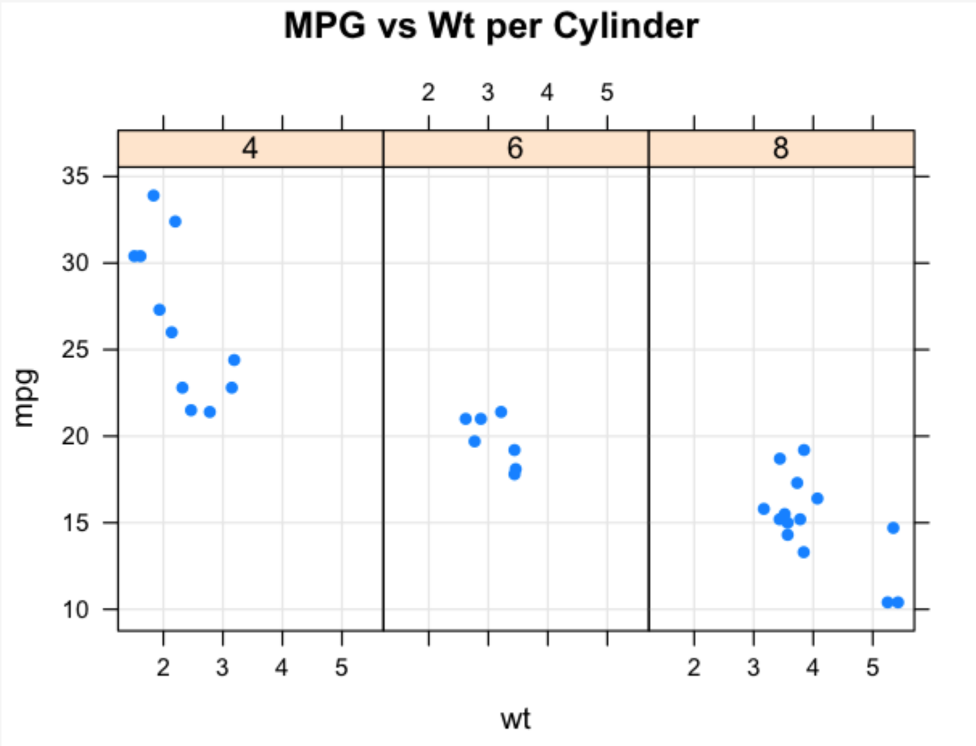
```
labs <- gsub("\\d+.","",Wage$education,perl=T)   # Get rid of the numbers
densityplot(~wage,groups=labs,data=Wage,auto.key=list(cex=0.7),type=c("g"))
```



Graphics: lattice: grouping and conditions

```
xyplot(mpg ~ wt | factor(cyl), data=mtcars,
        pch=16,layout=c(3,1), main="MPG vs Wt per Cylinder",
        type=c("p","g"))
```

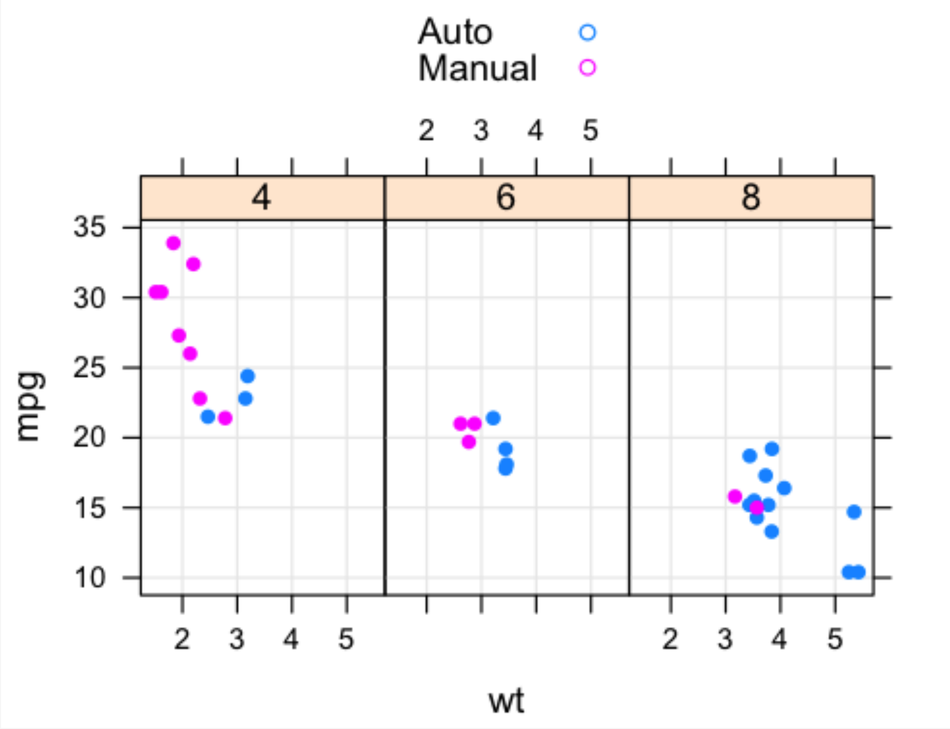
In this case we have a conditioning variable, which in this example is the variable cyl . So we have three panels:



Graphics: lattice: grouping and conditions

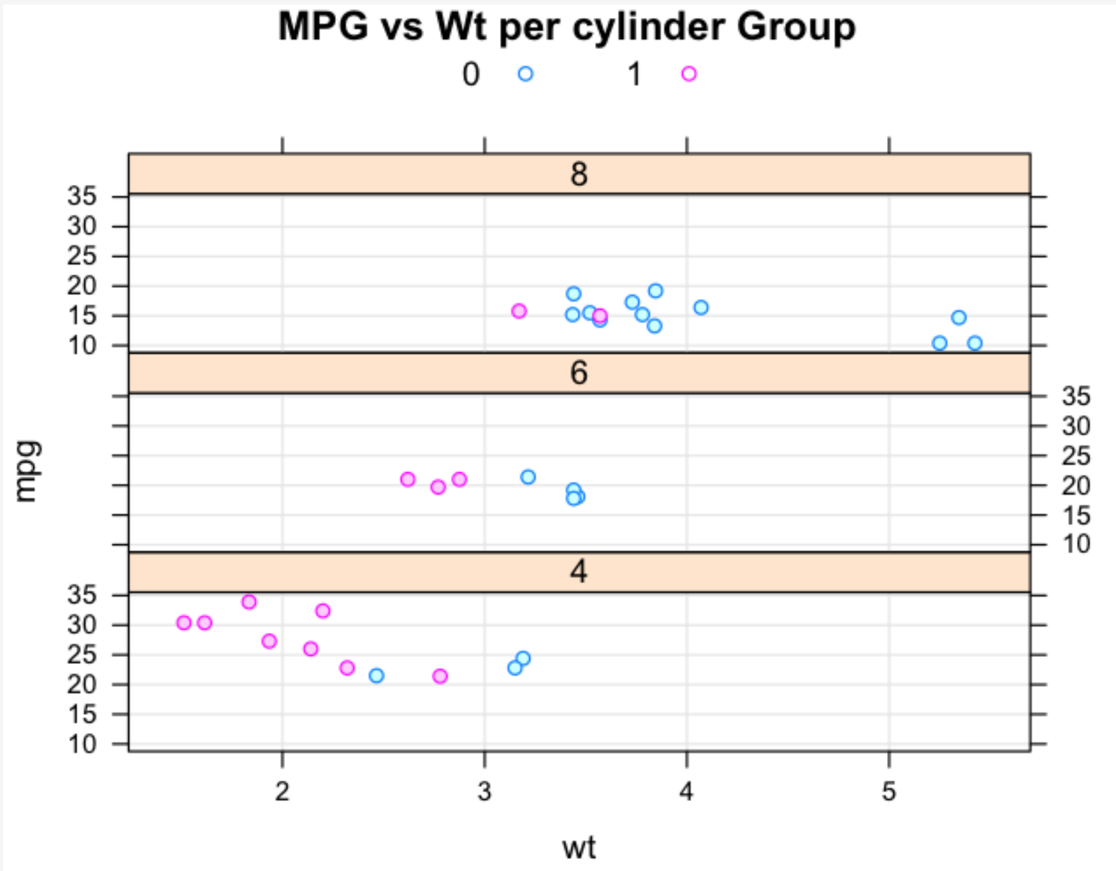
```
xyplot(mpg ~ wt | factor(cyl), data=mtcars,
       pch=16,layout=c(3,1),
       groups = factor(am,labels=c("Auto","Manual")),
       type=c("p","g"),auto.key = TRUE)
```

In this case we have a grouping variable, which in this example is the variable am . The grouping variable segregates data into subgroups within each panel via color.



Graphics: lattice: grouping and conditions

```
xyplot(mpg ~ wt | factor(cyl), data=mtcars,
       main = "MPG vs Wt per cylinder Group",
       groups = factor(am), pch=21, type=c("p","g"),
       layout = c(1,3), auto.key=list(columns=2))
```



Graphics

Some useful arguments that you will see again and again:

data = (this specifies the data frame of interest)

xlab = and **ylab =** (this indicates the X/Y axis labels

aspect = (sets the aspect ration of the plot – not so common but useful)

xlim = and **ylim =** (sets the numerical limits of the X and Y vals)

main = (sets the title for the plot)

cex = (changes the size of an element like text or the plotting symbol

http://polisci.msu.edu/jacoby/icpsr/graphics/lattice/Lattice,%20ICPSR%202012%20Outline,%20Ver%201.pdf

Graphics

Some useful arguments that you will see again and again:

The **auto.key = T** argument gives you an automatic legend.

The **scales =** argument uses a "mini-language" to modify the characteristics of the display axes such as ticks, and tick labels. Its basically a "list" (in the R sense)

The **group =** argument lets you pass a categorical variable that can be used to differentiate subgroups in a single display.

`http://polisci.msu.edu/jacoby/icpsr/graphics/lattice/Lattice,%20ICPSR%202012%20Outline,%20Ver%201.pdf`

Summary

Strengths of Base Graphics:

- Oldest and Most Well Known
- Has Both High Level and Low Level Functions
- Can easily assemble a plot in stages
- Primitive functions (e.g. points, abline, lines) are simple to use

Weaknesses of Base Graphics:

- Lots of independent functions to keep up with
- Each high level plot command has its own specific arguments
- You have to pick colors and plot characters using basic programming tricks

Summary

Strengths of Lattice Graphics

- Developed according to a well-thought out philosophy
- Can generate colors, legends, and axes as part of the high level commands
- Can use "condition" variables
- Can group variables

Weaknesses of Lattice Graphics:

- Commands can get long and involved
- Commands can have many arguments

Graphics: lattice: panel functions

Every lattice function has a default "panel" function. It is usually the name of the function prefixed by **panel.** As an example here is the basic xyplot command:

```
xyplot (y ~ x, data= dataset)
```

This is actually equivalent to:

```
xyplot (y ~ x, data= dataset, panel = panel.xyplot)
```

Yea, its a bit weird but if you have to stack up a bunch of options and arguments it becomes easier. You'll see eventually.

So a call like this:

```
xyplot(y ~ x, data=dataset, col="black")
```

will "silently" pass the "col='black' argument to panel.xyplot.

`http://polisci.msu.edu/jacoby/icpsr/graphics/lattice/Lattice,%20ICPSR%202012%20Outline,%20Ver%201.pdf`

Graphics: lattice: panel functions

So a call like this:

```
xyplot(y ~ x, data=dataset, col="black")
```

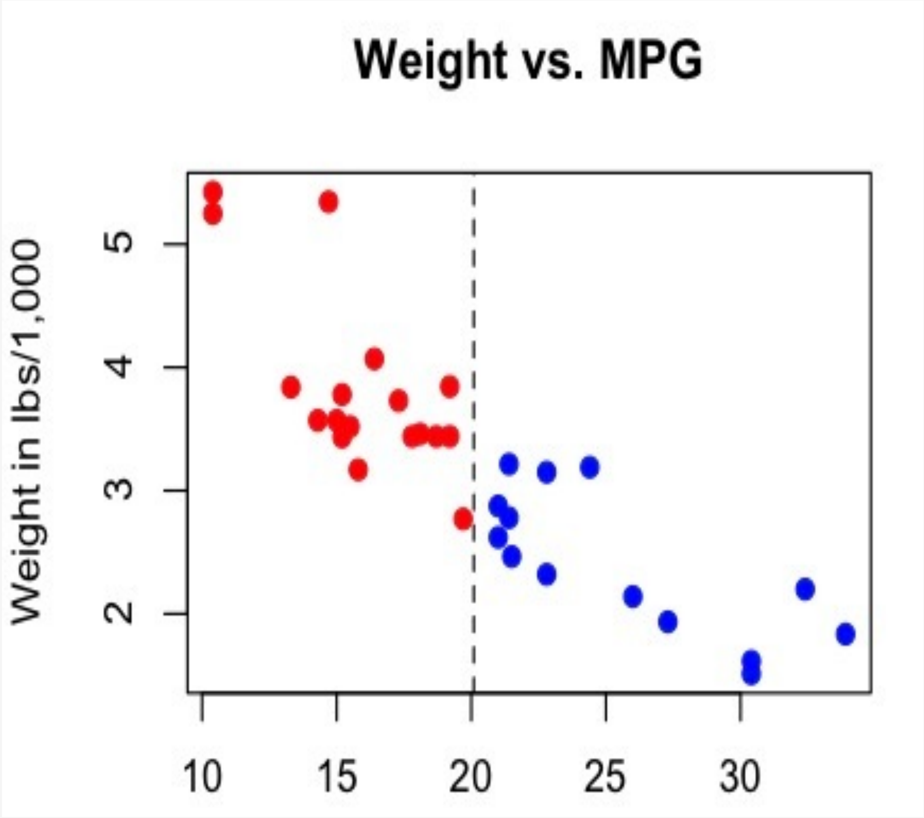
will "silently" pass the "col='black' argument to panel.xyplot. Its basically the equivalent of:

```
xyplot(y ~ x, data = dataset,
   panel = function (x, y) {
       panel.xyplot(x, y, col = "black") }
   )
```

http://polisci.msu.edu/jacoby/icpsr/graphics/lattice/Lattice,%20ICPSR%202012%20Outline,%20Ver%201.pdf

Graphics: lattice: panel functions

So remember that we did this in BASE graphics to get a plot with points less than the mean MPG to be one color and the points greater than the mean to be another.



Graphics: lattice: panel functions

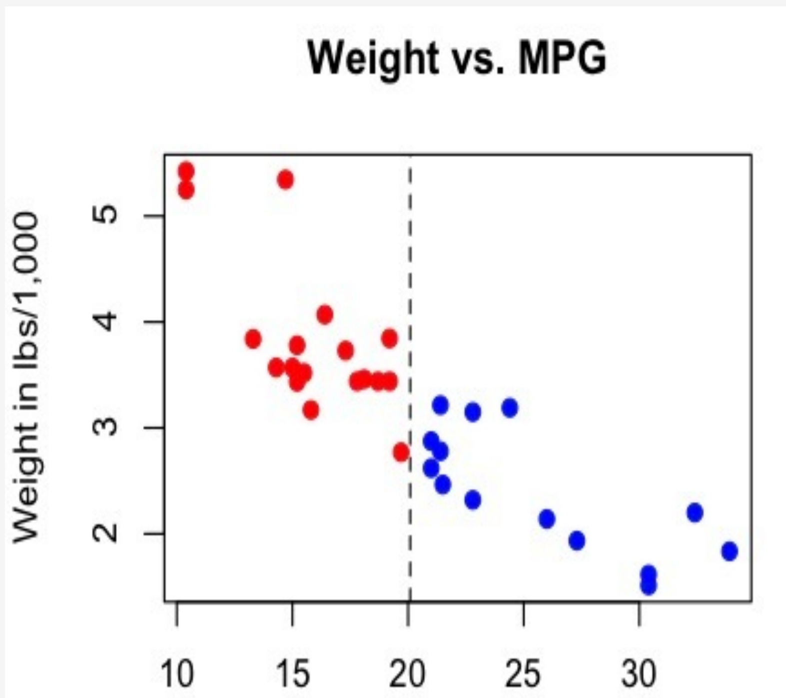
So remember that we did this in BASE graphics to get a plot with points less than the mean MPG to be one color and the points greater than the mean to be another.

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

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


points(below.mean$wt, below.mean$mpg,col="blue",bg="blue",
         pch=21)

points(above.mean$wt, above.mean$mpg, col="red",bg="red",
         pch=21)

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

Graphics: lattice: panel functions

We simplified this to:

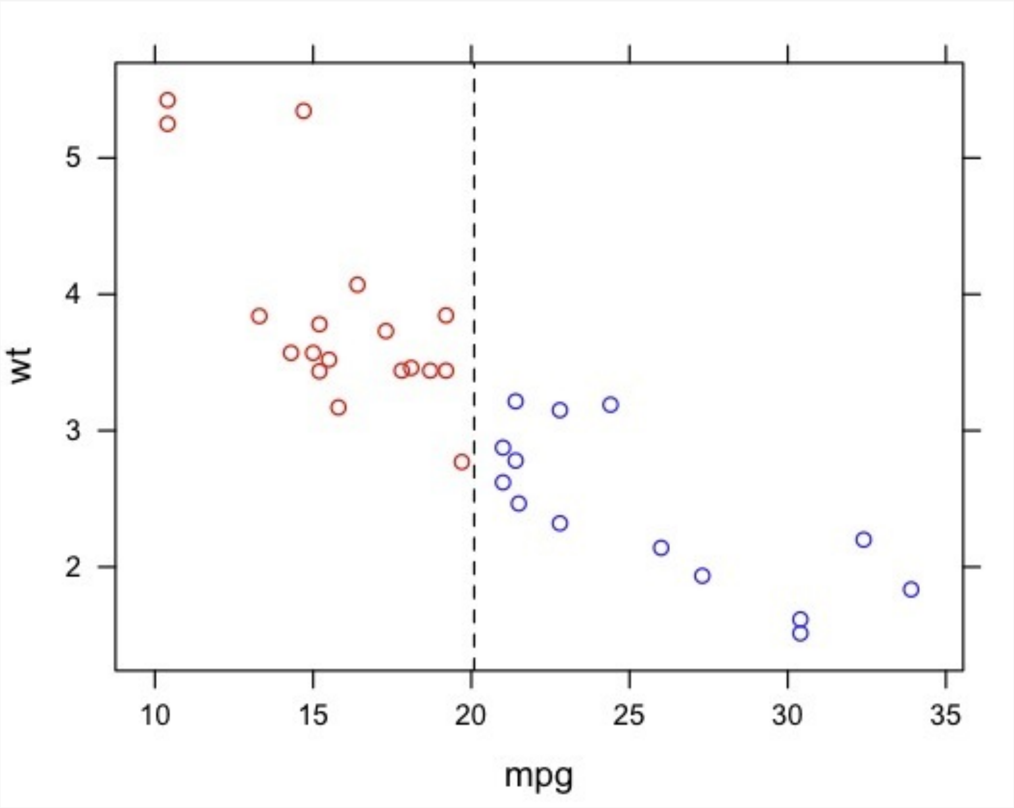
```
colvec <- ifelse(mtcars$mpg > mean(mtcars$mpg),"red","blue")

plot(mtcars$wt, mtcars$mpg, main="Weight vs. MPG",
     ylab="Weight in lbs / 1,000",col=colvec, pch=19)

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



Graphics: lattice: panel functions

Here is one way to do it with lattice graphics:

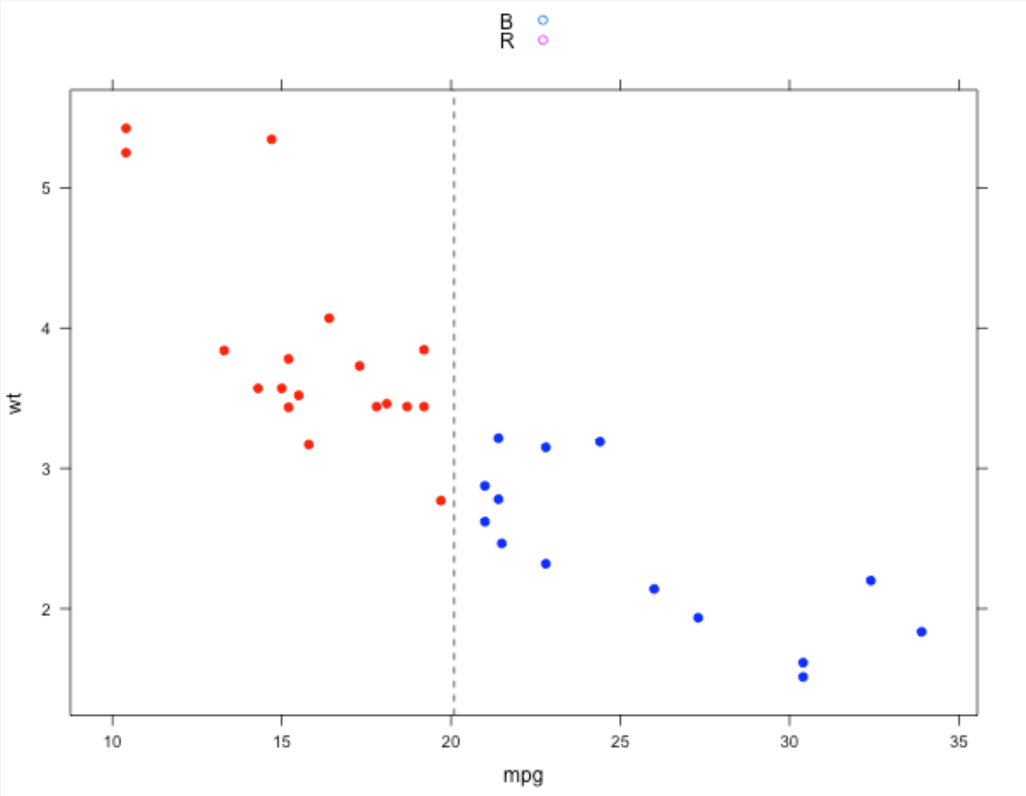
```
xyplot(mpg ~ wt, mtcars, pch=19,
   panel = function(x,y) {
     panel.xyplot(x[x <= mean(x)], y[x <= mean(x)], col="red")
     panel.xyplot(x[x  > mean(x)], y[x  > mean(x)], col="blue")
     panel.abline(v=mean(x),lty="dashed")
   }
)
```



Graphics: lattice: panel functions

Or alternatively:

```
my.mean <- ifelse(mtcars$mpg > mean(mtcars$mpg),"B","R")

xyplot(wt ~ mpg, mtcars, groups = my.mean, col=c("blue","red"), pch=19,
       auto.key=T,
          panel = function(...) {
           panel.abline(v=mean(mtcars$mpg), lty="dashed")
           panel.xyplot(...)
          }
)
```



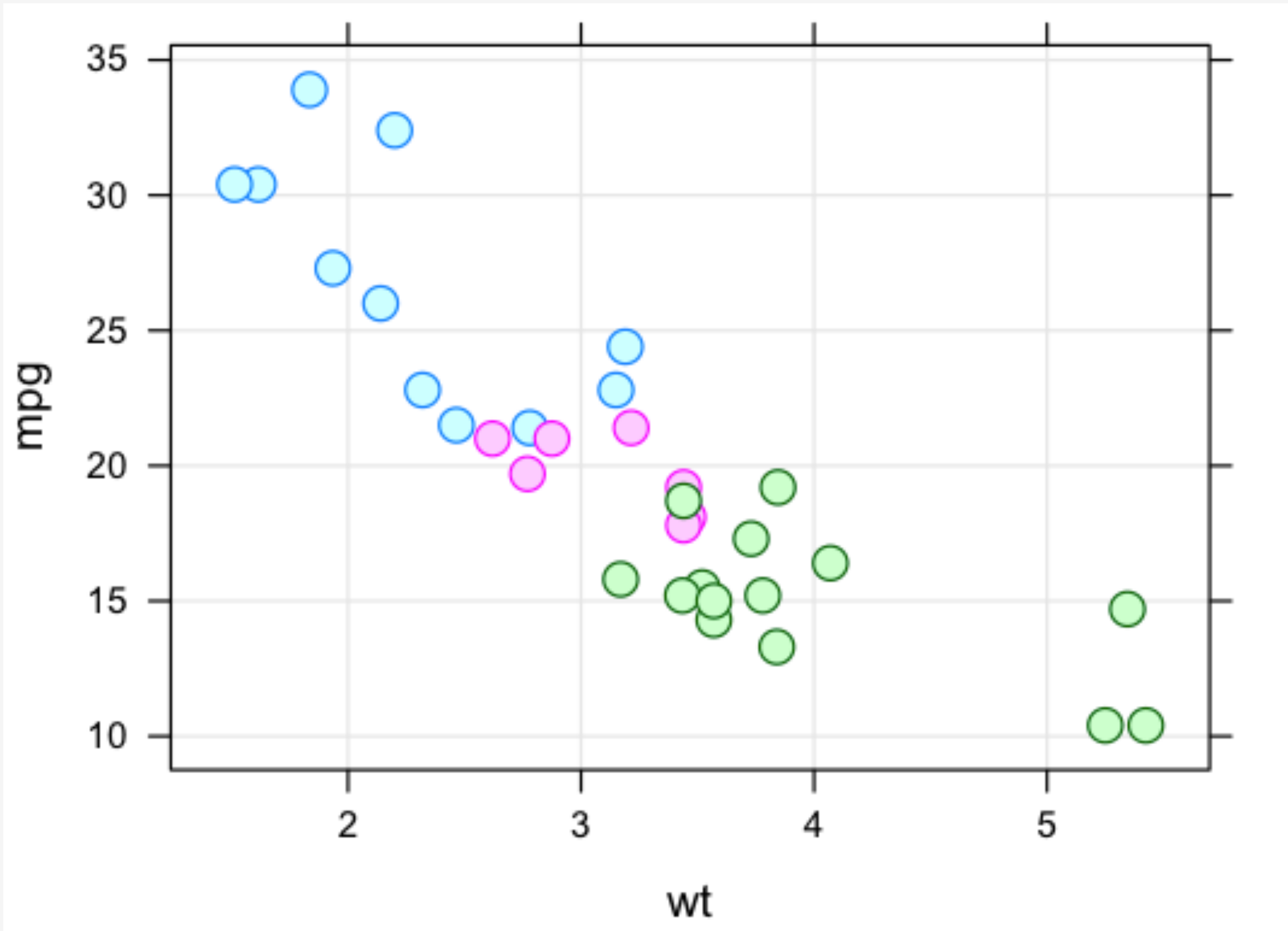
Graphics: lattice: panel functions

So these two commands are basically the same:

```
xyplot(mpg~wt, data=mtcars, groups=factor(cyl),
    panel = function(x,y,...) {
      panel.xyplot(x,y, cex=1.5, pch=21,...)
      panel.grid()
    }
)

xyplot(mpg~wt, data=mtcars, groups=factor(cyl),
       cex=1.5, pch=21, type=c("p","g"))
```

Graphics: lattice: panel functions

So the two commands are basically the same:

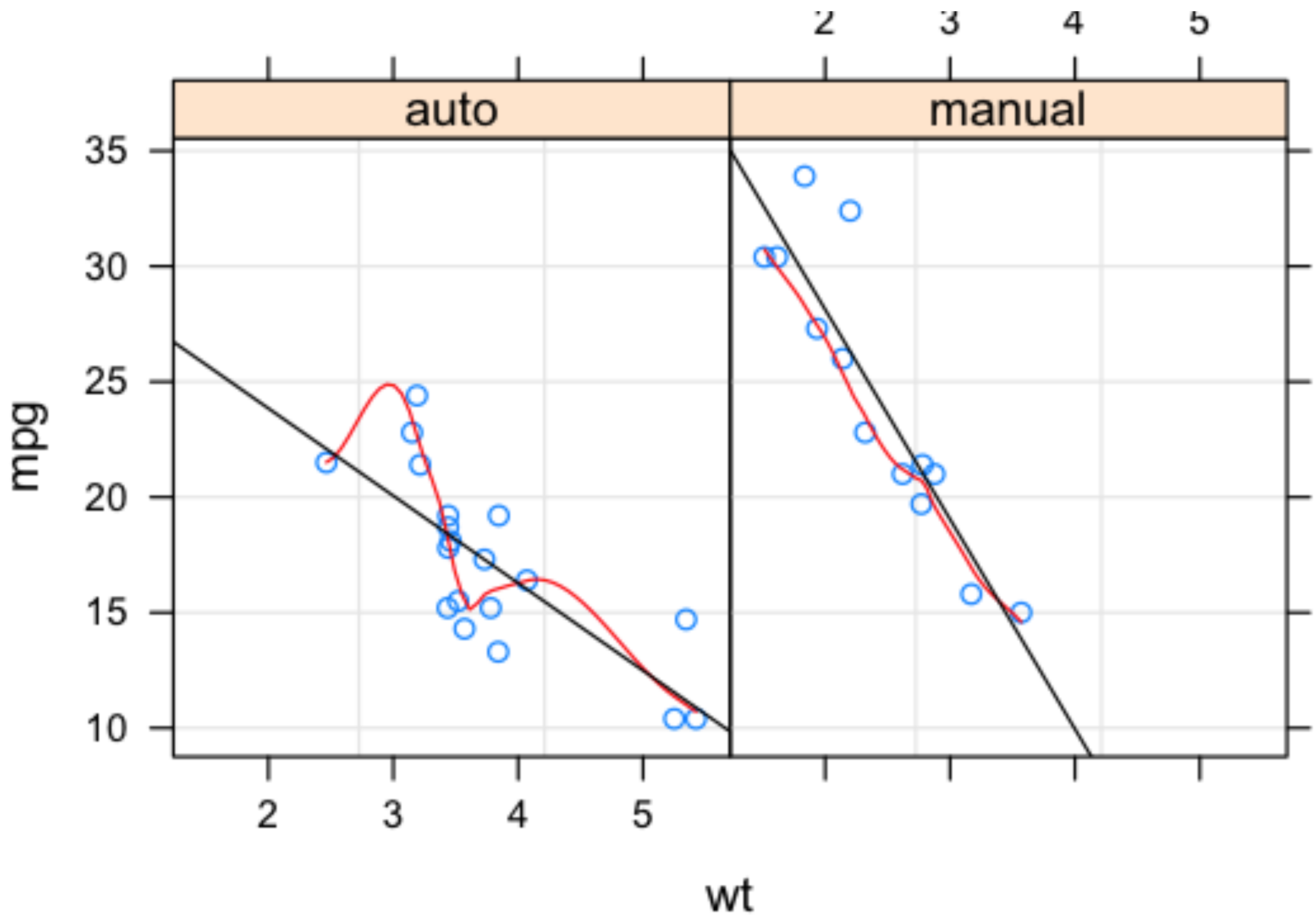


Graphics: lattice: panel functions

The default panel function for the xyplot() function is panel.xyplot(). This is a "busy" example but it drives home the point that you can do a lot of customization within the panel function. You don't always HAVE to but its a good option to have.

```
xyplot(mpg ~ wt | factor(am,labels=c("auto","manual")), data=mtcars,
auto.key=TRUE,
          panel = function(x, y) {
            panel.grid(h = -1, v = 2)
            panel.xyplot(x, y)
            panel.loess(x, y, span=0.5, col='red')
            panel.lmline(x, y)
          }
        )
```

Graphics: lattice: xyplot



Graphics: ggplot2

The ggplot2 package is unique in that we can combine attributes of lattice and Base.

That is we can use high level commands to draw a pretty complete chart with a single command.

But we can also assemble a plot in layers as we could with Base graphics, which means that ggplot2 routines can be called from a program that you write to assemble a plot in stage.

Graphics: ggplot2

It is different from the existing packages because it has a very deep underlying grammar based on the "Grammar of Graphics" (Wilkinson 2005). ggplot2 has a set of core principals that are supposed to be easy to learn.

It is designed to work in a layered fashion, which permits you to build your own custom plots without having to "hack" the existing plots in the package (like you have to do in BASE and lattice).

If you don't want to dive right in then you can use the "qplot" command which is like "training wheels" for the grammar.

Graphics: ggplot2

The parts of a ggplot consist of:

1) the actual **data** that get mapped to **aesthetics**

2) the **geometry** that represent the data (e.g. points, lines, etc)

3) any **statistics** that you want to be displayed

4) **scales** that might represent the size of objects

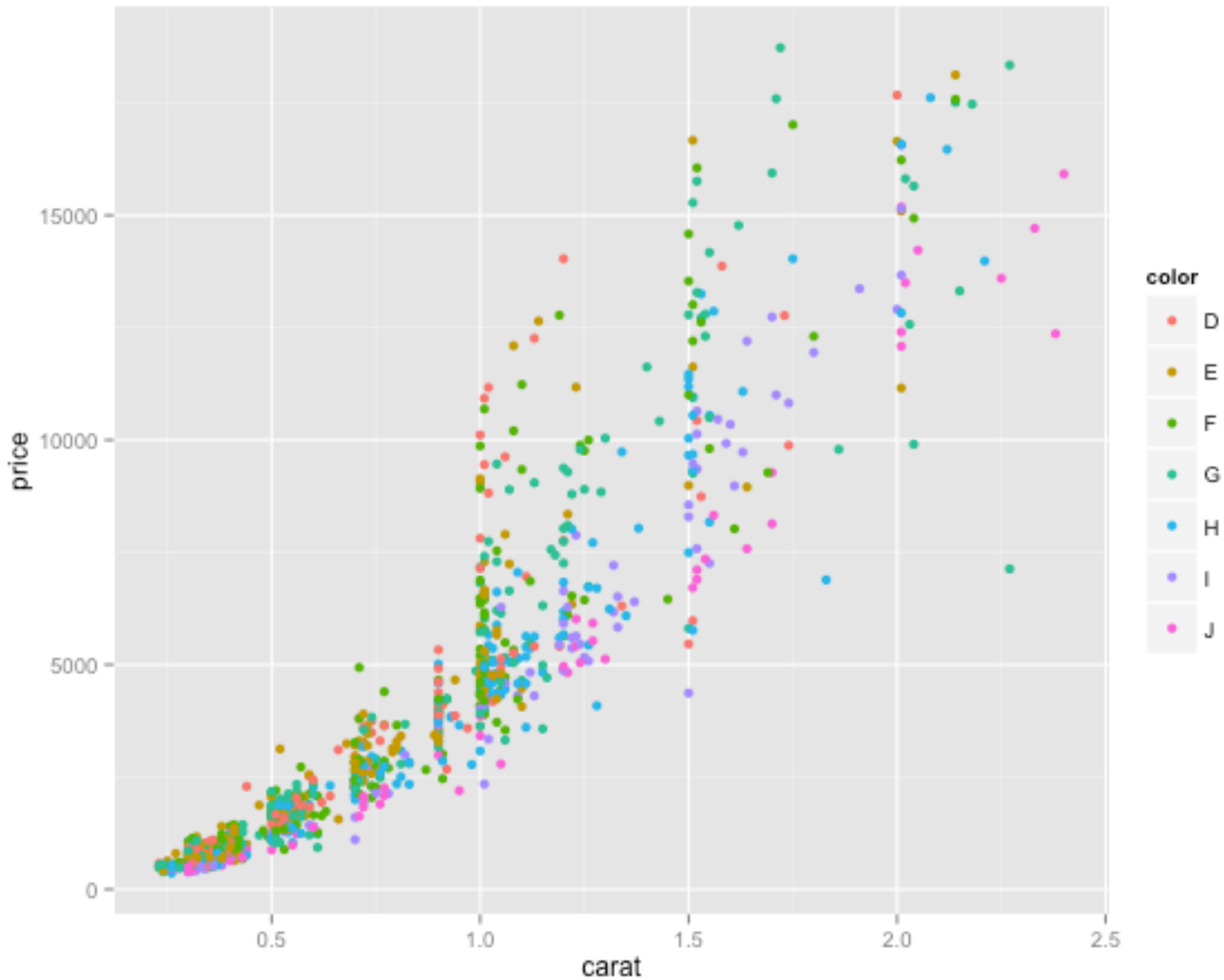
5) **facteting** that allow you to display multiple panels (like lattice graphics)

6) **coordinates** of a graph (usually cartesian)

The simplest way to get started is to use the qplot function

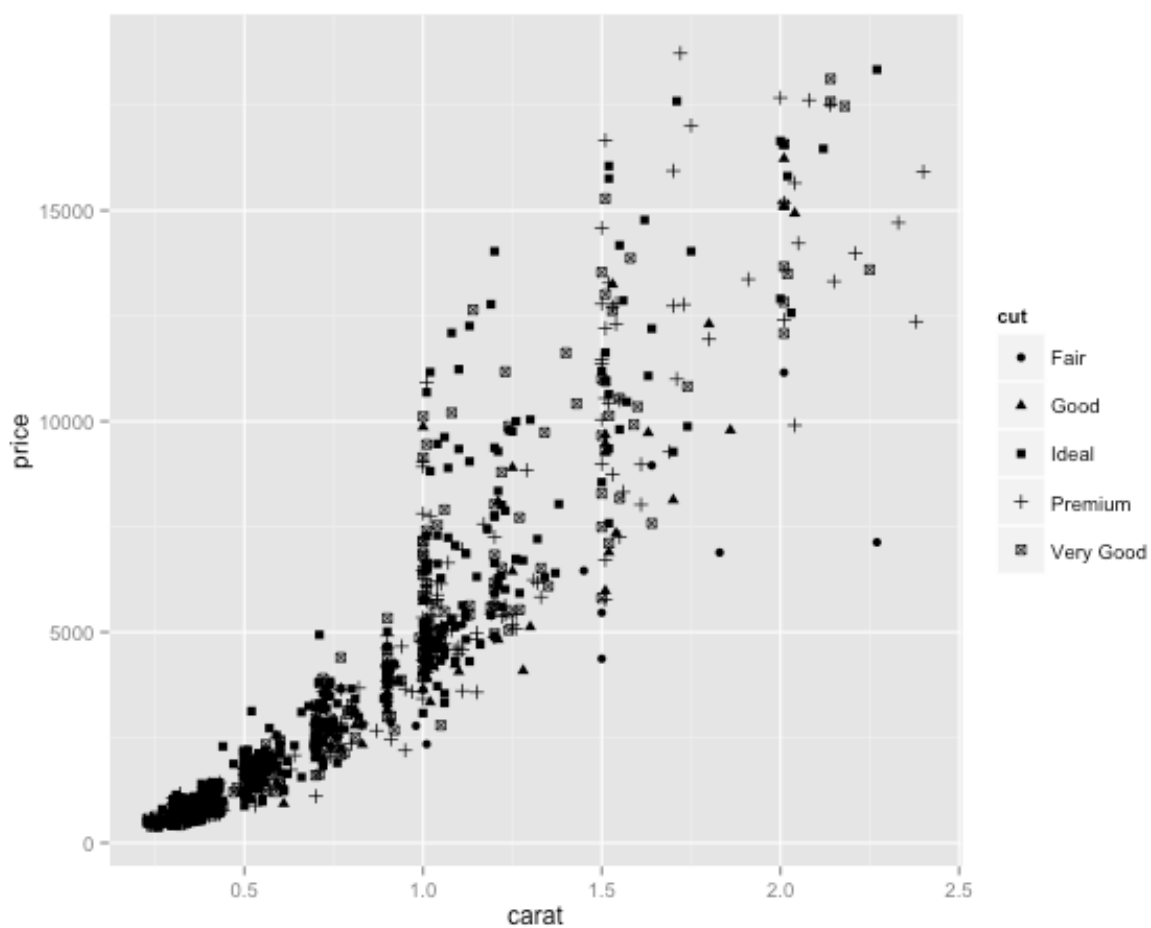
Graphics: ggplot2

```
url <- "http://steviep42.bitbucket.org/bios545r/DATA.DIR/my.diamonds.csv"

diamonds <- read.csv(url)

qplot(carat, price, data = diamonds, color = color)
```



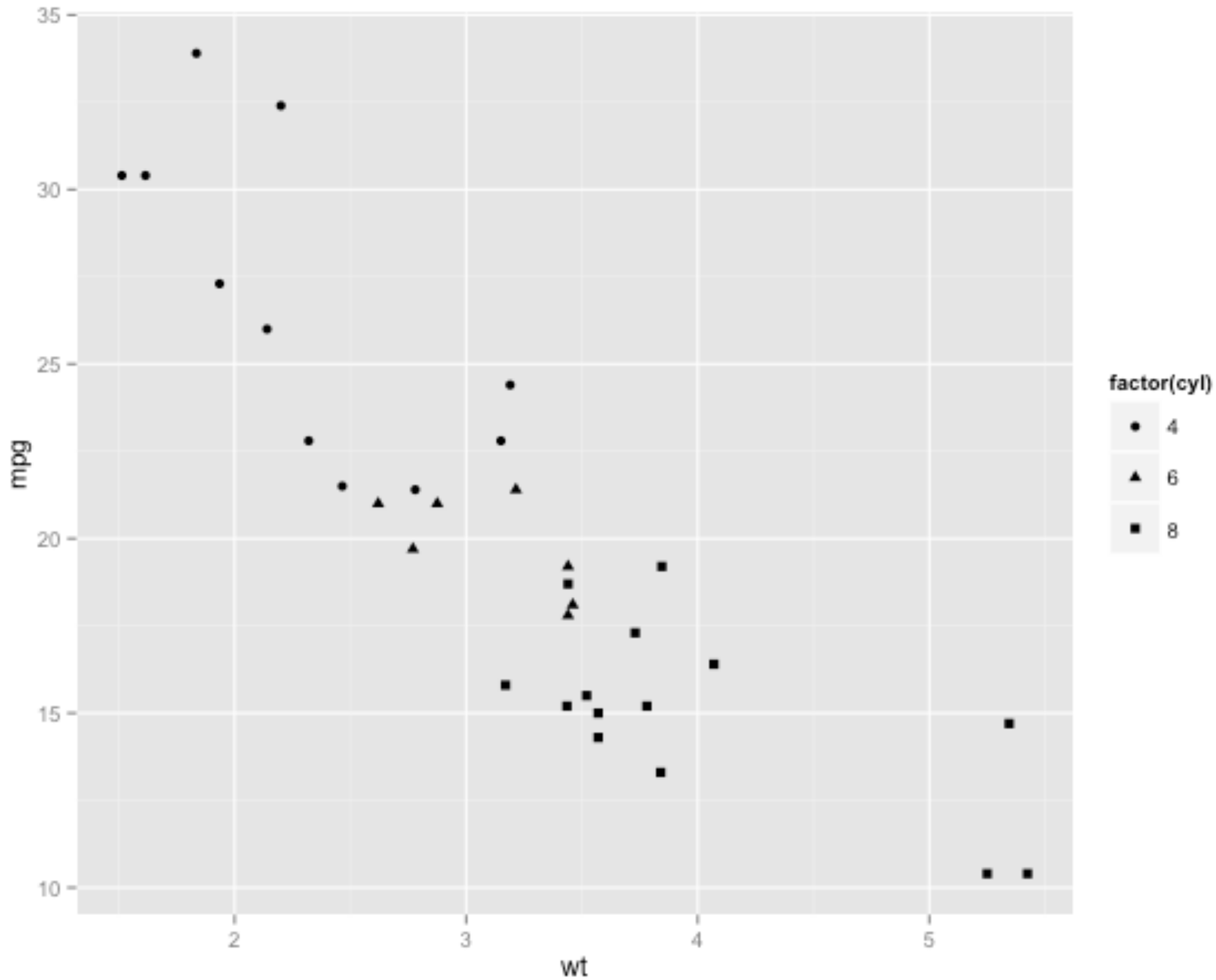
Graphics: ggplot2

```
url <- "http://steviep42.bitbucket.org/bios545r/DATA.DIR/my.diamonds.csv"

diamonds <- read.csv(url)

qplot(carat, price, data = diamonds, shape = cut)
```



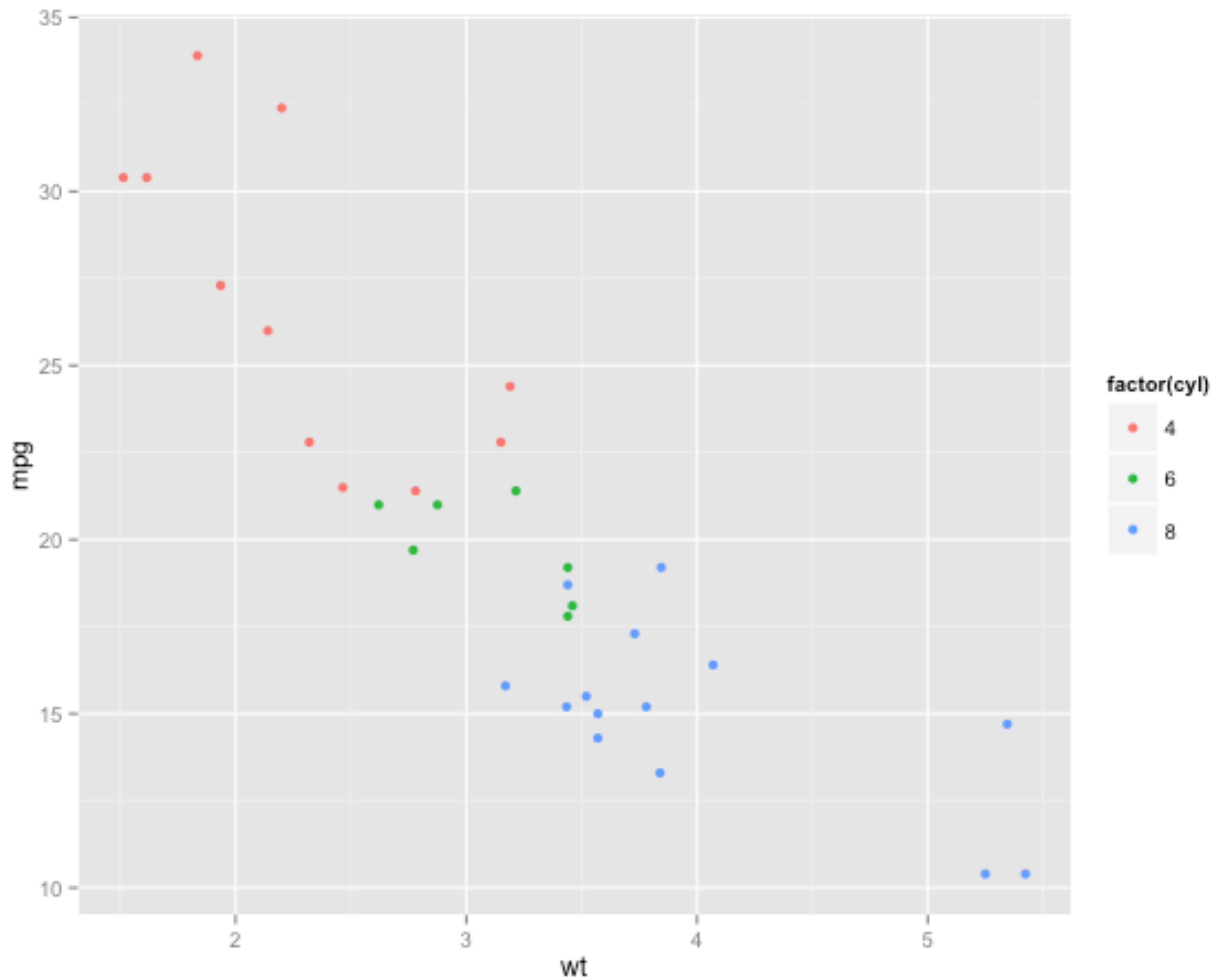
Graphics: ggplot2

```
qplot(wt, mpg, data = mtcars, shape = factor(cyl))
```



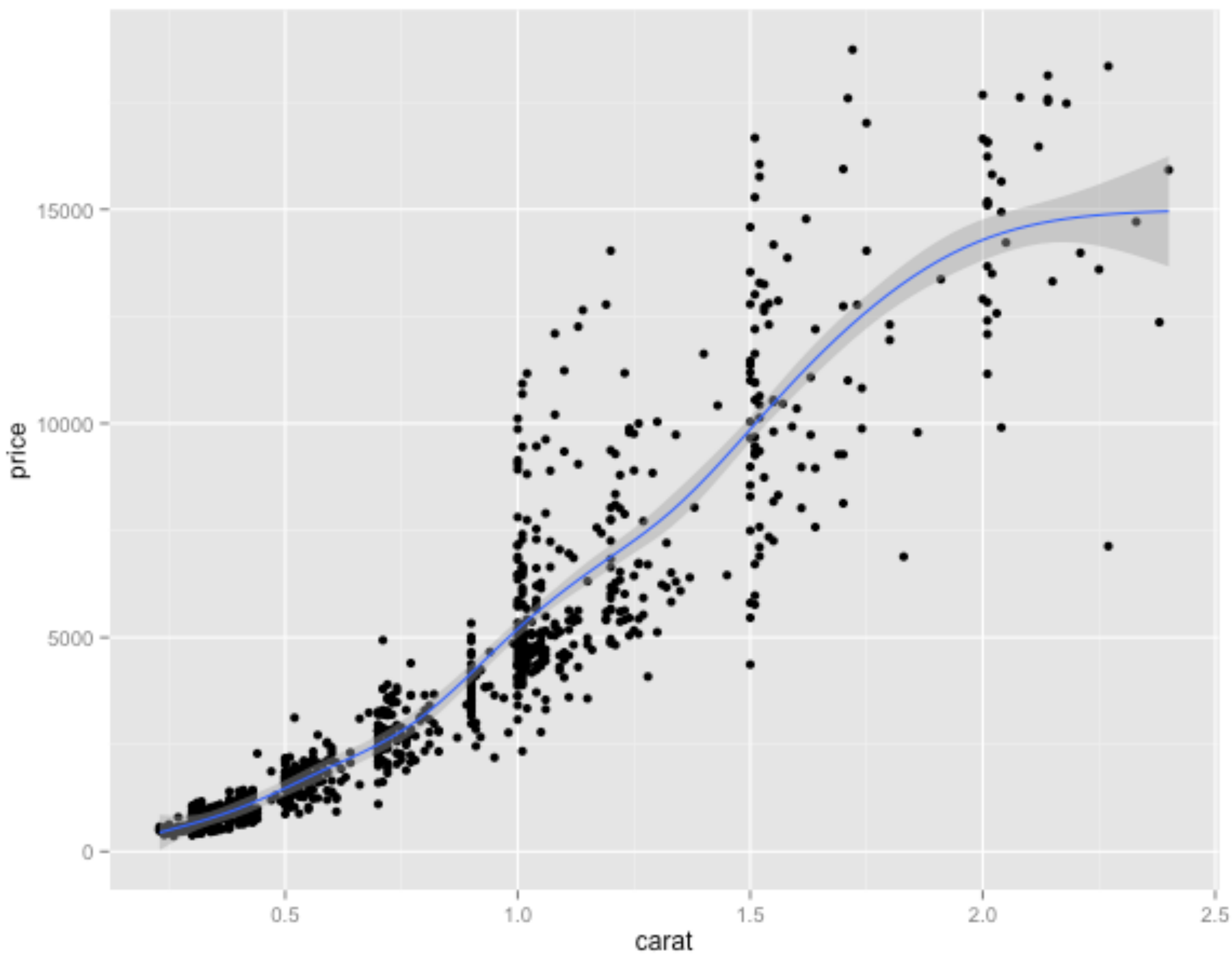
Graphics: ggplot2

```
qplot(wt, mpg, data = mtcars, color = factor(cyl))
```



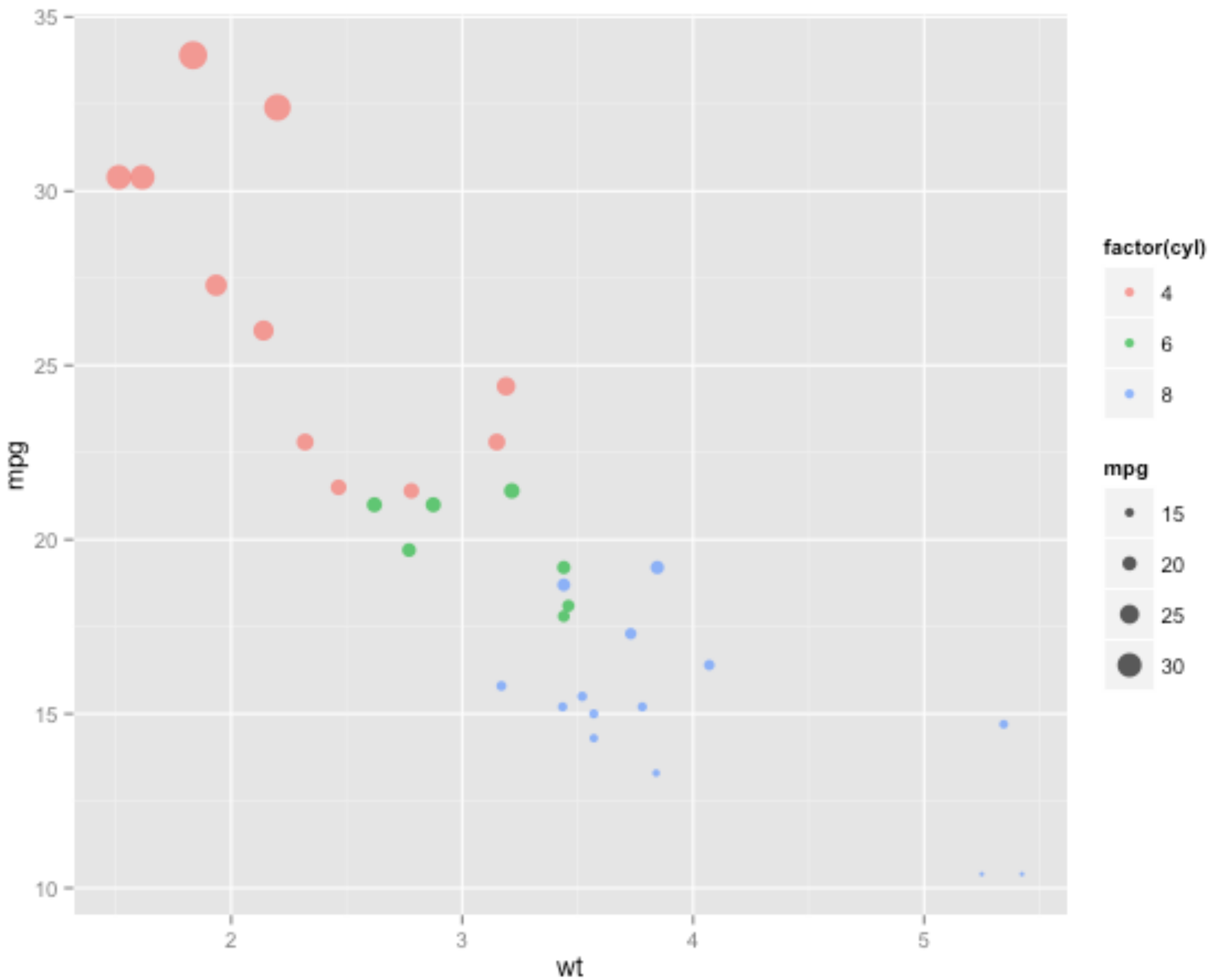
Graphics: ggplot2

```
qplot(carat, price, data = diamonds, geom = c("point", "smooth"))
```



Graphics: ggplot2

```
qplot(wt,mpg, data = mtcars, color = factor(cyl), size = mpg, alpha = I(0.7))
```



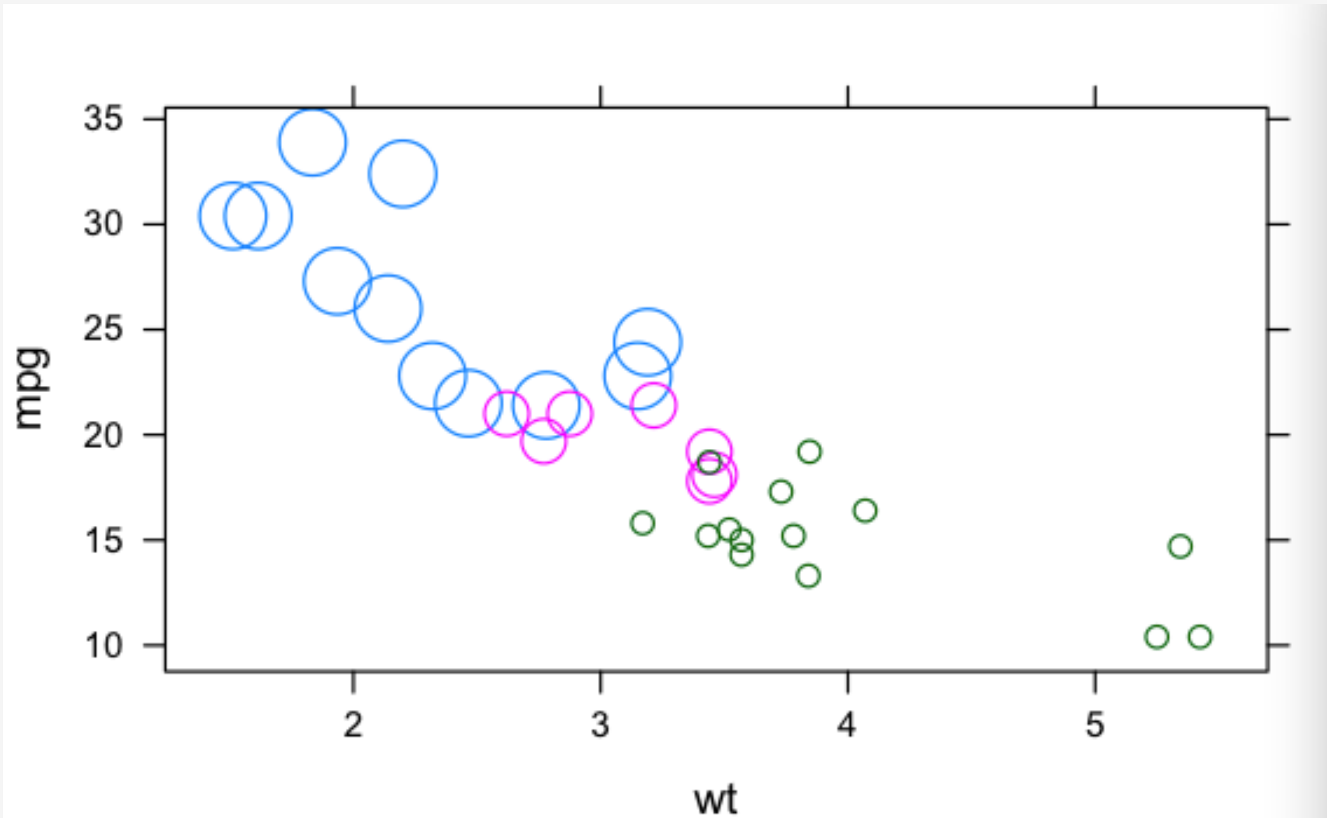
Graphics: lattice: xyplot

```
THE FOLLOWING SLIDES ARE SUPPLEMENTAL THOUGH ARE VERY USEFUL
```

Graphics: lattice: xyplot

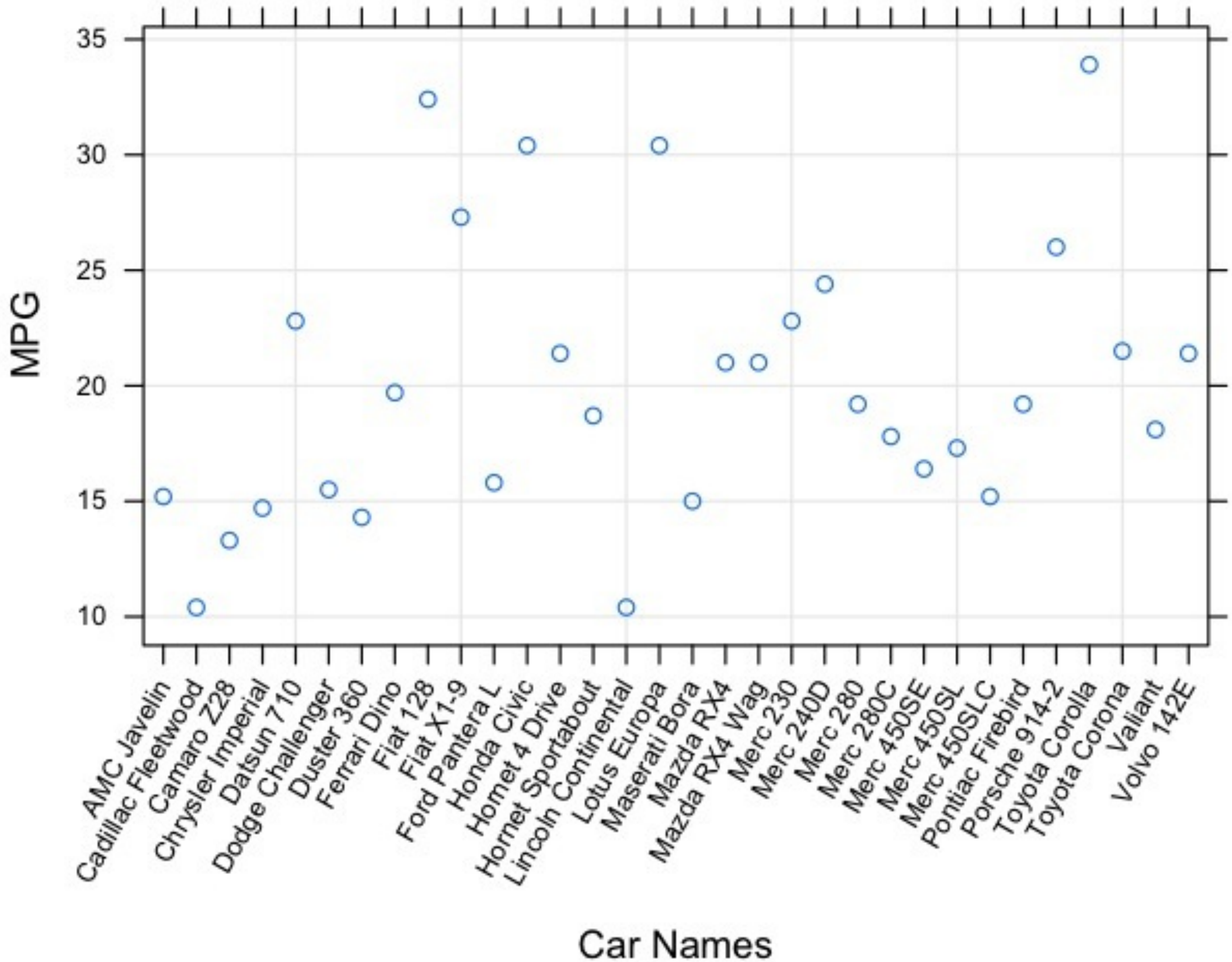
Remember our early X/Y plot with Base graphics where we wanted to plot MPG vs Weight and have the point sizes to reflect the cylinder group (4,6, or 8) ? It was quite a bit of work to do with Base graphics. Here we can do it with one line:

```
xyplot(mpg ~ wt, groups = factor(cyl), cex=3:1, auto.key=T)
```



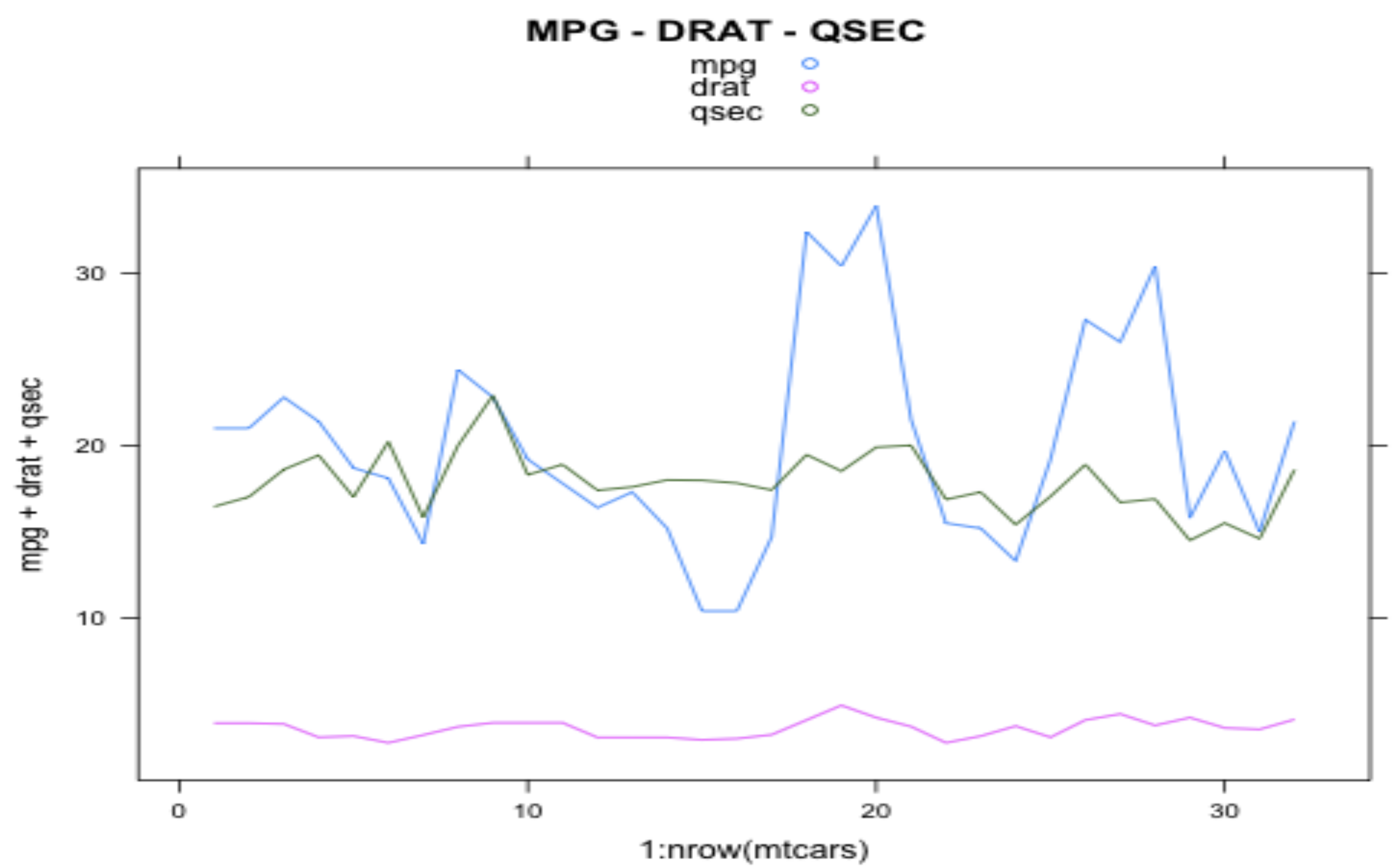
Graphics: lattice: xyplot

```
xyplot(mpg ~ factor(rownames(mtcars)),
       mtcars, xlab = "Car Names", ylab = "MPG",
       scales = list(cex = 0.7,x = list(rot = 60)),type=c("p","g"))
```



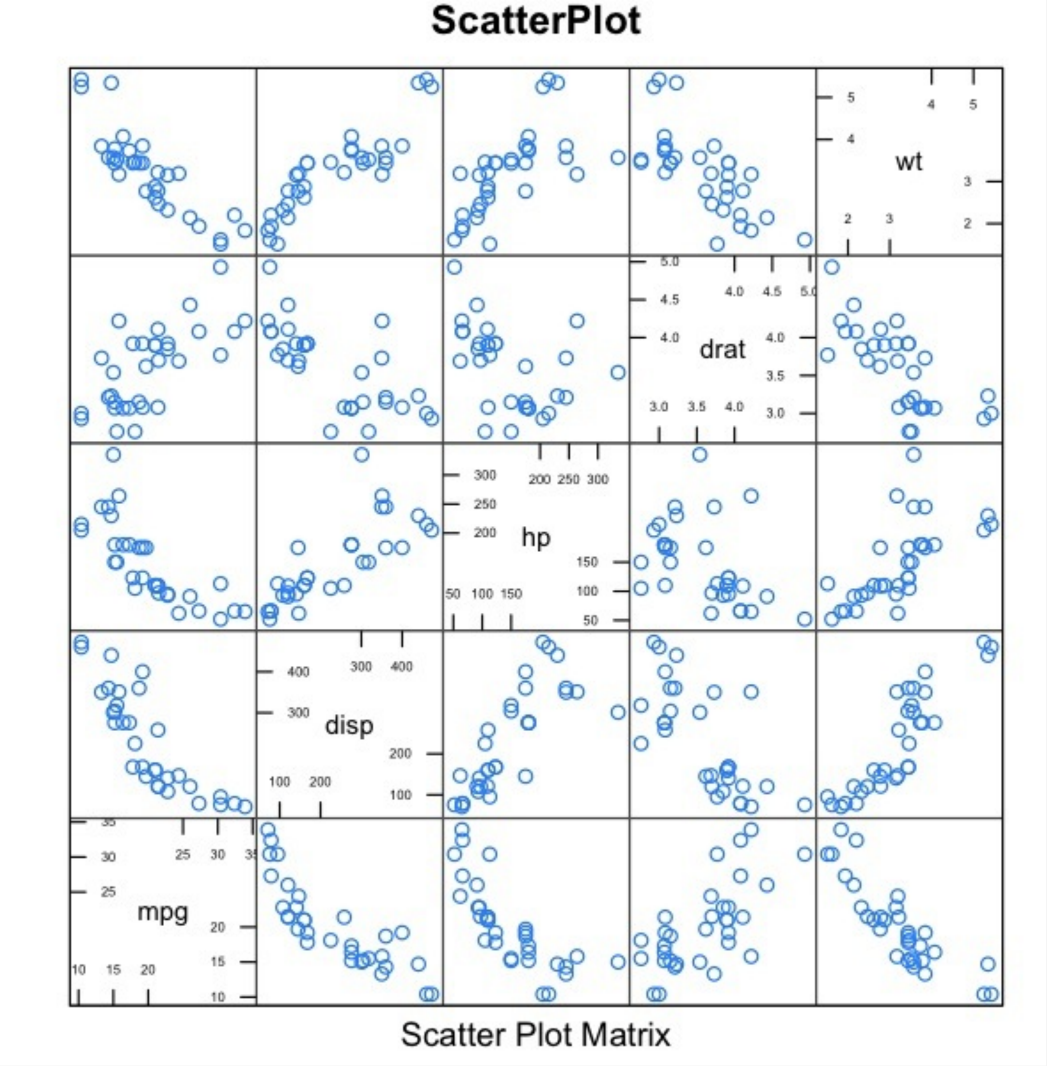
Graphics: lattice: xyplot

```
xyplot(mpg + drat + qsec ~ 1:nrow(mtcars),
       data= mtcars, type="l",auto.key=T,
       main = "MPG - DRAT - QSEC")
```



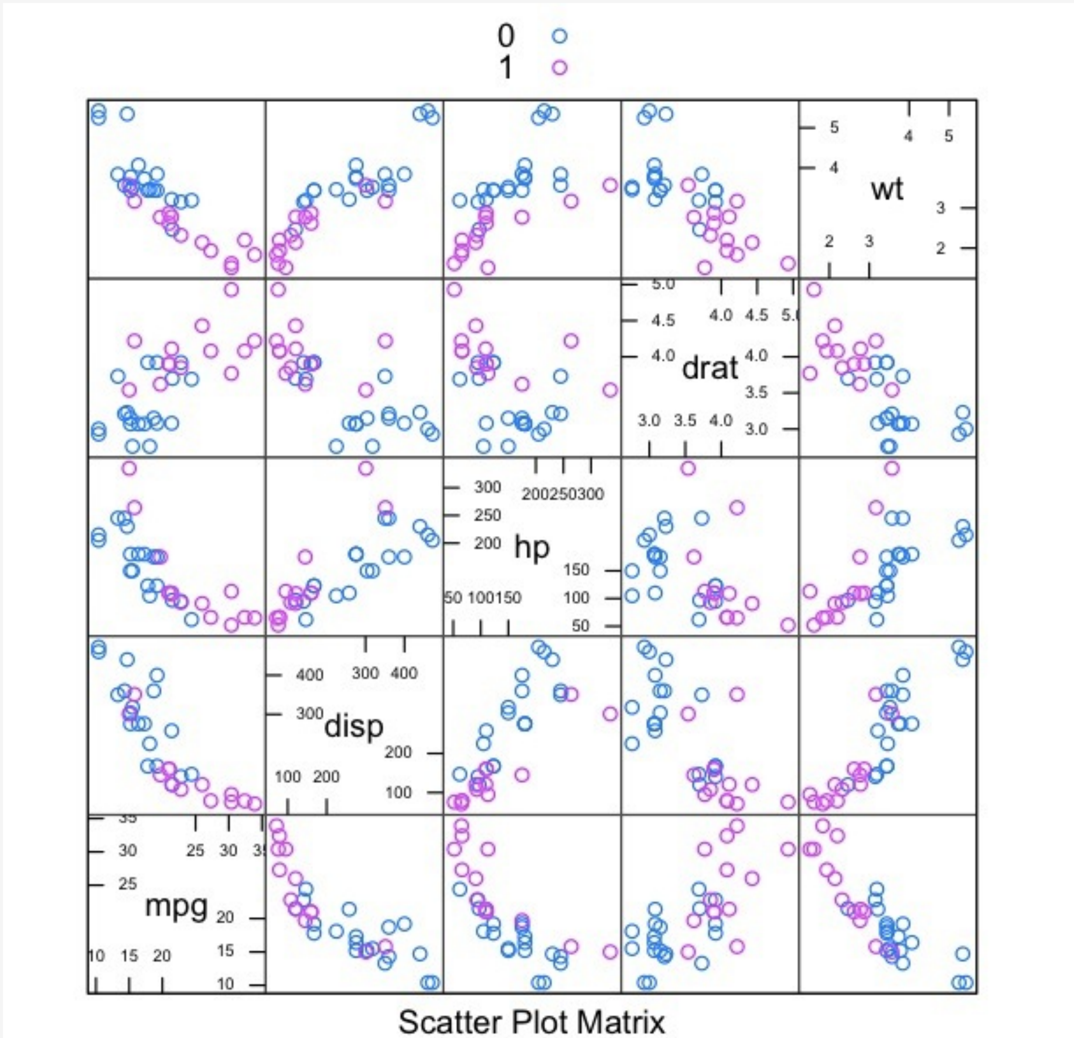
Graphics: lattice: splom

```
splom(~mtcars[,c(1,3:6)], data=mtcars, main="ScatterPlot",
      varname.cex=.8,axis.text.cex=0.4)
```



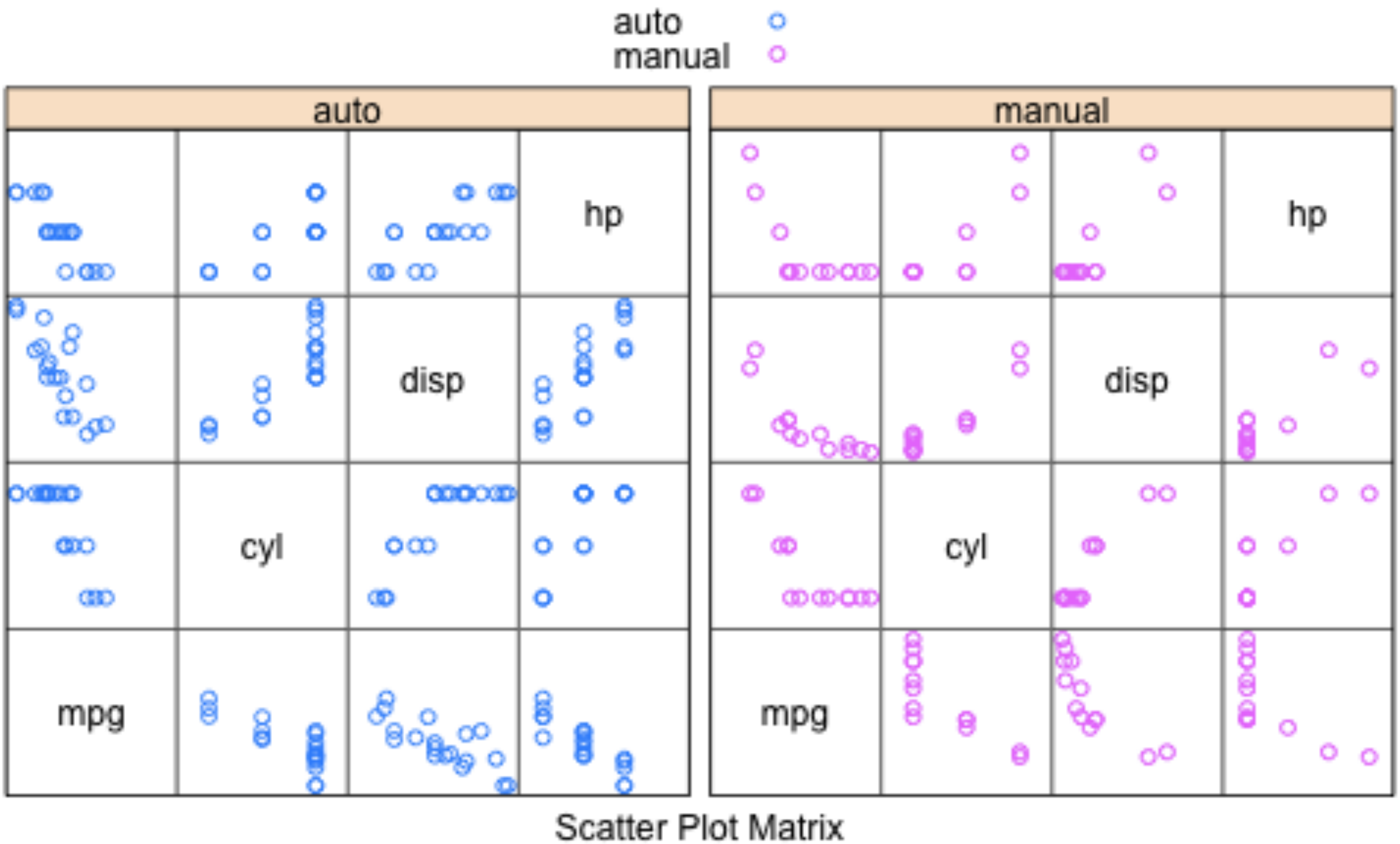
Graphics: lattice: splom

```
splom(~mtcars[c(1,3:6)],groups = am, mtcars,
       auto.key = TRUE,axis.text.cex=0.5)
```



Graphics: lattice: splom

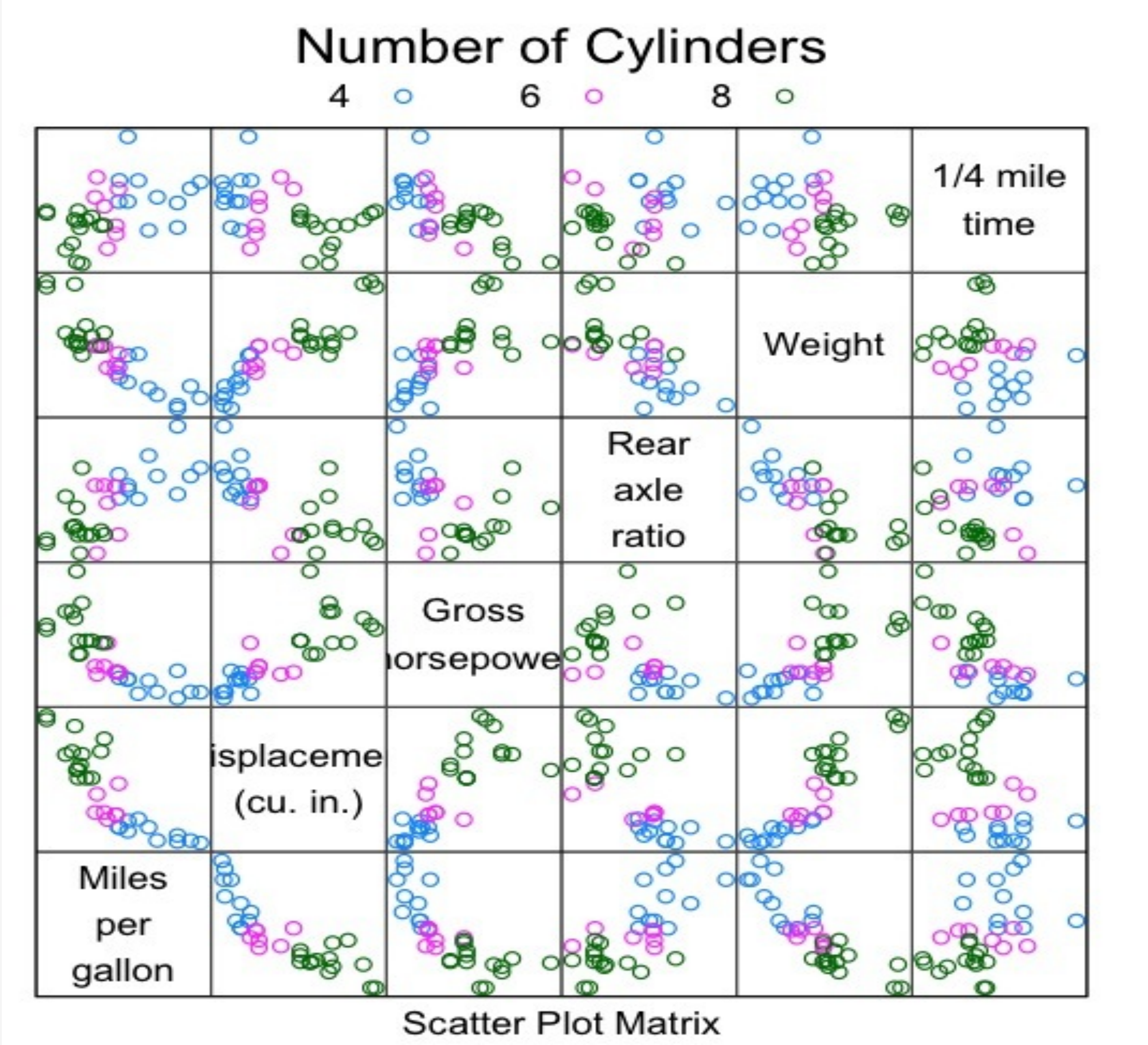
```
splom(~mtcars[c(1:4)] |am,groups=am,mtcars,auto.key=TRUE,pscales=0)
```



Graphics: lattice: splom

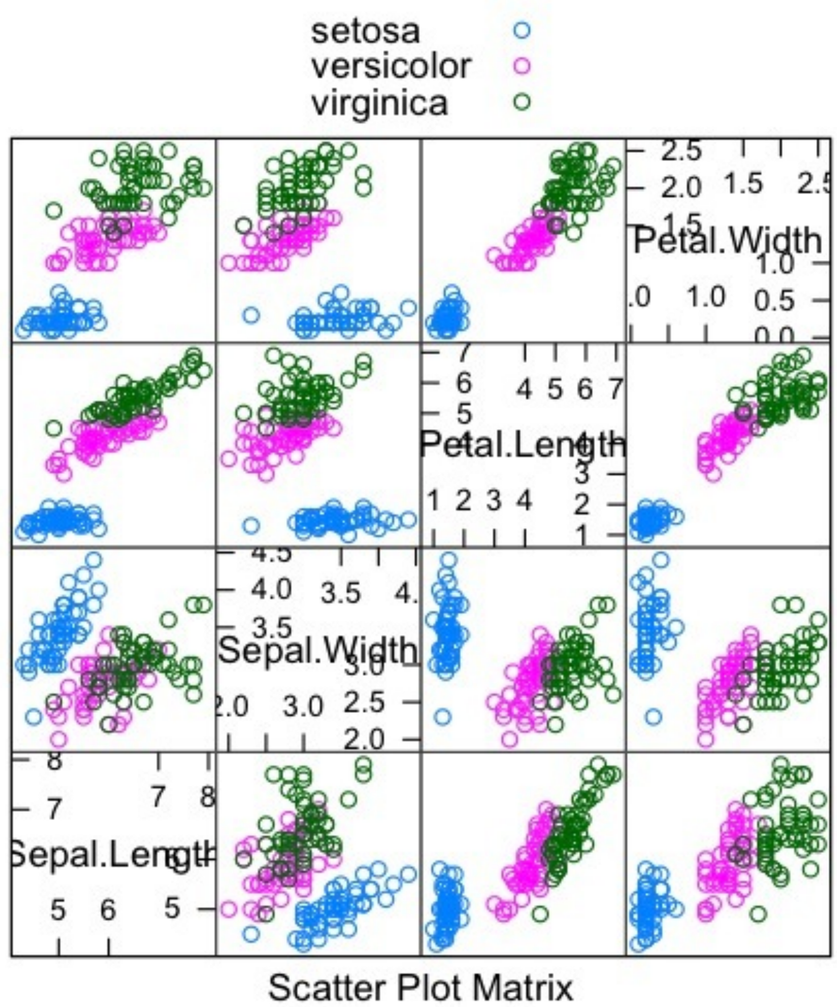
```
splom(~data.frame(mpg, disp, hp, drat, wt, qsec),
       data = mtcars, groups = cyl, pscales = 0,
       varnames = c("Miles\nper\ngallon", "Displacement\n(cu. in.)",
                    "Gross\nhorsepower", "Rear\naxle\nratio",
                    "Weight", "1/4 mile\ntime"),
       auto.key = list(columns = 3, title = "Number of Cylinders"),
       varname.cex=0.7)
```

Graphics: lattice: splom



Graphics: lattice: splom

```
splom(~iris[1:4], groups = Species, data = iris,auto.key=T)
```



Graphics: lattice

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

X/Y, Scatterplot, Sunflower Plot

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

Let's look at a different data set that is smaller. For small samples, summarizing is often unnecessary, and simply plotting all the data reveals interesting features of the distribution.

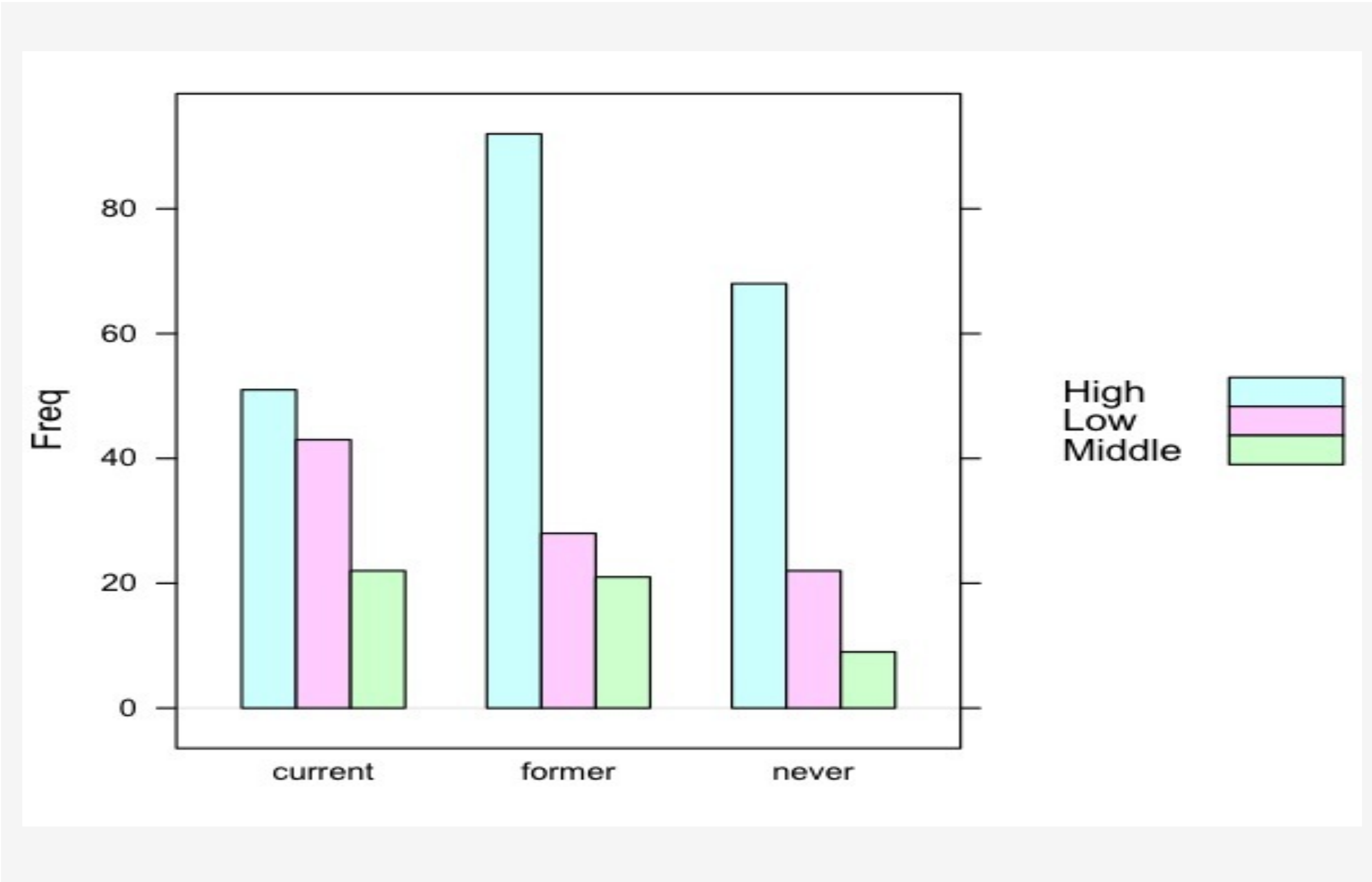
```
head(quakes)
     lat   long depth mag stations
1 -20.42 181.62   562 4.8       41
2 -20.62 181.03   650 4.2       15
3 -26.00 184.10    42 5.4       43
4 -17.97 181.66   626 4.1       19
5 -20.42 181.96   649 4.0       11
6 -19.68 184.31   195 4.0       12

sapply(quakes,class)
      lat      long     depth       mag  stations
"numeric" "numeric" "integer" "numeric" "integer"

sapply(quakes,range)
        lat   long depth mag stations
[1,] -38.59 165.67    40 4.0       10
[2,] -10.72 188.13   680 6.4      132
```

Graphics: lattice: barchart

We surveyed people to see if they smoked ever, heavily, or previously. We were then given some idea of their socioeconomic status (“high”,”middle”,”low”). Let’s check it out:

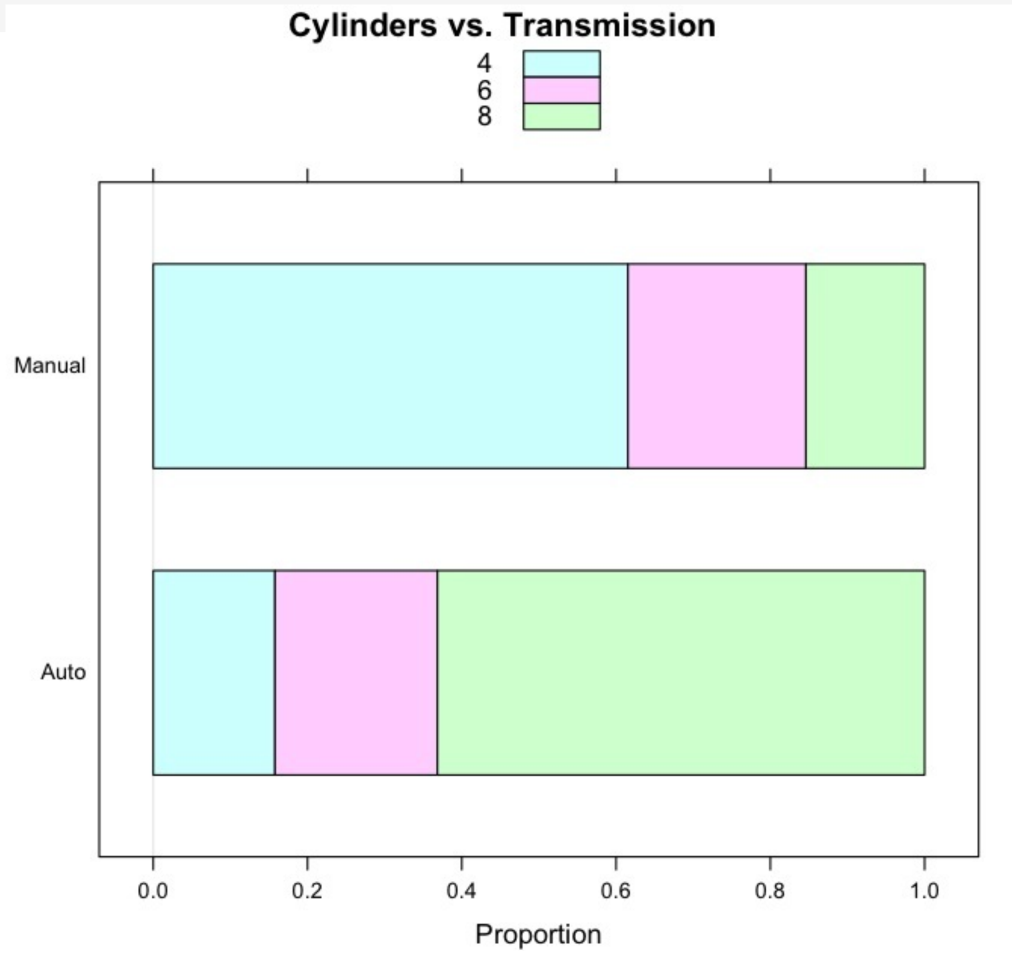
```
smokers <- read.table("http://www.cyclismo.org/tutorial/R/
smoker.csv",header=T,sep=",")

head(smokers)
     Smoke  SES
1 former High
2 former High

( my.table <- table(smokers$Smoke,smokers$SES) )

          High Low Middle
  current   51  43     22
  former    92  28     21
  never     68  22      9

> barchart(my.table,auto.key=list(space="right"),stack=F,horizontal=F)
```

Graphics: lattice: barchart



Graphics: lattice: barchart

```
my.table <- table(factor(mtcars$am,labels=c("Auto","Manual")),
           mtcars$cyl)

barchart(prop.table(my.table,margin=1),xlab="Proportion",
         auto.key = T, main = "Cylinders vs. Transmission")
```



Graphics: lattice

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

X/Y, Scatterplot, Sunflower Plot

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

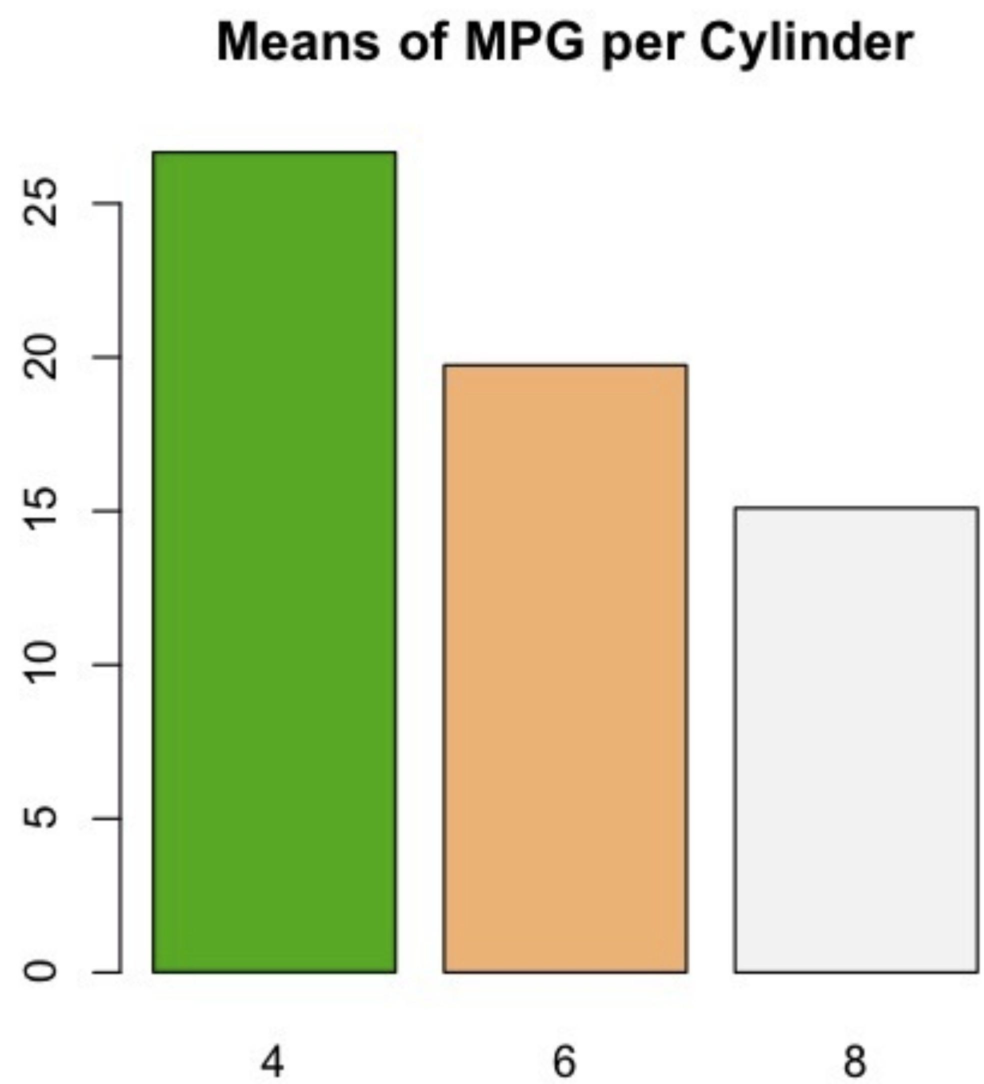
plot(x,y) where one of x and y is continuous and the other is discrete

Side-by-Side DotPlot and BoxPlot, Notched BoxPlot

Graphics: lattice: barchart

```
my.table <- tapply(mtcars$mpg,mtcars$cyl,mean)
       4        6        8
26.66364 19.74286 15.10000



barplot(my.table, col=terrain.colors(3),
        main="Means of MPG per Cylinder")
```

Graphics: lattice: barchart



Graphics: lattice: bwplot

A well-known graphical design that allows comparison between an arbitrary number of samples is the comparative box-and-whisker plot. They are related to the Q-Q plot: the values compared are five "special" quantiles, the median, the first and third quartiles, and the extremes.

More commonly, the extents of the "whiskers" are defined differently, and values outside plotted explicitly, so that heavier-than-normal tails tend to produce many points outside the extremes.

```
> bwplot(factor(score) ~ gcsescore | gender, Chem97,main="A-
level score vs. GCSES score \n by Gender")
```

The decreasing lengths of the boxes and whiskers suggest decreasing variance, and the large number of outliers on one side indicate heavier left tails (characteristic of a left-skewed distribution).

Graphics: lattice: bwplot

Next. Let's look at some other examples. In We'll be using the mtcars data set as well as the Chem97 dataset contained in the mlmRev package. If you don't have that package installed please install it using your GUI or at the command line by doing:

```
> install.packages("mlmRev")
```

Graphics: lattice: bwplot

```
data(Chem97, package="mlmRev")

head(Chem97)
  lea school student score gender age gcsescore   gcsecnt
1   1      1       1     4      F   3     6.625 0.3393157
2   1      1       2    10      F  -3     7.625 1.3393157
3   1      1       3    10      F  -4     7.250 0.9643157
4   1      1       4    10      F  -2     7.500 1.2143157
5   1      1       5     8      F  -1     6.444 0.1583157
6   1      1       6    10      F   4     7.750 1.4643157
```

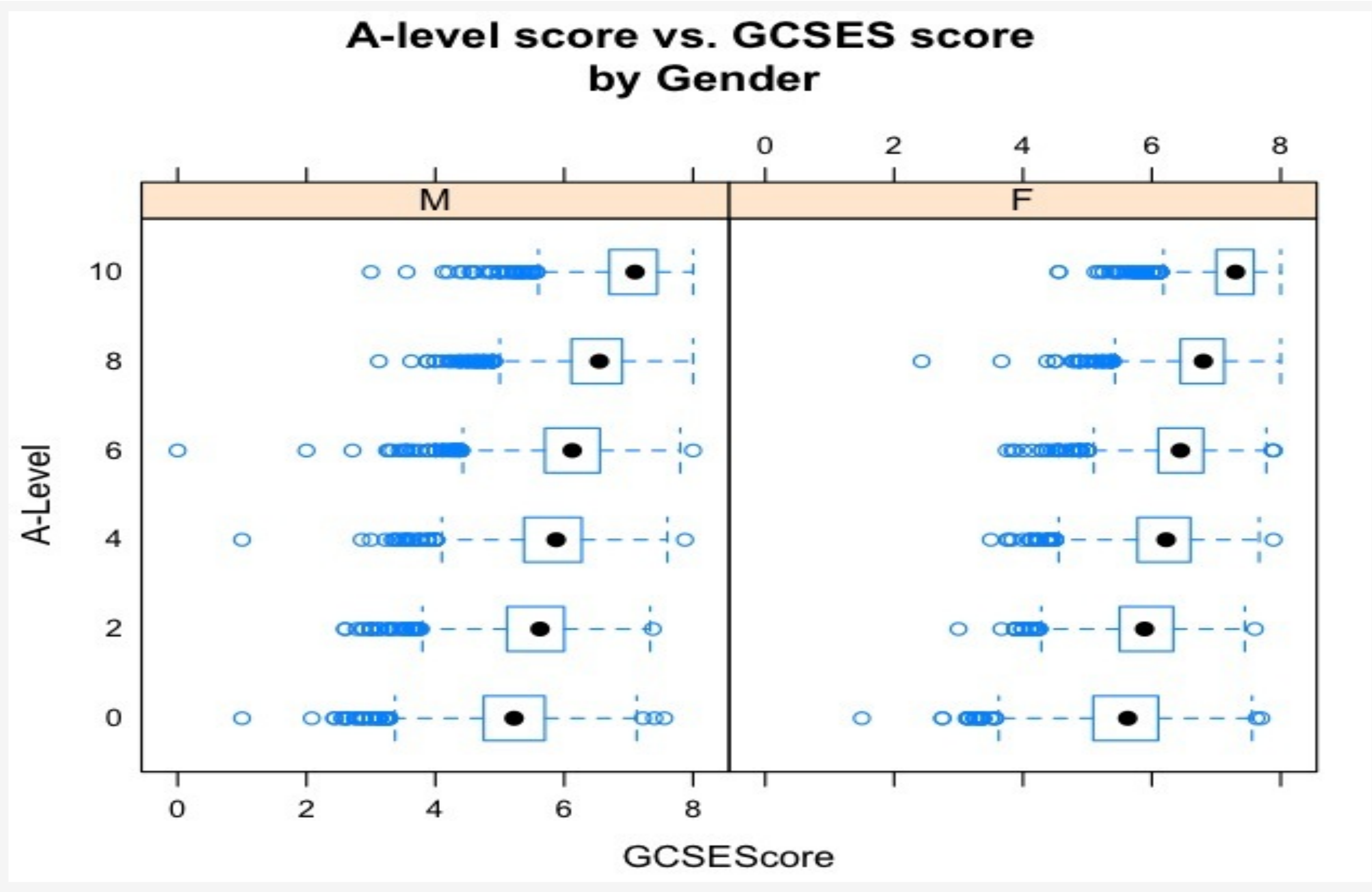
This dataset contains information in the 1997 A-level chemistry examination in Britain. Let's focus on the the following variables:

* score: point score in the exam, with six possible values (0,2,4,6,8) (discrete)

* gcsescore: average score in GCSE exams, This is a continuous score that can be used to predict the A-level scores. (continuous)

* gender: Gender of the student (discrete/binary)

Graphics: lattice: bwplot



Graphics: lattice: bwplot

Note that we change the plot to get a different view. We do this by switching the order of the variables. The previous example looks like:

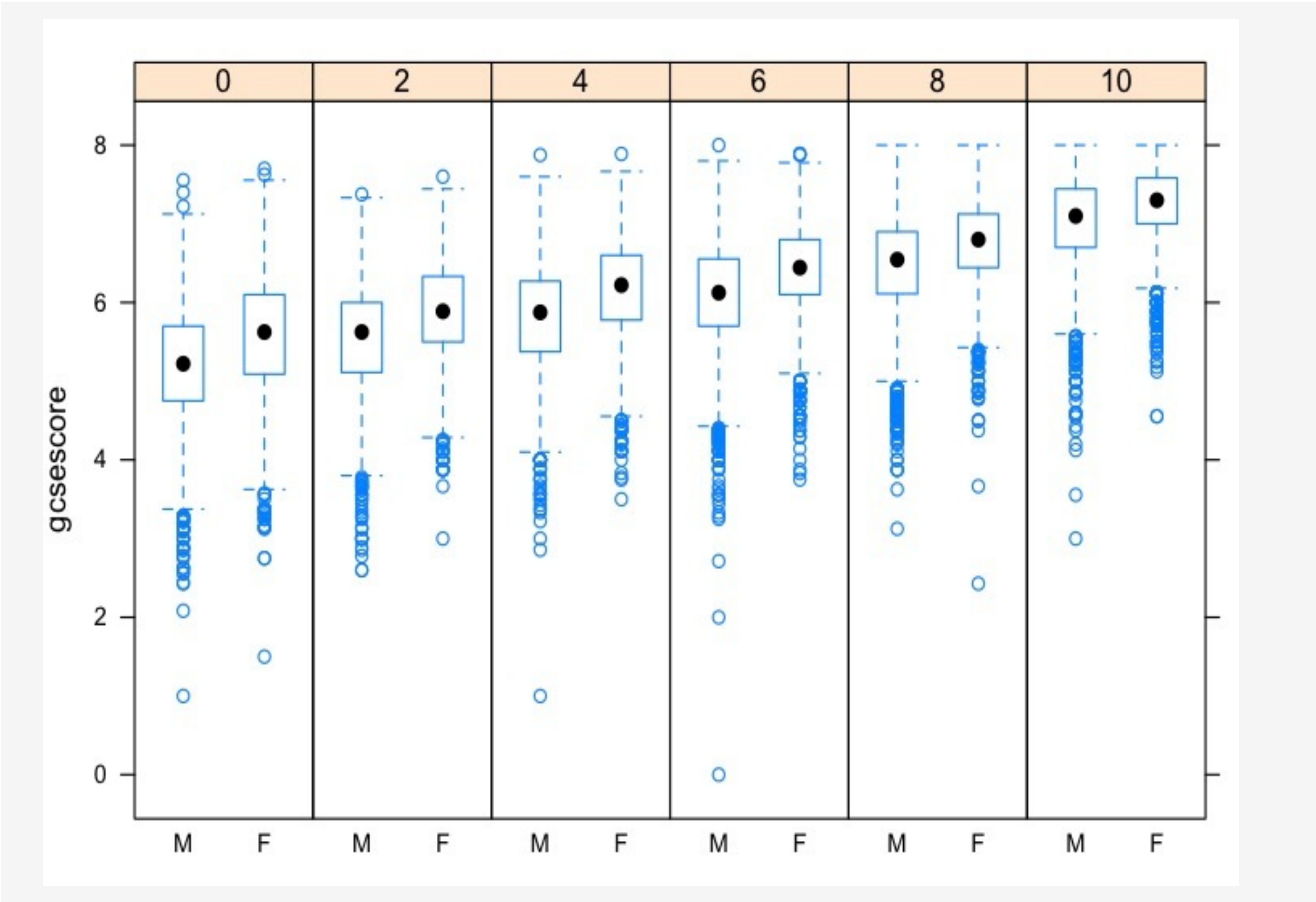
```
bwplot(factor(score) ~ gcsescore | gender, Chem97,main="A-level
score vs. GCSES score \n by Gender")
```

Let's do this:

```
bwplot(gcsescore ~ gender | factor(score), Chem97,
layout=c(6,1))
```

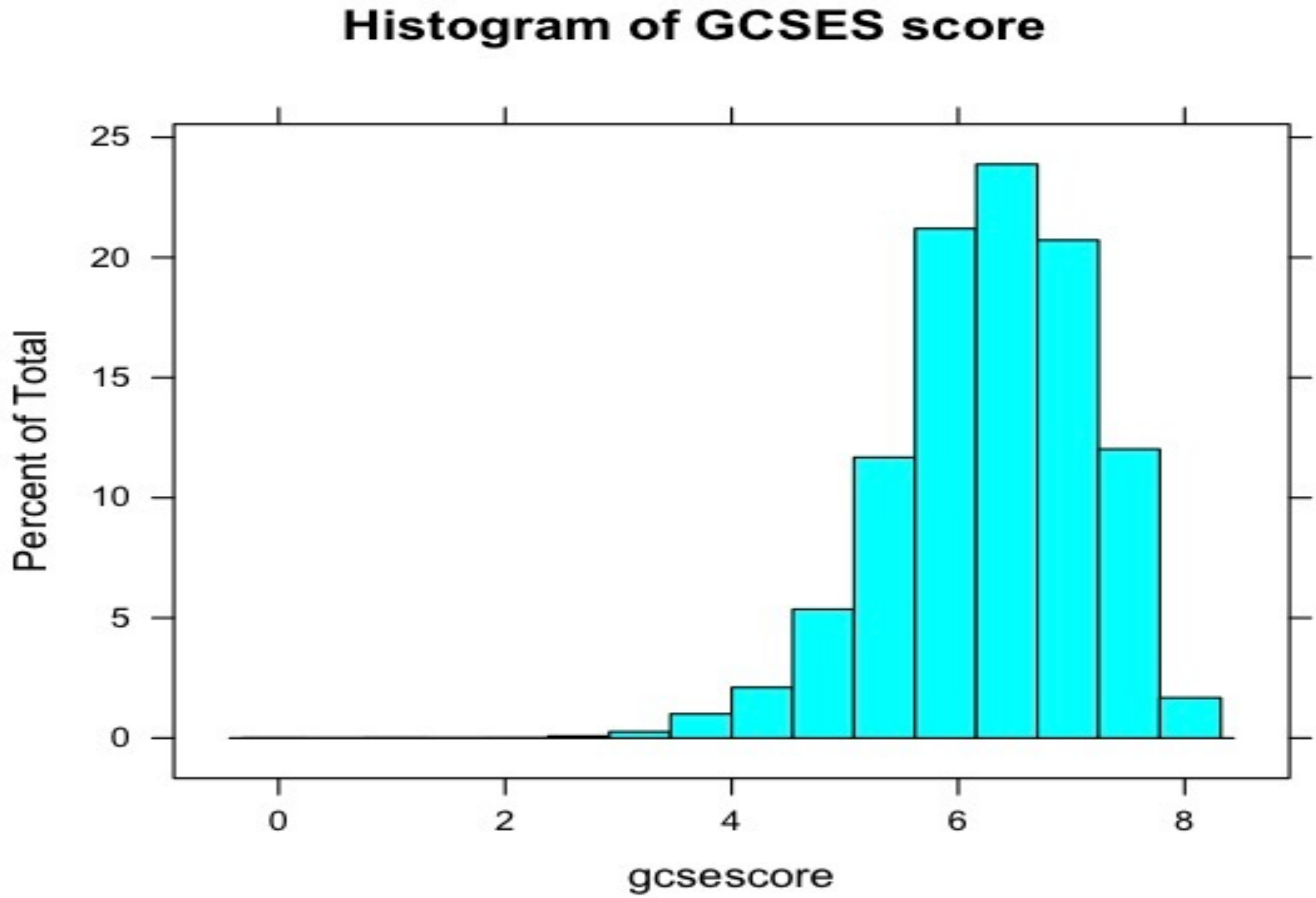
We get a different view of this information:

Graphics: lattice: bwplot



Graphics: lattice: histogram

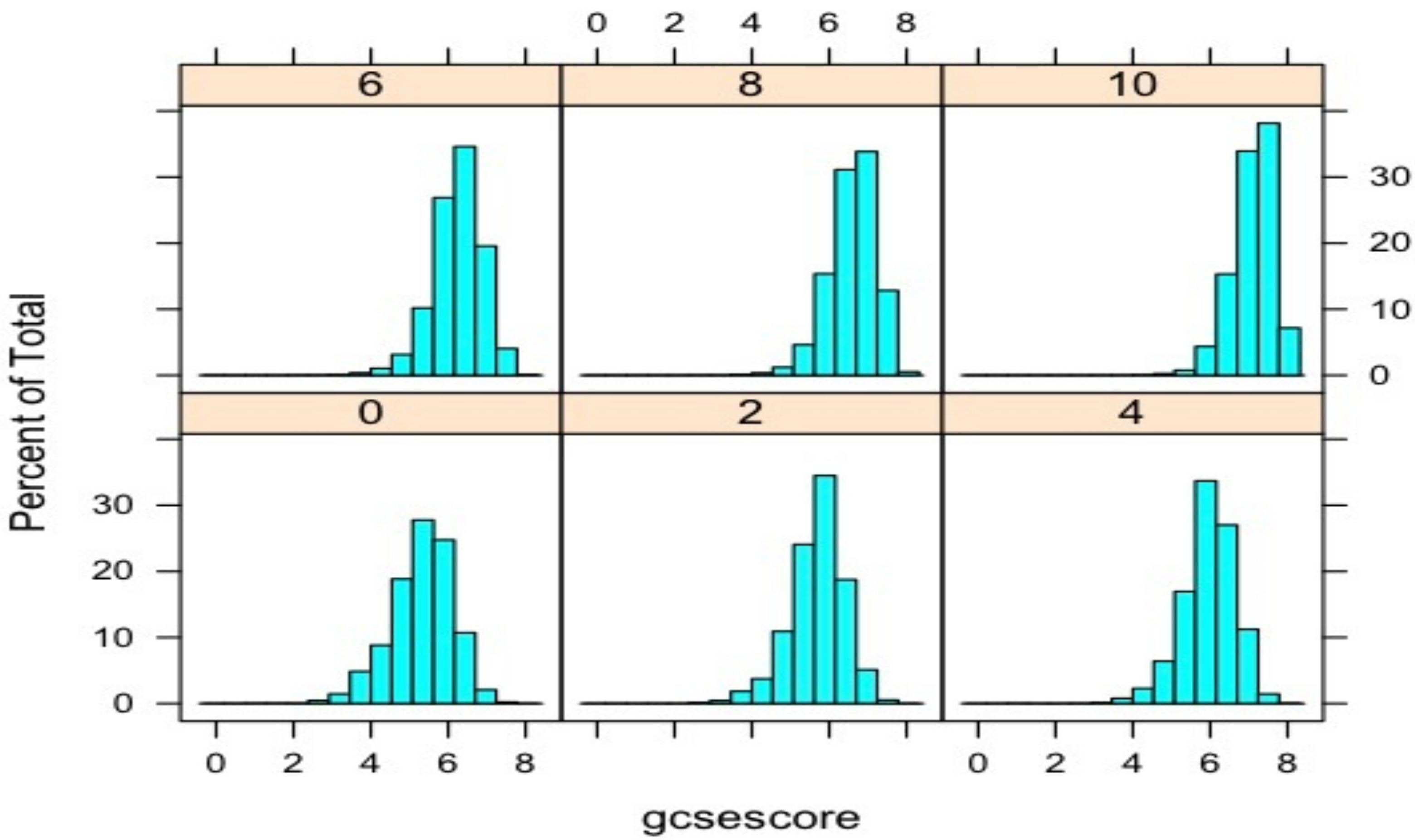
```
histogram(~ gcsescore,data=Chem97,
            main="Histogram of GCSES score")
```



Graphics: lattice: histogram

Okay, that's cool but it is kind of boring and uninformative. It might be better to look at a histogram across the scores, which could be considered as a factor grouping.

```
histogram(~ gcsescore | factor(score), data = Chem97)
```



Graphics: lattice: histogram

```
histogram(~ gcsescore | factor(score), data = Chem97,
     xlab = "Height (inches)", type = "density",
     panel = function(x, ...) {
          panel.histogram(x, ...)
          panel.mathdensity(dmath = dnorm, col = "black",
                            args = list(mean=mean(x),sd=sd(x)))
     })
```

Graphics: lattice: histogram