Data Visualization in Base R

Adam Kuczynski

UNIVERSITY OF WASHINGTON

Why use R for data visualization?

- R data visualization is extremely flexible! Almost any data visualization you can think of is possible to create in R
- Creating visualizations in R allows you to create dynamic plots that change with new data. This is useful when you want to create plots on a recurring basis (e.g., monthly revenue reports) or even realize that you missed some data initially. Repeat the same code every time!

- There are dozens of packages that make it easier to create complex figures, including `ggplot2`, `patchwork`, `lattice`, `diagrammeR`, and more!
- Create interactive visualizations with `plotly`, `ggvis`, `htmlwidgets`, `leaflet`, `shiny` apps, and other R tools

🧠 Psychology's new home

The Generic `plot()` Function

Many data visualizations created in R start with the same function: `plot()`

`plot()` knows how to handle several different types of objects because it is a **generic function** with lots of methods:

```
methods(plot)
```

```
##  [1] plot.acf*           plot.data.frame*    plot.decomposed.ts*
##  [4] plot.default        plot.dendrogram*    plot.density*
##  [7] plot.ecdf           plot.factor*        plot.formula*
## [10] plot.function       plot.hclust*        plot.histogram*
## [13] plot.HoltWinters*   plot.isoreg*        plot.lm*
## [16] plot.medpolish*     plot.mlm*           plot.ppr*
## [19] plot.prcomp*        plot.princomp*      plot.profile.nls*
## [22] plot.R6*            plot.raster*        plot.shingle*
## [25] plot.spec*          plot.stepfun        plot.stl*
## [28] plot.table*         plot.trellis*       plot.ts
## [31] plot.tskernel*      plot.TukeyHSD*      plot.zoo
## see '?methods' for accessing help and source code
```

`plot()` Arguments

```
plot(x, y = NULL, type = "p",  xlim = NULL, ylim = NULL,
     log = "", main = NULL, sub = NULL, xlab = NULL, ylab = NULL,
     ann = par("ann"), axes = TRUE, frame.plot = axes,
     panel.first = NULL, panel.last = NULL, asp = NA,
     xgap.axis = NA, ygap.axis = NA,
     ...)
```

There are **a lot** of arguments to `plot()`!

Several of these arguments will be discussed in these slides, but not all of them. That means that making plots often involves teaching yourself something new each time with the help pages, Stack Overflow, and other various websites and blogs.

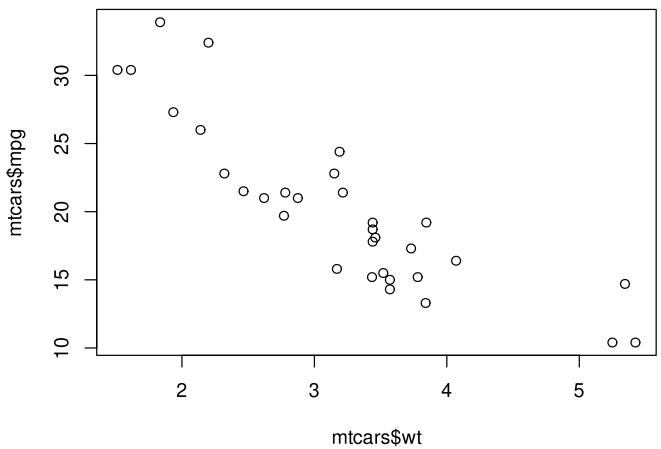
See `help(par)` for a full list of graphical parameters, many of which can be used within the `...` argument

Scatterplot

```
# Vectors of coordinates
plot(x = mtcars$wt,
     y = mtcars$mpg)
```

```
# Formula (`y~x`)
plot(mtcars$mpg ~ mtcars$wt)
```

```
# Two-column dataframe of x, y coordinates
plot(mtcars[, c("wt", "mpg")])
```

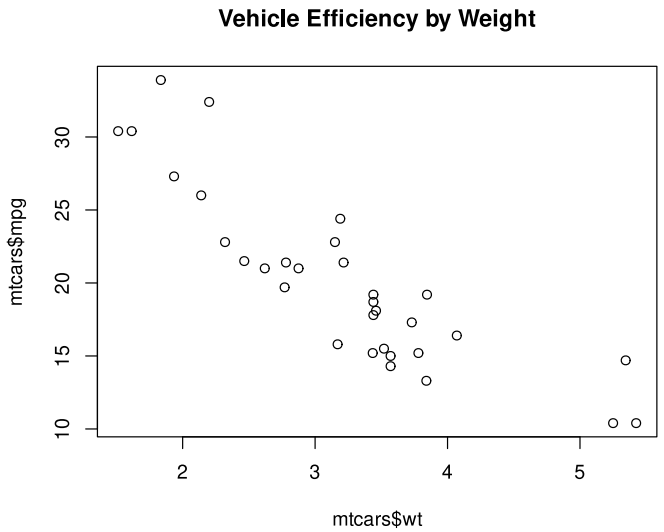


- What defaults do you notice?
  - Plots points (`type = "p"`) of a specific shape (`pch = 1`)
  - Axis labels (R code supplied to the arguments)
  - No header (`main = NULL`)
  - Chooses axis ticks for you
  - ...and hundreds more!

Plot Titles

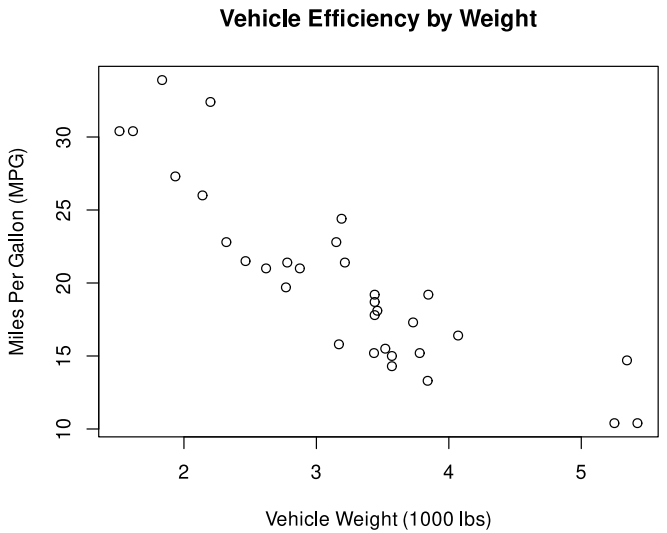
Main Title

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight")
```



Axis Titles

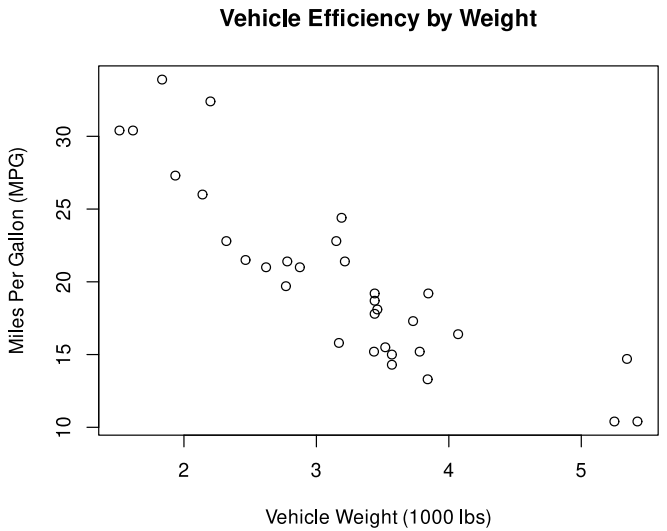
```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)")
```



Fixing Ugly Axes

R default axes are not publication ready!

- The axes overlap with the box around the plot
- The y-axis tickmarks are vertical
- The axes are thin and hard to see
- The default tick marks may not be desirable
- The default tick labels may not be desirable



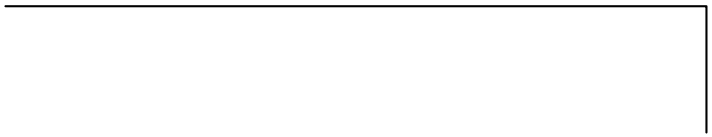
box()

The `box()` function is responsible for placing a box around your points. There are several different box types (specified with the `bty` **b**ox **ty**pe argument):

```
# full box (default)
plot.new()
box(bty = "o")
```

```
# bottom and left
plot.new()
box(bty = "L")
```

```
# top and right
plot.new()
box(bty = "7")
```

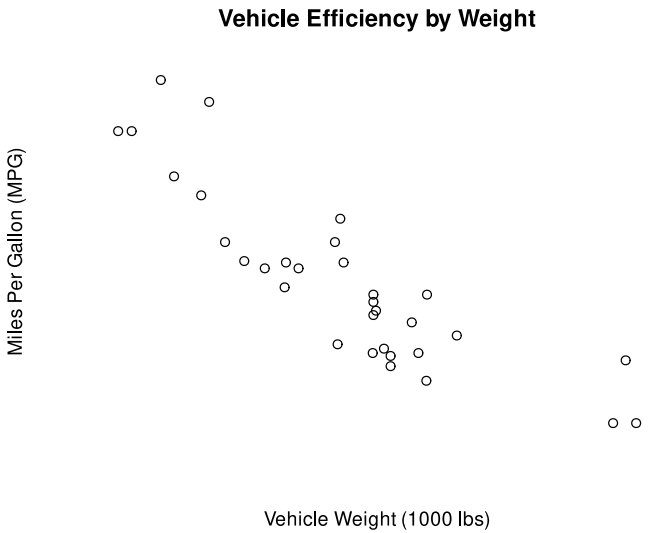


```
# top, left, and bottom
plot.new()
box(bty = "C")
```

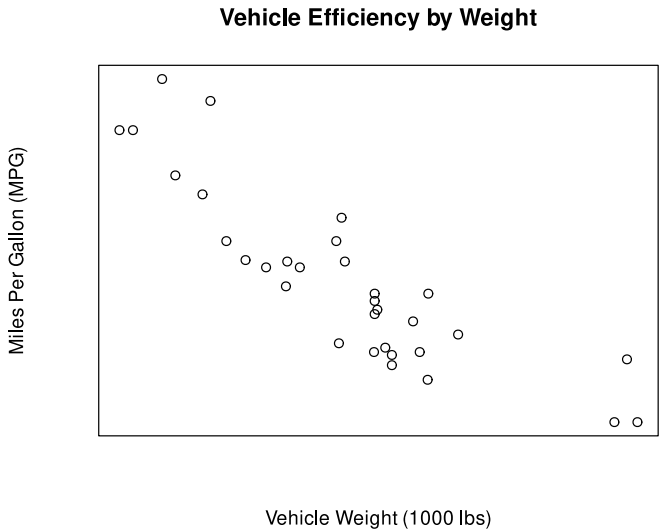
```
# left, bottom, and right
plot.new()
box(bty = "U")
```

Fixing the `box()`

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     axes = F) # do not plot axes
```



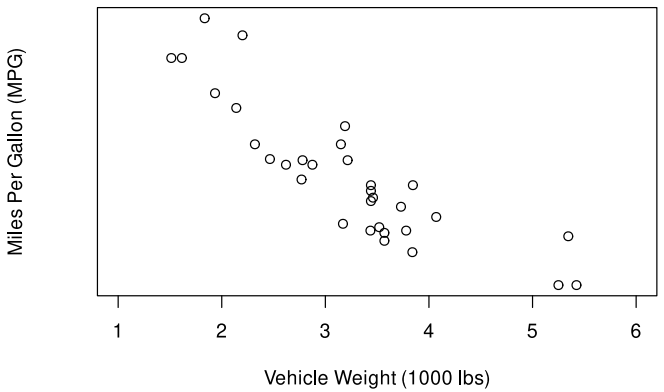

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     axes = F)
box() # plot box
```



Add the axes back in

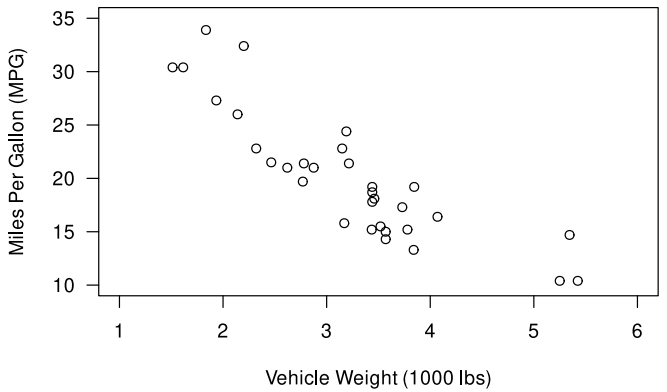
x-axis

```
plot(...,
     axes = F,
     xlim = c(1, 6))

box()

axis(side = 1, # x-axis
     at = 1:6, # ticks at 1 through 6
     labels = 1:6, # labels numbers 1 throu
     lwd = 0, # do not plot axis
     lwd.ticks = 1) # plot tick marks
```



y-axis

```
plot(...,
     axes = F,
     xlim = c(1, 6),
     ylim = c(10, 35))
box()
axis(side = 1, at = 1:6, labels = 1:6,lwd =
axis(side = 2, # y-axis
     at = seq(10, 35, 5), # ticks every 5 p
     labels = seq(10, 35, 5), # labels 10:3
     lwd = 0, lwd.ticks = 1,
     las = 1) # horizonal tick labels
```



Change `box()` width and line type

```
box(bty = "o",
    lwd = 3,
    lty = 1)
```

```
box(bty = "o",
    lwd = 3,
    lty = 2)
```

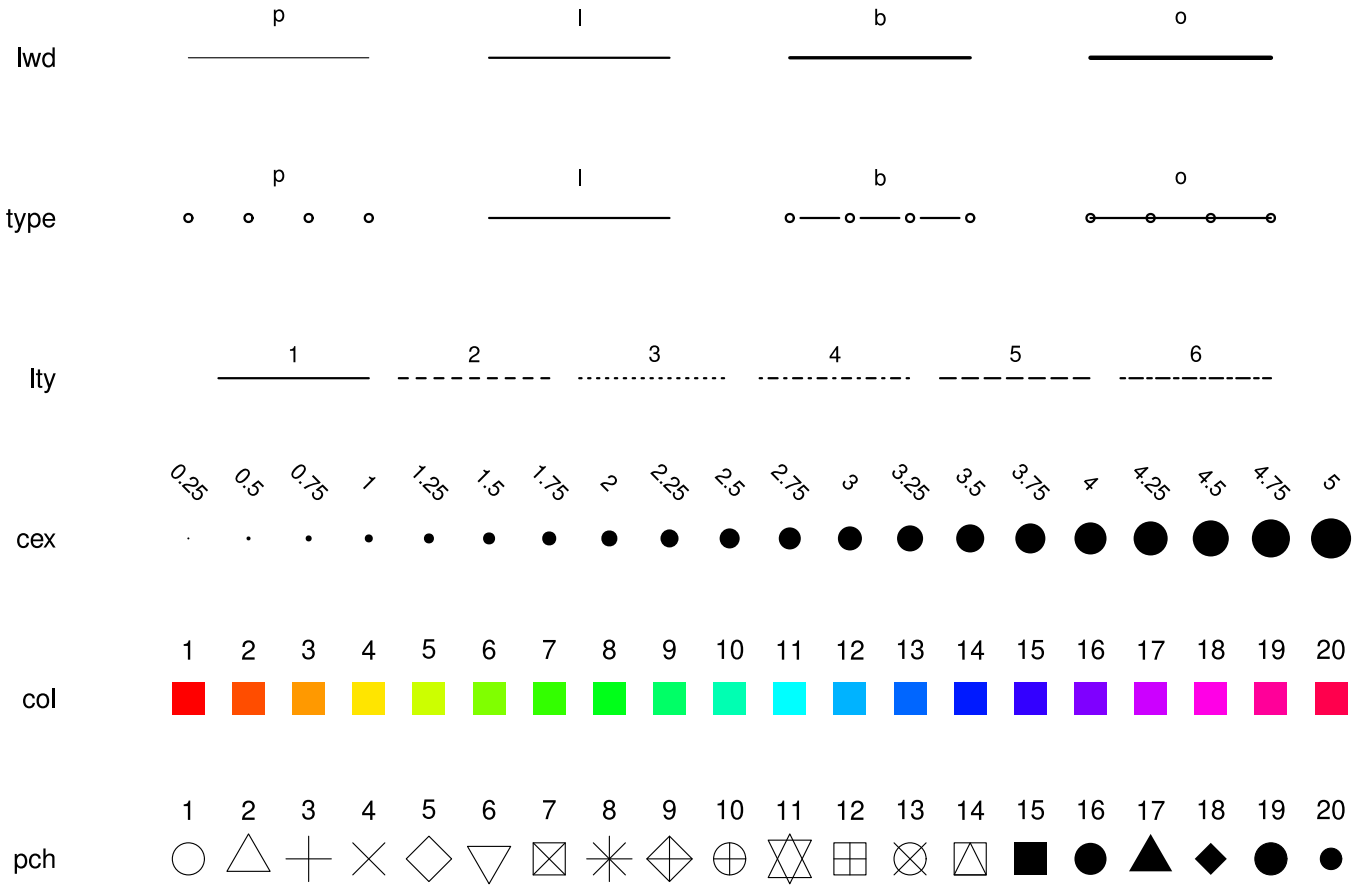
```
box(bty = "o",
    lwd = 3,
    lty = 3)
```

```
box(bty = "o",
    lwd = 3,
    lty = 4)
```

```
box(bty = "o",
    lwd = 3,
    lty = 5)
```

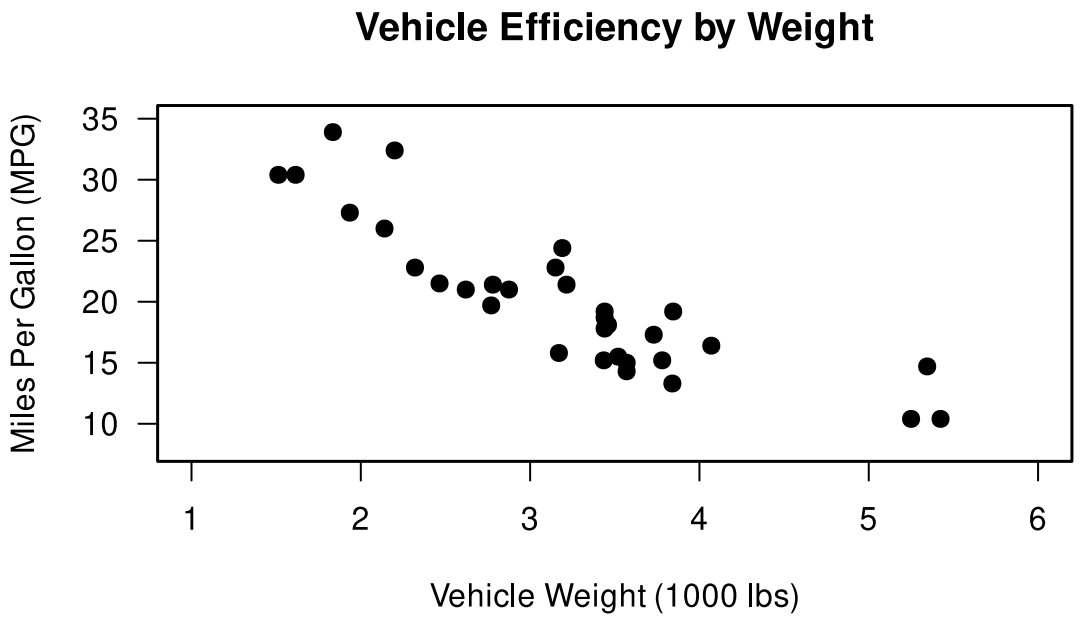
```
box(bty = "o",
    lwd = 3,
    lty = 6)
```

Point and Line Types



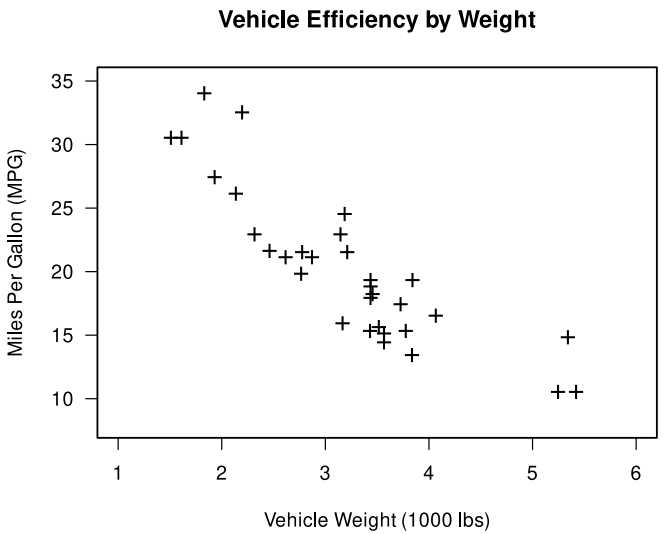
Adjusting Point Shape with `pch`

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.25, # size
     pch = 16) # shape
```

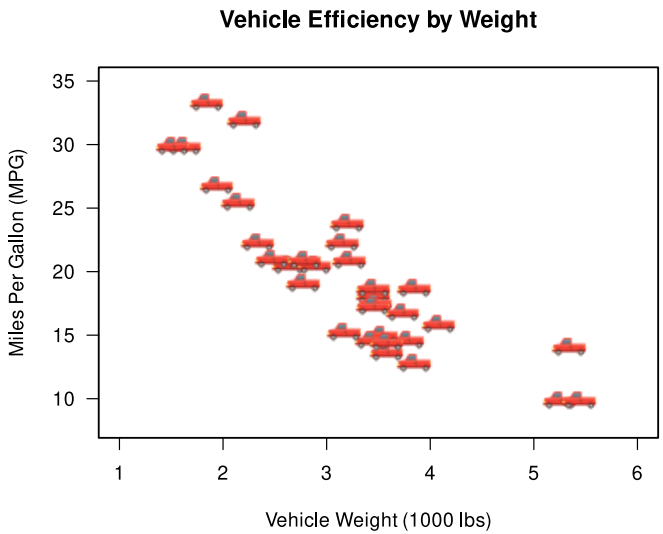


`pch` is customizable

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5,
     pch = "+")
```




```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5,
     pch = "🚚") # truck emoji
```

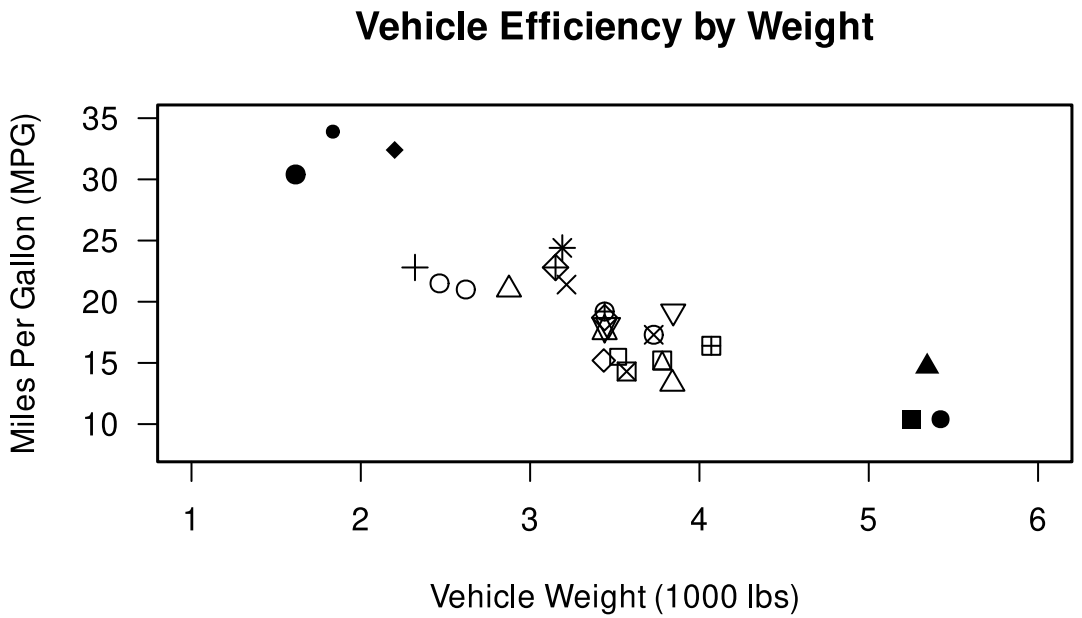


`pch` is vectorized

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.25,
     pch = 1:nrow(mtcars))
```

👈 Because there are only 1:20 valid values of `pch`, R will give you a warning and recycle the 1:20 vector

👈 Each value 1:20 maps onto the element passed to `x` and `y`



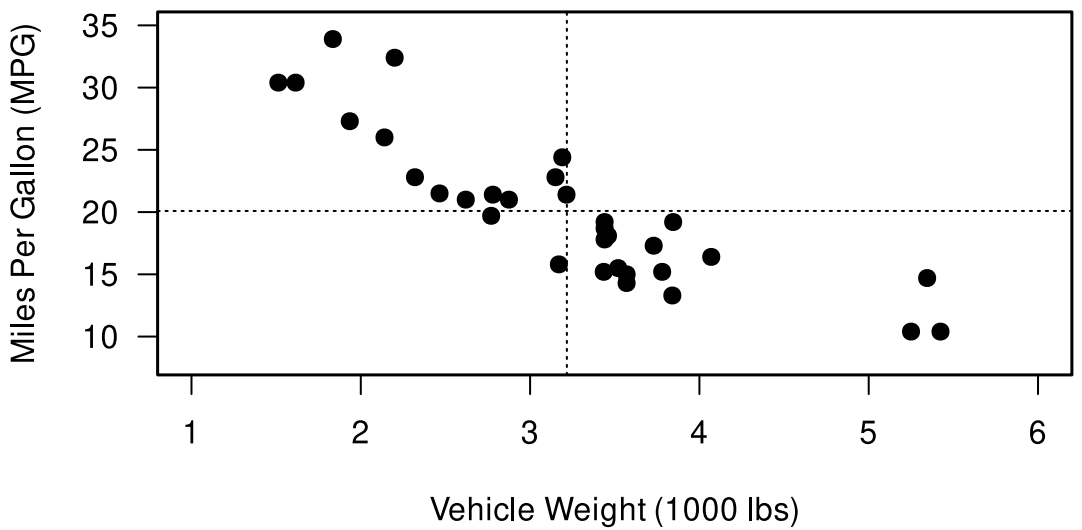
Adding lines to your plot

There are *many* ways to add lines to a plot in R. Some of the most common lines are vertical or horizontal lines, regression lines, and local regression (LOWESS) lines.

The `abline()` function can take either **(a)** a fitted regression object, **(b)** the intercept (`a`) and slope (`b`) values, **(c)** a y-axis value for horizontal lines (`h`), or **(d)** an x-axis value for vertical lines (`v`).

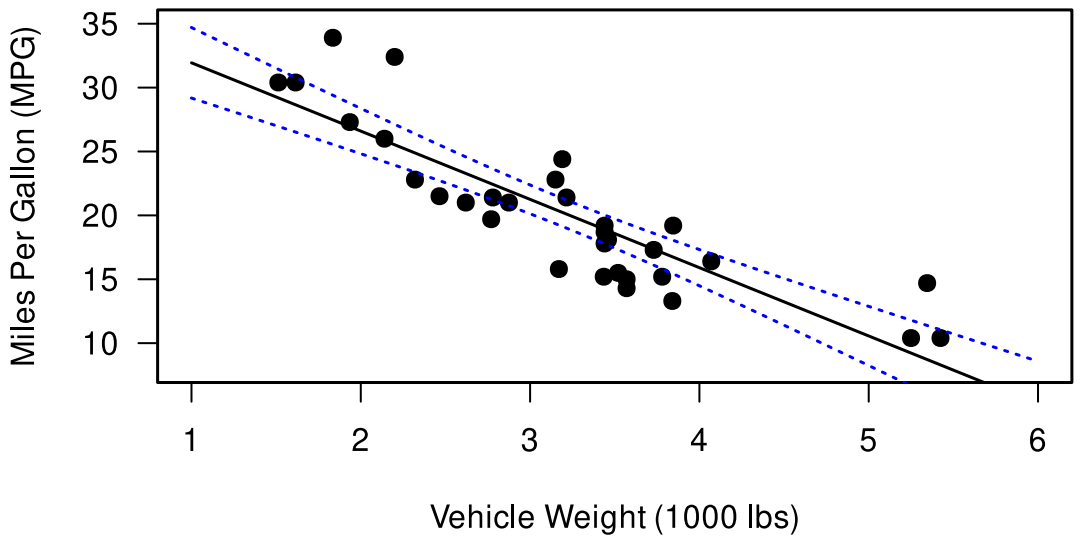
For example, to add lines at the mean of x and y:

```
plot(...)
abline(v = mean(mtcars$wt, na.rm = T),
       h = mean(mtcars$mpg, na.rm = T),
       lty = 3)
```



matlines()

```
plot(...)

fit <- lm(mpg ~ wt,
          data = mtcars)

new_wt <- seq(1, 6, .05)
pred <- predict(fit,
                newdata = data.frame(wt = new_wt),
                interval = "confidence",
                level = 0.95)

# Plots multiple lines based on a matrix of cols (with x and y line coords)
matlines(new_wt, pred,  lty = c(1, 3, 3), lwd = 1.5, col = c("black", "blue", "blue"))
```

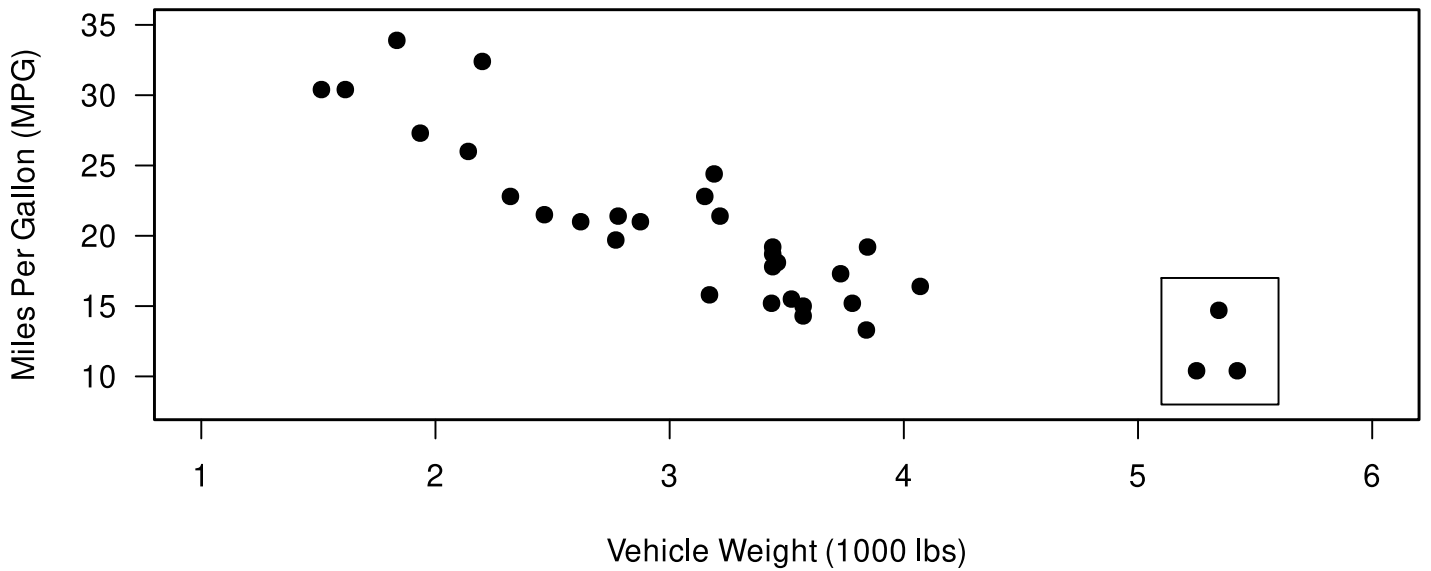


`lines()`

The `lines()` function is a generic function that takes either `x` and `y` coordinates to plot a line (similar to `matlines()`) or a formula to compute these coordinates

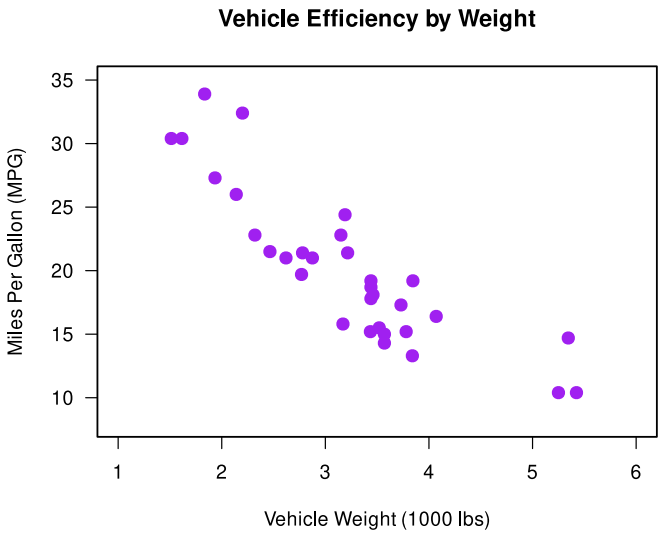
For example, let's draw a box around the three heaviest cars:

```
plot(...)

lines(x = c(5.1, 5.6, 5.6, 5.1, 5.1),
      y = c(17, 17, 8, 8, 17))
```

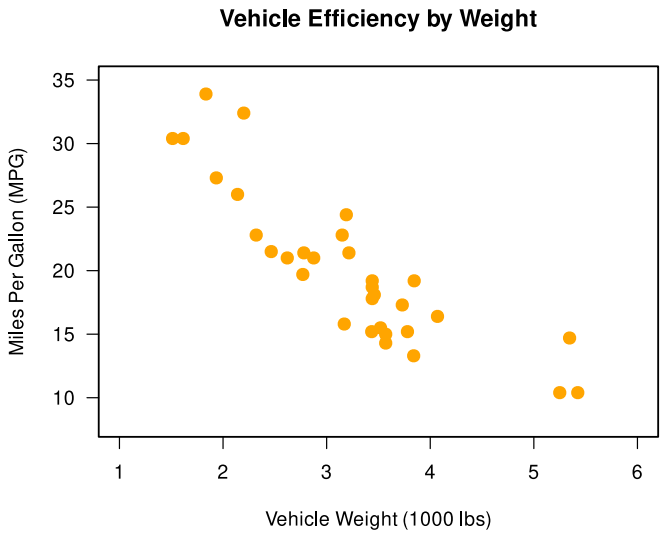


Adjusting Point Colors with `col`

```r
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5,
     pch = 16,
     col = "purple")
```

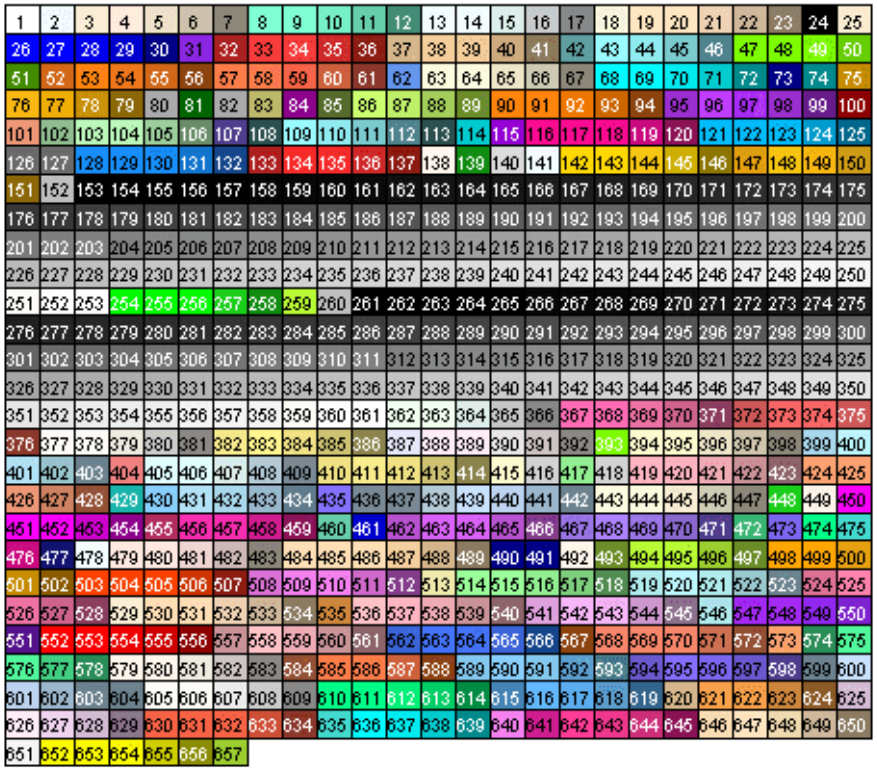



```r
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5,
     pch = 16,
     col = "orange")
```



R's Colors

R has built-in colors that can be accessed by name or by index with the `col` argument (we did this in the previous slide). To see the list of all 657 colors, use the `colors()` function, or see this PDF.



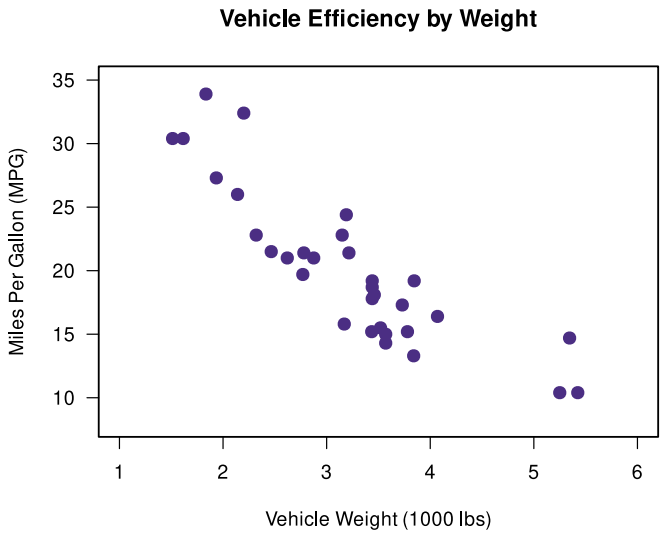
HTML Color Codes

R can also take hex codes or RGB (red, blue, green) color codes, which gives you access to infinite colors. Use this tool to help you find exactly the color you want.

When you use RGB color codes you can also specify the **alpha channel**, which gives the colors transparency (this is also possible with HEX codes, just harder)

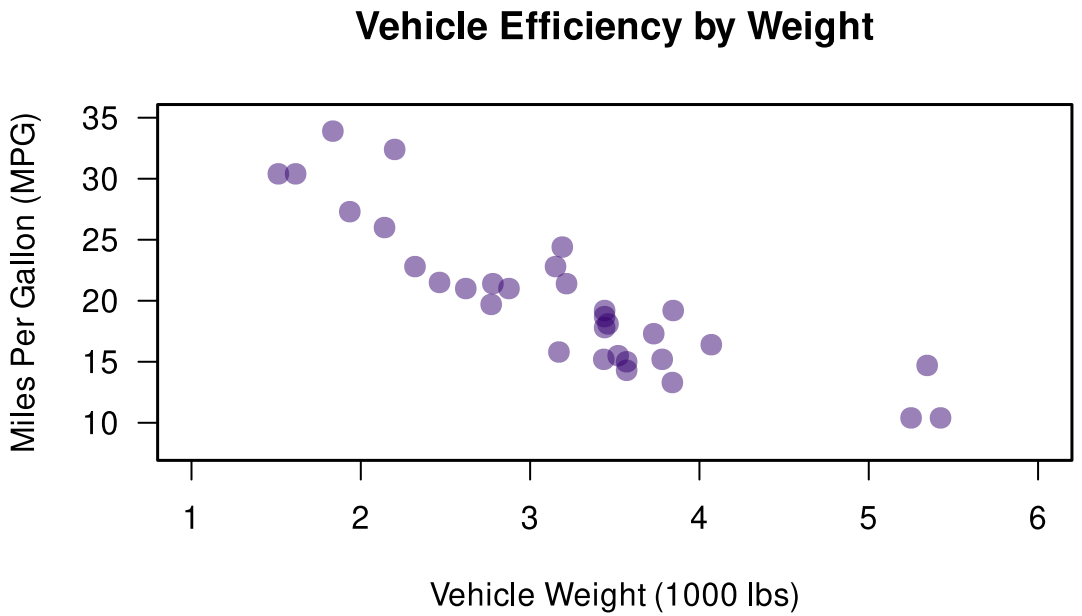
```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5, pch = 16,
     col = "#4b2e83") # UW purple
```

```
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5, pch = 16,
     col = rgb(51, 0, 111,  # UW purple
               maxColorValue = 255))
```



Transparency with Alpha

```r
plot(x = mtcars$wt, y = mtcars$mpg,
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     cex = 1.5, pch = 16,
     col = rgb(51, 0, 111, 255*.5, # 0 = transparent, 1 = completely opaque
               maxColorValue = 255))
```



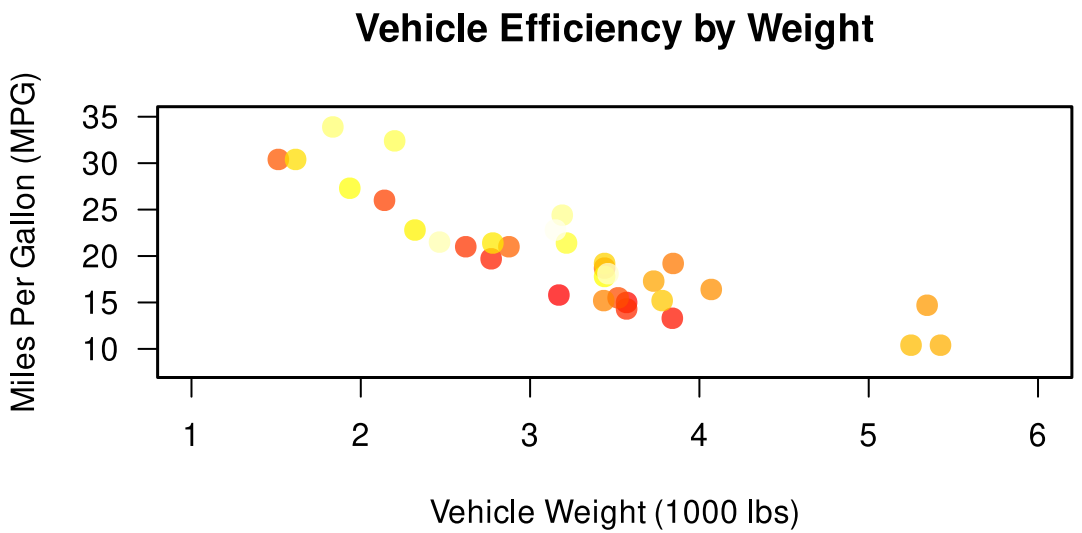
R's Color Functions

- `rainbow()`: `n` colors (with `alpha` transparency) corresponding with the rainbow color spectrum
- `heat.colors()`: `n` colors (with `alpha` transparency) ranging from red to light yellow
- `terrain.colors()`: `n` colors (with `alpha` transparency) corresponding with terrain map colors
- `topo.colors()`: `n` colors (with `alpha` transparency) corresponding with topography map colors
- `cm.colors()`: `n` colors (with `alpha` transparency) ranging from cyan to magenta
- `hcl()`: create vector of colors from vectors specifying hue (`h`), chroma (`c`), and luminance (`l`)
- RColorBrewer: An R package with convenient color scheme and functions. See `RColorBrewer::display.brewer.all()` to plot the available color palettes.

`col` is vectorized

The `col` argument is vectorized, which means you can do things like create another dimension (color) in your data to represent more information. For example, using `heat.colors()`, we will color the fastest 1/4 mile time red and the slowest light yellow:

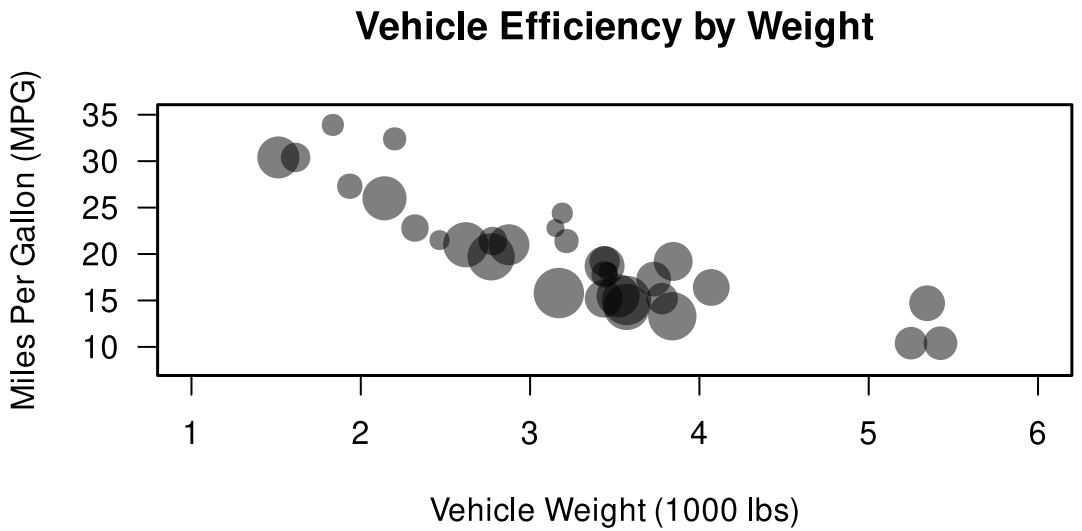
```
plot(x = mtcars[order(mtcars$qsec), c("wt", "mpg")], # order rows by qsec
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     pch = 16, cex = 1.50,
     col = heat.colors(length(mtcars$wt), alpha = .75))
```



`cex` is vectorized

The `cex` argument is also vectorized and can be used to create new dimensions in your figures. In this plot, larger points represent faster 1/4 mile times.

```
plot(x = mtcars[order(mtcars$qsec), c("wt", "mpg")], # order rows by qsec
     main = "Vehicle Efficiency by Weight",
     xlab = "Vehicle Weight (1000 lbs)",
     ylab = "Miles Per Gallon (MPG)",
     pch = 16,
     cex = seq(3.5, 1.25, length.out = nrow(mtcars)),
     col = rgb(0, 0, 0, .5))
```

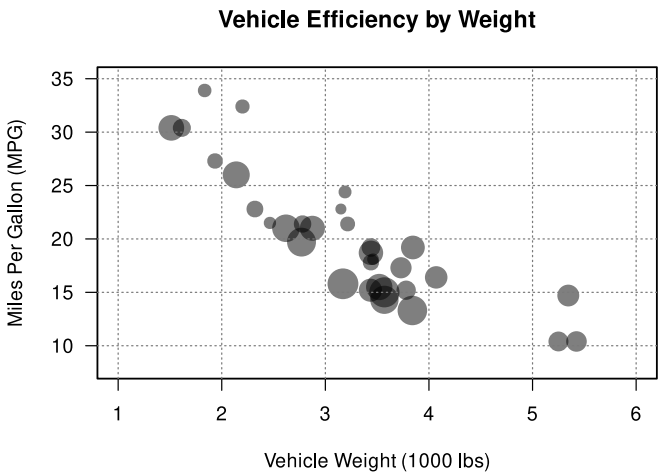


Creating Grids

```
grid(nx = NULL, ny = nx, col = "lightgray", lty = "dotted",
     lwd = par("lwd"), equilogs = TRUE)
```

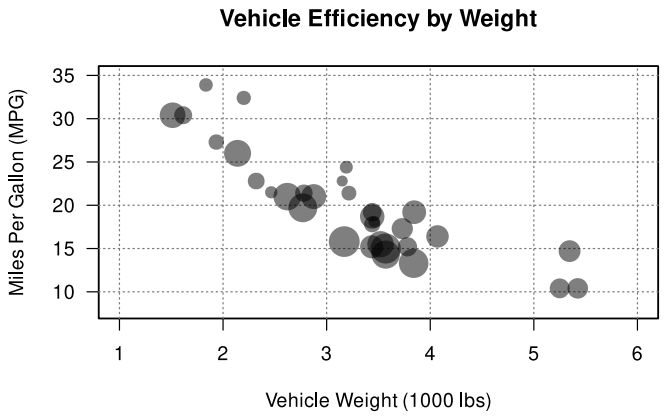
By default the number of lines in the x and y directions will match the number of tick marks

```
plot(...)
grid(col = "gray48")
```



☝Problem: gridlines placed on top of the points

```
plot(..., type = "n") # do not plot points
grid(col = "gray48")
points(x = mtcars[order(mtcars$qsec), c("wt
       pch = 16,
       cex = seq(3.5, 1.25, length.out = nr
       col = rgb(0, 0, 0, .5))
```

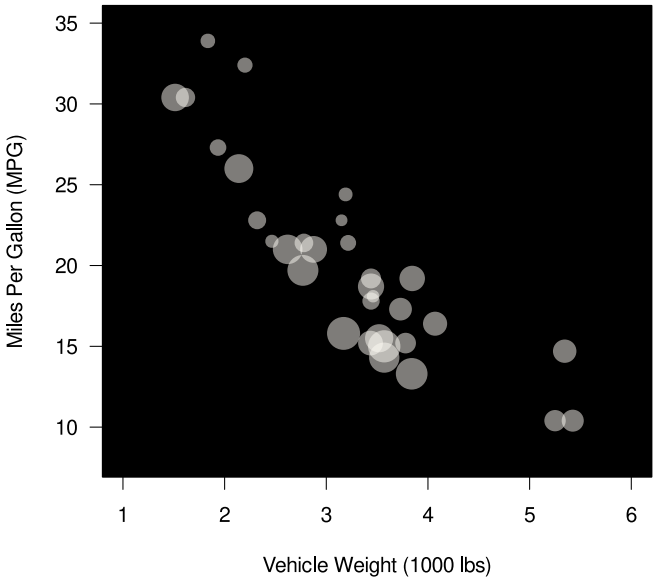


Plot Background

To change the background of *just the plot region* (i.e., where the points go), you need to:

1. Create an empty plot
2. Create a rectangle using `rect()` of the plotting region
3. Create points (and anything else you want to plot) over the rectangle

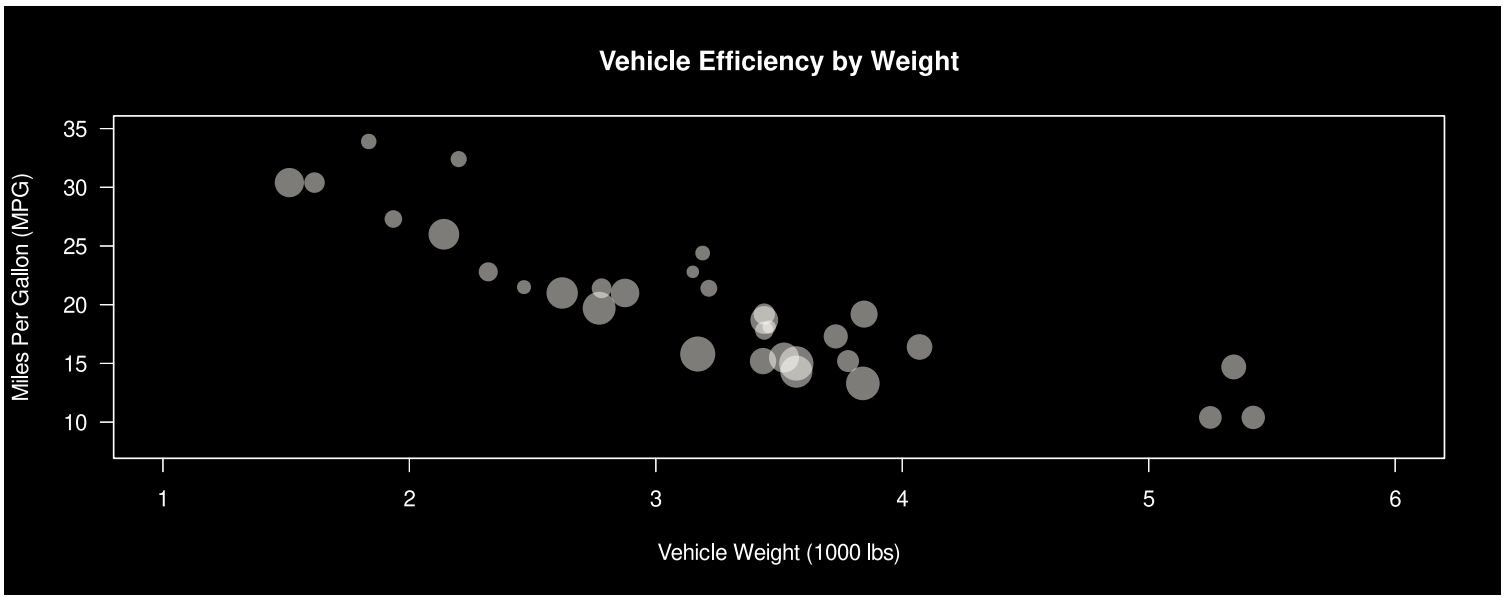
```
plot(..., type = "n")

rect(xleft = par("usr")[1],
     ybottom = par("usr")[3],
     xright = par("usr")[2],
     ytop = par("usr")[4],
     col = "black")

points(x = mtcars[order(mtcars$qsec), c("wt
       pch = 16,
       cex = seq(3.5, 1.25, length.out = nr
       col = rgb(255, 252, 245, 255*.5, max
```



Plotting Area Background

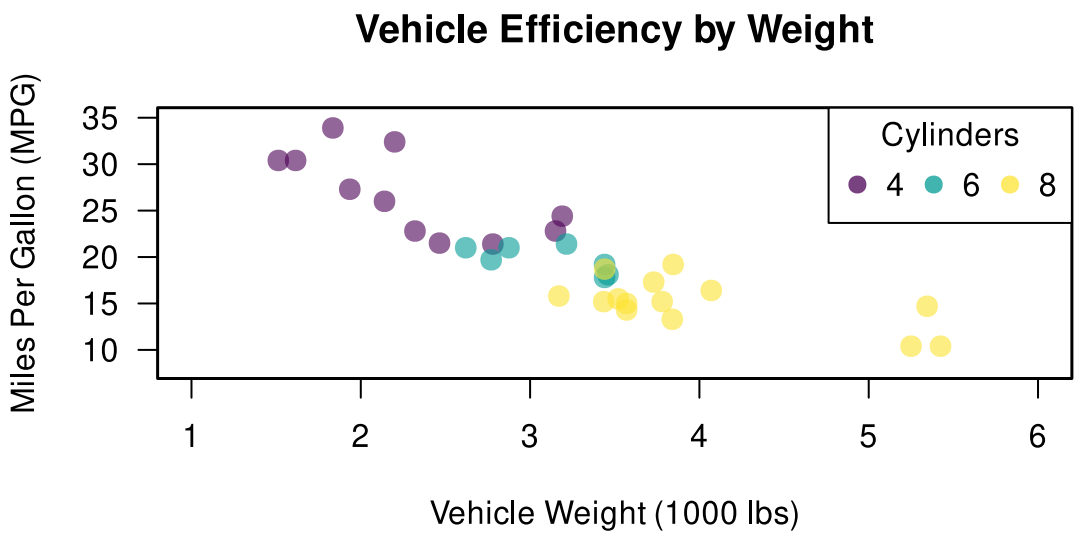
Changing the background of the entire plotting area is much easier than changing just the plotting region

```
par("bg" = "black", # Change background color
    "fg" = "white") # Change foreground color (box, axes, tick marks)

plot(...,
     col = "white",      # Points
     col.main = "white", # Main title
     col.lab = "white",  # Axis labels
     col.axis = "white") # Tick labels
```



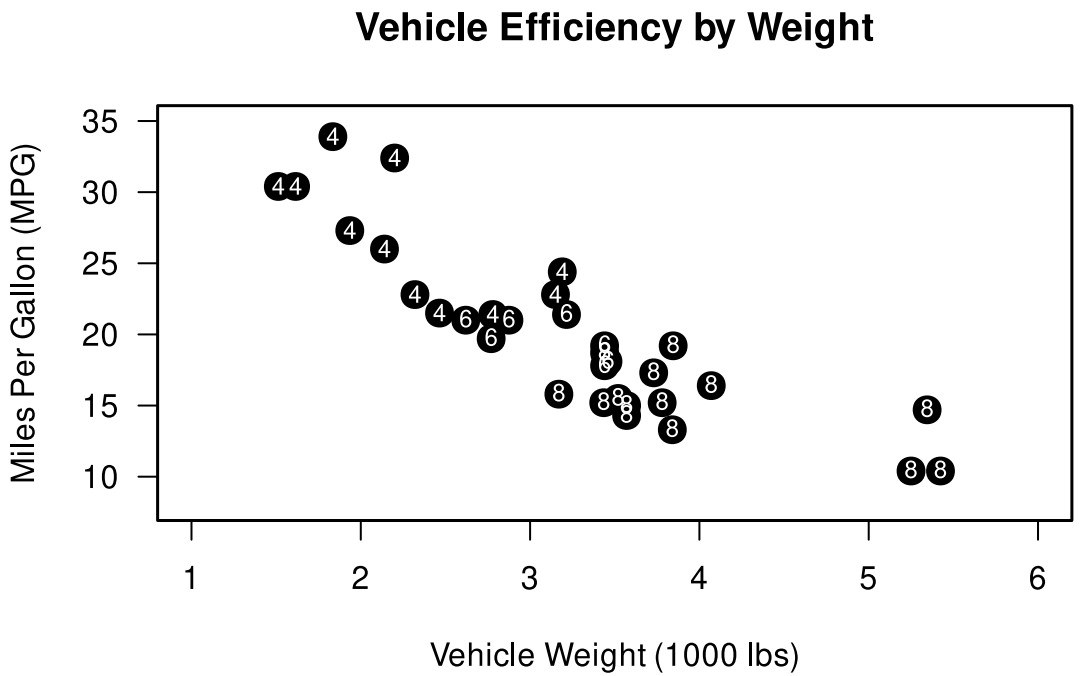
Legends

```
plot(x = mtcars[order(mtcars$cyl), c("wt", "mpg")], # order rows by cyl
     col = rep(hcl.colors(3, alpha = .6), times = table(mtcars$cyl)), # color by cyl
     ...) # color by cyl

legend(x = "topright", # takes keywords OR x, y coordinates
       title = "Cylinders", # legend title
       legend = seq(4, 8, 2), # values inside legend
       col = hcl.colors(3, alpha = .75), # colors corresponding with values
       horiz = T, # plot legend horizontally
       pch = 16) # shape of legend point
```



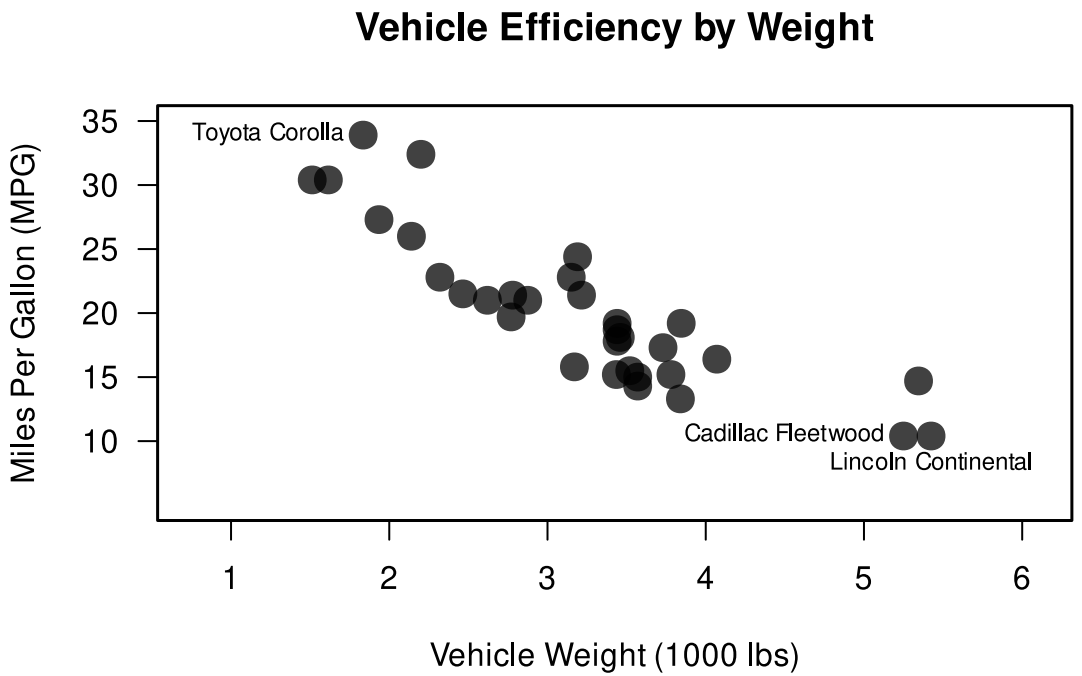
Adding Text to Plots

```
plot(...)

text(x = mtcars[, c("wt", "mpg")], # x,y coordinates of labels
     labels = mtcars$cyl,
     col = "white",
     cex = .75)
```



Labeling Specific Points

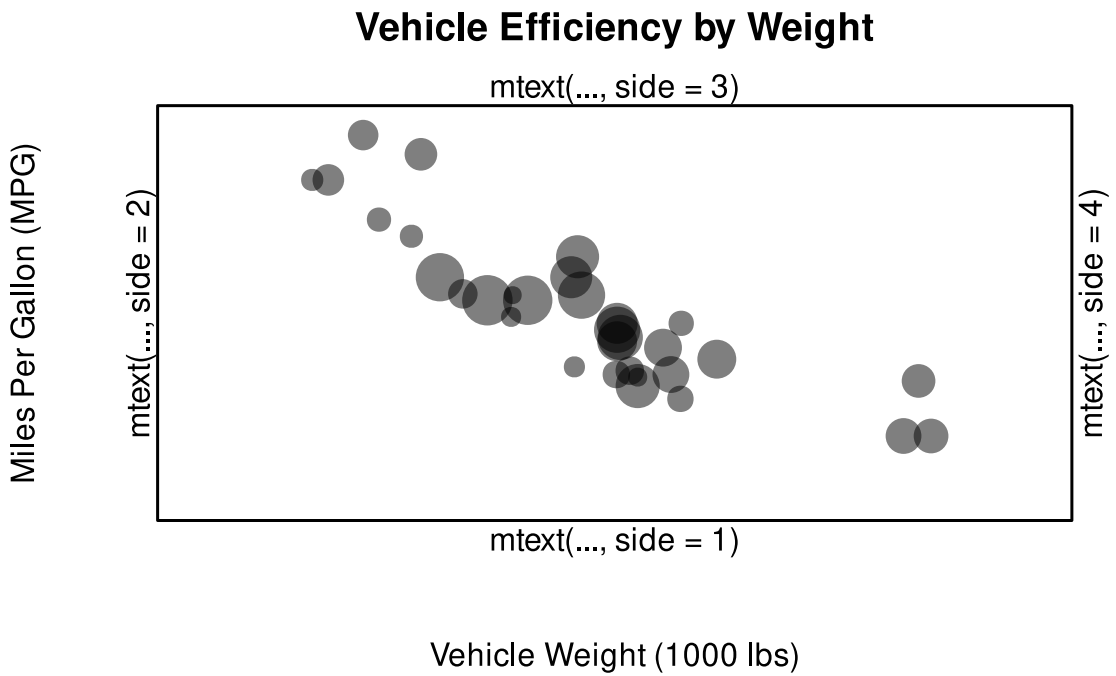
```
plot(...)

text(x = mtcars[mtcars$mpg %in% c(min(mtcars$mpg), max(mtcars$mpg)), c("wt", "mpg")],
     labels = rownames(mtcars)[mtcars$mpg %in% c(min(mtcars$mpg), max(mtcars$mpg))],
     cex = .75,
     pos = c(2, 1, 2))
```



Margin text with `mtext()`

Sometimes you want to put text in the margins of the plot (e.g., when you have multiple plots and you want to give them all one title). For that you can use the `mtext()` function (for **m**argin **text**).

```
for(i in 1:4){
  mtext(paste0("mtext(..., side = ", i, ")"), side = i)
}
```



Changing Fonts

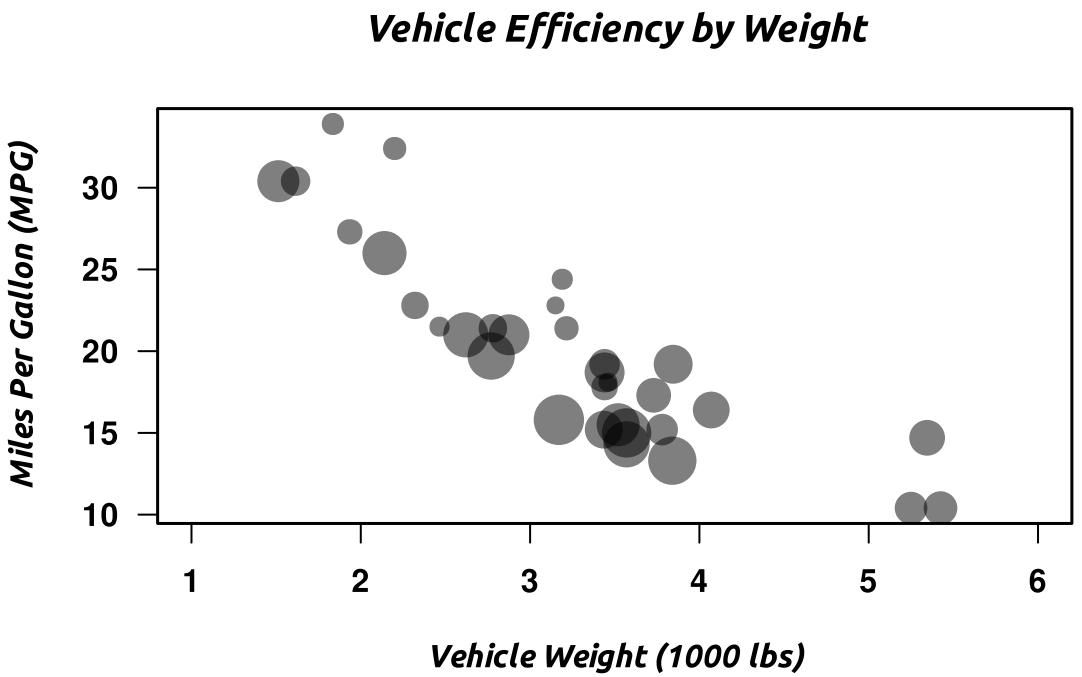
Changing font size and style is easy, but changing font family is a bit trickier because it depends on the fonts you have installed on your operating system

The `extrafont` package extends the fonts available for plotting in R. First, install the package with `install.packages("extrafont")` then import the fonts with `extrafont::font_import()`

Font `par` arguments:

- `font`: Integer which specifies which font style to use for text
    - 1 = plain
    - 2 = **bold**
    - 3 = *italic*
    - 4 = ***bold italic***
- `font.axis`: Integer which specifies which font to use for axis annotation
- `font.lab`: Integer which specifies which font to use for x and y labels (axis labels)
- `font.main`: Integer which specifies which font to use for main titles
- `font.sub`: Integer which specifies which font to use for subtitles

```
plot(...,
     family = "Ubuntu", # Ubuntu font
     font.main = 4, # Title (bold, italic)
     font.axis = 2, # Axis tick mark labels (bold)
     font.lab = 4) # Axis labels (bold italic)
```



Multiple Plots in Same Window

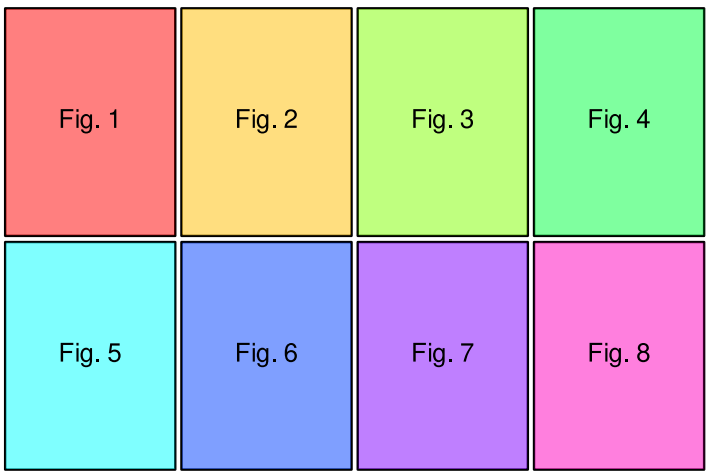
There are two primary ways of creating multiple figures within the same window in R:

- `par`'s `mfrow` and `mfcol` arguments
- the `layout()` function

`mfrow` and `mfcol`

These functions take a vector of two elements (nrow, ncol) and draw a grid on the graphing screen that is filled with figures by row (`mfrow`) or by column (`mfcol`)

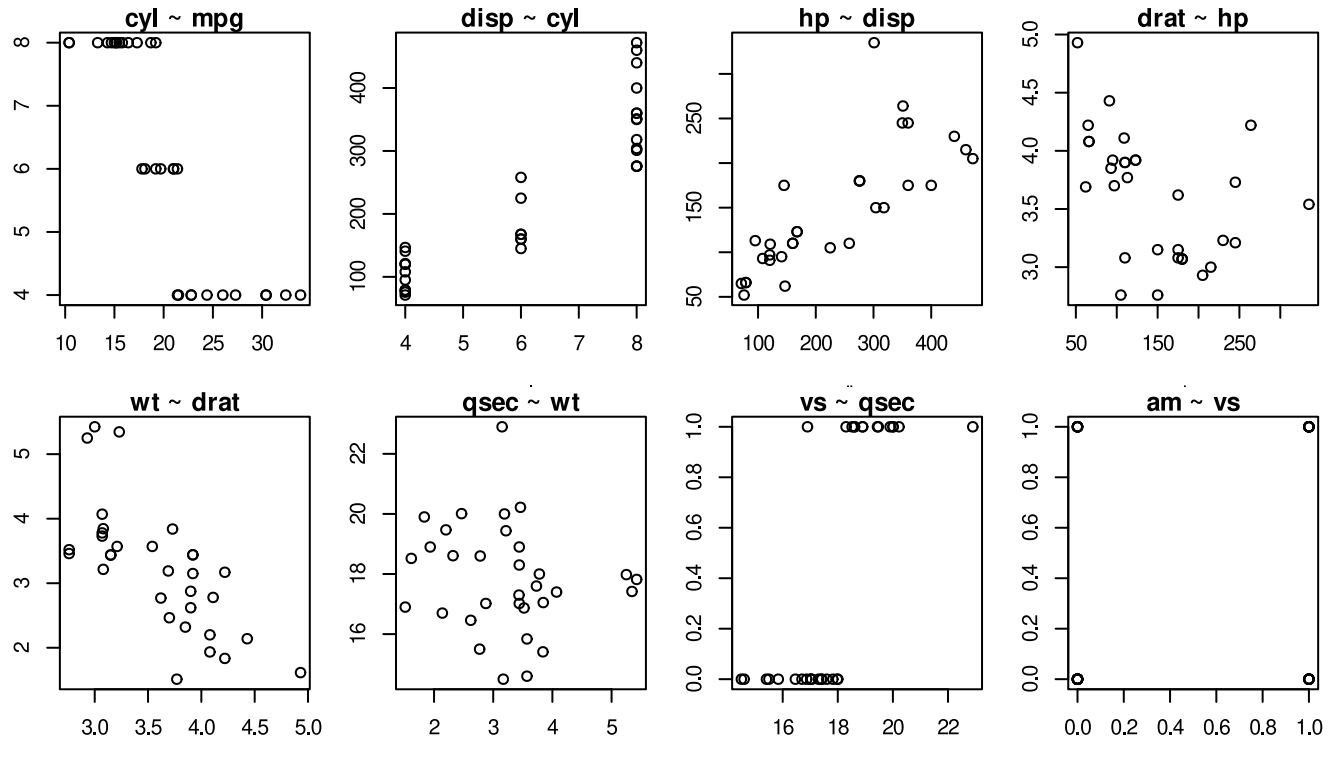
```
par(mfrow = c(2, 4)
```




```
par(mfcol = c(2, 4)
```

`mfrow`/`mfcol` example:

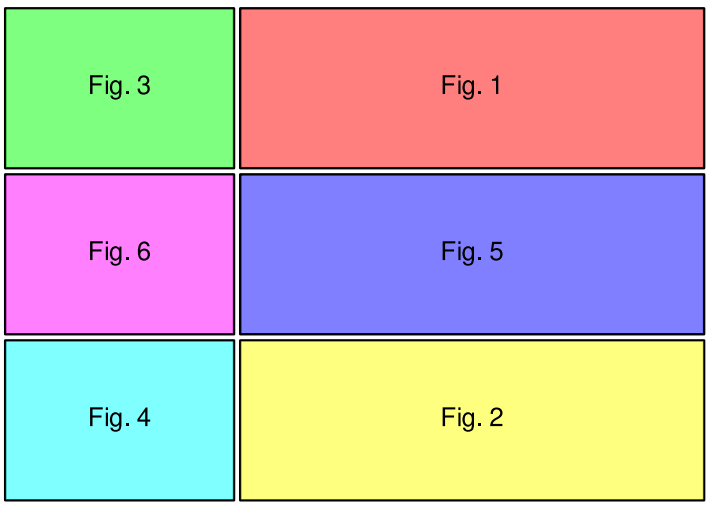
```
par(mfrow = c(2, 4))
for(i in 1:8){
  plot(mtcars[, c(i, i+1)],
       main = paste(colnames(mtcars[, c(i+1, i)]),
                    collapse = " ~ "))
}
```



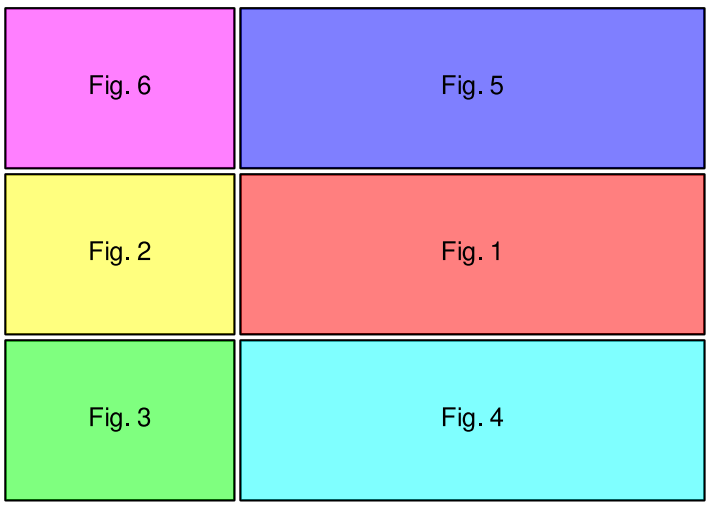
Multiple figures with `layout()`

The `layout` function takes a matrix that specifies the location of the next *N* figures created **and** the order in which they will be placed. The `widths` and `heights` arguments take the relative (or in centimeters if you prefer) row/col widths. For example:

```
layout_mat <- matrix(c(3, 1,
                       6, 5,
                       4, 2),
                     nrow = 3,
                     byrow = T)

layout(layout_mat, c(1, 2), c(1, 1, 1))
```

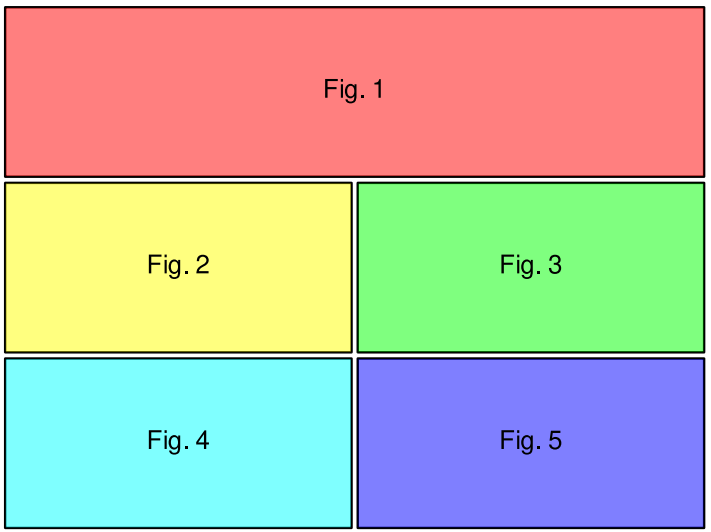



```
layout_mat <- matrix(c(6, 5,
                       2, 1,
                       3, 4),
                     nrow = 3,
                     byrow = T)

layout(layout_mat, c(1, 2), c(1, 1, 1))
```

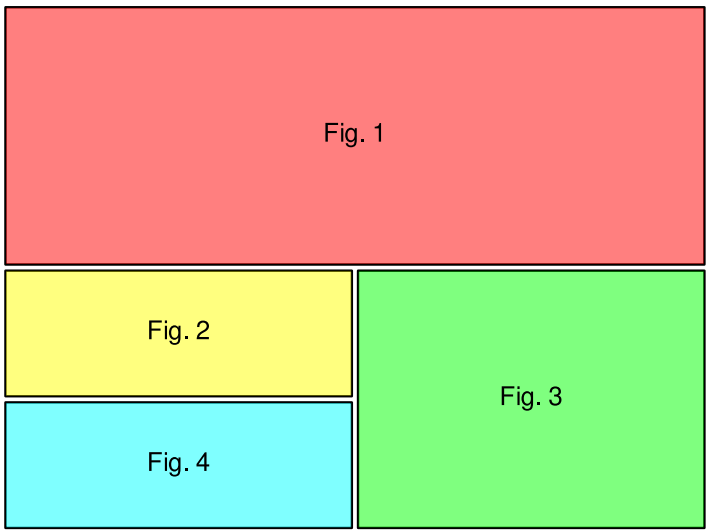


Complex layouts with `layout()`

```
layout_mat <- matrix(c(1, 1,
                       2, 3,
                       4, 5),
                     nrow = 3,
                     byrow = T)

layout(layout_mat, c(1, 1), c(1, 1, 1))
```

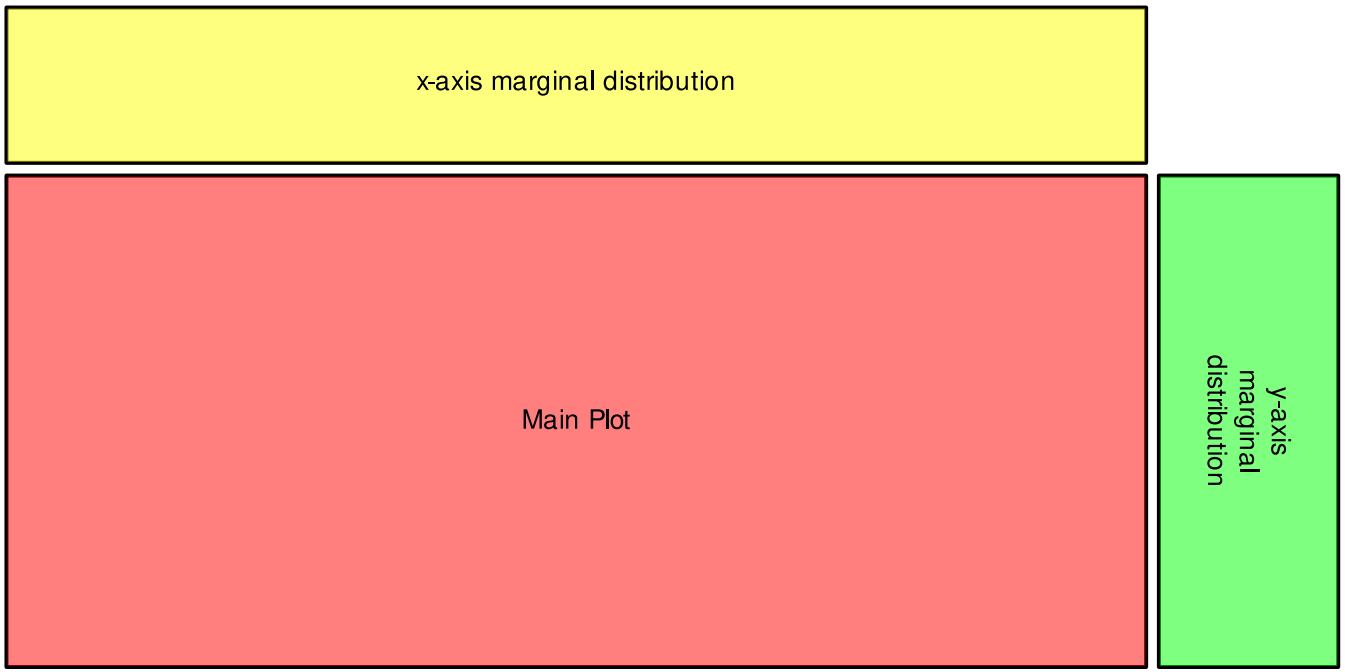



```
layout_mat <- matrix(c(1, 1,
                       2, 3,
                       4, 3),
                     nrow = 3,
                     byrow = T)

layout(layout_mat, c(1, 1), c(2, 1))
```

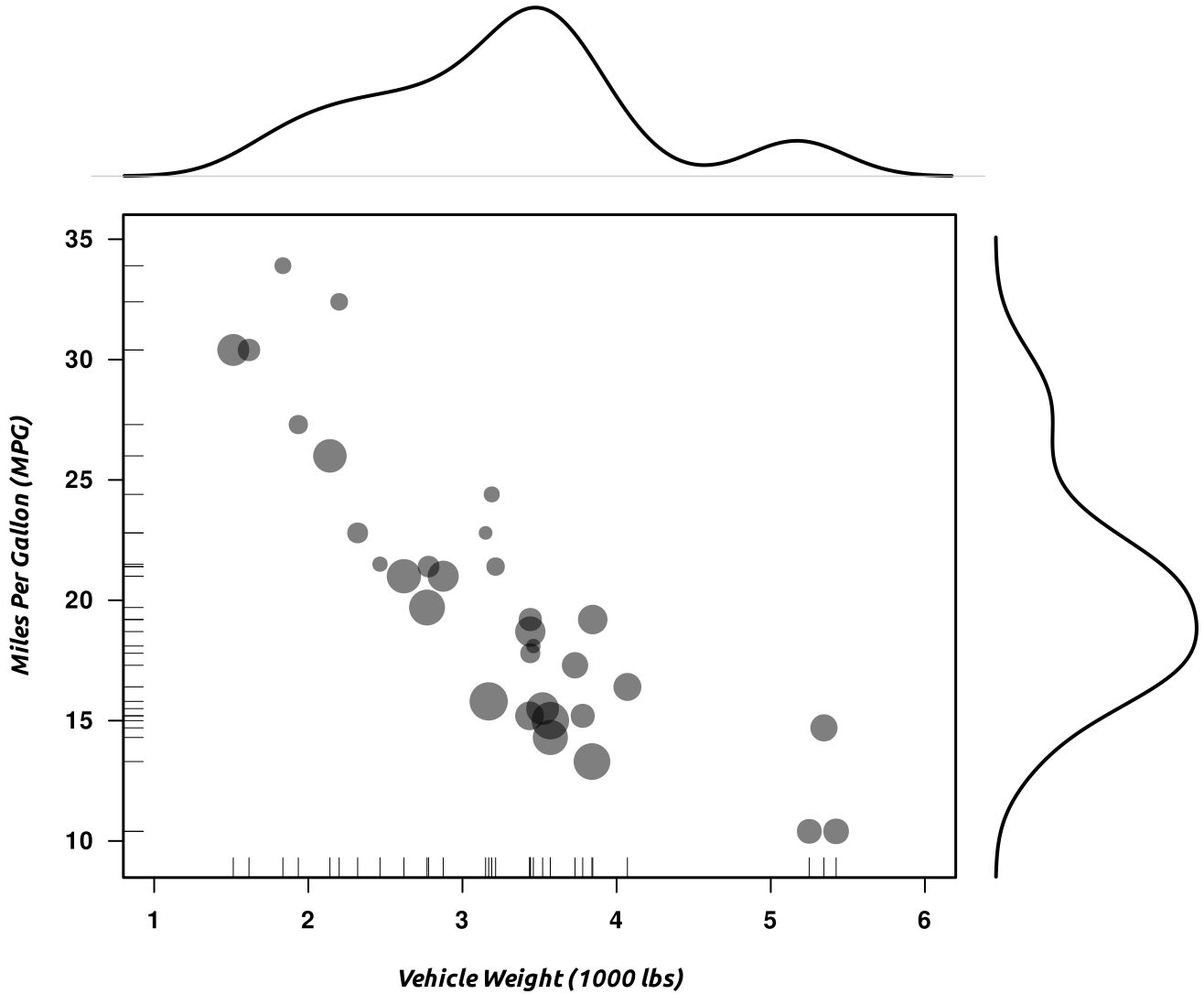


Example: Adding Marginal Distributions

```
layout_mat <- matrix(c(2, 0,
                       1, 3),
                     nrow = 2 byrow = T)

layout(mat = layout_mat,
       widths = c(3, 0.5),
       heights =  c(1, 3))
```



```r
# Plot main scatterplot
par(mar = c(5, 4, 1, 1) + 0.1)
plot(...)

# Add marginal rugs to x and y axes
rug(mtcars$wt, side = 1)
rug(mtcars$mpg, side = 2)

# Get densities of `wt` and `mpg`
d_wt <- density(mtcars[order(mtcars$qsec), "wt"])
d_mpg <- density(mtcars[order(mtcars$qsec), "mpg"])

par(mar = c(0,3,1,.1))
plot(d_wt, axes = F, main = "", xlab= "", ylab = "", lwd = 2)

par(mar = c(4.25,0,1,1))
plot(d_mpg$y, d_mpg$x, type="l", axes = F, main = "",
     xlab= "", ylab = "", lwd = 2)
```


Miles Per Gallon (MPG)
35
30
25
20
15
10
1
2
3
4
5
6
Vehicle Weight (1000 lbs)

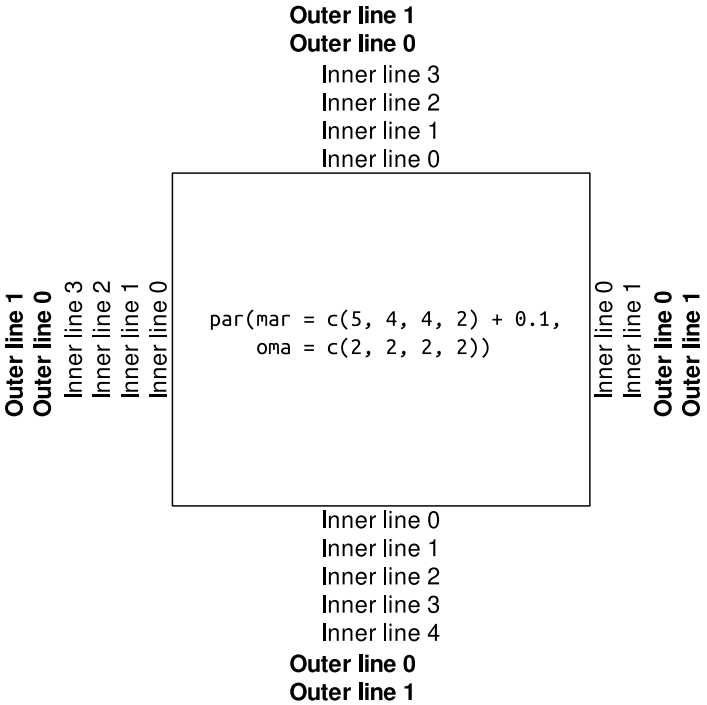
Plot Margins

Inner Margins

Inner margins refer to the margins on each axis

`par("mar")` is a numerical vector corresponding with `c(bottom, left, top, right)` that specifies the number of lines of margin on each side of the plot (default = `c(5, 4, 4, 2) + 0.1`)

`par("mai")` is similar to `mar`, except the margins are specified in inches (default = `c(1.02, 0.82, 0.82, 0.42)`)



Outer Margins

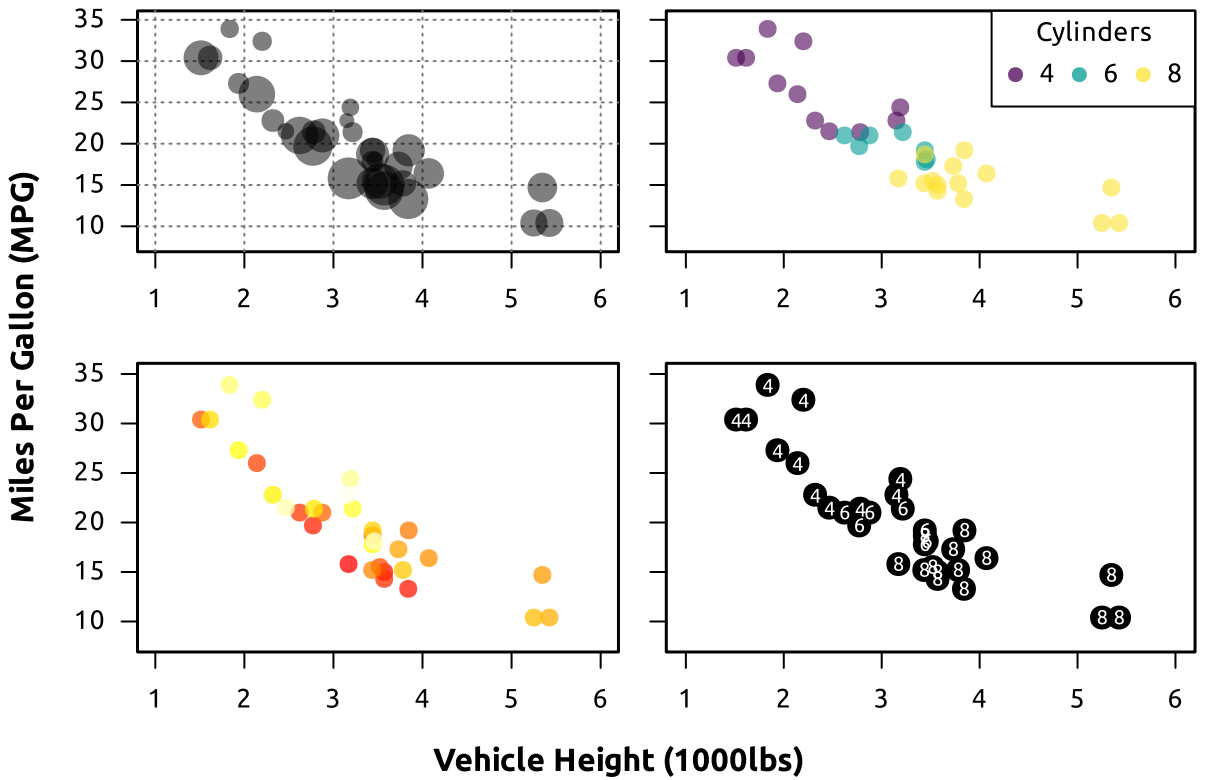
Outer margins correspond with the entire plotting region, not just the axes

`par("oma")` is a numerical vector corresponding with `c(bottom, left, top, right)` that specifies the number of lines of margin on each side of the plot (default is no margin)

`par("omi")` is similar to `oma`, except the margins are specified in inches

Example: Outer Margin Labels

```
par(..., oma = c(2, 2, 0, 4), family = "Ubuntu")

mtext(text="Vehicle Height (1000lbs)", side = 1, line = 0, outer = TRUE, font = 2)
mtext(text="Miles Per Gallon (MPG)", side = 2, line = 0, outer = TRUE, font = 2)
```



Other Types of Plots

Line Graph

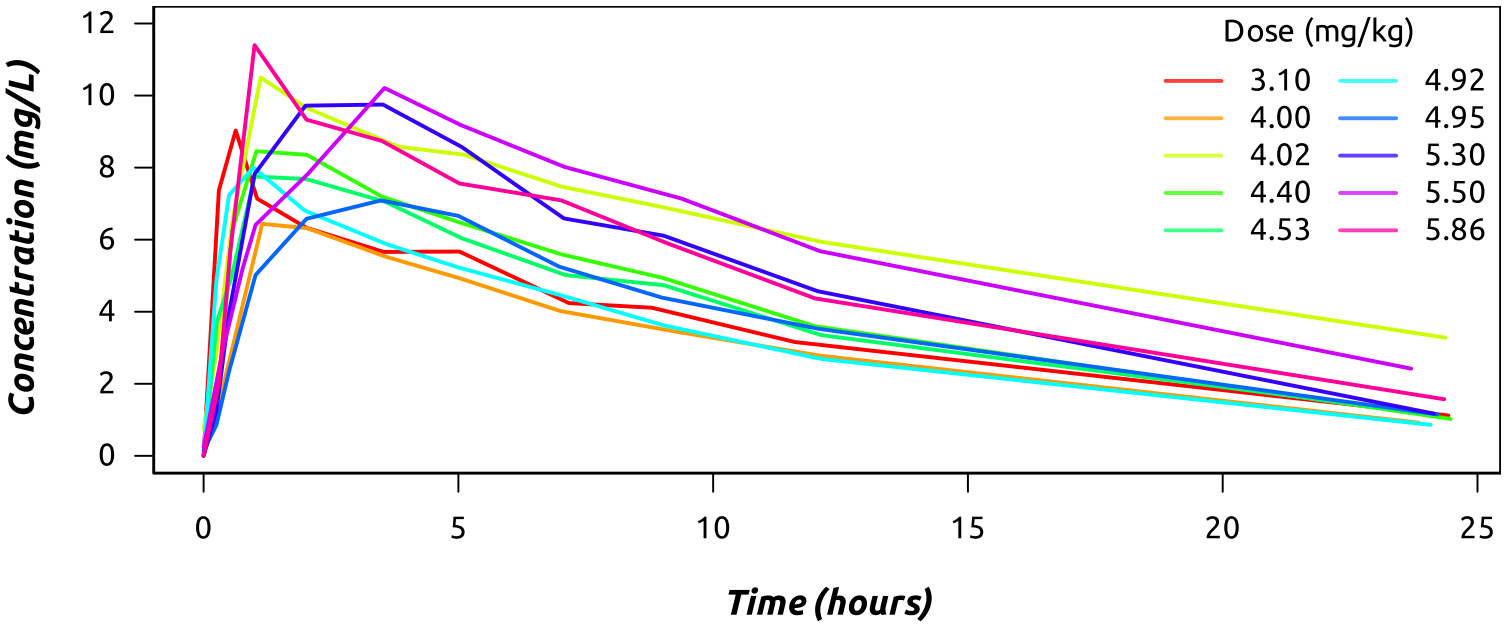
The `Theoph` dataset in Base R has data from an experiment on the pharmacokinetics of theophylline (a medication for lung diseases like COPD). Let's plot the mean theophylline concentration (mg/L) over time (within-subjects) by dose administered (between-subjects).

Data need to be in long form for line graphs

```
conc_data <- Theoph %>%
  mutate(Subject = as.numeric(Subject)) %>%
  group_by(Subject) %>%
  arrange(Time) %>%
  mutate(timepoint = 1:n()) %>%
  group_by(Dose, timepoint) %>%
  summarize(conc = mean(conc, na.rm = T),
            Time = mean(Time, na.rm = T))

glimpse(conc_data)
```

```
## Rows: 110
## Columns: 4
## Groups: Dose [10]
## $ Dose      <dbl> 3.10, 3.10, 3.10, 3.10, 3.10, 3.10, 3.10, 3.10, 3.10, 3.10, …
## $ timepoint <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 1, 2, 3, 4, 5, 6, 7, 8, 9…
## $ conc      <dbl> 0.00, 7.37, 9.03, 7.14, 6.33, 5.66, 5.67, 4.24, 4.11, 3.16, …
## $ Time      <dbl> 0.00, 0.30, 0.63, 1.05, 2.02, 3.53, 5.02, 7.17, 8.80, 11.60,…
```

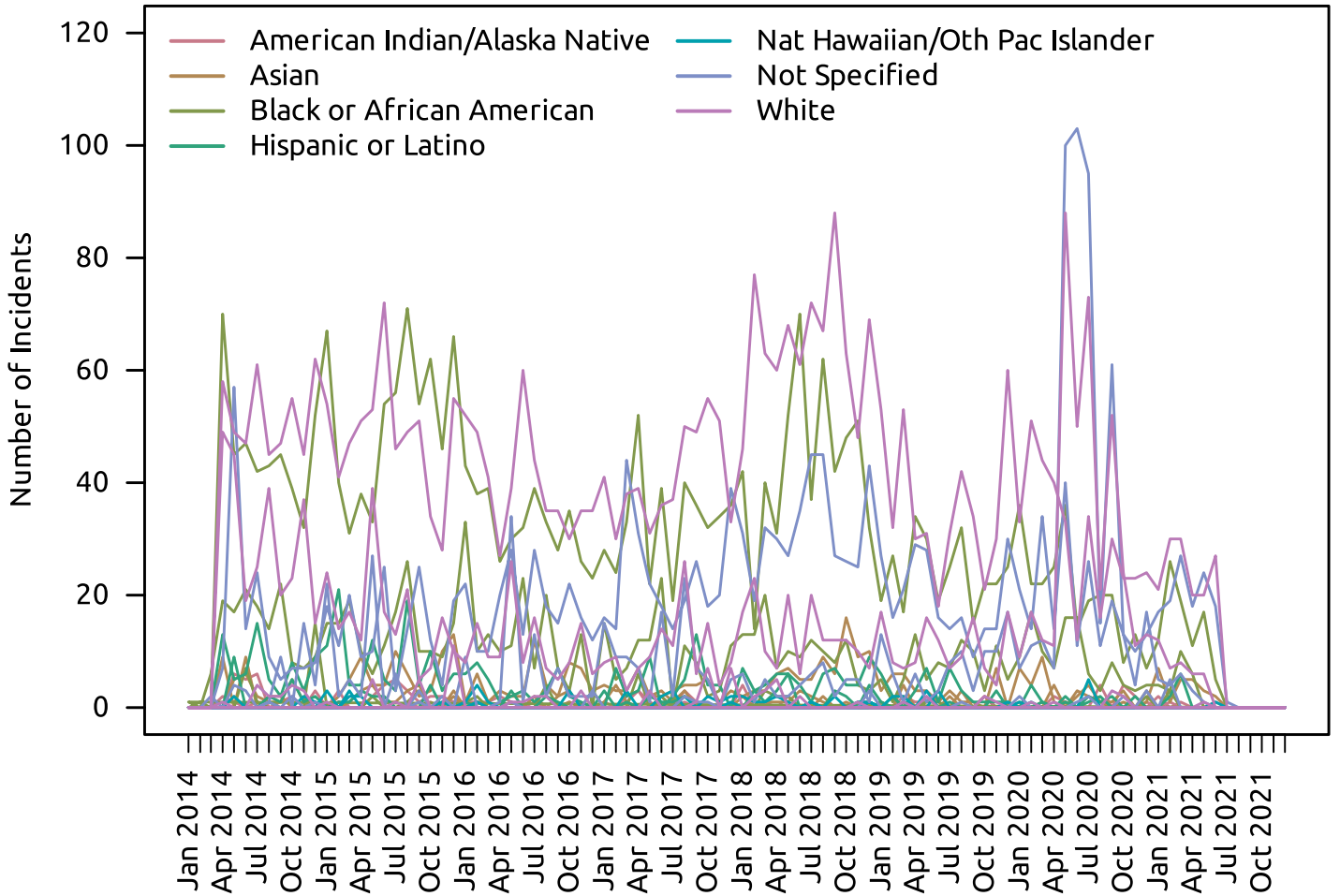
```r
par(mar = c(5, 4, 0, 0))
par(family = "Ubuntu",
    font.lab = 4,
    cex.lab = 1.15)

# Plot empty plot with correct dimensions
plot(x = conc_data$Time, y = conc_data$conc, type = "n", axes = F,
     xlab = "Time (hours)", ylab = "Concentration (mg/L)",
     ylim = c(0, 12))
box(lwd = 1.5)
axis(side = 1, at = axTicks(1), labels = axTicks(1), lwd = 0, lwd.ticks = 1)
axis(side = 2, at = seq(0, 12, 2), labels = seq(0, 12, 2), lwd = 0, lwd.ticks = 1, las = 1)

# Plot line of each dose over time
# lines() is similar to points(type = "l")
```



Plotting dates on the x-axis

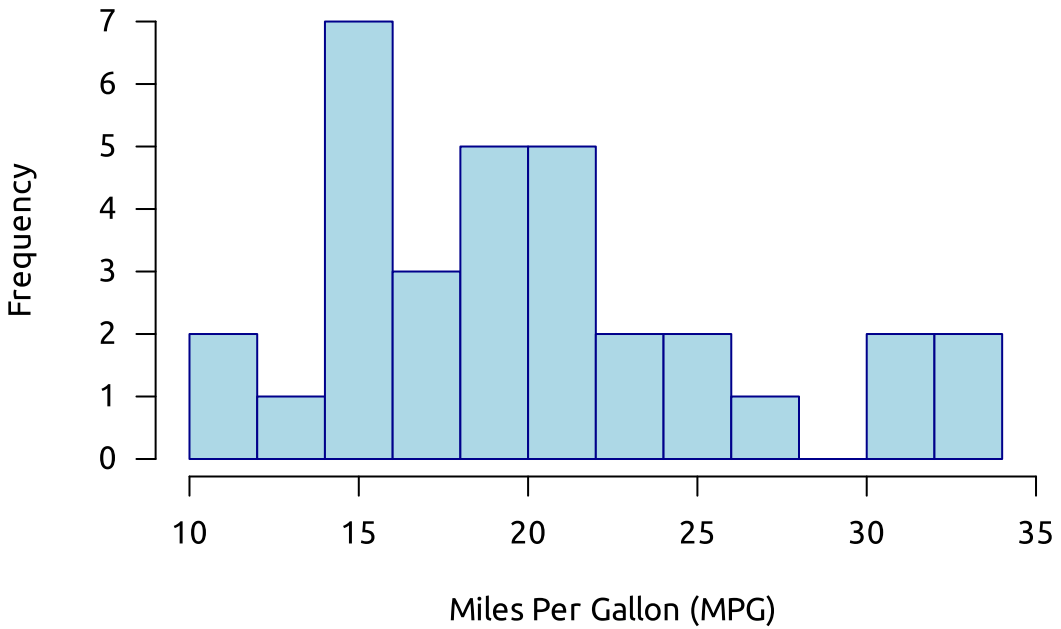
When you have a `Date` column, R's `plot()` will automatically plot the dates properly on the x-axis. If you want to change the x-axis at all (labels, tick marks, other aesthetics), your best bet is to use the special `axis.Date()` function

```
# Axis ticks at each month Jan - Dec
axis.Date(
  # x-axis
  side = 1,

  # Date object to create axis
  x = counts$Date,

  # Ticks from Jan to Dec each year in the data
  at = seq.Date(min(counts$Date),
                max(counts$Date),
                by = "month"),

  # Labels from Jan to Dec each year in the data
  # formatted to Year and abbreviated month name
  # (e.g., 2021 Aug)
  labels = format(seq.Date(min(counts$Date),
                           max(counts$Date),
                           by = "month"), "%b %Y"),

  # Rotate text -90 degrees
  las = 2
)
```


SPD Use-of-Force Incidents by Victim Race
American Indian/Alaska Native
Asian
Black or African American
Hispanic or Latino
Nat Hawaiian/Oth Pac Islander
Not Specified
White
Number of Incidents
120
100
80
60
40
20
0
Jan 2014
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Jan 2016
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017
Jan 2018
Apr 2018
Jul 2018
Oct 2018
Jan 2019
Apr 2019
Jul 2019
Oct 2019
Jan 2020
Apr 2020
Jul 2020
Oct 2020
Jan 2021
Apr 2021
Jul 2021
Oct 2021

Histogram

```
hist(x = mtcars$mpg, # data to plot
     breaks = 15, # change default number of bars
     xlim = c(10, 35), # change size of x-axis
     main = "", # no main title
     xlab = "Mile Per Gallon (MPG)", # x-axis title
     las = 1, # y-axis ticks horizontal
     border = "darkblue", # bar border color
     col = "lightblue") # bar fill color
```

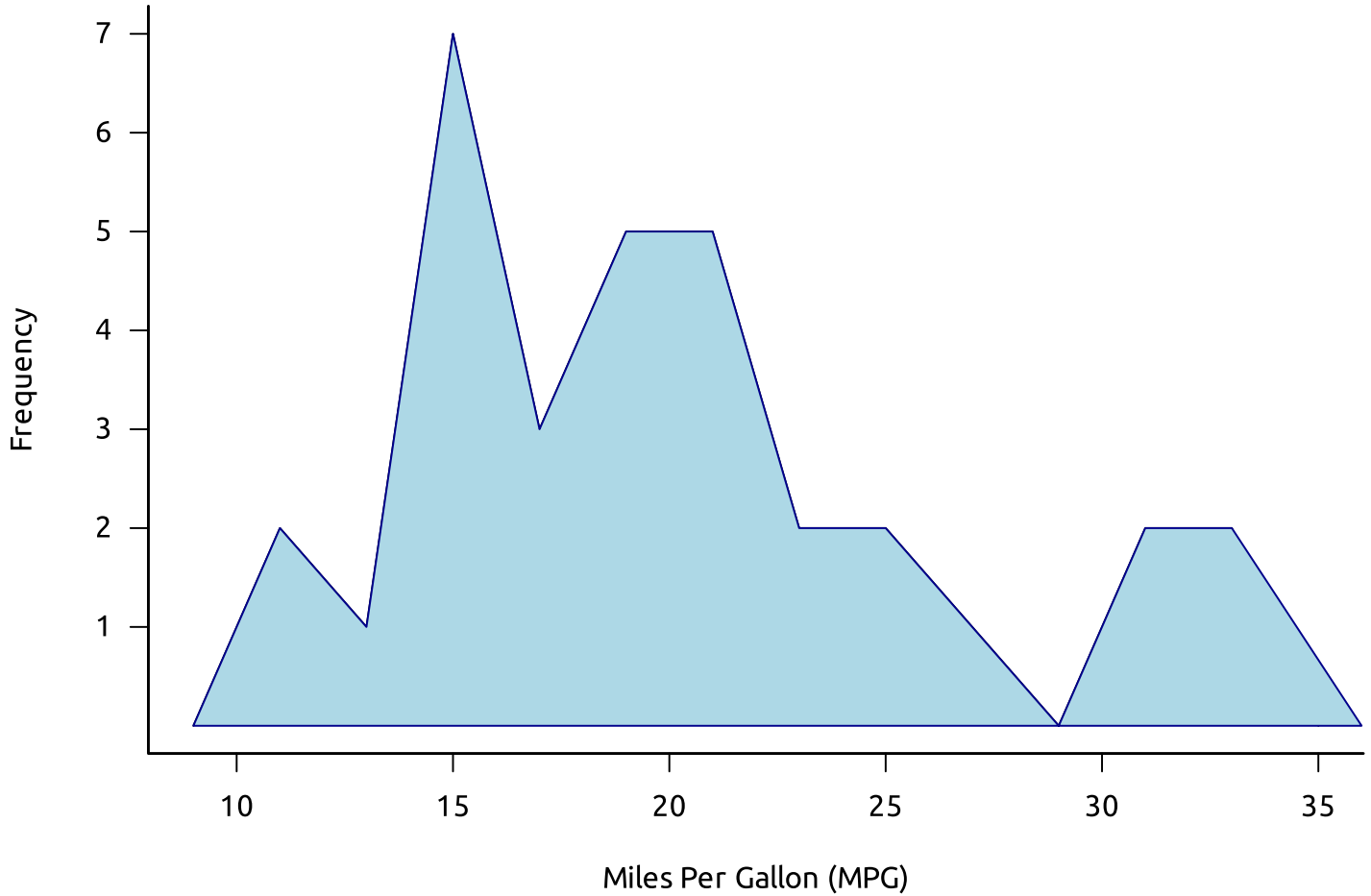


Frequency Polygon

```
# Get histogram parameters without plotting it
p <- hist(x = mtcars$mpg, breaks = 15, plot = F)
str(p)
```

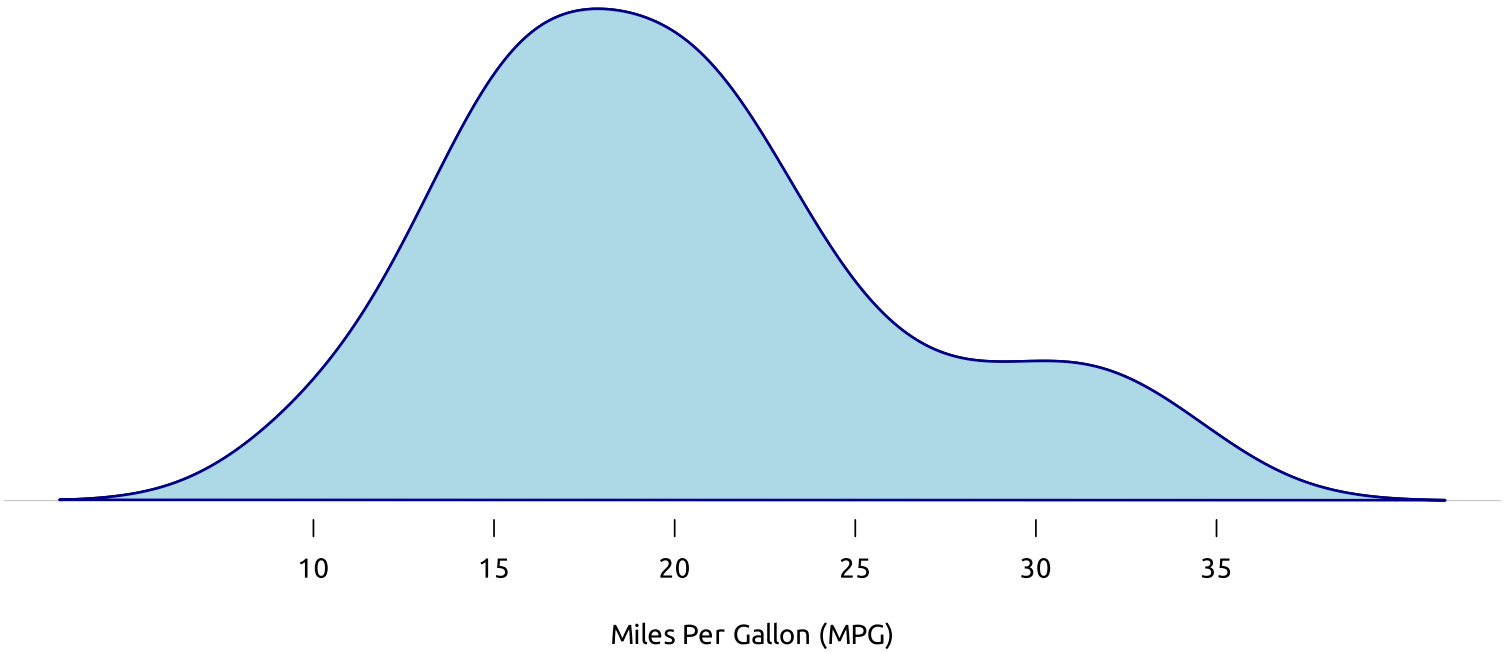
```
## List of 6
##  $ breaks  : int [1:13] 10 12 14 16 18 20 22 24 26 28 ...
##  $ counts  : int [1:12] 2 1 7 3 5 5 2 2 1 0 ...
##  $ density : num [1:12] 0.0312 0.0156 0.1094 0.0469 0.0781 ...
##  $ mids    : num [1:12] 11 13 15 17 19 21 23 25 27 29 ...
##  $ xname   : chr "mtcars$mpg"
##  $ equidist: logi TRUE
##  - attr(*, "class")= chr "histogram"
```

```
# Plot the midpoints and associated frequencies
plot(x = c(min(p$mids)-2, p$mids, max(p$mids)+2),
     y = c(0, p$counts, 0),
     type = "l",
     xlab = "Miles Per Gallon (MPG)",
     ylab = "Frequency",
     axes = F)

... # axes, box

# Create polygon to fill in area below curve
polygon(x = c(min(p$mids)-2, p$mids, max(p$breaks)+2), # create 0 min and max
        y = c(0, p$counts, 0),
        col = "lightblue",
        border = "darkblue")
```


Frequency
7
6
5
4
3
2
1
10
15
20
25
30
35
Miles Per Gallon (MPG)

Density plot

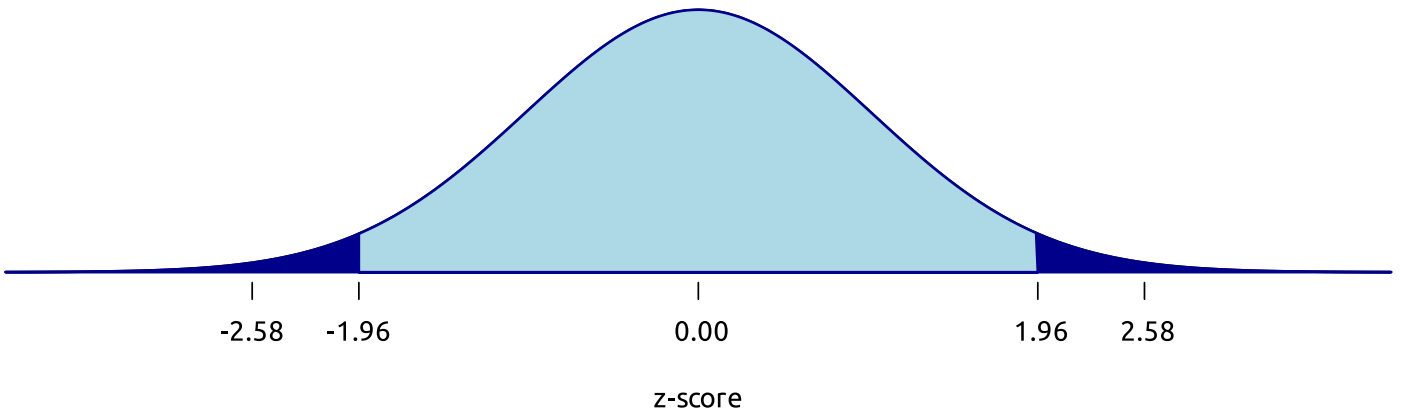
```
# Get density vals
dens <- density(mtcars$mpg)

# Plot density object (with other plotting args)
plot(x = dens, ...)
axis(side = 1, ...) # no side 2

polygon(dens, col = "lightblue", border = "darkblue")
```



The Normal Curve

The `polygon()` function can be used to plot any area(s) you want. For example:

```
par(mar=c(4,0,0,0),
    family = "Ubuntu")

curve(expr = dnorm(x, mean = 0, sd = 1),
      xlim = c(-4, 4),
      xlab = "z-score",
      ylab = "",
      lwd = 1.5,
      axes = FALSE)

axis(side = 1, at = qnorm(c(0.005, 0.025, .50, 0.975, .995)),
     labels = format(qnorm(c(0.005, 0.025, .50, 0.975, .995)), nsmall = 2, digits = 3),
     lwd = 0, lwd.ticks = 1)

# Z scores to draw polygon (tails)
```



Barplots

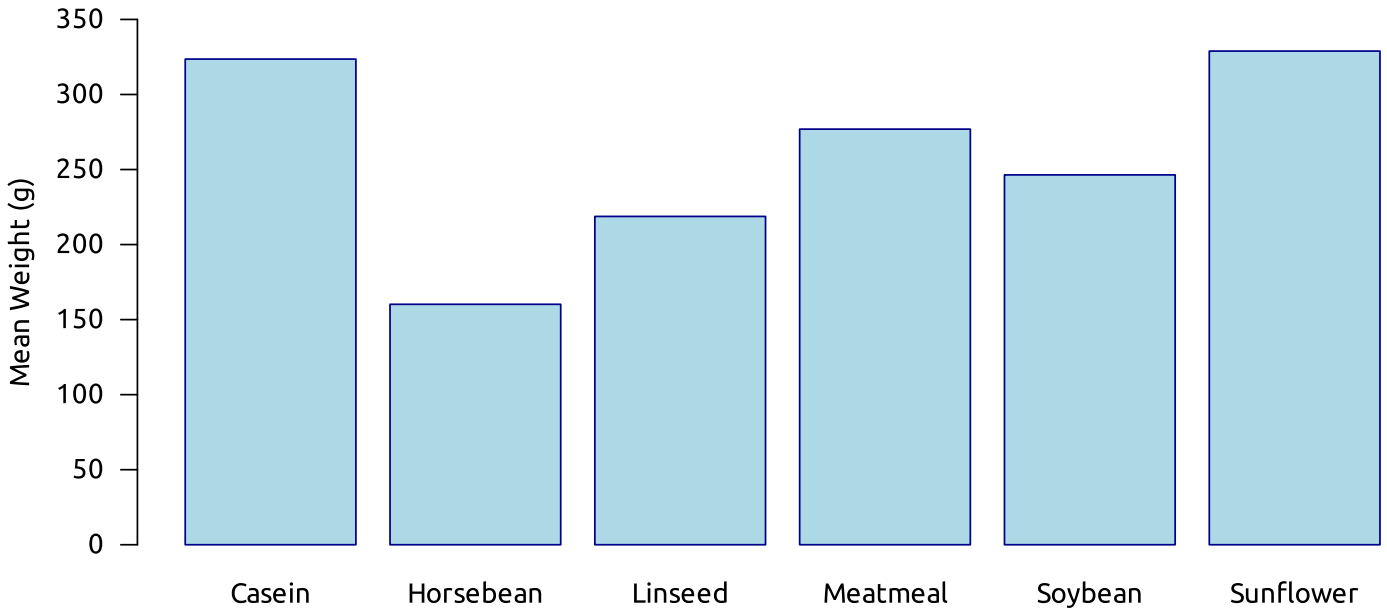
R's `chickwts` data comes from a between-subjects experiment on the effect of chicken feed supplements on chicken growth rate at 6 weeks old:

```
## 'data.frame':    71 obs. of  2 variables:
##  $ weight: num  179 160 136 227 217 168 108 124 143 140 ...
##  $ feed  : Factor w/ 6 levels "casein","horsebean",..: 2 2 2 2 2 2 2 2 2 2 ...
```

```
# Calculate means and info for CI error bars (n, SD)
chickwts_desc <- chickwts %>%
  group_by(feed) %>%
  summarize(n = n(),
            mean_weight = mean(weight, na.rm = T),
            sd_weight = sd(weight, na.rm = T))
```

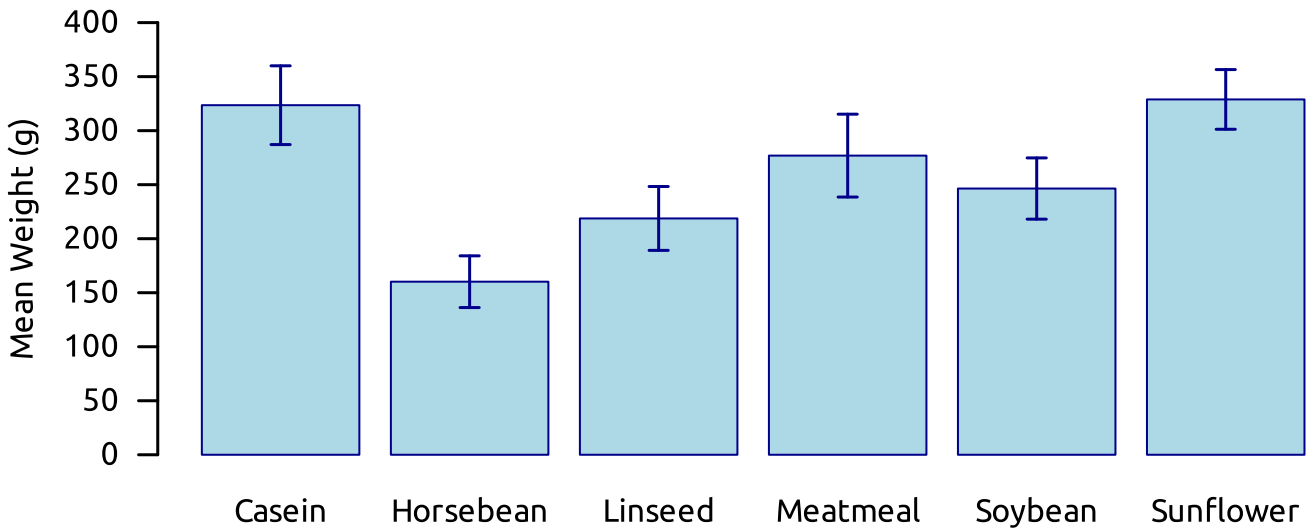
feed	n	mean_weight	sd_weight
casein	12	323.5833	64.43384
horsebean	10	160.2000	38.62584
linseed	12	218.7500	52.23570
meatmeal	11	276.9091	64.90062
soybean	14	246.4286	54.12907
sunflower	12	328.9167	48.83638

```r
barplot(chickwts_desc$mean_weight,
        names.arg = stringr::str_to_title(chickwts_desc$feed),
        ylim = c(0, 350),
        las = 1,
        ylab = "Mean Weight (g)",
        border = "darkblue",
        col = "lightblue")
```



Error Bars

```r
# Save barplot x values
bp <- barplot(...)

# with() lets you reference columns without subsetting each time
with(chickwts_desc,
     # draw arrows with flat lines on each head
     arrows(x0 = bp,
            x1 = bp,
            y0 = mean_weight - qnorm(.025, lower.tail = F) * (sd_weight / sqrt(n)),
            y1 = mean_weight + qnorm(.025, lower.tail = F) * (sd_weight / sqrt(n)),
            lwd = 1.5, angle = 90, code = 3, length = 0.05, col = "darkblue")
)
```



Pie Chart

The `pie()` functions uses a table of counts (i.e. relative proportions) to build the initial pie chart

The `table()` and `tapply()` functions from base R are both very helpful for this

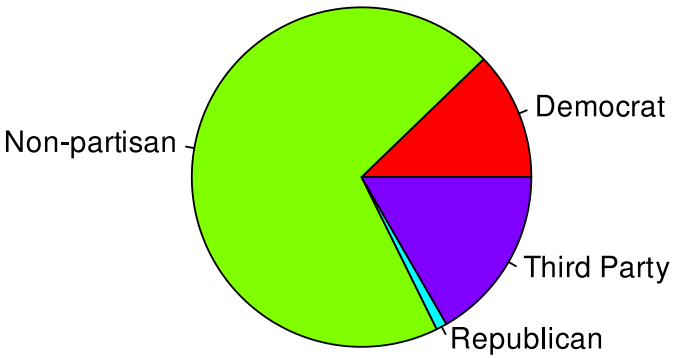
`group_by()` and `summarize(n = n())` from `dplyr` are also very helpful

From the King County 2016 elections data:

```
counts <- d %>%
  group_by(Party_Simplified) %>%
  summarize(n = n())
```

```
## # A tibble: 4 × 2
##   Party_Simplified      n
##   <chr>             <int>
## 1 Democrat          31931
## 2 Non-partisan     182983
## 3 Republican         2683
## 4 Third Party       43518
```

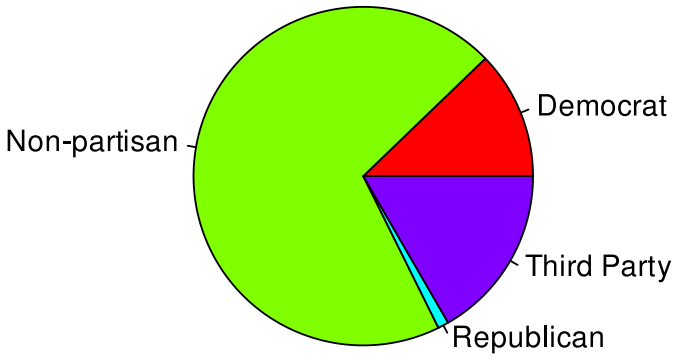
```
pie(x = counts$n,
    labels = counts$Party_Simplified,
    col = rainbow(4))
```



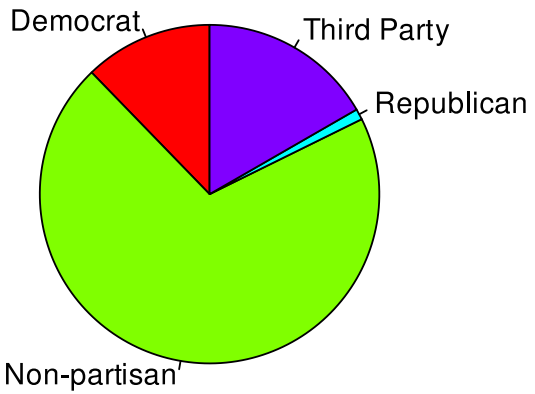
Use the `init.angle` argument to control the initial rotation of the pie chart

See `help("pie")` for more pie chart plotting options

```
pie(x = counts$n,
    labels = counts$Party_Simplified,
    col = rainbow(4))
```



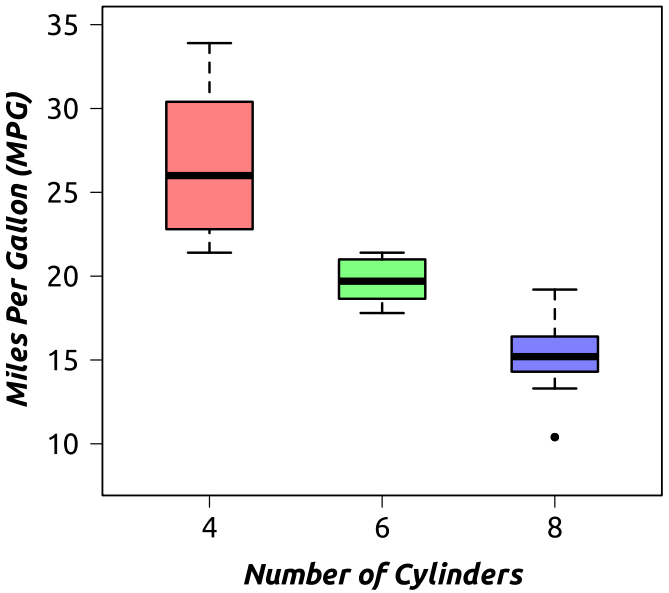

```
pie(x = counts$n,
    labels = counts$Party_Simplified,
    col = rainbow(4),
    init.angle = 90)
```

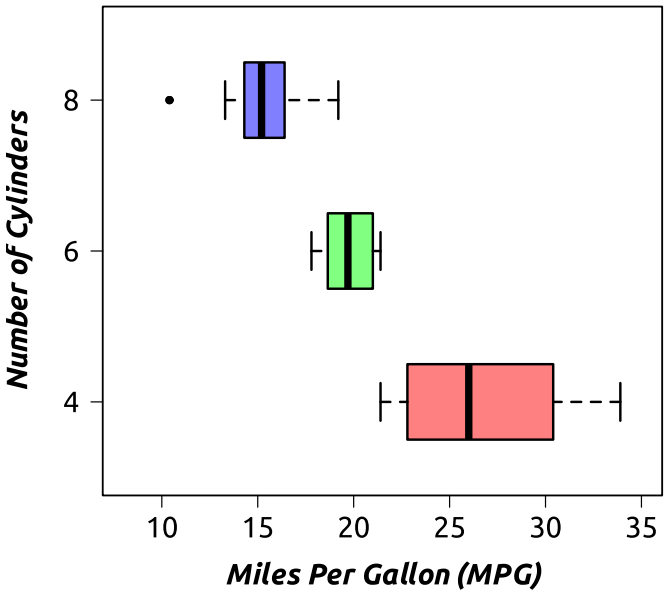


Boxplot

```
# See `help("bxp")` for boxplot options
boxplot(mpg ~ cyl, data = mtcars,
        xlab="Number of Cylinders",
        ylab="Miles Per Gallon",
        pch = 20,
        col = rainbow(3, .5),
        boxwex = 0.5)
```

```
boxplot(mpg ~ cyl, data = mtcars,
        ylab="Number of Cylinders",
        xlab="Miles Per Gallon",
        pch = 20,
        col = rainbow(3, .5),
        boxwex = 0.5,
        horizontal = TRUE)
```

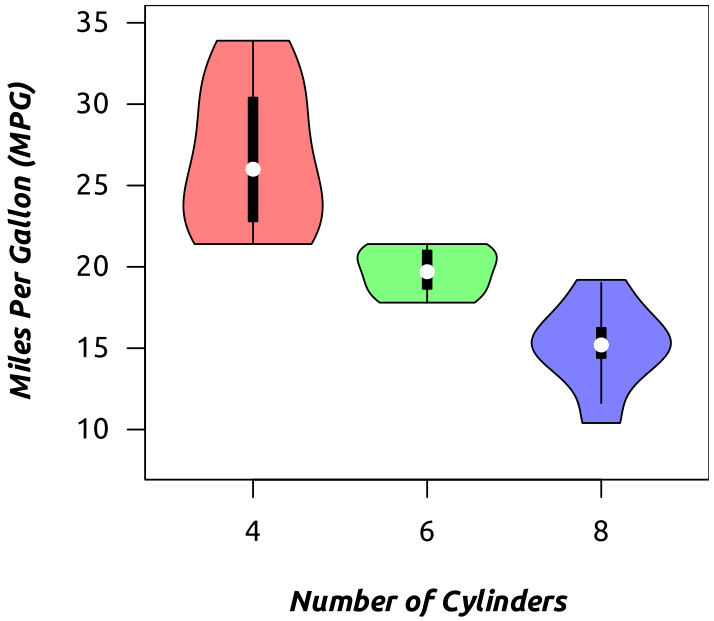




Violin Plot

You *can* make violin plots in base R, but it would require a lot of work and there's a package to make your life easier (while still using base R graphics) works just like the code for boxplot

```
vioplot(mpg ~ cyl, data = mtcars,
        xlab="Number of Cylinders",
        ylab="Miles Per Gallon (MPG)",
        pch = 20,
        ylim = c(8, 35),
        col = rainbow(3, .5),
        las = 1)
```




```
vioplot(mpg ~ cyl, data = mtcars,
        xlab="Number of Cylinders",
        ylab="Miles Per Gallon (MPG)",
        pch = 20, las = 1,
        ylim = c(8, 35),
        col = rainbow(3, .5),
        horizontal = TRUE)
```