Base Plotting System

Swirl Exploratory Data Analysis Lesson 5

Slides for this and other Data Science courses may be found at github https://github.com/DataScienceSpecialization/courses/. If you care to use them, they must be downloaded as a zip file and viewed locally. This lesson corresponds to 04_ExploratoryAnalysis/PlottingBase.

In another lesson, we gave you an overview of the three plotting systems in R. In this lesson we'll focus on the base plotting system and talk more about how you can exploit all its many parameters to get the plot you want. We'll focus on using the base plotting system to create graphics on the screen device rather than another graphics device.

The core plotting and graphics engine in R is encapsulated in two packages. The first is the graphics package which contains plotting functions for the "base" system. The functions in this package include `plot`, `hist`, `boxplot`, `barplot`, etc. The second package is grDevices which contains all the code implementing the various graphics devices, including X11, PDF, PostScript, PNG, etc.

Base graphics are often constructed piecemeal, with each aspect of the plot handled separately through a particular function call. Usually you start with a plot function (such as `plot`, `hist`, or `boxplot`), then you use annotation functions (`text`, `abline`, `points`) to add to or modify your plot.

Before making a plot you have to determine where the plot will appear and what it will be used for. Is there a large amount of data going into the plot? Or is it just a few points? Do you need to be able to dynamically resize the graphic?

What do you think is a disadvantage of the Base Plotting System?

1. It mirrors how we think of building plots and analyzing data
2. It's intuitive and exploratory
3. A complicated plot is a series of simple R commands
4. **You can't go back once a plot has started**

Yes! The base system is very intuitive and easy to use. You can't go backwards, though, say, if you need to readjust margins or have misspelled a caption. A finished plot will be a series of R commands, so it's difficult to translate a finished plot into a different system.

Calling a basic routine such as `plot(x, y)` or `hist(x)` launches a graphics device (if one is not already open) and draws a new plot on the device. If the arguments to plot or hist are not of some special class, then the default method is called.

As you'll see, most of the base plotting functions have many arguments, for example, setting the title, labels of axes, plot character, etc. Some of the parameters can be set when you call the function or they can be added later in a separate function call.

Now we'll go through some quick examples of basic plotting before we delve into gory details. We'll use the dataset `airquality` (part of the library datasets) which we've loaded for you. This shows ozone and other air measurements for New York City for 5 months in 1973.

Use the R command `head` with `airquality` as an argument to see what the data looks like.

```
head(airquality)
```

Hide

	Ozone <int>	Solar.R <int>	Wind <dbl>	Temp <int>	Month <int>	Day <int>
1	41	190	7.4	67	5	1
2	36	118	8.0	72	5	2
3	12	149	12.6	74	5	3
4	18	313	11.5	62	5	4
5	*NA*	*NA*	14.3	56	5	5
6	28	*NA*	14.9	66	5	6

6 rows

We see the dataset contains 6 columns of data. Run the command `range` with two arguments. The first is the ozone column of airquality, specified by `airquality$Ozone`, and the second is the boolean `na.rm` set equal to `TRUE`. If you don't specify this second argument, you won't get a meaningful result.

```
range(airquality$Ozone, na.rm = TRUE)
```

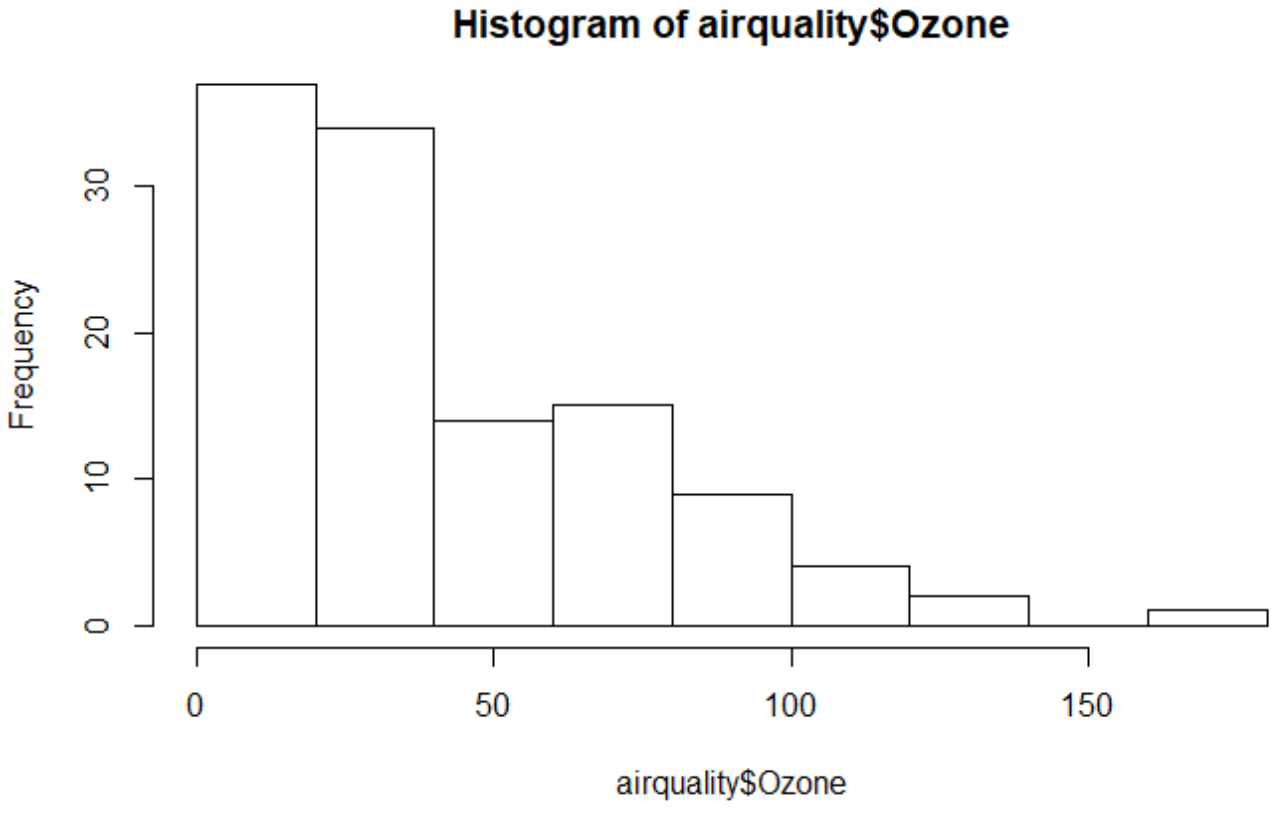
Hide

```
[1]   1 168
```

So the measurements range from 1 to 168. First we'll do a simple histogram of this ozone column to show the distribution of measurements. Use the R command `hist` with the argument `airquality$Ozone`.

```
hist(airquality$Ozone)
```

Hide



Simple, right? R put a title on the histogram and labeled both axes for you.

What is the most frequent count?

1. Between 60 and 75
2. Over 100
3. Over 150
4. **Under 25**

Next we'll do a boxplot. First, though, run the R command `table` with the argument `airquality$Month`.

```
table(airquality$Month)
```

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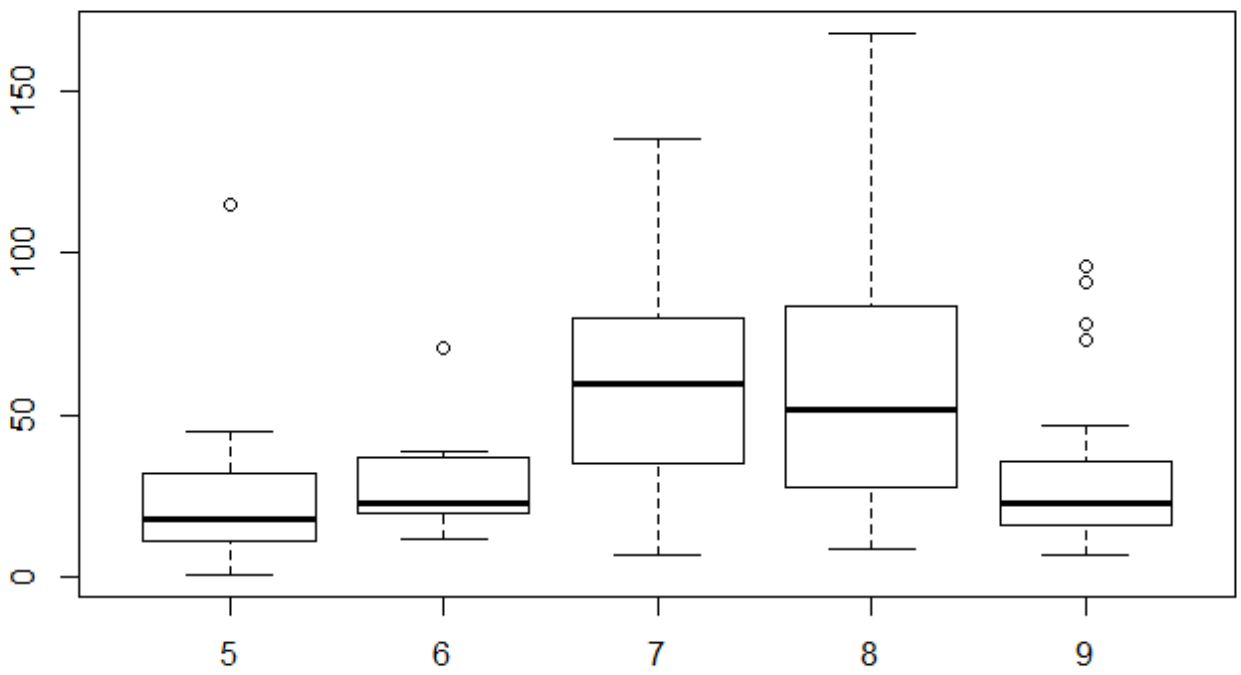
```
 5  6  7  8  9
31 30 31 31 30
```

We see that the data covers 5 months, May through September. We'll want a boxplot of ozone as a function of the month in which the measurements were taken so we'll use the R formula `Ozone~Month` as the first argument of `boxplot`. Our second argument will be `airquality`, the dataset from which the variables of the first argument are taken. Try this now.

```
boxplot(Ozone~Month, airquality)
```

Hide

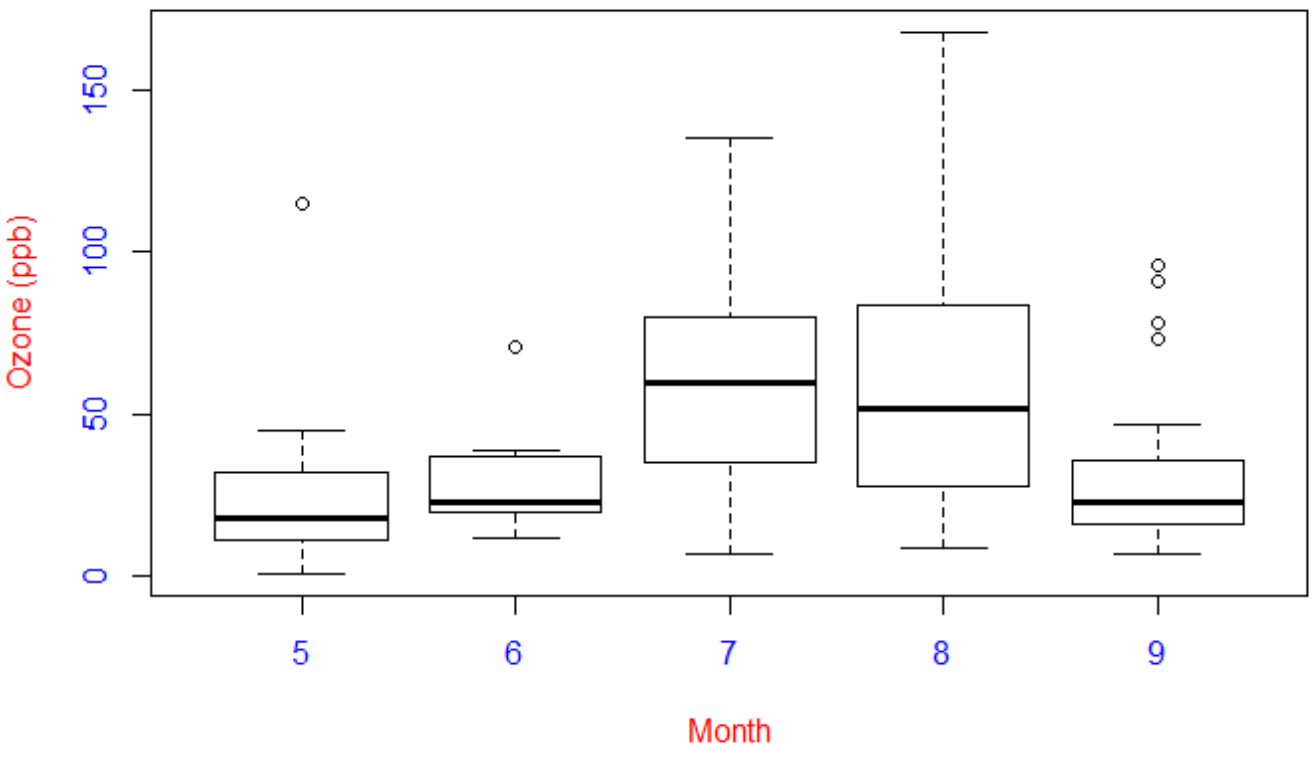


Note that boxplot, unlike hist, did NOT specify a title and axis labels for you automatically.

Let's call `boxplot` again to specify labels. (Use the up arrow to recover the previous command and save yourself some typing.) We'll add more arguments to the call to specify labels for the 2 axes. Set `xlab` equal to `"Month"` and `ylab` equal to `"Ozone (ppb)"`. Specify `col.axis` equal to `"blue"` and `col.lab` equal to `"red"`. Try this now.

```
boxplot(Ozone~Month, airquality, xlab = "Month", ylab = "Ozone (ppb)", col.axis = "blue", col.lab = "red")
```

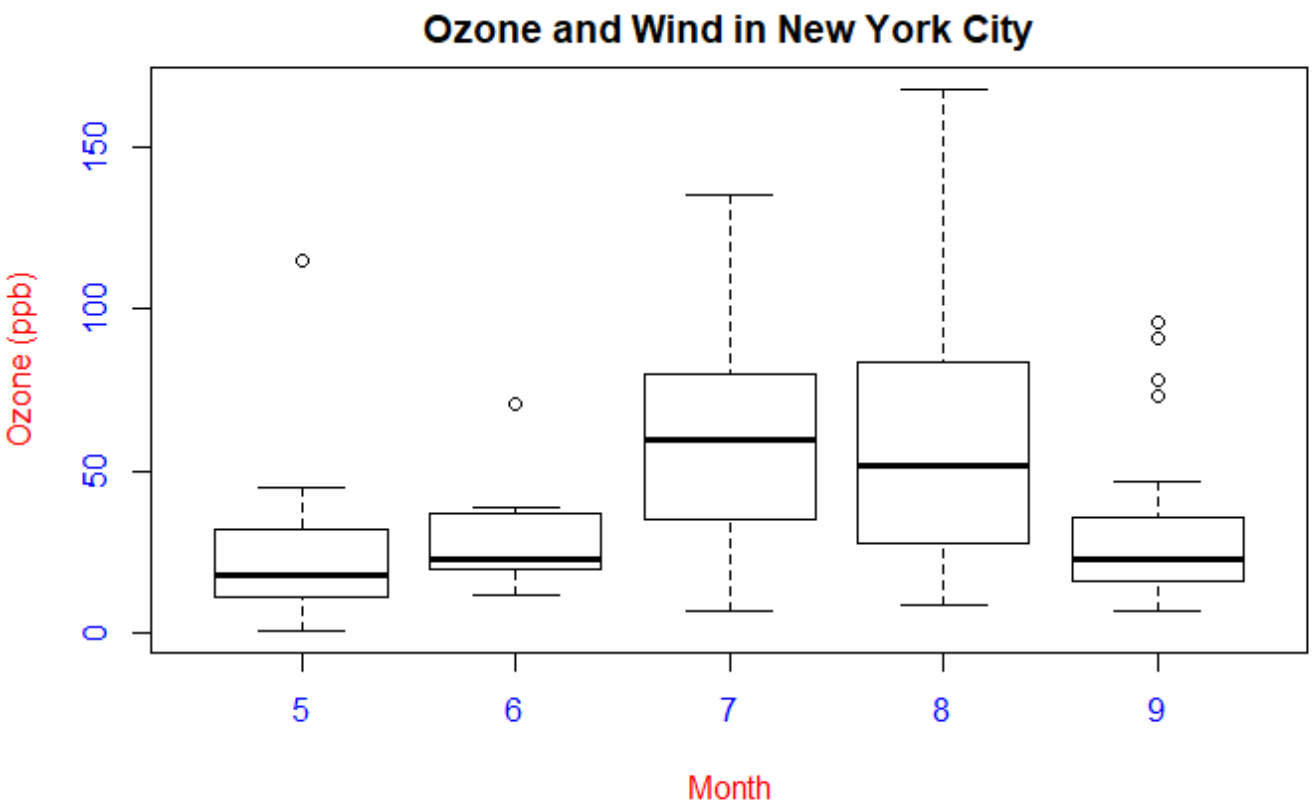
Hide



Nice colors, but still no title. Let's add one with the R command `title`. Use the argument `main` set equal to the string `"Ozone and Wind in New York City"`.

```
boxplot(Ozone~Month, airquality, xlab = "Month", ylab = "Ozone (ppb)", col.axis = "blue", col.lab = "red")
title(main="Ozone and Wind in New York City")
```

Hide



Now we'll show you how to plot a simple two-dimensional scatterplot using the R function `plot`. We'll show the relationship between `Wind` (x-axis) and `Ozone` (y-axis). We'll use the function `plot` with those two arguments (`Wind` and `Ozone`, in that order). To save some typing, though, we'll call the R command `with` using 2 arguments. The first argument of with will be `airquality`, the dataset containing `Wind` and `Ozone`; the second argument will be the call to `plot`. Doing this allows us to avoid using the longer notation, e.g., `airquality$Wind`. Try this now.

```
with(airquality, plot(Wind, Ozone))
```

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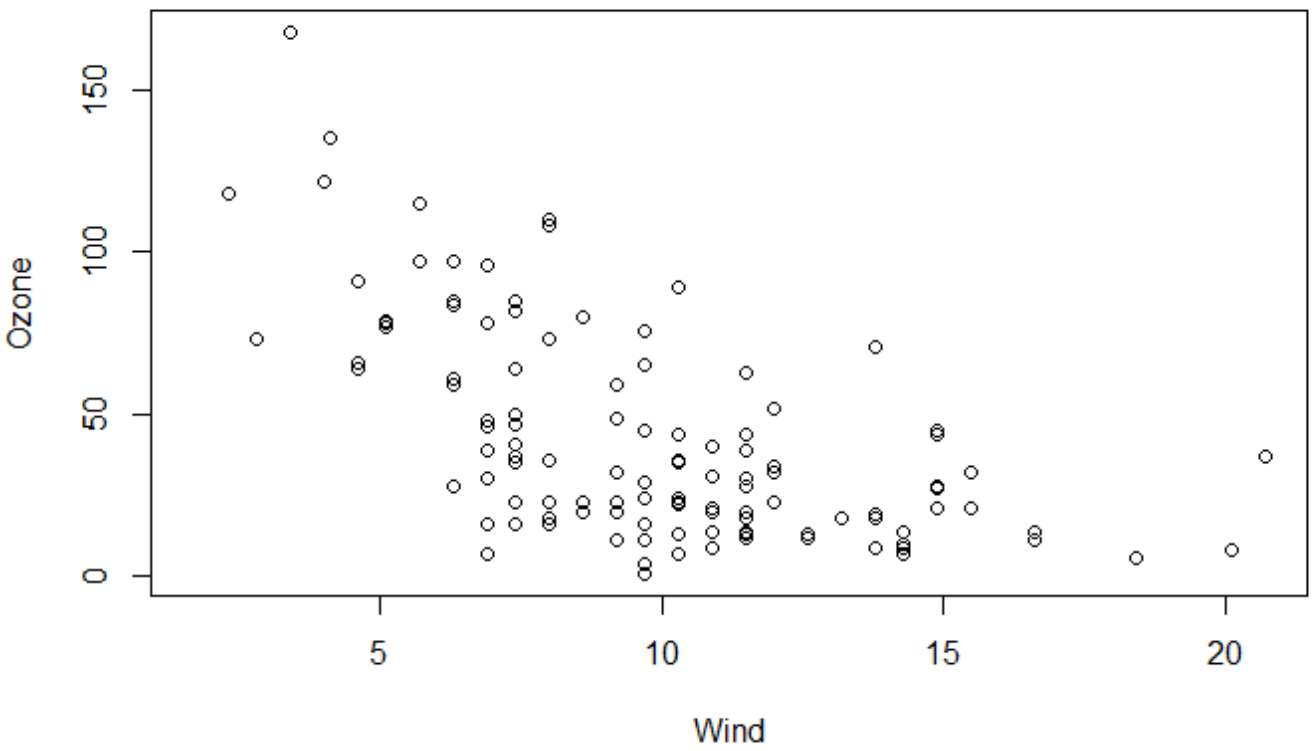
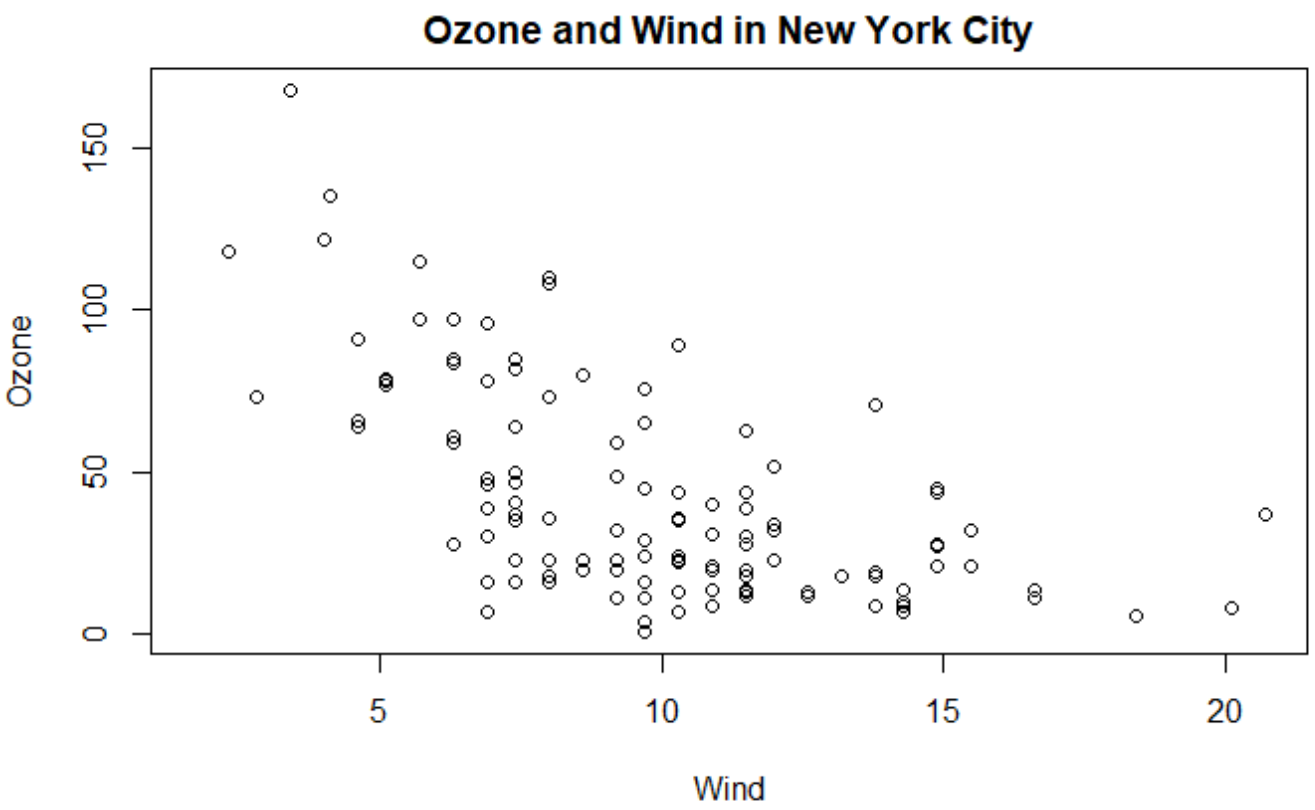


Note that plot generated labels for the x and y axes but no title.

Add one now with the R command `title`. Use the argument main set equal to the string `"Ozone and Wind in New York City"`. (You can use the up arrow to recover the command if you don't want to type it.)

```
with(airquality, plot(Wind, Ozone))
title(main="Ozone and Wind in New York City")
```

Hide



The basic plotting parameters are documented in the R help page for the function `par`. You can use `par` to set parameters OR to find out what values are already set. To see just how much flexibility you have, run the R command `length` with the argument `par()` now.

```
length(par())
```

Hide

```
[1] 72
```

So there are a boatload (72) of parameters that `par()` gives you access to. Run the R function `names` with `par()` as its argument to see what these parameters are.

```
names(par())
```

Hide

```
 [1] "xlog"     "ylog"     "adj"      "ann"      "ask"      "bg"       "bty"      "cex"
 [9] "cex.axis" "cex.lab"  "cex.main" "cex.sub"  "cin"      "col"      "col.axis" "col.lab"
[17] "col.main" "col.sub"  "cra"      "crt"      "csi"      "cxy"      "din"      "err"
[25] "family"   "fg"       "fig"      "fin"      "font"     "font.axis" "font.lab"  "font.main"
[33] "font.sub" "lab"      "las"      "lend"     "lheight"  "ljoin"    "lmitre"   "lty"
[41] "lwd"      "mai"      "mar"      "mex"      "mfcol"    "mfg"      "mfrow"    "mgp"
[49] "mkh"      "new"      "oma"      "omd"      "omi"      "page"     "pch"      "pin"
[57] "plt"      "ps"       "pty"      "smo"      "srt"      "tck"      "tcl"      "usr"
[65] "xaxp"     "xaxs"     "xaxt"     "xpd"      "yaxp"     "yaxs"     "yaxt"     "ylbias"
```

Variety is the spice of life. You might recognize some of these such as `col` and `lwd` from previous swirl lessons. You can always run `?par` to see what they do. For now, run the command `par()$pin` and see what you get.

```
par()$pin
```

Hide

```
[1] 6.051666 3.059999
```

Alternatively, you could have gotten the same result by running `par("pin")` or `par('pin'))`.

What do you think these two numbers represent? The function `par` specifies graphical parameters so the answer should deal with plots. That leaves two choices. The 'in' in `'pin'` specifies inches.

1. **Plot dimensions in inches**
2. A confidence interval
3. Coordinates of the center of the plot window
4. Random numbers

Now, run the command `par("fg")` or or `par('fg')` or par `()$fg` and see what you get.

```
par("fg")
```

Hide

```
[1] "black"
```

It gave you a color, right? Since `par()$fg` specifies foreground color, what do you think `par()$bg` specifies?

1. Beautiful color
2. **Background color**
3. blue-green
4. Better color

Many base plotting functions share a set of parameters. We'll go through some of the more commonly used ones now. See if you can tell what they do from their names.

What do you think the graphical parameter `pch` controls?

1. **plot character**
2. point control height
3. pc help
4. picture characteristics

The plot character default is the open circle, but it "can either be a single character or an integer code for one of a set of graphics symbols." Run the command `par("pch")` to see the integer value of the default. When you need to, you can use R's Documentation (`?pch`) to find what the other values mean.

```
par("pch")
```

Hide

```
[1] 1
```

So 1 is the code for the open circle. What do you think the graphical parameters `lty` and `lwd` control respectively?

1. line slope and intercept
2. line width and type
3. line length and width
4. **line type and width**

Run the command `par("lty")` to see the default line type.

```
par("lty")
```

Hide

```
[1] "solid"
```

So the default line type is *solid*, but it can be dashed, dotted, etc. Once again, R's ?par documentation will tell you what other line types are available. The line width is a positive integer; the default value is 1.

We've seen a lot of examples of `col`, the plotting color, specified as a number, string, or hex code; the `colors()` function gives you a vector of colors by name.

What do you think the graphical parameters `xlab` and `ylab` control respectively?

1. **labels for the x- and y- axes**
2. labels for the y- and x- axes

The `par()` function is used to specify global graphics parameters that affect all plots in an R session. (Use `dev.off` or `plot.new` to reset to the defaults.) These parameters can be overridden when specified as arguments to specific plotting functions. These include `las` (the orientation of the axis labels on the plot), `bg` (background color), `mar` (margin size), `oma` (outer margin size), `mfrow` and `mfcol` (number of plots per row, column).

The last two, `mfrow` and `mfcol`, both deal with multiple plots in that they specify the number of plots per row and column. The difference between them is the order in which they fill the plot matrix. The call `mfrow` will fill the rows first while `mfcol` fills the columns first.

So to reiterate, first call a basic plotting routine. For instance, `plot` makes a scatterplot or other type of plot depending on the class of the object being plotted.

As we've seen, R provides several annotating functions. Which of the following is NOT one of them?

1. title
2. text
3. points
4. **hist**
5. lines

So you can add *text*, *title*, *points*, and *lines* to an existing plot.

To add **lines**, you give a vector of x values and a corresponding vector of y values (or a 2-column matrix); the function `lines` just connects the dots. The function `text` adds text labels to a plot using specified x, y coordinates.

The function **`title`** adds annotations. These include x- and y- axis labels, title, subtitle, and outer margin.

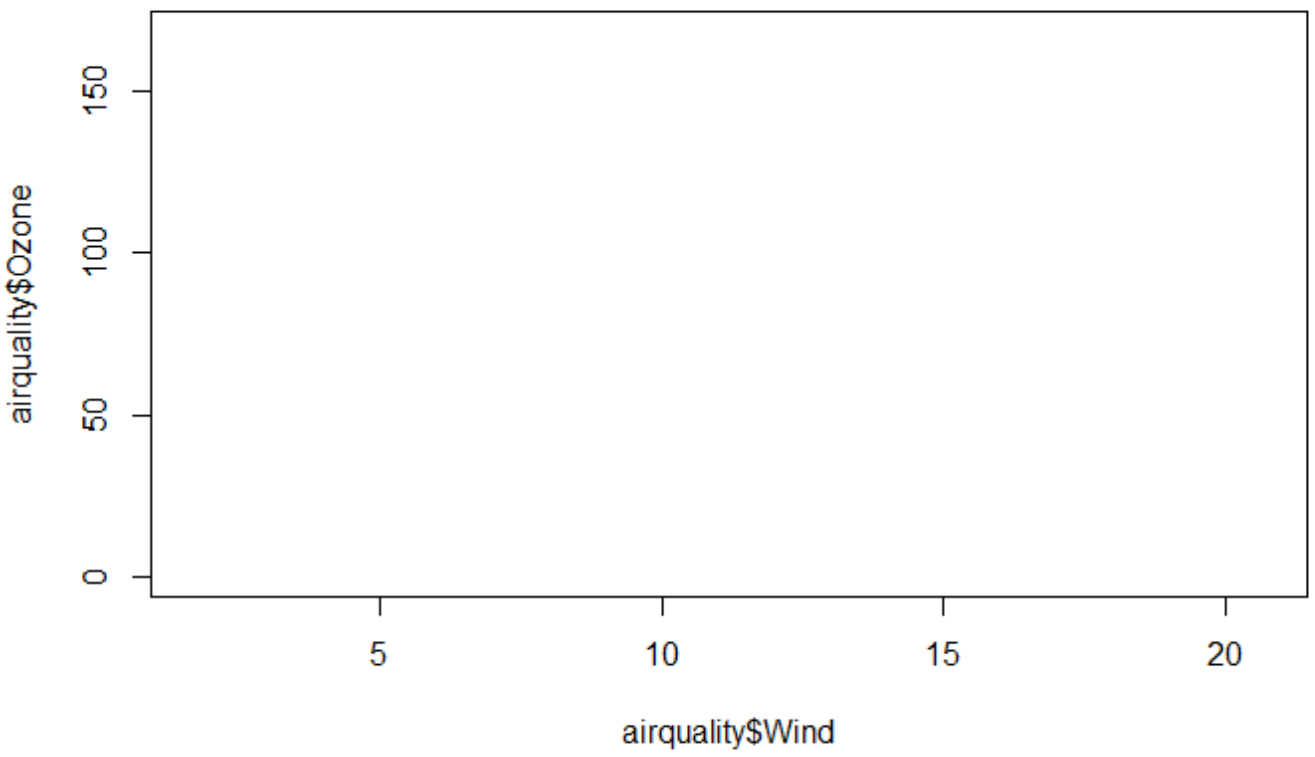
Two other annotating functions are **`mtext`** which adds arbitrary text to either the outer or inner margins of the plot and axis which adds axis ticks and labels.

Another useful function is **`legend`** which explains to the reader what the symbols your plot uses mean.

Before we close, let's test your ability to make a somewhat complicated scatterplot. First run `plot` with 3 arguments. `airquality$Wind`, `airquality$Ozone`, and `type` set equal to `"n"`. This tells R to set up the plot but not to put the data in it.

```
plot(airquality$Wind, airquality$Ozone, type = "n")
```

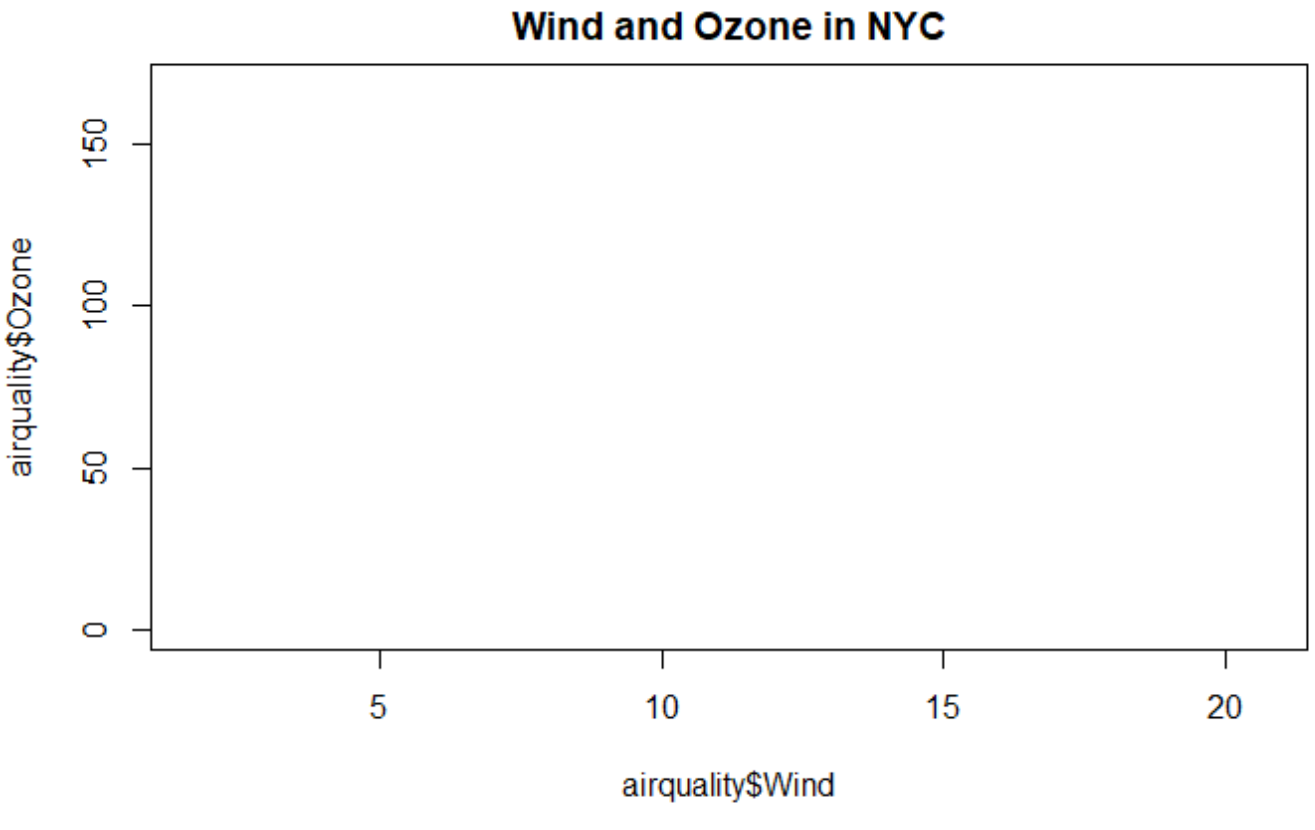
Hide



Now for the test. (You might need to check R's documentation for some of these.) Add a `title` with the argument `main` set equal to the string `"Wind and Ozone in NYC"`

```
plot(airquality$Wind, airquality$Ozone, type = "n")
title(main = "Wind and Ozone in NYC")
```

Hide



Now create a variable called `may` by subsetting `airquality` appropriately. (Recall that the data specifies months by number and May is the fifth month of the year.)

```
may <- subset(airquality, Month == 5)
```

Hide

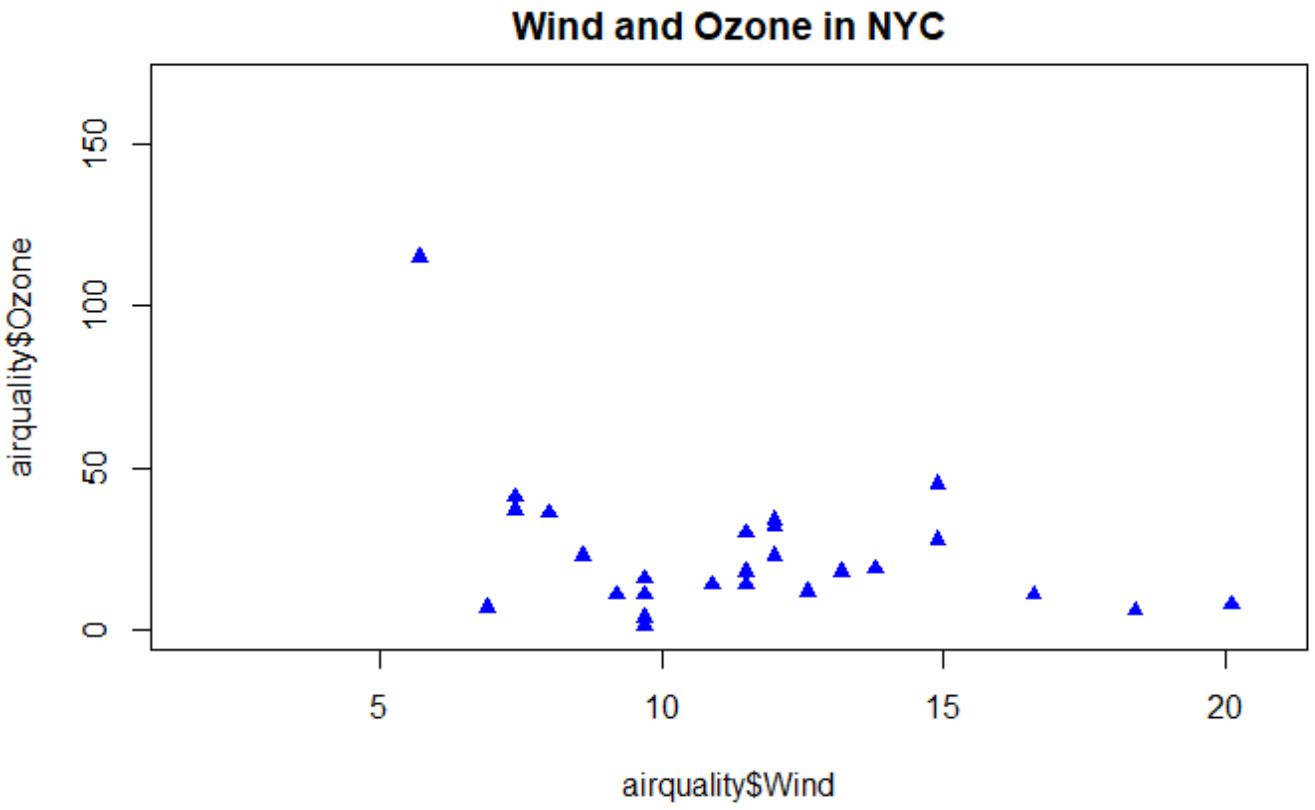
Now use the R command `points` to plot May's wind and ozone (in that order) as solid blue triangles. You have to set the color and plot character with two separate arguments. Note we use `points` because we're adding to an existing plot.

```
plot(airquality$Wind, airquality$Ozone, type = "n")
title(main = "Wind and Ozone in NYC")
```

Hide

```
points(may$Wind, may$Ozone, col="blue",pch=17)
```

Hide



Now create the variable `notmay` by subsetting `airquality` appropriately.

Hide

```
notmay <- subset(airquality, Month != 5)
```

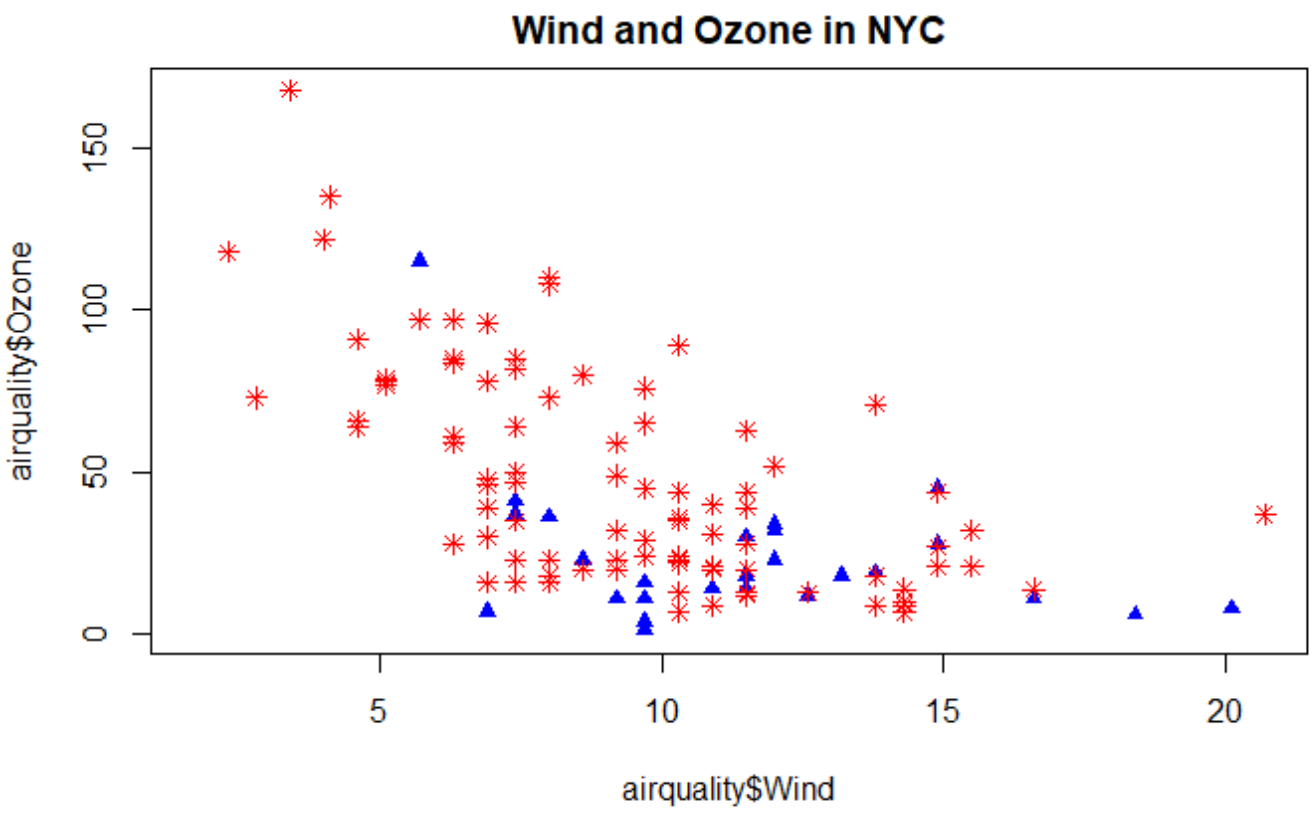
Now use the R command `points` to plot these notmay's wind and ozone (in that order) as red snowflakes.

Hide

```
plot(airquality$Wind, airquality$Ozone, type = "n")
title(main = "Wind and Ozone in NYC")
```

Hide

```
points(may$Wind, may$Ozone, col="blue",pch=17)
notmay <- subset(airquality, Month != 5)
points(notmay$Wind, notmay$Ozone, col = "red", pch = 8)
```



Now we'll use the R command `legend` to clarify the plot and explain what it means. The function has a lot of arguments, but we'll only use 4. The first will be the string `"topright"` to tell R where to put the legend. The remaining 3 arguments will each be 2-long vectors created by R's concatenate function, e.g., c(). These arguments are `pch`, `col`, and `legend`. The first is the vector `(17,8)`, the second `("blue","red")`, and the third `("May","Other Months")`. Try it now.

Hide

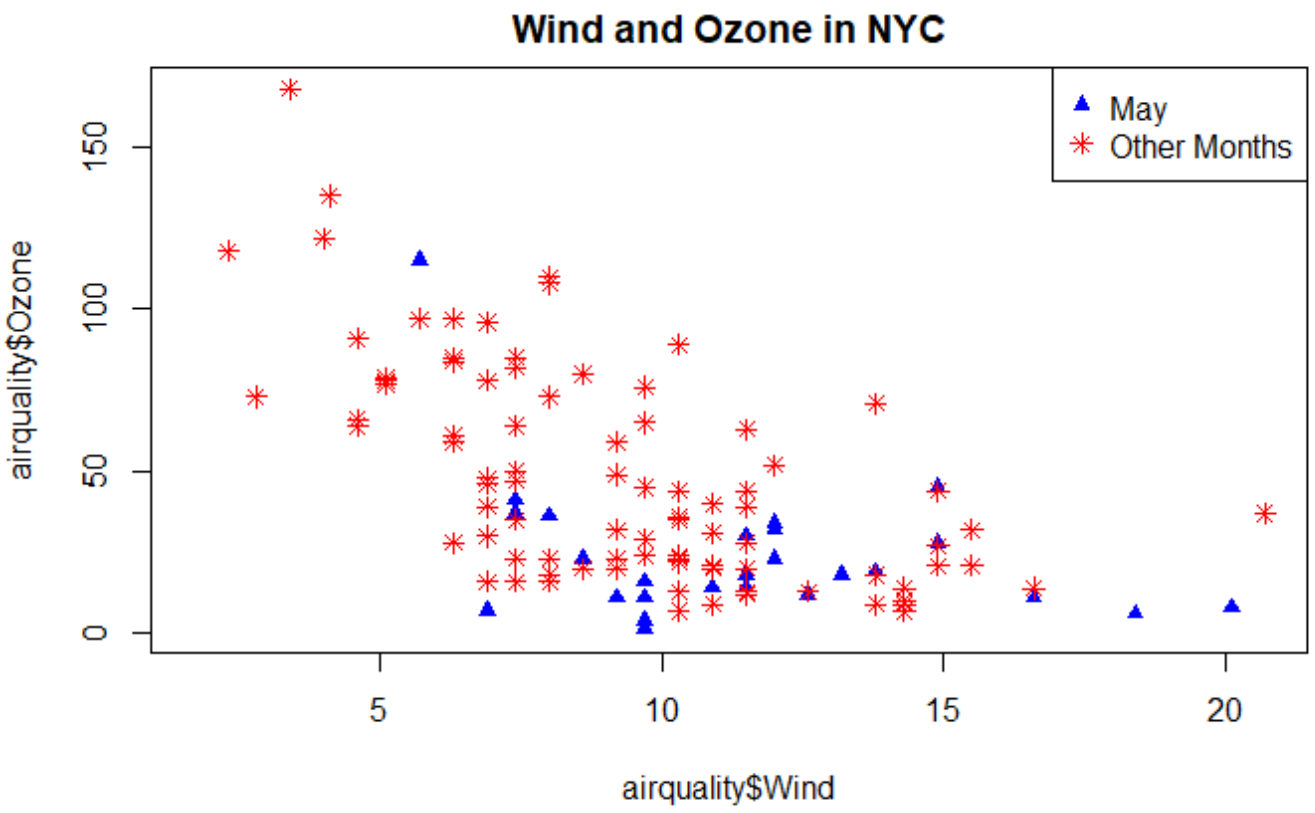
```
plot(airquality$Wind, airquality$Ozone, type = "n")
title(main = "Wind and Ozone in NYC")
```

Hide

```
points(may$Wind, may$Ozone, col="blue",pch=17)
notmay <- subset(airquality, Month != 5)
points(notmay$Wind, notmay$Ozone, col = "red", pch = 8)
```

Hide

```
legend("topright", pch = c(17, 8), col = c("blue", "red"), legend = c("May", "Other Months"))
```



Now add a vertical line at the median of `airquality$Wind`. Make it dashed (`lty=2`) with a `width` of `2`.

```
plot(airquality$Wind, airquality$Ozone, type = "n")
title(main = "Wind and Ozone in NYC")
```

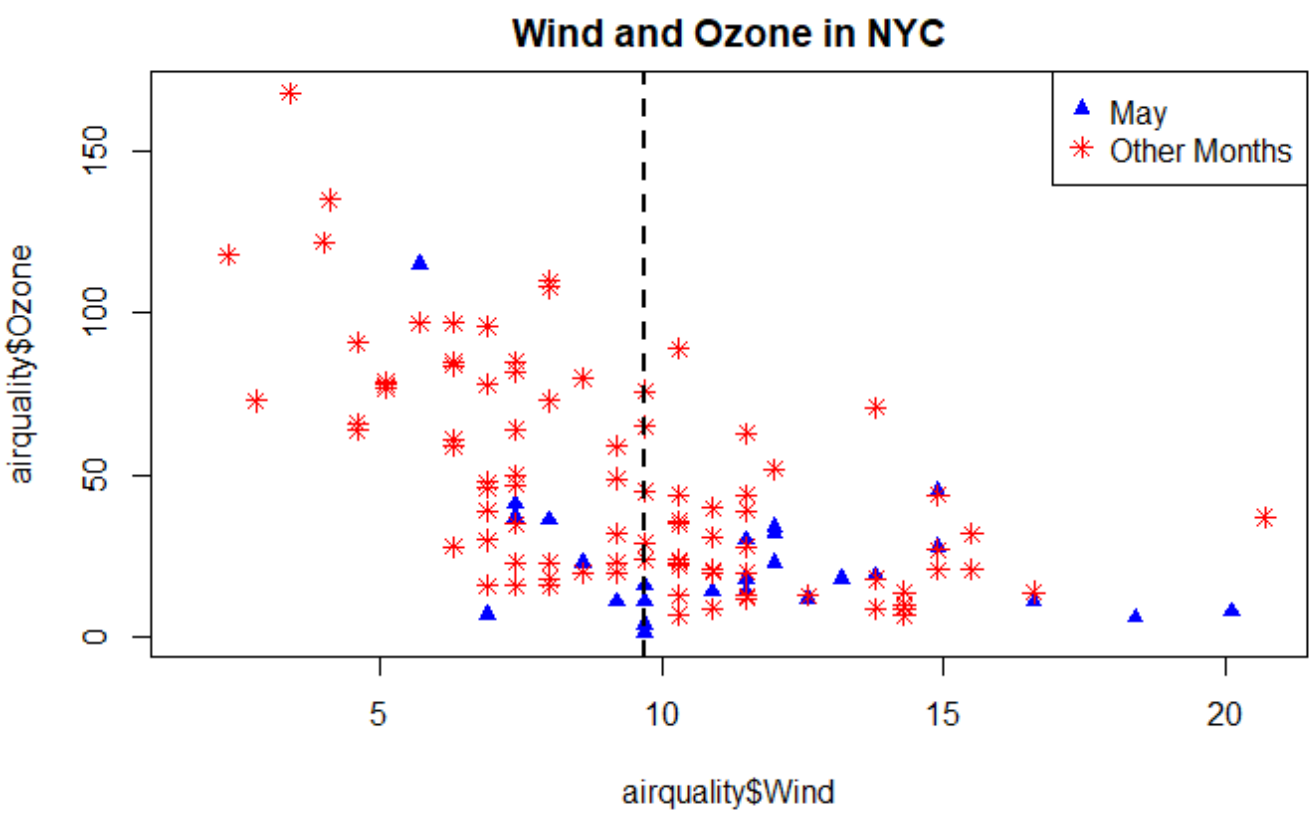
Hide

```
points(may$Wind, may$Ozone, col="blue",pch=17)
notmay <- subset(airquality, Month != 5)
points(notmay$Wind, notmay$Ozone, col = "red", pch = 8)
```

Hide

```
legend("topright", pch = c(17, 8), col = c("blue", "red"), legend = c("May", "Other Months"))
abline(v = median(airquality$Wind), lty=2, lwd=2)
```

Hide



Use `par` with the parameter `mfrow` set equal to the vector `(1,2)` to set up the plot window for two plots side by side. You won't see a result.

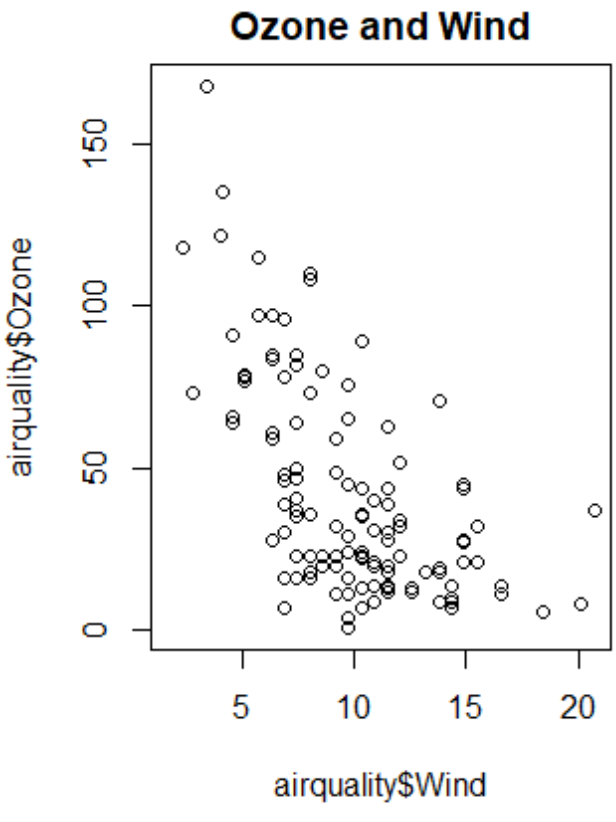
```
par(mfrow = c(1, 2))
```

Hide

Now plot `airquality$Wind` and `airquality$Ozone` and use `main` to specify the title `"Ozone and Wind"`.

```
par(mfrow = c(1, 2))
plot(airquality$Wind, airquality$Ozone, main = "Ozone and Wind")
```

Hide

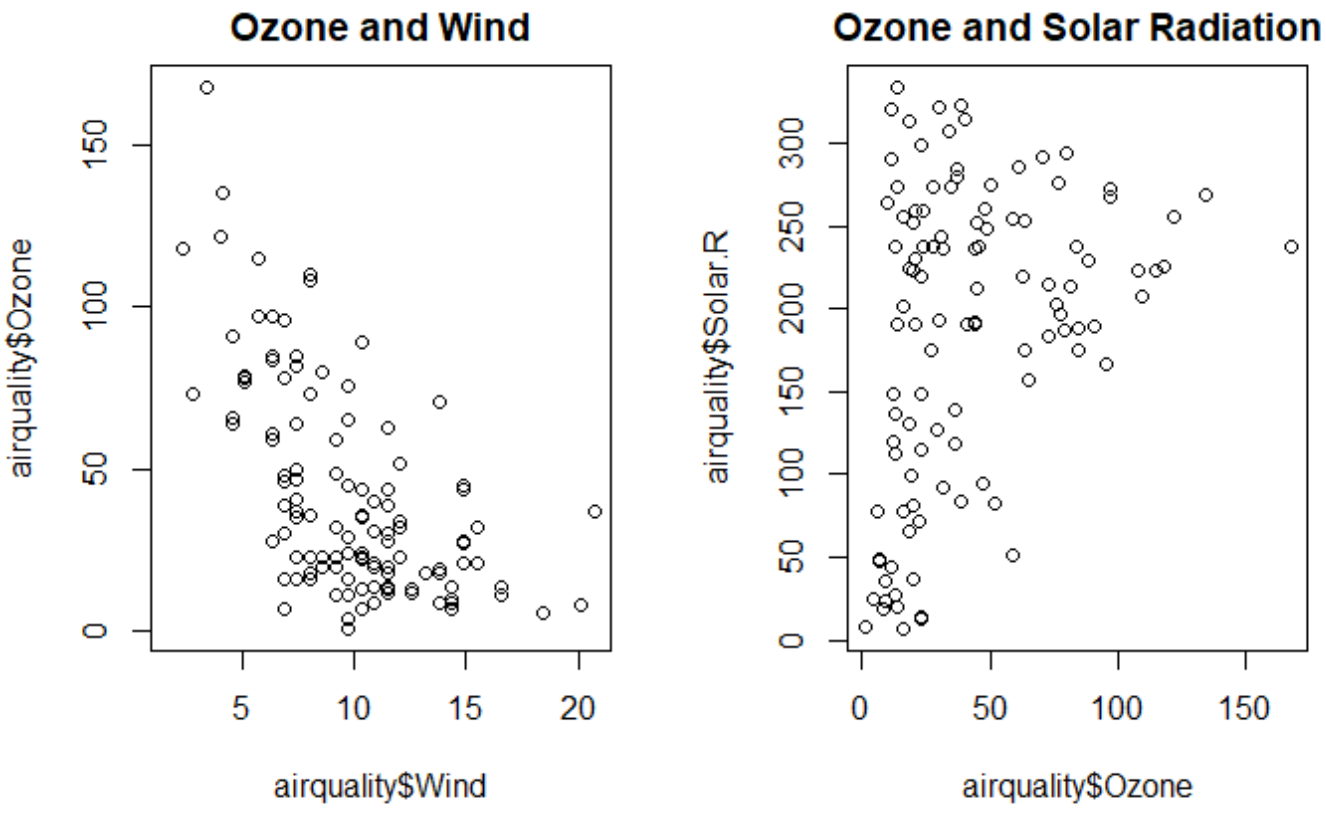


Now for the second plot.

Plot `airquality$Ozone` and `airquality$Solar.R` and use `main` to specify the title `"Ozone and Solar Radiation"`.

```
par(mfrow = c(1, 2))
plot(airquality$Wind, airquality$Ozone, main = "Ozone and Wind")
plot(airquality$Ozone, airquality$Solar.R, main = "Ozone and Solar Radiation")
```

Hide



Now for something more challenging.

This one with 3 plots, to illustrate inner and outer margins. First, set up the plot window by typing `par(mfrow = c(1, 3), mar = c(4, 4, 2, 1), oma = c(0, 0, 2, 0))`

```
par(mfrow = c(1, 3), mar = c(4, 4, 2, 1), oma = c(0, 0, 2, 0))
```

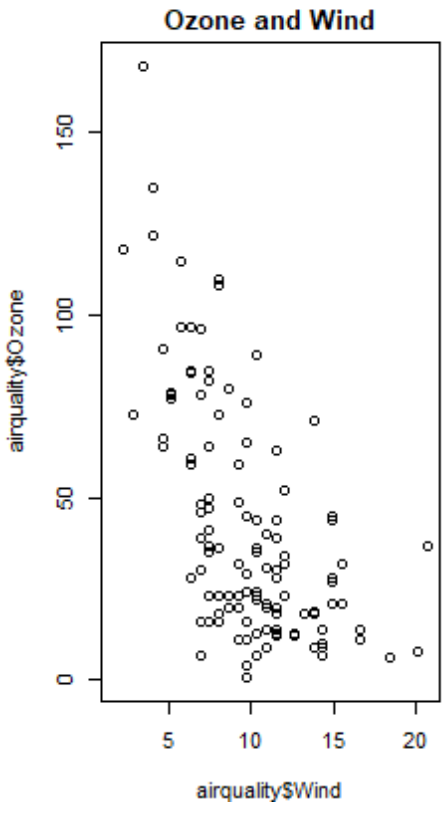
Hide

Margins are specified as 4-long vectors of integers. Each number tells how many lines of text to leave at each side. The numbers are assigned clockwise starting at the bottom. The default for the inner margin is c(5.1, 4.1, 4.1, 2.1) so you can see we reduced each of these so we'll have room for some outer text.

The first plot should be familiar. Plot `airquality$Wind` and `airquality$Ozone` with the title (argument `main`) as `"Ozone and Wind"`.

```
par(mfrow = c(1, 3), mar = c(4, 4, 2, 1), oma = c(0, 0, 2, 0))
plot(airquality$Wind, airquality$Ozone, main = "Ozone and Wind")
```

Hide

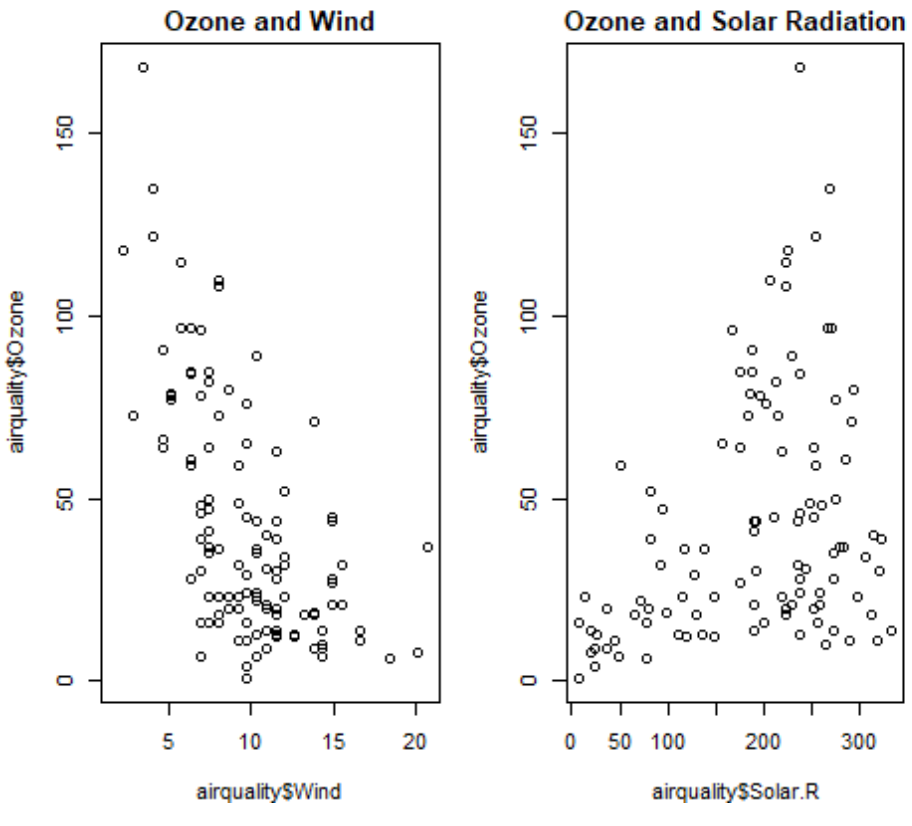


The second plot is similar.

Plot `airquality$Solar.R` and `airquality$Ozone` with the title (argument `main`) as `"Ozone and Solar Radiation"`.

Hide

```
par(mfrow = c(1, 3), mar = c(4, 4, 2, 1), oma = c(0, 0, 2, 0))
plot(airquality$Wind, airquality$Ozone, main = "Ozone and Wind")
plot(airquality$Solar.R, airquality$Ozone, main = "Ozone and Solar Radiation")
```



Now for the final panel.

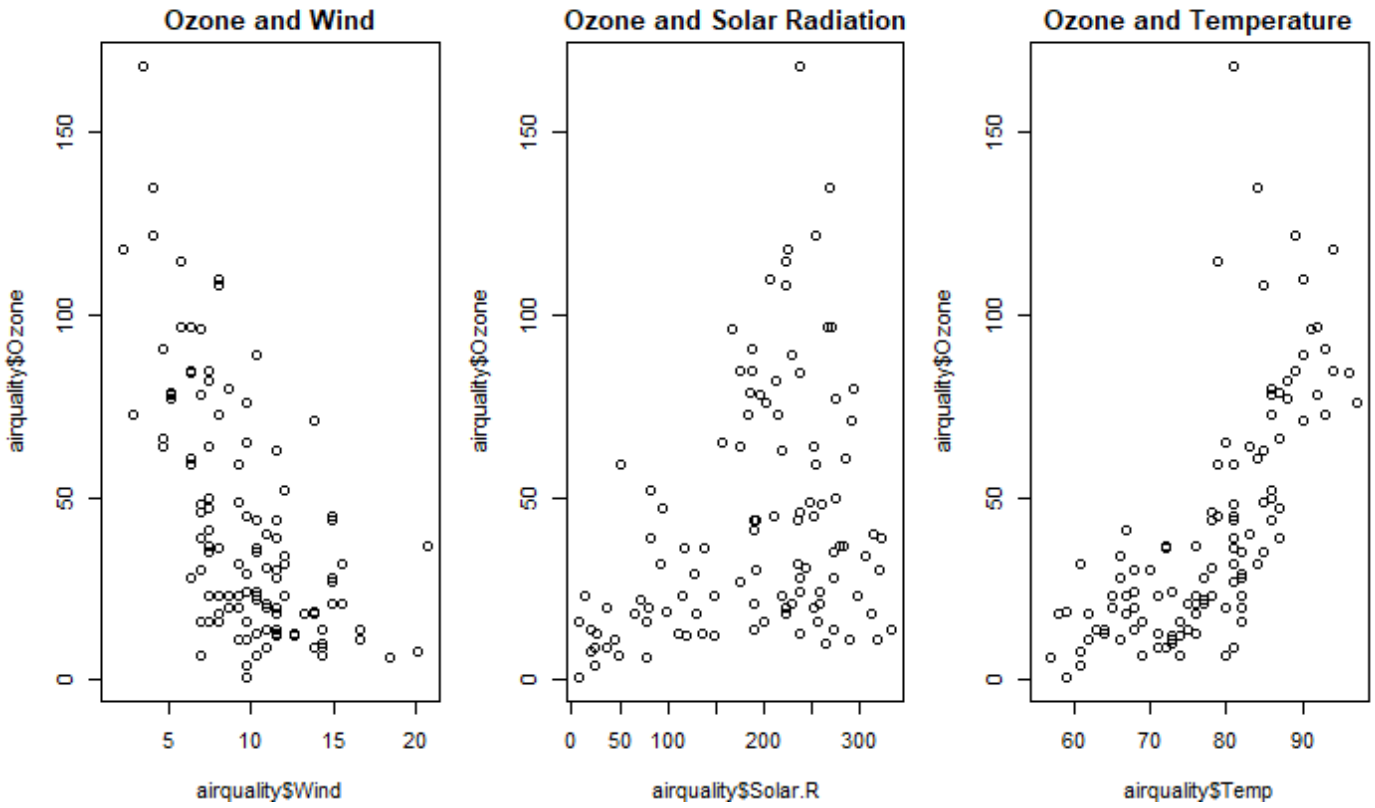
Plot `airquality$Temp` and `airquality$Ozone` with the title (argument `main`) as `"Ozone and Temperature"`.

Hide

```
par(mfrow = c(1, 3), mar = c(4, 4, 2, 1), oma = c(0, 0, 2, 0))
plot(airquality$Wind, airquality$Ozone, main = "Ozone and Wind")
plot(airquality$Solar.R, airquality$Ozone, main = "Ozone and Solar Radiation")
```

Hide

```
plot(airquality$Temp, airquality$Ozone, main = "Ozone and Temperature")
```



Now we'll put in a title.

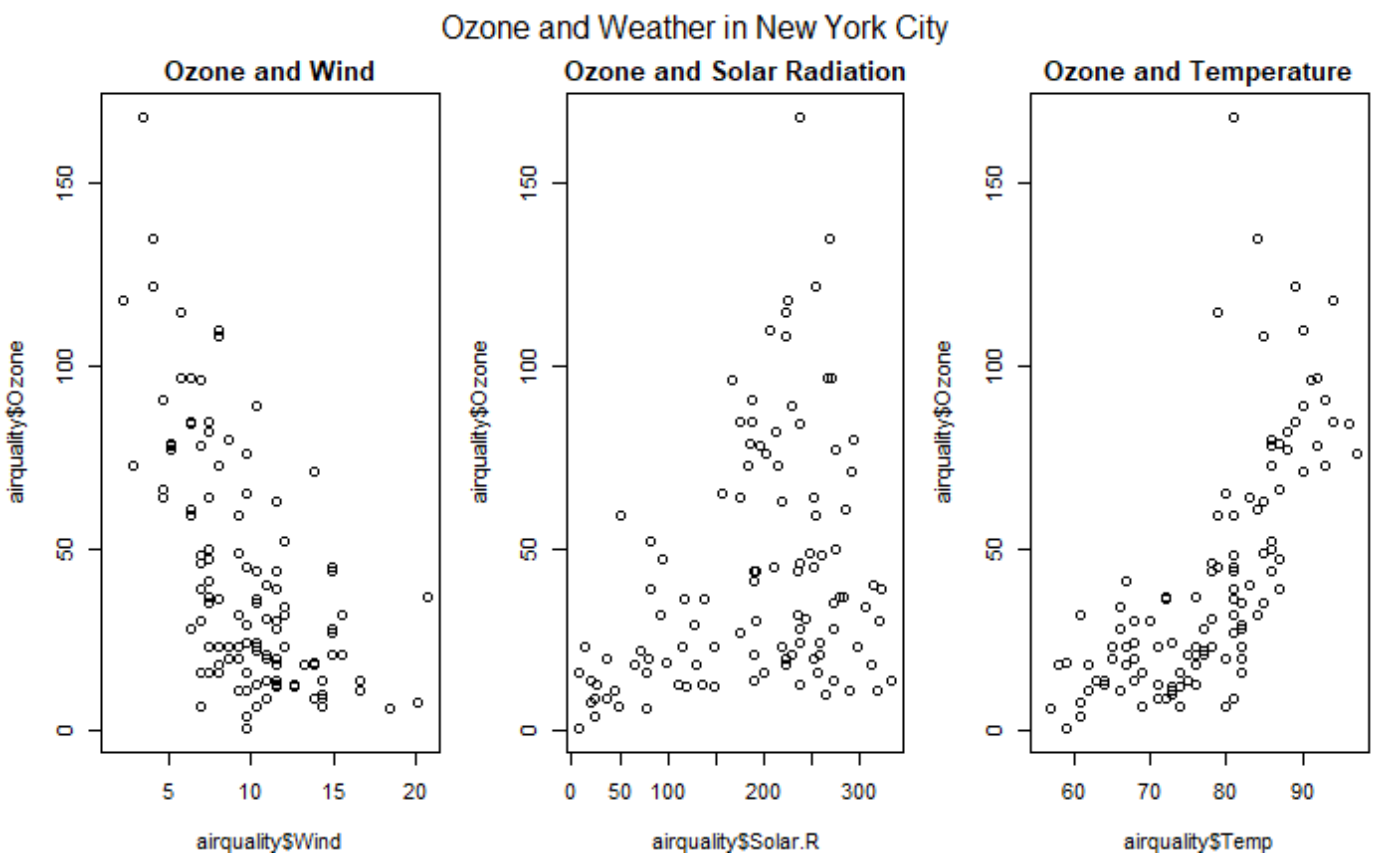
Since this is the main title, we specify it with the R command `mtext`. Call `mtext` with the string `"Ozone and Weather in New York City"` and the argument `outer` set equal to `TRUE`.

Hide

```
par(mfrow = c(1, 3), mar = c(4, 4, 2, 1), oma = c(0, 0, 2, 0))
plot(airquality$Wind, airquality$Ozone, main = "Ozone and Wind")
plot(airquality$Solar.R, airquality$Ozone, main = "Ozone and Solar Radiation")
```

Hide

```
plot(airquality$Temp, airquality$Ozone, main = "Ozone and Temperature")
mtext("Ozone and Weather in New York City", outer = TRUE)
```



Voila! Beautiful, right?

Congrats! You've weathered this lesson nicely and passed out of the No!zone.

END
