MFE R Programming Workshop

Week 4

Brett Dunn and Mahyar Kargar

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Introduction

Questions

Any questions before we start?

Overview of Week 4

- Strings
- Dates
- Lab

Strings

Strings

- A string is a sequence of characters.
- In `R`, a sting falls in the `character` class.

```
mystring <- "Hello"
str(mystring)
```

```
##  chr "Hello"
```

- Character vectors are created like numeric vectors.

```
myvec <- c("Hello", "Goodbye")
str(myvec)
```

```
##  chr [1:2] "Hello" "Goodbye"
```

Manipulating Strings

- `R` provides many functions to manipulate strings.
  - `grep()`: Searches for a substring, like the Linux command of the same name.
  - `nchar()`: Finds the length of a string.
  - `paste()` and `paste0()`: Assembles a string from parts.
  - `sprintf()`: Assembles a string from parts.
  - `substr()`: Extracts a substring.
  - `strsplit()`: Splits a string into substrings.
- Hadley Wickham's `stringr` package provides additional functions for using regular expressions and examining text data.

grep()

- The call `grep(pattern,x)` searches for a specified substring pattern in a vector `x` of strings.
- If `x` has `n` elements—that is, it contains `n` strings—then `grep(pattern,x)` will return a vector of length up to `n`.
  -Each element of this vector will be the index in `x` at which a match of pattern as a substring of `x` was found.

```
grep("Pole",c("Equator","North Pole","South Pole"))
```

```
## [1] 2 3
```

nchar()

- The call `nchar(x)` finds the length of a string `x`.

```
nchar("South Pole")
```

```
## [1] 10
```

paste()

- The call `paste(...)` concatenates several strings, returning the result in one long string.

```
paste("North","and","South","Poles")
```

```
## [1] "North and South Poles"
```

```
paste("North","Pole",sep="")
```

```
## [1] "NorthPole"
```

```
# paste0 is same as sep="" (more efficient)
paste0("North","Pole") == paste("North","Pole",sep="")
```

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

sprintf()

- The call `sprintf(...)` assembles a string from parts in a formatted manner.
- Similar to the `C` function `printf`.

```
i <- 8
sprintf("the square of %d is %d",i,i^2)
```

```
## [1] "the square of 8 is 64"
```

substr()

- The call `substr(x,start,stop)` returns the substring in the given character position range `start:stop` in the given string `x`.

```
substring("Equator",3,5)
```

```
## [1] "uat"
```

strsplit()

- The call `strsplit(x,split)` splits a string `x` into an `R` list of substrings based on another string `split` in `x`.

```
strsplit("10-05-2017",split="-")
```

```
## [[1]]
## [1] "10"   "05"   "2017"
```

Example: Creating File Names

- Suppose we want to create five files, `q1.pdf` through `q5.pdf`, consisting of histograms of 100 random N(0,i2) variates. We could execute the following code:

```
for (i in 1:5) {
  fname <- paste("q",i,".pdf")
  pdf(fname)
  hist(rnorm(100,sd=i))
  dev.off()
}
```

Dates

Why do we need date/time classes?

COMPARATIVE TIME-TABLE,

SHOWING THE TIME AT THE PRINCIPAL CITIES OF THE UNITED STATES.

COMPARED WITH NOON AT WASHINGTON, D. C.

There is no "Standard Railroad Time" in the United States or Canada; but each railroad company adopts independently the time of its own locality, or of that place at which its principal office is situated. The inconvenience of such a system, if system it can be called, must be apparent to all, but is most annoying to persons strangers to the fact. From this cause many miscalculations and misconnections have arisen, which not unfrequently have been of serious consequence to individuals, and have, as a matter of course, brought into disrepute all Railroad Guides, which of necessity give the local times. In order to relieve, in some degree, this anomaly in American railroading, we present the following table of local time, compared with that of Washington, D. C.

NOON AT WASHINGTON, D. C.	NOON AT WASHINGTON, D. C.	NOON AT WASHINGTON, D. C.
Albany, N. Y.....12 14 P.M.	Indianapolis, Ind..11 26 A.M.	Philadelphia, Pa...12 08 P.M.
Augusta Ga.....11 41 A.M.	Jackson, Miss.....11 08 "	Pittsburg, Pa.....11 48 A.M.
Augusta, Me. .....11 31 "	Jefferson, Mo.....11 00 "	Plattsburg, N. Y..12 15 P.M.
Baltimore, Md.....12 02 P.M.	Kingston, Can.....12 02 P.M.	Portland, Me.....12 28 "
Beaufort, S. C.....11 47 A.M.	Knoxville, Tenn...11 33 A.M.	Portsmouth, N. H.12 25 "
Boston, Mass.....12 24 P.M.	Lancaster, Pa.....12 03 P.M.	Pra. du Chien, Wis.11 04 A.M.
Bridgeport, Ct.....12 16 "	Lexington, Ky.....11 31 A.M.	Providence, R. I...12 23 P.M.
Buffalo, N. Y.....11 53 A.M.	Little Rock, Ark...11 00 "	Quebec, Can.....12 23 "
Burlington, N. J...12 09 P.M.	Louisville, Ky.....11 26 "	Racine, Wis.....11 18 A.M.
Burlington, Vt....12 16 "	Lowell, Mass.....12 23 P.M.	Raleigh, N. C.. ...11 53 "
Canandaigua, N. Y.11 59 A.M.	Lynchburg, Va....11 51 A.M.	Richmond, Va.....11 58 "
Charleston, S. C...11 49 "	Middletown, Ct....12 18 P.M.	Rochester, N. Y...11 57 "
Chicago, Ill.....11 18 "	Milledgeville, Ga...11 35 A.M.	Sacketts H'bor, NY.12 05 P.M.
Cincinnati, O.....11 31 "	Milwaukee, Wis....11 17 A.M.	St. Anthony Falls,..10 56 A.M.
Columbia, S. C.....11 44 "	Mobile, Ala.....11 16 "	St. Augustine, Fla.11 42 "
Columbus, O.....11 36 "	Montpelier, Vt.....12 18 P.M.	St. Louis, Mo.....11 07 "
Concord, N. H.....12 23 P.M.	Montreal, Can.....12 14 "	St. Paul, Min.....10 56 "
Dayton, O.....11 32 A.M.	Nashville, Tenn...11 21 A.M.	Sacramento, Cal... 9 02 "
Detroit, Mich.....11 36 "	Natchez, Miss.....11 03 "	Salem, Mass.....12 26 P.M.
Dover, Del.....12 06 P.M.	Newark, N. J.....12 11 P.M.	Savannah, Ga.....11 44 A.M.
Dover, N. H.....12 37 "	New Bedford, Mass.12 25 "	Springfield, Mass...12 18 P.M.
Eastport, Me.....12 41 "	Newburg, N. Y....12 12 "	Tallahassee, Fla....11 30 A.M.
Frankfort, Ky.....11 30 A.M.	Newburyport, Ms..12 25 "	Toronto, Can.....11 51 "
Frederick, Md.....11 59 "	Newcastle, Del....12 06 "	Trenton, N. J.....12 10 P.M.
Fredericksburg, Va.11 58 "	New Haven, Conn..12 17 "	Troy, N. Y.....12 14 "
Frederickton, N. Y.12 42 P.M.	New London, " ..12 20 "	Tuscaloosa, Ala....11 18 A.M.
Galveston, Texas..10 49 A.M.	New Orleans, La...11 08 A.M.	Utica, N. Y.....12 08 P.M.
Gloucester, Mass..12 26 P.M.	Newport, R. I.....12 23 P.M.	Vandalia, Ill.....11 18 A.M.
Greenfield, " ..12 18 "	New York, N. Y...12 12 "	Vincennes, Ind....11 19 "
Hagerstown, Md...11 58 A.M.	Norfolk, Va.....12 03 "	Wheeling, Va.....11 45 "
Halifax, N. S.....12 54 P.M.	Northampton, Ms..12 18 "	Wilmington, Del...12 06 P.M.
Harrisburg, Pa....12 01 "	Norwich, Ct.....12 20 "	Wilmington, N. C..11 56 A.M.
Hartford, Ct.....12 18 "	Pensacola, Fla.....11 20 A.M.	Worcester, Mass...12 21 P.M.
Huntsville, Ala....11 21 A.M.	Petersburg, Va....11 59 "	York, Pa.....12 02 "

By an easy calculation, the difference in time between the several places above named may be ascertained. Thus, for instance, the difference of time between New York and Cincinnati may be ascertained by simple comparison, that of the first having the Washington noon at 12 12 P. M., and of the latter at 11 31 A. M.; and hence the difference is 43 minutes, or, in other words, the noon at New York will be 11.17 A. M. at Cincinnati, and the noon at Cincinnati will be 12 43 P. M. at New York. Remember that places *West* are "slower" in time than those *East*. and *vice versa*.

Date Classes in R

- `Date` is in `yyyy-mm-dd` format and represents the number of days since Jamuary 1, 1970
- `POSIXct` represents the (signed) number of seconds since Jamuary 1, 1970 (in the UTC time zone) as a numeric vector.
- `POSIXlt` is a named list of vectors representing `sec`, `min`, `hour`, `mday`, `mon`, `year`, time zone par maters, and a few other items.

```
x <- Sys.time()  # clock time as a POSIXct object
x; as.numeric(x)
```

```
## [1] "2017-10-24 14:41:39 PDT"
```

```
## [1] 1508881299
```

Creating Dates

- Typically, dates come into R as character strings.
- By default, R assumes the string is in the format `yyyy-mm-dd` or `yyyy-mm-dd`

```
mychar <- "2017-10-05"
mydate <- as.Date(mychar)
str(mydate)
```

```
##  Date[1:1], format: "2017-10-05"
```

Date Formats

- R can parse many other types of date formats.
- See `?strptime` for details.

```
mychar <- "October 5th, 2017"
mydate <- as.Date(mychar, format = "%B %eth, %Y")
str(mydate)
```

```
##  Date[1:1], format: "2017-10-05"
```

Extract Parts of a Date Object

```
mydate <- as.Date("2017-10-05")
weekdays(mydate)
```

```
## [1] "Thursday"
```

```
months(mydate)
```

```
## [1] "October"
```

```
quarters(mydate)
```

```
## [1] "Q4"
```

Generate Regular Sequences of Dates

```
## first days of years
seq(as.Date("2007/1/1"), as.Date("2010/1/1"), "years")
```

```
## [1] "2007-01-01" "2008-01-01" "2009-01-01" "2010-01-01"
```

```
## by month
seq(as.Date("2000/1/1"), by = "month", length.out = 4)
```

```
## [1] "2000-01-01" "2000-02-01" "2000-03-01" "2000-04-01"
```

```
## quarters
seq(as.Date("2000/1/1"), as.Date("2001/1/1"), by = "quarte
```

```
## [1] "2000-01-01" "2000-04-01" "2000-07-01" "2000-10-01"
```

Time Intervals / Differences

- Function difftime calculates a difference of two date/time objects and returns an object of class "difftime" with an attribute indicating the units.

```
time1 <- as.Date("2017-10-05")
time2 <- as.Date("2008-07-08")
time1 - time2
```

```
## Time difference of 3376 days
```

```
difftime(time1, time2, units = "weeks")
```

```
## Time difference of 482.2857 weeks
```

Dates in Microsoft Excel

- Microsoft Excel stores dates as the number of days since Decemeber 31, 1899.
- However, Excel also incorrectly assumes that the year 1900 is a leap year to allow for compatability with Lotus 1-2-3.
- Therefore, for dates after 1901, set the origin to Decemeber 30, 1899 to convert an Excel date to an R date.

```
as.Date(43013, origin = "1899-12-30")
```

```
## [1] "2017-10-05"
```

Lubridate

Lubridate

- Lubridate is an R package that makes it easier to work with dates and times.
- Lubridate was created by Garrett Grolemund and Hadley Wickham.

```
# install.packages("lubridate")
library(lubridate)
```

```
##
## Attaching package: 'lubridate'

## The following object is masked from 'package:base':
##
##     date
```

Parse a date

- Lubridate accepts lots of formats

```
ymd("20110604")
```

```
## [1] "2011-06-04"
```

```
mdy("06-04-2011")
```

```
## [1] "2011-06-04"
```

```
dmy("04/06/2011")
```

```
## [1] "2011-06-04"
```

Parse a date and time

```
ymd_hms("2011-06-04 12:00:00", tz = "Pacific/Auckland")
```

```
## [1] "2011-06-04 12:00:00 NZST"
```

Extraction

```
arrive <- ymd_hms("2011-06-04 12:00:00")
second(arrive)
```

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

```
second(arrive) <- 25
arrive
```

```
## [1] "2011-06-04 12:00:25 UTC"
```

Intervals

```
arrive <- ymd_hms("2011-06-04 12:00:00")
leave <- ymd_hms("2011-08-10 14:00:00")
interval(arrive, leave)
```

```
## [1] 2011-06-04 12:00:00 UTC--2011-08-10 14:00:00 UTC
```

Arithmetic

```
mydate <- ymd("20130130")
mydate + days(2)
```

```
## [1] "2013-02-01"
```

```
mydate + months(5)
```

```
## [1] "2013-06-30"
```

Arithmetic

```
mydate <- ymd("20130130")
mydate + days(1:5)
```

```
## [1] "2013-01-31" "2013-02-01" "2013-02-02" "2013-02-03"
```

End of (next) month

```
jan31 <- ymd("2013-01-31")
jan31 + months(1)
```

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

```
ceiling_date(jan31, "month") - days(1)
```

```
## [1] "2013-01-31"
```

```
floor_date(jan31, "month") + months(2) - days(1)
```

```
## [1] "2013-02-28"
```

Plotting in R

Motivation

One skill that isn't taught in grad school is how to make a nice chart.

- Managing Director at Citigroup

What makes a chart nice?

- The reader should look at the chart and immediately understand what data are displayed.
- This means we need:
  - A clear title.
  - Clear labels for each axis (scale and units).
  - A legend if more than one time series is displayed.
  - Different colors and line formats for different time series.
  - Grid lines.
  - Labels.

Plotting Facilities in R

- R has excellent plotting methods built-in.
- I will focus on base R.
- As a next step, I recommend learning `ggplot2`, an excellent plotting package.
- http://www.r-graph-gallery.com/

Basic Plotting

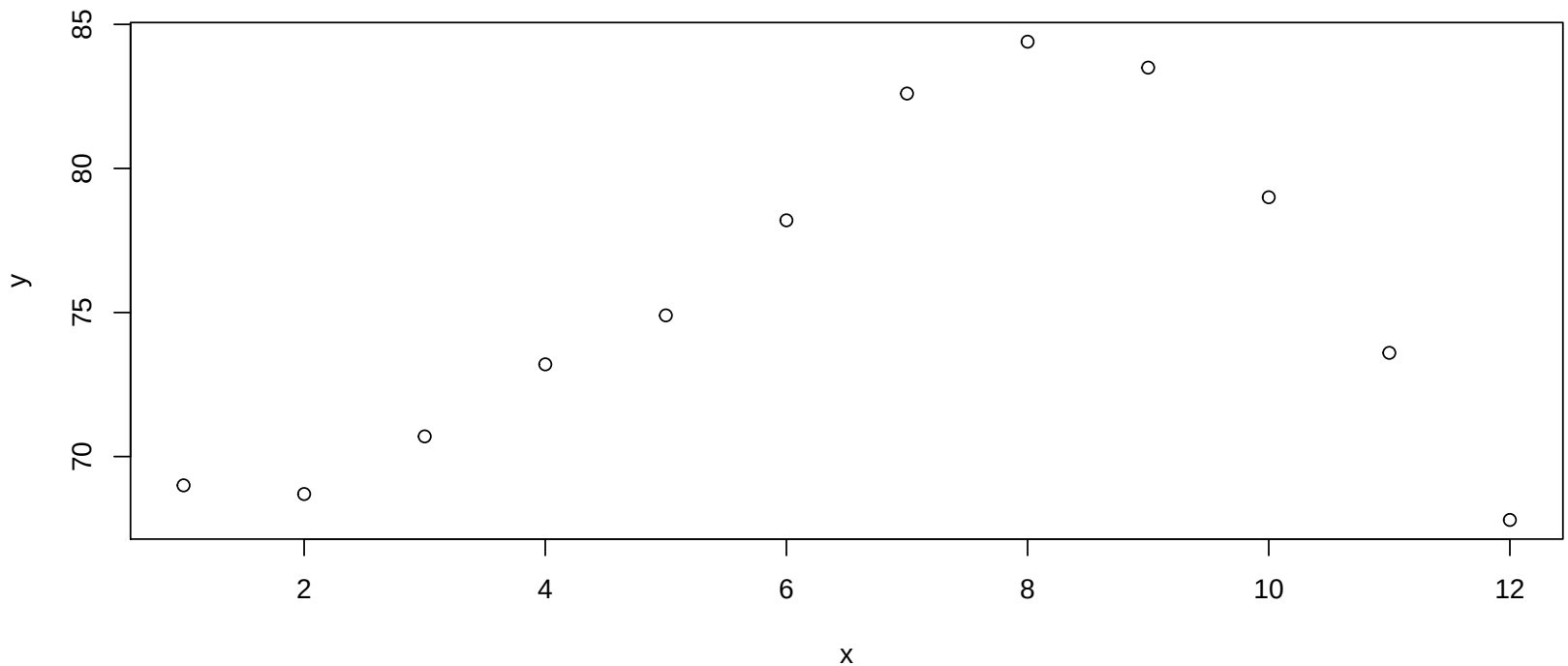
- `example(plot)`
- `example(hist)`
- `?par`
- `?plot.default`

The `plot()` Function

- `plot()` is generic function, i.e. a placeholder for a family of functions.
  - the function that is actually called depends on the class of the object on which it is called.
- `plot()` works in stages.
  - you can build up a graph in stages by issuing a series of commands.
- We will see how this works with an example.

A Basic Plot

```
x <- seq(1:12)
y <- c(69, 68.7, 70.7, 73.2, 74.9, 78.2,
       82.6, 84.4, 83.5, 79, 73.6, 67.8)
plot(x, y)
```



`xlim()` and `ylim()`

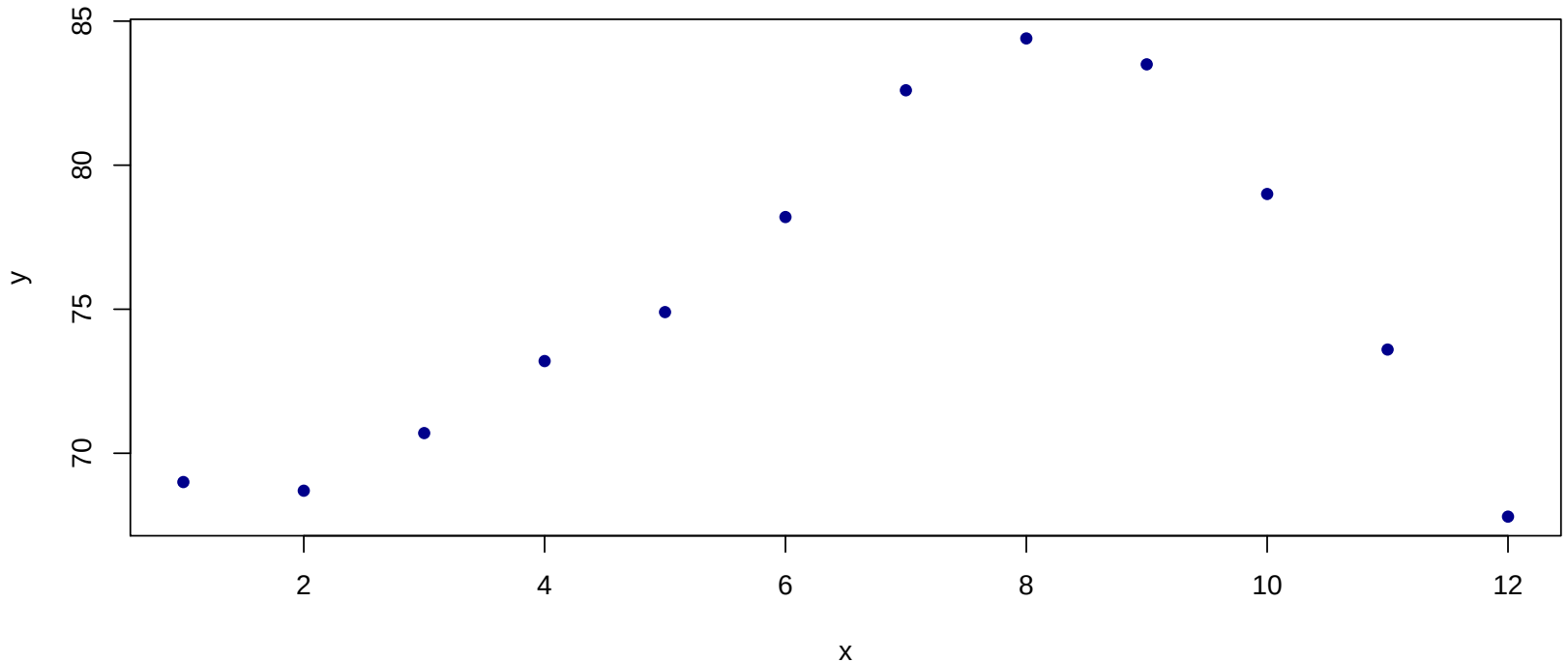
Graphical `paramaters`

- Graphical parameters can be set as arguments to the `par` function, or they can be passed to the `plot` function.
- Make sure to read through `?par`.
- Some useful parameters:
  - `cex`: sizing of text and symbols
  - `pch`: point type.
  - `lty`: line type.
    - 0=blank, 1=solid (default), 2=dashed, 3=dotted, 4=dotdash, 5=longdash, 6=twodash
  - `lwd`: line width.
  - `mar`: margins.

pch

- pch sets how points are displayed

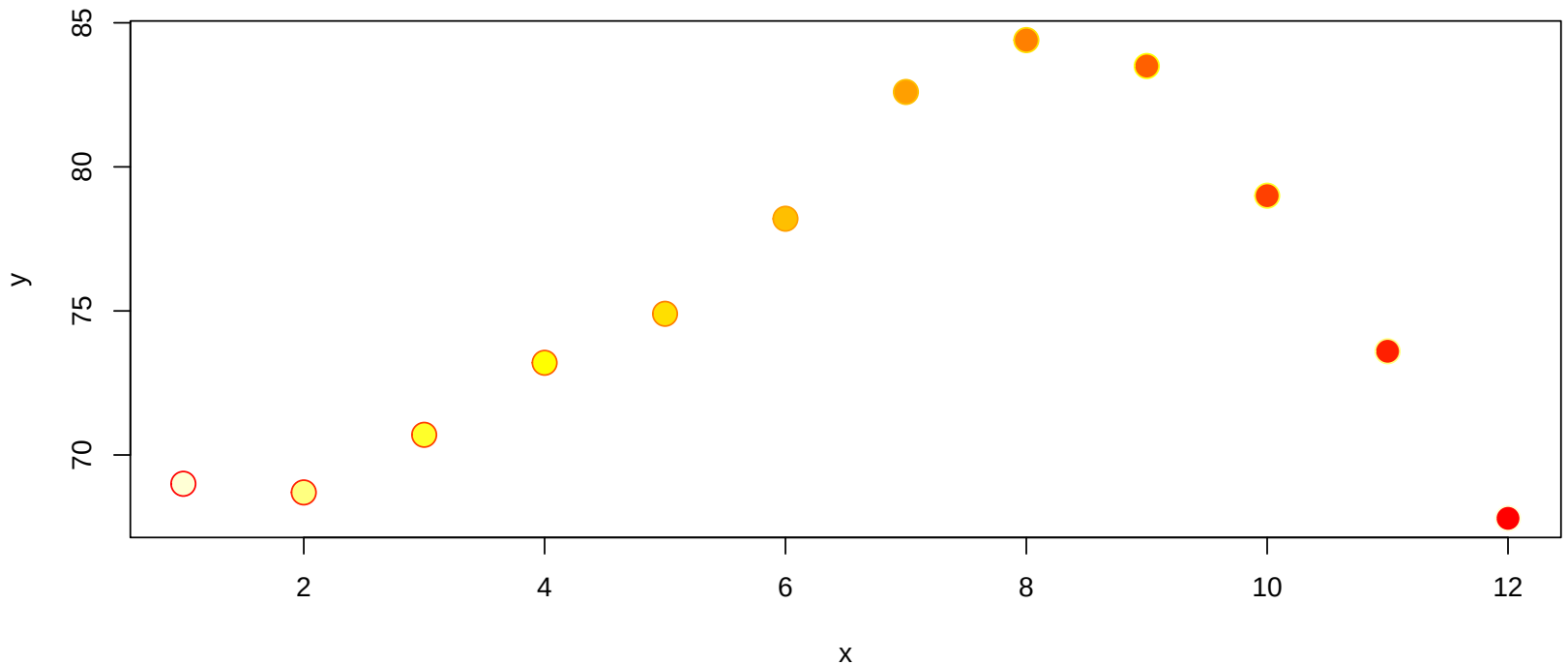

```
plot(x,y, pch = 16, col='darkblue')
```



Colors in R

- `colors()` returns all available color names.
- `rainbow(n)`, `heat.colors(n)`, `terrain.colors(n)` and `cm.colors(n)` return a vector of `n` contiguous colors.

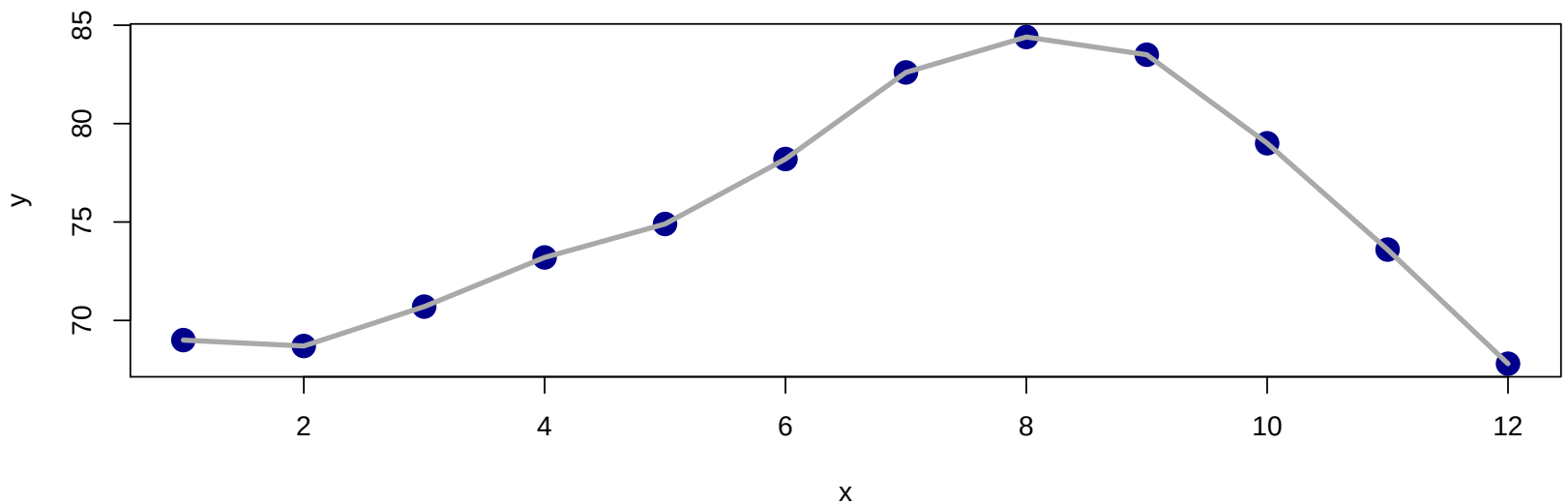
```
plot(x, y, pch = 21, col=heat.colors(12),
     cex = 2, bg = rev(heat.colors(12)))
```



lines()

- `lines()` takes coordinates and joins the corresponding points with line segments.
  - Notice, by calling `lines` after `plot` the line is on top of the points.
  - This is why we want to build the plot in stages.

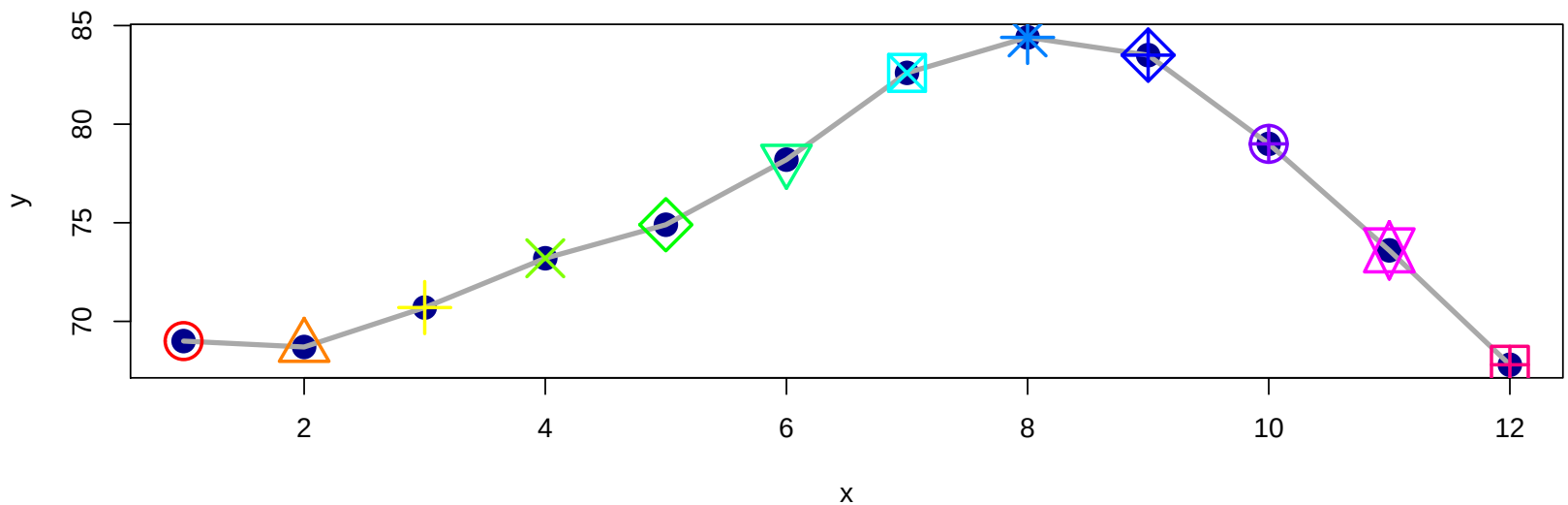
```
plot(x,y, pch = 16, col='darkblue', cex=2)
lines(x, y, col='darkgrey', lwd = 3)
```



points()

- `points` is a generic function to draw a sequence of points at the specified coordinates. The specified character(s) are plotted, centered at the coordinates.

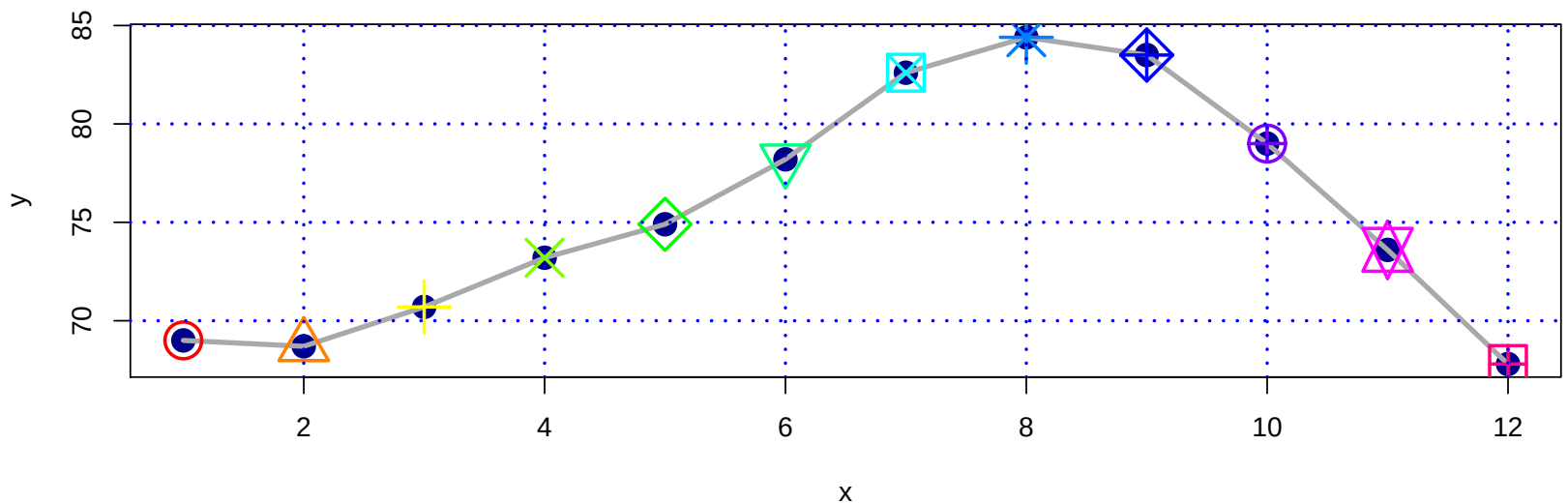
```
plot(x,y, pch = 16, col='darkblue', cex=2)
lines(x, y, col='darkgrey', lwd = 3)
points(x, y, col=rainbow(12), pch=1:12, cex=3, lwd=2)
```



grid()

- grid adds a rectangular grid to an existing plot.
- ?grid for more details.

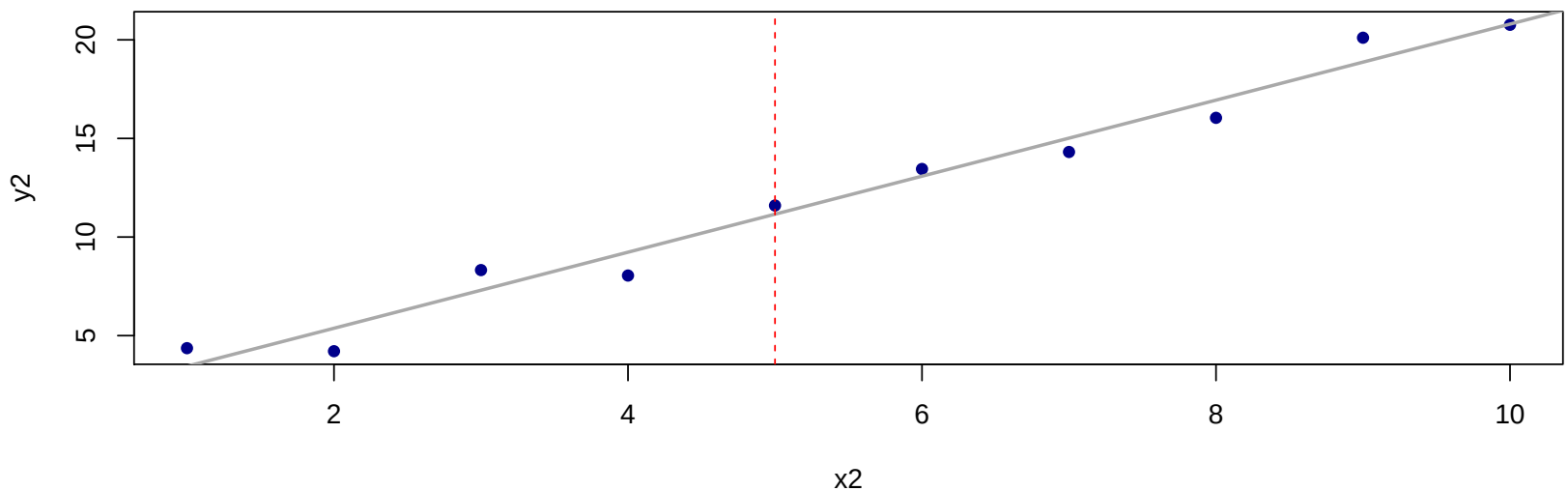
```
plot(x,y, pch = 16, col='darkblue', cex=2)
lines(x, y, col='darkgrey', lwd = 3)
points(x, y, col=rainbow(12), pch=1:12, cex=3, lwd=2)
grid(col="blue", lwd=2)
```



abline()

- abline adds one or more straight lines through the current plot.

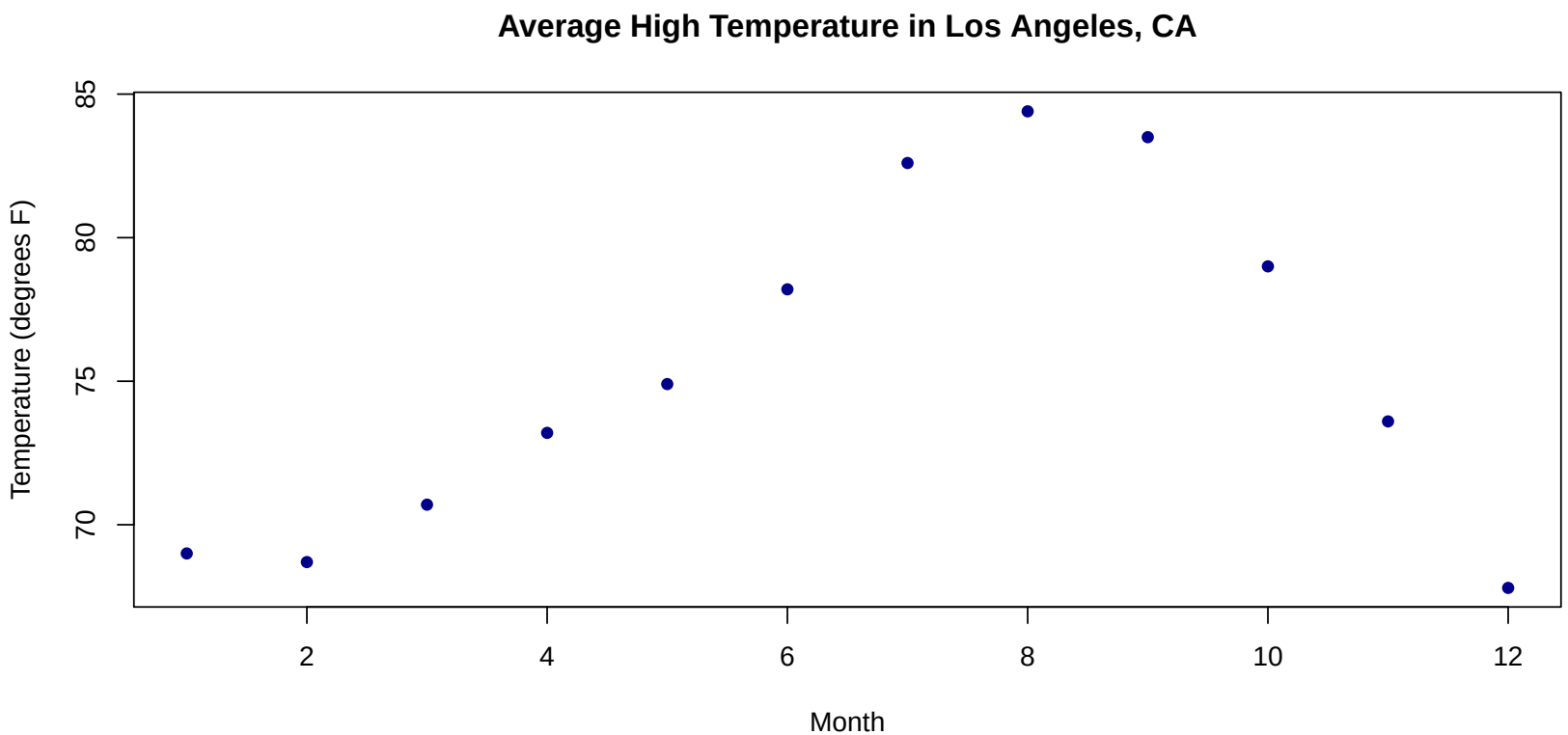
```
x2 <- 1:10; y2 <- 1 + 2*x2 + rnorm(10)
plot(x2,y2, pch = 16, col='darkblue')
model <- lm(y2 ~ x2)
abline(model, col="darkgrey", lwd=2)
abline(v = 5, col = "red", lty = 2)
```



Adding a Title in Lables

- Use the `main` argument for a title.
- Use the `xlab` and `ylab` for axis labels.

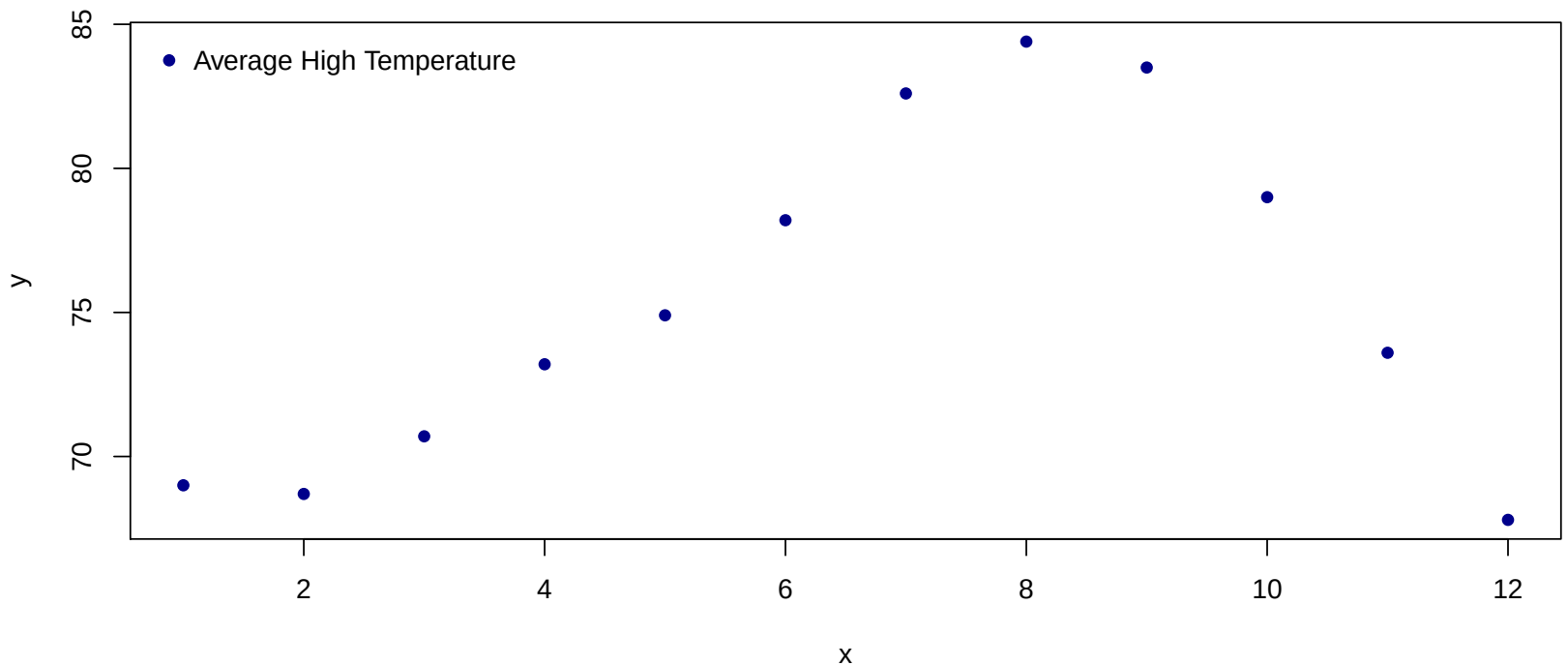
```
plot(x,y, pch = 16, col='darkblue',
     xlab = "Month", ylab = "Temperature (degrees F)",
     main = "Average High Temperature in Los Angeles, CA")
```



Adding a Legend: The `legend()` Function

- see `?legend` and `example(legend)`

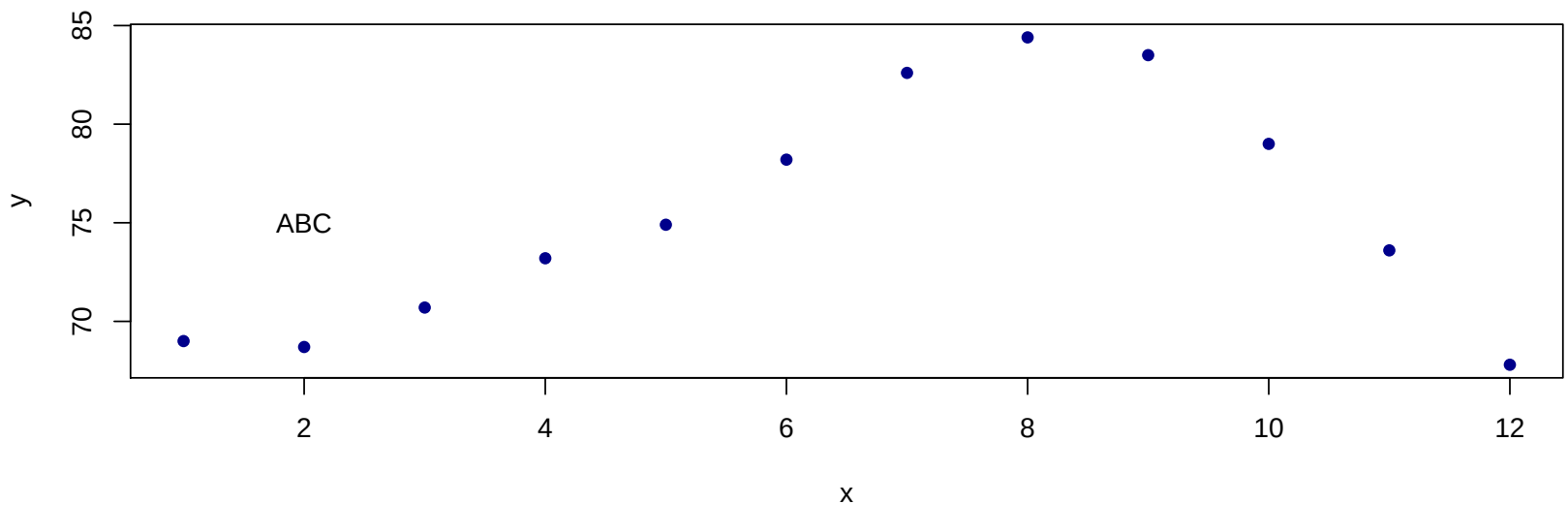
```
plot(x,y, pch = 16, col='darkblue')
legend("topleft", inset=.01, "Average High Temperature",
  col = "darkblue", pch = 16, bg="white",box.col="white")
```



text() and locator()

- Use the `text()` function to add text anywhere in the current graph.
- `locator()` allows you to click on a point in the chart and returns the location.

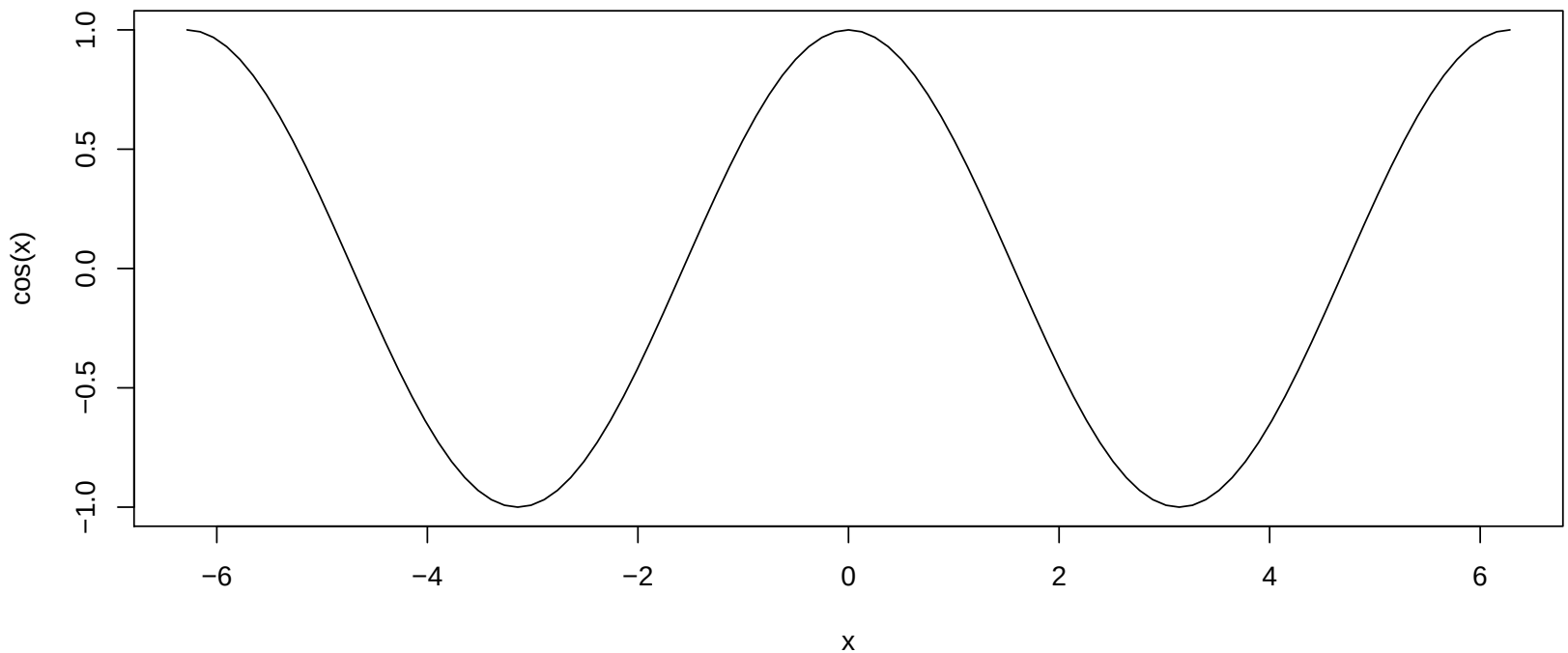
```
plot(x,y, pch = 16, col='darkblue')
text(2,75, "ABC")
```



curve()

- With `curve()`, you can plot a function.

```
curve(cos(x), -2*pi, 2*pi)
```



Saving a Plot to a File

1. Open a file: `pdf("name.pdf")`
2. Create the plot.
3. Close the device with `dev.off()`

- You can use `dev.copy()` to save the displayed graph.
- See `library(help = "grDevices")` for more information.

An Example of Plotting in R

- Let's plot the cumulative (gross) return of IBM and the S&P 500 since 1980.

```
library(quantmod)
getSymbols(c("^GSPC", "IBM"),from = "1979-12-31")
```

```
## [1] "GSPC" "IBM"
```

```
adj_close <- merge(GSPC$GSPC.Adjusted, IBM$IBM.Adjusted)
daily_returns <- diff(adj_close)/lag(adj_close)
cum_ret <- cumprod(1+daily_returns[-1,])
ret1 <- xts(matrix(1, ncol=2), as.Date("1979-12-31"))
cum_ret <- (rbind(cum_ret, ret1) - 1)*100
colnames(cum_ret) <- c("GSPC", "IBM")
```

The Data

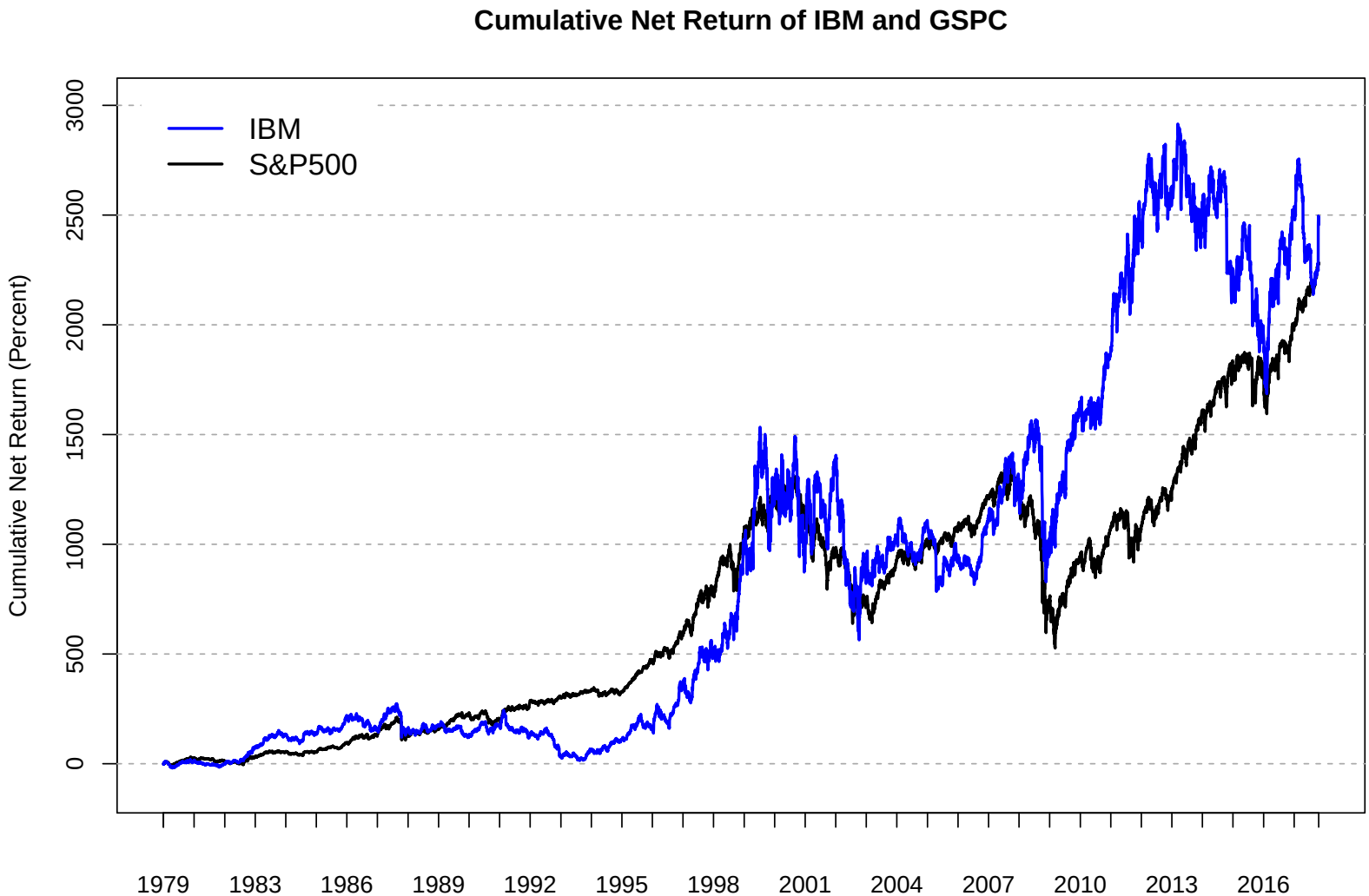
```
head(cum_ret, 9)
```

```
##                   GSPC       IBM
## 1979-12-31  0.0000000  0.000000
## 1980-01-02 -2.0196405 -2.912548
## 1980-01-03 -2.5199194 -1.359205
## 1980-01-04 -1.3155503 -1.553311
## 1980-01-07 -1.0468816 -1.941698
## 1980-01-08  0.9357004  4.660284
## 1980-01-09  1.0283500  1.553471
## 1980-01-10  1.8065564  4.854470
## 1980-01-11  1.8343487  4.077727
```

Start with a Blank Chart and Build it Up

```
plot(cum_ret$IBM, xlab="", ylab = "Cumulative Net Return (P
     main="", major.ticks="years", minor.ticks=F,
     type="n", major.format = "%Y", auto.grid=F,
     ylim = c(-500, 3000))
abline(h=seq(-500,3000,500), col="darkgrey", lty=2)
lines(cum_ret$GSPC, col="black", lwd=2)
lines(cum_ret$IBM, col="blue", lwd=2)
legend("topleft", inset=.02,
       c("IBM","GSPC"), col=c("blue", "black"),
       lwd=c(2,2),bg="white", box.col="white")
```

The Chart


Cumulative Net Return of IBM and GSPC
IBM
S&P500
Cumulative Net Return (Percent)
0
500
1000
1500
2000
2500
3000
1979
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016

Lab 2

Let's work on Lab 2.