An Introduction to *R*

Part 1: Basics

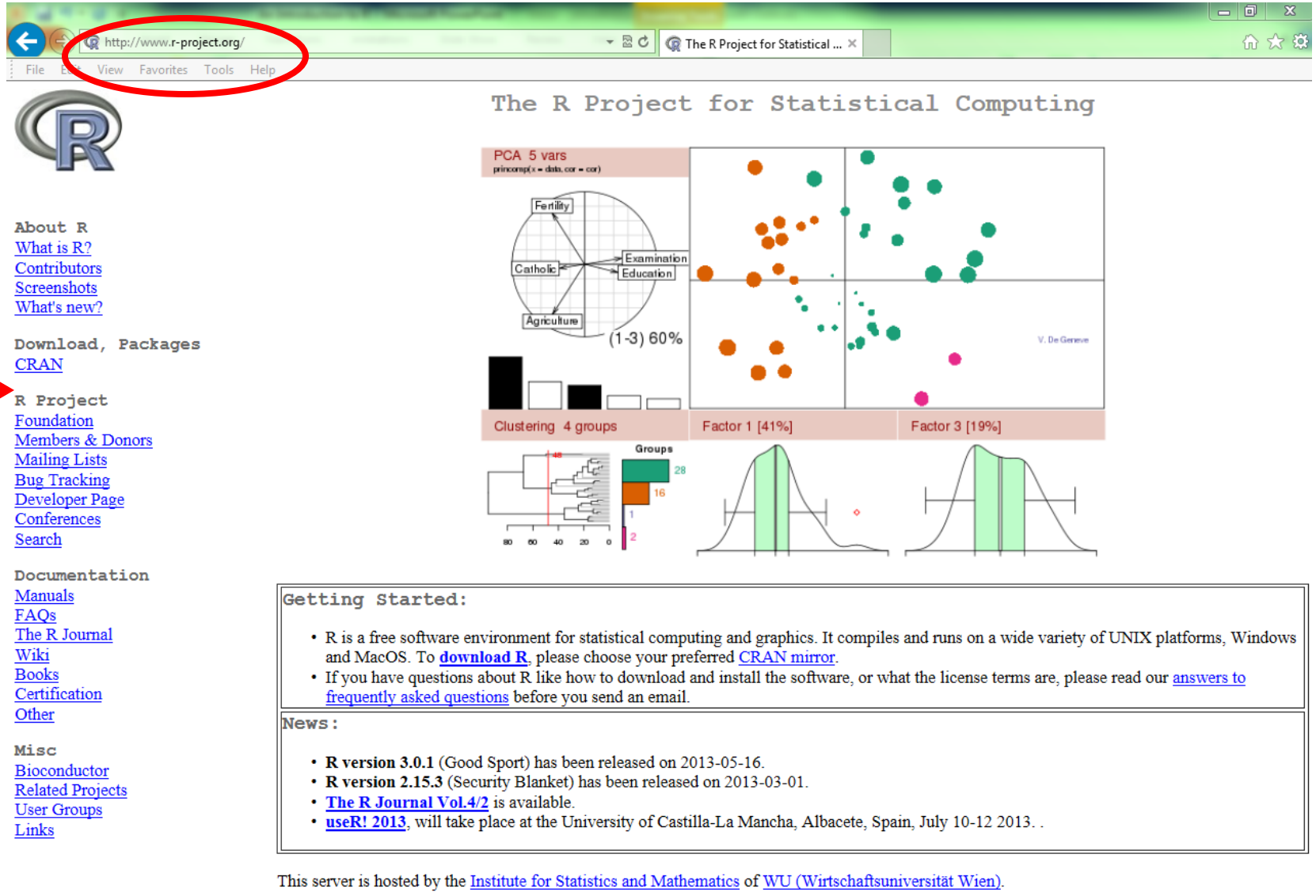
Kjell Johnson

Arbor Analytics, LLC

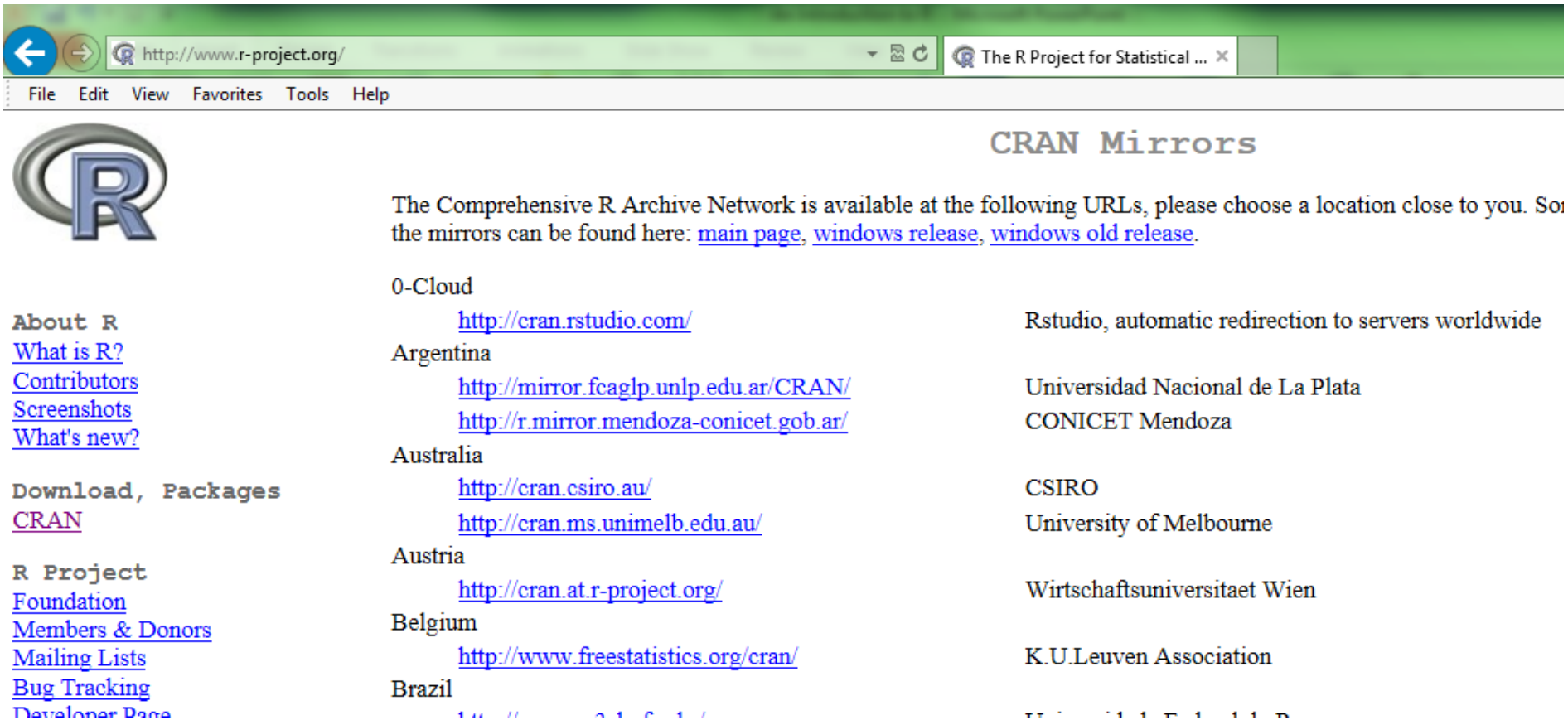
Overview

- Installing R
- Editors
- Data types
- Subsetting data
- Row and column information
- Importing data
- Installing packages
- Basics of visualizing data

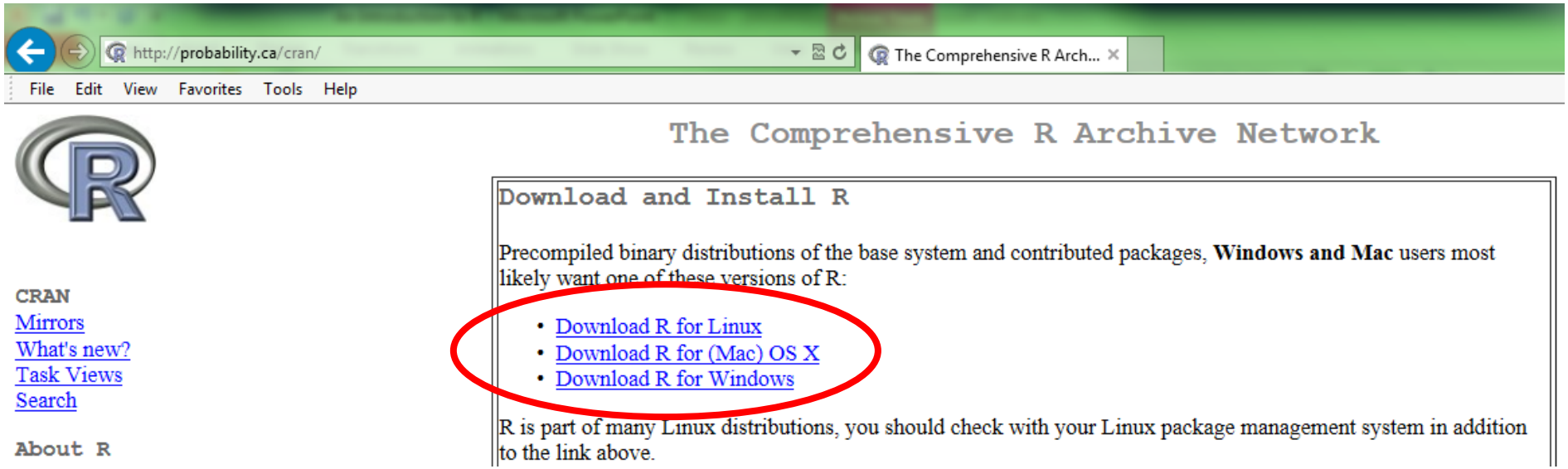
Installing R from r-project.org



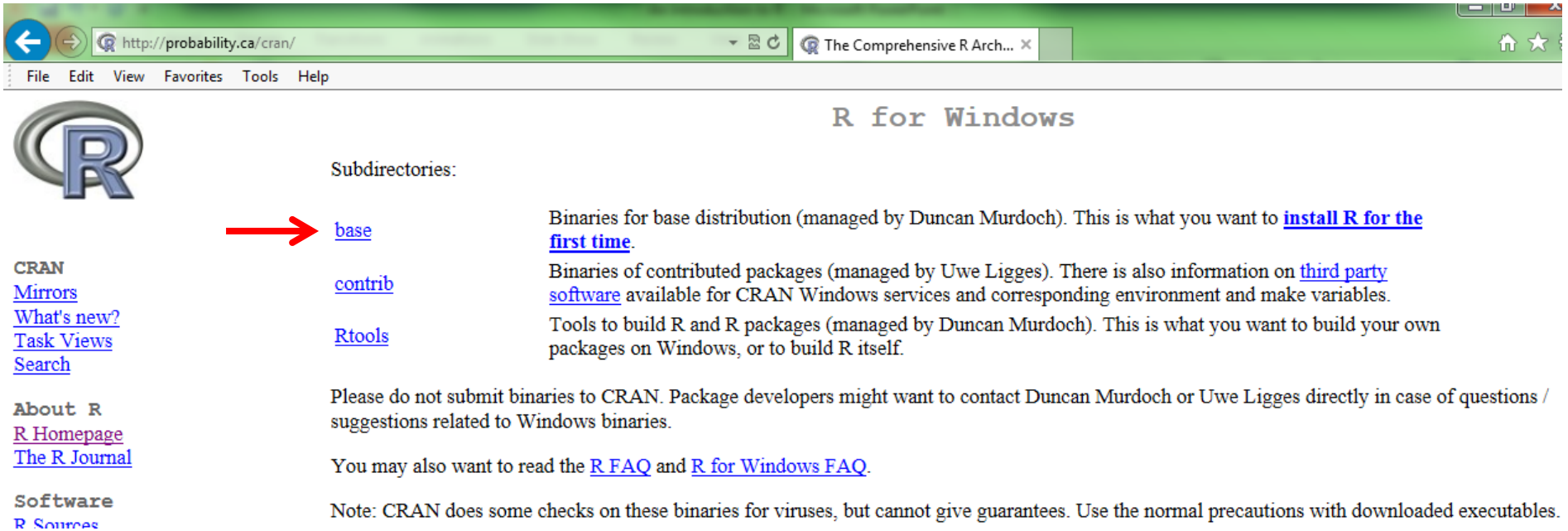
Pick a Mirror Site



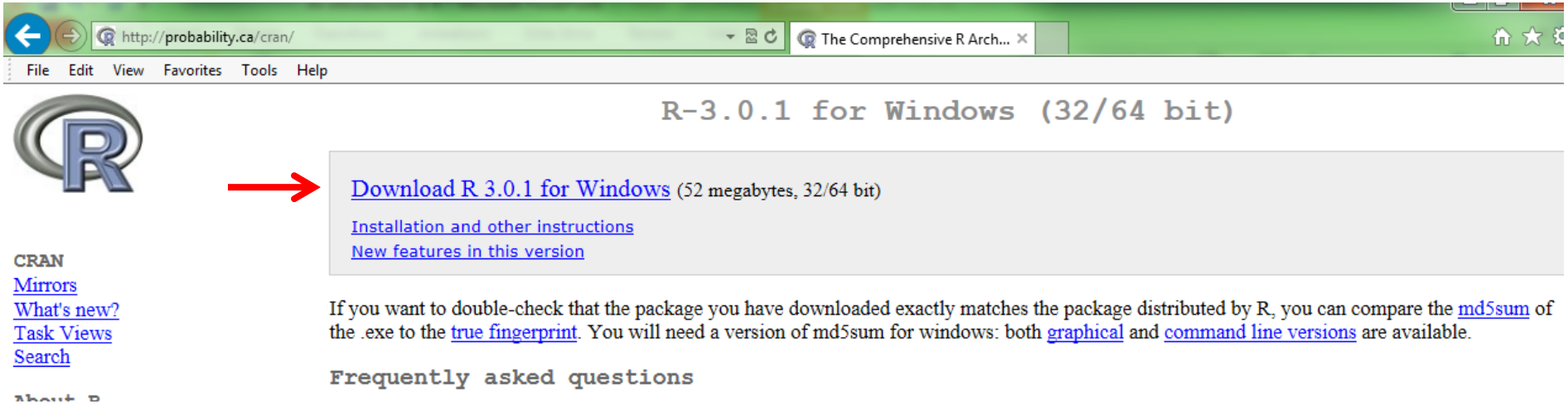
Select Your Operating System



Select “base”


http://probability.ca/cran/
The Comprehensive R Arch...
File Edit View Favorites Tools Help
R for Windows
Subdirectories:
base
Binaries for base distribution (managed by Duncan Murdoch). This is what you want to install R for the first time.
contrib
Binaries of contributed packages (managed by Uwe Ligges). There is also information on third party software available for CRAN Windows services and corresponding environment and make variables.
Rtools
Tools to build R and R packages (managed by Duncan Murdoch). This is what you want to build your own packages on Windows, or to build R itself.
CRAN
Mirrors
What's new?
Task Views
Search
About R
R Homepage
The R Journal
Software
Please do not submit binaries to CRAN. Package developers might want to contact Duncan Murdoch or Uwe Ligges directly in case of questions / suggestions related to Windows binaries.
You may also want to read the R FAQ and R for Windows FAQ.
Note: CRAN does some checks on these binaries for viruses, but cannot give guarantees. Use the normal precautions with downloaded executables.

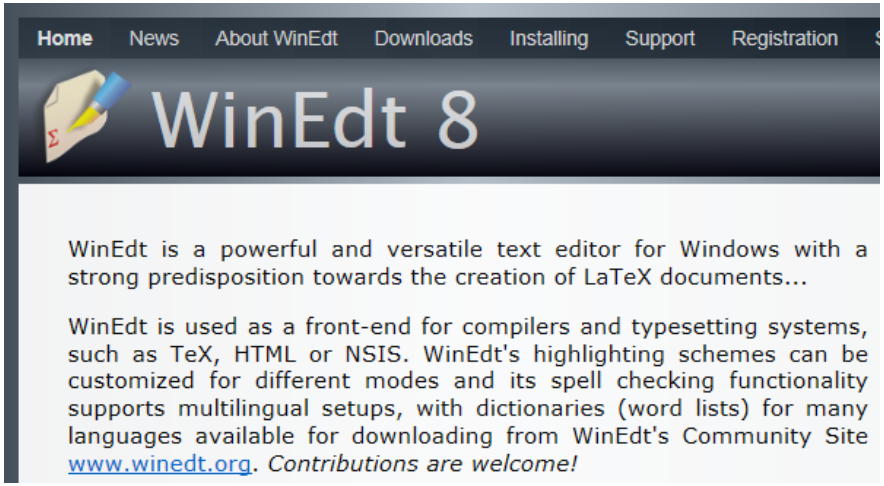
Download R and Follow Prompts



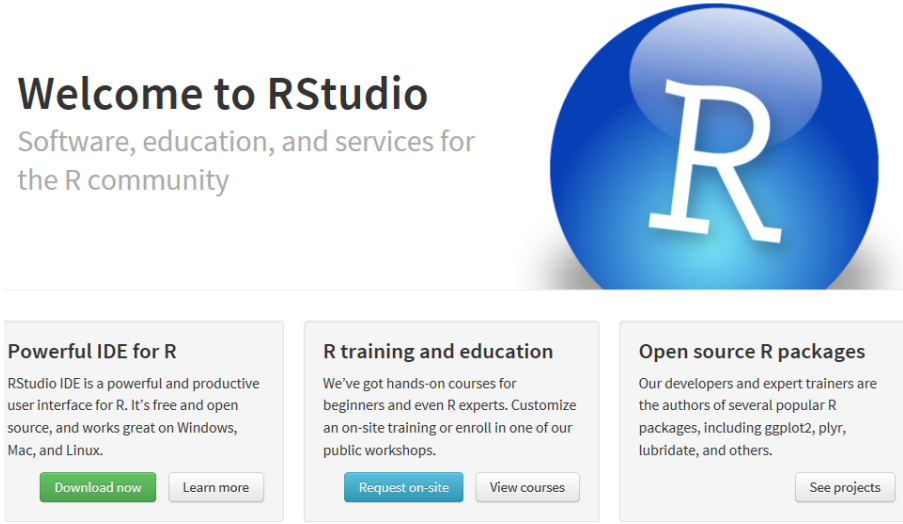
Editors for R

- Any text editor will work:
  - Notepad, Wordpad, Word,vi, etc.
- More sophisticated editing can be done with:

winedt.com

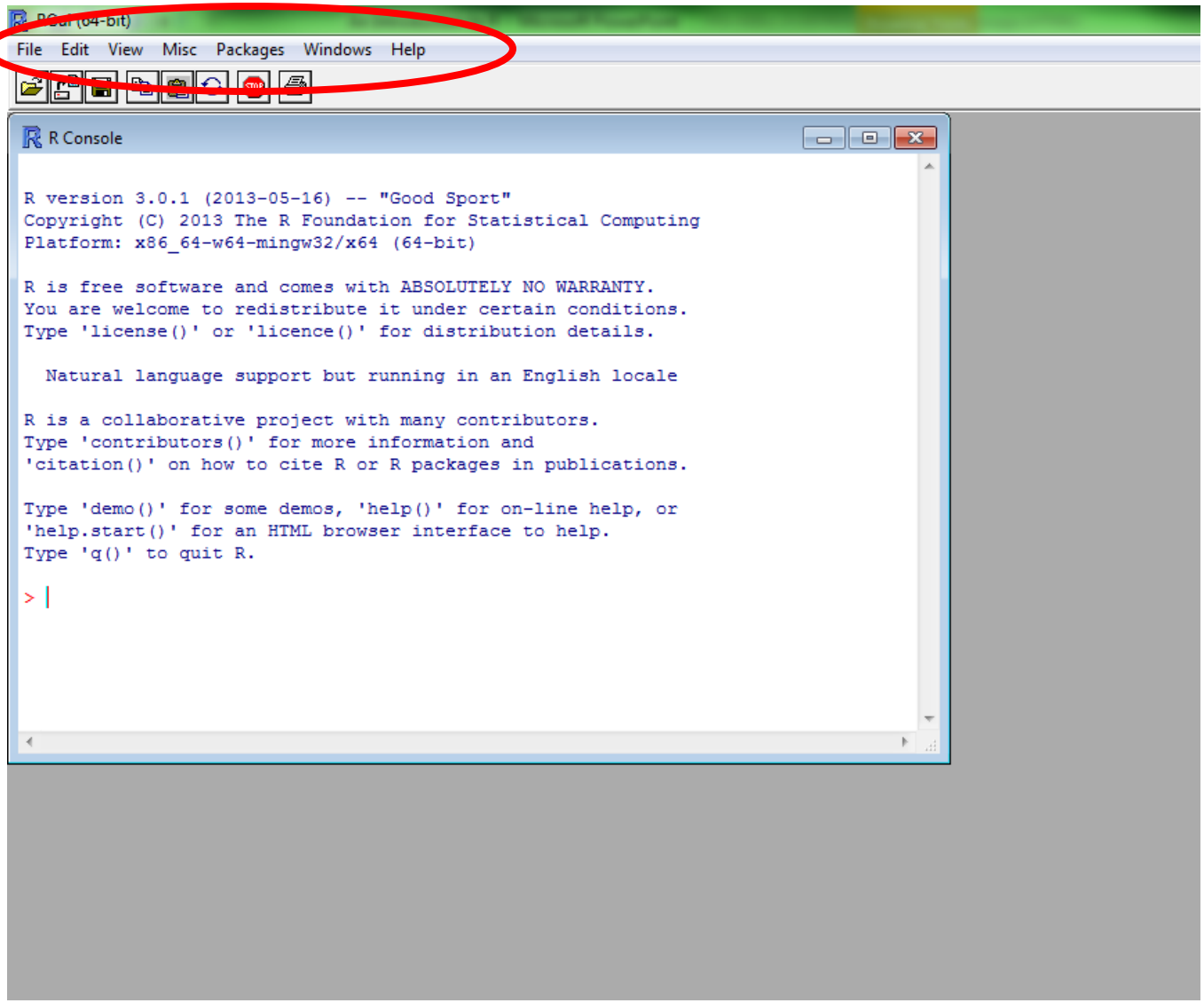


rstudio.com



The R Console

Let's briefly explore the menu items



We enter code at the prompt:

Beginning Notes

- Beware: R is case sensitive!
- Help documentation can be found by typing `help(`*`function name`*`)` or `?(`*`function name`*`)`
  - If you only remember part of the name, then using `??(`*`function name`*`)` will search for any help documentation with that name
- The up arrow at the command prompt gives previous command prompt entries

Telling R Where to Work

The `setwd` function sets the working directory for R:

```
setwd("c:/Part1")
```

Note: R requires forward slashes between levels (or double backslashes):

```
setwd("c:\\Part1")
```

Alternatively we can define an object with the file location and then set the working directory:

```
myLocation <- "c:/Part1"
setwd(myLocation)
```

Notes:

`myLocation` is an object in the current R session

We can see what objects are in the current session with the `ls()` command

We can see what directory we are in with the `getwd()` command

Creating Data in R

A vector is an object that contains elements. Elements can be numeric:

```
scores <- c(89,102,73,54,92,27)
```

Or elements can be character:

```
sample <- c("a","a","b","b","c","c")
```

To check to see if a vector is numeric or character use the following functions:

```
is.numeric(scores)
is.character(sample)
```

To see the contents of scores or sample, type `scores` or `sample` at the R prompt

Functions like `head()` or `tail()` give the first 5 or last 5 elements of a data set.

Factor

- A *factor* is an important data structure in R
- This data structure contains the original values of the variable as well as labels corresponding to each “level” of the factor
  - Levels are often necessary for graphing and analyzing data

To convert an object to a factor:

```
sample.f <- factor(sample)
is.factor(sample.f)
sample.f
```

Matrices

- A *matrix* is a two dimensional object that contains data of the same type (i.e. only numeric or only character)
- Matrices are more efficient for some operations, but not as convenient as data frames…

Create a matrix:

```
prepTime <- c(9,10,7,4,9,3)
myMatrix <- cbind(prepTime,scores)
```

The function `dim()` tells us the number of rows and columns in the matrix. See also `nrow()` and `ncol()`

Data Frame

- A *data frame* is another important data structure in R. A data frame is often rectangular with rows (samples) and columns (variables)
  - Data frames can contain a mix of character, numeric, and factor variables

Create a data frame:

```
myData <- data.frame(sampleID = sample.f, Score = scores,
                     Prep = prepTime)
```

`sampleID`, `Score`, and `Prep` are the column names that contain the data from `sample.f`, `scores`, and `prepTime`.

The function `colnames()` returns the column names of the data frame
The function `rownames()` returns the row names of the data frame

Accessing Information in a Data Frame

To access data in an individual column of a data frame, we use the `$` operator:

```
myData$Score
myData$sampleID
myData$Prep
```

We can also access data in a data frame using row and column location identification:

All of the data in the first column:

```
myData[,1]
```

All of the data in the second row:

```
myData[2,]
```

Rows 3 through 5 of the second column:

```
myData[3:5,2]
```

All of the data in rows 2, 4, and 6:

```
myData[c(2,4,6),]
```

Other Ways to Subset or Select Data

The subset function:

```
?subset
```

Select samples with scores greater than 50:

```
subset(myData, Score > 50)
```

Select samples with scores greater than 50 and less than or equal to 89:

```
subset(myData, Score > 50 & Score <= 89)
```

Select samples with sampleID's of "a":

```
subset(myData, sampleID == "a")
```

Select samples with sampleID's of "a" or "b":

```
subset(myData, sampleID %in% c("a","b"))
```

Select samples with scores greater than 50 and keep the sampleID and Score variables:

```
subset(myData, Score > 50, select=c("sampleID","Score"))
```

Other Ways to Subset or Select Data

Logical constraints with row and column referencing:

Select samples with scores greater than 50:

```
myData[myData$Score > 50,]
```

Select samples with scores greater than 50 and less than or equal to 89:

```
myData[myData$Score > 50 & myData$Score <= 89,]
```

Select samples with sampleID's of "a":

```
myData[myData$sampleID == "a",]
```

Select samples with sampleID's of "a" or "b":

```
myData[myData$sampleID %in% c("a","b"),]
```

Select samples with scores greater than 50 and keep the sampleID and Score variables:

```
myData[myData$Score > 50, c("sampleID","Score")]
```

Renaming Rows and Columns

A few options:

1) Rename all rows or columns

```
rownames(myData) <- c("Kermit","Miss Piggy","Rizzo",
                      "Gonzo","Animal","Fozzy")
colnames(myData) <- c("Column1","Column2")
```

2) Renaming one row or column:

```
rownames(myData)[rownames(myData) == "Kermit"] <- "Ralph"
colnames(myData)[colnames(myData) == "Column2"] <- "C2"
```

3) Renaming rows or columns by index numbers:

```
rownames(myData)[1:2] <- c("Ralph","Swedish Chef")
colnames(myData)[1] <- "C1"
```

Missing Data

Suppose that the last score was missing. That entry needs to be represented with a value of NA:

```
scores <- c(89,102,73,54,92,NA)
is.numeric(scores)
```

Using another value to represent missing will change the object's type:

```
scores <- c(89,102,73,54,92,".")
is.numeric(scores)
```

What can we do with missing values?
Omit them with the `na.omit` function:

```
myData <- data.frame(sampleID = sample.f, Score = scores,
                     Prep = prepTime)
myData.omit <- na.omit(myData)
```

Replace them using logical referencing:

```
myData.replace <- myData
myData.replace$Score[is.na(myData.replace$Score)] <- 0
```

The Problem with Missing Data; Other Useful Functions

Let's start with:

```
scores <- c(89,102,73,54,92,NA)
```

Find the mean of the vector:

```
mean(scores)
```

Oops…

Omit them:

```
mean(scores, na.rm = TRUE)
```

Other useful functions:

```
mean()
sd()
summary()
str()
```

What Objects are in the R Session?

The `ls()` command list all of the objects in the current session:

```
ls()
```

We may want to eliminate an object that we've created. The `rm()` function does that:

```
rm(sample)
```

If we have been working in R for awhile, objects may need to be cleared from the session:

```
rm(list=ls())
```

Or we may want to clear all but a few objects:

```
rm(list= ls()[!(ls() %in% c('myData','sample','scores'))])
```

Reading External Data

- Example data:
  - Forced expiratory volume from 654 children
  - Several measurements were collected from each child:

	A	B	C	D	E
1	age	FEV	height	sex	smoke
2	9	1.708	57	female	nonsmoker
3	8	1.724	67.5	female	nonsmoker
4	7	1.72	54.5	female	nonsmoker
5	9	1.558	53	male	nonsmoker
6	9	1.895	57	male	nonsmoker
7	8	2.336	61	female	nonsmoker
8	6	1.919	58	female	nonsmoker
9	6	1.415	56	female	nonsmoker
10	8	1.987	58.5	female	nonsmoker
11	9	1.942	60	female	nonsmoker
12	6	1.602	53	female	nonsmoker
13	8	1.735	54	male	nonsmoker

Reading External Data

- We usually want to read in an external file
  - There are several functions to do this

First set the working directory:

```
myLocation <- "c:/Part1"
setwd(myLocation)
```

For .csv files, we can use the read.csv function:

```
fev <- read.csv("fev_dat.csv", header = TRUE)
```

Or:

```
fev <- read.table("fev_dat.csv", header = TRUE, sep = ",")
```

`fev` is now a data frame. We can check the contents with the `str()` function

Tab delimited text files can be read with the `read.table` function:

```
fev <- read.table("fev_dat.txt", header = TRUE, sep = "\t")
```

Other Important Options with the Read Function

- `as.is = TRUE or FALSE`
  - FALSE: converts character variables to factors
  - TRUE: does not convert character variables to factors
- `na.strings`
  - A character vector of strings that are to be interpreted as missing values. For example if "." and "miss" represent missing values, the we would define:
  - `na.strings = c(".", "miss")`
- `Skip`
  - The number of rows to skip before reading the file

Visualizing Data

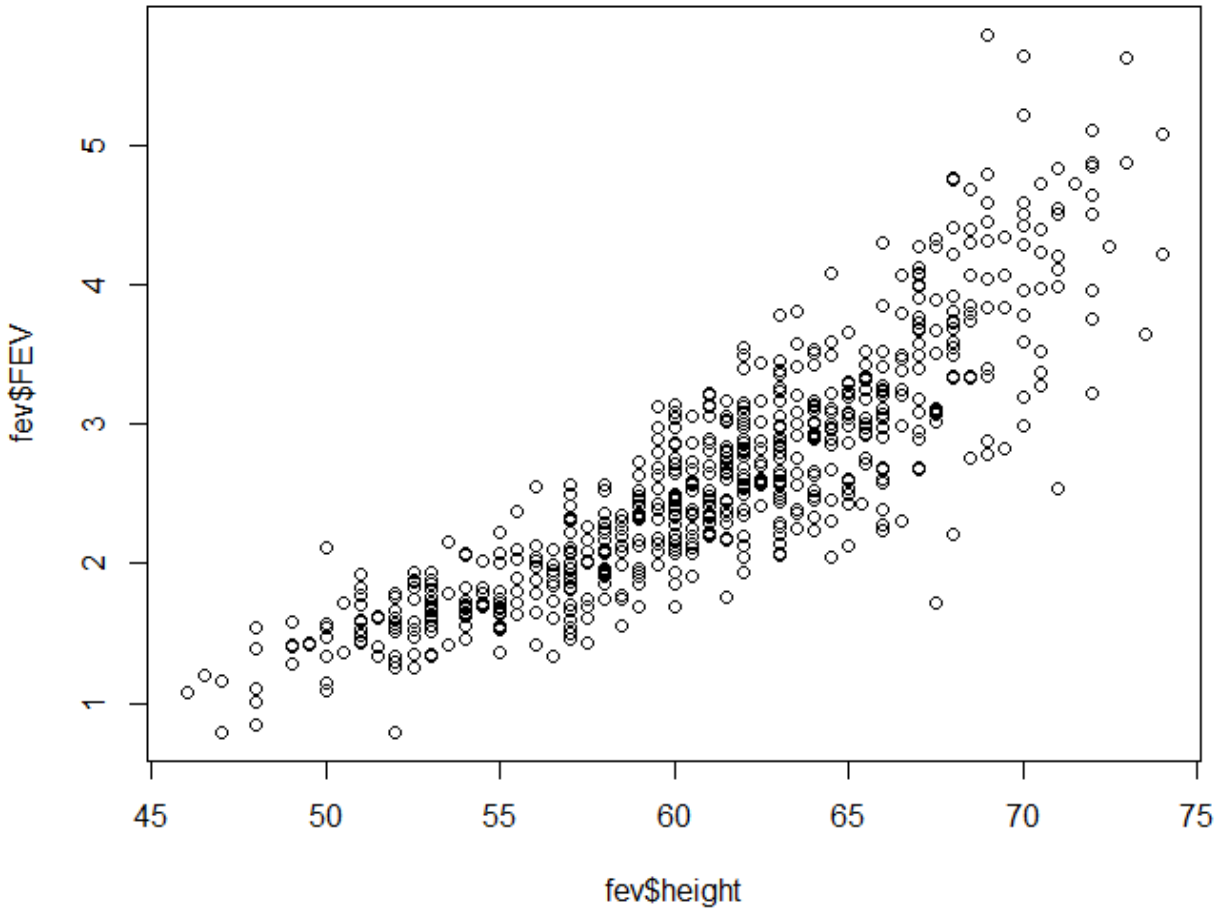
- Once the data is in R, we should begin to understand relationships between variables. Visualization is a good way to do this
- R has LOTS of ways to visualize data. Some are simple and straightforward…others are NOT.
- Let's examine the relationship between height and fev

The `plot()` function takes as input the x-axis variable and y-axis variable:

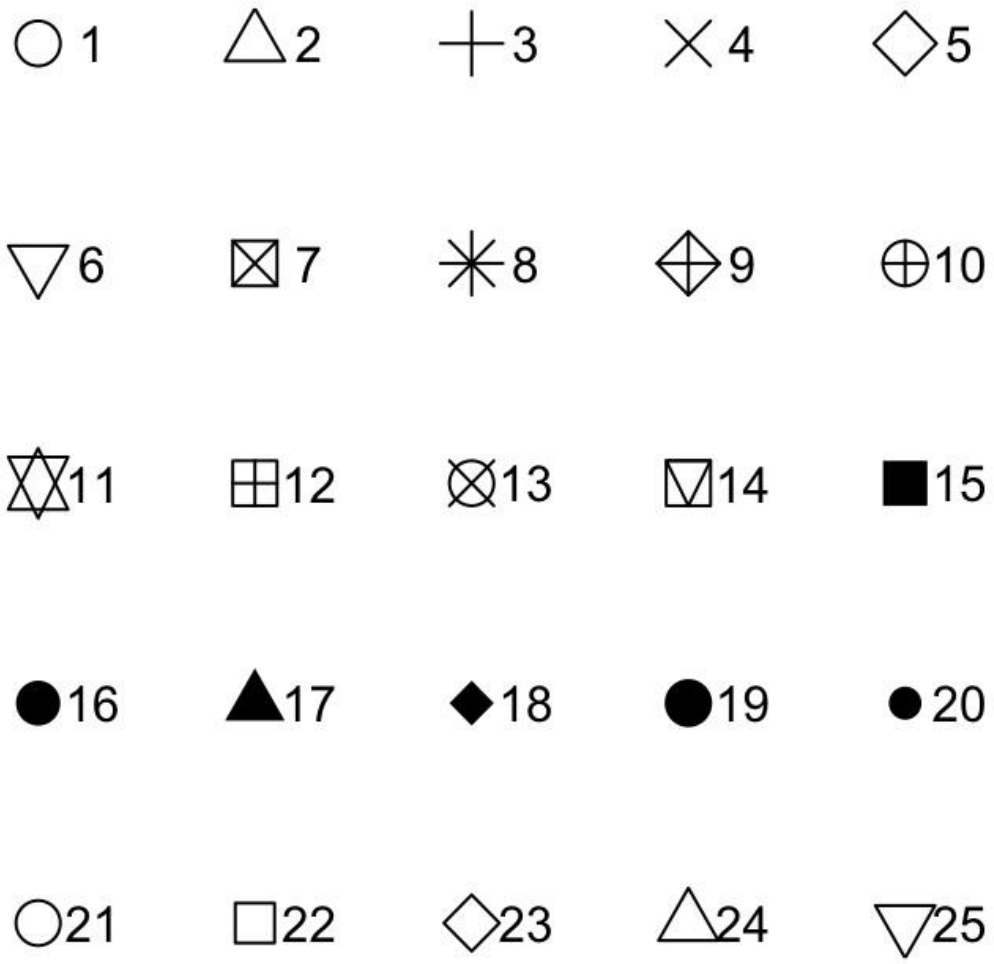
```
plot(fev$height,fev$FEV)
```

Output

Decent output for rough investigation, but we can customize the output further with a title, axis labels, different symbols, colors, font sizes, etc…

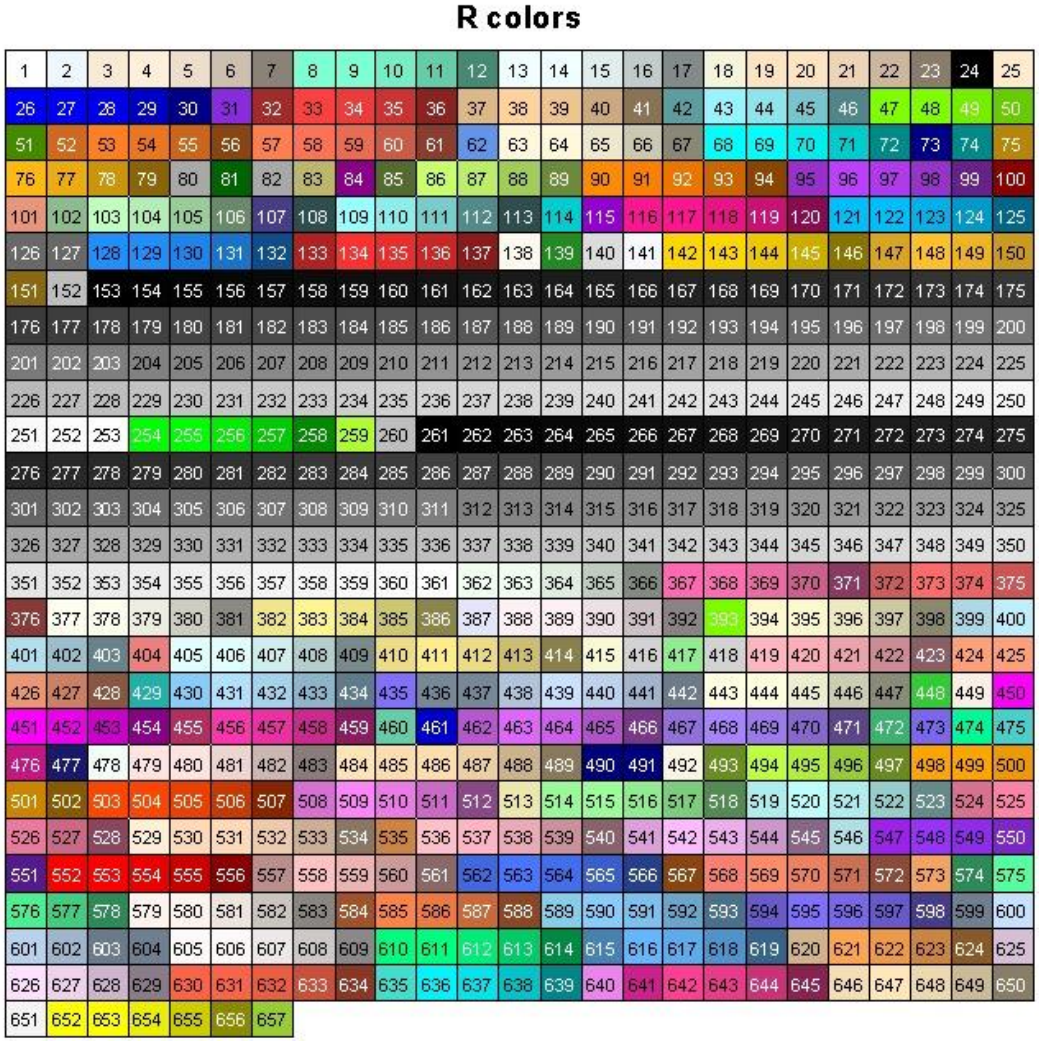


R Symbols



R Colors

(and there are many more!)



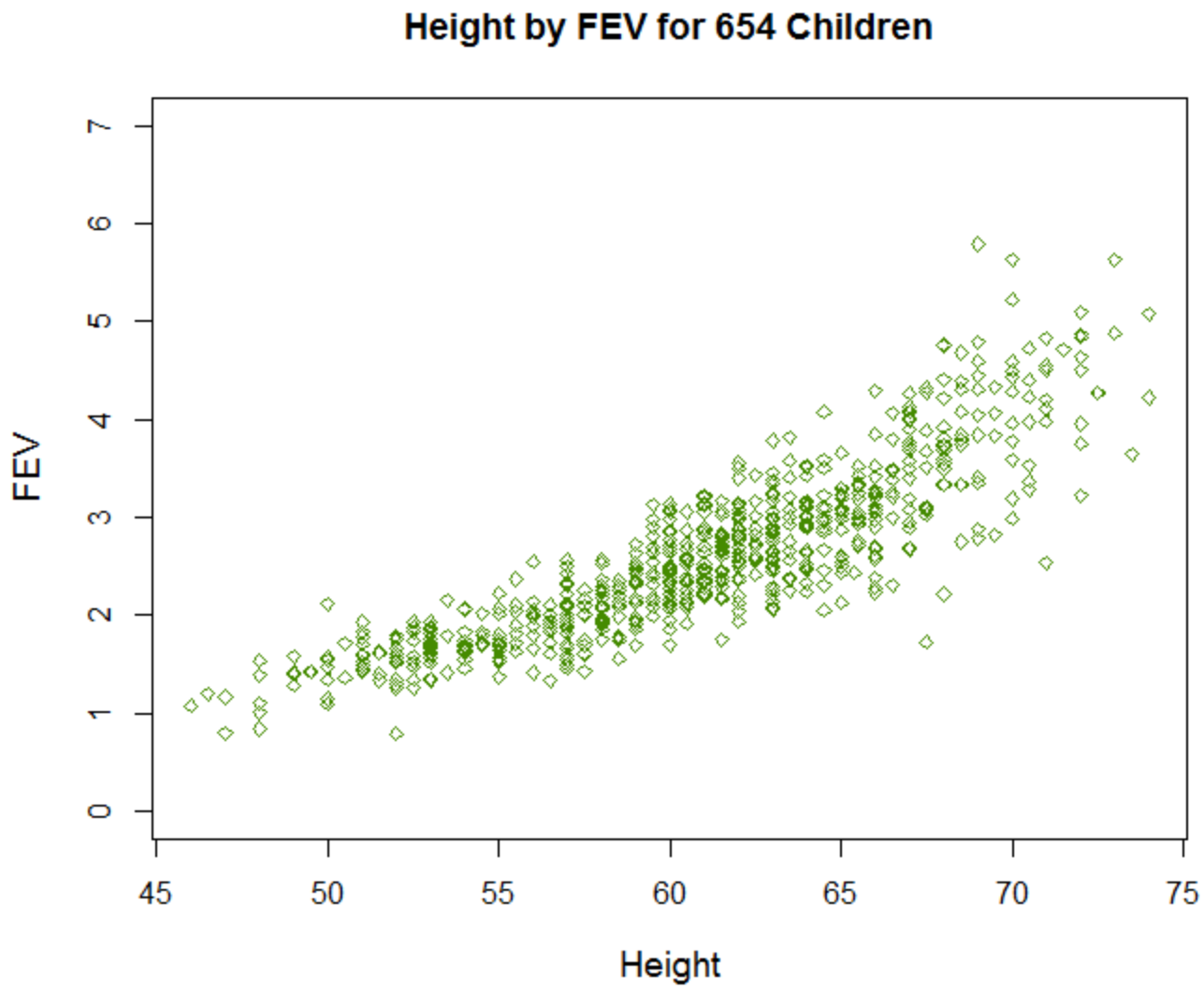
1	white	#FFFFFF	255 255 255
2	aliceblue	#F0F8FF	240 248 255
3	antiquewhite	#FAEBD7	250 235 215
4	antiquewhite1	#FFEFDB	255 239 219
5	antiquewhite2	#EEDFCC	238 223 204
6	antiquewhite3	#CDC0B0	205 192 176
7	antiquewhite4	#8B8378	139 131 120
8	aquamarine	#7FFFD4	127 255 212
9	aquamarine1	#7FFFD4	127 255 212
10	aquamarine2	#76EEC6	118 238 198
11	aquamarine3	#66CDAA	102 205 170
12	aquamarine4	#458B74	69 139 116
13	azure	#F0FFFF	240 255 255
14	azure1	#F0FFFF	240 255 255
15	azure2	#E0EEEE	224 238 238
16	azure3	#C1CDCD	193 205 205
17	azure4	#838B8B	131 139 139
18	beige	#F5F5DC	245 245 220
19	bisque	#FFE4C4	255 228 196
20	bisque1	#FFE4C4	255 228 196
21	bisque2	#EED5B7	238 213 183
22	bisque3	#CDB79E	205 183 158
23	bisque4	#8B7D6B	139 125 107
24	black	#000000	0 0 0
25	blanchedalmond	#FFEBCD	255 235 205
26	blue	#0000FF	0 0 255
27	blue1	#0000FF	0 0 255
28	blue2	#0000EE	0 0 238
29	blue3	#0000CD	0 0 205
30	blue4	#00008B	0 0 139
31	blueviolet	#8A2BE2	138 43 226
32	brown	#A52A2A	165 42 42
33	brown1	#FF4040	255 64 64
34	brown2	#EE3B3B	238 59 59
35	brown3	#CD3333	205 51 51
36	brown4	#8B2323	139 35 35
37	burlywood	#DEB887	222 184 135
38	burlywood1	#FFD39B	255 211 155
39	burlywood2	#EEC591	238 197 145
40	burlywood3	#CDAA7D	205 170 125
41	burlywood4	#8B7355	139 115 85
42	cadetblue	#5F9EA0	95 158 160
43	cadetblue1	#98F5FF	152 245 255
44	cadetblue2	#8EE5EE	142 229 238
45	cadetblue3	#7AC5CD	122 197 205
46	cadetblue4	#53868B	83 134 139
47	chartreuse	#7FFF00	127 255 0
48	chartreuse1	#7FFF00	127 255 0
49	chartreuse2	#76EE00	118 238 0
50	chartreuse3	#66CD00	102 205 0
51	chartreuse4	#458B00	69 139 0
52	chocolate	#D2691E	210 105 30
53	chocolate1	#FF7F24	255 127 36
54	chocolate2	#EE7621	238 118 33
55	chocolate3	#CD661D	205 102 29
56	chocolate4	#8B4513	139 69 19
57	coral	#FF7F50	255 127 80
58	coral1	#FF7256	255 114 86
59	coral2	#EE6A50	238 106 80
60	coral3	#CD5B45	205 91 69
61	coral4	#8B3E2F	139 62 47
62	cornflowerblue	#6495ED	100 149 237
63	cornsilk	#FFF8DC	255 248 220
64	cornsilk1	#FFF8DC	255 248 220
65	cornsilk2	#EEE8CD	238 232 205
66	cornsilk3	#CDC8B1	205 200 177
67	cornsilk4	#8B8878	139 136 120
68	cyan	#00FFFF	0 255 255
69	cyan1	#00FFFF	0 255 255
70	cyan2	#00EEEE	0 238 238
71	cyan3	#00CDCD	0 205 205
72	cyan4	#008B8B	0 139 139
73	darkblue	#00008B	0 0 139
74	darkcyan	#008B8B	0 139 139
75	darkgoldenrod	#B8860B	184 134 11
76	darkgoldenrod1	#FFB90F	255 185 15
77	darkgoldenrod2	#EEAD0E	238 173 14
78	darkgoldenrod3	#CD950C	205 149 12
79	darkgoldenrod4	#8B6508	139 101 8
80	darkgray	#A9A9A9	169 169 169
81	darkgreen	#006400	0 100 0
82	darkgrey	#A9A9A9	169 169 169
83	darkkhaki	#BDB76B	189 183 107
84	darkmagenta	#8B008B	139 0 139
85	darkolivegreen	#556B2F	85 107 47
86	darkolivegreen1	#CAFF70	202 255 112
87	darkolivegreen2	#BCEE68	188 238 104
88	darkolivegreen3	#A2CD5A	162 205 90
89	darkolivegreen4	#6E8B3D	110 139 61
90	darkorange	#FF8C00	255 140 0
91	darkorange1	#FF7F00	255 127 0
92	darkorange2	#EE7600	238 118 0
93	darkorange3	#CD6600	205 102 0
94	darkorange4	#8B4500	139 69 0
95	darkorchid	#9932CC	153 50 204
96	darkorchid1	#BF3EFF	191 62 255
97	darkorchid2	#B23AEE	178 58 238
98	darkorchid3	#9A32CD	154 50 205
99	darkorchid4	#68228B	104 34 139
100	darkred	#8B0000	139 0 0

Customizing a Simple Plot

```
plot(fev$height,fev$FEV,
     xlab = list("Height",cex=1.2),
     ylab = list("FEV",cex=1.2),
     ylim = c(0,7),
     main = "Height by FEV for 654 Children",
     col = "chartreuse4",
     pch = 5,
     cex = 0.7)
```

This plot statement does the following:
--changes the x-axis label to Height and makes it 1.2 times larger than normal
--changes the y-axis label to FEV and makes it 1.2 times larger than normal
--changes the y-axis range to 0 to 7
--adds the title of Height by FEV for 654 Children
--changes the symbol color to chartreuse 4
--changes the symbol to an open diamond
--makes the symbols 70% of normal size

Modified Output



How to Save the Graph?

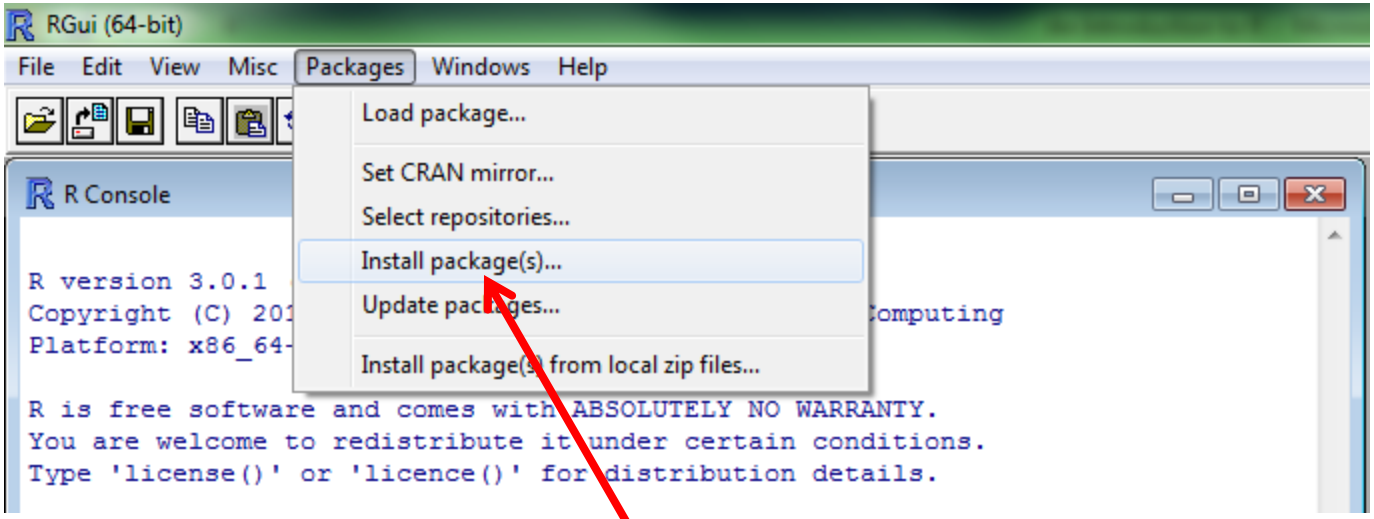
- A couple approaches
  - Right-click the graph and manually save it, OR…

```
png(filename = "FEVplot.png", width=600, height=600)
  plot(fev$height,fev$FEV,
       xlab = list("Height",cex=1.2),
       ylab = list("FEV",cex=1.2),
       ylim = c(0,7),
       main = "Height by FEV for 654 Children",
       col = "chartreuse4",
       pch = 5,
       cex = 0.7)
dev.off()
```

Using Packages

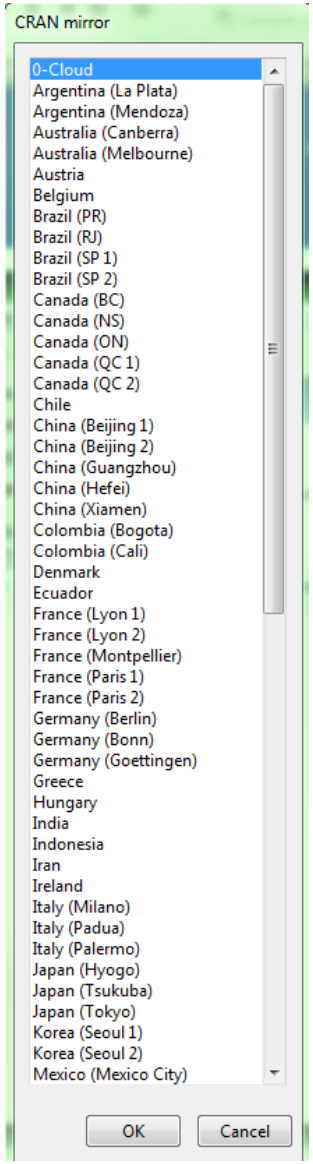
- Packages are pre-packaged code to implement specific types of analyses, visualizations, etc.
- Anyone can develop a package, and submit it for posting on the CRAN site
  - User beware!
- How do you obtain packages?
  - A couple of ways
- Let's download the `ggplot2` package, which generates more elegant figures

Installing Packages Through the Menu

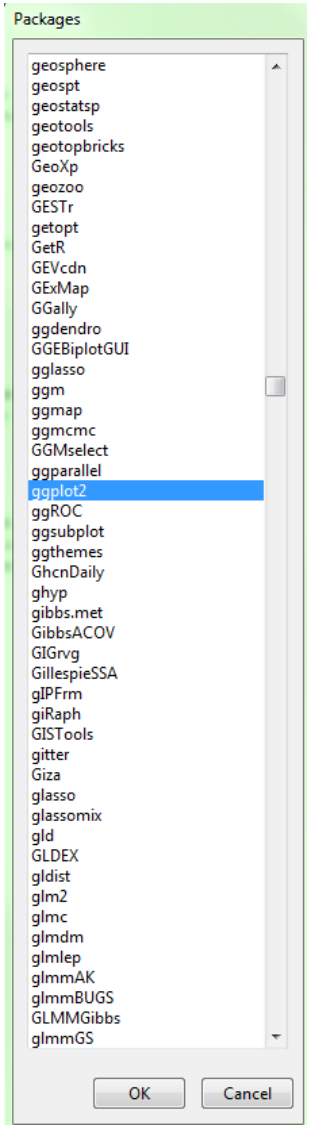


Select “Install package(s)”,

then select a CRAN mirror



Select a Package



R will install the package and any other dependent packages if not already installed.

Command Prompt Approach for Installing and Updating Packages

- Another convenient approach is to install a package through the command prompt

We can install one package:

```
install.packages("ggplot2", dependencies=TRUE)
```

Or we can install multiple packages at once:

```
graphicPackages = c("lattice","ggplot2")
install.packages(graphicPackages,dependencies=TRUE)
```

Note: the base R code is frequently updated. If you install a new version of R, you will also need to update the packages you have already installed in the new version of R. This is easy to do:

```
update.packages()
```

Loading a Package

- Once a package is installed, it must be loaded into the current R session

Loading a package:

```
library(ggplot2)
```

Or we can install multiple packages at once:

```
graphicPackages = c("lattice","ggplot2")
install.packages(graphicPackages,dependencies=TRUE)
```

Note: the base R code is frequently updated. If you install a new version of R, you will also need to update the packages you have already installed in the new version of R. This is easy to do:

```
update.packages()
```

Understanding What's in a Package

- A package usually contain more than just code to implement analyses or graphs. They can also contain data set, help documentation, and vignettes (short descriptions of the package)

Understanding what's in the package:

```
library(help=ggplot2)
```

Loading a data set from the package:

```
data(diamonds)
```

Get help for the `ggplot` function

```
?ggplot
```

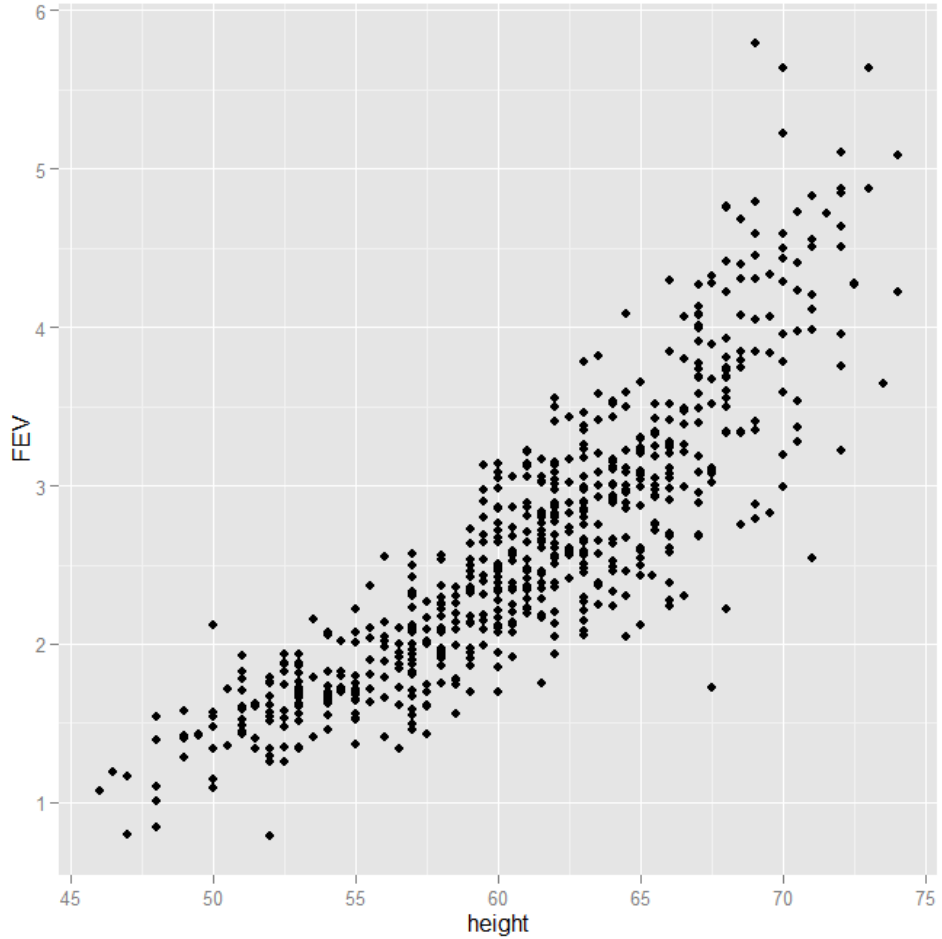
An example vignette for the `caret` package

```
vignette("caret")
```

Creating a Scatterplot with ggplot

We can create a simple scatterplot as follows:

```
ggplot(fev, aes(height,FEV))+ geom_point()
```



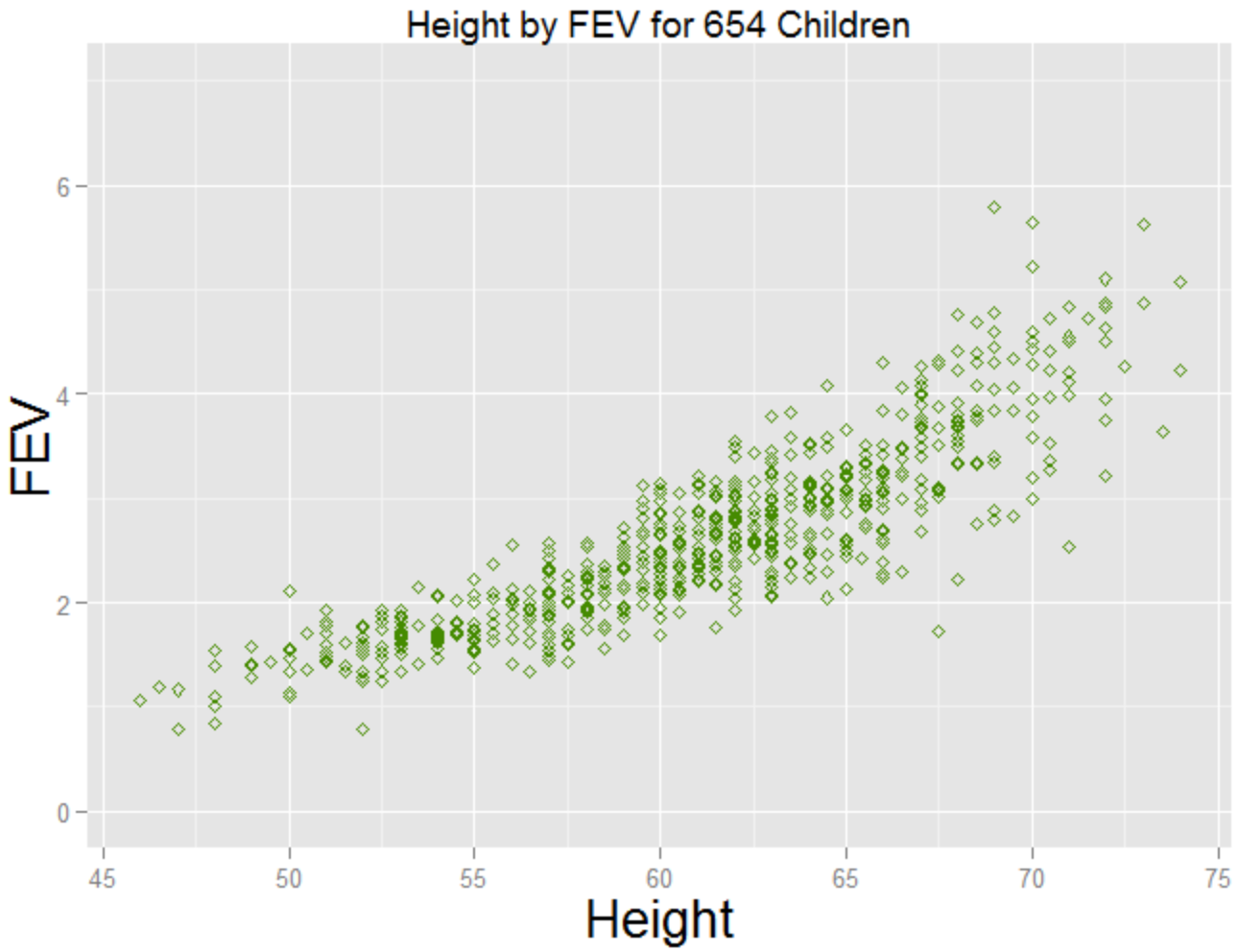
Customizing a ggplot

```
ggplot(fev, aes(height,FEV,ymin=0,ymax=7)) +
       geom_point(colour = "chartreuse4",
                  shape = 5,
                  size = 1.5) +
       ggtitle("Height by FEV for 654 Children") +
       xlab("Height") +
       ylab("FEV") +
       theme(axis.title.x = element_text(size=20),
             axis.title.y = element_text(size=20))
```

`ggplot` works with layers. It first creates the scatterplot, then we adjust the plot with subsequent commands. This plot statement does the following:

--changes the y-axis range to 0 to 7
--adds the title of Height by FEV for 654 Children
--changes the x-axis label to Height and makes it size 20
--changes the y-axis label to FEV and makes it size 20
--changes the symbol color to chartreuse 4
--changes the symbol to an open diamond
--makes the symbols size 1.5

Modified Output



Further Customization

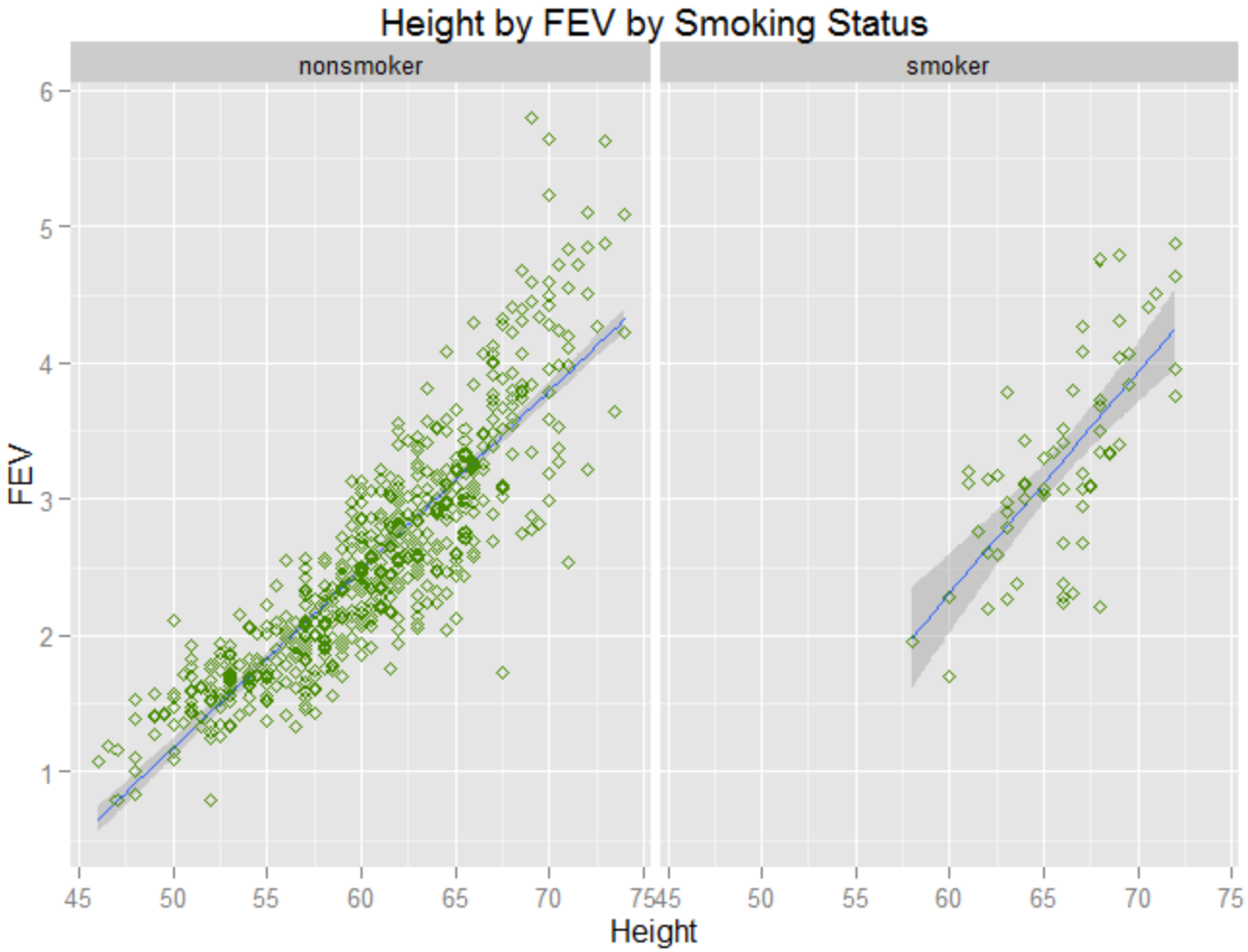
We can also create separate scatterplots by home smoking status and add a regression line to each:

```
ggplot(fev, aes(height,FEV)) +
       geom_smooth(method = "lm") +
       facet_grid(. ~ smoke) +
       geom_point(colour = "chartreuse4",
                  shape = 5,
                  size = 1.5) +
       ggtitle("Height by FEV by Smoking Status") +
       xlab("Height") +
       ylab("FEV")
```

The graph can be copied by right-clicking on the graph can copying. Or we can save the graph as follows:

```
ggsave(file = "fevBySmoke.png")
```

Modified Output



We will use ggplot to visualize data in the upcoming sessions.

http://www.statmethods.net/ is a good location for help with ggplot2 and R in general.

Saving: History, Data, & Workspace

We have created a number of objects, and we may want to recall how some of those were created. We can do that with this history function:

```
history(100)
```

This gives the previous 100 command prompt entries.

We may also want to save data set(s) that were modified during the session. This can be done with the write.csv or write.table functions:

```
write.csv(myData, file = "myData.csv", row.names = FALSE)
```

The entire workspace can be saved as follows:

```
save.image("part1.RData")
```

This image can be reloaded for use at another time. All objects in the current session are saved:

```
fileLocation <- "C:/Part1"
setwd(fileLocation)
load.image("part1.RData")
```

Upcoming Sessions

- Part 2: Comparing Groups (1)
  - Data shaping, ANOVA, post-hoc test, two-way ANOVA, and visualization
- Part 3: Comparing Groups (2)
  - Fixed and random effects, how to model data with mixed (fixed and random) effects, repeated measures data, visualization
- Part 4: Covariance Structures in Mixed Models and Dimension Reduction and Classification
  - Principal component analysis (PCA), partial least squares (PLS), recursive partitioning (RPart), and random forests (RF)