An Introduction to *R*

Part 1: Basics

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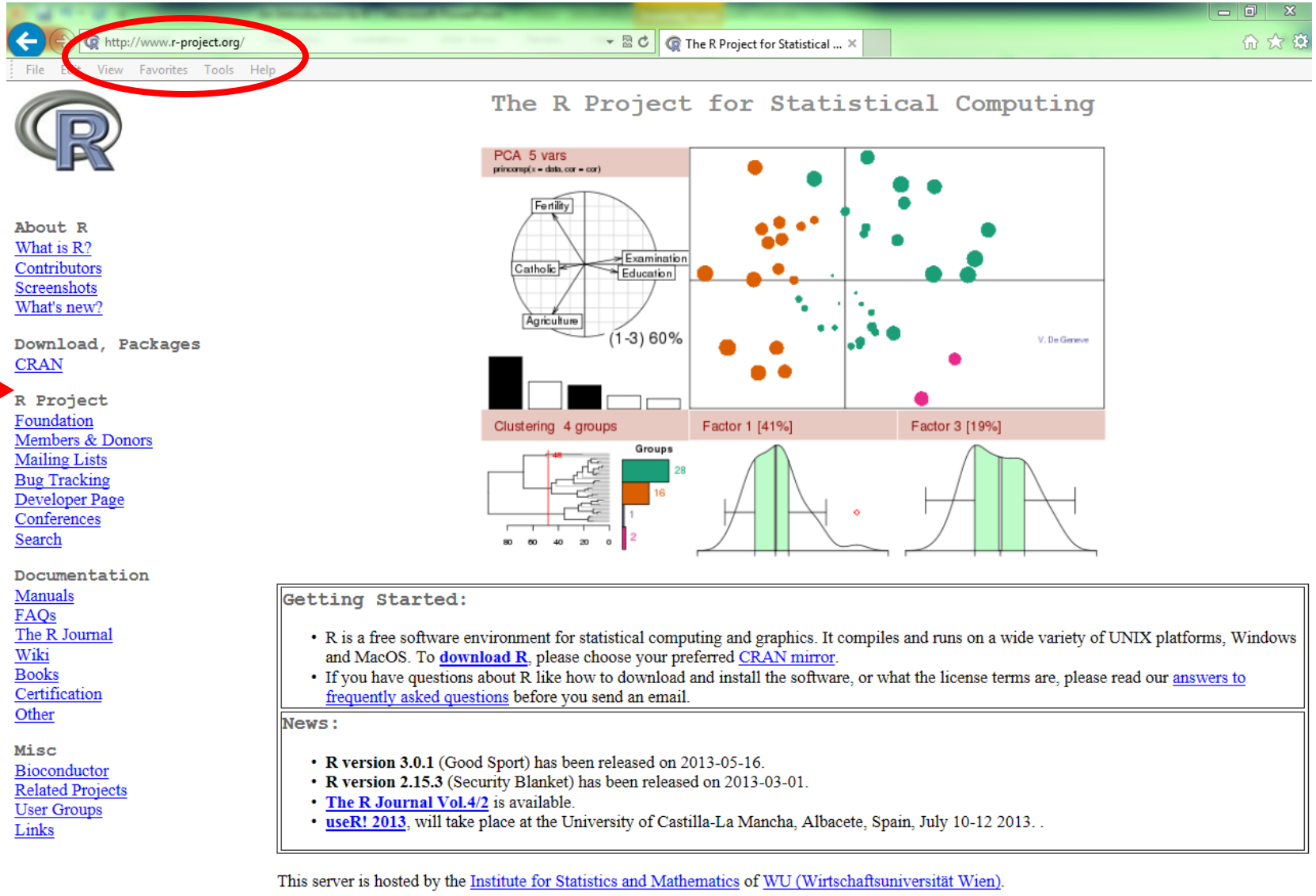
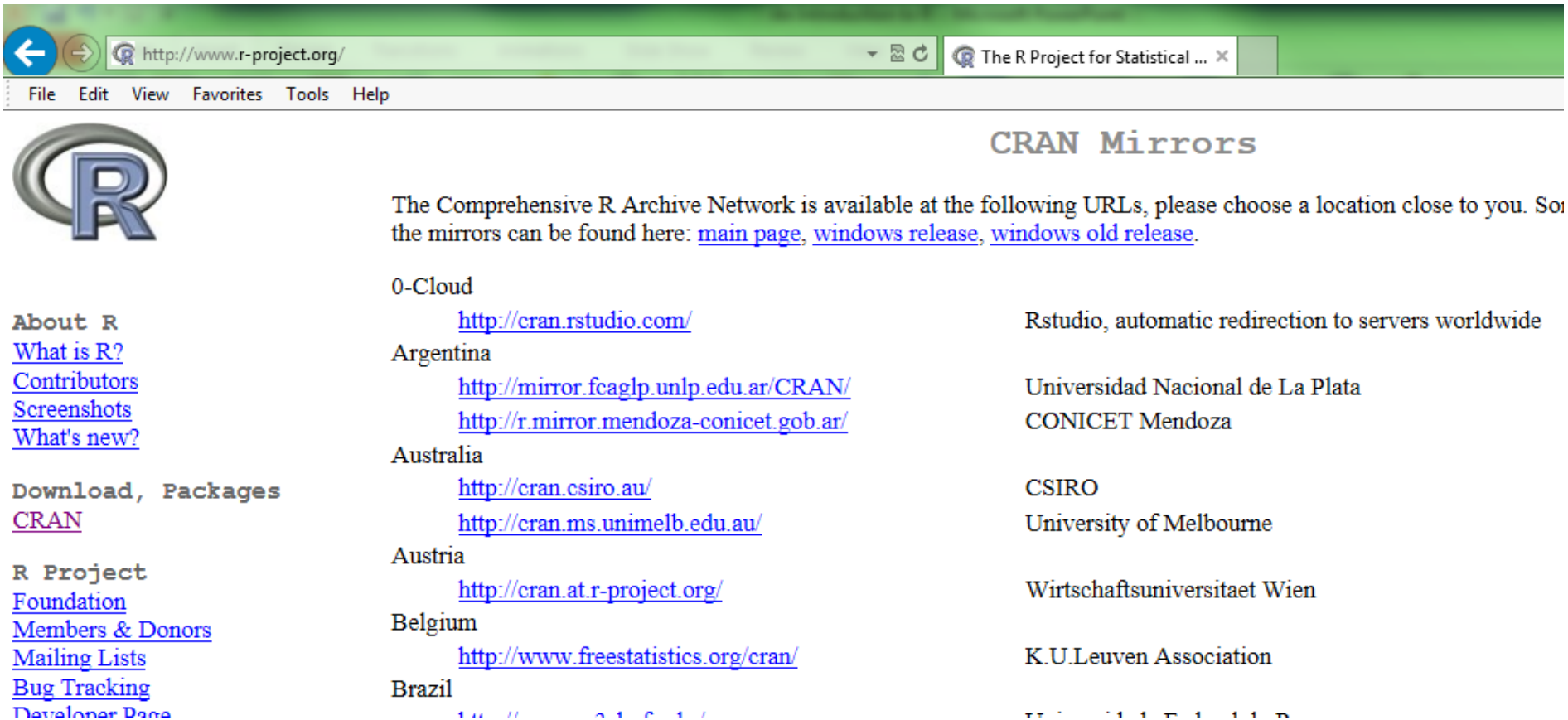
Overview

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

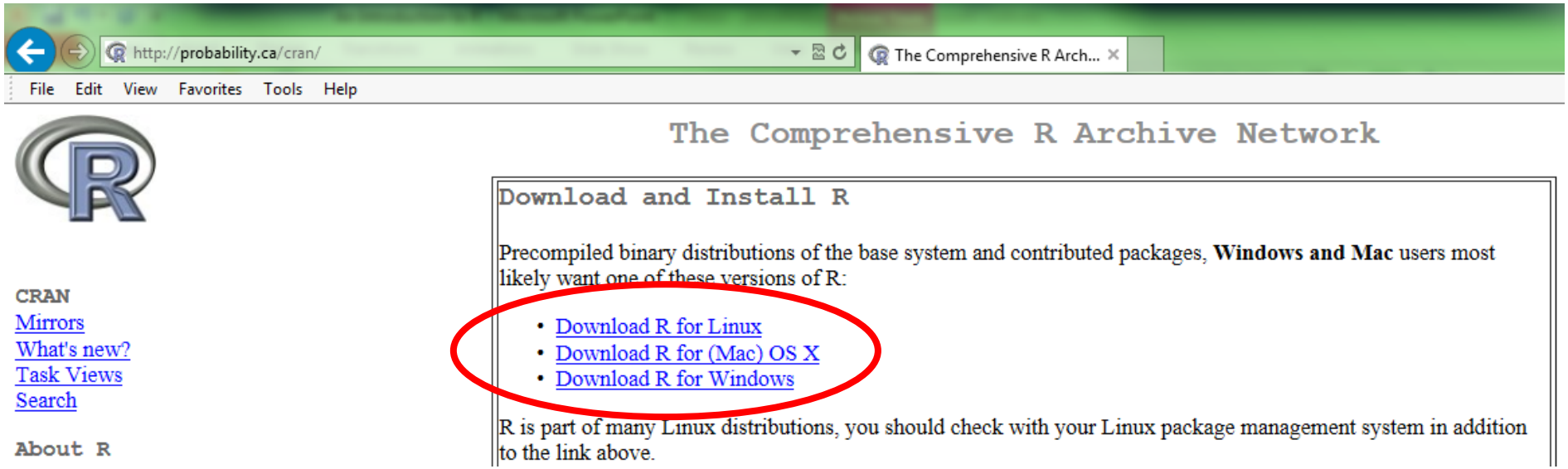
Installing R from r-project.org



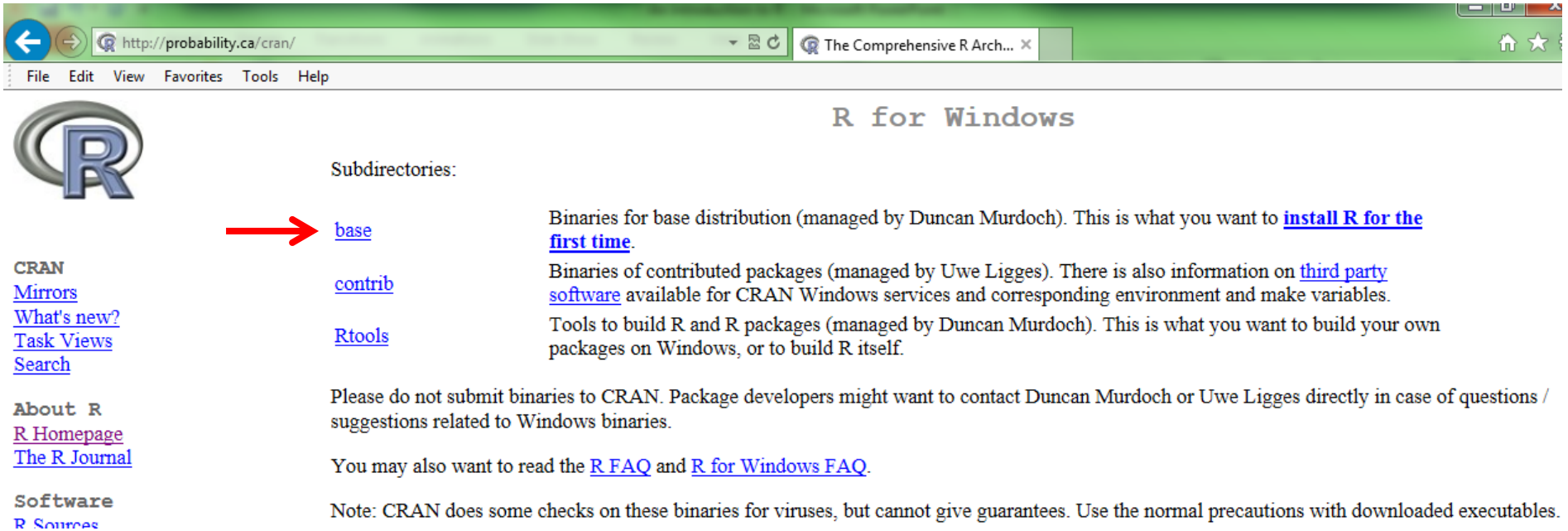
Pick a Mirror Site



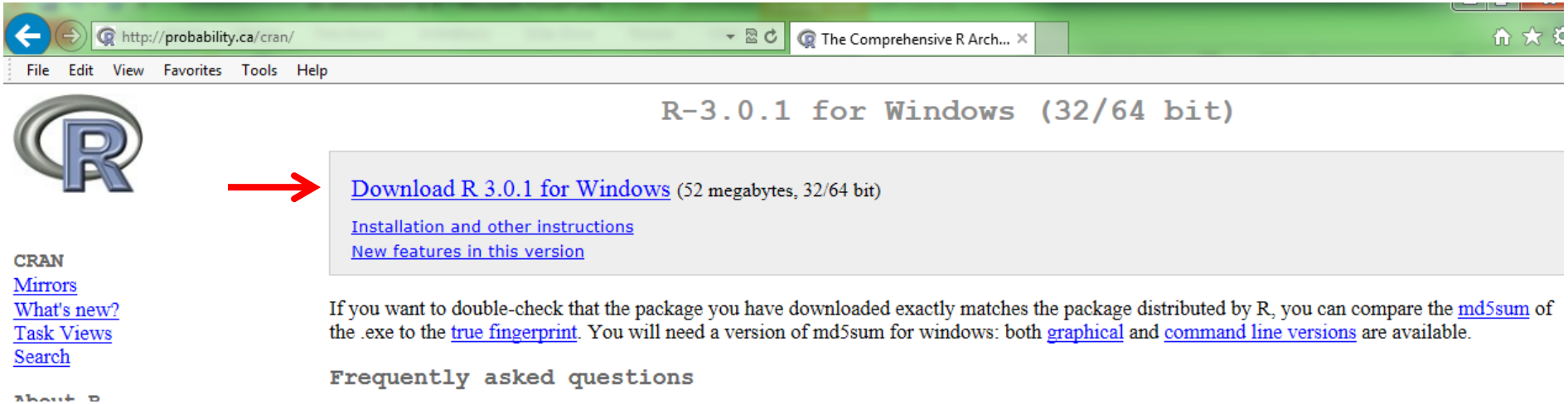
Select Your Operating System



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.

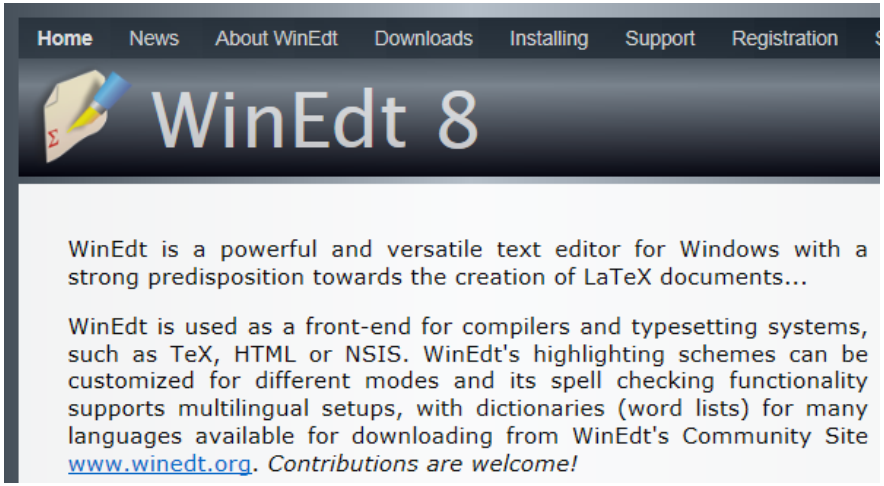
Download R and Follow Prompts



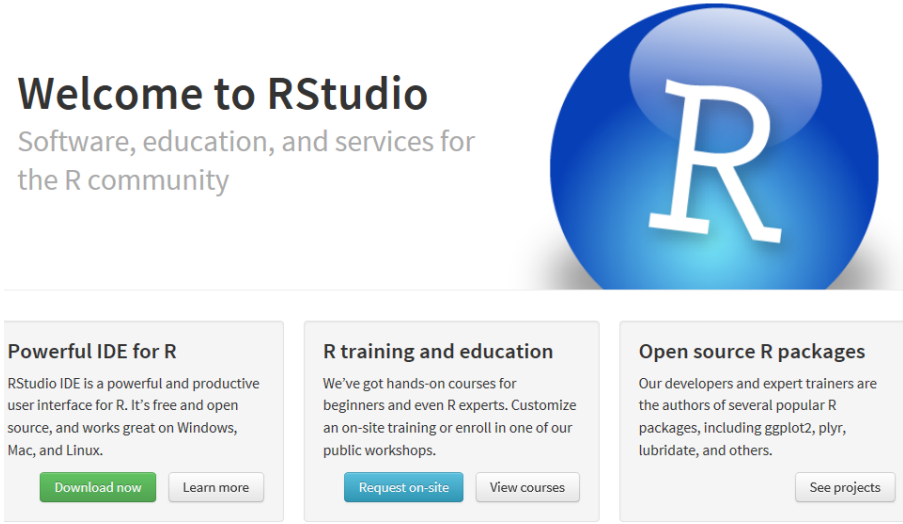
Editors for R

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

winedt.com



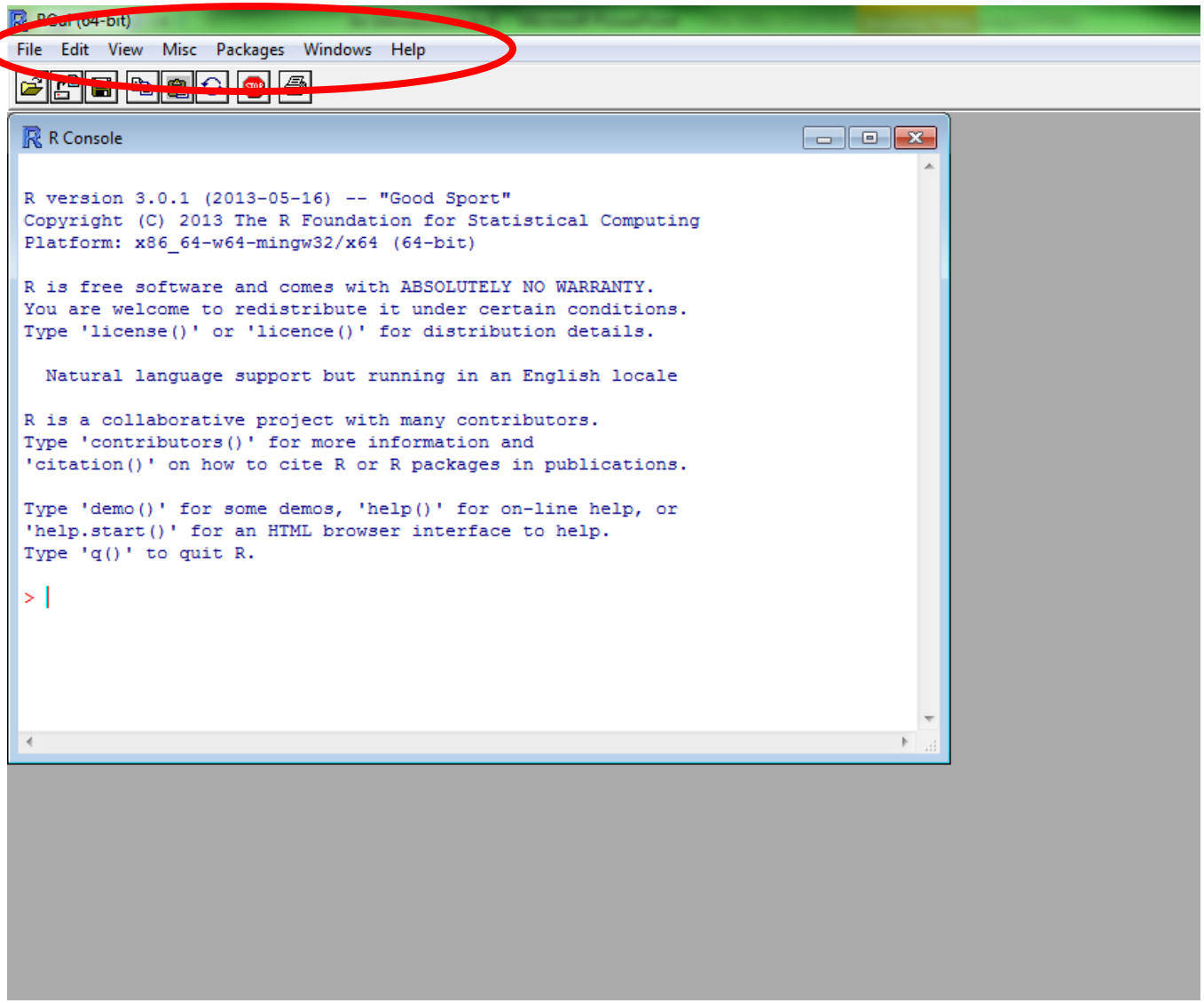
rstudio.com



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:/Documents and Settings/johns94/Desktop/Part1")
```

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

```
setwd("c:\\Documents and Settings\\johns94\\Desktop\\Part1")
```

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

```
myLocation <- "c:/Documents and Settings/johns94/Desktop/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)
```

<u>Other useful functions:</u>

```
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:/Documents and Settings/johns94/Desktop/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

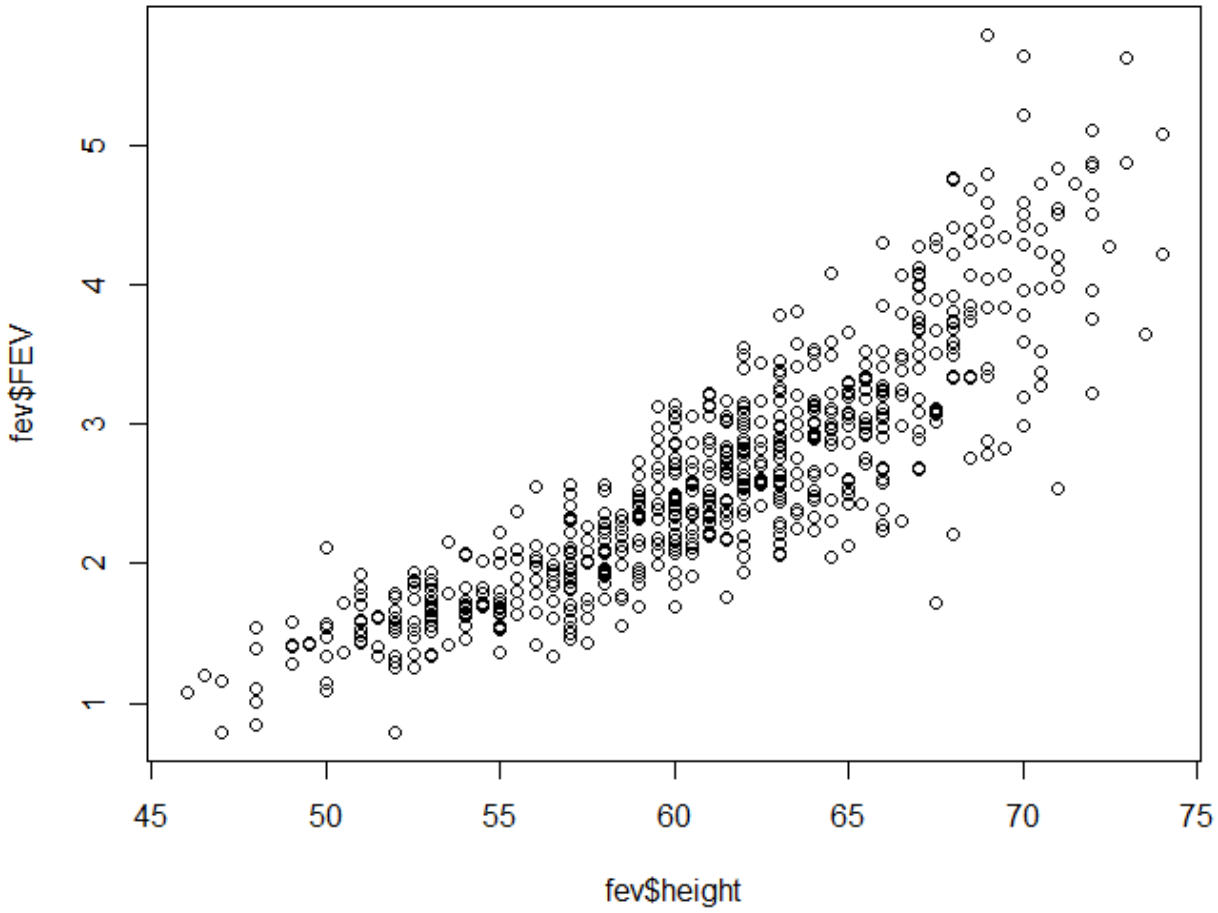
- Once the data is in R, we should begin to understand relationships between variables. Visualization is a good way to do this
- R has LOTS of ways to visualize data. Some are simple and straightforward…others are NOT.
- Let's examine the relationship between height and fev

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

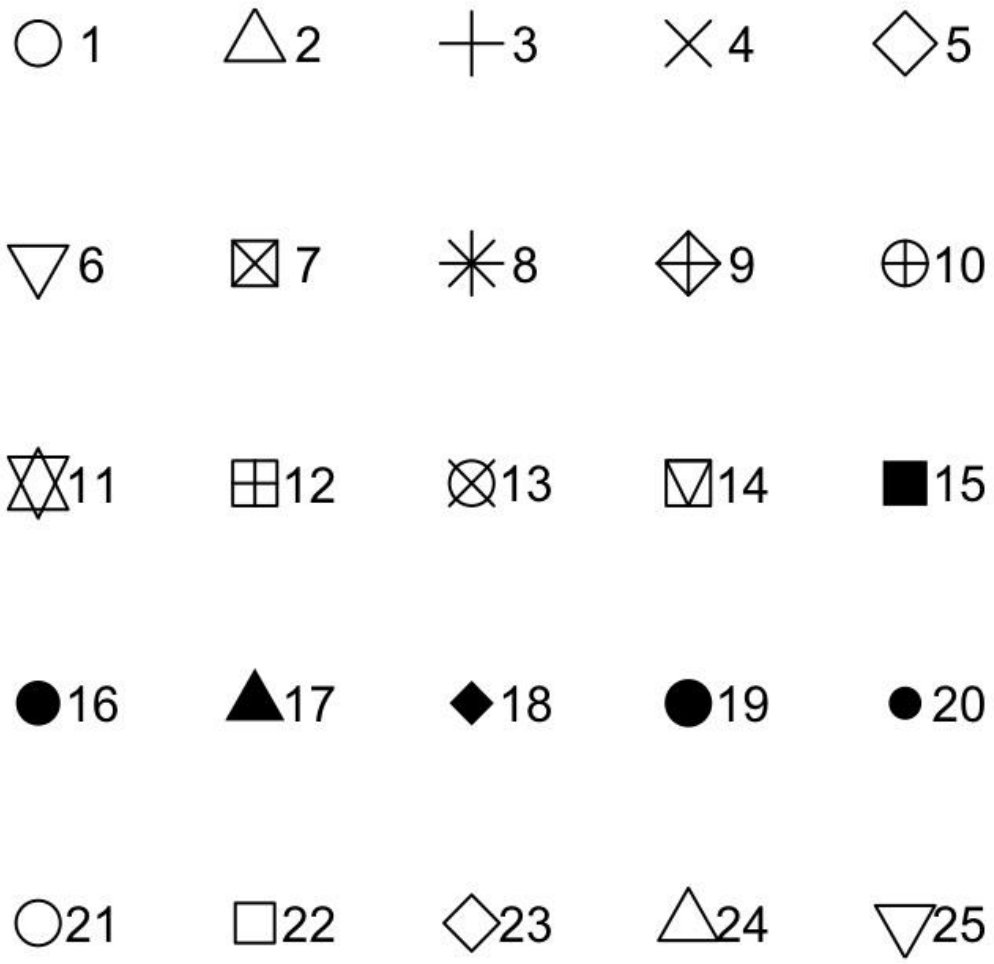
```
plot(fev$height,fev$FEV)
```

Output

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



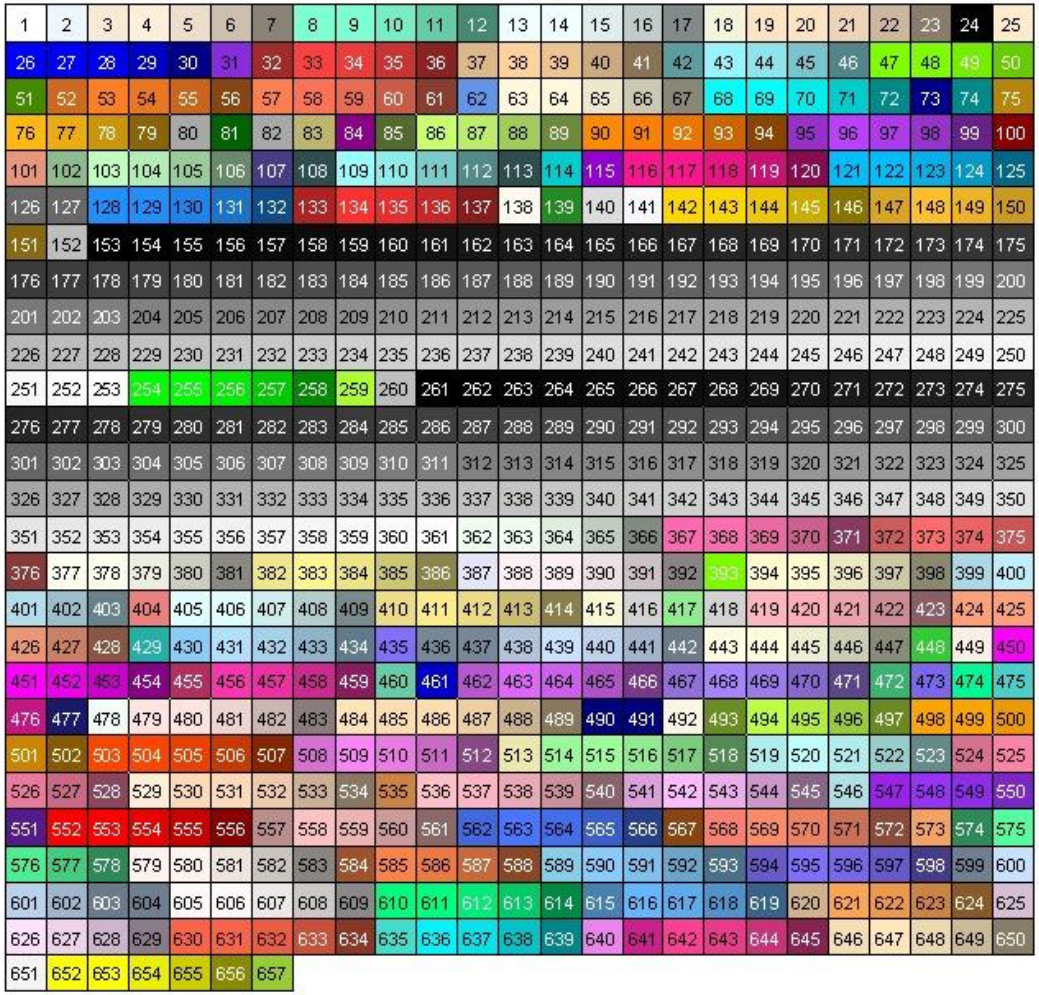
R Symbols



R Colors

(and there are many more!)

R colors



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125
126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175
176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250
251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275
276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325
326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350
351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375
376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425
426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475
476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525
526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575
576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625
626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657																		

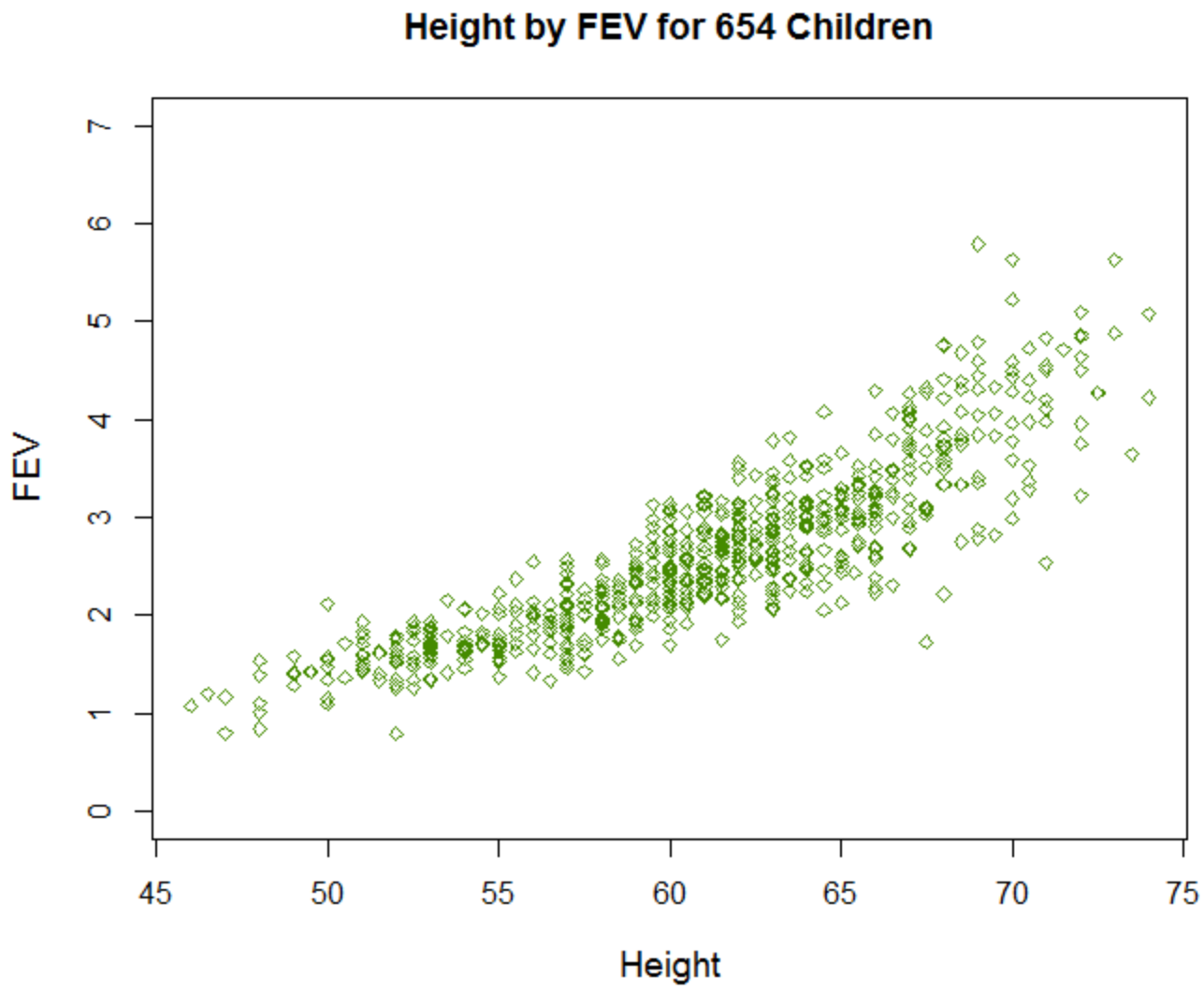
1	white	#FFFFFF	255	255	255	51	chartreuse4	#458B00	69	139	0
2	aliceblue	#F0F8FF	240	248	255	52	chocolate	#D2691E	210	105	30
3	antiquewhite	#FAEBD7	250	235	215	53	chocolate1	#FF7F24	255	127	36
4	antiquewhite1	#FFEFDB	255	239	219	54	chocolate2	#EE7621	238	118	33
5	antiquewhite2	#EEDFCC	238	223	204	55	chocolate3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

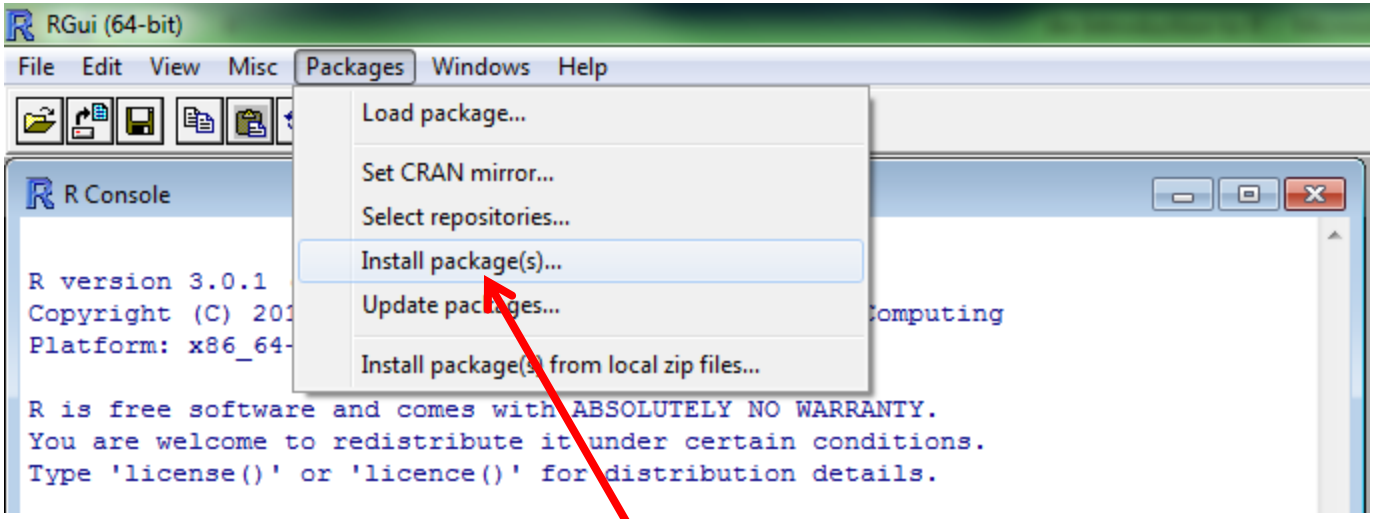
- A couple approaches
  - Right-click the graph and manually save it, OR…

```
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

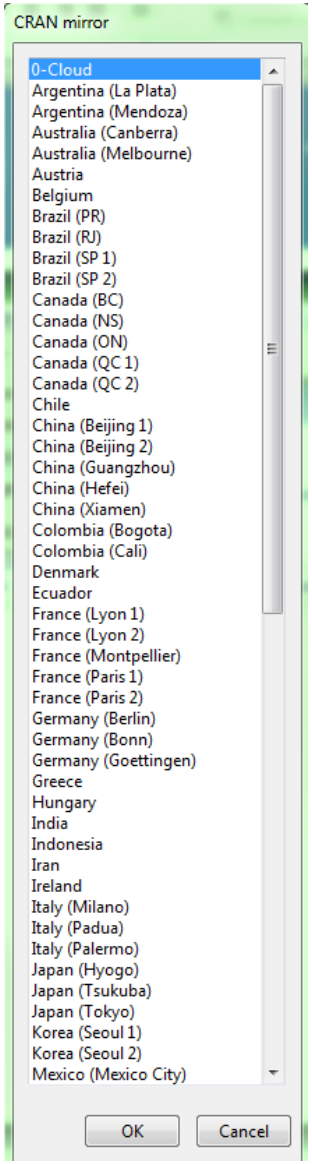
- Packages are pre-packaged code to implement specific types of analyses, visualizations, etc.
- Anyone can develop a package, and submit it for posting on the CRAN site
  - User beware!
- How do you obtain packages?
  - A couple of ways
- Let's download the `ggplot2` package, which generates more elegant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

Installing Packages Through the Menu

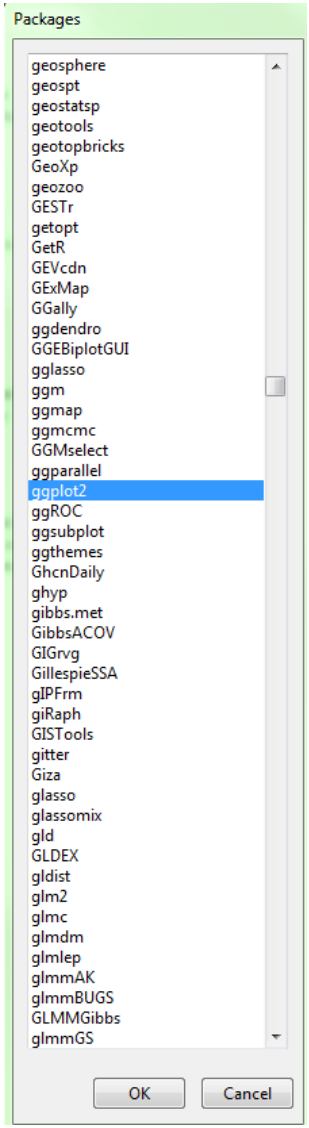


Select “Install package(s)”,

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
```

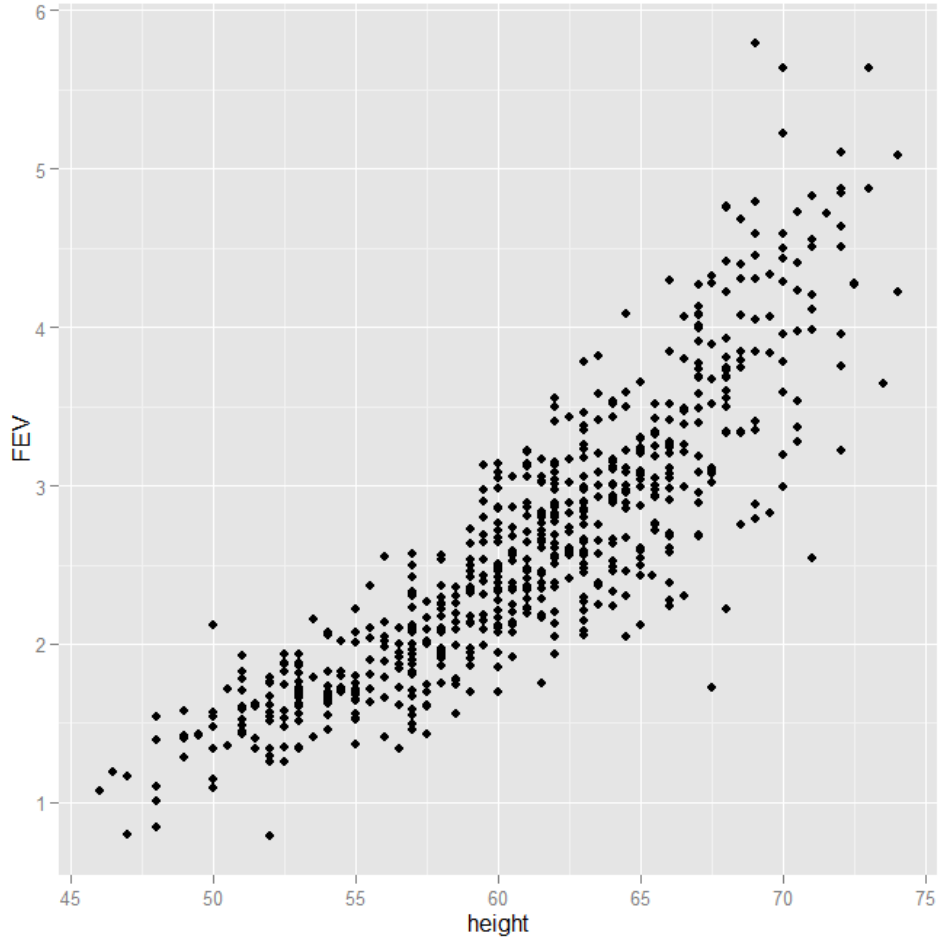
An example vignette for the `caret` package

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

Creating a Scatterplot with ggplot

We can create a simple scatterplot as follows:

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



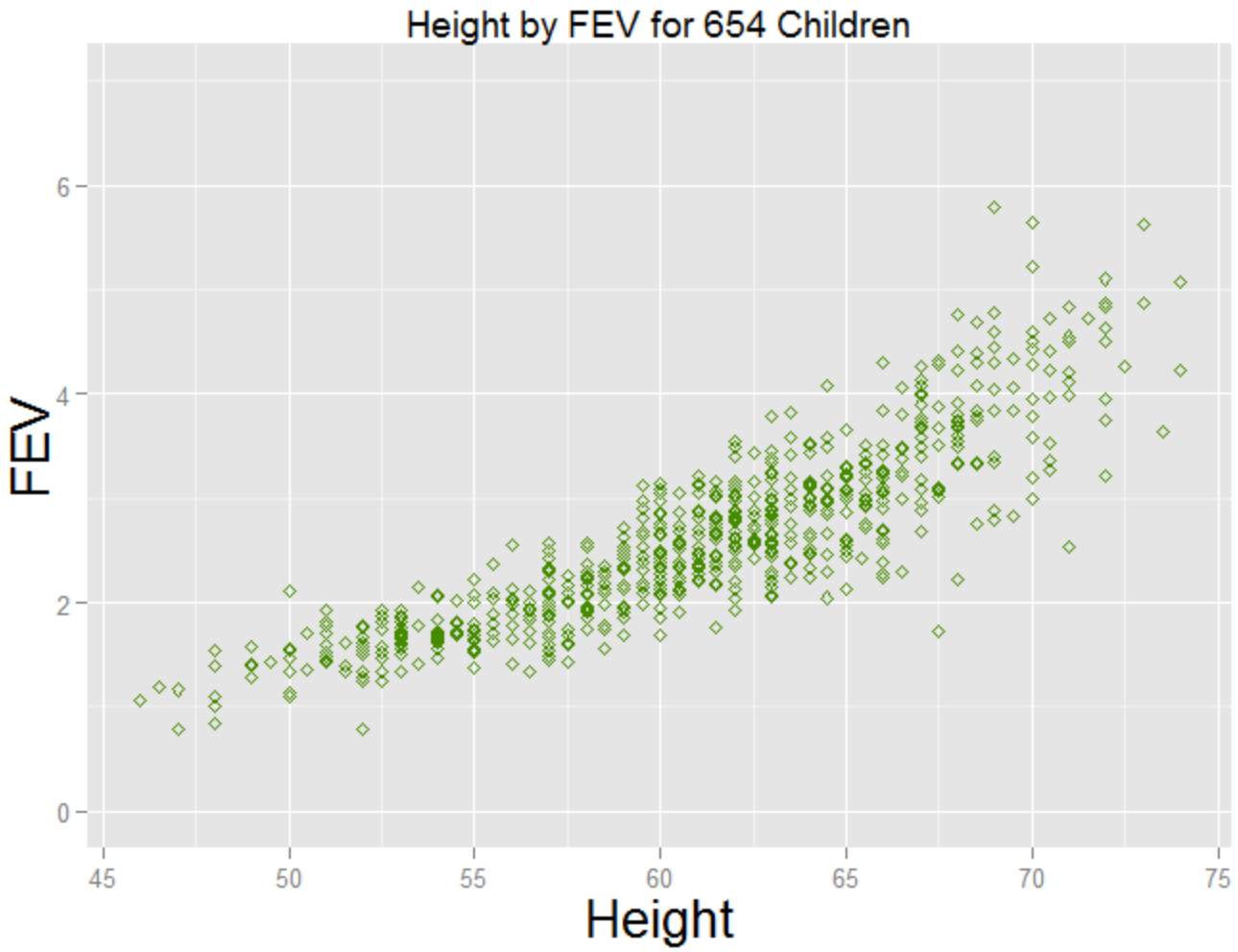
Customizing a ggplot

```
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

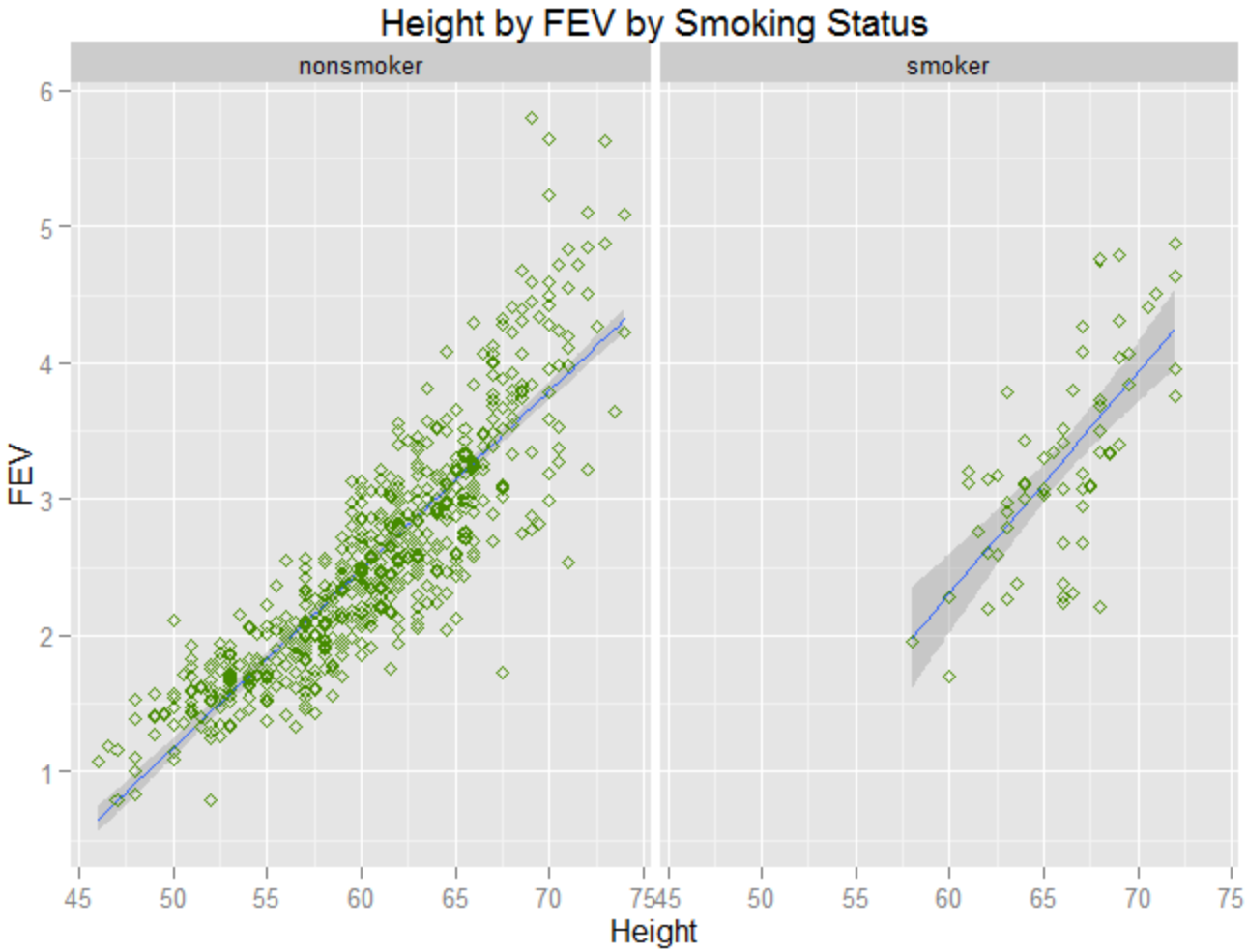
We can also create separate scatterplots by home smoking status and add a regression line to each:

```
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:/Users/johns94/Dropbox/Training Materials/R"
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)