Beginner Friendly Introduction to R

November, 2017

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What is R

- R is a system for statistical computing and graphics, includes:
  - R language to script math operations
  - R environment to run R scripts
  - RServe – an interface for analytical applications
- R is interpreted language
  - You do not have to write a program to run it
  - Every line is interpreted on the fly
- R is free under GNU General Public License
- R is maintained by volunteers at https://www.r-project.org
- R is well developed, well documented, and extensively used around the world
  - Over 2000 extension packages expanding R functionality

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RStudio

- RStudio is a development environment for R
- Created by a company called RStudio
  - ➢ A member of R community
- One can develop directly in R, but RStudio is more productive
- Every DSVD user will have his/her own RStudio Desktop
- RStudio closely resembles Eclipse
- Rstudio requires R

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Working with RStudio in DSVD

- Login into Horizon Client
- Open GSA Pool 6
- Open All Programs
- Open RStudio folder (not R folder!)
- Open Rstudio
- Connect to/upload your data
- Develop your R script

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R Basic Concepts

- **Workspace**

  The workspace is your current R working environment and includes any user-defined objects, e.g. variables and functions

- **R Session**

  Time you work in R. At the end of an R session, the user can save an image of the current workspace and use it later

- **Data Types**

  Numeric, integer, character, logical

- **Variables**

  Scalars, vectors, matrices, data frames, and lists

- **Commands and Operators**

- **Functions**

  A piece of code written to carry out a specific task

- **Comments**

  # not executable lines

- **Extension Packages**

  Additional functionality

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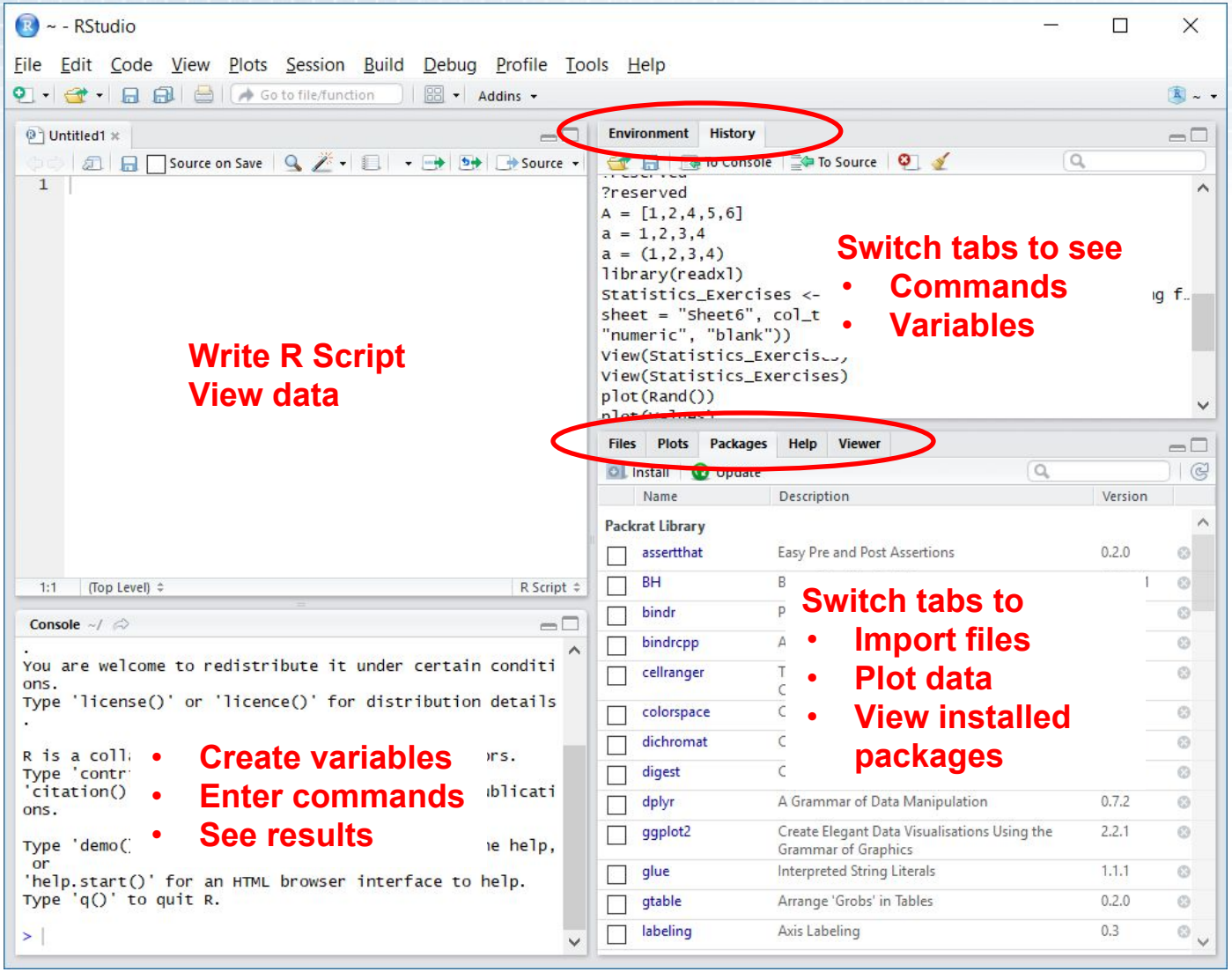
RStudio Interface



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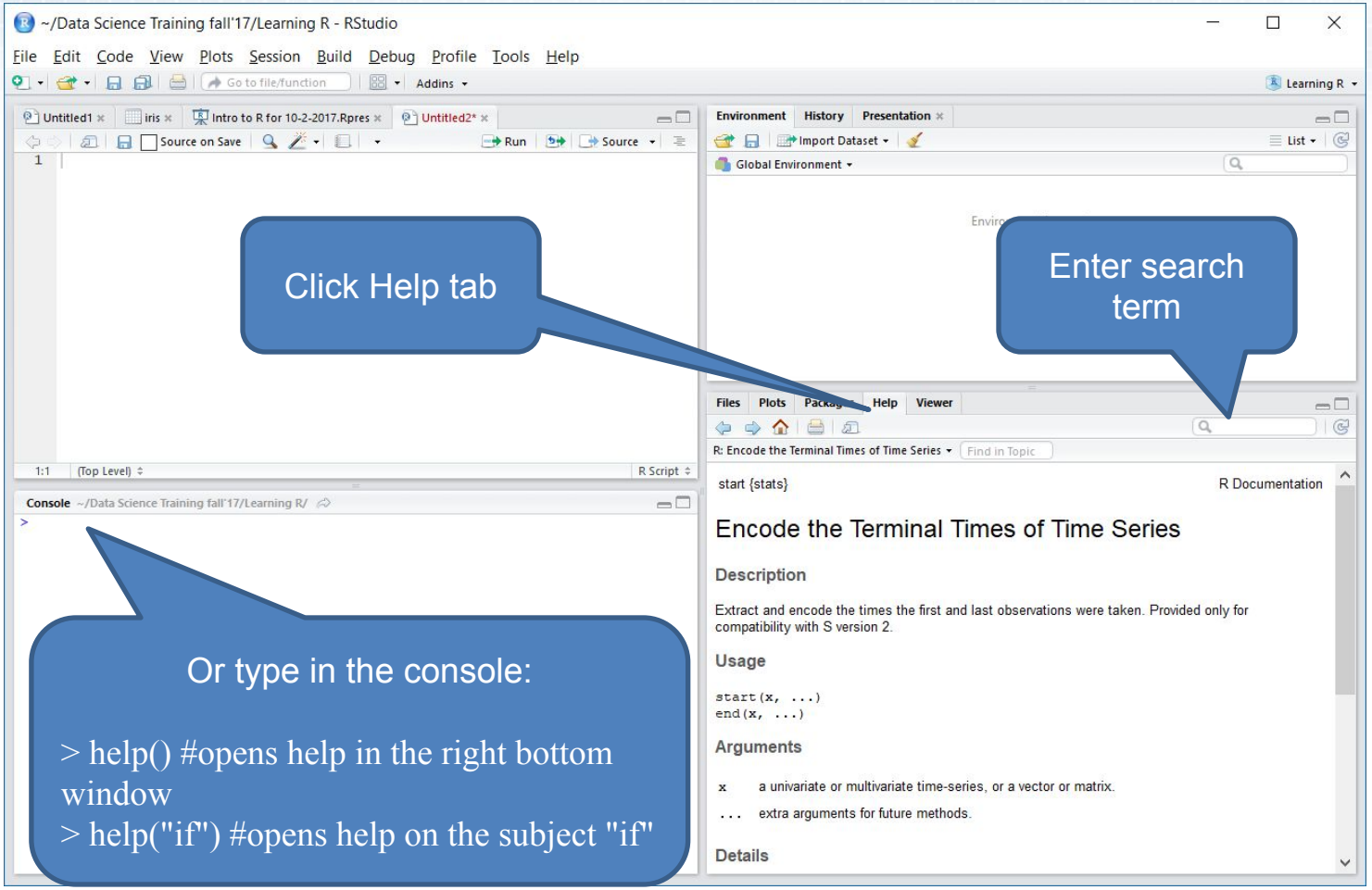
Help


~/Data Science Training fall'17/Learning R - RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Click Help tab
Enter search term
Or type in the console:
> help() #opens help in the right bottom window
> help("if") #opens help on the subject "if"
start {stats}
R Documentation
Encode the Terminal Times of Time Series
Description
Extract and encode the times the first and last observations were taken. Provided only for compatibility with S version 2.
Usage
start(x, ...)
end(x, ...)
Arguments
x a univariate or multivariate time-series, or a vector or matrix.
... extra arguments for future methods.
Details

Data Types

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Data Types: Numeric and Integer

- **Numeric**

```
> k = 1
> k             # print the value of k
[1] 1
> class(k)      # print the class name of k
[1] "numeric“

> is.integer(k)  # is k an integer?
[1] FALSE
```

- **Integer**

```
> y = as.integer(3)
> y             # print the value of y
[1] 3
> class(y)      # print the class name of y
[1] "integer"
> is.integer(y)  # is y an integer?
[1] TRUE
```

- **Try this**

```
> y = as.integer(3.14)
> y
[1] 3
```

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Data Types: Complex

- A **complex** value in R is defined via the pure imaginary value I = sqrt(−1) = i

```
> z = 1 + 2i     # create a complex number
> z              # print the value of z
[1] 1+2i
> class(z)       # print the class name of z
[1] "complex"
```

- The following gives an error as −1 is not a complex value

```
> sqrt(−1)       # square root of −1
[1] NaN
Warning message:
In sqrt(−1) : NaNs produced
```

- Instead, we have to use the complex value −1 + 0*i*

```
> sqrt(−1+0i)    # square root of −1+0i
[1] 0+1i
```

- An alternative is to coerce −1 into a complex value

```
> sqrt(as.complex(−1))
[1] 0+1i
```

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Data Types: Logical

- A **logical** value is often created via comparison between variables

```
> x = 1; y = 2   # sample values
> z = x > y      # is x larger than y?
> z              # print the logical value
[1] FALSE
> class(z)       # print the class name of z
[1] "logical"
```

- Standard logical operations are "&" (and), "|" (or), and "!" (negation)

```
> u = TRUE; v = FALSE
> u & v          # u AND v
[1] FALSE
> u | v          # u OR v
[1] TRUE
> !u             # negation of u
[1] FALSE
```

Case sensitive!

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Data Types: Character

- A **character** object is used to represent string values in R. We convert objects into character values with the as.character() function

```
> x = as.character(3.14)
> x             # print the character string
[1] "3.14"
> class(x)      # print the class name of x
[1] "character"
```

- Two character values can be concatenated with the paste function

```
> fname = "Joe"; lname ="Smith"
> paste(fname, lname)
[1] "Joe Smith“
```

- Try this:

```
> z = as.character(3.14)
> 2 * z
```

Error in 2 * z : non-numeric argument to binary operator

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Data Types: Character (Cont.)

- It is convenient to create a readable string with the sprintf function, which has a C language syntax.

```
> sprintf("%s has %d dollars", "Sam", 100)
[1] "Sam has 100 dollars"
```

- To extract a substring, we apply the substr function. Here is an example showing how to extract the substring between the third and twelfth positions in a string.

```
> substr("Mary has a little lamb.", start=3, stop=12)
[1] "ry has a l"
```

- To replace the first occurrence of the word "little" by another word "big" in the string, we apply the sub function.

```
> sub("little", "big", "Mary has a little lamb.")
[1] "Mary has a big lamb."
```

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Variables

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Variables: Vector

- A **vector** is a sequence of data elements of the same data type
- A vector containing three numeric values 2, 3 and 5

```
> c(2, 3, 5)
[1] 2 3 5
```

c() function
(mnemonic: combine)

- A vector of logical values

```
> c(TRUE, FALSE, TRUE, FALSE, FALSE)
[1]  TRUE FALSE  TRUE FALSE FALSE
```

- A vector of character strings

```
> c("aa", "bb", "cc", "dd", "ee")
[1] "aa" "bb" "cc" "dd" "ee"
```

- The number of members in a vector is given by the length function

```
> length(c("aa", "bb", "cc", "dd", "ee"))
[1] 5
```

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Variables: Matrix

- A **matrix** is a collection of data elements arranged in a two-dimensional rectangular layout. The following is an example of a matrix with 2 rows and 3 columns

$$A = \begin{bmatrix} 2 & 4 & 3 \\ 1 & 5 & 7 \end{bmatrix}$$

- We reproduce a memory representation of the matrix in R with the matrix function. The data elements must be of the same basic type

```
> A = matrix(
+   c(2, 4, 3, 1, 5, 7),      # the data elements
+   nrow=2,                   # number of rows
+   ncol=3,                   # number of columns
+   byrow = TRUE)             # fill matrix by rows
```

A = matrix(c(2, 4, 3, 1, 5, 7),nrow=2, ncol=3,byrow = TRUE)

"Shift" + "Enter" to get to the next line

```
> A                           # print the matrix
     [,1] [,2] [,3]
[1,]    2    4    3
[2,]    1    5    7
```

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Variables: Matrix (Cont.)

- We reproduce a memory representation of the matrix in R with the matrix function. The data elements must be of the same basic type.

```
> A = matrix(
+   c(2, 4, 3, 1, 5, 7),    # the data elements
+   nrow=2,                 # number of rows
+   ncol=3,                 # number of columns
+   byrow = TRUE)           # fill matrix by rows

> A                         # print the matrix
     [,1] [,2] [,3]
[1,]    2    4    3
[2,]    1    5    7
```

- An element at the m^{th} row, n^{th} column of A can be accessed by the expression A[m, n].

```
> A[2, 3]      # element at 2nd row, 3rd column
[1] 7
```

- The entire m^{th} row A can be extracted as A[m,].

```
> A[2, ]       # the 2nd row
[1] 1 5 7
```

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Variables: Matrix (Cont. 2)

- Similarly, the entire n^{th} column A can be extracted as A[,n].

```
> A[ ,3]      # the 3rd column
[1] 3 7
```

- We can extract more than one rows or columns at a time.

```
> A[ ,c(1,3)]  # the 1st and 3rd columns
     [,1] [,2]
[1,]    2    3
[2,]    1    7
```

- If we assign names to the rows and columns of the matrix, than we can access the elements by names.

```
> dimnames(A) = list(
+   c("row1", "row2"),        # row names
+   c("col1", "col2", "col3")) # column names

> A                 # print A
     col1 col2 col3
row1    2    4    3
row2    1    5    7

> A["row2", "col3"] # element at 2nd row, 3rd column
[1] 7
```

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Variables: List

- A **list** is a generic vector containing other objects.
- For example, the following variable x is a list containing copies of three vectors n, s, b, and a numeric value 3.

```
> n = c(2, 3, 5)
> s = c("aa", "bb", "cc", "dd", "ee")
> b = c(TRUE, FALSE, TRUE, FALSE, FALSE)
> x = list(n, s, b, 3)   # x contains copies of n, s, b
```

- **List Slicing:** retrieve a list slice with the *single square bracket* "[]" operator. The following is a slice containing the second member of x, which is a copy of s.

```
> x[2]
[[1]]
[1] "aa" "bb" "cc" "dd" "ee"
```

- With an index vector, we can retrieve a slice with multiple members. Here a slice containing the second and fourth members of x.

```
> x[c(2, 4)]
[[1]]
[1] "aa" "bb" "cc" "dd" "ee"
[[2]]
[1] 3
```

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Variables: List (Cont.)

- To reference a list member directly, we have to use the *double square bracket* "[[]]"operator. The following object x[[2]] is the second member of x. In other words, x[[2]] is a copy of s, but is *not* a slice containing s or its copy.

```
> x[[2]]
[1] "aa" "bb" "cc" "dd" "ee"
```

- We can modify its content directly.

```
> x[[2]][1] = "ta"
> x[[2]]
[1] "ta" "bb" "cc" "dd" "ee"
> s
[1] "aa" "bb" "cc" "dd" "ee"   # s is unaffected
```

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Variables: List (Cont. 2)

- To reference a list member directly, we have to use the *double square bracket* "[[]]"operator. The following object x[[2]] is the second member of x. In other words, x[[2]] is a copy of s, but is *not* a slice containing s or its copy.

```
> x[[2]]
[1] "aa" "bb" "cc" "dd" "ee"
```

- We can modify its content directly.

```
> x[[2]][1] = "ta"
> x[[2]]
[1] "ta" "bb" "cc" "dd" "ee"
> s
[1] "aa" "bb" "cc" "dd" "ee"   # s is unaffected
```

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Variables: Data Frame

- A **data frame** is used for storing data tables. It is a list of vectors of equal length. For example, the following variable df is a data frame containing three vectors n, s, b.

```
> n = c(2, 3, 5)
> s = c("aa", "bb", "cc")
> b = c(TRUE, FALSE, TRUE)
> df = data.frame(n, s, b)      # df is a data frame
```

- **Build-in Data Frame**

For example, here is a built-in data frame in R, called **iris**

```
> iris
    Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
1            5.1         3.5          1.4         0.2     setosa
2            4.9         3.0          1.4         0.2     setosa
3            4.7         3.2          1.3         0.2     setosa
4            4.6         3.1          1.5         0.2     setosa
5            5.0         3.6          1.4         0.2     setosa
6            5.4         3.9          1.7         0.4     setosa
```

.....

R Objects

- **Variables are objects, they have**
  - mode – class(), numeric, character, etc.
  - length() – number of elements
- **Object name can be**
  - Letters (A – Z and a – z)
  - Numbers (0 – 9)
  - Dots (.)
  - Underscores (_)

R is case sensitive!

- **Can reuse object names**

```
> k = 1
> k
[1] 1
> k = 2
> k
[1] 2
```

[1] – means first element

- **Remove object**

```
> rm(k)
```

- **Create multiple objects at once**

```
> n =  2; m = 3; l = 4
```

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Commands

Input and Display Commands

```
x <- c(1,2,4,8,16 )          #create a data vector with specified elements
y <- c(1:10)                 #create a data vector with elements 1-10
n <- 10 x1 <- c(rnorm(n))          #create a n item vector of random normal deviates
y1 <- c(runif(n))+n          #create another n item vector that has n added
                        to each random uniform distribution
z <- rbinom(n,size,prob)           #create n samples of size "size" with probability
                        prob from the binomial
vect <- c(x,y)               #combine them into one vector of length 2n
mat <- cbind(x,y)            #combine them into a n x 2 matrix
mat[4,2]                     #display the 4th row and the 2nd column
mat[3,]                      #display the 3rd row
mat[,2]                      #display the 2nd column
subset(dataset,logical)            #those objects meeting a logical criterion
subset(data.df,select=variables,logical)  #get those objects from a data frame that meet a criterion
data.df[data.df=logical]           #yet another way to get a subset
x[order(x$B),]               #sort a dataframe by the order of the elements in B
x[rev(order(x$B)),]          #sort the dataframe in reverse order
```

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Moving Around Commands

```
ls()              #list the variables in the workspace
rm(x)             #remove x from the workspace
rm(list=ls())             #remove all the variables from the workspace
attach(mat)               #make the names of the variables in the matrix
                  or data frame available in the workspace
detach(mat)               #releases the names
                  (remember to do this each time you attach something)
with(mat, .... )          #a preferred alternative to attach ... detach
new <- old[,-n]           #drop the nth column
new <- old[-n,]           #drop the nth row
new <- old[,-c(i,j)]      #drop the ith and jth column
new <- subset(old,logical)  #select those cases that meet the logical condition
complete <- subset(data.df,complete.cases(data.df))
                  #find those cases with no missing values
new <- old[n1:n2,n3:n4]     #select the n1 through n2 rows of variables n3 through n4)
```

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Arithmetic Operators

Operator	Description
+	addition
-	subtraction
*	multiplication
/	division
^ or **	exponentiation
x %% y	modulus (x mod y) 5%%2 is 1
x %/% y	integer division 5%/%2 is 2

```
2^10
[1] 1024
2**10
[1] 1024
```

Logical Operators

Operator	Description
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
==	exactly equal to
!=	not equal to
!x	Not x
x | y	x OR y
x & y	x AND y
isTRUE(x)	test if X is TRUE

```
x = c(1:10)
x
1 2 3 4 5 6 7 8 9 10
x > 8
F F F F F F F F T T
x < 5
T T T T F F F F F F
```

Functions

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Built-in Numeric Functions

Function	Description
abs(*x*)	absolute value
sqrt(*x*)	square root
ceiling(*x*)	ceiling(3.475) is 4
floor(*x*)	floor(3.475) is 3
trunc(*x*)	trunc(5.99) is 5
round(*x*, digits=*n*)	round(3.475, digits=2) is 3.48
signif(*x*, digits=*n*)	signif(3.475, digits=2) is 3.5
cos(*x*), sin(*x*), tan(*x*)	also acos(*x*), cosh(*x*), acosh(*x*), etc.
log(*x*)	natural logarithm
log10(*x*)	common logarithm
exp(*x*)	e^*x*

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Built-in Statistical Functions

Function	Description
mean(*x*, trim=0, **na.rm=**FALSE**)**	mean of object x # trimmed mean, removing any missing values and # 5 percent of highest and lowest scores mx <- mean(x,trim=.05,na.rm=TRUE)
sd(*x*)	standard deviation of object(x). also look at var(x) for variance and mad(x) for median absolute deviation.
median(*x*)	median
quantile(*x*, *probs*)	quantiles where x is the numeric vector whose quantiles are desired and probs is a numeric vector with probabilities in [0,1]. # 30th and 84th percentiles of x y <- quantile(x, c(.3,.84))
range(*x*)	range
sum(*x*)	sum
diff(*x*, lag=*1*)	lagged differences, with lag indicating which lag to use
min(*x*)	minimum
max(*x*)	maximum
scale(*x*, center=TRUE**, scale=**TRUE**)**	column center or standardize a matrix

$x = c(1:10)$

```
>  X = c(1:10)
> mean(x) [1] 5.5
> range(x) [1] 1 10
> sum(x) [1] 55
```

```
> x = rnorm(100)
> x[1]= NA
> mean(x) [1] NA
> mean(x, na.rm = TRUE)
> [1] -0.007524422
```

Built-in Statistical Probability Functions

Function	Description

dnorm(*x***)**	normal density function (by default m=0 sd=1)
	# plot standard normal curve
	x <- pretty(c(-3,3), 30)
	y <- dnorm(x)
	plot(x, y, type='l', xlab="Normal Deviate", ylab="Density", yaxs="i")

pnorm(*q***)**	cumulative normal probability for q (area under the normal curve to the left of q) pnorm(1.96) is 0.975
qnorm(*p***)**	normal quantile. value at the p percentile of normal distribution qnorm(.9) is 1.28 # 90th percentile
rnorm(*n***, m=**0**,sd=**1**)**	n random normal deviates with mean m and standard deviation sd. #50 random normal variates with mean=50, sd=10 x <- rnorm(50, m=50, sd=10)

dbinom(*x***, *size*, *prob*)**
pbinom(*q***, *size*, *prob*)**
qbinom(*p***, *size*, *prob*)**
rbinom(*n***, *size*, *prob*)**
	binomial distribution where size is the sample size
	and prob is the probability of a heads (pi)
	# prob of 0 to 5 heads of fair coin out of 10 flips
	dbinom(0:5, 10, .5)
	# prob of 5 or less heads of fair coin out of 10 flips
	pbinom(5, 10, .5)

dpois(*x***, *lamda*)**
ppois(*q***, *lamda*)**
qpois(*p***, *lamda*)**
rpois(*n***, *lamda*)**
	poisson distribution with m=std=lamda
	#probability of 0,1, or 2 events with lamda=4
	dpois(0:2, 4)
	# probability of at least 3 events with lamda=4
	1- ppois(2,4)

dunif(*x***, min=**0**, max=**1**)** **punif(***q***, min=0, max=**1**)** **qunif(***p***, min=**0**, max=**1**)** **runif(***n***, min=**0**, max=**1**)**	uniform distribution, follows the same pattern as the normal distribution above. #10 uniform random variates x <- runif(10)

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Built-in Character Functions

Function	Description
substr(*x*, **start=***n1*, **stop=***n2***)**	Extract or replace substrings in a character vector. x <- "abcdef" substr(x, 2, 4) is "bcd" substr(x, 2, 4) <- "22222" is "a222ef"
grep(*pattern*, *x* , **ignore.case=**FALSE, **fixed=**FALSE**)**	Search for *pattern* in *x*. If fixed =FALSE then *pattern* is a regular expression. If fixed=TRUE then *pattern* is a text string. Returns matching indices. grep("A", c("b","A","c"), fixed=TRUE) returns 2
sub(*pattern*, *replacement*, *x*, **ignore.case =**FALSE, **fixed=**FALSE**)**	Find *pattern* in *x* and replace with *replacement* text. If fixed=FALSE then *pattern* is a regular expression. If fixed = T then *pattern* is a text string. sub("\\s",".","Hello There") returns "Hello.There"
strsplit(*x*, *split***)**	Split the elements of character vector *x* at *split*. strsplit("abc", "") returns 3 element vector "a","b","c"
paste(..., sep="")	Concatenate strings after using *sep* string to seperate them. paste("x",1:3,sep="") returns c("x1","x2" "x3") paste("x",1:3,sep="M") returns c("xM1","xM2" "xM3") paste("Today is", date())
toupper(*x***)**	Uppercase
tolower(*x***)**	Lowercase

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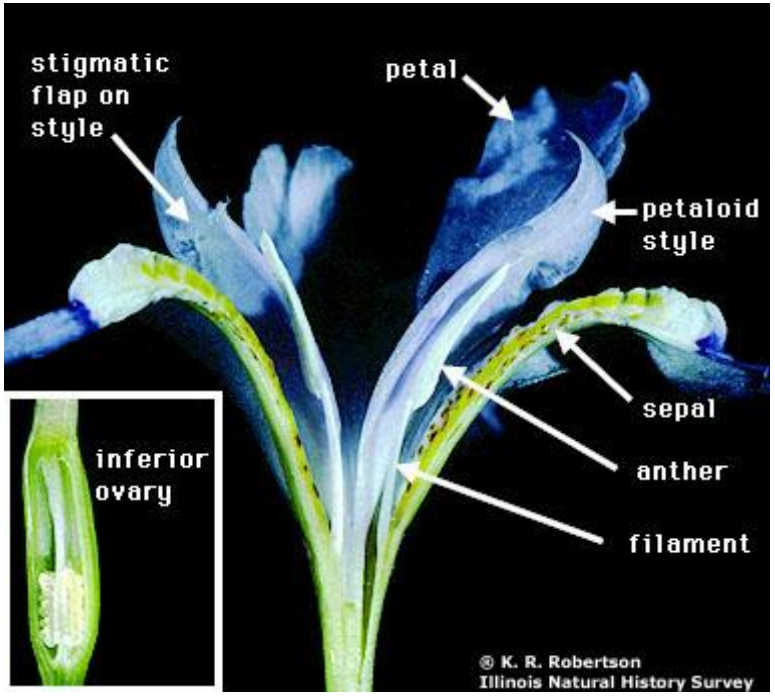
Some Useful Built-in Functions

Function	Description
seq(*from* , *to*, *by***)**	generate a sequence indices <- seq(1,10,2) #indices is c(1, 3, 5, 7, 9)
rep(*x*, *ntimes***)**	repeat *x n* times y <- rep(1:3, 2) # y is c(1, 2, 3, 1, 2, 3)
subset(x, …)	select columns from variable subset(mydata, columnname == “x”)

```
> Setosa = subset(iris, Species == "setosa")
```

Data Exploration: Iris



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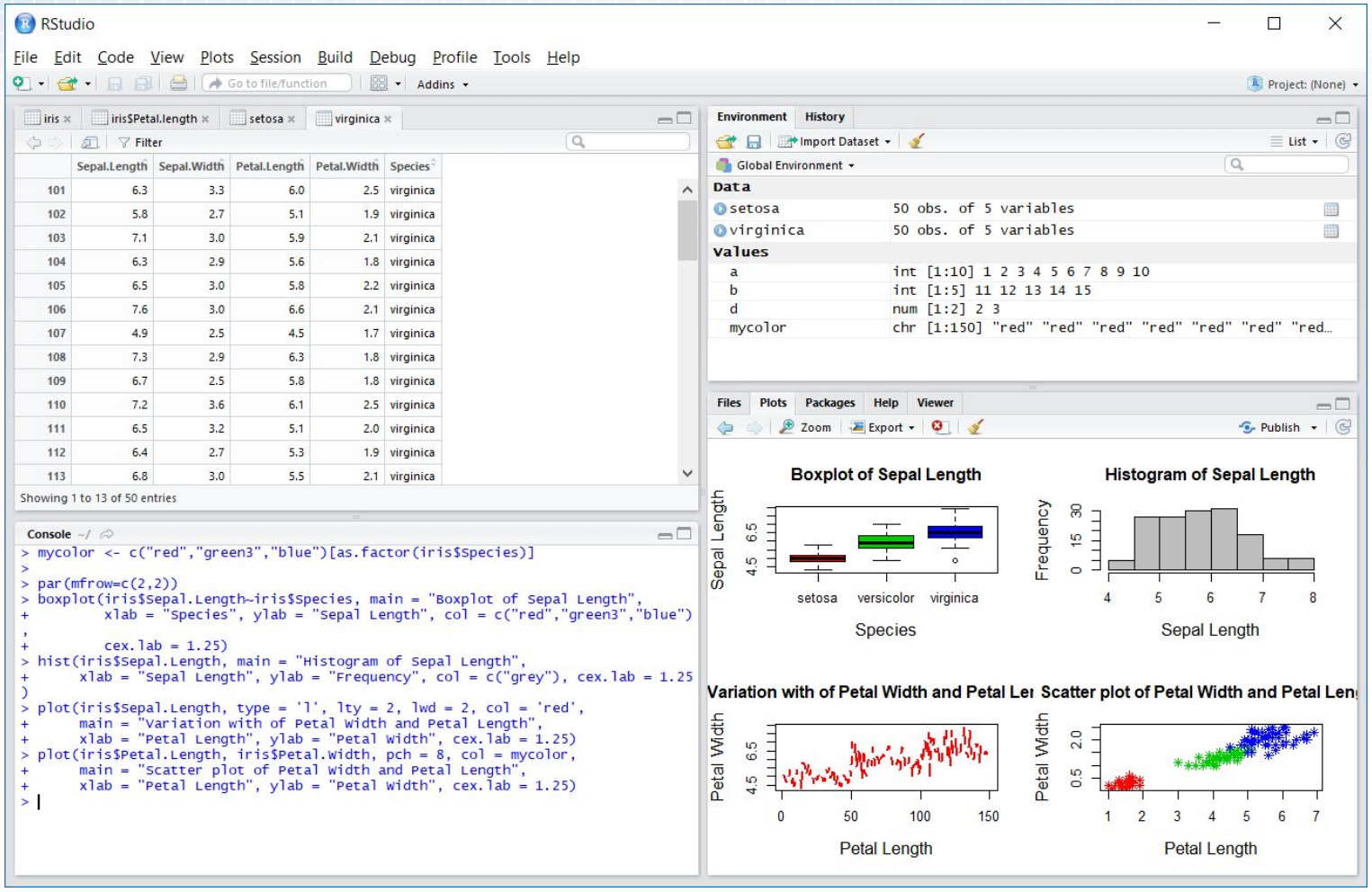
Example of R Plotting Capabilities



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Scripts for Iris Example

```
> mycolor <- c("red","green3","blue")[as.factor(iris$Species)]

> par(mfrow=c(2,2))        # split plotting area

> boxplot(iris$Sepal.Length~iris$Species, main = "Boxplot of Sepal Length", xlab = "Species", ylab =
"Sepal Length", col = c("red","green3","blue"), cex.lab = 1.25)

> hist(iris$Sepal.Length, main = "Histogram of Sepal Length",
xlab = "Sepal Length", ylab = "Frequency", col = c("grey"), cex.lab = 1.25)

> plot(iris$Sepal.Length, type = 'l', lty = 2, lwd = 2, col = 'red', main = "Variation with of Petal Width and
Petal Length", xlab = "Petal Length", ylab = "Petal Width", cex.lab = 1.25)

> plot(iris$Petal.Length, iris$Petal.Width, pch = 8, col = mycolor)
```

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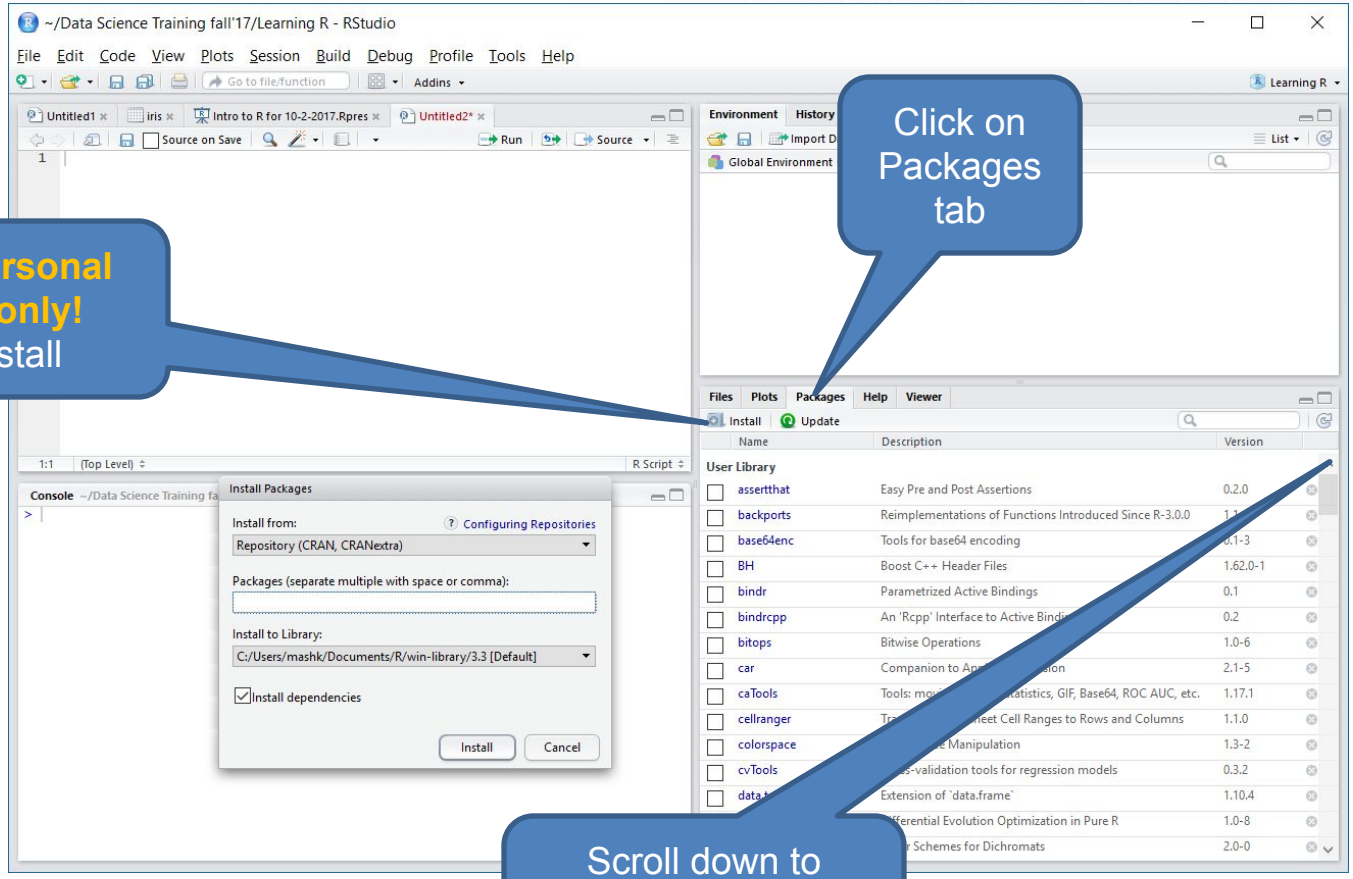
Extension Packages

Open ServiceNow ticket to request a new Package on DSVD



Data Import

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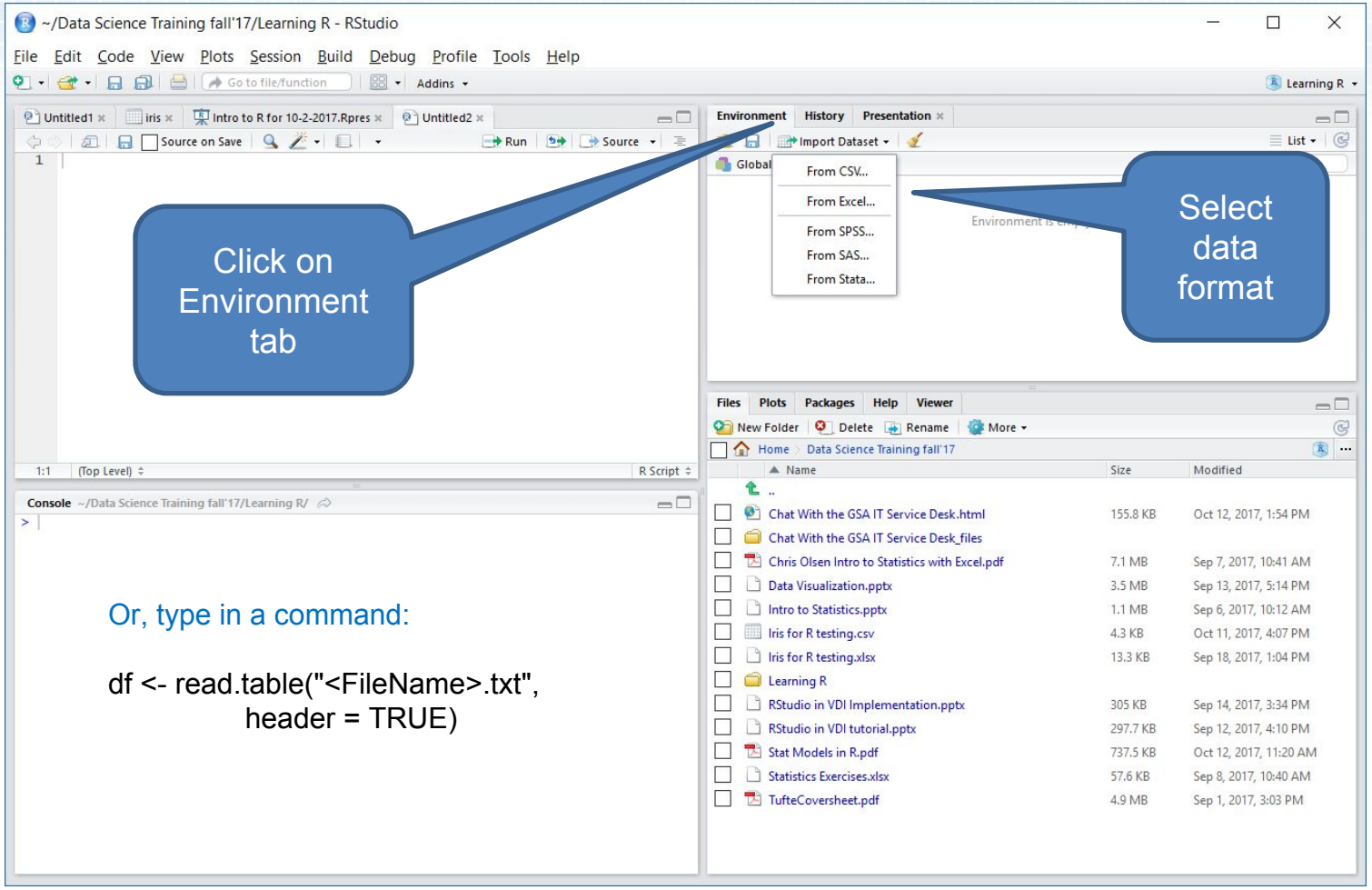
Import Data



Or, type in a command:

```
df <- read.table("<FileName>.txt",
                 header = TRUE)
```

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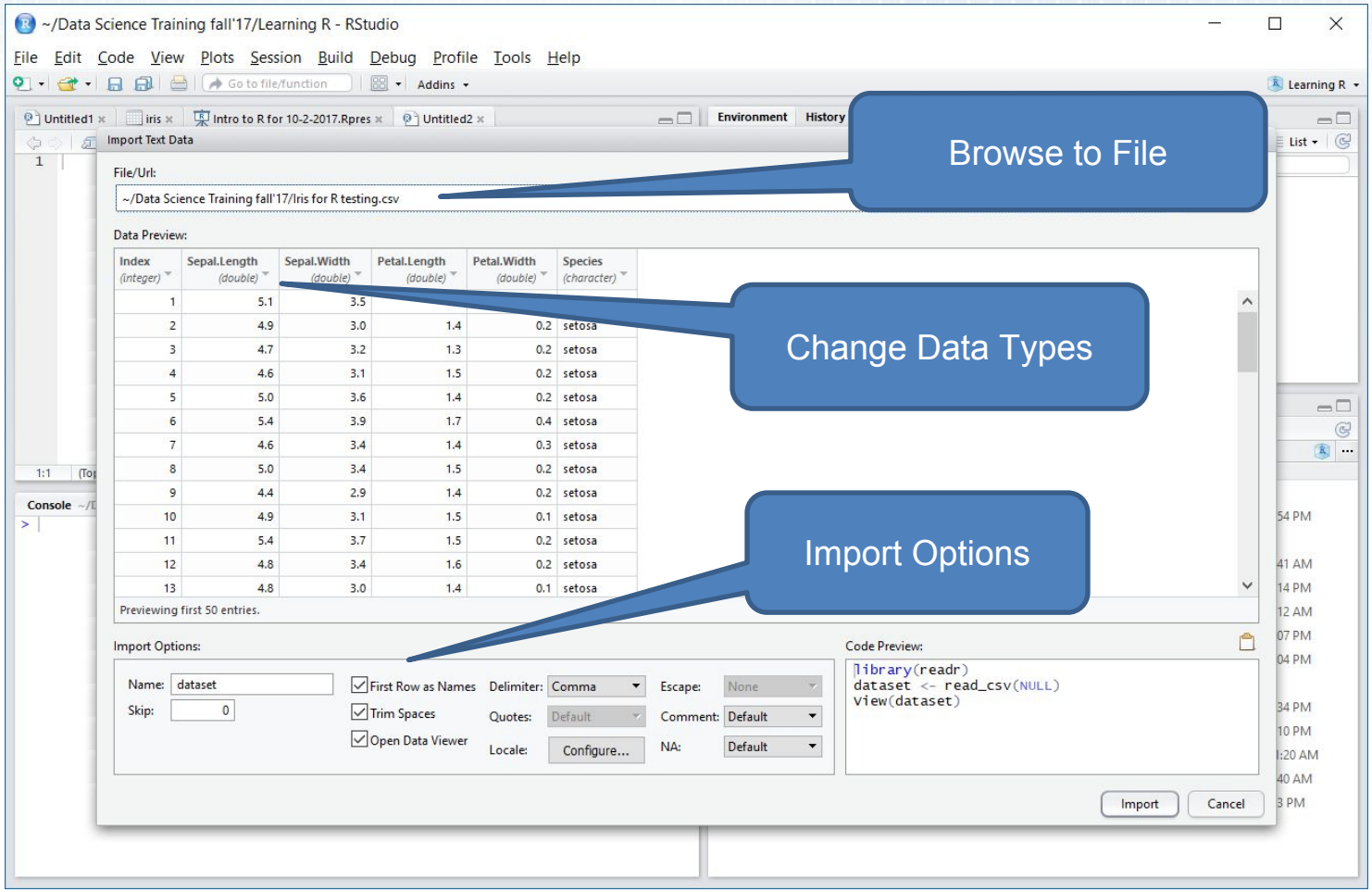
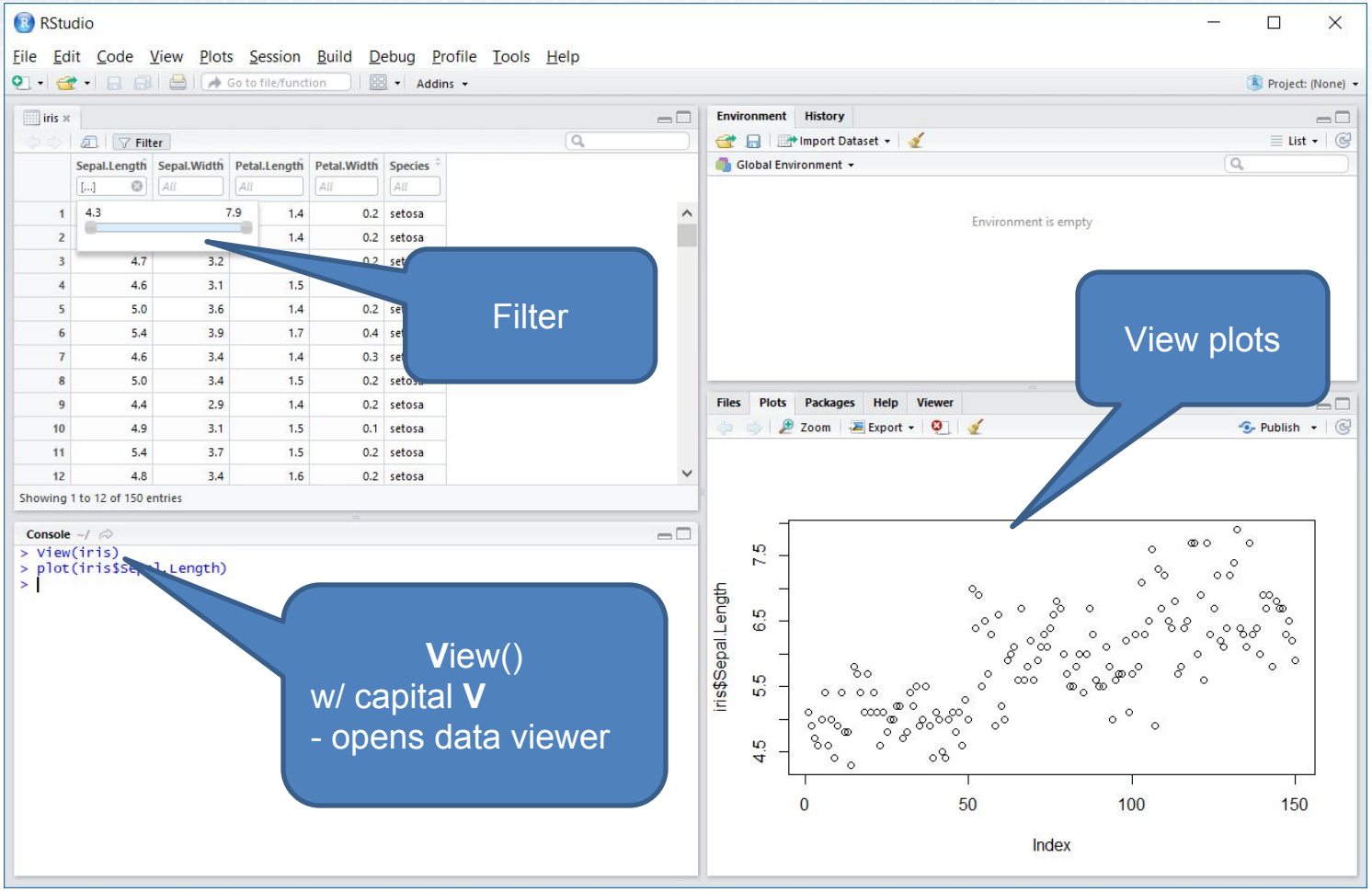
Wrangle Data



Data Viewer for Simple Exploratory Data Analysis



Summary of Plotting Commands

- High level graphical commands create the plot
  - plot( ) Scatter plot, and general plotting
  - hist( ) Histogram
  - stem( ) Stem-and-leaf
  - boxplot( ) Boxplot
  - qqnorm( ) Normal probability plot
  - mosaicplot( ) Mosaic plot 2
- Low level graphical commands add to the plot
  - points( ) Add points
  - lines( ) Add lines
  - text( ) Add text
  - • abline( ) Add lines
  - • legend( ) Add legend
- Most commands accept additional graphical parameters par( ) Set parameters for plotting
  - cex Font size
  - col Color of plotting symbols
  - lty Line type
  - lwd Line width
  - mar Inner margins
  - mfrow Splits plotting area (mult. figs. per page) 16
  - oma Outer margins
  - pch Plotting symbol
  - xlim Min and max of X axis range
  - ylim Min and max of Y axis range

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Useful Links

https://www.r-project.org/

https://www.rstudio.com/products/RStudio/

http://www.statmethods.net/r-tutorial/index.html

R commands
https://www.personality-project.org/r/r.commands.html

Plotting in R
http://gfc.ucdavis.edu/events/arusha2016/_static/labs/day2/day2_lab2a_graphics.pdf
http://www.cyclismo.org/tutorial/R/plotting.html

https://www.datacamp.com/community/tutorials/r-tutorial-read-excel-into-r

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Q & A