Beginner Friendly Introduction to R

October, 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

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

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**

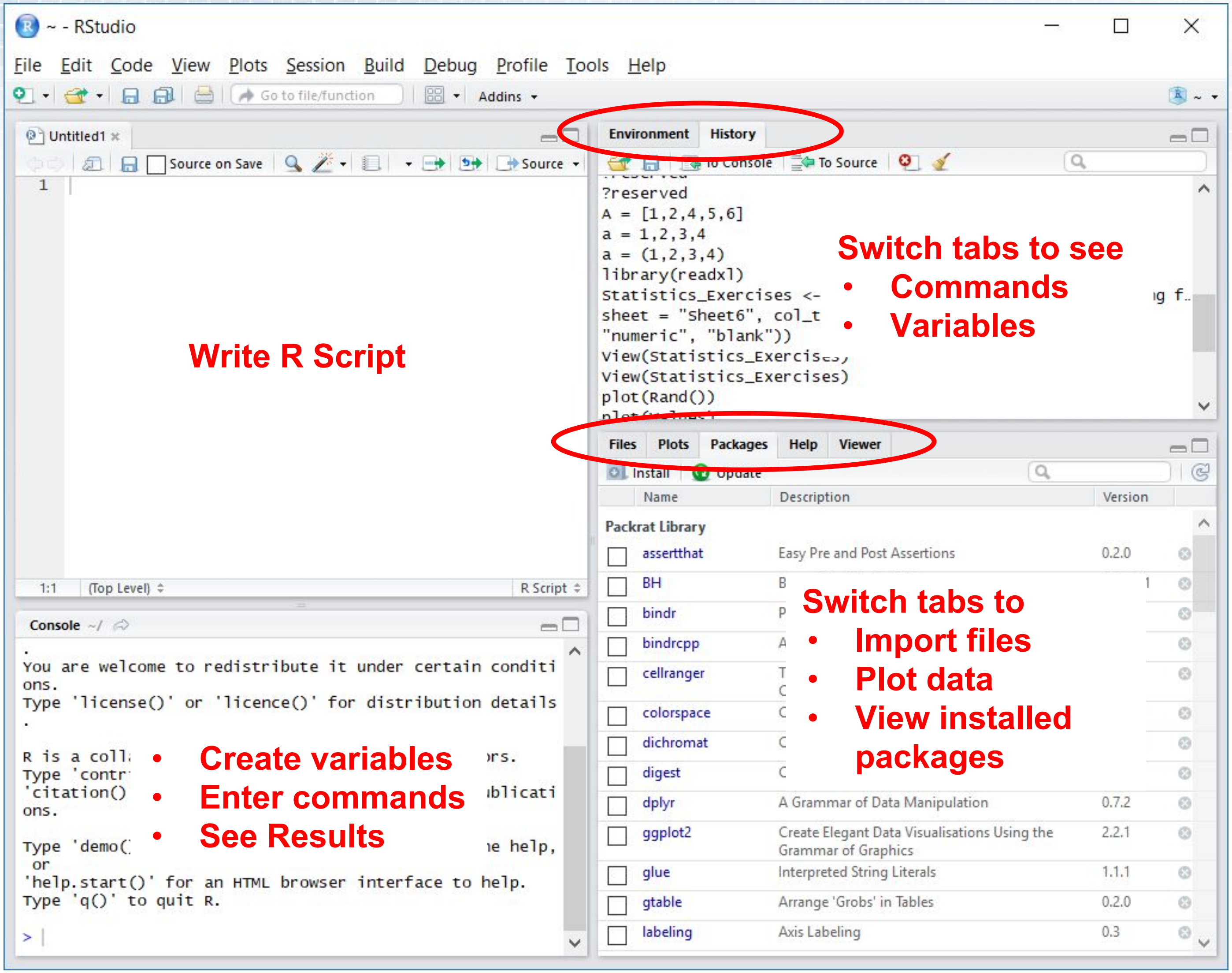
  Scalars, vectors, matrices, data frames, and lists
- **Commands and Operators**
- **Functions**

  A piece of code written to carry out a specific task
- **Comments**

  # not executable lines
- **Extension Packages**

  Additional functionality
- **Help**

RStudio Interface



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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
```

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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
```

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"
```

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Data Types: Character (Cont.)

- It is often more 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: 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
```

- 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
```

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

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
```

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 also 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
```

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
```

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**

We use built-in data frames in R for our tutorials. For example, here is a built-in data frame in R, called **mtcars**.

```
> mtcars
               mpg cyl disp  hp drat   wt ...
Mazda RX4     21.0   6  160 110 3.90 2.62 ...
Mazda RX4 Wag 21.0   6  160 110 3.90 2.88 ...
Datsun 710    22.8   4  108  93 3.85 2.32 ...
           ............
```

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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
```

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
```

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*

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

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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)

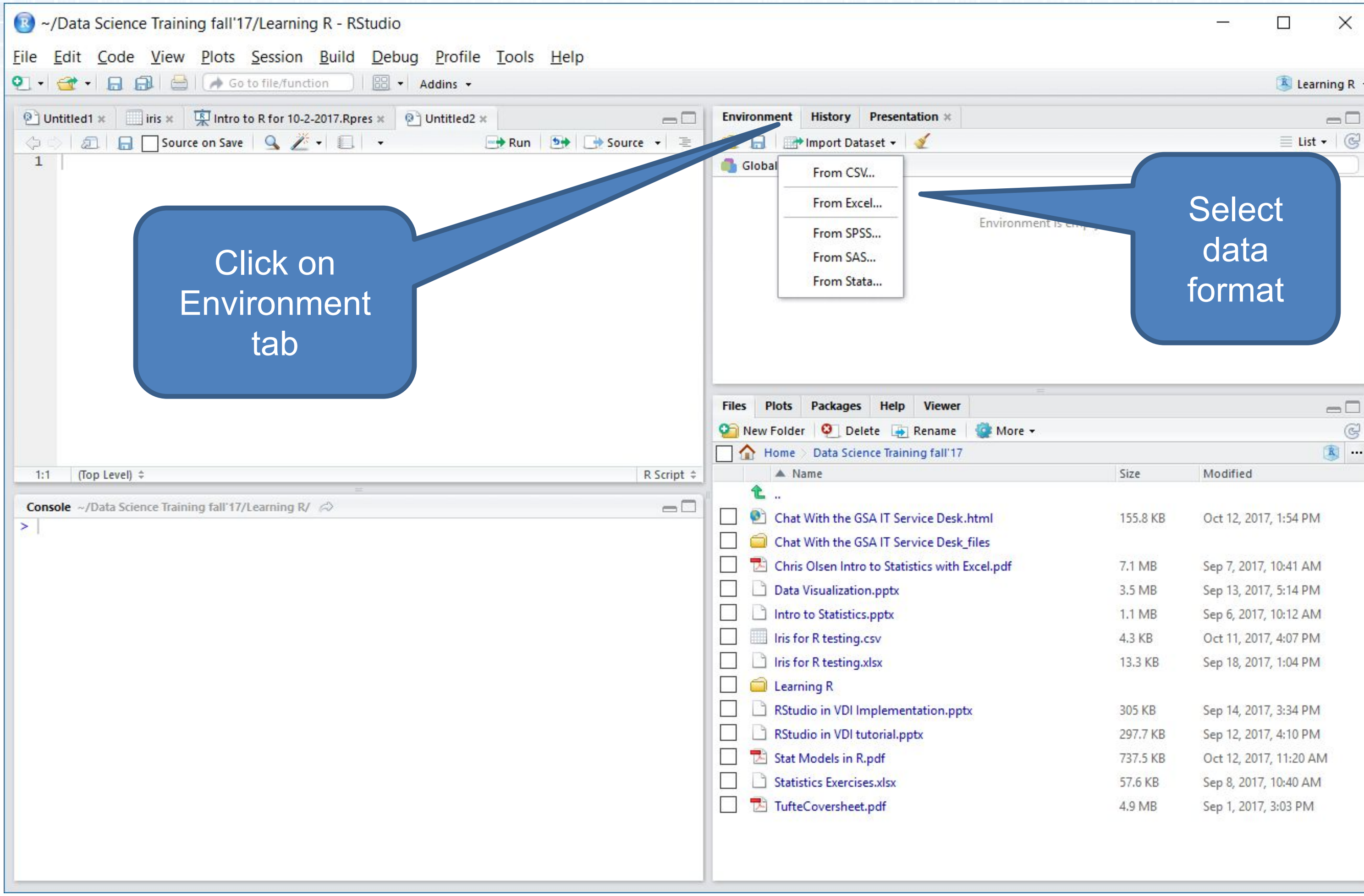
Built-in Character Functions

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

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)
cut(*x***,** *n***)**	divide continuous variable in factor with *n* levels y <- cut(x, 5)

Import Data : .csv and .xls(x)



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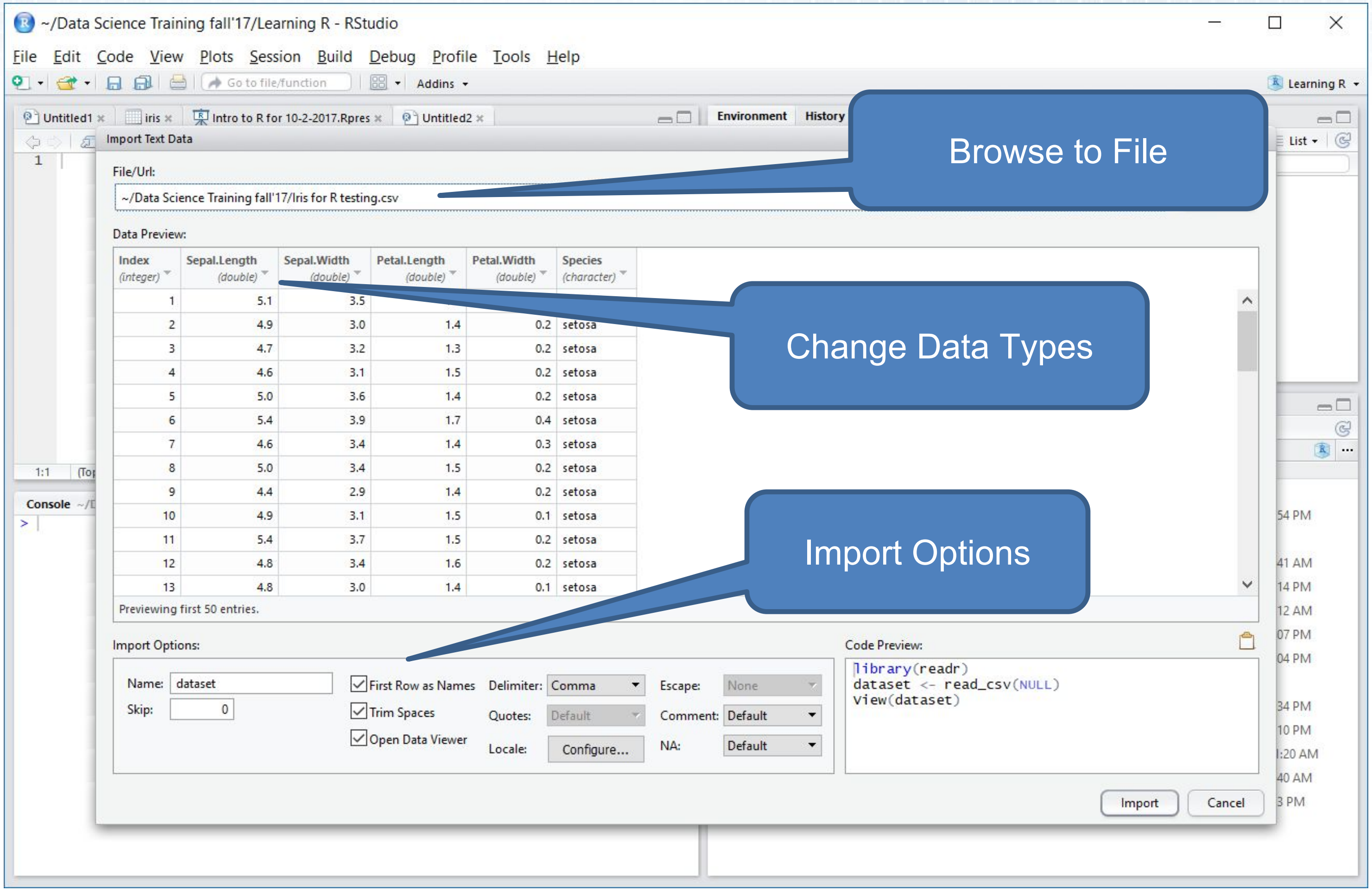
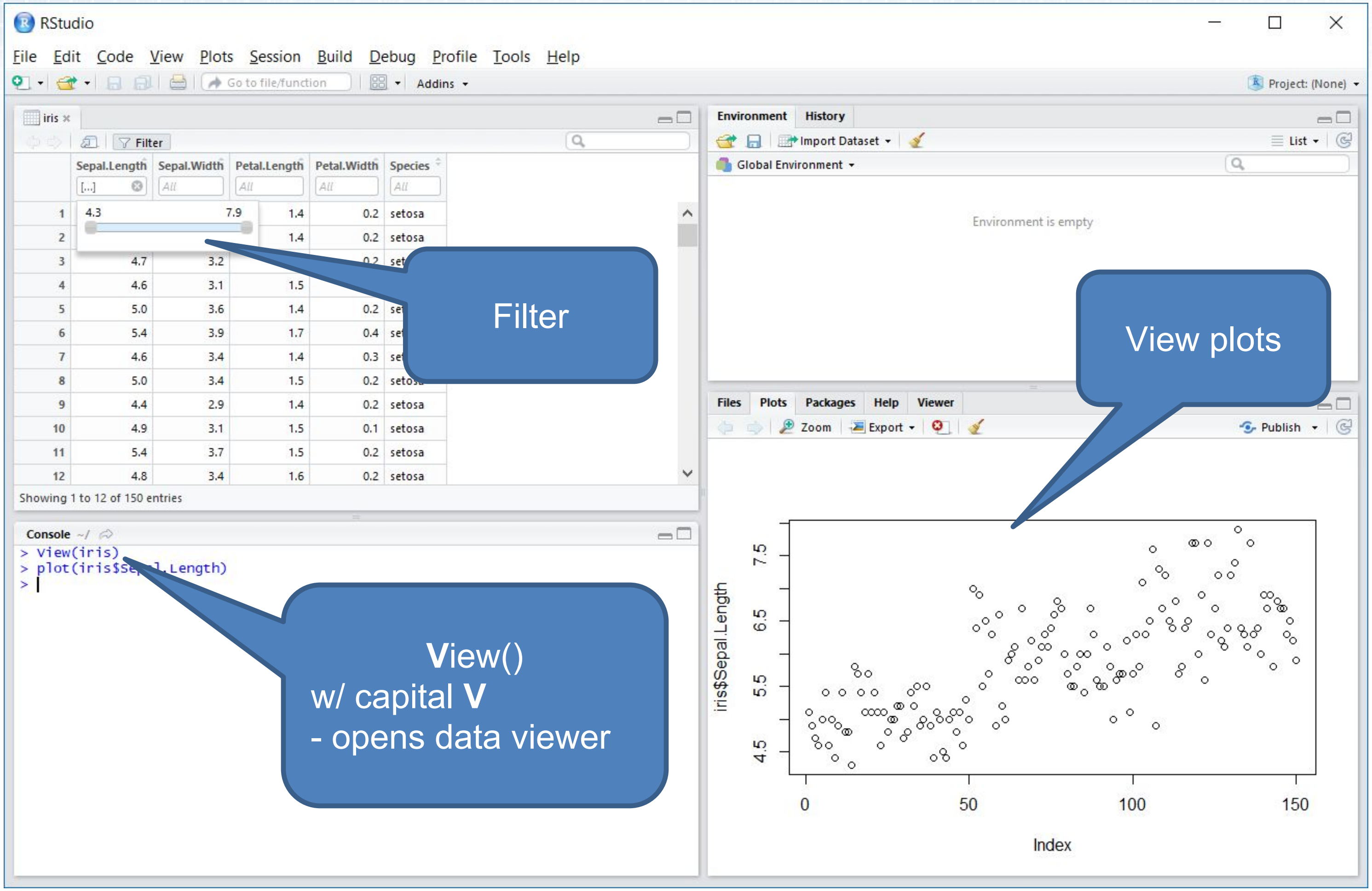
Wrangle Data



Data Viewer for Simple Exploratory Data Analysis



Plotting Exercise View(iris)

- **Histogram**

  hist(iris$Petal.Length)

- **Scatter plot**

  plot(iris$Sepal.Length, type = 'p'), OR

  plot(iris$Sepal.Length)

  plot(iris$Sepal.Length, iris$Sepal.Width, type = 'p')

- **Line chart**

  plot(iris$Sepal.Length, type = 'l')

- **Box plot**

  boxplot(iris$Sepal.Length ~ iris$Species)

- **Bar chart**

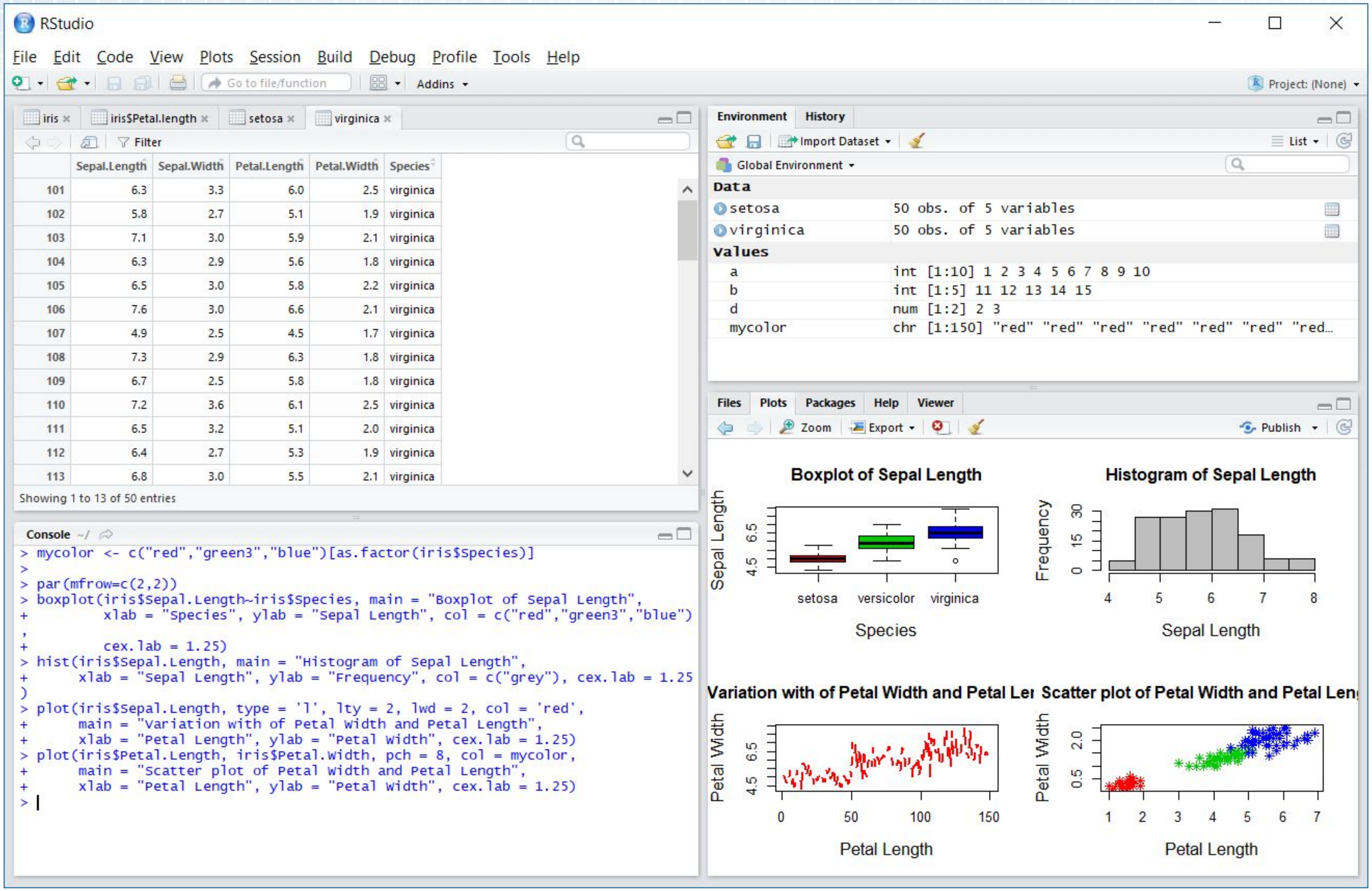
- **Customize titles and axis labels**

  plot(iris$Petal.Length, iris$Petal.Width, main = "Edgar Anderson's Iris Data", xlab = "Petal Length", ylab = "Petal Width")

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

Example of R Plotting Capabilities



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Command to Create the Example

```
> mycolor <- c("red","green3","blue")[as.factor(iris$Species)]
>
> par(mfrow=c(2,2))
> boxplot(iris$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,
+     main = "Scatter plot of Petal Width and Petal Length",
+     xlab = "Petal Length", ylab = "Petal Width", cex.lab = 1.25)
```

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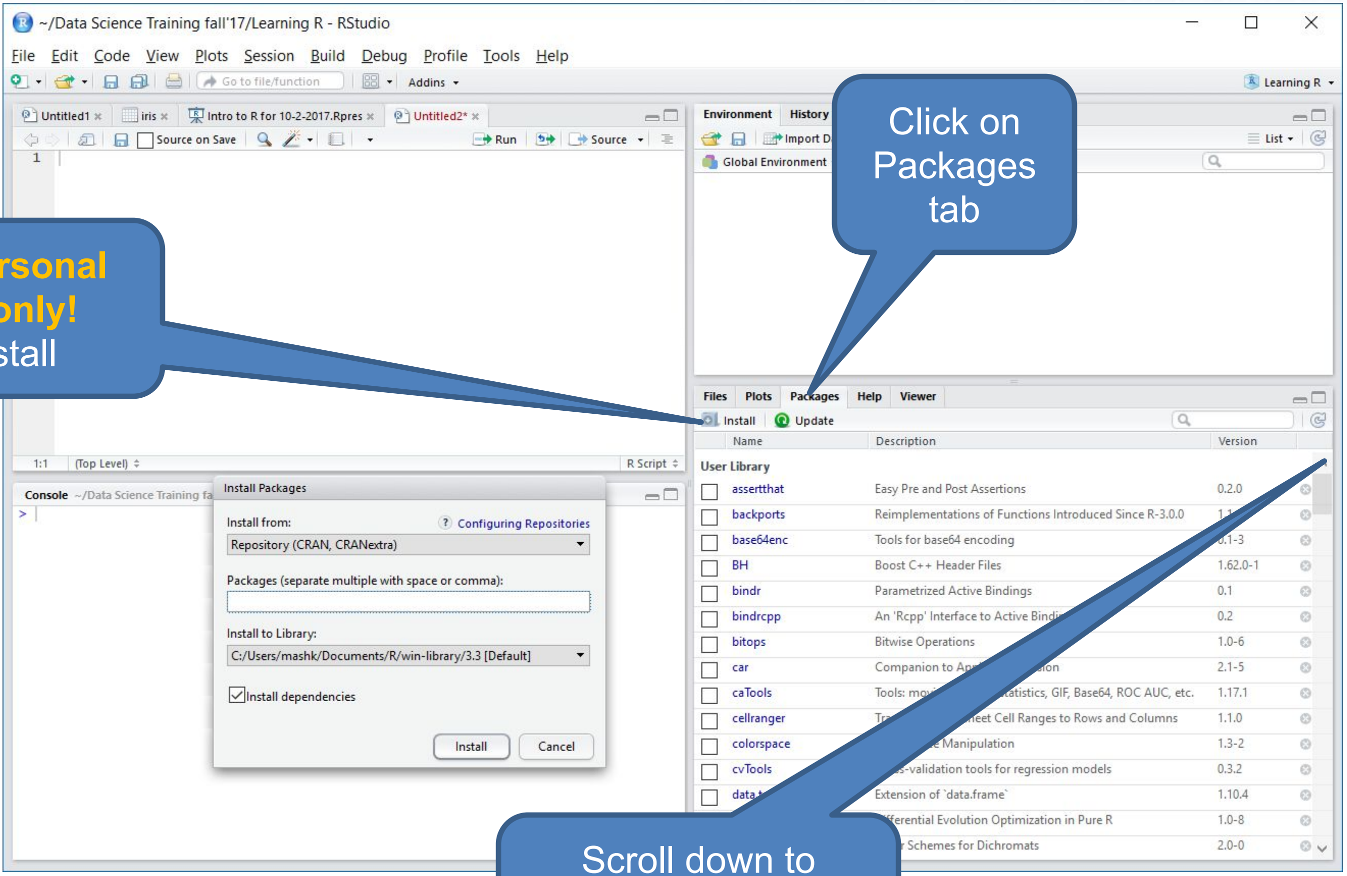
Extension Packages

Open ServiceNow ticket to request a new Package on DSVD

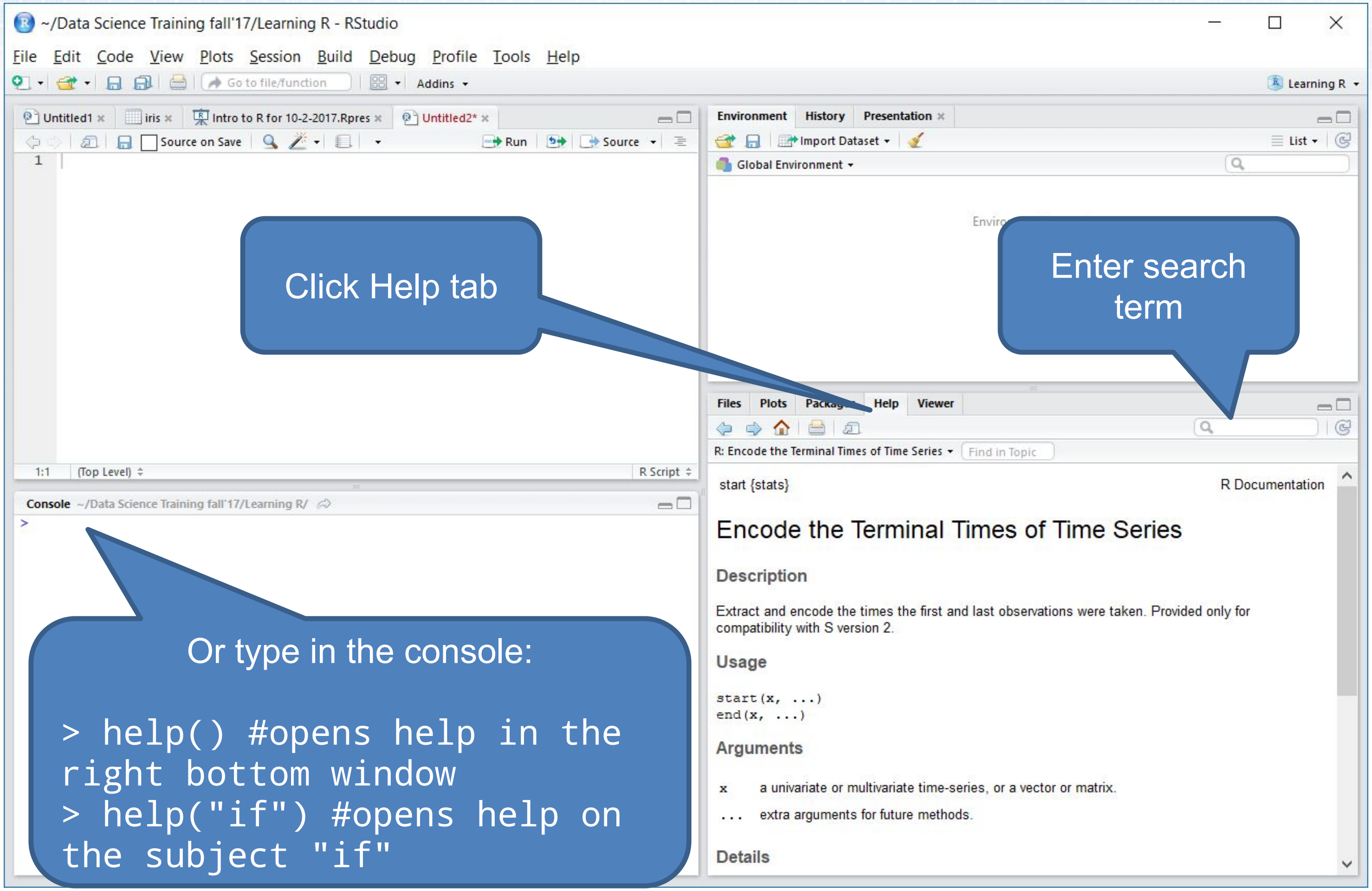


In your personal version only!
Click Install

Click on Packages tab

Scroll down to review installed packages

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"
```

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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

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Q & A