Introduction to R at CDC Part 2

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Learning Resources

Additional Resources

- HHS Learning Portal
  - Introduction to R Programming (PG_RPRG_A01_IT_ENUS, 2.2)
  - Books 24x7 (under IT Skills -> Software Design and Development -> R).
- Massive online courses (MOC's) Coursera Data Science Specialization by John Hopkins
- Swirl (`http://swirlstats.com/`)
  - Interactive learning using R
- R users group (`http://rug.biotech.cdc.gov/presentations.html`)
- Online books (free)
  - R for Data Science by Garrett Grolemund and Hadley Wickham (`http://r4ds.had.co.nz/index.html`)

Basic R Syntax

Data for Today

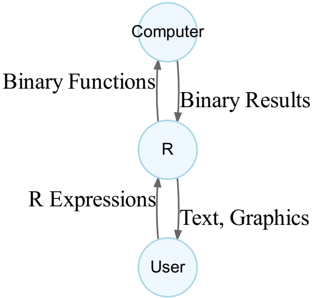
Available at `http://rug.cdc.gov/data/`

- `http://rug.cdc.gov/data/AGE_Surveillance_Log.xls`
- save in ../data/ directory
- also available as a csv file

The R Console

Interactive Use

- R is an interpreted high level language
- Uses either command line interface or console to communicate with user
- Programs (sometimes called scripts) can either be passed through the console or interpreter.
- Results are returned through the interpreter to the user.



Basic Example Operations in Console

- Typing the following after the > and pressing enter will cause R to evaluate the expression.
- R will return either a value or an error. If the statement is incomplete, it will display a continuation prompt (+).
- Any characters on a line with # will be disregarded as a comment.
- Multiple expressions on one line can be seperated by ;

```
1 + 1  #Add 1 plus 1
sqrt(5000) # square root 5000
3/3
4*2
2*pi
pi%%pi
5 %/% 2
```

Arthmetic Operators

These operators perform basic arithmatic in R

Operator	Operation
+	addition
-	subtraction
*	multiplication
/	division
^	exponentiation
**	exponentiation
%%	modulus
%/%	integer division

Scientific Notation

Scientific Notation consists of: - A floating point number - "e", a + or − and - Number indicating the direction and amount to shift the decimal point - By default, R will convert small scientific numbers to fixed notation, see `?options`

```
1.3e3 ; 1.3e-3; 1e4 ; 1e-4
```

```
## [1] 1300
```

```
## [1] 0.0013
```

```
## [1] 10000
```

```
## [1] 1e-04
```

Logs, Roots

- To obtain natural log, use `log()` function
- Inverse of `log()` is `exp()`
- `log10()` is base 10 logarithms, `log2()` is base 2 logarithms
- other logs can be calculated `log()` with base argument e.g.

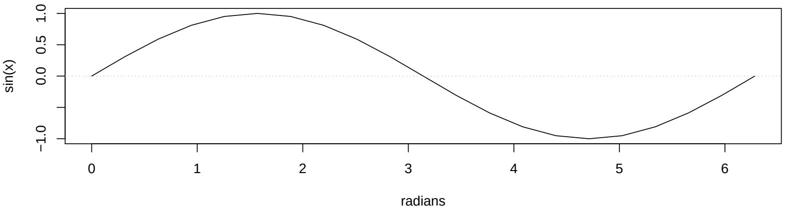
```
log(9, base = 3)
```

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

Trigonometry Functions

- `sin()`, `cos()`, `tan()`, `asin()`, `acos()`, `atan()`
- For help on trigonometry functions see `?Trig`
- But input is radians!

```r
plot(x = seq(0, 2, 0.1) * pi, y = sin(seq(0, 2, 0.1) * pi),
     type="l", xlab = "radians", ylab = "sin(x)")
abline(h=0, lty = 3, col = "grey")
```



Objects, class and Type

Assignments

Variables are stored in R by *assigning* them. You can see what variables are in R's memory environment by using the function `objects()`or `ls()`. You can use <- or = for assignment.

- Note that R is case sensitive!
- Object names cannot start with a number!
- (Shortcut key: Alt + -) in Rstudio for <-

```
x = 7 # same as:
x <- 7
print(x)
```

```
## [1] 7
```

```
print(X) # error!
```

```
## Error in print(X): object 'X' not found
```

```
y <- 10 - 9
```

Objects and Clearing Environment

To see what objects are stored in memory:

```r
ls()
```

To clear all objects from memory:

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

Logic Examples

To use logical comparisons, use the symbols `<`, `>`, `>=`, `<=`, `==`, `!=`

```
x <- 1
x > 2
```

```
## [1] FALSE
```

```
x < 0
```

```
## [1] FALSE
```

```
x >= 4
```

```
## [1] FALSE
```

```
x <= 5
```

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

```
x == 1
```

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

Logical Comparisons

Operator	Operation
<	less than
<=	less than or equal
>	greater than
>=	greater than or equal
==	equal
!=	not equal
!	NOT
$\vert$	OR
&	AND
$\vert\vert$	ALL OR
&&	ALL AND

Atomic structures

Objects can have classes. Atomic structures are the lowest level of class.

```
#Variable classes
x <- 1.7
class(x)
```

```
## [1] "numeric"
```

```
typeof(x)
```

```
## [1] "double"
```

```
y <- 'Hello World!'
class(y)
```

```
## [1] "character"
```

```
z <- TRUE
class(z)
```

```
## [1] "logical"
```

Complex and Raw class

```r
a_complex_number <- 1+0i
class(a_complex_number)
```

```
## [1] "complex"
```

```r
xx <- charToRaw("I am not raw")
xx
```

```
##  [1] 49 20 61 6d 20 6e 6f 74 20 72 61 77
```

```r
class(xx)
```

```
## [1] "raw"
```

```r
rawToChar(xx)
```

```
## [1] "I am not raw"
```

Precision

- Computers are not perfectly perfect
- Uses IEEE 754 double precision floating-point numbers
- Generally accurate to about 16 significant digits
- The RUG hosted a talk on precision by Seth Simms (`http://rug.biotech.cdc.gov/slides/13_slides.pptx`)

```r
1e-324 == 0 ; 1e-323 == 0
```

```
## [1] TRUE

## [1] FALSE
```

```r
1 - 1e-16 == 1 ;1 - 1e-17 == 1
```

```
## [1] FALSE

## [1] TRUE
```

```r
a <- sqrt(2) ; a^2 == 2
```

```
## [1] FALSE
```

Significant Digits

- You can use the `signif()` function to set significant digits
- You can use `print()` with `digits =` to see more digits
- By default R will print a set number of digits (`getOption("digits")`)

Vectors

Numeric Vectors

- Data structures hold data.
- There are different classes of data structures.
- Simpliest data structure is a vector.
- All items in vector must have same atomic class.

```
X <- c(10.4, 5.6, 3.1, 6.4, 21.7)   # creates a numeric vector
1/X
```

```
## [1] 0.09615385 0.17857143 0.32258065 0.15625000 0.04608295
```

```
Y <- 1/X
X**2
```

```
## [1] 108.16  31.36   9.61  40.96 470.89
```

```
summary(Y)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 0.04608 0.09615 0.15625 0.15993 0.17857 0.32258
```

Regular and Random Sequences

- R can be used to create regular sequencies of numbers using `seq`.
- Random numbers at created using random number generating functions (e.g. `rnorm`).
- `set.seed` can be used to ensure reproducability.

```
#regular sequences
seq(from = -5, to = 5, by = 2)
```

```
## [1] -5 -3 -1  1  3  5
```

```
1:15
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
```

Numeric Summaries

```r
set.seed(123)
randomNums <- rnorm(1000)
summary(randomNums); mean(randomNums); sd(randomNums)
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
## -2.80978 -0.62832  0.00921  0.01613  0.66460  3.24104
```

```
## [1] 0.01612787
```

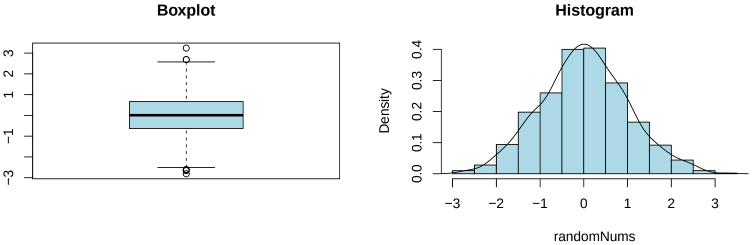
```
## [1] 0.991695
```

```r
fivenum(randomNums)
```

```
## [1] -2.809774679 -0.628742409  0.009209639  0.664787870
## [5]  3.241039935
```

Numeric Vectors Summary and Visualizations

```
oldpar <- par(mfrow = c(1,2))
boxplot(randomNums, main = "Boxplot", col="lightblue")
hist(randomNums, main = "Histogram", col="lightblue", freq=FALSE
lines(density(randomNums), main = "Density")
```




```
par(oldpar)
```

Character Vectors

Character vectors behave in a different manner than numeric vectors.

```
Stooges <- c("Moe", "Larry", "Curly")
lastNames <- c("Howard", "Fine", "Howard")
1/Stooges # Error
```

```
## Error in 1/Stooges: non-numeric argument to binary operator
```

```
ThreeStooges <- paste(Stooges, lastNames)
ThreeStooges # prints
```

```
## [1] "Moe Howard"   "Larry Fine"   "Curly Howard"
```

```
plot(ThreeStooges)
```

```
## Warning in xy.coords(x, y, xlabel, ylabel, log): NAs
## introduced by coercion
```

```
## Warning in min(x): no non-missing arguments to min;
## returning Inf
```

Logical Vectors

Logical vectors can be created as well, either directly by assignment or evaluating a vector.

```
logicVector1 <- c(TRUE, FALSE, FALSE, TRUE)
logicVector2 <- c(T,F,F,T) #T or F means TRUE or FALSE
(logicVector3 <- X < 10)
```

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

```
summary(logicVector3)
```

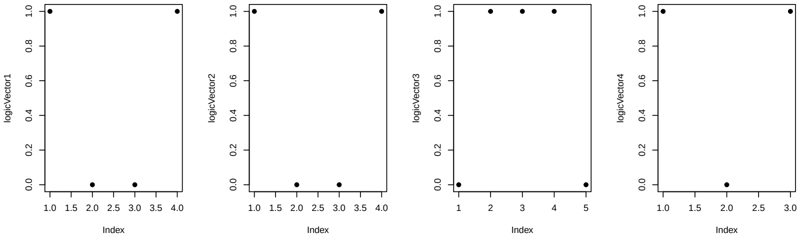
```
##    Mode   FALSE    TRUE
## logical       2       3
```

```
(logicVector4 <- lastNames == "Howard")
```

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

Plotting Logical Vectors

```
oldpar <- par(mfrow=c(1,4))
plot(logicVector1, pch = 19)
plot(logicVector2, pch = 19)
plot(logicVector3, pch = 19)
plot(logicVector4, pch = 19)
```




```
par(oldpar)
```

Subsetting Vectors

Logical vectors are often used to subset other vectors. TRUE values are retained, while FALSE are discarded. Numeric values can also be used to subset vectors.

```
V <- 1:10
V[V<5]
```

```
## [1] 1 2 3 4
```

```
lastNames[1]
```

```
## [1] "Howard"
```

```
lastNames[c(1,3)]
```

```
## [1] "Howard" "Howard"
```

```
logicVector1[logicVector1]
```

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

Factors

Factor variables are used to indicate discrete classification, or grouping.

```
factorStates <- as.factor(sample(sample(state.abb, 10), 100,
                                 replace = TRUE))
factorStates
```

```
##   [1] AL WI NV MD GA WY AZ WI MO DE GA MN GA WY WY WI MD NV
##  [19] MN AZ NV NV NV WI WY AZ MD GA GA AZ MN WY MN AZ GA GA
##  [37] AL WY DE MN NV DE GA WY GA WY MD AZ AZ MD WY AL MD AL
##  [55] WY DE MO WI AL GA WY GA MD MN MD AZ NV MO GA DE WY MD
##  [73] AZ WY MN MD MO GA MD MO WY MO DE DE MO AZ GA MN NV DE
##  [91] MD MO MN GA MD AZ WY WI AL AL
## Levels: AL AZ DE GA MD MN MO NV WI WY
```

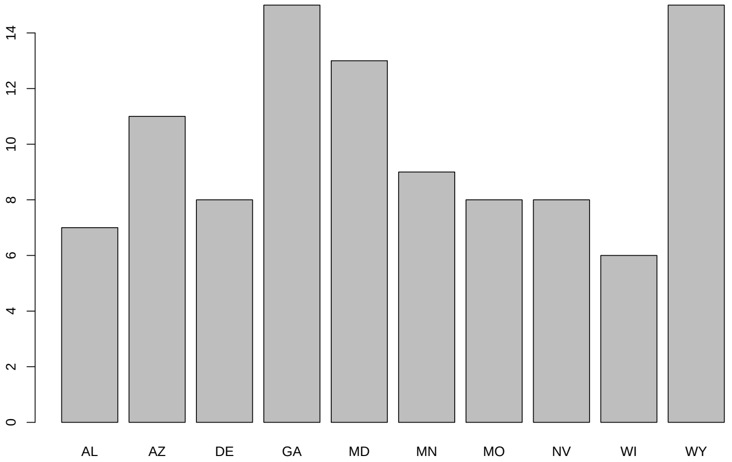
```
summary(factorStates)
```

```
## AL AZ DE GA MD MN MO NV WI WY
##  7 11  8 15 13  9  8  8  6 15
```

```
# table(factorStates)
```

Factors Plotting

```
plot(factorStates)
```



Coercion

- Numbers concatnated together will create a numeric vector
- Charcter strings will create a character vector
- Numeric data and character data concatnation will make a character
- conversion of one type of data into another will:
  - result in either NA (character to number - unless the string is a number)
  - result in a factor level number (if factor)

```r
as.numeric(factorStates)
```

```
##   [1]  1  9  8  5  4 10  2  9  7  3  4  6  4 10 10  9  5  8
##  [19]  6  2  8  8  8  9 10  2  5  4  4  2  6 10  6  2  4  4
##  [37]  1 10  3  6  8  3  4 10  4 10  5  2  2  5 10  1  5  1
##  [55] 10  3  7  9  1  4 10  4  5  6  5  2  8  7  4  3 10  5
##  [73]  2 10  6  5  7  4  5  7 10  7  3  3  7  2  4  6  8  3
##  [91]  5  7  6  4  5  2 10  9  1  1
```

```r
class(c("One", 2, 3, "four"))
```

```
## [1] "character"
```

```r
(dontdothis <-as.numeric(factor(c(10,20,30))))
```

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

```r
(lookout <- as.numeric(c("One", 2, 3, "four")))
```

```
## Warning: NAs introduced by coercion
```

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

Dates and Time

- Date class contains dates without time
- POSIXct is dates and times (including timezones). These are stored as a numeric value (seconds since 01/01/1970) and displayed as a string.
- POSIXlt is also dates and times (including timezones) but these are stored in a more complicated list format
- `as.Date()` creates a date from a string
- `strptime()` create POSIXlt

Creating a Date

```r
(adate <- as.Date("11/11/2011", format = "%m/%d/%Y"))
```

```
## [1] "2011-11-11"
```

```r
class(adate)
```

```
## [1] "Date"
```

```r
(bdate <- strptime("11-17-2014 13:30",
              format = "%m-%d-%Y %H:%M", tz = "US/Eastern"))
```

```
## [1] "2014-11-17 13:30:00 EST"
```

```r
class(bdate) ; bdate$wday; format(bdate, "%a")
```

```
## [1] "POSIXlt" "POSIXt"
```

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

```
## [1] "Mon"
```

Vector Manipulations

- You can index a vector and use the assignment to change its value:

```
ThreeStooges[2] <- "James Durant"
ThreeStooges
```

```
## [1] "Moe Howard"   "James Durant" "Curly Howard"
```

```
X[X<5] <- 0
X
```

```
## [1] 10.4  5.6  0.0  6.4 21.7
```

```
X[X<5] <- rnorm(100) #warning
```

```
## Warning in X[X < 5] <- rnorm(100): number of items to
## replace is not a multiple of replacement length
```

```
X[X>50] <- rnorm(100)
```

Missing Values

- Missing, not available or unknown values are coded with `NA`.
- `is.na(x)` gives logical vector of length `x` with value of `TRUE` for `NA` values in vector `x`.

```
x <- c(1:3,NA)
is.na(x)
```

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

```
x == NA
```

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

Setting vector elements to NA

If you have a missing code in your data (e.g. -999), then you will need to set that value to `NA`. To do that, you must pass `is.na` a logical vector.

```
mydata <- c( 1, 2.4, pi, 40, -999)
mean(mydata)
```

```
## [1] -190.4917
```

```
is.na(mydata) <- mydata == -999
mean(mydata)
```

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

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

```
## [1] 11.6354
```

R by default will assume you do *NOT* want to drop `NA` values.

Not a Number Values

- Results of math computations that are not nubmers are coded as `NaN`.
- `is.nan(x)` gives logical vector of length `x` with value of `TRUE` for `NaN` values.

```
x[5] <- 0/0
x[6] <- Inf - Inf
is.na(x)
```

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

```
is.nan(x)
```

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

Vector Calculations and Concatnation

- You can calculate values using numeric vectors:

```
X1 <- c(1,2,3,4,5)
X2 <-c(1,2,3)
X1 + X2
```

```
## Warning in X1 + X2: longer object length is not a multiple
## of shorter object length
```

```
## [1] 2 4 6 5 7
```

```
X2 <- c(X2, 4, 5)
X1 + X2
```

```
## [1]  2  4  6  8 10
```

Regular Expressions

XKCD

Figure 2: xkcd

What are Regular Expressions?

Represent language using:

- literals: are the words/text matched literally.
- matacharacters: "special meaning" characters. Together they find classes of words or patterns in strings.

Regular Expression Functions

`grep` , `grepl`, `sub` and `gsub`

- `grep` searches and returns matching string or index in vector
- `grepl` searches and returns a vector of TRUE/FALSE is matches occur
- `sub` substitutes first match for the second argument
- `gsub` substitutes all matches for the second argument
- `regexpr` and `gregexpr` seaches character vector and returns index and length of match

Regular Expressions - More Training

documentation is challenging - 2 good videos to watch

- https://www.youtube.com/watch?v=NvHjYOilOf8
- https://www.youtube.com/watch?v=q8SzNKib5-4

Regular Expression Examples

```r
grep("A", state.name)
```

```
## [1] 1 2 3 4
```

```r
grep("A", state.name, value=TRUE)
```

```
## [1] "Alabama"  "Alaska"   "Arizona"  "Arkansas"
```

```r
grep("A", state.name, ignore.case = TRUE)
```

```
##  [1]  1  2  3  4  5  6  8  9 10 11 12 14 15 16 18 19 20 21
## [19] 22 23 26 27 28 29 33 34 36 38 39 40 41 43 44 46 47 48
```

```r
grep("A", state.name, ignore.case = TRUE,
     invert = TRUE, value = TRUE )
```

```
##  [1] "Connecticut" "Illinois"    "Kentucky"    "Mississippi"
##  [5] "Missouri"    "New Jersey"  "New Mexico"  "New York"
##  [9] "Ohio"        "Oregon"      "Tennessee"   "Vermont"
## [13] "Wisconsin"   "Wyoming"
```

Regular Expression Examples

```r
grep("^A.+b", state.name, value = TRUE)
```

```
## [1] "Alabama"
```

```r
grep("9.*11", c("911", "9/11", "9/123116/1212"))
```

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

```r
grep("9.*11$", c("911", "9/11", "9/123116/1212"))
```

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

Application

Importing a data.frame

- Data.frame is just a set of vectors arranged in columns
- Line listing of cases of acute gastroenteritis (AGE) on cruise
- You can import using from Excel "Import Dataset" wizard in Rstudio

```
library(readxl)
 Age_sl <- read_excel(
   "../data/AGE_Surveillance_Log.xls",
   skip = 7)
names(Age_sl)[
  grepl(
    "^X__[0-9]|Y/N__[0-9]|#|^.F$|^Y/N$",names(Age_sl))
  ] <-
  c(
    "Age", "Sex", "Pax_or_Crew", "Cabin", "Meal_seat",
    "Crew_position", "Diarrhea_n", "Vomiting_n",
    "Fever", "Temp", "Cramps", "Headache", "Myalgia",
    "Spec_req", "Spec_rec", "AD_meds", "Reportable",
    "UI"
  )
```

Vectors in Data.Frames

- Vectors within `data.frame` objects can be addressed with a `$`.

```
summary(Age_sl$Age)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   21.00   54.00   65.00   58.77   70.25   83.00
```

```
table(Age_sl$Sex)
```

```
##
##  F  M
## 28 32
```

Application Activities

- Using R, create a new vector `Age_sl$adj.temp` that changes any aberent temperatures in cases to missing.
- Let's assume the aberant temperatures were recorded in centigrade, convert only those values in the `Age_sl$Temp` to Fahrenheit scale. $F = \frac{9}{5}C + 32$.
- Standardize the `Age_sl$Meal_seat` vector.
- Make a boxplot of ages of only male non-crew cases.
- Create `Age_sl$dt_ill` which captures the date-time of illness onset.