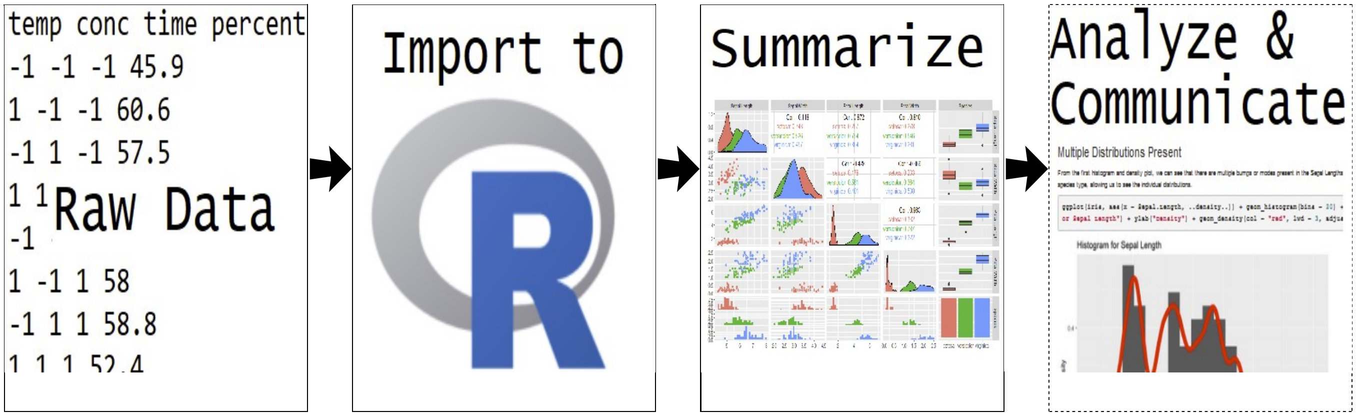
NC STATE UNIVERSITY

R Programming: Data Objects

Justin Post

What is this course about?



```
temp conc time percent
-1 -1 -1 45.9
1 -1 -1 60.6
-1 1 -1 57.5
1 1
-1
1 -1 1 58
-1 1 1 58.8
1 1 1 52.4
```

Raw Data

Import to

Summarize

Analyze & Communicate

Multiple Distributions Present

From the first histogram and density plot, we can see that there are multiple bumps or modes present in the Sepal Lengths species type, allowing us to see the individual distributions.

```
ggplot(iris, aes(x = Sepal.Length, ..density..)) + geom_histogram(bins = 20) +
or Sepal Length") + ylab("density") + geom_density(col = "red", lwd = 3, adjus
```

Histogram for Sepal Length

Lecture focus: How do we commonly store information in R?

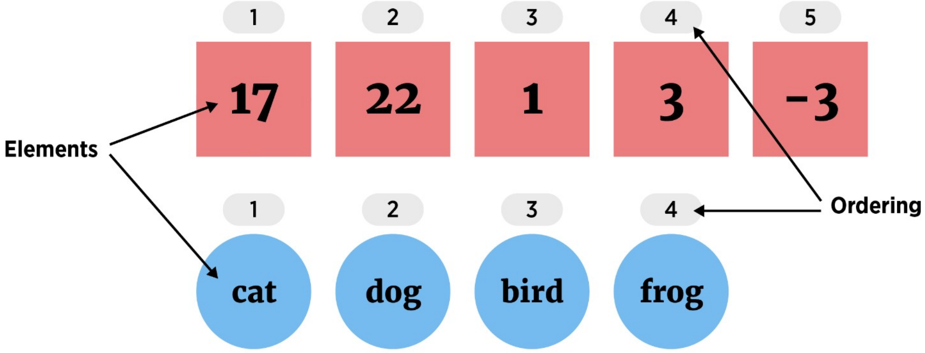
Data Objects

- Understand data structures first: Five major types

  1. Atomic Vector (1d)
  2. Matrix (2d)
  3. Array (nd) (not covered)
  4. Data Frame (2d)
  5. List (1d)

Vector

1. Atomic Vector (1D group of elements with an ordering)



- Elements must be same ‘type’
    - numeric (integer or double), character, or logical

Vector

1. Atomic Vector (1D group of elements with an ordering)

- Create with `c()` function (‘combine’)

```
#vectors (1 dimensional) objects
x <- c(17, 22, 1, 3, -3)
y <- c("cat", "dog", "bird", "frog")
x
```

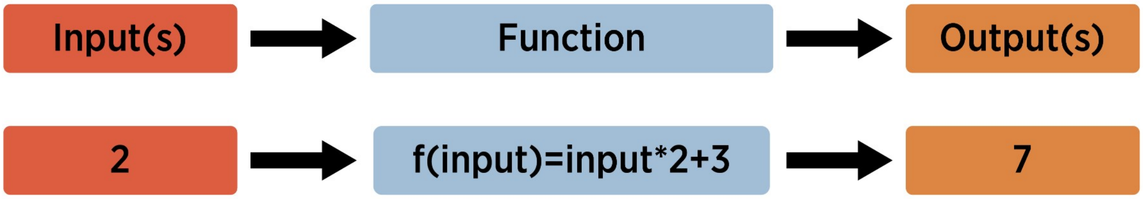
```
## [1] 17 22  1  3 -3
```

```
y
```

```
## [1] "cat"  "dog"  "bird" "frog"
```

Vector

- Many ‘functions’ output a numeric vector
- Function concept:

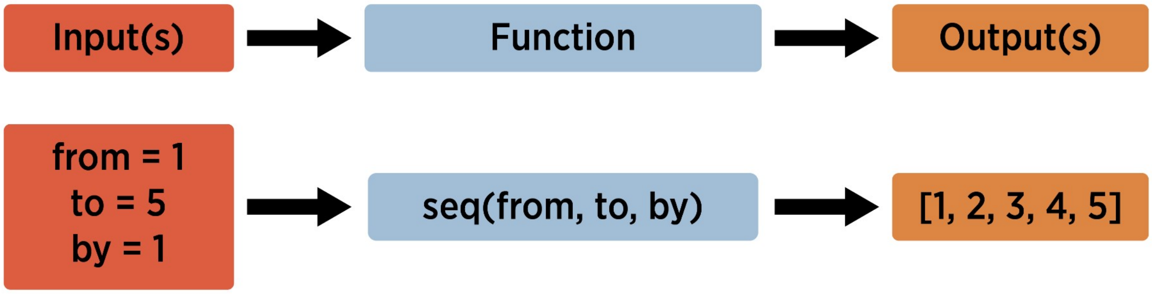


Input(s) → Function → Output(s)

2 → f(input)=input*2+3 → 7

Vector

- Many ‘functions’ output a numeric vector
- Ex: `seq()`
  - Inputs = from, to, by (among others)
  - Output = a sequence of numbers



Vector

```
seq(from = 1, to = 1, by = ((to - from)/(length.out - 1)),
length.out = NULL, along.with = NULL, ...)
```

```
v <- seq(from = 1, to = 5, by = 1)
v
```

```
## [1] 1 2 3 4 5
```

Vector

```
seq(from = 1, to = 1, by = ((to - from)/(length.out - 1)),
length.out = NULL, along.with = NULL, ...)
```

```
v <- seq(from = 1, to = 5, by = 1)
v
```

```
## [1] 1 2 3 4 5
```

```
str(v)
```

```
##  num [1:5] 1 2 3 4 5
```

- `num` says it is numeric
- `[1:5]` implies one dimensional with elements 1, 2, 3, 4, 5

Vector

Shorthand `seq()` with `:`

```
1:20
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
```

Vector

Shorthand `seq()` with `:`

- R generally does elementwise math

```
1:20/20
```

```
##  [1] 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75
## [16] 0.80 0.85 0.90 0.95 1.00
```

```
1:20 + 1
```

```
##  [1]  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21
```

Help Files

- Functions are ubiquitous in R!
- To find out about a function's arguments use `help()`
- Understanding the syntax in the help files is key!
- Ex: Can create randomly generated values in any interval:
    - `help(runif)`

Vector

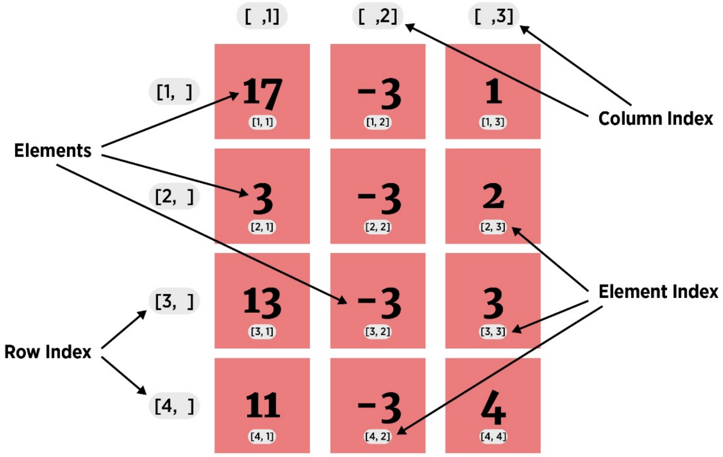
1. Atomic Vector (1D group of elements with an ordering)

- Vectors useful to know about
- Not usually useful for a dataset
- Often consider as ‘building blocks’ for other data types

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**



Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**

```
#populate vectors
x <- c(17, 3, 13, 11)
y <- rep(-3, times = 4)
z <- 1:4
```

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**

```
#populate vectors
x <- c(17, 3, 13, 11)
y <- rep(-3, times = 4)
z <- 1:4
```

```
#check 'type'
is.numeric(x)
```

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

```
is.numeric(y)
```

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

```
is.numeric(z)
```

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

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**

```
#populate vectors
x <- c(17, 3, 13, 11)
y <- rep(-3, times = 4)
z <- 1:4
```

```
#check 'type'
is.numeric(x)
```

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

```
is.numeric(y)
```

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

```
is.numeric(z)
```

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

```
#check 'length'
length(x)
```

```
## [1] 4
```

```
length(y)
```

```
## [1] 4
```

```
length(z)
```

```
## [1] 4
```

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**
- Create with `matrix()` function (see help)

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**
- Create with `matrix()` function (see help)

```
#populate vectors
x <- c(17, 3, 13, 11)
y <- rep(-3, times = 4)
z <- 1:4
#combine in a matrix
matrix(c(x, y, z), ncol = 3)
```

```
##      [,1] [,2] [,3]
## [1,]   17   -3    1
## [2,]    3   -3    2
## [3,]   13   -3    3
## [4,]   11   -3    4
```

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**
- Create with `matrix()` function

```
x <- c("Hi", "There", "Friend", "!")
y <- c("a", "b", "c", "d")
z <- c("One", "Two", "Three", "Four")
is.character(x)
```

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

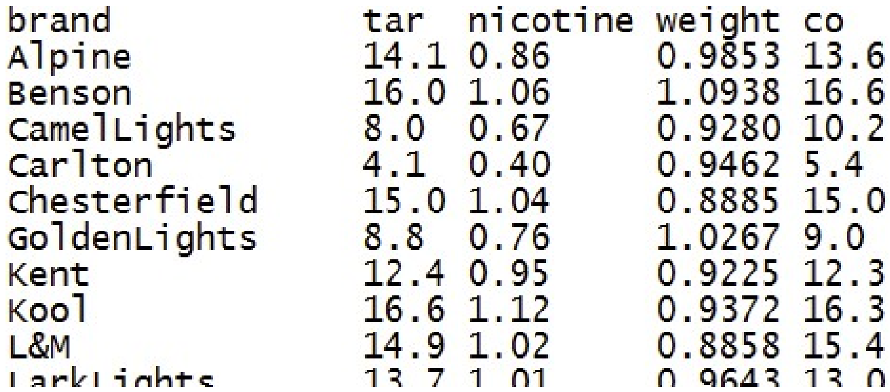
```
matrix(c(x, y, z), nrow = 6)
```

```
##      [,1]     [,2]
## [1,] "Hi"     "c"
## [2,] "There"  "d"
## [3,] "Friend" "One"
## [4,] "!"      "Two"
## [5,] "a"      "Three"
## [6,] "b"      "Four"
```

Matrix

2. Matrix (2D data structure)

- (think) columns are vectors of the same **type and length**
- Useful for some data but often some numeric and some character variables:

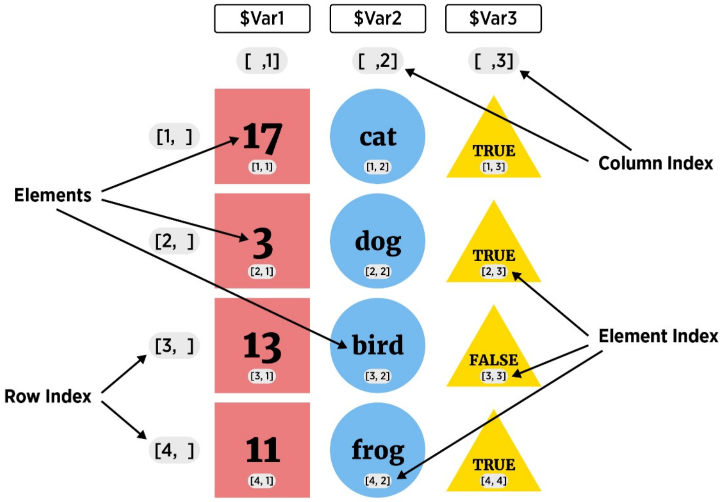


```
brand            tar  nicotine weight co
Alpine           14.1 0.86     0.9853 13.6
Benson           16.0 1.06     1.0938 16.6
CamelLights      8.0  0.67     0.9280 10.2
Carlton          4.1  0.40     0.9462 5.4
Chesterfield     15.0 1.04     0.8885 15.0
GoldenLights     8.8  0.76     1.0267 9.0
Kent             12.4 0.95     0.9225 12.3
Kool             16.6 1.12     0.9372 16.3
L&M              14.9 1.02     0.8858 15.4
LarkLights       13.7 1.01     0.9643 13.0
```

Data Frame

4. Data Frame (2D data structure)

- collection (list) of *vectors* of the same **length**



Data Frame

4. Data Frame (2D data structure)

- collection (list) of *vectors* of the same **length**
- Create with `data.frame()` function

```
x <- c("a", "b", "c", "d", "e", "f")
y <- c(1, 3, 4, -1, 5, 6)
z <- 10:15
data.frame(x, y, z)
```

```
##   x  y  z
## 1 a  1 10
## 2 b  3 11
## 3 c  4 12
## 4 d -1 13
## 5 e  5 14
## 6 f  6 15
```

Data Frame

4. Data Frame (2D data structure)

- collection (list) of *vectors* of the same **length**
- Create with `data.frame()` function

```
data.frame(char = x, data1 = y, data2 = z)
```

```
##   char data1 data2
## 1    a     1    10
## 2    b     3    11
## 3    c     4    12
## 4    d    -1    13
## 5    e     5    14
## 6    f     6    15
```

- char, data1, and data2 become the variable names for the data frame

Data Frame

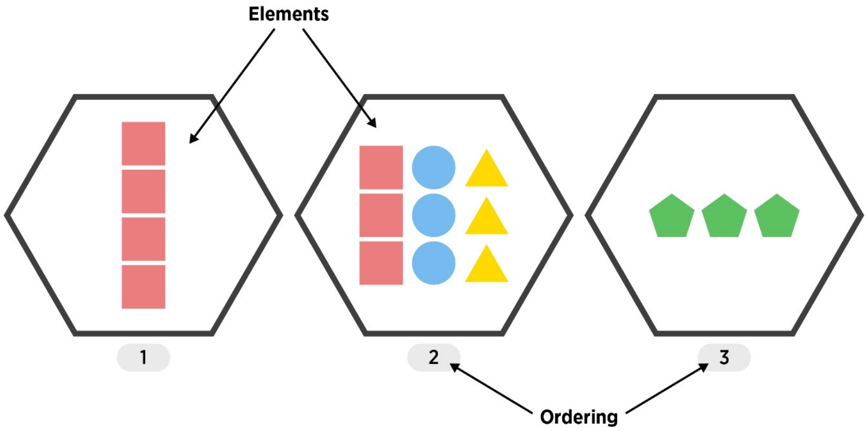
4. Data Frame (2D data structure)

- collection (list) of *vectors* of the same **length**
- Create with `data.frame()` function
- Perfect for most data sets!
- Most functions that read 2D data store it as a data frame

List

5. List (1D group of objects with ordering)

- a vector that can have differing elements



List

5. List (1D group of objects with ordering)

- a vector that can have differing elements
- Create with `list()`

```
list(1:3, rnorm(2), c("!", "?"))
```

```
## [[1]]
## [1] 1 2 3
##
## [[2]]
## [1] -2.081577 -1.484374
##
## [[3]]
## [1] "!" "?"
```

List

5. List (1D group of objects with ordering)

- Add names to the list elements

```
list(seq = 1:3, normVals = rnorm(2), punctuation = c("!", "?"))
```

```
## $seq
## [1] 1 2 3
##
## $normVals
## [1] -1.1941854  0.8269273
##
## $punctuation
## [1] "!" "?"
```

List

5. List (1D group of objects with ordering)

- a vector that can have differing elements
- Create with `list()`
- More flexible than a Data Frame!
- Useful for more complex types of data

Recap!

Dimension	Homogeneous	Heterogeneous
1d	Atomic Vector	List
2d	Matrix	Data Frame

- For most data analysis you'll use data frames!
- Next up: How do we access/change parts of our objects?

Basic Data Manipulation

- **How do we access different parts of our object?**

Basic Data Manipulation

- **How do we access different parts of our object?**
- For data may want
  - One element
  - Certain columns
  - Certain rows

Basic Data Manipulation

Atomic Vectors (1D)

- Return elements using square brackets `[]`

```
letters #built-in vector
```

```
##  [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s"
## [20] "t" "u" "v" "w" "x" "y" "z"
```

```
letters[1] #R starts counting at 1!
```

```
## [1] "a"
```

```
letters[26]
```

```
## [1] "z"
```

Basic Data Manipulation

Atomic Vectors (1D)

- Can ‘feed’ in a vector of indices to return

```
letters[1:4]
```

```
## [1] "a" "b" "c" "d"
```

```
letters[c(5, 10, 15, 20, 25)]
```

```
## [1] "e" "j" "o" "t" "y"
```

```
x <- c(1, 2, 5); letters[x]
```

```
## [1] "a" "b" "e"
```

Basic Data Manipulation

Atomic Vectors (1D)

- Return elements using square brackets `[]`
- Can ‘feed’ in a vector of indices to return
- Use negative indices to return without

```
letters[-(1:4)]
```

```
##  [1] "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s" "t" "u" "v" "w"
## [20] "x" "y" "z"
```

```
x <- c(1, 2, 5); letters[-x]
```

```
##  [1] "c" "d" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s" "t" "u" "v"
## [20] "w" "x" "y" "z"
```

Basic Data Manipulation

Matrices (2D)

- Use square brackets with a comma `[ , ]`
- Notice default row and column names!

```
mat <- matrix(c(1:4, 20:17), ncol = 2)
mat
```

```
##      [,1] [,2]
## [1,]    1   20
## [2,]    2   19
## [3,]    3   18
## [4,]    4   17
```

Basic Data Manipulation

Matrices (2D)

- Use square brackets with a comma `[ , ]`

```
mat
```

```
##      [,1] [,2]
## [1,]    1   20
## [2,]    2   19
## [3,]    3   18
## [4,]    4   17
```

```
mat[c(2, 4), ]
```

```
##      [,1] [,2]
## [1,]    2   19
## [2,]    4   17
```

```
mat[, 1]
```

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

```
mat[2, ]
```

```
## [1]  2 19
```

```
mat[2, 1]
```

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

Basic Data Manipulation

Matrices (2D)

- Can give columns names
- `help(matrix)` can show us how!

Basic Data Manipulation

Matrices (2D)

- Can use columns names to subset

```
mat <- matrix(c(1:4, 20:17), ncol = 2,
          dimnames = list(NULL,
                c("First", "Second"))
        )
mat
```

```
##      First Second
## [1,]     1     20
## [2,]     2     19
## [3,]     3     18
## [4,]     4     17
```

```
mat[, "First"]
```

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

Basic Data Manipulation

Matrices (2D)

- Use square brackets with a comma `[ , ]`
- Can use columns names to subset
- Negative still removes but won’t work with column name

```
mat[-c(1,3), -"First"]
```

```
## Error in -"First": invalid argument to unary operator
```

```
mat[-c(1,3), "First"]
```

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

Basic Data Manipulation

Data Frames (2D)

- Consider ‘built-in’ `iris` data frame

```
str(iris)
```

```
## 'data.frame':    150 obs. of  5 variables:
##  $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
##  $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
##  $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
##  $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
##  $ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1 1 1 1 1 ...
```

Basic Data Manipulation

Data Frames (2D)

- Data Frame is 2D similar to a matrix - access similarly!
- Use square brackets with a comma `[ , ]`

```
iris[1:4, 2:4]
```

```
##   Sepal.Width Petal.Length Petal.Width
## 1         3.5          1.4         0.2
## 2         3.0          1.4         0.2
## 3         3.2          1.3         0.2
## 4         3.1          1.5         0.2
```

Basic Data Manipulation

Data Frames (2D)

- Data Frame is 2D similar to a matrix - access similarly!
- Use square brackets with a comma `[ , ]`

```
iris[1, ]
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
```

Basic Data Manipulation

Data Frames (2D)

- Can use columns names to subset

```
iris[ , c("Sepal.Length", "Species")]
```

```
##     Sepal.Length    Species
## 1            5.1     setosa
## 2            4.9     setosa
## 3            4.7     setosa
## 4            4.6     setosa
## 5            5.0     setosa
## 6            5.4     setosa
## 7            4.6     setosa
## 8            5.0     setosa
## 9            4.4     setosa
## 10           4.9     setosa
## 11           5.4     setosa
## 12           4.8     setosa
## 13           4.8     setosa
## 14           4.3     setosa
## 15           5.8     setosa
## 16           5.7     setosa
## 17           5.4     setosa
## 18           5.1     setosa
## 19           5.7     setosa
## 20           5.1     setosa
## 21           5.4     setosa
## 22           5.1     setosa
## 23           4.6     setosa
## 24           5.1     setosa
## 25           4.8     setosa
## 26           5.0     setosa
## 27           5.0     setosa
## 28           5.2     setosa
## 29           5.2     setosa
## 30           4.7     setosa
## 31           4.8     setosa
## 32           5.4     setosa
## 33           5.2     setosa
## 34           5.5     setosa
## 35           4.9     setosa
## 36           5.0     setosa
## 37           5.5     setosa
## 38           4.9     setosa
```

Basic Data Manipulation

Data Frames (2D)

- Dollar sign allows easy access to a single column!

```
iris$Sepal.Length
```

```
##   [1] 5.1 4.9 4.7 4.6 5.0 5.4 4.6 5.0 4.4 4.9 5.4 4.8 4.8 4.3 5.8 5.7 5.4 5.1
##  [19] 5.7 5.1 5.4 5.1 4.6 5.1 4.8 5.0 5.0 5.2 5.2 4.7 4.8 5.4 5.2 5.5 4.9 5.0
##  [37] 5.5 4.9 4.4 5.1 5.0 4.5 4.4 5.0 5.1 4.8 5.1 4.6 5.3 5.0 7.0 6.4 6.9 5.5
##  [55] 6.5 5.7 6.3 4.9 6.6 5.2 5.0 5.9 6.0 6.1 5.6 6.7 5.6 5.8 6.2 5.6 5.9 6.1
##  [73] 6.3 6.1 6.4 6.6 6.8 6.7 6.0 5.7 5.5 5.5 5.8 6.0 5.4 6.0 6.7 6.3 5.6 5.5
##  [91] 5.5 6.1 5.8 5.0 5.6 5.7 5.7 6.2 5.1 5.7 6.3 5.8 7.1 6.3 6.5 7.6 4.9 7.3
## [109] 6.7 7.2 6.5 6.4 6.8 5.7 5.8 6.4 6.5 7.7 7.7 6.0 6.9 5.6 7.7 6.3 6.7 7.2
## [127] 6.2 6.1 6.4 7.2 7.4 7.9 6.4 6.3 6.1 7.7 6.3 6.4 6.0 6.9 6.7 6.9 5.8 6.8
## [145] 6.7 6.7 6.3 6.5 6.2 5.9
```

Basic Data Manipulation

Data Frames (2D)

- Dollar sign allows easy access to a single column!
- Most used method for accessing a single variable
- RStudio fills in options.
    - Type `iris$`
    - If no choices - hit tab
    - Hit tab again to choose

Basic Data Manipulation

Data Frames (2D)

- Data Frame is 2D similar to a matrix - access similarly!
- Use square brackets with a comma `[ , ]`
- Can use columns names to subset
- Dollar sign allows easy access to a single column!

Basic Data Manipulation

Lists (1D)

- Use single square brackets `[ ]` for multiple list elements

```
x <- list("HI", c(10:20), 1)
x
```

```
## [[1]]
## [1] "HI"
##
## [[2]]
##  [1] 10 11 12 13 14 15 16 17 18 19 20
##
## [[3]]
## [1] 1
```

Basic Data Manipulation

Lists (1D)

- Use single square brackets `[ ]` for multiple list elements

```
x <- list("HI", c(10:20), 1)
x[2:3]
```

```
## [[1]]
##  [1] 10 11 12 13 14 15 16 17 18 19 20
##
## [[2]]
## [1] 1
```

Basic Data Manipulation

Lists (1D)

- Use double square brackets `[[ ]]` (or `[ ]`) for single list element

```
x <- list("HI", c(10:20), 1)
x[1]
```

```
## [[1]]
## [1] "HI"
```

```
x[[1]]
```

```
## [1] "HI"
```

```
x[[2]]
```

```
##  [1] 10 11 12 13 14 15 16 17 18 19 20
```

```
x[[2]][4:5]
```

```
## [1] 13 14
```

Basic Data Manipulation

Lists (1D)

- If named list elements, can use $

```
x <- list("HI", c(10:20), 1)
str(x)
```

```
## List of 3
##  $ : chr "HI"
##  $ : int [1:11] 10 11 12 13 14 15 16 17 18 19 ...
##  $ : num 1
```

```
x <- list(First = "Hi", Second = c(10:20), Third = 1)
x$Second
```

```
##  [1] 10 11 12 13 14 15 16 17 18 19 20
```

Basic Data Manipulation

Lists & Data Frames

- Connection: Data Frame = *List* of equal length vectors

```
str(x)
```

```
## List of 3
##  $ First : chr "Hi"
##  $ Second: int [1:11] 10 11 12 13 14 15 16 17 18 19 ...
##  $ Third : num 1
```

```
str(iris)
```

```
## 'data.frame':    150 obs. of  5 variables:
##  $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
##  $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
##  $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
##  $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
##  $ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1 1 1 1 1 ...
```

Basic Data Manipulation

Lists & Data Frames

- Connection: Data Frame = *List* of equal length vectors

```
typeof(x)
```

```
## [1] "list"
```

```
typeof(iris)
```

```
## [1] "list"
```

Basic Data Manipulation

Lists & Data Frames

- Connection: Data Frame = *List* of equal length vectors

```
iris[[2]]
```

```
##   [1] 3.5 3.0 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 3.7 3.4 3.0 3.0 4.0 4.4 3.9 3.5
##  [19] 3.8 3.8 3.4 3.7 3.6 3.3 3.4 3.0 3.4 3.5 3.4 3.2 3.1 3.4 4.1 4.2 3.1 3.2
##  [37] 3.5 3.6 3.0 3.4 3.5 2.3 3.2 3.5 3.8 3.0 3.8 3.2 3.7 3.3 3.2 3.2 3.1 2.3
##  [55] 2.8 2.8 3.3 2.4 2.9 2.7 2.0 3.0 2.2 2.9 2.9 3.1 3.0 2.7 2.2 2.5 3.2 2.8
##  [73] 2.5 2.8 2.9 3.0 2.8 3.0 2.9 2.6 2.4 2.4 2.7 2.7 3.0 3.4 3.1 2.3 3.0 2.5
##  [91] 2.6 3.0 2.6 2.3 2.7 3.0 2.9 2.9 2.5 2.8 3.3 2.7 3.0 2.9 3.0 3.0 2.5 2.9
## [109] 2.5 3.6 3.2 2.7 3.0 2.5 2.8 3.2 3.0 3.8 2.6 2.2 3.2 2.8 2.8 2.7 3.3 3.2
## [127] 2.8 3.0 2.8 3.0 2.8 3.8 2.8 2.8 2.6 3.0 3.4 3.1 3.0 3.1 3.1 3.1 2.7 3.2
## [145] 3.3 3.0 2.5 3.0 3.4 3.0
```

Partial Matching

Lists & Data Frames

With `[[` or `$` partial matching can be used

```
iris$Sp
```

```
##   [1] setosa     setosa     setosa     setosa     setosa     setosa    
##   [7] setosa     setosa     setosa     setosa     setosa     setosa    
##  [13] setosa     setosa     setosa     setosa     setosa     setosa    
##  [19] setosa     setosa     setosa     setosa     setosa     setosa    
##  [25] setosa     setosa     setosa     setosa     setosa     setosa    
##  [31] setosa     setosa     setosa     setosa     setosa     setosa    
##  [37] setosa     setosa     setosa     setosa     setosa     setosa    
##  [43] setosa     setosa     setosa     setosa     setosa     setosa    
##  [49] setosa     setosa     versicolor versicolor versicolor versicolor
##  [55] versicolor versicolor versicolor versicolor versicolor versicolor
##  [61] versicolor versicolor versicolor versicolor versicolor versicolor
##  [67] versicolor versicolor versicolor versicolor versicolor versicolor
##  [73] versicolor versicolor versicolor versicolor versicolor versicolor
##  [79] versicolor versicolor versicolor versicolor versicolor versicolor
##  [85] versicolor versicolor versicolor versicolor versicolor versicolor
##  [91] versicolor versicolor versicolor versicolor versicolor versicolor
##  [97] versicolor versicolor versicolor versicolor virginica  virginica 
## [103] virginica  virginica  virginica  virginica  virginica  virginica 
## [109] virginica  virginica  virginica  virginica  virginica  virginica 
## [115] virginica  virginica  virginica  virginica  virginica  virginica 
## [121] virginica  virginica  virginica  virginica  virginica  virginica 
## [127] virginica  virginica  virginica  virginica  virginica  virginica 
## [133] virginica  virginica  virginica  virginica  virginica  virginica 
## [139] virginica  virginica  virginica  virginica  virginica  virginica 
## [145] virginica  virginica  virginica  virginica  virginica  virginica 
## Levels: setosa versicolor virginica
```

Partial Matching

Lists & Data Frames

With `[[` or `$` partial matching can be used

```
iris[["Petal.Len", exact = FALSE]]
```

```
##   [1] 1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 1.5 1.6 1.4 1.1 1.2 1.5 1.3 1.4
##  [19] 1.7 1.5 1.7 1.5 1.0 1.7 1.9 1.6 1.6 1.5 1.4 1.6 1.6 1.5 1.5 1.4 1.5 1.2
##  [37] 1.3 1.4 1.3 1.5 1.3 1.3 1.3 1.6 1.9 1.4 1.6 1.4 1.5 1.4 4.7 4.5 4.9 4.0
##  [55] 4.6 4.5 4.7 3.3 4.6 3.9 3.5 4.2 4.0 4.7 3.6 4.4 4.5 4.1 4.5 3.9 4.8 4.0
##  [73] 4.9 4.7 4.3 4.4 4.8 5.0 4.5 3.5 3.8 3.7 3.9 5.1 4.5 4.5 4.7 4.4 4.1 4.0
##  [91] 4.4 4.6 4.0 3.3 4.2 4.2 4.2 4.3 3.0 4.1 6.0 5.1 5.9 5.6 5.8 6.6 4.5 6.3
## [109] 5.8 6.1 5.1 5.3 5.5 5.0 5.1 5.3 5.5 6.7 6.9 5.0 5.7 4.9 6.7 4.9 5.7 6.0
## [127] 4.8 4.9 5.6 5.8 6.1 6.4 5.6 5.1 5.6 6.1 5.6 5.5 4.8 5.4 5.6 5.1 5.1 5.9
## [145] 5.7 5.2 5.0 5.2 5.4 5.1
```

Basic Data Manipulation

Lists (1D)

- Use single square brackets `[ ]` for multple list elements
- Use double square brackets `[[ ]]` (or `[ ]`) for single list element
- If named list elements, can use $

Recap!

Dimension	Homogeneous	Heterogeneous
1d	Atomic Vector	List
2d	Matrix	Data Frame

Basic access via

- Atomic vectors - `x[ ]`
- Matrices - `x[ , ]`
- Data Frames - `x[ , ]` or `x$name`
- Lists - `x[ ]`, `x[[ ]]`, or `x$name`

What is this course about?

Basic use of R for reading, manipulating, and plotting data!

- **read and write basic R programs**
- import well formatted data into R
- *do basic data manipulation in R*
- produce common numerical and graphical summaries in R
- describe a use case of an analysis done in R