

Introduction to R

“How do you turn this thing on?”

Samuel Robinson, Ph.D.

Sep. 4 2023

Motivation

- ▶ “Why do I need to learn R?”

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data
 - ▶ Writing presentations and papers

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data
 - ▶ Writing presentations and papers
 - ▶ *Keeping a record of what you've done*

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data
 - ▶ Writing presentations and papers
 - ▶ *Keeping a record of what you've done*
- ▶ “What is R bad at?”

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data
 - ▶ Writing presentations and papers
 - ▶ *Keeping a record of what you've done*
- ▶ “What is R bad at?”
 - ▶ No point-and-click interface; simple things can take more time

Motivation

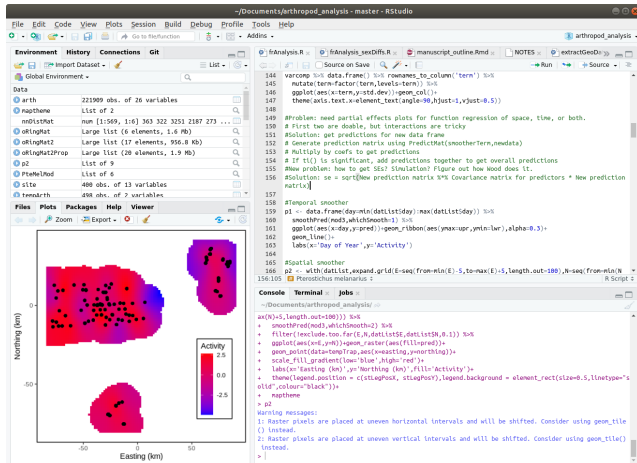
- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data
 - ▶ Writing presentations and papers
 - ▶ *Keeping a record of what you've done*
- ▶ “What is R bad at?”
 - ▶ No point-and-click interface; simple things can take more time
 - ▶ Can be slow if datasets are large

Motivation

- ▶ “Why do I need to learn R?”
 - ▶ Free, powerful, and very common
 - ▶ Interfaces with other languages (e.g. C++), and can help you learn other languages
- ▶ “What is R good at?”
 - ▶ Displaying data, running models, and processing data
 - ▶ Writing presentations and papers
 - ▶ *Keeping a record of what you've done*
- ▶ “What is R bad at?”
 - ▶ No point-and-click interface; simple things can take more time
 - ▶ Can be slow if datasets are large
- ▶ This is not a course in R programming (see [here](#), [here](#), [here](#) , but you do need some basic techniques

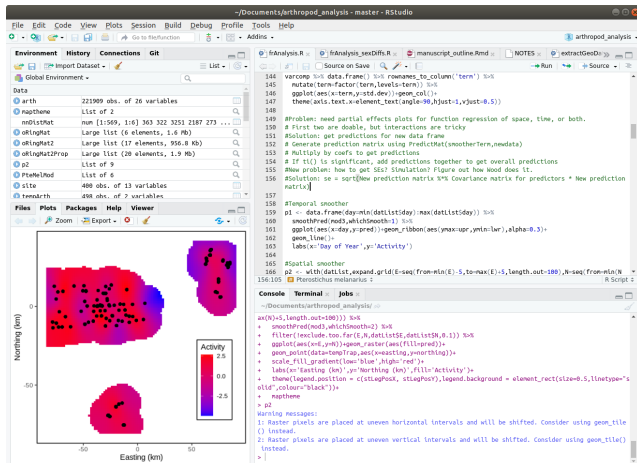
RStudio GUI

- The **Console** is the main input into R (where you tell it to do things)



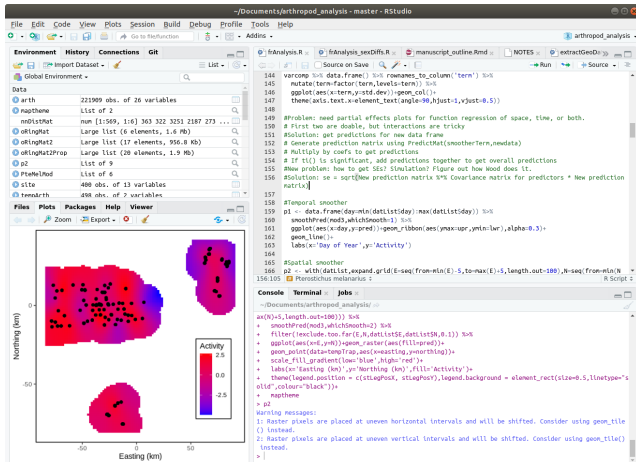
RStudio GUI

- ▶ The **Console** is the main input into R (where you tell it to do things)
- ▶ **Scripts** are lists of commands that get passed into the console



RStudio GUI

- ▶ The **Console** is the main input into R (where you tell it to do things)
- ▶ **Scripts** are lists of commands that get passed into the console
- ▶ If you're using RStudio, 2 of the 4 panes will be dedicated to the console and scripts



Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices
 - ▶ Dataframes & Lists

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices
 - ▶ Dataframes & Lists
- ▶ Some common **functions** (things done to objects):

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices
 - ▶ Dataframes & Lists
- ▶ Some common **functions** (things done to objects):
 - ▶ *mean, sd, median, quantile, c, paste*

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices
 - ▶ Dataframes & Lists
- ▶ Some common **functions** (things done to objects):
 - ▶ *mean, sd, median, quantile, c, paste*
 - ▶ *plot, summary*

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices
 - ▶ Dataframes & Lists
- ▶ Some common **functions** (things done to objects):
 - ▶ *mean, sd, median, quantile, c, paste*
 - ▶ *plot, summary*
 - ▶ these are polymorphic functions: they do different things to different types of objects

¹Two guys named Steve at a party: which one is which?

Objects and Functions

- ▶ Everything in R is either an **Object** or a **Function**. All must have a unique name, or else the *Steve Problem*¹ occurs.
- ▶ Some common **objects** (things stored in memory):
 - ▶ Characters, Logicals, & Numerics
 - ▶ Vectors & Matrices
 - ▶ Dataframes & Lists
- ▶ Some common **functions** (things done to objects):
 - ▶ *mean, sd, median, quantile, c, paste*
 - ▶ *plot, summary*
 - ▶ these are polymorphic functions: they do different things to different types of objects
 - ▶ Control flow - *if* and *for*

¹Two guys named Steve at a party: which one is which?

Objects

- ▶ Let's make some objects. These are all single objects:

```
myString <- "Hello world" #A string object  
myNumeric <- 12345 #A numeric object  
myLogical <- TRUE #A logical object
```

Objects

- ▶ Let's make some objects. These are all single objects:

```
myString <- "Hello world" #A string object  
myNumeric <- 12345 #A numeric object  
myLogical <- TRUE #A logical object
```

- ▶ These are objects joined into a *vector*, joined by the function `c` (concatenate):

```
myCharVec <- c("I like pie", "I like cake", "I like anything you bake")  
myNumVec <- c(1, 2, 3, 4, 5)  
myLogVec <- c(TRUE, TRUE, FALSE, TRUE, FALSE, FALSE)
```

Objects

- ▶ Let's make some objects. These are all single objects:

```
myString <- "Hello world" #A string object  
myNumeric <- 12345 #A numeric object  
myLogical <- TRUE #A logical object
```

- ▶ These are objects joined into a vector, joined by the function c (concatenate):

```
myCharVec <- c("I like pie", "I like cake", "I like anything you bake")  
myNumVec <- c(1, 2, 3, 4, 5)  
myLogVec <- c(TRUE, TRUE, FALSE, TRUE, FALSE, FALSE)
```

- ▶ How long are each of these vectors?

```
howLong <- c(length(myCharVec), length(myNumVec), length(myLogVec))  
howLong #This executes the `print` command on `howLong`
```

```
## [1] 3 5 6
```

Vectors - “getting”

```
myCharVec #Here's what's inside the whole thing
```

```
## [1] "I like pie"           "I like cake"
```

```
## [3] "I like anything you bake"
```

Vectors - “getting”

```
myCharVec #Here's what's inside the whole thing
```

```
## [1] "I like pie"           "I like cake"
```

```
## [3] "I like anything you bake"
```

► Single number:

```
myCharVec[1]
```

```
## [1] "I like pie"
```

Vectors - “getting”

```
myCharVec #Here's what's inside the whole thing
```

```
## [1] "I like pie"           "I like cake"  
## [3] "I like anything you bake"
```

► Single number:

```
myCharVec[1]
```

```
## [1] "I like pie"
```

► Vector of numbers

```
myCharVec[c(2,3)]
```

```
## [1] "I like cake"           "I like anything you bake"
```

Vectors - “getting”

```
myCharVec #Here's what's inside the whole thing
```

```
## [1] "I like pie"           "I like cake"  
## [3] "I like anything you bake"
```

► Single number:

```
myCharVec[1]
```

```
## [1] "I like pie"
```

► Vector of numbers

```
myCharVec[c(2,3)]
```

```
## [1] "I like cake"           "I like anything you bake"
```

► Logical vector

```
myCharVec[c(TRUE,FALSE,TRUE)]
```

```
## [1] "I like pie"           "I like anything you bake"
```


Vectors - “setting”

Vectors are set in the same way, using the assignment operator: `<-` OR `=`

Vectors - “setting”

Vectors are set in the same way, using the assignment operator: `<-` OR `=`

- ▶ String vector

```
myCharVec[c(2,3)] <- c('Cats', 'Dogs')
```

Vectors - “setting”

Vectors are set in the same way, using the assignment operator: `<-` OR `=`

- ▶ String vector

```
myCharVec[c(2,3)] <- c('Cats','Dogs')
```

- ▶ Logical vector

```
myCharVec[c(TRUE,FALSE,FALSE)] = 'Parakeets'
```

Vectors - “setting”

Vectors are set in the same way, using the assignment operator: `<-` OR `=`

- ▶ String vector

```
myCharVec[c(2,3)] <- c('Cats','Dogs')
```

- ▶ Logical vector

```
myCharVec[c(TRUE,FALSE,FALSE)] = 'Parakeets'
```

- ▶ Results:

```
myCharVec #Here's what's inside the whole thing
```

```
## [1] "Parakeets" "Cats"      "Dogs"
```

Class conversions

Vectors (or other data) can be converted between **classes**, usually using *as.something* statements:

Class conversions

Vectors (or other data) can be converted between **classes**, usually using *as.something* statements:

- Logical to numeric

```
as.numeric(myLogVec)
```

```
## [1] 1 1 0 1 0 0
```

Class conversions

Vectors (or other data) can be converted between **classes**, usually using *as.something* statements:

- ▶ Logical to numeric

```
as.numeric(myLogVec)
```

```
## [1] 1 1 0 1 0 0
```

- ▶ Numeric to character

```
as.character(myNumVec)
```

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

Class conversions

Vectors (or other data) can be converted between **classes**, usually using *as.something* statements:

- ▶ Logical to numeric

```
as.numeric(myLogVec)
```

```
## [1] 1 1 0 1 0 0
```

- ▶ Numeric to character

```
as.character(myNumVec)
```

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

- ▶ Characters to **factors**: these represent *categories* or experimental levels

```
as.factor(myCharVec) #Default order is alphabetical
```

```
## [1] Parakeets Cats      Dogs
```

```
## Levels: Cats Dogs Parakeets
```


Dataframes

- Dataframes look similar to matrices, but can hold different data types in each column:

```
myDF <- data.frame(stringCol=myCharVec, numCol=myNumVec[c(1:3)],  
  logCol=myLogVec[c(1:3)])  
myDF
```

```
##   stringCol numCol logCol  
## 1 Parakeets      1  TRUE  
## 2       Cats      2  TRUE  
## 3       Dogs      3 FALSE
```

Dataframes

- ▶ Dataframes look similar to matrices, but can hold different data types in each column:

```
myDF <- data.frame(stringCol=myCharVec, numCol=myNumVec[c(1:3)],
  logCol=myLogVec[c(1:3)])
myDF
```

```
##   stringCol numCol logCol
## 1 Parakeets     1    TRUE
## 2      Cats     2    TRUE
## 3     Dogs     3   FALSE
```

- ▶ `summary(myDF)` *#This function summarizes each column*

```
##   stringCol          numCol      logCol
## Length:3          Min.    :1.0    Mode :logical
## Class :character  1st Qu.:1.5    FALSE:1
## Mode  :character  Median  :2.0    TRUE  :2
##                  Mean     :2.0
##                  3rd Qu.:2.5
##                  Max.     :3.0
```

Accessing Dataframes

Dataframes can be accessed numerically, by their name slots (using the \$ operator), or with a mixture of the two:

Accessing Dataframes

Dataframes can be accessed numerically, by their name slots (using the \$ operator), or with a mixture of the two:

```
► myDF[1,2]
```

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

Accessing Dataframes

Dataframes can be accessed numerically, by their name slots (using the \$ operator), or with a mixture of the two:

```
▶ myDF[1,2]
```

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

```
▶ myDF$numCol #This gets all of the column "numCol"
```

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

Accessing Dataframes

Dataframes can be accessed numerically, by their name slots (using the \$ operator), or with a mixture of the two:

▶ `myDF[1,2]`

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

▶ `myDF$numCol` *#This gets all of the column "numCol"*

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

▶ `myDF[1,"numCol"]`

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

Accessing Dataframes

Dataframes can be accessed numerically, by their name slots (using the \$ operator), or with a mixture of the two:

```
▶ myDF[1,2]
```

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

```
▶ myDF$numCol #This gets all of the column "numCol"
```

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

```
▶ myDF[1,"numCol"]
```

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

```
▶ myDF$numCol[1]
```

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

Manipulating dataframe

Like other objects, you can alter dataframes

- ▶ You can add columns

```
myDF$numCol2 <- myDF$numCol*3 #Multiplies numCol by 3
```


Manipulating dataframe

Like other objects, you can alter dataframes

- ▶ You can add columns

```
myDF$numCol2 <- myDF$numCol*3 #Multiplies numCol by 3
```

- ▶ You can also alter columns in place, or elements within columns

```
myDF$numCol <- (myDF$numCol)^2 #Square of numCol  
myDF$numCol[3] <- myDF$numCol[3] - myDF$numCol[2] #Subtracts 2nd from 3rd
```

Manipulating dataframe

Like other objects, you can alter dataframes

- ▶ You can add columns

```
myDF$numCol2 <- myDF$numCol*3 #Multiplies numCol by 3
```

- ▶ You can also alter columns in place, or elements within columns

```
myDF$numCol <- (myDF$numCol)^2 #Square of numCol  
myDF$numCol[3] <- myDF$numCol[3] - myDF$numCol[2] #Subtracts 2nd from 3rd
```

- ▶ You can delete columns by subsetting the dataframe, or assigning the column to NULL

```
myDF <- myDF[,c(1,2)] #Selects only column 1 and 2  
myDF$numCol <- NULL #Removes numCol
```

Manipulating dataframe

Like other objects, you can alter dataframes

- ▶ You can add columns

```
myDF$numCol2 <- myDF$numCol*3 #Multiplies numCol by 3
```

- ▶ You can also alter columns in place, or elements within columns

```
myDF$numCol <- (myDF$numCol)^2 #Square of numCol  
myDF$numCol[3] <- myDF$numCol[3] - myDF$numCol[2] #Subtracts 2nd from 3rd
```

- ▶ You can delete columns by subsetting the dataframe, or assigning the column to NULL

```
myDF <- myDF[,c(1,2)] #Selects only column 1 and 2  
myDF$numCol <- NULL #Removes numCol
```

- ▶ We'll learn easier ways of doing this next week using the tidyverse

Reading csv files

- One common practice is to read in your own dataframe from a csv file ²

```
testDat <- read.csv('test_results.csv') #Path to csv file  
head(testDat) #head shows only the first 6 rows of dataframe
```

##	Concentration	Treatment	Lab.Member	Time.of.Day
## 1	2.9	Control	Will	Morning
## 2	3.2	Control	Will	Morning
## 3	3.6	Control	Will	Morning
## 4	5.6	A	Will	Morning
## 5	6.8	A	Will	Morning
## 6	7.0	A	Will	Morning

²Excel files can be read in, but can cause problems

Reading csv files

- ▶ One common practice is to read in your own dataframe from a csv file ²

```
testDat <- read.csv('test_results.csv') #Path to csv file  
head(testDat) #head shows only the first 6 rows of dataframe
```

##	Concentration	Treatment	Lab.Member	Time.of.Day
## 1	2.9	Control	Will	Morning
## 2	3.2	Control	Will	Morning
## 3	3.6	Control	Will	Morning
## 4	5.6	A	Will	Morning
## 5	6.8	A	Will	Morning
## 6	7.0	A	Will	Morning

- ▶ R can't handle spaces or other special characters in the column headers (replaces them with periods). It also tries to guess the proper data type for each column

²Excel files can be read in, but can cause problems

Reading csv files

- ▶ One common practice is to read in your own dataframe from a csv file ²

```
testDat <- read.csv('test_results.csv') #Path to csv file  
head(testDat) #head shows only the first 6 rows of dataframe
```

##	Concentration	Treatment	Lab.Member	Time.of.Day
## 1	2.9	Control	Will	Morning
## 2	3.2	Control	Will	Morning
## 3	3.6	Control	Will	Morning
## 4	5.6	A	Will	Morning
## 5	6.8	A	Will	Morning
## 6	7.0	A	Will	Morning

- ▶ R can't handle spaces or other special characters in the column headers (replaces them with periods). It also tries to guess the proper data type for each column
- ▶ Make sure that the csv file is in your *working directory*

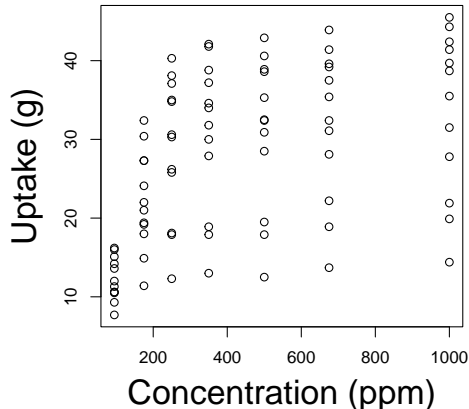
²Excel files can be read in, but can cause problems

Plotting

- The *plot* command is useful for quickly looking at sets of data. The following CO2 dataset is built-in to R.³

```
#Makes a plot of the uptake (y) and  
# concentration (x) columns of CO2  
# dataframe, and customizes axis labels  
plot(x = CO2$conc, y = CO2$uptake,  
      xlab = 'Concentration (ppm)',  
      ylab = 'Uptake (g)',  
      main = 'Plot of CO2 Concentrations',  
      cex.lab = 2, cex.main=2)
```

Plot of CO2 Concentrations



³To see others, type `data()` in the console

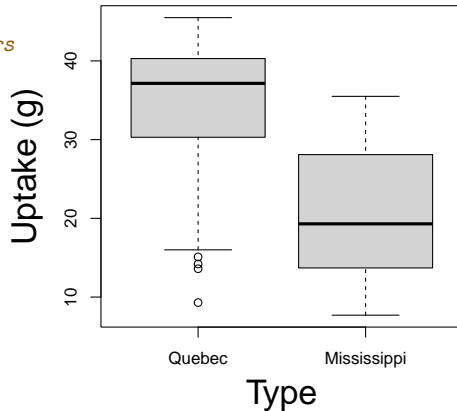
More Plotting

- The boxplot command can summarize *continuous* and *categorical* data

#Boxplot uses a formula rather than x,y vectors

#Formula: uptake depends on (~) Type

```
boxplot(CO2$uptake ~ CO2$Type,  
        xlab='Type',  
        ylab='Uptake (g)',  
        cex.lab = 2, cex.main=2)
```



First challenge

Your supervisor has just given you a dataset (*test_results.csv*) recorded by two undergrads. However, these undergrads were in a hurry and have made some mistakes:

- ▶ Make a **script** in R, and use this to record what you do
- ▶ Read the *csv* file and fix any mistakes. Bonus if you do this without using Excel!
- ▶ Plot the concentration data by treatment group, then plot it for each undergrad. Does there look like much of a difference?
- ▶ Some useful commands: **read.csv**, **boxplot**, **is.na**, **as.factor**, **summary**

Functions

- Functions take objects as **arguments** (input) and return other **objects** (output)

```
myNumVec <- c(1,2,3,4,5)
meanVec <- mean(myNumVec) #Arithmetic mean (average)
sdVec <- sd(myNumVec) #Standard deviation (sqrt(variance))
meanSdVec <- c(meanVec,sdVec) #Joins mean and SD into a vector
meanSdVec
```

```
## [1] 3.000000 1.581139
```

Functions

- Functions take objects as **arguments** (input) and return other **objects** (output)

```
myNumVec <- c(1,2,3,4,5)
meanVec <- mean(myNumVec) #Arithmetic mean (average)
sdVec <- sd(myNumVec) #Standard deviation (sqrt(variance))
meanSdVec <- c(meanVec,sdVec) #Joins mean and SD into a vector
meanSdVec
```

```
## [1] 3.000000 1.581139
```

- If you can't remember how a command works, use ? in the console to access the help files (e.g. ?median)

Homemade Functions

- You can make your own functions! This is useful if you have to do the same thing to many different input objects.

```
myFun <- function(input){ #Takes a vector of numbers  
  A <- mean(input) #Take the mean of INPUT  
  B <- sd(input) #Take the SD of INPUT  
  C <- c(A,B) #Join A and B into a vector C  
  return(C) #Return (output) C, then end the function  
}  
myFun(myNumVec) #Same as previous slide
```

```
## [1] 3.000000 1.581139
```

Homemade Functions

- ▶ You can make your own functions! This is useful if you have to do the same thing to many different input objects.

```
myFun <- function(input){ #Takes a vector of numbers  
  A <- mean(input) #Take the mean of INPUT  
  B <- sd(input) #Take the SD of INPUT  
  C <- c(A,B) #Join A and B into a vector C  
  return(C) #Return (output) C, then end the function  
}  
myFun(myNumVec) #Same as previous slide
```

```
## [1] 3.000000 1.581139
```

- ▶ The objects inside of functions (A, B, C in the one above) disappear after the function runs. However, *functions can see objects in the outer environment*, so beware of the Steve Problem*

Summary statistics

Often we want to get the mean of one columns, but split it up by other things in the dataframe.

Summary statistics

Often we want to get the mean of one columns, but split it up by other things in the dataframe.

- Using the CO2 plant example, how does *uptake* differ between *Type*?

```
#Split up uptake by Type and Treatment, then take the mean  
tapply(CO2$uptake, list(CO2$Type, CO2$Treatment), mean)
```

```
##                nonchilled  chilled  
## Quebec           35.33333  31.75238  
## Mississippi      25.95238  15.81429
```

Summary statistics

Often we want to get the mean of one columns, but split it up by other things in the dataframe.

- ▶ Using the CO2 plant example, how does *uptake* differ between *Type*?

```
#Split up uptake by Type and Treatment, then take the mean  
tapply(CO2$uptake, list(CO2$Type, CO2$Treatment), mean)
```

```
##                nonchilled  chilled  
## Quebec             35.33333 31.75238  
## Mississippi        25.95238 15.81429
```

- ▶ Typing “CO2” over and over again is annoying. You can use *with* to avoid repeating the name of the dataframe (avoid using *attach*)

```
#Runs command inside the name space of the CO2 object  
with(CO2,tapply(uptake, list(Type, Treatment), sd))
```


if statements

- R can be told to do things only *if* certain conditions apply. This is useful inside of functions for error handling:

```
myFun2 <- function(x){  
  xClass <- class(x) #What class is x? (Numeric, character, boolean)  
  
  if(xClass=='character'){ == means "are these things equal"?  
    return('This is a string') #If x is a character, returns a message  
  } else {  
    return(mean(x)) #If x isn't a character, returns the mean of x  
  }  
}
```

myFun2(myCharVec)

```
## [1] "This is a string"
```

```
myFun2(myNumVec)
```

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

for loops

- R can be told to do things repeatedly, using an *index* inside a loop:

```
classVec <- rep(0,10) #Storage vector of zeros, 10 long
classVec[c(1,2)] <- 1 #Set first two slots to 1

#Each time the loop repeats, i will take on values 3 to 10
for(i in 3:length(classVec)){
  #ith slot of classVec becomes the sum of the previous two slots
  classVec[i] <- classVec[i-1] + classVec[i-2]
}
```

for loops

- R can be told to do things repeatedly, using an *index* inside a loop:

```
classVec <- rep(0,10) #Storage vector of zeros, 10 long
classVec[c(1,2)] <- 1 #Set first two slots to 1

#Each time the loop repeats, i will take on values 3 to 10
for(i in 3:length(classVec)){
  #ith slot of classVec becomes the sum of the previous two slots
  classVec[i] <- classVec[i-1] + classVec[i-2]
}
```

- classVec *#First 10 numbers in the Fibonacci sequence*

```
## [1] 1 1 2 3 5 8 13 21 34 55
```

Second challenge

Population growth models are common in ecology, and usually often take the form $n_t = n_{t-1} + rn_{t-1}$, where n is the number of critters at some time point t , and r is the change in n from one point to the next ($r = 0$: no change).

- Write a function (with a for loop inside) that performs a simple population simulation using the following models:

Hint: functions need input variables that tell them what to do. The input variables here could be things like *starting population* (n_0), *growth rate* (r), and *number of time steps* (T) to simulate

Second challenge

Population growth models are common in ecology, and usually often take the form $n_t = n_{t-1} + rn_{t-1}$, where n is the number of critters at some time point t , and r is the change in n from one point to the next ($r = 0$: no change).

- ▶ Write a function (with a for loop inside) that performs a simple population simulation using the following models:
 - ▶ Exponential growth: $n_t = n_{t-1}(1 + r)$

Hint: functions need input variables that tell them what to do. The input variables here could be things like *starting population* (n_0), *growth rate* (r), and *number of time steps* (T) to simulate

Second challenge

Population growth models are common in ecology, and usually often take the form $n_t = n_{t-1} + rn_{t-1}$, where n is the number of critters at some time point t , and r is the change in n from one point to the next ($r = 0$: no change).

- ▶ Write a function (with a for loop inside) that performs a simple population simulation using the following models:
 - ▶ Exponential growth: $n_t = n_{t-1}(1 + r)$
 - ▶ Logistic growth: $n_t = n_{t-1}(1 + r(1 - \frac{n_{t-1}}{k}))$

Hint: functions need input variables that tell them what to do. The input variables here could be things like *starting population* (n_0), *growth rate* (r), and *number of time steps* (T) to simulate

Second challenge

Population growth models are common in ecology, and usually often take the form $n_t = n_{t-1} + rn_{t-1}$, where n is the number of critters at some time point t , and r is the change in n from one point to the next ($r = 0$: no change).

- ▶ Write a function (with a for loop inside) that performs a simple population simulation using the following models:
 - ▶ Exponential growth: $n_t = n_{t-1}(1 + r)$
 - ▶ Logistic growth: $n_t = n_{t-1}(1 + r(1 - \frac{n_{t-1}}{k}))$
- ▶ Make a simple plot of your results

Hint: functions need input variables that tell them what to do. The input variables here could be things like *starting population* (n_0), *growth rate* (r), and *number of time steps* (T) to simulate

Lists

- ▶ Lists look similar to vectors, but can hold anything in each slot, including other lists.
- ▶ LOTS of things in R (e.g. model output) are specially-structured lists at their core

```
myList <- list(charSlot=myCharVec,  
               numSlot=myNumVec,  
               logSlot=myLogVec,  
               dfSlot = myDF)
```

```
## $charSlot  
## [1] "Parakeets" "Cats"      "Dogs"  
##  
## $numSlot  
## [1] 1 2 3 4 5  
##  
## $logSlot  
## [1] TRUE TRUE FALSE TRUE FALSE FALSE  
##  
## $dfSlot  
##   stringCol numCol logCol  
## 1 Parakeets      1  TRUE  
## 2      Cats      2  TRUE  
## 3      Dogs      3 FALSE
```


Accessing Lists

Lists can be accessed numerically or logically, or by their name slots:

```
myList[[2]] #Needs 2 square brackets to isolate object
```

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

```
myList[['numSlot']]
```

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

```
myList$numSlot
```

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

```
myList[[4]][,3] #Same as myList$dfSlot$logCol
```

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

lapply and *sapply*

Loops can be slow: using a **functional** is generally better (if each step doesn't depend on the previous one)

lapply and sapply

Loops can be slow: using a **functional** is generally better (if each step doesn't depend on the previous one)

```
input <- c(1,2,3) #Input vector
pFun <- function(N,type='normal'){
  if(type=='poisson') rpois(N,3) else rnorm(N,3)
}
lapply(input,pFun,type='poisson') #Generates a list of N Poisson random numbers
```

```
## [[1]]
## [1] 4
##
## [[2]]
## [1] 3 2
##
## [[3]]
## [1] 4 0 3
```

lapply and *sapply*

Loops can be slow: using a **functional** is generally better (if each step doesn't depend on the previous one)

```
input <- c(1,2,3) #Input vector
pFun <- function(N,type='normal'){
  if(type=='poisson') rpois(N,3) else rnorm(N,3)
}
lapply(input,pFun,type='poisson') #Generates a list of N Poisson random numbers
```

```
## [[1]]
## [1] 4
##
## [[2]]
## [1] 3 2
##
## [[3]]
## [1] 4 0 3
```

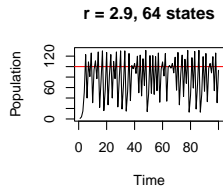
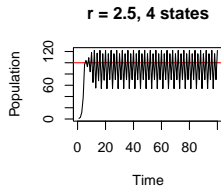
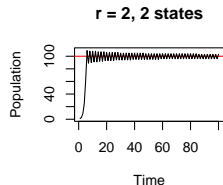
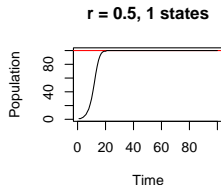
Different output formats: *lapply* uses a list, *sapply* uses a vector (or matrix)

Third challenge

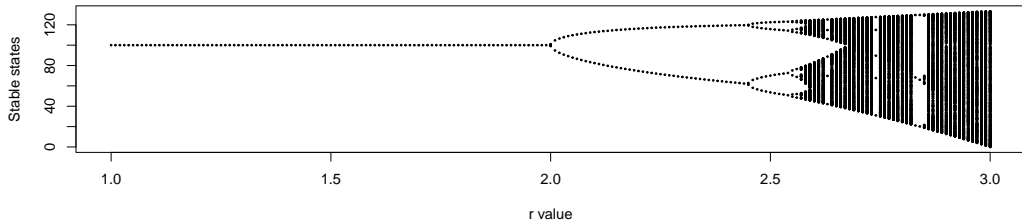
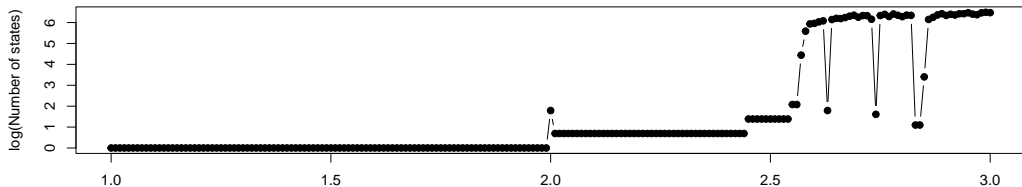
The discrete logistic growth equation has some interesting mathematical properties (see [here](#) and [here](#)). At certain values of r the population converges to the carrying capacity K , while at other values it cycles between multiple values.

Using *lapply*, *sapply* and the logistic function you wrote for the second challenge:

- ▶ Write a script that iterates across a range of r values: $1 \leq r \leq 3$
- ▶ At each r value, how many unique values exist?
- ▶ Keep K at 100 and n_0 at 1 for now. Use a simulation time of $t = 1000$, but discard the first 100 points



Complex behaviour from a simple system



To do this week:

Get a dataset to work with! This can be:

1. Your own dataset that you want to analyze

Try loading this data into R and play around with it: make some simple plots, or get some summary statistics. Bring it next week and we'll continue using it.

To do this week:

Get a dataset to work with! This can be:

1. Your own dataset that you want to analyze
2. Another dataset that you think might look like your future one

Try loading this data into R and play around with it: make some simple plots, or get some summary statistics. Bring it next week and we'll continue using it.

To do this week:

Get a dataset to work with! This can be:

1. Your own dataset that you want to analyze
2. Another dataset that you think might look like your future one
 - ▶ Can be from another student (ask your supervisor if they have any “leftovers” from previous students)

Try loading this data into R and play around with it: make some simple plots, or get some summary statistics. Bring it next week and we'll continue using it.

To do this week:

Get a dataset to work with! This can be:

1. Your own dataset that you want to analyze
2. Another dataset that you think might look like your future one
 - ▶ Can be from another student (ask your supervisor if they have any “leftovers” from previous students)
 - ▶ Take a look at a data repository like Dryad

Try loading this data into R and play around with it: make some simple plots, or get some summary statistics. Bring it next week and we'll continue using it.