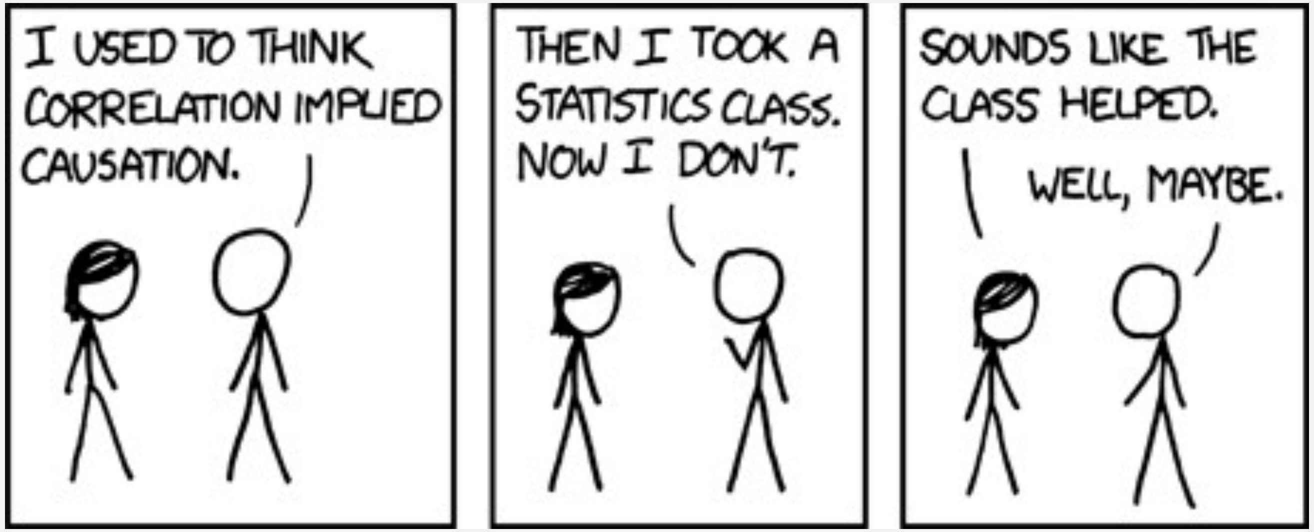
Experimental Design

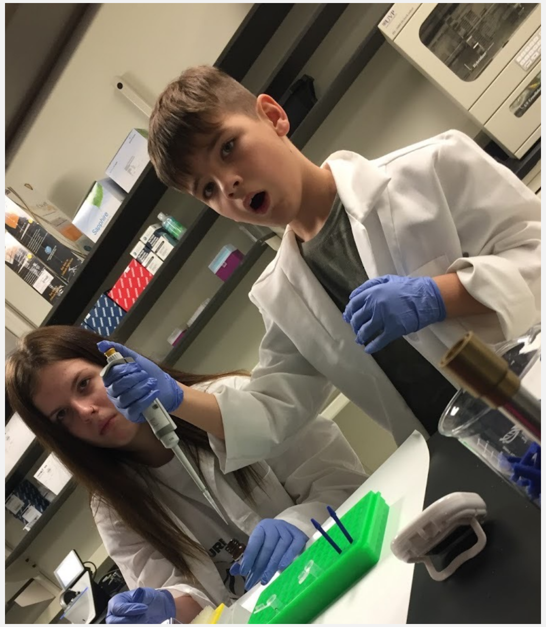
Biology 683

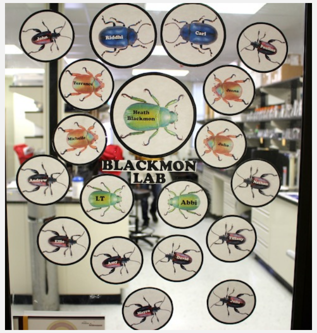
Lecture 1

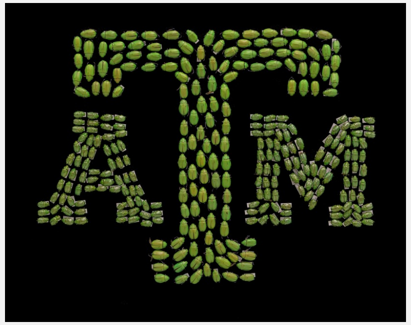
Heath Blackmon


I USED TO THINK CORRELATION IMPLIED CAUSATION.
THEN I TOOK A STATISTICS CLASS. NOW I DON'T.
SOUNDS LIKE THE CLASS HELPED.
WELL, MAYBE.

Me







I study the **evolution of traits**. Especially genomic traits. I use a variety of methods next-gen sequencing, experimental evolution, phylogenetic comparative methods, and theoretical approaches. I don’t work with a single taxa; we have projects involving fish, mammals, reptiles, amphibians, and insects all ongoing in my lab.

Today

- Syllabus / website / calendar
- Big problems in stats (outside world / within academia)
- Why you need this class
- Prep for future classes

My Objectives

- *Help you build an intuitive understanding of statistics*
- *Help you develop the confidence to think about the characteristics of the data that you will be collecting in your research and how you might analyze it.*
- *Get you comfortable with the idea of coding in R*
- *Help you develop the skills to handle datasets in R*
- *Help you develop the skills to build informative, honest, and intuitive data visualizations in R*

The public impression of statistics

- *You can make statistics say anything*

- *Statistics are no substitute for common sense*

  "I got sick after I got a flu shot so I don't get them anymore"

My opinions

Misuse of statistics is unethical as a scientist

My opinions

Misuse **or ignorance** of statistics is unethical as a scientist

Poor training and maleficence are both responsible for failures

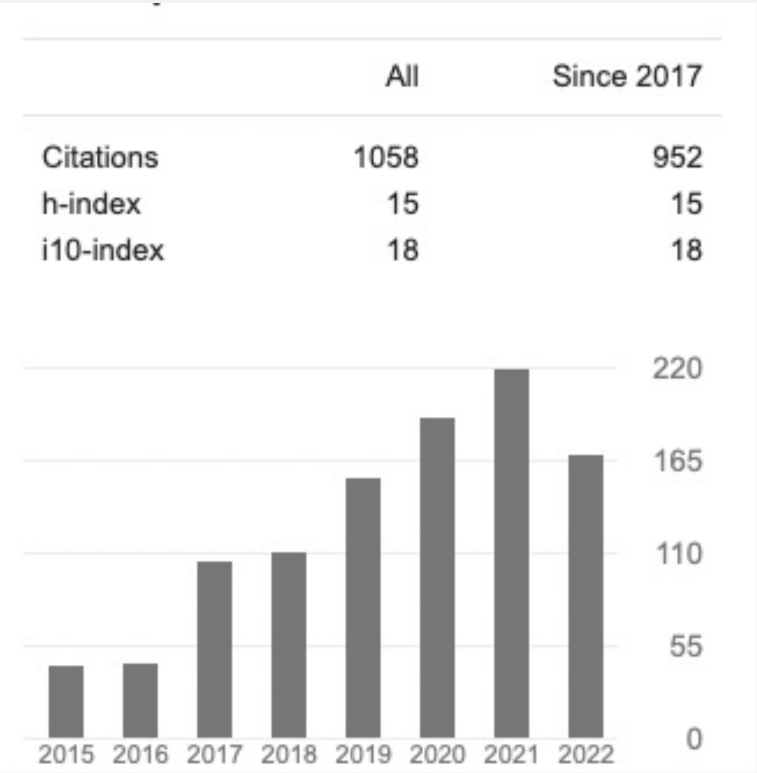
Statistical literacy in the general public is essential and lacking

Do your part: learn science of important topics and help friends and family understand them! **This includes the statistical analysis and how we should let them inform our belief!**

Reproducibility crisis

- Started in the social sciences but some problems are widespread

- pressure to publish
- file drawer problem
- small sample sizes
- p-hacking
- unethical researchers



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Amy Cuddy
TED Talk 60 Million views
(2nd most populat TED Talk)

Can we trust the science we read?

You have a question: are fish in lake A or B on average bigger.

Collect N fish from both lakes using identical sampling methods.

Use a statistical test to ask if they differ in size then report your result.

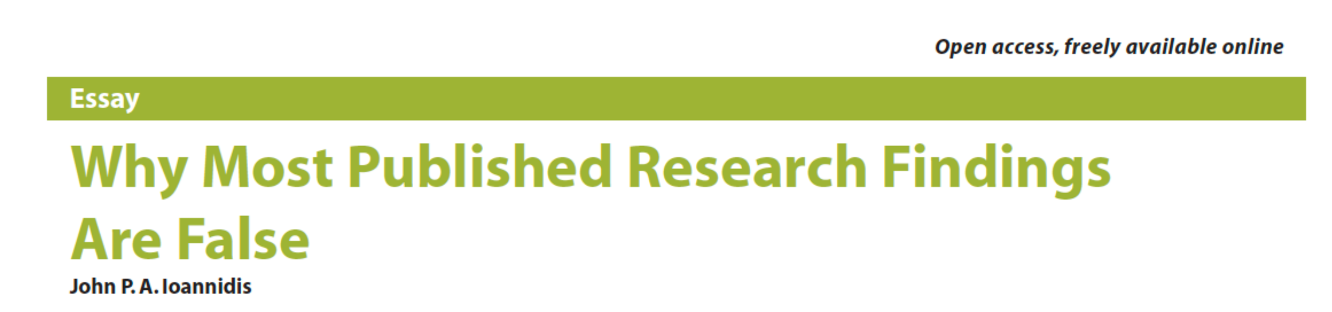
Now lets assume that the fish are on average the same how often will you report the wrong thing?

Can we trust the science we read?

You collect fish in lake A and B and it seems like lake B has bigger fish.

You start recording sizes of the fish and do a test to ask if lake B has bigger fish.

You get a positive/negative result and that drives your decision to report.



Open access, freely available online

Essay

Why Most Published Research Findings Are False

John P. A. Ioannidis

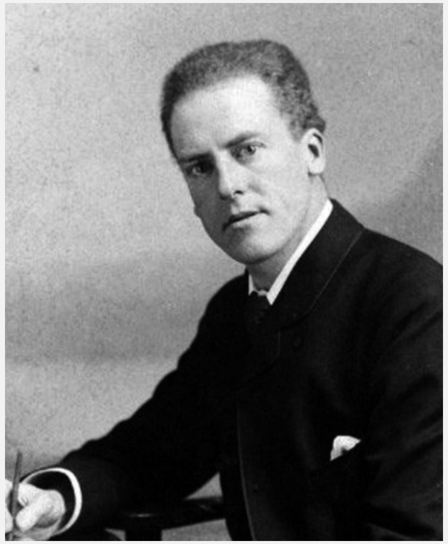
Solutions

- Study preregistration (COS)
- PeerJ / PLOS ONE
- Preprint Servers
- Altimetrics
- Systemic change - unlikely

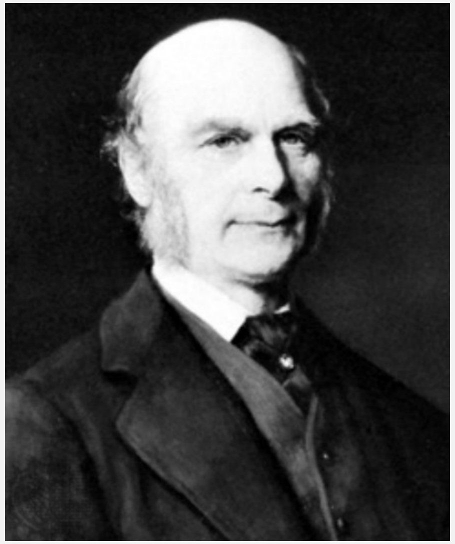
The Origin of Statistics

Much of modern statistics was an offshoot of genetics and evolution

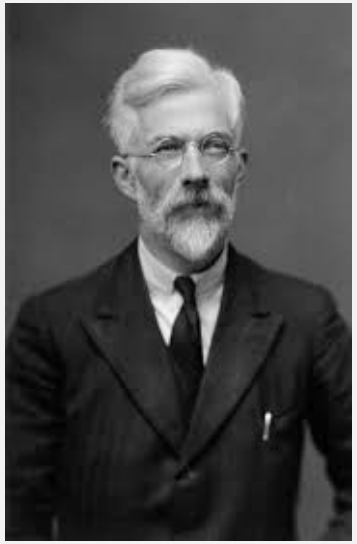
K. PEARSON
1857-1936
CORRELATION



F. GALTON
1822-1911
REGRESSION



R. FISHER
1890-1962
ANOVA

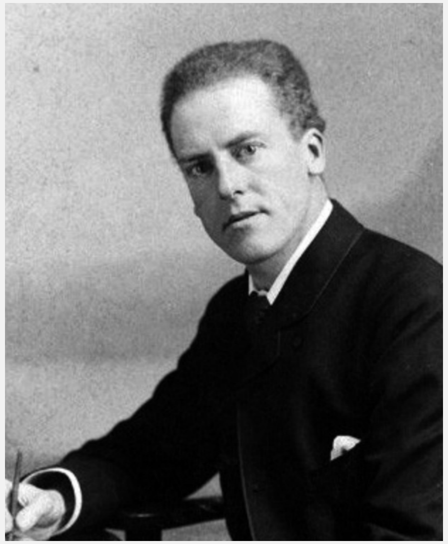


S. WRIGHT
1889-1988
PATH ANALYSIS

1900 rediscovery of Mendel's work was motivating problem.

The Origin of Statistics

K. PEARSON
1857-1936
CORRELATION



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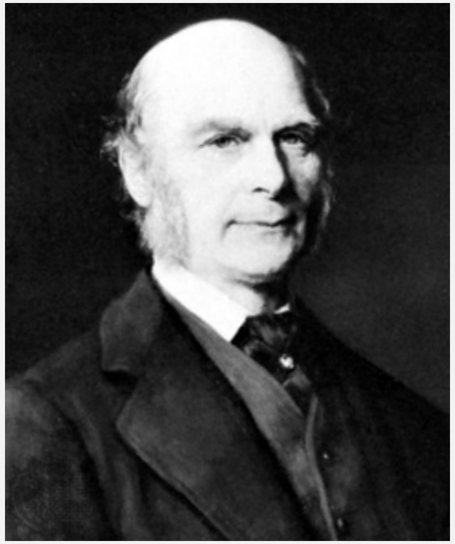

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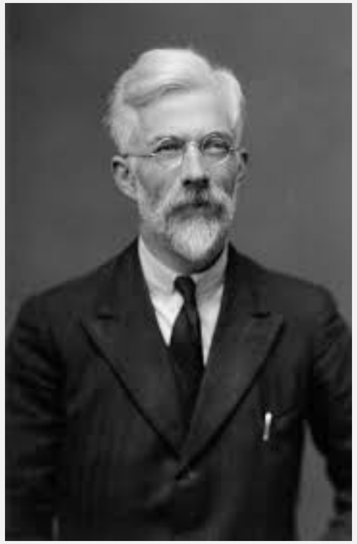
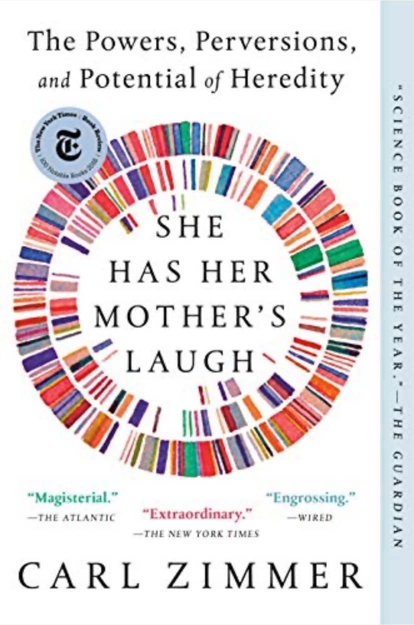


The disgraceful history of biostatistics

- Much of statistics was developed with the idea of showing that we could measure, scientifically analyze, and improve the "quality" of humans.
- The majority of geneticists and statisticians in the early 1900s were proponents of eugenics.

- What are the problems with this scientific/ethical


The Powers, Perversions, and Potential of Heredity
SHE HAS HER MOTHER'S LAUGH
"Magisterial." —THE ATLANTIC
"Extraordinary." —THE NEW YORK TIMES
"Engrossing." —WIRED
CARL ZIMMER
"SCIENCE BOOK OF THE YEAR." —THE GUARDIAN

Why do biologists need statistics

- We want to learn about the world often by testing hypotheses.
- To test a hypothesis we have to design an experiment
- Not all experiments have a traditional control and experimental treatment and this isn’t always how we want to test a hypothesis
- It is quite possible to design a study or collect data that cannot answer the questions that we have
- This leads to poor manuscripts and can lead to bad practices like p-hacking

Experimental Design

To design an experiment you need to understand how the data will be analyzed statistically.

1. How can you sample the population in which you are interested?
2. What tests are appropriate for your data?
3. What biases must be controlled for?
4. What sample size will be necessary?

Why not just collaborate with a statistician

1. In some cases this is a great option, but you have to understand enough to communicate.
2. If you publish a study you are responsible for its validity.
3. For most experiments simple methods suffice.
4. In many fields of biology there are sets of statistical tests that are expected for certain types of data.
5. For all of these reasons statistical analysis **needs to involve people who understand the biological problem and the field of study.**

My stats philosophy

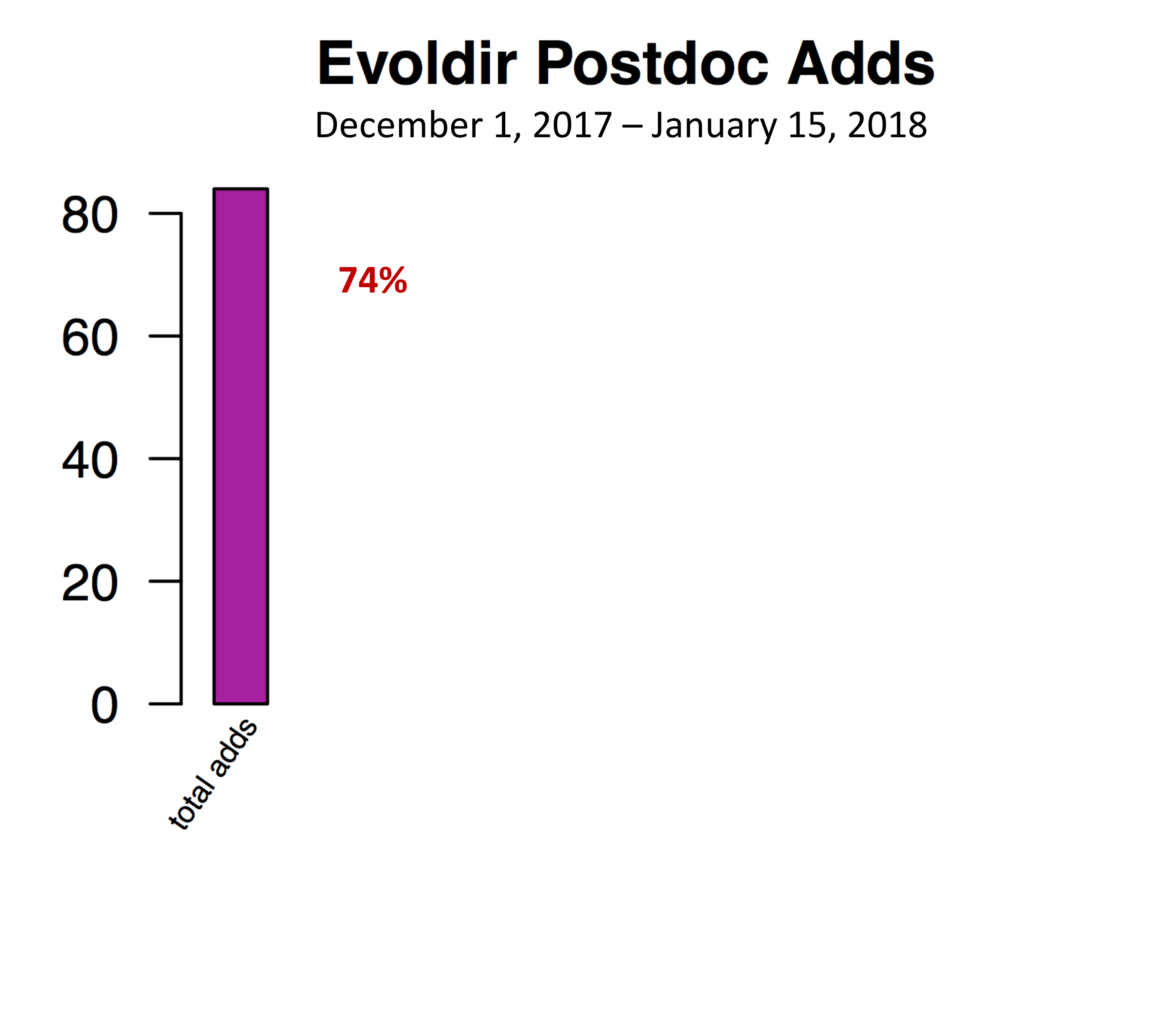
- Statistics is just another tool

- My responsibility as a scientists is to report the truth as accurately as possible and statistics help me in this regard

- We may NEED statistics to discern patterns in our data

- You need to understand where the signal that makes for a significant test comes from. Visualizing your data in the right way can do this!

Why am I teaching this class?



What is R

- R is an open and free statistical programming language that focuses on stats and graphics

- It works very similarly on all major operating systems

- It’s also a full-fledged high level programming language (similar to Python)

- *FYI: Very popular in industry so looks great on a CV.*

Why use R

1. Many statistical approaches have been implemented in the R environment.

2. Because it’s open source, there are no proprietary secrets, as might be hiding in commercially available statistical packages.

3. Any program written in R will have access to all of R’s tools for statistics and graphing.

4. New methods of analysis are being implemented in R by the scientists developing the methods.

Why use R

5. If you use R you can include a script with your manuscript example
   - Reproducibility / Open science
   - Reviewing
   - Revising

6. Many methods (mixed models, quantitative genetics, etc.) are only available in R.

7. PLOTTING

8. Once you’ve learned one language you can learn others more easily.

Downsides of R

- Learning curve
- Anyone can make a package - so there is some junk out there
- Memory issues
- No language lasts forever and no language can do everything
    - Python
    - Awk
    - Julia

For Next Week

1. Do introductions questions (link on course website).
2. Install R and Rstudio on the computer you will use this semester
3. **See me next week if you run into problems**

You can bring your laptop to class to follow along on coding that I do in front of you but this is not a requirement. Our room has insufficient plugs so charge ahead of time.

Heath Blackmon
BSBW 119C
coleoguy@gmail.com

Installing R and RStudio

Installing R

1. Go to the R homepage and click download R.
2. Pick a mirror that is in Texas or at least in the United States.
3. Select the correct version for your system and follow the prompts.

Installing Rstudio

1. Go to the RStudio homepage and click on the download link below the free version of RStudio Desktop.
2. Select the correct version for your system and follow the prompts.

How you will be learning

1. I will code live in front of you, I will have some days times that we set aside extra time for help. HOMEWORK!

Basics of R

1. Demo R

Data structures

- vector
- matrix
- dataframe
- list

Data types

- numeric
- character
- logical
- factor

Control elements

- for
- if
- while

Common functions

- c
- matrix
- list
- sum
- mean
- sd
- sqrt
- abs
- paste
- rnorm
- rbinom
- rexp
- sample
- rep
- data
- Help
- which

Basic base R plotting functions

- hist
- plot
- density
- abline
- lines

Operators

- <-
- ==
- >
- <
- %in%
- {
- [
- + - * / ^ %%

Practice

```
install.packages(“swirl”)
library(“swirl”)
swirl()

Complete two lessons of your choice
```