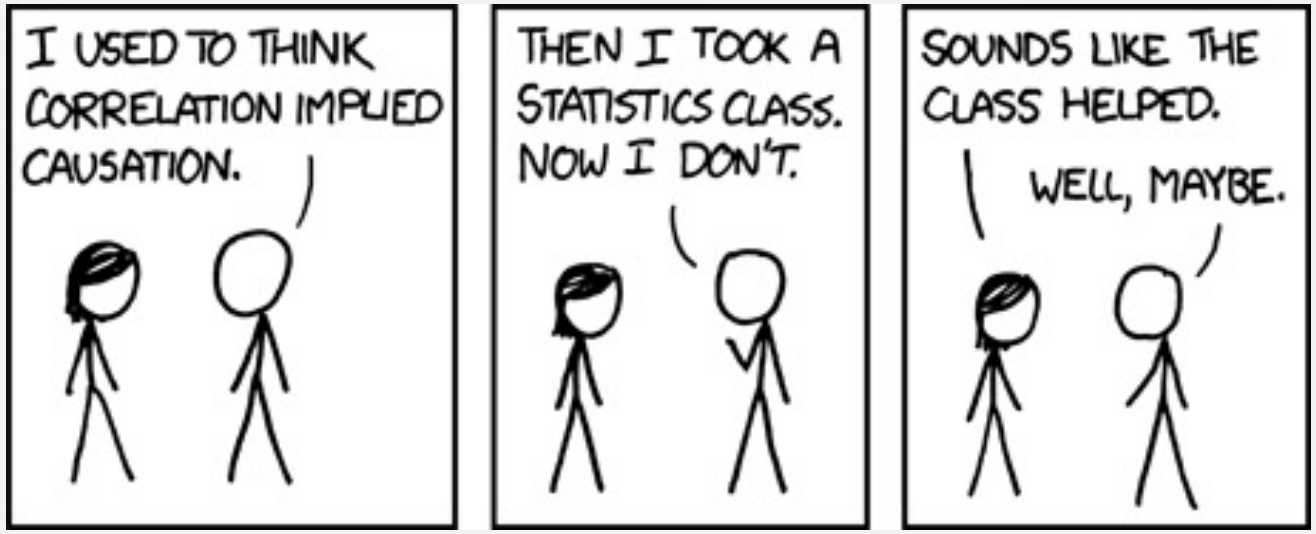
# Experimental Design

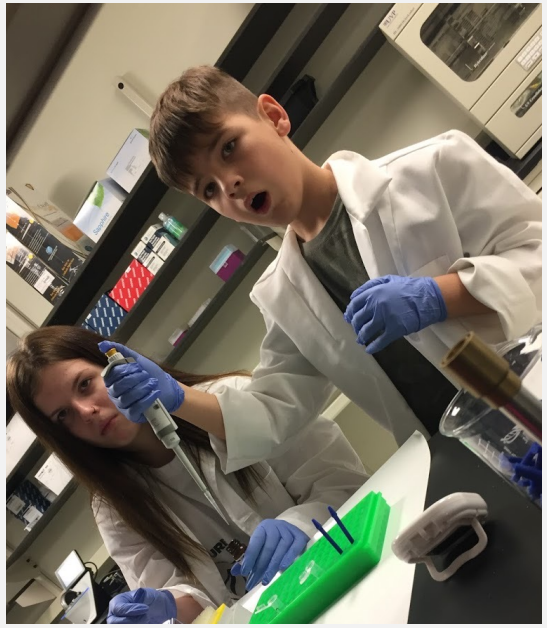
## Biology 683

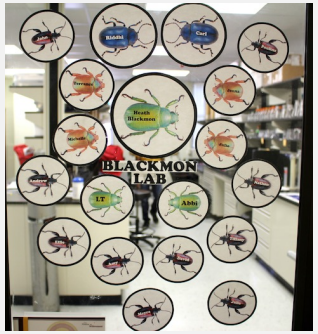
## Lecture 1

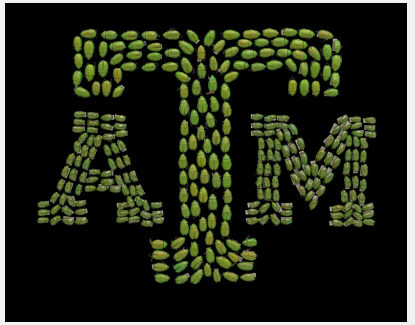
Heath Blackmon



# Me





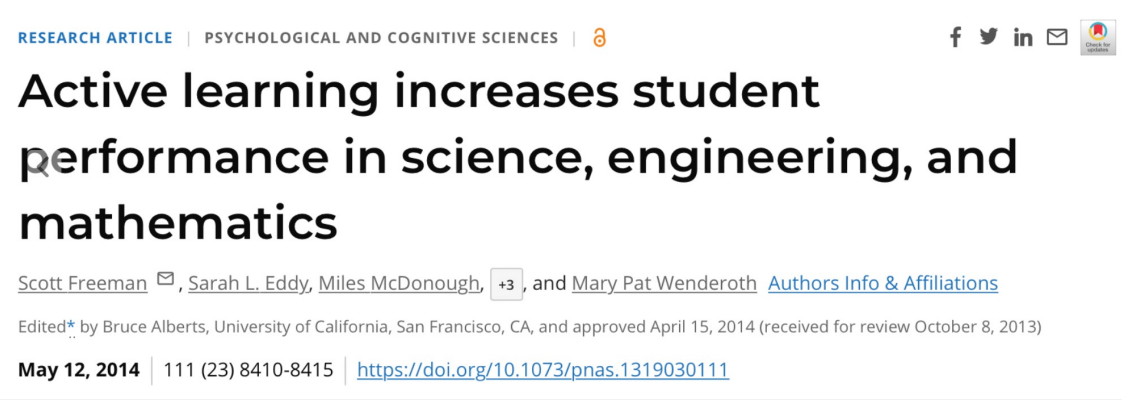

I study the **evolution of traits**. Especially genomic traits. I use a variety of methods next-gen sequencing, experimental evolution, phylogenetic comparative methods, and theoretical approaches. I don't work with a single taxa; we have projects involving fish, mammals, reptiles, amphibians, insects,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

# You all

**Talk to those around you.**

1. Find someone whose research interests or background you don’t know—learn them.
2. Find out if you all have any concerns about this class

# Pedagogy



RESEARCH ARTICLE | PSYCHOLOGICAL AND COGNITIVE SCIENCES |

## Active learning increases student performance in science, engineering, and mathematics

Scott Freeman, Sarah L. Eddy, Miles McDonough, +3, and Mary Pat Wenderoth Authors Info & Affiliations

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

**May 12, 2014** | 111 (23) 8410-8415 | https://doi.org/10.1073/pnas.1319030111

RESEARCH ARTICLE | APPLIED PHYSICAL SCIENCES |

## Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom

Louis Deslauriers, Logan S. McCarty, Kelly Miller, +1, and Greg Kestin Authors Info & Affiliations

Edited by Kenneth W. Wachter, University of California, Berkeley, CA, and approved August 13, 2019 (received for review December 24, 2018)

**September 4, 2019** | 116 (39) 19251-19257 | https://doi.org/10.1073/pnas.1821936116

*Educational Evaluation and Policy Analysis*
*Summer 1990, Vol. 12, No. 2, pp. 213–227*

**Class Size and Student Achievement: Research-Based Policy Alternatives**

**Allan Odden**
*University of Southern California*

# Our approach

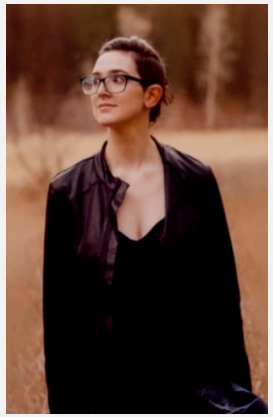
- In class (MW 4-5:15) – lecture, discussion, questions and answers, live coding

- Office hours (4 per week, 1 hour each) – these are optional-ish **you need to be there if you can not complete practice problems** without assistance. Each office hour session will include a 30 minute live coding session followed by 30 minutes of question and answer time.

# Our Team

**Jorja Elliott**
3 year Ph.D. student
Quantitative Genetics

**Jorja Elliott**
2 year Ph.D. student
Phylogenetics



**Jorja Elliott**
2 year Ph.D. student
Genomics

# My Goals

- I want to challenge each of you to grow as a scientist
- I want to make you better at “doing” science
- I want to have fun together as we work our way through a lot of material this semester!

# My View on Graduate Courses

- I think graduate courses should open the door for you to become an expert in a field.
- However, you shouldn't need to become an expert to do well. Not every class is super central to your research.
- Therefor, I'm going to expose you to a lot of material and I hope really challenge you with some of the problems we solve. However, each of you can earn an A if you simply put forth an appropriate and reasonable amount of effort.

# Today

- Teaching approach
- 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*
- ***Make you a more productive and successful scientist!***

# 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

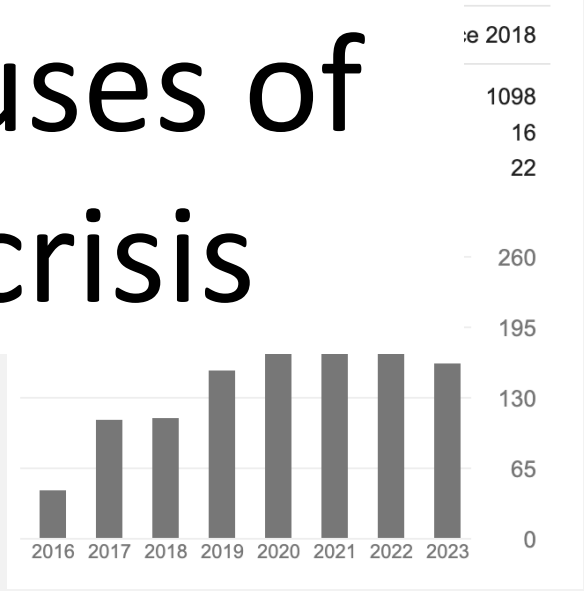
Statistical literacy in the general public is essential and lacking

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
- p
- f
- small sample sizes
- p-hacking
- unethical researchers/developers

Discuss possible causes of the reproducibility crisis




Amy Cuddy
TED Talk 68.9 Million views
(2nd most popular TED Talk)

# Can we trust the science we read?

**Scenario 1**

You have a question: Are fish in lake A or B on average bigger?

Collect N fish from both lakes using identical sampling methods. You then use a two-sample two sided T-test to determine if they differ in size then report your result.

**Scenario 2**

You collect N fish from both lakes using identical sampling methods you noticed that fish in lake A seems bigger than those in lake B

You use a two-sample one sided T-test to determine fish in lake A are larger than lake B.

Discuss What proportion of the time will these two scenarios each suggest a positive result even when the fish in the two lakes are on average identical. In other words what is the false positive rate for these two scenarios?

# Can we trust the science we read?

**Example in R**

*Open access, freely available online*

Essay

## Why Most Published Research Findings Are False

John P. A. Ioannidis

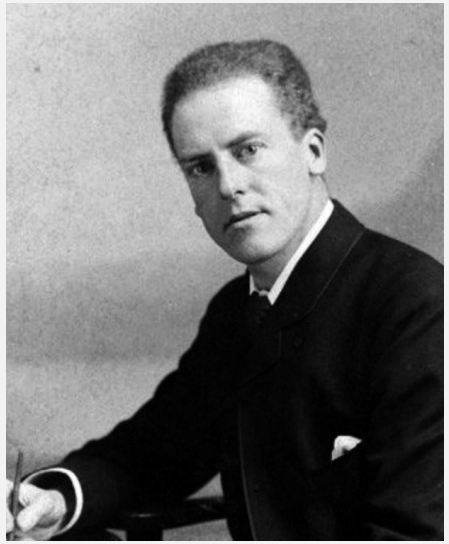
# Solutions

- Study preregistration (COS)
- Discuss What are possible solutions to the reproducibility crisis?
- Altmetrics
- Systemic change - unlikely

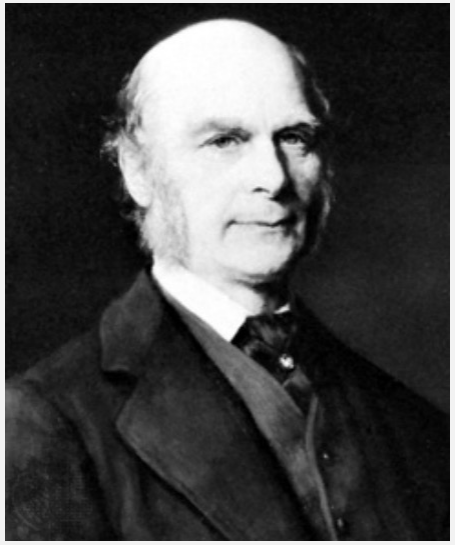
# The Origin of Statistics

*Much of modern statistics was an offshoot of genetics and evolution*

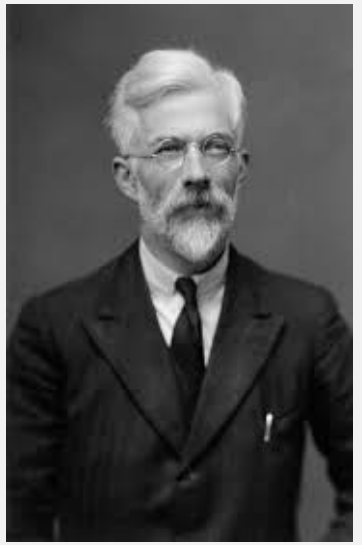
K. PEARSON
1857-1936
CORRELATION



F. GALTON
1822-1911
REGRESSION



R. FISHER
1890-1962
ANOVA

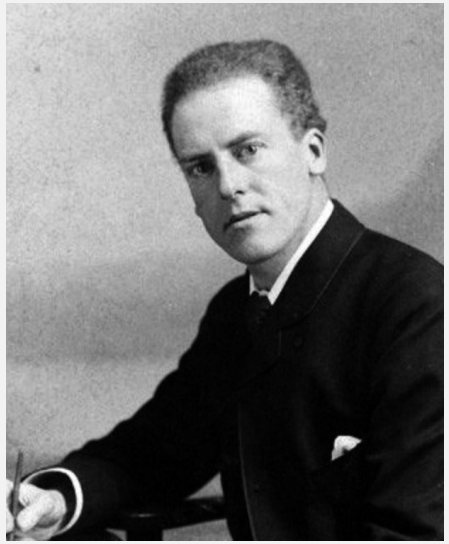


S. WRIGHT
1889-1988
PATH ANALYSIS

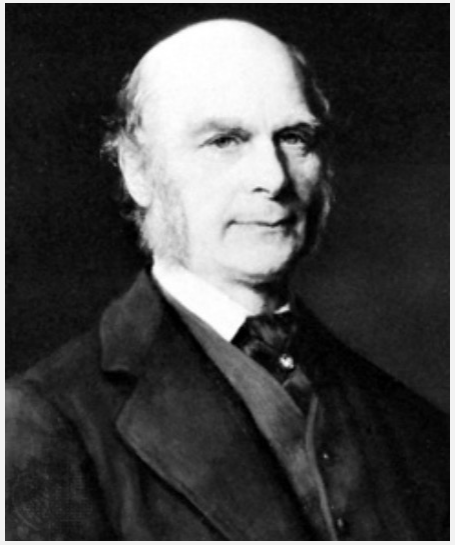
*1900 rediscovery of Mendel's work was motivating problem.*

# The Origin of Statistics

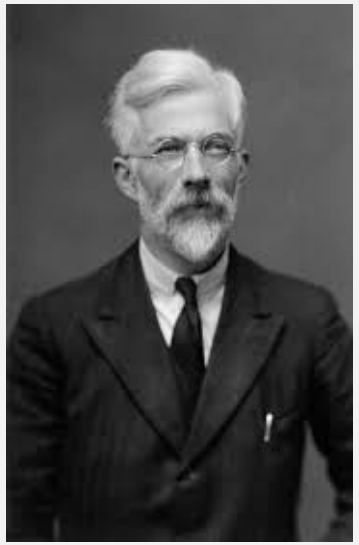
K. PEARSON
1857-1936
CORRELATION



F. GALTON
1822-1911
REGRESSION



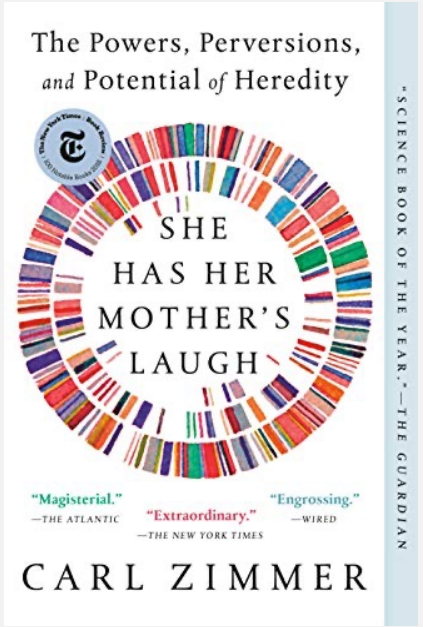
R. FISHER
1890-1962
ANOVA



# 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



# 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?

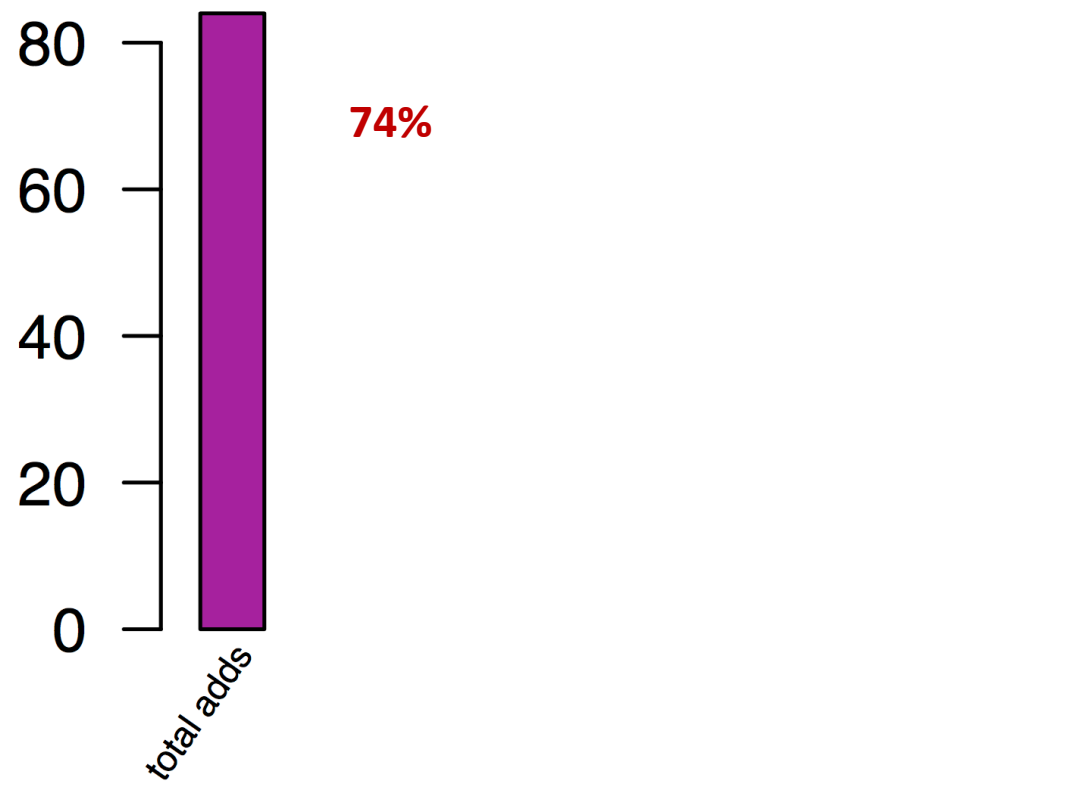
# Why not just collaborate with a statistician

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)
- 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 Wednesday

1. Do office hours survey (link on course website).
2. Install R and Rstudio on the computer you will use this semester
3. **See me if you have problems installing.**

**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. I expect you to practice outside of class and come to office hours if you have problems**

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
```