Scientific Inquiry

Introduction to Evolution and Scientific Inquiry

Dr. Spielman; spielman@rowan.edu

The hypothesis-driven scientific method

- Make observation(s)
- Ask a question
- Form a *scientific* hypothesis
- Design an experiment to test whether data supports the hypothesis
- Make predictions about what your experiment might show
- Perform the experiment; collect and analyze the data
- Draw conclusions
- Reproduce results

Scientific Hypotheses

- To be *scientific*, a hypothesis must be **testable** and **falsifiable**
  - **Yes:** Fruit flies prefer to eat bananas over apples.
  - **No:** Loch Ness contains a giant reptile/monster.
- We call these **alternative hypotheses**
  - Compare to a **null hypothesis**: "nothing interesting is going on".
- Analogy: the legal system!
  - **Alternative hypothesis** ~ the charges against someone
  - **Null hypothesis ~** "innocent until proven guilty".
- The goal of the scientific method is to **test** for whether there is **evidence for the alternative hypothesis.**
  - NOT TO PROVE!!! NOT TO PROVE!!!! WE NEVER EVER PROVE!!!
  - We are NOT choosing between null and alternative. ONLY TESTING ALTERNATIVE.

Developing a scientific hypothesis

https://www.youtube.com/watch?v=Uc7Ahp5--eE

What are your **observations**?

What **questions** could we ask?

What are the **scientific hypotheses** to test these questions?

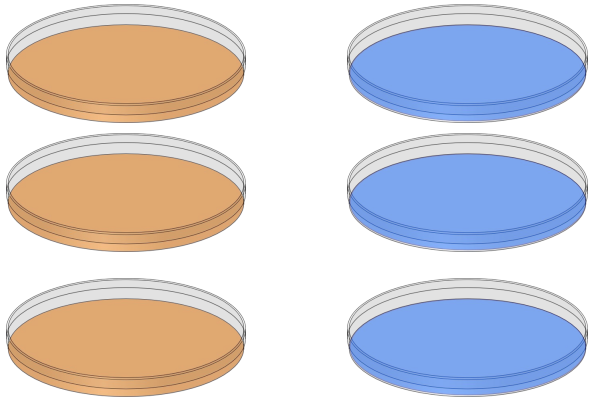
What **other questions and hypotheses** could we ask/test?

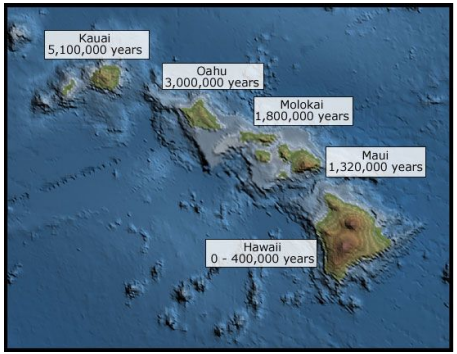
Developing an experiment to test whether there is evidence for the alternative hypothesis

- An experiment needs several key components for it to be scientifically reliable
  - There must be treatment group(s) and a **control group**
  - The experiment must have **repetition i.e. replication** (more than one individual is examined)
  - The experiment must be **randomized** ("unbiased")
  - The experiment must be **reproducible** (someone else can repeat your experiment)

Types of experiments

- Controlled or *manipulative* experiment (we're talking about this!)
- Natural or *observational* experiment
- ...The other kind of observational study





Example experimental scenario

Alternative hypothesis: Using rocks helps otters open clam shells.

Null hypothesis: Using rocks do not affect otters' ability to open clam shells.

Experiment: We randomly place 10 otters into "treatment group" and 10 otters into "control group." All otters are provided with delicious, delicious closed-shell clams.

We give each otter in the treatment group a rock, but we do not give any rocks to the control group otters. We measure how many otters in each group successfully eat their clam.

What is the purpose of experimental design?

- We use **control groups** to isolate what we are testing.
  - Control and treatment groups should be as similar as possible, with the *only difference* being what we are testing.

- We **randomize** to minimize **bias and random error.**
  - **Bias***: Systematic* (or nonrandom) variation in treatment groups
  - **Random Error**: *Random* variation in groups, measurements. Often stems from **individual or environmental variation**.

- We include **repetition (replication)** to further reduce **random error due to individual variation**.

Hypotheses versus predictions

- Hypotheses are technical scientific statements, but predictions are more like a thought experiment

- **IF** the alternative hypothesis is true, what should I observe in my results?
- **IF** the alternative hypothesis is false, what should I observe in my results?

- ***You may have learned that a prediction is a hypothesis - it is not!!!***

Special names for variables in your experiment

- **Response variable:** What we are actually measuring (be specific!)
  - AKA "dependent" variable

- **Independent variable:** What quality differs among treatment and control groups? I.e. what are we testing?

- **Confounding variable:** Anything (yes, anything) that could *confound* your ability to cleanly interpret your experimental results
  - Confound = to fail to find differences between (think: diff between control and treatment)

Pop Quiz! (not really)

- If the alternative hypothesis is *false*, does that mean the null hypothesis is *true*?

- How do we know *for sure* if the alternative is *definitely* true or false?

Forming conclusions

The data/evidence supports the alternative hypothesis.

The data/evidence do not support the alternative hypothesis.

~~The null hypothesis is proven true.~~

~~The null hypothesis is proven false.~~

~~The alternative hypothesis is proven true.~~

~~The alternative hypothesis is proven false.~~

Example results

Experimental replicate	# control otters who got their clam (of 10)	# treatment otters who got their clam (of 10)	Supports alternative hypothesis?
1	**5**	**6**	
2	**4**	**3**	
3	**8**	**8**	
4	**1**	**2**	
5	**2**	**9**	