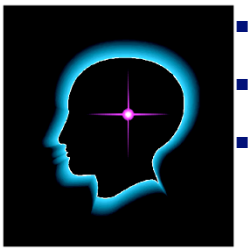
WHAT IS SCIENCE ?



- Attempts to discover the order in nature
- Makes predictions about what will happen
- Methodical process of discovery and understanding

WHAT IS SCIENCE ?

- Discrimination of what is true (reality) from what only appears to be true (illusion, prejudice, & story-telling)

"Science as a way of knowing"

PROCESS SCIENTISTS USE TO ANSWER QUESTIONS ABOUT NATURE

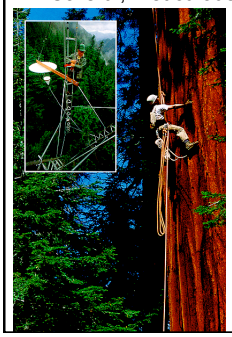
- Hypothetico-deductive method

6A 6B 6C

- Observations
- Question
- Hypothesis
- Prediction
- Experiment
- Conclusions

It all starts with Observations

- Careful, meticulous, well-documented observations!



- Naturalists and explorers
  - Detailed descriptions, illustrations, maps, & anecdotes
- Published scientific reports
  - Peer-reviewed journals
- Personal experiences

Let the observations inspire specific questions!

Why do frogs call at night?

Propose plausible answers to your question (inductive reasoning).

- reduced predation rates
- reduced loss of foraging
- reduced water loss rates
- reduced phone rates

Proximate vs. Ultimate Questions

- Proximate questions (descriptive)
  - what is it?
  - how does it function?
- Ultimate questions (causal)
  - why is something the way it is?
  - what would be predicted about how it
    - breaths
    - reproduces
    - is related to other organisms

The Hypothesis

- Hypotheses are possible explanations of an observation.
- Scientists formulate hypotheses based on:
  1) previous knowledge
  2) inference from similar situations
  3) common sense
- The more basic facts you know, the better your questions & hypotheses.

The Hypothesis

- Word it as **falsifiable** (testable)
- Formulate a **specific prediction**
- Formulate falsifiable alternative hypotheses (include **null hypothesis**)
- Design **tests** (experiments or observations) of the alternative predictions

RELATIONSHIP BETWEEN HYPOTHESIS AND PREDICTION

Deductive reasoning —

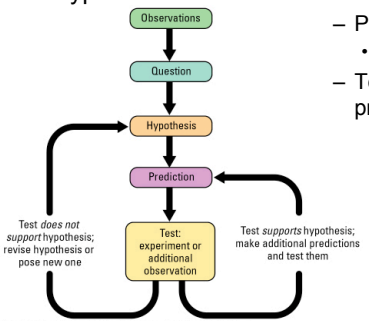
- If the hypothesis is correct....
- Then we predict the following outcome from our experiment

Hypothesis Testing

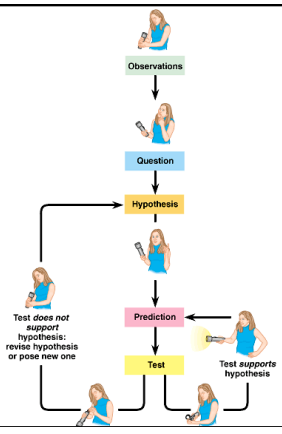
- **Reproducibility**: Repeated testing of a hypothesis precedes its tentative acceptance.
- Only testable hypotheses are worthwhile.
- Untestable hypotheses are not generally considered science.

SCIENTIFIC METHOD

- Hypothesis-driven science



  - Prediction
    - If…then
  - Test the prediction



Test the Hypothesis

- Observations
- Questions
- Hypothesis/Predictions
- **Tests** (Experiments)
  - Control Group
  - Experimental Group
- Data/Results
- Conclusion

Experiments test the Hypothesis

- Experiments refute or support hypotheses:
  - good tests can be hard and must often be clever.
- Experiments involve an

- **experimental group** which has variable under study experimentally altered, and a
- **control group** which receives the same treatment as the experimental group except for the variable in question.

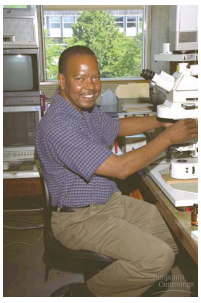
WHY IS IT DIFFICULT TO DRAW A CONCLUSION FROM AN EXPERIMENT THAT IS NOT CONTROLLED?

- Controlled experiment has two parallel tests
  - Experimental
  - Control

- Only the "tested variable" is different
- Without control you do not know if the outcome is caused by the variable in question

Experimental Variables

- Tests (Experiments)
  - Control Group
    - Standardized Variables
  - Experimental Group
    - Standardized Variables
    - Independent Variable
- Data/Results
  - Dependent Variable
- Conclusion



A controlled study

1. Hypothesis: Antibiotic B is better at treating ulcers than Antibiotic A.
2. Alternative Hypothesis: Antibiotic A is better at treating ulcers than Antibiotic B.
3. **Null** Hypothesis: treatment of ulcers is uncorrelated with Antibiotic A or B.

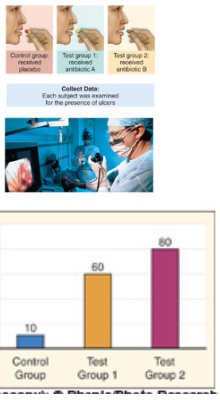
"Double-blind" controls: Neither the subjects nor the endoscopists know which subject is in which group.

A controlled study

Analysis of Results:

1. **Correlation**: Dependent variable (% effectiveness) is dependent upon independent variable (treatment group).
2. **Affirmation**: Hypothesis prediction supported.
   - *Caution*: correlation does not always mean causation!
3. **Statistics**: Groups are large enough & results are distinct enough, apparent correlation is not just coincidence.

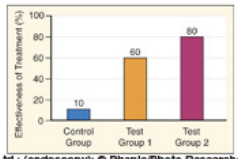
Then → **Conclusion**: Hypothesis is supported!



A controlled study

Presentation of Results (the Graph):

- **Y-axis**: Dependent variable is *dependent* upon independent variable — amount of % effectiveness varied because of treatment group.



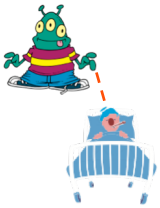
- **X-axis**: Independent variable is *not dependent* upon dependent variable — assignment to treatment group was made without knowing future % effectiveness.

- **Bar Graph**: since values of independent variable are in discrete groups
  - If values had been *continuous* (e.g., dosage of antibiotic B), use a **line graph** [regression].

Doing Science

1) Get all background information possible (lots of it normally)
2) Collect data (often several years of work)
3) Analyze data (can take months or years)
4) Write up results & submit for peer review and publication (often >1 year until publication)

SOME QUESTIONS ARE OUTSIDE THE REALM OF SCIENCE



- Hypothesis - "Ulcers are caused by negative energy waves from extra-terrestrial organisms"
- Design an experiment....?
- Questions/Predictions must be testable!

Theory

- philosophical or popular "theory": Speculation or conjecture regarding unproven or immeasurable phenomena
  - Ph.D. — "philosophy doctorate"
  - "If everyone was vegan, they'd be less violent!"

Contrasted with **Scientific** Theory

- **Widely supported** explanation of broadly occurring phenomena
  - Theory of relativity
  - Cell Theory
  - DNA (Gene) Theory of Inheritance
  - Theory of evolution

- "Evolution": **change over time**

Scientific Theory of Evolution

- Populations include individuals with differences in heritable characteristics. The frequency of those variations in the population can **change over time**.
- Sometimes that change is the result of **natural selection**.
- Separate populations may change differently and become reproductively isolated (**speciation**)

Contrast with personal and philosophical "theories" of evolution

Biophilia

a love of life and its forms

Biologist Carlos Rivera Gonzales examining a tiny tree frog in Peru