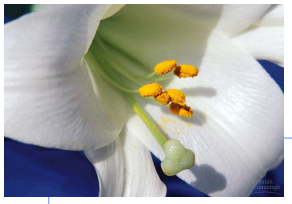
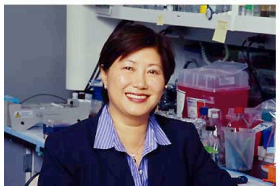


What is
Science?

What is Science?



Science is a process of questioning.

Science as Inquiry

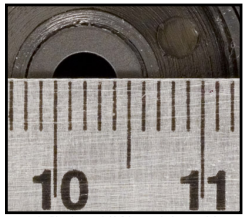
- **Biology** = the Study of Life
  (From the Greek *bios=life* and *logos=the study of*)
- At the heart of science is **INQUIRY**
  - Inquiry is a process of investigation, with thoughtful questions leading to a search for answers.

Observations & Data

- Observations = The use of the senses to gather and record information about structures or processes.
- Data = Recorded Observations
- Scientific instruments vastly increase the range of possible observations

Observations & Data

- Quantitative Data = Observations recorded as measurements.
  - *In science, such measurements using the Metric System.*



- Qualitative Data = Data in the form of descriptions instead of measurements.
- Data is best when it is clearly organized, consistently recorded, and reliable.

Science is questioning in order to describe or explain

- **Scientific Method**: A process of critical thinking that uses observations and experiments to investigate testable predictions about physical universe.

- Two type main types of scientific inquiry:
  1. Discovery Science
     (Descriptive Science)
  2. Hypothesis-Based Science
     (Experimental Research)

DISCOVERY SCIENCE / OBSERVATIONAL RESEARCH

- **Discovery Science**
  - Accurately describes natural structures & processes.
  - Based on observation & data analysis.
    - Investigators observe subjects and measure variables of interest without assigning treatments to the subjects.
      - Ex: Jane Goodall's studies on Chimpanzees

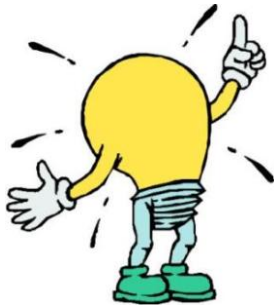
Discovery Science

- Sometimes discoveries happen by accident.
  - In 1928, Alexander Flemings discovered that mold had contaminated his culture of bacteria.
  - No bacteria were growing near the mold.
  - Without meaning too, Fleming discovered this antibacterial substance that was being produced by the fungus, later named penicillin.

  - Penicillin revolutionized medicine.

Inferences in Science

Inference = **A logical conclusion based on observations**



- Inferences help convert general questions into more specific questions that can be explored in depth.
  - Inferences must not stretch too far beyond the data.

Inferences in Science

Observation: Two meals are sitting on a table. The table and food is outdoors. It's daylight.

Inference: Two people are having lunch together.

Inferences have less certainty than observations.

It could be that 4 people are sharing the food in two plates.

It would a stretch to infer that the people got kidnapped before they could eat lunch.

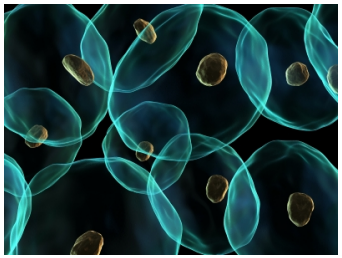
Generalizations in Discovery Science***

Generalization = A general conclusion reached by scientists after they putting together the data from many specific observations.

In the 1800's, scientists noticed in both plants and animals tiny units called cells.

But it was the accumulation of many observations that gave them the confidence to make the generalization that…

"all living things are made of of cell"



Hypothesis-Based Science

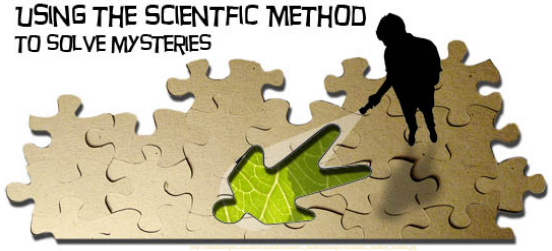
Discovering something interesting inspires us humans to seek explanations.

Discovery science seeks **DESCRIBE** nature, but Hypothesis-based Science seeks to **EXPLAIN** nature.

Hypothesis-based Science depends on the "Scientific Method." However, science is less rigidly structured than many realize.

All hypothesis-based science does have in common is …

THE HYPOTHESIS

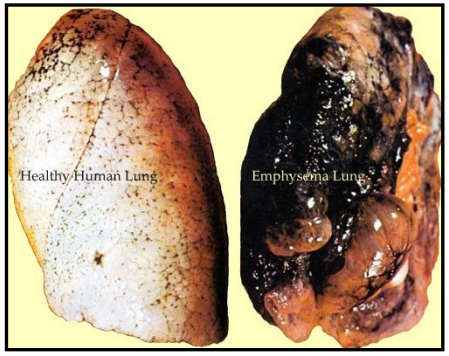


EXPERIMENTAL RESEARCH / CONDUCTING EXPERIMENTS

- **Experimental Science** (Hypothesis-based Science)
  - Experiment = a methodical procedure carried out with the goal of verifying, falsifying, or establishing the accuracy of a hypothesis.
    - Experimentation is the step in the scientific method that helps people decide if a hypothesis is false
      - If not proven false, the hypothesis is supported but it can never be proven correct….
        - Investigators apply treatments to experimental groups (people, animals, plots of land, etc.) and then proceed to observe the effect of the treatments on the experimental group to see if the treatment had an effect.

Comparing the Types of Research

- For example, suppose we want to study the effect of smoking on lung capacity in women…
  - What would be a descriptive study on this?
  - What would be an experiment on this?



Types of Research

- What would be a descriptive study on this?

Observational Study

- Find 100 women age 30 of which 50 have been smoking a pack a day for 10 years while the other 50 have been smoke free for 10 years.
- Measure lung capacity for each of the 100 women.
- Analyze, interpret, and draw conclusions from data.

4

Types of Research

- What would be an experimental study on this?

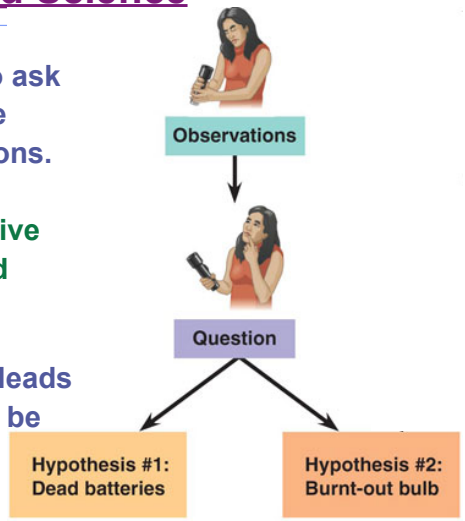
Experiment

- Find 100 women age 20 who do not currently smoke.
- Randomly assign 50 of the 100 women to the smoking treatment and the other 50 to the no smoking treatment.
- Those in the smoking group smoke a pack a day for 10 years while those in the control group remain smoke free for 10 years.
- Measure lung capacity for each of the 100 women.
- Analyze, interpret, and draw conclusions from data.

3

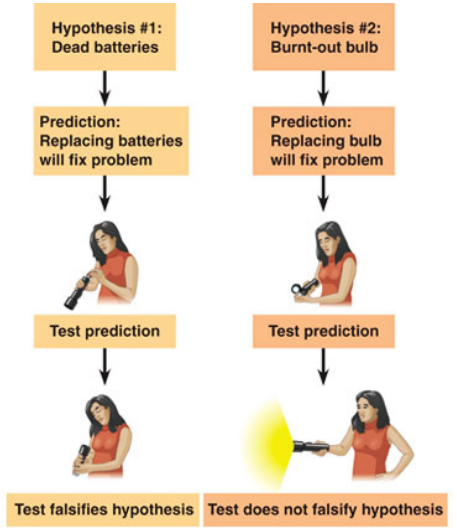
Hypothesis-Based Science

- **Observations** lead us to ask questions and propose hypothetical explanations.
- A **hypothesis** is a tentative answer to a well-framed question.
- A scientific hypothesis leads to **predictions** that can be tested by **observation** or **experimentation**.



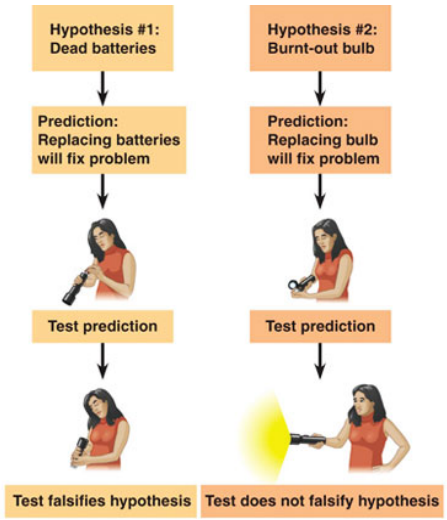
A hypothesis MUST be testable and falsifiable.

- ✓ There must be some way to **check the validity** of the idea.
- ✓ There must be some observation or experiment that could **reveal if this explanation is actually NOT true**.

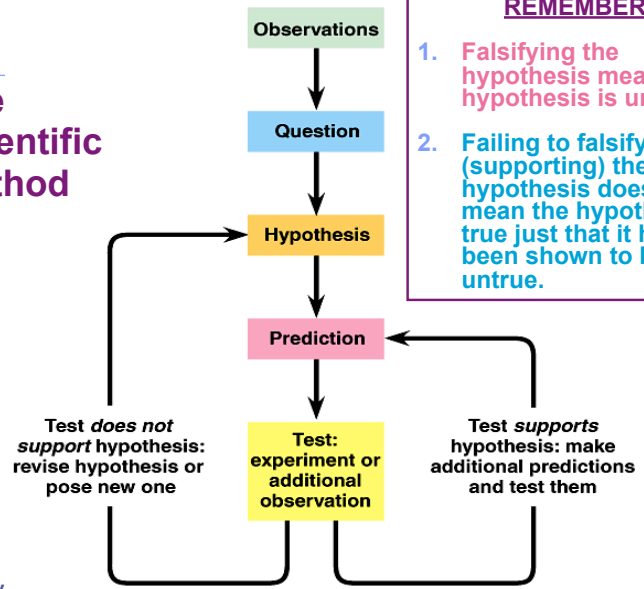


FAILURE TO FALSIFY A HYPOTHESIS DOES NOT PROVE THAT HYPOTHESIS!!!

- If you replace the bulb, and it works, you have FAILED TO FALSIFY the hypothesis that your flashlight does not work because the light was burnt out.
- You HAVE FALSIFIED the hypothesis that the defective flashlight was caused by dead batteries.
- The RESULTS SUPPORT the hypothesis that your bulb was burnt out
  - This explanation is **NOT PROVEN** *(perhaps the first bulb was inserted correctly and not burnt out at all)*



The Scientific Method



REMEMBER:

1. Falsifying the hypothesis means the hypothesis is untrue.
2. Failing to falsify (supporting) the hypothesis does not mean the hypothesis is true just that it hasn't been shown to be untrue.

Example of Hypothesis-Based Science

Michael Sheehan and Elizabeth Tibbetts study individual recognition in wasps.

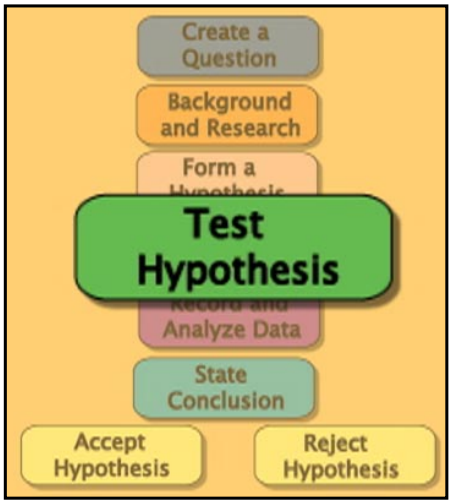
- Observation = Some wasps get attacked less often.
- Question = Why do some wasps get attacked less?
- Hypothesis = Distinctive-looking individuals benefit, because they get in fewer fights over dominance. (Educated guess/tentative explanation)
- Logic/Reasoning = With individual recognition, you only have to fight each wasp once since you know which is dominant.
- Prediction = The non-painted wasp will get attacked fewer times
- Experiment = They painted wasp faces, so that three in a group of four looked the same and one was different to see if the one different looking wasp was recognized upon a second encounter by being attacked a fewer number of repeated times.
- **Results** = Consistent with their hypothesis, the distinct-looking one was attacked less by the others.

The Scientific Method - Review

Scientific Method necessitates hypotheses that can be proven or not proven wrong!

Hypothesis are NEVER proven right.

Evidence only supports a given hypothesis



The Scientific Method - Review

Scientific Process involves….

- Observations, Questions, Hypothesis (then prediction), Experimentation, Conclusions

Hypothesis - a testable statement that should be able to be proven false by experiment or observation if false.

- *Hypothesis must not be ambiguous!*

Good	Bad
1. Plants will grow taller when given Miracle Grow. 2. Girls will score higher on math tests than boys. 3. Hermit crabs choose colorful shells over drab shells.	1. Plants will grow better when given Miracle Grow. 2. Girls are smarter than boys. 3. Hermit crabs like colorful shells.

The Scientific Method - Review

- After creating a hypothesis, a prediction is made.
  - A prediction is an expected outcome.
    - A hypothesis is then tested by **experimentation:**
      - a planned procedure designed to test the hypothesis.

Elaboration on Hypotheses

- Actually, whenever I talk about an hypothesis, I am really thinking simultaneously about *two* hypotheses.
  - In science you cannot assume there exists a relationship between variables without evidence to back up your explanation.
    - Let's say that you think that there exists a relationship between two variables in your study. One of two explanations might be true:
      1. Variable A and variable B are ***not*** related.
      2. Variable A and variable B ***are*** related

Null & Alternative Hypothesis

- The hypothesis that describes the starting baseline *(with no assumptions of connections between two variables)* is the ***null*** hypothesis. H_O or H_0
  - This explanation states that X has NO effect on Y
- The explanation that there *IS* a connection between two variables then is the ***alternative*** hypothesis H_A or H_1
  - "That X has an effect on Y"
  - **Caution:**
    - Often the hypothesis that you support is the H_A
    - In some studies though, your prediction might be that there will be no difference or change.
      - *Here you are trying to find support for the null hypothesis and you are opposed to the alternative.*

Null & Alternative Hypothesis

- The null hypothesis is what the researcher often tries to disprove, reject or nullify.
  - This is the baseline or often common view of something
- The alternative hypothesis is often what the researcher really thinks is the cause of a phenomenon.
  - An experiment conclusion always refers to the null, rejecting or failing to reject "accepting" H_O rather than H_A.
    - EXAMPLES OF THE ALTERNATE HYPOTHESIS:
      - H_1 or H_A: Tomato plants exhibit a higher rate of growth when planted in compost rather than in soil.
    - EXAMPLE OF NULL HYPOTHESIS:
      - H_0: Tomato plants do not exhibit a higher rate of growth when planted in compost rather than soil.

Types of data (information) in Experiments

- Variables are conditions, characteristics, or values that can change
- Scientists want to explain which variables influence other variables so we can reach a greater understanding of nature and the universe.

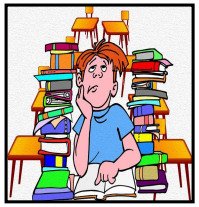
Explaining Phenomena

- Many variables may influence a given variable.
  - What could potentially effect the growth plant in height?
    - Amount of Sunlight
    - Wavelength of light
    - Amount of Rainfall
    - Nutrient content in soil
    - Amount of soil
    - Time of day when watered
    - Volume of pot
    - Species of plant
    - Humidity in air
    - Temperature of air

- You cannot just assume one variable affects another though just because you think it should! *Evidence is needed!*
  - By conducting experiments, scientists will test the effects of one of these variables on height to see if indeed there is a causal link between the variable and plant growth.

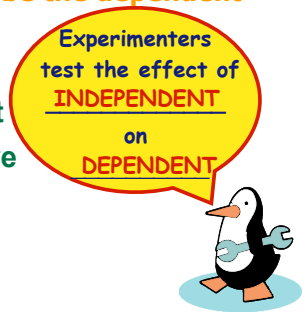
Types of data (information) in Experiments

- What are the variables dealt with in an experiment?
- Independent variable
  - The independent variable is the variable that is controlled and manipulated by the experimenter.
    - Ex: in a study on the impact of sleep deprivation on test performance, sleep deprivation would be the independent variable.
  - manipulated variable
  - predictable change: it only changes because we choose to change it in a specific way
    - Shown on the X-axis



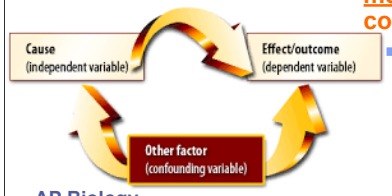
Type of Variables

- Dependent variable
  - The dependent variable is the variable that is measured by the experimenter.
    - In our previous example, the scores on the test performance measure would be the dependent variable.
  - Its the measured variable
  - Unpredictable change: we don't know how it will change until we do the experiment
    - Placed along the Y-axis



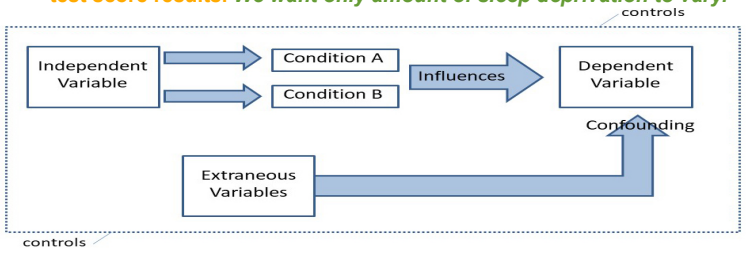
Type of Variables

- The independent and dependent variables are *NOT* the only variables present in experiments.
  - When conducting an experiment, you want to make sure that you have tested the effects of your independent variable on your dependent variable and not accidentally tested the effects of another variable on your dependent variable.
- Extraneous and Confounding Variables Exist too
  - These types of variables are ones that may have an impact on the dependent variable measured as part of your experimental data collected.
  - *For example, in an experiment on the effects of sleep deprivation on math test performance, other factors such as age, gender, anxiety, and academic background may also have an impact on the test results.*



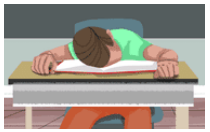
Type of Variables

- **Extraneous Variables**
  - Extraneous variables must be controlled for by the experimenter
    - To control a variable means setting up your experiment so that all subjects experience the same amount of these variables *or* that these variables are allowed to vary in the same way from subject to subject in the experiment.
  - Controlled variables are called constants.
    - In the case of your subjects taking the math test, the experimenter might select participants that have the same academic background and age and give each the test in a room with the same temperature to ensure variations in these factors are not the reason for differences in test score results. *We want only amount of sleep deprivation to vary.*



Type of Variables

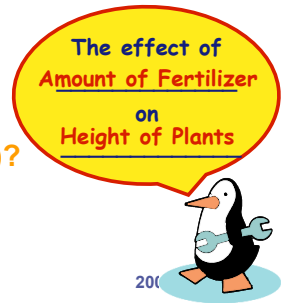
- **Confounding Variables**
  - These are extraneous variables that no matter how much you try, they cannot be controlled for by the researcher.
    - These are variables that differ from one subject to the next in your experiment but you cannot do anything about it - *there is no way to make sure every subject experiences this variable in a similar way.*
      - Since you cannot control the fluctuation of this variable between subjects - the variable cannot be controlled or held constant - this type of variable *CAN* have an impact on the dependent variable.
      - This reality makes it difficult to determine if the results of your experiment are due to the influence of the independent variable, confounding variable, or an interaction of the two.



- In the case of your subjects taking the math test, even if my subjects are all the same age, in good health, have similar math backgrounds, and take the test under the same conditions, their individual nervous systems may still vary slightly affecting each one's math performance under conditions of lots or no sleep.

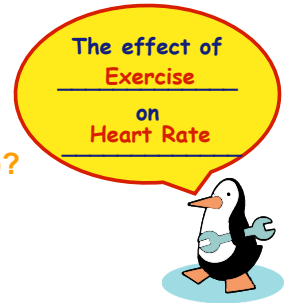
Examples of experiments 1

- How does fertilizer affect the growth rate of plants?
  - we set up an experiment testing different amounts of fertilizer on different plants & measuring the growth (height) of the plants:
    - dependent variable (Y-axis)?
      - height of plants
    - independent variable (X-axis)?
      - amount of fertilizer



Examples of experiments 2

- How does exercise affect heart rate of 10th grade student?
  - we set up an experiment testing different lengths of time of exercise (minutes) on the heart rate of students:
    - dependent variable (Y-axis)?
      - heart rate
    - independent variable (X-axis)?
      - minutes of exercise



Controlled Experiments

Suppose you were testing the effects of a drug. You believe that this medication will lower blood pressure. You have your experimental group take the drug and measure their blood pressure before taking the medication as well after and blood pressure decreased.

- **Did the blood pressure decrease because of the medication? You sure?**
  - **Might there be other variables that caused decrease?**

What about the Placebo Effect? What if by being given a pill with medication in it, the subject psychologically believed their blood pressure should decrease and so they relax mentally causing their blood pressure to decrease but not because of the drug itself.

Controlled Experiments

One way to pinpoint the effects specifically of the drug is to divide the subjects being tested into two groups. Scientists will try to control both groups to keep them as identical as possible and keep the environment as identical as possible.

- **Then only *one* group will be given a pill that actually contains the drug while the other group gets a fake pill that looks the same but has no medicine in it!!!**
- **One group gets a certain level of the independent variable (amount of medication) and the other doesn't.**

One group gets a certain TREATMENT and the other does not.

- **The blood pressure can be checked in both the group receiving the drug (experimental group) and the group that did not receive the drug (control group).**
  - **The effects of the drug is now isolated since, though both groups take a pill, the medication is the *ONLY* thing that differs between the two groups.**

Controlled Experiments

- **Ideally experiments are made up of an experimental and a control group that differ in only 1 factor, this being the factor that the experiment is designed to test the effects of.**
  - **The control group remains "constant" during the experiment *(It doesn't receive the TREATMENT)***
- **Control group: The group of subjects that is not manipulated.**
  - **They are the foundational point to compare the experimental group against.**
- **Experimental group: The group being treated, or otherwise manipulated, for the sake of the experiment *(aka treatment group).***
  - **This group is identical to the control group EXCEPT that it is manipulated. *It receives a certain treatment.***

Controlled Experiments

To test the effect excessive water drinking has on humans.

Experimental Group: Make a group of people drink a lot of water.

Based on the effects they display you might be inclined to attribute to excessive water drinking.

HOWEVER, how do you know that all the symptoms they display are from drinking lots of water?

Controlled Experiments

Maybe some of the symptoms they display are totally unrelated to water and are the result of some other factor
(like being together in an isolated group or being exposed to UV light if they are standing outside)

Therefore, in order to separate excessive water symptoms from other symptoms you gather a second group of people together and place them in exactly the same environment as the first group **EXCEPT you do not give them excess water.**

This is your control group.

You can now be more confident in claiming that the differences that you observed between your experimental group and your control group are due solely to excess water.

Another example of a controlled experiment…

Hypothesis: Plants will grow taller when given Miracle Grow.

Plants A & B are both given the same amount of light, water, and are stored at the same temperature.

Plant A is given Miracle Grow.

All the variables are kept constant except the one you are testing.

Another example of a controlled experiment…

Plants A & B are both given the same amount of light, water, and are stored at the same temperature. Plant A is given Miracle Grow.

Independent Variable - the factor you change, what you do to your exp. group.

- What is the Independent variable?
  - Miracle Grow

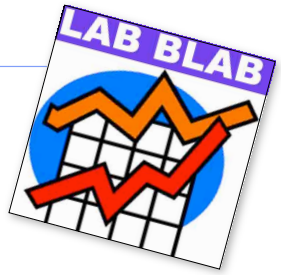
Dependent Variable - what happens as a result of that treatment, what you are measuring

- What is the dependent Variable?
  - Height of the plant

Necessity of a control

Controls are needed to eliminate alternate explanations for the experimental results obtained.

Types of Research & Graphing Your Data



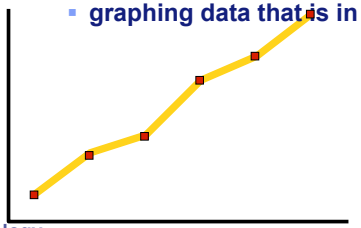
Graphs can show patterns & trends

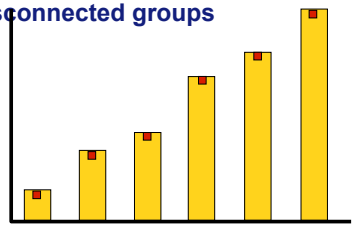
A picture is worth a thousand words!

Making pictures out of data

- A scientist carefully collects and organizes data from the experiment often in tables or graphs.
- Graphs Examples:
  - line graphs
    - graphing data that shows continuous change
  - bar graphs (or histograms)
    - graphing data that is in disconnected groups

How's a critter to choose?



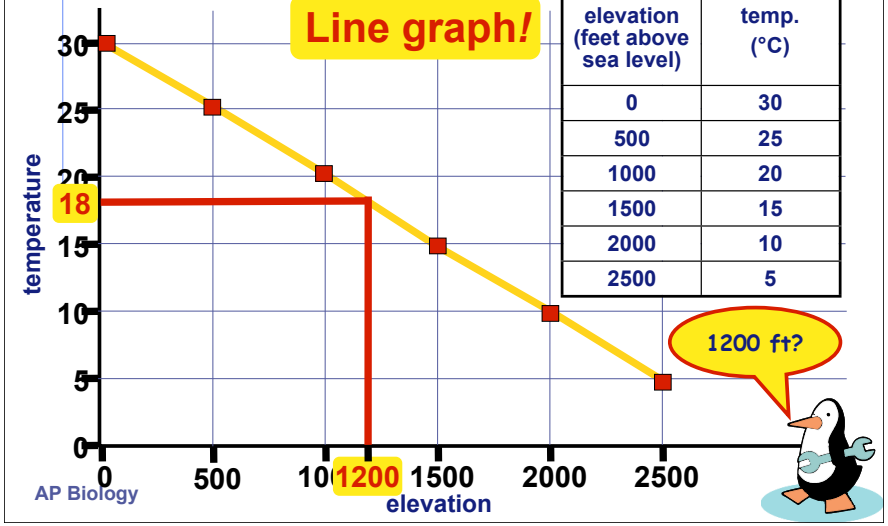


AP Biology

How does elevation affect temperature?

Line graph!

elevation (feet above sea level)	temp. (°C)
0	30
500	25
1000	20
1500	15
2000	10
2500	5

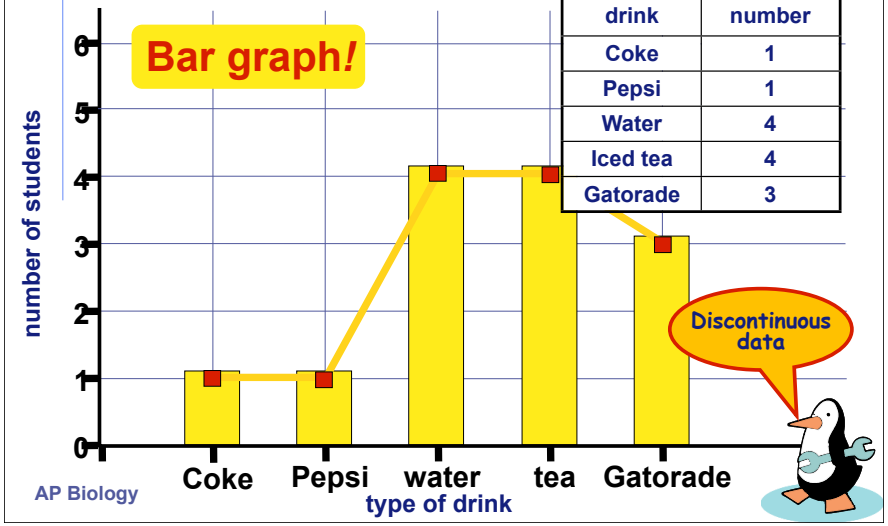


AP Biology

Which drink do you like best?

Bar graph!

drink	number
Coke	1
Pepsi	1
Water	4
Iced tea	4
Gatorade	3



AP Biology

Collecting & Graphing Data

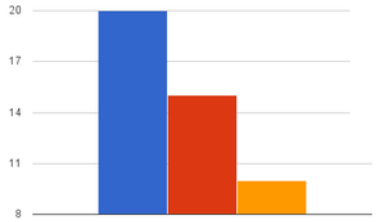
- **Collecting Data**
  - The graph you choose depends on the data and what you want to illustrate/show.

- Based on the data, a scientist determines whether the hypothesis was supported or refuted.
- In science, every conclusion must assume that the conclusion is only "true to the best of our knowledge" not proven.

Data can be powerfully displayed as a graph

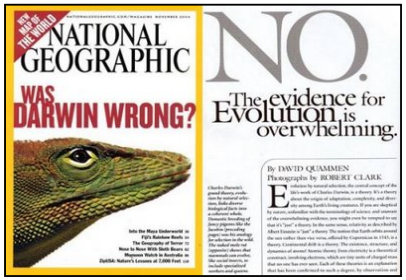
LABEL LABEL LABEL

- **What labels are needed?**
  1. Title (The effect of Independent Variable on Dependent Variable)
  2. Label X-Axis - Independent Variable
  3. Label Y-Axis - Dependent Variable
  4. Always include units of measurement on x and y axis
  5. Include a key to identify meaning of lines or bars
  6. Make sure there is even spacing in x and y unit increments



Credibility in Science

A **hypothesis** gains credibility by surviving repeated attempts to falsify it while testing eliminates (falsifies) alternative hypotheses.



- A THEORY:
  - supported by a large body of evidence in comparison to a hypothesis
  - broader in scope than hypothesis
  - more general than a hypothesis.
- A theory is an explanation for natural events that is based on a large number of observations.

Credibility in Science

- Theories EXPLAIN what we observe.
  - Ex: the Germ Theory explains why we get sick and why we get infections - it uses observation of viruses and bacteria as well as data from those who get ill to create a theory on what causes the illness.

Credibility in Science

- **Theories are changeable, expandable, and FALSIFIABLE. There must be some way that an observation or experiment could prove it to be false *(if it is a wrong explanation).***
  - **Ex: Einstein's theory of Relativity made predictions about the results of experiments, which could have produced results that contradicted Einstein, so the theory was (and still is) falsifiable**
  - **Ex: The theory that ``the moon is populated by little green men who will hide whenever anyone on Earth looks for them'' is not falsifiable: *these green men are designed so that no one can ever see them.***
  - **The theory that there are no little green men on the moon is scientific: *you can disprove it by catching one.***

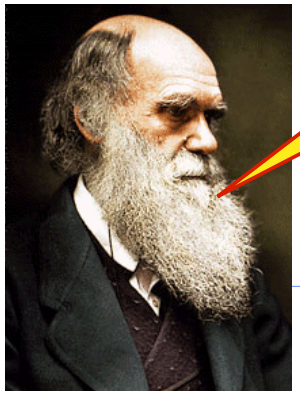
1. **Theories must explain a wide range of observations**
2. **Theories must be falsifiable**
3. **Theories can be changed if new evidence presents itself**

Are there Limitations to what Science can Study?

Science requires natural explanations for natural phenomena.

- **Observations and experimental results must be REPEATABLE *(A sighting of the Virgin Mary cannot be repeated at will)***
- **Hypothesis must be FALSIFYABLE if those explanations are NOT true.**
  (What experiment could ever be done to falsify the existence of unicorns?)

Science cannot support or falsify supernatural explanations, which are outside the bounds of science.



ANY QUESTIONS?