Part I: Science and the Scientific Method

There are many different and often valid ways to look at the world and to explain natural phenomena. For example, history, religion, art, philosophy, literature, astronomy, and sociology all provide ways for people to examine the world we live in, and they all contribute to today’s body of knowledge.

Science is one way of explaining the world, and the characteristics of science serve as a basis for establishing what qualifies as science. Several characteristics generally define science.

1) Science is based on the results of observations and experiments
2) The results of these observations and experiments must be (at least in principle) repeatable and verifiable by other scientists.
3) The findings of science must be refutable. In other words, if many scientists have accepted a hypothesis (explanation to a natural phenomena), and later another explanation becomes better supported by evidence, there must be a way to disprove the original hypothesis.
   This same principle holds true for theories: a hypothesis that is supported by many experimental procedures.
4) Science is based on the assumption that the natural world can be investigated and explained in terms we can understand.

Science is also committed to the idea that our explanations will change or become modified through time as new knowledge is acquired. Methods of explaining natural phenomena that do not meet these standards do not qualify as science.

The information and activities that follow in this packet deal with the process that is known as the scientific method. This method is a way of studying the natural world, and developing a body of knowledge called science. The key elements of the scientific method include observations, questions, hypothesis, predictions and tests. It should be noted that it is not possible to study all natural phenomena using all the steps of the scientific method, but the method always acts as a general framework for scientific understanding.

General definitions you should be familiar with:

Assumption - a statement accepted without proof. I assumed that you could read and write when you entered my class.
Observation - an observed or measured phenomena. Observations lead to problems or questions to be answered.
Hypothesis - an idea used as the basis for experimentation. Sometimes called an educated guess to the problem, it describes what is happening in a given situation. It is the “If” part of the “If…then,” statement.
Deduction or prediction - a statement that logically follows the hypothesis. It is the “then” part of the “If…then,” statement. If the hypothesis is correct, then ‘such and such’ should happen. The ‘such and such’ is the deduction. A deduction normally defines how an experiment will be designed.
Controlled experiment - the procedure designed to determine whether the hypothesis - is true. The experiment tests only one variable or factor at a time.
Experimental group - the test group that is exposed to all factors including the experimental variable.
Control group - the test group that is exposed to all factors excluding the experimental variable. All experimental groups are compared to the control group therefore it is considered the standard of comparison for the experiment.
Independent or Experimental variable - the single factor that the experiment tests. Time can be an additional, independent variable.
Dependent variable or Data - the facts collected in an experiment. The data is dependent on the independent variable.
Qualitative and Quantitative data - Qualitative data cannot be measured and is subjective or based on the opinion of the scientist. Quantitative data is objective, not based on opinion and can be measured.
Controlled variables - factors that are kept constant between the experimental and control groups so that you can observe the effect of the experimental variable alone.
Analysis - the interpretation of the data. What do the numbers or observations mean?
Conclusion - whether the hypothesis has been supported by the data. A conclusion of a controlled experiment is one of the following: The data supports the hypothesis, or the data do not support or rejects the hypothesis.

**Sequence of Steps in The Scientific Method**

**Observations**- of natural phenomena and information from other sources such as the Internet, library or other researchers.

[Diagram: Observations may lead to Questions]

**Questions**- ask, “What is causing the observed phenomena?”

[Diagram: Questions which lead to Hypothesis]

**Hypothesis**- an educated guess that answers the question asked. The hypothesis identifies a factor called an experimental variable, that may be causing the outcome of observations.

[Diagram: Hypothesis must be tested by Controlled Experiment]

**Controlled Experiment**- A procedure designed to test the effect of the identified variable. Only one variable is tested at a time.

Contains two parts:

a) **Experimental/test/variable group**- group of test subjects that will receive the experimental variable.

b) **Control group**- group of test subjects that do not receive the experimental variable or they receive a standard level of the variable.

NOTE: Both the experimental and control groups are exposed to controlled variables.

[Diagram: Controlled Experiment which leads to Prediction/deduction Statement]

**Prediction/deduction Statement**- A statement in “If…,then…” format. If (hypothesis), then (prediction). The prediction statement identifies what the difference between the control and experimental group will be if the hypothesis is true.

[Diagram: Prediction/deduction Statement what follows is Data Collection]

**Data Collection**- observations of the experiment are collected.

Data comes in two forms:

a) **Quantitative data**- data that is measured or counted. For example, the length of a butterfly wing, Quantitative data is objective in that it is not based on emotion or personal opinion.

b) **Qualitative data**- data that is based on the opinion or judgment of the person observing the experiment. For example, how many people like a new flavor of soft drink. Qualitative data is subjective because it is based on personal opinion, prejudices or emotion.
Conditions: data can be placed in tables or graphed to make interpretation of the results easier.

Data undergoes

Analysis- interpretation of the data. An attempt is made to determine if the data supports the hypothesis or rejects it.

Experimenter makes a

Conclusion- a statement that restates the hypothesis as supported or rejected by the data.

There are two possible outcomes to a conclusion:

a) The hypothesis... is supported by the data. In other words, the data collected is the same as expected by the prediction statement. If the hypothesis is supported, the experiment should be repeated many times to further confirm the results. The findings of science must be refutable. A hypothesis can never be proven! Example: The hypothesis, water is essential for life, is supported by the data.

b) The hypothesis... is rejected, refuted or not supported by the data. In other words, the data collected is not the same as expected by the prediction statement. If the hypothesis is rejected by the data, the experimenter will need to rethink the hypothesis and formulate a different hypothesis to explain the observations. Example: The hypothesis, alcohol has no effect on the nervous system, is rejected by the data.

There is usually more than one way to test a given hypothesis. If you want to know if a cancer medication will kill cancer cells, you could test it on cancer cells in a petri-dish. If that works, you may test it in rats, or monkeys. If the data supports your hypothesis, your final test will be on humans.

If a hypothesis is tested and supported many times over, it can lead to the development of a theory.

Theory- The best explanation that science can offer in order to explain a natural phenomenon. A theory is a explanatory hypothesis that is based on many observations and data from experiments.

The development of a theory depends upon the input of many researchers in many different fields of science. For example, the most accepted theory of evolution, proposed originally by Charles Darwin in 1859, has been supported by evidence from such fields of science as zoology, botany, anthropology, archeology, geology, ecology, etc. The theory of evolution by natural selection, as proposed by Charles Darwin, is still the most accepted explanation for how evolution occurs, but recent evidence suggests that there might be other possible mechanisms. As stated earlier, even theories have to be able to be changed in light of new evidence. Today there is a worldwide network of communication between scientists in many countries where information can be shared so that everyone can remain up to date and contribute to ongoing research.

Technological advances, developed using The Scientific Method, allow us to apply scientific discoveries to benefit our lives. Examples include advances such as the microscope, DNA fingerprinting, agricultural advances, genetic engineering, and medical advances such as organ transplants, new medications, artificial hearts and pacemakers.
Homework:
1) Use your own words to define science (include something about the four characteristics of science):
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2) True or False (circle one). Once a scientist collects data to support his hypothesis, it can never be disproven.
3) List the 8 steps to the scientific method (go to pages 2-3 in the packet for the answers):
   _1_______________________________________5
   _2_______________________________________6
   _3_______________________________________7
   _4_______________________________________8
4) What is a hypothesis?
   ______________________________________________________________________________________
   ______________________________________________________________________________________
   ______________________________________________________________________________________
   ______________________________________________________________________________________
5) What are the names of the two, test groups in a controlled experiment?
   _1________________________________________
   _2____________________________________________________________________________________
6) What is the name of the most important factor tested for in a controlled experiment?
   ____________________________variable.
7) What is the difference between a controlled variable and a control group?
   ______________________________________________________________________________________
   ______________________________________________________________________________________
   ______________________________________________________________________________________
8) What is the difference between a experimental variable and an experimental group?
   ______________________________________________________________________________________
   ______________________________________________________________________________________
   ______________________________________________________________________________________
9) What is the difference between a controlled variable and an experimental variable?
   ______________________________________________________________________________________
   ______________________________________________________________________________________
   ______________________________________________________________________________________
10) What is the difference between a hypothesis and prediction statement?

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11) What does the letter ‘d’ in dependent variable stand for? ______________

12) What are the two types of data called? __________________ and ______________

13) Which type of data can be measured? __________________ Which is based on opinion? ______________

14) Omit

15) What does the word interpretation mean? (You can use a dictionary if you wish) ______________

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16) True or False (circle one) A conclusion to an experiment can prove the hypothesis is true.

17) The previous statement is false, correct it.

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18) What is the difference between a hypothesis and a theory?

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19) What is the difference between a theory that states that “All cells come from preexisting cells,” and the ‘theory’ that “Little green men live in outer space?”

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Homework: Science and the Scientific Method

Directions:
- Read the introduction completely before starting this activity. Write in full sentences for credit. Please re-read your sentences out loud. Do they make sense to you? Would someone who was not in class with you know what your answers mean?

Introduction:
Science is more than a lot of information. Science is a way of knowing - it is constantly growing and changing. Scientists carry on an unending search for new information. With that new information, they reevaluate old information to find out if it is still accurate.

The scientific method offers a means of testing ideas and solving problems. Experimentation is the foundation upon which all science rests.

Procedure
The following fictional experiment demonstrates the use of the scientific method.

Many people in the small Midwestern town of Hootville are stricken with the disease "Buggo." Most of those who get sick recover in seven to nine days.

Buggo has been shown to be caused by a bacterium (single for bacteria) called "Gotcha." Antibiotic "X" is a new drug that has been shown to kill Gotcha bacteria in a test tube. Antibiotic X was also found to cure dogs that were sick with Buggo.

Researchers decided to test the new drug on some of the people in Hootville. They hypothesized that the drug would effectively cure Buggo in humans. They decided that if they gave patients Antibiotic X, the patients would recover more quickly than those who did not take the antibiotic.

The researchers prepared tablets containing Antibiotic X. They also prepared a second batch that contained all the same ingredients (inactive ingredients) as Antibiotic X without any antibiotic. A table like this that is similar but without medication is called a placebo.

The researchers selected two groups of people who had just contracted the disease. Twenty-five people in group A were given tablets containing the drug Antibiotic X. Twenty-five people in group B were given the placebos.

Twenty of the twenty-five people given the drug recovered within one day. The other five people took seven to nine days to recover - the normal recovery time for people sick with Buggo.

One of the people given the placebo recovered in one day. The rest of the people in group B took from seven to nine days to recover.

1). List three facts or observations known before the start of the experiment.

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_______________________________________________________________________________________
_______________________________________________________________________________________

2) State the researchers' hypothesis.

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3) Form a prediction statement for the experiment. Use the “If…, then…” format.

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4) What is the independent variable in this study?

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5). Describe a dependent variable for this experiment. Will the data be quantitative or qualitative?

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6) What analysis do you think the researchers made of the data?

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7) What conclusion do you think they reached?

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Homework: Identifying Parts of The Scientific Method:

1) Given the following hypotheses, underline the experimental variable.
   a) Plant growth is dependent on light.
   b) Water is necessary for life.
   c) Bacterial infections of the human ear can be cured by antibiotics.
   d) The survival rate of baby pigs is increased by warm-water baths.
   d) High levels of pesticides in drinking water can reduce egg laying in hens.
   e) The number of colds experienced by school children can be reduced if they take vitamins.
   f) For maximum growth, orchids require a 25-30% nitrogen concentration in the soil.

2) In the following examples, you will read a description of an experiment and identify the experimental and control groups. Underline the control group and circle the experimental group.

   a) An experimenter wants to know the effect of a particular pesticide (poison) on the growth of tobacco caterpillars. One group of caterpillars will be sprayed with 2% pesticide in water and another group will be sprayed only with water.

   b) A hypothesis stating that added vitamins will improve longevity of housecats is being tested. An experiment is run in which cats are fed a normal diet with added minerals and a second experiment will be run with cats fed a normal diet without added minerals.

   c) A doctor predicts that walking two miles per day will improve the health of his cardiac patients. He compares the health of patients that walk two miles per day to the health of patients who don’t.

   d) A horse trainer wants to know if an extra 3 laps around the racetrack will improve the performance of his racing horses. He runs a group of 5 horses for the usual 2 laps around the track and runs a different group for 5 laps around the track.

3) A farmer wants to know if a pesticide application will increase the yield of her crop of tomatoes. She chooses a large field and applies two different pesticides. Each pesticide is applied to one half of the field. At harvest time, she determines the yield (bushels per acre) of tomatoes on each half of the field. Field A yields 35 bushels per acre and Field B yields the same. Her conclusion is that since both halves of the field had the same yield of tomatoes, a pesticide application of some type was necessary. Explain what is wrong with this experiment.

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4) The following statements are in an “If…,then…” format. Underline the hypothesis and circle the prediction. a) If there is life in outer space, then we should be able to pick up radio signals from extraterrestrials. b) If calcium is necessary for healthy bones, then mice fed a diet rich in calcium should have healthier bones than mice fed a regular diet. c) If 20 acres of grassland is necessary to raise one cow, then cows raised on at least 20 acres will be healthier than cows raised on fewer acres.

5) Label each of the following as Qualitative or Quantitative data:
   a) Customers in a pet store are asked to pick their favorite pet.
   b) The altitude (feet above sea level) of several mountains is determined.
   c) Data from taste tests is collected to determine how sour a new candy is.
   d) Length of the index fingers of 8 year old boys is collected.
   e) Color of hair in humans is observed.
   f) The number of scorpions entering an underground den is counted.
   g) A group of students is asked to rate their teacher’s intelligence.

6) Review the format for an appropriate conclusion statement on page 3. Write a conclusion statement for the following experimental results.
   a) An experimenter predicts that the size of the heart in mammals is dependent on the weight or mass of the organism. The data is graphed to the right.
      Conclusion statement:
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      __________________________________________
      __________________________________________
      __________________________________________
   
b) Frogs have the ability to take in oxygen through their skin and through their lungs. An experiment is conducted to determine if oxygen uptake is the same between the two organs. The following results are graphed.
      Conclusion statement:
      __________________________________________
      __________________________________________
      __________________________________________
      __________________________________________
   
c) If either of the hypotheses in the heart mass or frog experiment were rejected, rewrite the hypothesis so that it is supported by the data.