LABORATORY #1 -- BIOL 111
Spring 2018
Science and the Scientific Method

The **scientific method** is the "program" that scientists use to understand the patterns (e.g., how far away is Mars?) and processes (e.g., how did the rocks on Mars form?) that we observe in the natural universe. Because the method is used to understand the natural universe, it cannot be used to ask more metaphysical questions (e.g., did God create Mars?). A person that uses the scientific method considers themself a **scientist**, and you will be a scientist anytime you use this method to understand the biological patterns and processes that you explore in lab. More important, in your daily life, **you** should be able to judge whether a hypothesis of another person is reasonable and well tested and conclusions based on the process are sound.

The most important tool used in the scientific method is not fancy equipment, rare chemicals, or supercomputers; it is the **hypothesis** (plural form is "hypotheses"). A hypothesis is a direct and bold statement/prediction about some aspect of the natural world. For example, the statement "All swans are white" is a hypothesis. A scientist "formulates" a hypothesis and then seeks to "test" the hypothesis (called the **hypothesis test**). This is where the fancy (or sometimes quite basic) equipment comes in. The hypothesis test is not necessarily designed to support the hypothesis; often it is designed to **attempt to reject** the hypothesis.

It may sound like a silly procedure, but the idea is to make as strong an inference about nature as one can. Consider this: one can choose to attempt to support the hypothesis that "all swans are white." How to do this? Find every swan that has ever existed (or will exist), and determine its color. Sound impossible (or at least very expensive)? Indeed it is. The best one can do in this case is to find a little bit of evidence that might support the idea that all swans are white. But it leaves us wondering…have we done enough to test our hypothesis?

Now try this: Find a single non-white swan. You have now rejected the hypothesis that all swans are white and have made the very strong statement that "Not all swans are white." That's convincing.

Another advantage of the "silly" procedure of rejecting hypotheses is that it provides a good scientist a means of being objective (i.e., non-biased). The good scientist tries hard to reject the favorite hypothesis; this helps to avoid the temptation to find support by biasing one's observations/data collection or by falsifying ("fudging") data. Scientists must be careful. **In the end, scientists strive to test hypotheses until they have one that cannot be rejected with the most careful testing possible at the time. The evidence coming from these tests, provides support which should be trusted until/unless that hypothesis can be rejected. For example, virtually any medicine or medical treatment you receive has been thoroughly tested based on hypotheses! We trust that the evidence led to the best approach to medical treatment.**

Today you will use the scientific method with sealed boxes. You will formulate hypotheses (with support) based on your life experience, perform hypotheses tests (without any fancy equipment), work as a team (both at your table and with the whole class) to evaluate the outcome of your tests, and then make reasonable conclusions about the contents of the boxes.

Procedure---read your lab requirements (next page) completely before beginning!!!

1. To start, each team should obtain one of 6 boxes. Each box has some unknown item(s) inside. You will be attempting to characterize (i.e., describe) the item(s) without ever seeing it or touching them.

2. After doing some preliminary/quick observation (scientists would call this a "pilot study"), formulate a hypothesis about the object. Don't be afraid to develop a hypothesis you can reject easily! (e.g., "I hypothesize that box # 4 contains ten gold bricks and a kitten").

3. Explain your hypothesis. Write it down, being as explicit as possible (i.e., after your quick observation, how did the box feel, sound, weigh, etc. How did this information lead you to your hypothesis?)

4. Develop a test for your hypothesis. (be more careful now than in your pilot study).

5. Interpret the results, i.e., would you "reject" or "fail-to-reject" your hypothesis? Make sure you explain your interpretation.

6. If you reject your hypothesis, refine the hypothesis and do more careful testing…repeat steps 3-5.

Keeping track of each hypothesis on scratch paper, repeat with each of the other boxes.

7. Following the directions of your instructor, share your conclusions on the contents of the boxes with the whole class. Pretend you are scientists from around the world working on the same scientific problem. The goal is to see whether you may have independently solved the problem and to reinforce your confidence in the hypothesis.

***Importantly, you may never look inside the box. This is an important lesson of this exercise. Scientists often do not get to look "inside the box." Your sense of this idea will increase during this semester. Thus, good scientists always entertain the notion that what they think is completely wrong. The scientific method is what defines the scientist. **Science is not a collection of facts about the universe (a collection of facts about the universe is called "a collection of facts about the universe"). Science is a process by which things can be known.**

Name_____

1. Write the number of your favorite box.

2. Write a hypothesis you eventually rejected for this box. (Be sure to explain, why you chose the hypothesis, even though you eventually rejected it.)

3. Explain the tests you did and why you rejected this hypothesis.

4. Write a hypothesis you eventually failed to reject for this box. (Be sure to explain, why you chose the hypothesis, and why you failed to reject it). How did you change your tests? Why did you fail to reject this hypothesis---write the evidence!

4. For which box/items was there the greatest consensus (i.e., agreement) among all groups of scientists (your classmates)? How specific were you able to be? Did your confidence increase when you saw the class results? What level of confidence do you have in this inference about the unknown item (s)? For example, are you 50% sure or 92% sure of the contents? Provide some reasoning to support your response to this question.