SCIENTIFIC METHODOLOGY

Methodology is how we design, or look at, scientific experimention. Basic methodology is consistent throughout science disciplines. Therefore, an understanding of methodology can help you in all of your science courses. It may even help you interpret everyday phenomena outside the classroom! The greatest scientific discoveries and the most simple ones are both fueled by CURIOSITY. You must be curious enough to observe "something", ask a question about it, identify a testable component and perform the experiment. Believe it or not, you do most of this every day. With practice, identifying these steps and putting them into correct scientific language will become second nature.

General Steps

- observation
- questioning
- testable statement
- experimentation
- analysis

Observation

Observing is using one or more of the senses to perceive the world around you. In the classroom what you observe and the sense you use is often predetermined - but not always.

Questioning

Ask questions about what you observe. Be curious! Questions will later be framed with experimental design and, therefore, need to be phrased in a testable, interpretive manner. Do not start questions with "How", or "Why". For example, "How come bubbles are round?" or "Why are bubbles round?" These questions cannot be tested - they are too general and must be answered with an explanation. (In general, if a first response to the question begins, "Because..." then it was not phrased properly.) When the bubble questions are phrased this way, "Are all bubbles round?" they now present a testable question. We can examine all of the bubbles and answer "yes", or "no".
It's OK if your question leads to more questions - that is a sure sign of curiosity at work! For example, the bubble question may lead you to ask. "If the shape of the wand is square will the bubbles be square?" or "Is there something in bubble juice that makes them round?" We can test these questions.

Testable Statement / Hypothesis

Now we must take our question and write it in scientific language. We will make a testable statement. This statement will predict what outcome we think we will see. **If** "this is done ..." **,then** "this will happen". For example,"**If,** bubbles are blown with a round wand, **then** all of the bubbles will be round." "**If** bubbles are blown with a square wand, **then** all of the bubbles will be square." It should be cut-and-dry. Did it happen or not? The best statements are not subjective or vague. They do not predict that "sometimes" something will happen, or that *MAYBE* something will happen. As a rule, the more detailed your statement, the more testable it is likely to be and the more likely it is to fit easily into experimental design . "If 100 bubbles are blown with the same wand, then all 100 bubbles will be round." "If 100 bubbles are blown with the same wand, then 50 will be round and 50 will be square."

Did you notice the two words **"If"** and **"then"**? In this class, all testable statements **must be** written this way. (The explanation for this will be made clear to you soon.) It is OK to write a statement that is false, or will not be supported by the experimentation - you still learned something, right? You do not score more points because your data supported your prediction. Likewise, don't be tempted to go back and rewrite your statement *after* the experiment.

Experimentation

During this step, the statement you made about your observation will be tested. Your experiment will provide either support, or a lack of support (by way of data) for your statement. **Be advised:** During this class WE WILL NOT **PROVE** ANYTHING. Our experimentation will only *support* or *not support* our predictions.

Before any experimentation can take place, the experiment must be designed. This means that components of the experiment must be clarified. These components are described in the section **Experimental Design.**

Experimental Design

The basic concepts of experimental design are:

1. the hypothesis or testable statement
2. variables
3. a control group
4. constants
5. repeated trials

1. Hypothesis / testable statement: We have already covered this. What observation have you made that has led you to ask a question? Now, change the question into a statement. Remember - a *question* is an **asking** sentence and a *statement* is a **telling** sentence.

Your statement has two components within it that are called variables. The phrase that follows the **"If"** is called the *independent variable* and the phrase following the **"then"** is called the *dependent variable* . Keep reading!

2. Variables:
Variables are factors in an experiment that can change. (temperature, weight, height, instrument readings, etc.) Each experiment has several kinds of variables.

Manipulated (**Independent**) **variable**: The IV is the aspect of the experiment that is changed or manipulated. It is what "you" will do (or change) to cause a response. It will be the difference between your experimental group(s) and your control (see below). Independent variables can be used at varying levels. For example, if your IV is weight, the levels may be 0 mg, 5 mg, 10 mg, and 15 mg. ***You can have ONLY **ONE** independent variable in an experiment! Do you know why?

Responding (**Dependent**) **Variable**: The DV is the response that the IV caused. It is what you are observing, measuring or recording. In an experiment you can actually measure several dependent variables; however, we will usually focus on just one.

Constants: Constants are alternate independent variables that we keep the same throughout every aspect of the experiment to ensure that they will not cause the change (i.e., act as the IV). For example, if we wanted to see the effect of fertilizer (IV) on plant growth (DV), we would need to see that the same species of plant was used, same age, same type and amount of soil, same exposure to light and water ... The only difference between the plants would be whether or not it received fertilizer. This way we will know that it was ONLY the fertilizer that caused the change (DV).

3. Controls:
Controls are a very important part of experimentation. A control is the level of IV that you will compare all the other levels to. It is generally the level at which you do nothing. For example, with the plants, it is the plant that received NO fertilizer (the IV). With the IV weight, the level of "zero weight" would be the control. With solutions and chemical reactions, water usually acts as the control. **A control has to be the level at which you know a change will not occur**. This way you can verify that the DV actually took place and was caused by the IV.
Also, there are more than one type of control - positive and negative. **A positive control** should give a standard result. **A negative control** should not work. For example: If you wanted to test whether or not an unknown solution contained glucose, your positive control would be a solution containing pure glucose you purchased and your negative would be pure water - which we know does not contain glucose.

4. Repeated Trials:
Scientific investigations are not valid if based on one experiment. The more repetitions of an experiment that are performed, the more likely it is that the data are true (valid). We will seldom be able to repeat experiments due to the constraints of time and supplies. In research laboratories it often takes months to repeat and collect data. Data collected usually falls onto a bell-shaped curve. The more points you have to place on the curve, the smoother the curve will be. A need to repeat the investigation can always be used as a way to improve the experiment and increase its validity.

Analysis

During experimentation, data will be collected for analysis. (Collection and display of data will be covered in the section on Laboratory Write-Ups.) Both data collection and data analysis must be performed in very formal ways. Now that you are familiar with the variables of an experiment, both of these steps will be easier. In general, during analysis, you will take a close look at the data and search for trends or relationships that compare the **actual** results with the **predicted** results (what you hypothesized). During analysis, data is usually graphed and the results are also compared to work from other researchers. Analysis is a time to record modifications or improvements for the experimental design, mention areas for further study, and discuss sources of error (if any). If it seems that the analysis portion is involved - it is! Yet, this is where you get to show off your smarts and give the world a logical explanation - based on fact - for why something happened! **COOL!**

Now let's learn how to properly write-up all this information.
Laboratory Write-Ups

Name: ______________________________ **Date:** _______

Scientific Methodology: Questions to answer

1. What is the difference between an observation and an inference?

2. What is a testable question?

Make up three testable questions and write them below (use past science labs for reference. Do not write the same question that is in the handout!!).

1)

2)

3)

3. Write one hypothesis in **If......then....** format for one of your testable questions.

4. Instead of saying that your experiments PROVE your predictions, what should you say about your findings of your experiments?

5. What is the difference between an independent and a dependent variable (we will use the terms manipulated and responding variable)?

6. If I was measuring how many chocolate chips there are in different brands of cookies, identify the type of variable below (independent or dependent) :

#of chocolate chips per cookie   Different brands of cookies

7. Why are controls important? (what do they tell us)

8. What should be included in your analysis?