AP Biology: Laboratory 1: Principles of the Scientific Method

Pre-Lab

Pulse & Fitness Exercise

Before coming to class carefully read the following pages on the scientific method then answer these pre-lab questions. Be prepared to share at the start of class.

1. **Restate** the following hypothesis in an **"If-Then-Because"** statement. Hypothesis: Students that study two-hours outside of class for every one-hour in class usually get better grades than students that study half that amount of time.

2. **Identify** the independent and dependent variables in the following experiments:

Pea plant height measured daily for 30 days.

Dependent variable:

Independent variable:

Number of leaves found on pea plants 5 days after having been treated with gibberellic acid.

Dependent variable:

Independent variable:

3. **Suggest** a control for each of the following two experiments:

Pea plants are sprayed with an aqueous solution of gibberellic acid and their height determined daily after the spraying.

Control:

Pulse rate is determined after 3 minutes of aerobic exercise. (Hint: the control is what the pulse after exercise will be compared to.)

Control:

4. **Should** the data obtained from the following experiment be plotted as a line graph or a bar graph? ***Briefly*** explain your reasoning: **Pea plant height measured daily for 30 days.** (See **Appendix A** for help.)

Line graph or **Bar Graph** (circle one) **Why?**

5. **Write** a question, a hypothesis, and identify the independent, dependent and three control variables that you would like to investigate in this experiment (pulse experiment). **See pages of the Perspectives for help.**

Laboratory 1: Principles of the Scientific Method: Procedure

Adapted by permission from Steve Brumbaugh from the Green River Biology Lab Manual

Perspectives

Biology is a dynamic field of study whose aim is to unravel the mysteries of life itself. Throughout history, humans have been curious about the world around them. Through the millennia people have observed the natural world and have asked, "why?" Those that have advanced our biological knowledge the most, whether the great scientists of the centuries before us, such as Robert Hooke (discovered cells in 1665) and Charles Darwin (co-developer of the theory of evolution by natural selection in 1859), or modern molecular biologists such as James Watson and Francis Crick (discovered the structure of DNA in 1953), have certain traits in common. They have inquiring minds, great powers of observation, and they use a systematic approach to answer the questions that intrigue them, the scientific method, which is similar to you.

In this course you will have ample opportunity to develop your scientific skills. The laboratory exercises are designed not only to stimulate your curiosity and heighten your powers of observation, but also to introduce you to and allow you to practice the scientific method. This laboratory activity will allow you to practice the scientific method as you study the factors that influence your <u>pulse</u> and <u>level of physical fitness or the Fibonacci Series and the Fibonacci Ratio (sometimes called the Golden Ratio).</u> Let's first learn a bit about the scientific method in more detail.

Scientific Method

The scientific method is neither complicated nor intimidating, nor is it unique to science. It is a powerful tool of logic that can be employed any time a problem or question about the world around us arises. In fact, we all use the principles of the scientific method daily to solve problems that pop up, but we do it so quickly and automatically that we are not conscious of the methodology. In brief, the scientific method consists of

- Observing natural phenomena
- Asking a question based on one's observations
- Constructing a hypothesis to answer the question
- Testing the hypothesis with experiments or pertinent observations
- Drawing conclusions about the hypothesis based on the data resulting from the experiments or pertinent observation
- Publishing results (hopefully in a scientific journal!)

Observations

The scientific method begins with *careful* observation. An investigator may make observations from nature or from the written work of other investigators, which are published in books or research articles in scientific journals, available in the storehouses of human knowledge, libraries.

Let's use the following example as we progress through the steps of the scientific method. Suppose that over the last couple of years you have been observing the beautiful fall colors of the leaves on the vine maples that grow in your yard, on campus, and in the forests in the Cascade Mountains. You note that their leaves turn from green to yellow to orange to red as the weather turns progressively colder and the days get shorter and shorter. However, the leaves do not always go through their color changes on exactly the same days each year.

Questions

It is essential that the question asked is a ***scientific question***. I.e. The question must be ***testable, definable, measurable*** and ***controllable***. For example, one would have a tough time trying to test the following question; "Did a supernatural force create all life on earth?" Moreover, since the concept of supernatural force has many different meanings and definitions, it is difficult to define what is a supernatural force. Since this question is *not* a scientific question, and hence not testable, it becomes very difficult to obtain evidence to support this question.

Now, back to the vine maple example...Being a curious and inquisitive person you ask, "What's causing or stimulating the vine maple's leaves to change color?"

Hypotheses

The next step in the scientific method is to make a hypothesis, a tentative answer to the question that you have asked. A hypothesis is an educated guess that is based on your observations. It's a trial solution to your question that you will test through experimentation. Hypotheses are often stated as "If... then...because" statements.

Now back to the vine maples. You have noted that vine maples change color in the fall on *approximately* the same dates each year, but this varies by a week or two each year. You hypothesize, since air temperature is not constant each year in the fall, the progressively cooler days in fall are responsible for stimulating the color changes. Therefore, you develop and wish to test the following hypothesis: <u>If</u> progressively cooler temperatures are responsible for stimulating the color changes in the leaves of vine maples, <u>then</u> vine maples placed in an artificially cooled growth-house should go through the same color changes as would the vine maples in nature, even if the length of day/night are held constant via artificial lighting. The <u>because</u> piece would be any prior research you might have done to support this statement.

Testing Hypotheses via Experiments or by Pertinent Observations

The next step of the scientific method is to design an experiment or make pertinent observations to test the hypothesis. In any experiment there are three kinds of variables.

- **Independent variable:** The independent variable is the *single* condition (variable) that is manipulated to see what impact it has on a dependent variable (measured factor). The independent variable is the factor that causes the dependent variable to change. E.g. the temperatures the trees are exposed to is the independent variable in the vine maple example. The independent variable is the factor (i.e. experimental condition) you manipulate and test in an experiment. A great challenge when designing an experiment is to be certain that only one independent variable is responsible for the outcome of an experiment. As we shall see, there are often many factors (known as ***controlled variables***) that influence the outcome of an investigation. We attempt, but not always successfully, to keep all of the controlled variables constant and change only one factor, the independent variable, when conducting an experiment.
- **Dependent Variable:** The thing measured, counted, or observed in an experiment. E.g. the color of leaves is the dependent variable in the vine maple example.
- **Controlled Variables:** These are the variables that are kept constant during an experiment. It is assumed that the selected independent variable is the only factor affecting the dependent variable. This can only be true if all other variables are controlled (i.e. held constant). In the vine maple example: species of vine maple, age and health of the trees used, length of day, environmental conditions such as humidity, watering regime, fertilizer, etc. It is quite common for different researchers, or for that matter, the same researcher, to get different and conflicting results while conducting what they *think* is the very same experiment. Why? They were unable to keep all conditions identical, that is, they were unable to control all controlled variables.

In an experiment of *classica*l design, the individuals under study are divided into two groups: an ***experimental group*** that is exposed to the independent variable (e.g. the group of trees that are exposed to the varying temperatures), and a ***control group*** that is not. The control group would be exposed to the *identical* conditions as the experimental group, but the control group would not be exposed to the independent variable (e.g. The control group of vine maples would be kept at a constant temperature, everything else would remain identical.)

Sometimes the best test of a hypothesis is not an actual experiment, but pertinent observations. One of the most important principles of biology, Darwin's theory of natural selection, was developed and supported by his extensive observations of the natural world. Since Darwin's publication of his theory, a multitude of experiments and repeated observation of the natural world continue to support Darwin's theory.

An *important* hypothesis may become a theory after it stands up consistently to repeat testing by other researchers. A ***scientific theory*** is a hypothesis that has yet to be falsified and has stood the test of time. Hypotheses and theories can only be supported, but *cannot* be proved true by experimentation and careful observation. It is impossible to prove a hypothesis or theory to be true since it takes an infinite number of experiments to do this, but it only takes *one* experiment to disprove a hypothesis or a theory. Scientific knowledge is dynamic, forever changing and evolving as more and more is learned.

Conclusion

Making conclusions is the next step in the scientific method. You use the results and/or pertinent observations to test your hypothesis. However, you can never completely accept or reject a hypothesis. All that one can do is state the *probability* that one is correct or incorrect. Scientists use the branch of mathematics called statistics to quantify this probability. Later you will use a statistical test called the Chi-square test to determine the probability that your hypothesis is correct.

Publication in a Scientific Journal

Finally, if the fruits of your scientific labor were thought to be of interest and of value to your peers in the scientific community, then your work would be submitted as an article for publication in a scientific journal. The goal of the scientific community is to be both cooperative as well as competitive. Research articles both share knowledge and provide enough information so that the results of experiments or pertinent observations described by those articles may be repeated and tested by others. It is just as important to expose the mistakes of others, as it is to praise their knowledge.

Exercise A: Pulse and Fitness Exercise

Goals of Lab Exercise

- Learn *proper* graphing technique
- To learn and apply the steps of the scientific method to answer questions concerning physical fitness

Introduction (Background)

The Circulatory System

To carry out the steps of the scientific method, a substantial amount of research on the topic to be studied must sometimes be carried out. Below (or on a separate sheet of paper), please do online research on the circulatory system. Please emphasize the following:

1. **Primary function**
2. **Components**
3. **Mechanics behind a heartbeat (including the origination of the electrical stimulation)**
4. **Factors which affect the rate of the heart's beating**
5. **How a person's heart rate is measured**
6. **How exercise historically has been affected by fitness level (other studies that have been done)**

In this experiment, you will evaluate your physical fitness. An arbitrary rating system will be used to "score" fitness during a variety of situations. Tests will be made while in a resting position, in a prone position, as well as during and after physical exercise. Let's now take a look at the Scientific Method

Procedure

Developing a Question, Hypothesis, and performing an Experimental Procedure

1. In teams of 3-4, take a few minutes to discuss **several** specific questions about an independent variable related to cardiovascular fitness peculiar to your group. Select your group's best question and propose a testable hypothesis. Record on the Report Sheet (page 11).
2. Write your group's best question and hypothesis on the Report Sheet and contribute your group's question and hypothesis on the front board.
3. Cardiovascular fitness will be assessed for two individuals (one male/one female) in each group by determining and comparing the pulse rate while **standing**, **reclined**, **going from a reclined to a standing position**, and **before and after physical activity** as outlined in steps 1 - 11, under **Collecting Data from Test Subjects** (below). The question you will focus on is **"Is there a difference in cardiovascular fitness between males and females?"**
4. Develop a testable hypothesis of the "If....., then....., because…." variety. Record on the Report Sheet.

The Set Up

1. Each person in the group should practice measuring his/her own pulse while sitting. Two individuals in each group will be subjects. The data for each will be entered in Tables 6A and 6B. The other members of the group should record the data during the exercise. The group will share the data from both subjects after both subjects have completed the data collection.

Collecting Data from Test Subject

1. Stand upright, measure your pulse and then enter it in **Table 6A** or **6B**.
2. Compare your pulse rate to the values in **Table 1**. Assign fitness points based on **Table 1** and record on the Report Sheet.

Beats per minute	Fitness points	Beats per minute	Fitness Points
< 60 - 70	**12**	101 – 110	**8**
71 -80	**11**	111 – 120	**7**
81 - 90	**10**	121 -130	**6**
91 -100	**9**	131 -140	**4**

Table 1 Fitness Points for Standing Pulse Use this table to assign fitness points based on the subject's standing pulse.

3. Recline on the floor with your feet on the floor and knees bent. Wait until your pulse becomes stable, and then record it on the Report Sheet. Remain reclined until step 5.
4. Compare your reclining pulse to the values in **Table 2**, assign fitness points based on **Table 2**, and record the points on the Report Sheet.

Beats per minute	Fitness points	Beats per minute	Fitness Points
< 50 - 60	**12**	81 – 90	**8**
61 - 70	**11**	91 – 100	**6**
71 - 80	**10**	101 -110	**4**

Table 2 Fitness Points for Reclining Pulse Use this table to assign fitness points based on the subject's reclining pulse.

5. Quickly stand up next to the lab table and remain still. Measure your peak pulse upon standing and then record it on the Report Sheet.
6. Find how much the pulse increased after standing by subtracting the reclining rate value in Step 3 from the peak standing value in step 5.
7. Assign fitness points corresponding to your reclining to standing pulse in **Table 3** and record the fitness points on the Report Sheet. Stop data collection.
8. Stand and begin collecting pulse. Wait until the pulse becomes stabile, and then record your pulse in on the Lab Report Sheet.

	Pulse Increase after Standing				
Ave. Reclining rate (beats/min)	**0–10**	**11–17**	**18–24**	**25–33**	**34+**
50–60	12	11	10	8	6
61–70	12	10	8	6	4
71–80	11	9	6	4	2
81–90	10	8	4	2	0
91–100	8	6	2	0	0
101–110	6	4	0	0	0

Table 3 Fitness Points for Reclining to Standing Use this table to assign fitness points based on the subject's reclining to standing pulse changes.

9. Engage in aerobic exercise for three minutes by running in place. Record on the Report Sheet your pulse after 3 minutes of exercise. Your pulse immediately after the three minutes of exercise is a good estimate of how high it got during the exercise. Don't overdo it. The goal is not to shoot your pulse rate through the roof.
10. Subtract the standing pulse before exercise (Step 8) from the average pulse during exercise (Step 9). Record this pulse increase in the endurance row on the Report Sheet.

Standing rate	**Pulse increase after exercise**				
(beats/min)	**0–10**	**11–20**	**21–30**	**31–40**	**41+**
60–70	12	12	10	8	6
71–80	12	10	8	6	4
81–90	12	10	7	4	2
91–100	10	8	6	2	0
101–110	8	6	4	1	0
111–120	8	4	2	1	0
121–130	6	2	1	0	0
131+	5	1	0	0	0

Table 5 Fitness Points for Endurance Use this table to assign fitness points based on the subject's endurance rate.

11. Assign fitness points based on **Table 5** and record the value on the Report Sheet.

Report Sheet
Pulse & Fitness Exercise

Lab Section __________.
Group Names ___________________.
___________________.
___________________.
___________________.

<u>Question, Hypothesis, and Experiment</u>:

From step 1 of the Procedure:

1. Your group's best **question**:

Your group's **hypothesis**:

From step 2 of the Procedure:

2. **Question** selected by the class to investigate: **Is there a difference in cardiovascular fitness between males and females?**

Hypothesis proposed by the class:

Summary of the experimental procedure. NOT step by step, just a summary!!!

3. **List** below the various components of the experiment design

⇒ Dependent variable(s):

⇒ Independent variable(s):

⇒ Controlled variable(s):

Data:

						Treatment 1: MALE **Number of subject your group tested**:												
Situation:	**Pulse**									**Fitness Points**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Standing pulse (beats/min)																		
Reclining pulse (beats/min)																		
Peak pulse upon standing (beats/min)																		
Standing pulse just before step test (beats/min)																		
Ave. Pulse during step test (beats/min)																		
Endurance (beats/min)																		
				Total fitness points														
				Average total fitness points for treatment 1														

Table 6A Subject #1 Data Table Record your pulse and fitness points on this table captured from the male subject.

Data:

						Treatment 2: FEMALE **Number of subject your group tested**:												
Situation:	**Pulse**									**Fitness Points**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Standing pulse (beats/min)																		
Reclining pulse (beats/min)																		
Peak pulse upon standing (beats/min)																		
Standing pulse just before step test (beats/min)																		
Ave. Pulse during step test (beats/min)																		
Endurance (beats/min)																		
				Total fitness points														
				Average total fitness points for treatment 2														

Table 6B Subject #2 Data Table Record your pulse and fitness points on this table captured from the female subject.

Graphing the Data:

1. Read carefully "Graphing of Data" in **Appendix A**, and then construct a graph using Google docs that will assist you in interpreting the results from this investigation.
   - Graph **average total fitness points** for treatment 1 (male).
   - Graph **average total fitness points** for treatment 2 (female).
   - Appropriately **label** the graph with a **figure number**, **title**, and **descriptive sentence**.

PASTE/TAPE GRAPH HERE

Conclusions: (typed and attached to this packet)

1. Does the data support or refute the hypothesis proposed by the class? Explain **using data from the experiment** (refer to your figures**)**.
2. **Summarize** the trends in fitness displayed on your graph by referring to the data displayed on your graph (*refer to your Figure 1*).
3. **Using your data** (referring to a figure number), are there additional conclusions one could draw from this experiment?
4. Explain why an experiment has only one independent variable, **and** identify the independent variable for this experiment?
5. How could this experiment be improved to get results that would allow the formulation of more valid conclusions? Give specific ways the experiment could be improved!

Appendix A: Criteria for Graphing Scientific Data

Often the first step in analyzing the results of an experiment is the presentation of the data in the form of a graph. A **graph** is a visual representation of the data, which assists in bringing out and finding the possible relationship(s) between the independent and dependent variables. Examination of a graph makes it much easier to see the effect the independent variable has on the dependent variable(s).

Accurate and clearly constructed graphs will assist in the interpretation and communication of your data, and when presenting a well-documented argument supporting or falsifying your hypothesis in the final steps of a scientific investigation. All graphs should be easy to interpret and labeled fully. The following guidelines will help you construct a proper graph.

Graphing tips

1) Use graph paper of a high quality. **(or computer generate the graph)**
2) A ruler should be used to draw axes and to plot data neatly and accurately.
3) *Always* graph the independent variable on the x-axis (horizontal axis), and the dependent variable on the y-axis (vertical axis).
4) The scales of the axes should be adjusted so that the graph fills the page as much as possible. The axes often, but not always, start at zero. Choose your intervals and scales to maximize the use of the graph paper. Intervals should be logically spaced and easy to interpret when analyzing the graph (e.g. intervals of 1's, 5's, or 10's are easily interpreted, but non-integer intervals (e.g. 3.25's, 2.33's, etc.) are not.
5) Label both axes to indicate the variable and the units of measure. Write the specific name of the variable. Do *not* label the axes as the dependent variable and independent variable. Include a legend if different colors are used to indicate different aspects of the experiment.
6) Graphs (along with drawings, and diagrams) are called ***figures*** and are numbered consecutively throughout a lab report or scientific paper. **Each figure** is given a number, a title that describes contents, and an informative sentence giving enough information for the figure to be understandable apart from the text (e.g. **Figure 1 Temperature and Leaf Color Change**: **The relationship between the change in vine maple leaf color and changes in ambient temperature**). Generally, this information is placed *below* the figure or graph.
7) Choose the type of graph that best presents your data. Line and bar graphs are the most common. The choice of graph type depends on the nature of the variable being graphed.

Line Graphs are used to graph data that only involves ***continuous variables***. A continuous variable is capable of having values over a continuous range (i.e. anywhere between those that were measured in the experiment). For example, pulse rate, temperature, time, concentration, pH, etc. are all examples of continuous variables (**Figure 1**).

Making Line Graphs

1) Plot data as separate points. Make each point as fine as possible and then surround each data point with a small circle. If more than one set of data is plotted on the same graph, distinguish each set by using circles, boxes, triangles, etc.
2) Generally, do not connect the data points dot to dot. Draw smooth curves, or if there appears to be a linear relationship between the two variables, draw a *line of best fit*.
3) If more than one set of data is plotted on a graph, provide a key of legend to indicate identify each set. Label the graph as a figure, give it an informative title, and a descriptive sentence.

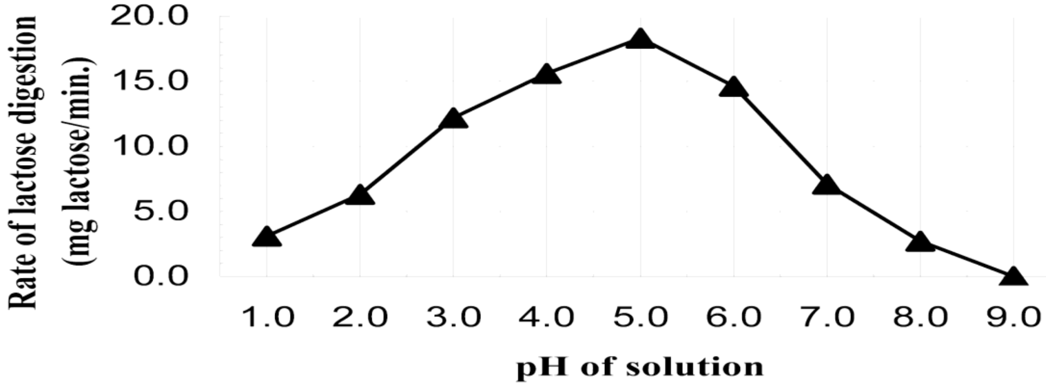

Figure 1 pH Effects on Lactase Note that a line graph was used to graph the data because both variables, pH and the rate of digestion, are *continuous* variables.

Bar Graphs are used if the data involves a ***discrete variable (non-continuous variable)***. A discrete variable, unlike a continuous variable, cannot have intermediate values between those measured. For example, a bar graph (**Figure 2**) would be used to plot the data in an experiment involving the determination of chlorophyll concentration (chlorophyll concentration is a continuous variable) found in the leaves of different tree species (The discrete variable is the species of tree). Bar graphs are constructed using the same principles as for line graphs, except that the vertical bars are drawn in a series along the horizontal axis (i.e. x-axis). In the example below, a bar graph was used to graph the data because tree species is a discrete variable since it is impossible to have a value or species between those used.

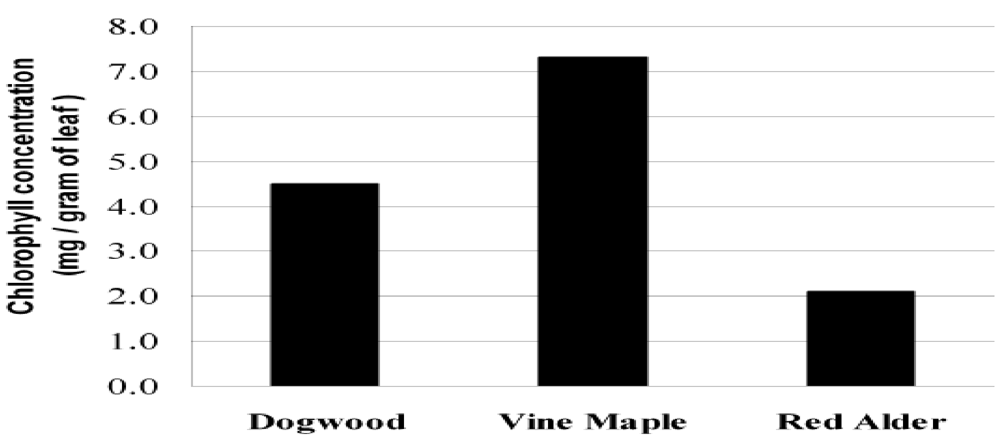

Figure 2 Chlorophyll Concentrations The chlorophyll concentrations were measured mg/grams of leaf in the leaves of three tree species.