MODULE 1

CLASS 2—INTRODUCTION TO SCIENCE AND BIOLOGY

Objectives for Today

The material in this module is structured to allow you to:

1. Understand the limitations of science and why some questions are inappropriate for scientific investigation.
2. **Understand the major parts of the scientific method and their relationships to each other, including *hypothesis, experiment, observation, control, variables,* and *theory**.**
3. Explore the unifying characteristics of living things, and develop definitions of life in order to understand why it may be hard to define "life."
4. Become familiar with the hierarchy of organizational levels that biologists study.
5. Understand the importance of *repeatability* and appropriate *sample size* in the design and interpretation of scientific investigations.
6. Perform a simple experiment and interpret the results.
7. Formulate scientific hypotheses and evaluate them.
8. Understand the difference between observational and experimental scientific investigations.

*NOTE: One of these objectives is printed in bold. Objectives in bold are broad objectives, of a more general sort than the other objectives. They are designed to aid you in integrating today's material into a bigger picture. By analogy, these general (meta) objectives are the forest, and the more specific regular objectives are the trees. Please try to keep the forest in mind as you navigate through the trees!

PLEASE READ THE FOLLOWING BEFORE COMING TO CLASS:

***Biology: Concepts and Investigations*, Hoefnagels, 2nd edition (2012)**

Chapter 1: The Scientific Study of Life

***Principles of Biology Studio Manual*, Rintoul et al., 14th edition**

Pre-class reading for Module 1, Class 2 (next page)

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PRE-CLASS READING FOR MODULE 1, CLASS 2: INTRODUCTION TO SCIENCE AND BIOLOGY

The Importance of Biological Information

Everyone affiliated with this course will tell you that having a solid understanding of biology is important for you to function as an educated member of society. Why do we feel this way? Hmmm... We're already asking you questions about biology even before we've formally introduced you to the science! How are you supposed to know why biology is important—that's part of the reason you're taking the course, right? Well, you probably already know *something* about biology, either through previous courses or merely because you are a biological organism. Therefore, biology shouldn't be an entirely foreign subject even if you haven't ever had a biology course, and you should already be able to comment on it, at least in general terms.

You're going to have to get used to being asked questions in Principles of Biology, and one of the skills we hope you develop in this course is the ability to **ask** as well as answer questions about biological topics. Too often, students are tasked only with answering questions, but it is equally important to know what to ask and how to ask it. What this means exactly may seem a little murky right now, but hopefully it'll be clearer before too long.

Back to the question we asked above. Why do we feel biology is so important? Is it because we as biologists are biased toward the subject? Maybe. But hopefully you'll see there's more to it than that. In the space below, write out a list of possible reasons why possessing a basic understanding of biology might be important, even to non-biologists. In other words:

Why is a basic understanding of biology important to you?

If we (instructors and students) are both doing our jobs correctly, this list should grow and become more detailed (and perhaps more believable for you) as the semester continues. You should keep this list and refer to and update it throughout the course. We will begin class by briefly discussing this list; be prepared to contribute to the discussion!

Additionally, it will be important for you to understand some more general scientific terms, both for today's material and throughout the semester. So in the spaces below, write your definitions of these terms, and be prepared to discuss (and perhaps refine) these definitions at the beginning of class.

Biology:

Science:

Theory:

Hypothesis:

Scientific Method:

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STUDIO CLASSROOM MATERIAL FOR MODULE 1, CLASS 2: INTRODUCTION TO SCIENCE AND BIOLOGY

Today we will be using a web browser to explore what science is and, more specifically, what biology is. As your studio instructor has emphasized, you should **take good notes**, using the spaces provided in this manual, on what you're doing. You also should **ask questions** of both each other and the instructors, who will be circulating through the room while you are working. The instructors, of course, will also be asking you questions about what you're doing. This is not meant as a way of checking to see whether you're actually doing the work (remember, that responsibility is yours) but to make sure that you are *understanding* the material. But please also remember that the answers in these spaces are not everything you need to learn. The basis of learning in a studio is that you **learn by doing**, so please DO all the experiments, read all the web material, and remember what you did as well as the answers you wrote down here.

As you learned last time, much of the material you will be covering will be provided by web browsing and via other computer programs. The web material will often prompt you to record information or answers to questions into your studio manual. MAKE SURE YOU DO SO! **What you write into your studio manual will be your only record of what you have done in class!**

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Exercise Material

Double-click on one of the internet browser icons (Internet Explorer, Mozilla Firefox, or Google Chrome) on your computer desktop. It will open to the index page for the BIOL 198 web material. Click on the link for Module 1, Class 2 and get started on today's computer material.

What is Life?

Imagine you are on a camping trip in the woods. It is likely that you will encounter the following: pine trees, squirrels, rocks, a campfire, and bacteria (although you probably won't notice the bacteria). You already have some sense of being able to list which of these are "alive" and which aren't. However, what may not be clear to you is why you can define one as "alive" but not another.

In the space below, define each as either living or non-living and describe how you know it is either alive or non-living. Work with your partner in generating these descriptions.

Pine tree:

Squirrel:

Rock:

Campfire:

Bacteria:

Do the living organisms share any characteristics with the non-living entities?

Do the living organisms share any characteristics that you do not find associated with the non-living entities?

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Hopefully you can see from this exercise that life forms are very diverse. Thus, defining life is an extraordinarily difficult task. In fact, it's impossible to simply define life. The list you created above should get you started, however, in defining *characteristics* of life.

Rather than trying to develop a definition of life that encompasses all life forms, scientists have assembled a list of characteristics that are common to all life forms. That is, what characteristics do all living things have in common? This list provides the basis for deciding whether we can classify something as "living" or "non-living." (This list will come up again when we talk about viruses later in the semester.)

In the space below, make a list of the characteristics that all living organisms share. Use your lab partners and the web material to help you.

Characteristics of Life

– Reproduction

What is Biology?

As noted in the computer material, scientists have classified the various levels of organization of living things. In the box on the next page, write down these levels of organization in the order described in the instructions given in the computer material.

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Levels of Organization in Living Things

1. Your proposed list (above) is a **hierarchy**. What does this imply about the relationships between one level and the level above it?

2. Do you think that the characteristics of one level in this hierarchy can affect neighboring levels? Explain your reasoning, or give an example.

3. Do you think these effects occur primarily upward (*i.e.*, to higher levels in the hierarchy), downward, or both?

4. At what level in your list does life, as we have just discussed it, appear to begin?

What is Science?

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Your text discusses science as a **process**, beginning with **observations** and ending in a **conclusion**. Let's practice that process, beginning with some observations. Go to page 8 of today's computer material to observe a short video.

Record your observations based on the video of the two animals pushing each other. Make sure you record **observations**, not **interpretations**, of what the two animals are doing.

Record the questions that arise based on your observation of the video.

Provide one **hypothesis** for the behavior you observed in the video about the animals pushing each other.

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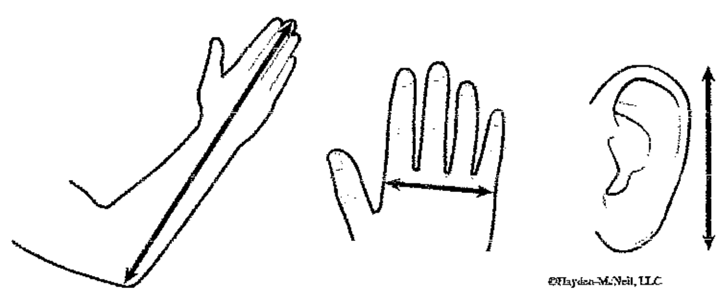
Provide an alternate **hypothesis** for the behavior you observed in the video.

Now, let's leave these mammals for a while and consider another set of observations, and make some more hypotheses.

Although you might consider yourself a budding scientist at this point in your educational career (or even a non-scientist), you have nonetheless made many observations over the course of your life. For example, you may have noticed that humans are, for the most part, fairly proportionately shaped. If someone has long legs, they tend to also have long arms. The question we would like you to now consider is whether there is any correlation between the length of some body part and overall height. That is, can one measure the length of some body part and use that measurement to predict height?

Your task is to work with the other students at your table to develop and test one hypothesis addressing the question: Which body part might be a good predictor of height? To keep things simple, you will be assigned one of the body parts below to use in your research:

- Arm length (from the elbow to the tip of the middle finger)
- Hand width (across the knuckles on the back of the hand)
- Ear height (from the bottom of the earlobe to the top of the ear)



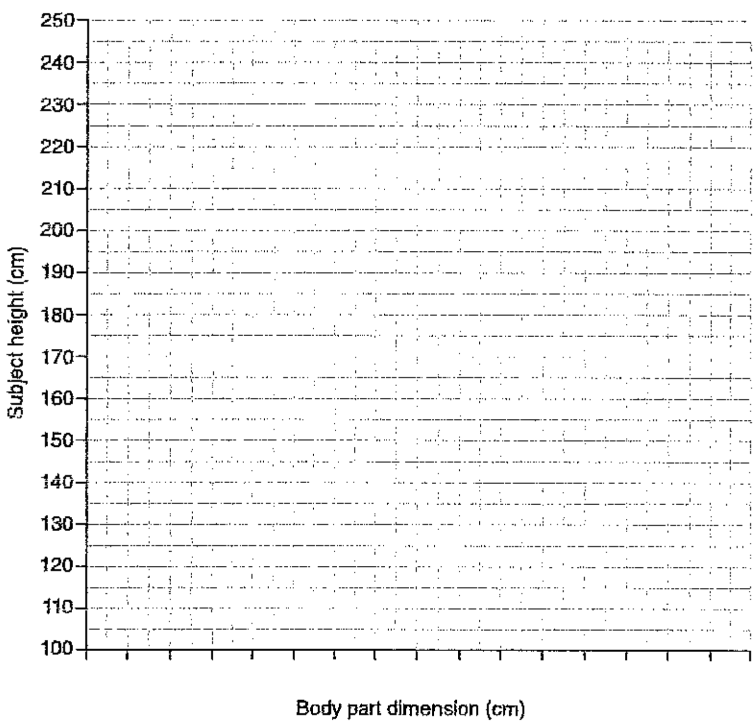
Hypothesis:

Testing your hypothesis requires two steps:

1. Collect data on body part and height in centimeters (cm) for the students at your table to develop a graph.
2. Test your hypothesis using the graph.

There are rulers and meter sticks at your table. Measuring sticks for determining height are attached to the back walls. Plot your data on the graph below. Use the full length of the x-axis to make it easier to interpret your data.

Body part (arm, hand, or ear)	Length, width, or height (cm)	Height of subject (cm)
Subject #1		
Subject #2		
Subject #3		
Subject #4		



Using a straight edge, draw a **single *straight* line** through your data points. You may not be able to draw a line that intersects all four of your data points; some of your data points may be above or below your line. Just do your best to draw a **single straight** line that best "fits" your data. (An example of how to do this is on the web pages for today; click the link for the Sample Graph.)

You will use the graph you've just created for predicting height based on body part length. Does it look like this body part might be useful for predicting height? Why or why not?

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Now you're going to use this graph to actually test your hypothesis. Choose another table in the room at random. Go to this table and, for at least three people, measure the length of the same body part that you measured at your table. Use the graph on the previous page to predict height for each person and record this information in the chart below.

Person number	Body part length (cm)	Predicted height (cm)	Actual height (cm)

Now go back and record the actual height of the same people on which you measured body part length. How well do your predictions match up with each person's actual height? Do these data support or falsify your hypothesis? Explain your answer.

Please report your data to your instructor. He or she will combine the class data so you can see what happens when we increase the sample size used to generate this graph and use it as a predictive tool.

During the wrap-up lecture, use the space below to discuss how sample size can affect our ability to adequately test hypotheses. In the meantime, please continue with the remaining studio material.

As discussed in your textbook (page 10), making observations, accumulating data, and generating hypotheses are part of the **process of science**. Indeed, these activities make up some important parts of the **scientific method**. Notice that the research you just conducted involved making **observations** of the experimental subjects, but did not involve manipulating or altering these subjects in any way. This type of study is called an observational study and is a perfectly valid approach in the biological sciences. Many important discoveries have been made using this approach.

However, other types of biological research involve additional steps, where changes are made to the experimental subjects or their surroundings, and additional observations are then collected (e.g., when a pharmaceutical company tests a drug, patients are actually given the drug to determine whether the drug is effective). This is the definition of an **experiment**. This is an important distinction between approaches to scientific research: the distinction between observational or descriptive methods, where the observer does not change the subjects or conditions, and experimental methods, where the observer changes the subjects or conditions.

In all cases, part of the scientific method is **testing** the hypothesis and arriving at a **conclusion**. Thus, a good hypothesis has to be testable; that is, we must be able to collect some data and work to determine whether the hypothesis is falsifiable or not.

Controls are important in the design and interpretation of scientific experiments. It is important to remember that experiments can have many controls. **Each control group is identical to the experimental group except for one variable,** and it should be obvious that there can be many variables in a given experiment. For example, if you hypothesized above that the elk battling each other were males, and that the male hormone testosterone was responsible for this behavior, you could test this hypothesis in a number of ways. You could observe female elk and see if they fought each other in a similar manner. In this case the female elk would be the control, and the single experimental variable would be the sex of the animals involved.

Or you could castrate a group of male elk to eliminate the source of testosterone in these creatures, inject half of them with testosterone, and observe them. In this case the control group would be the castrated elk that did not get the testosterone injection, and the single experimental variable would be the testosterone. But in this situation, would testosterone be the **ONLY** difference between the experimental group and the control group? How would you design the experiment (*i.e.*, add another control) in order to eliminate the possibility that simply poking the elk with the hypodermic needle caused them to fight?

Keeping in mind the definition of an experimental group and a control group, go to page 15 of the computer material for today and get started on your first virtual agronomy experiment. Record the results of the agronomy experiment here.

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Based on the results of this experiment, should you buy the fertilizer? Why, or why not?

Were there problems with the experimental design of this experiment? What modification(s) do you propose for the experimental design of this experiment?

Record the results of the **modified** agronomy experiment here.

Based on the results of your experimentation, should you buy the fertilizer? Why, or why not?

What conclusions can you draw about the role and importance of ***controls*** in scientific experiments?

Now you have some experience with almost all aspects of the scientific method. You have made **observations**, generated **hypotheses**, done **experiments** to test hypotheses, made **conclusions**, and learned the importance of **controls**.

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There is one more aspect of the scientific method that you need to consider, and it is just as important as any of these. That is the requirement that experimental results be **repeated**, both by you and by other scientists, before the results can gain acceptance. A single observation is never going to be widely accepted, no matter how exciting or compelling that observation is. For example, the experiments of Pasteur, disproving the notion of spontaneous generation of life, could be repeated by other scientists, which helped debunk spontaneous generation as a viable explanation for observations of life seemingly appearing from nowhere. Until the observation can be repeated, or until other types of measurements or observations can support the conclusions from that observation, it will remain merely an interesting anecdote.

Finally, we need to discuss the difference between the terms **hypothesis** and **theory**.

Define hypothesis, **using your own words**.

Define theory, **using your own words**.

Are these identical definitions? If not, what is the difference between a hypothesis and a theory? (HINT: See pages 10–12 of your textbook.)

Give two examples of current scientific theories. (HINT: If you can't think of any, try asking one of the staff members circulating in the room.)

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