ANTHR 1L – Biological Anthropology Lab **Name:**___________________________________

Scientific Method: Observation, Empiricism & Critical Thinking

PART 1 – Making Observations & Recording Data

Introduction
One of the main characteristics of scientists is the ability to carefully observe and record their surroundings. Making correct observations is a forgotten practice; and faulty ones are one of the main reasons why incorrect conclusions are developed. In order to develop this skill, one must make observations a part of their daily routine. In this lab you will be given the opportunity to develop your observational skills. Remember the sense of sight is not the only one you possess. Expand and use all your senses.

Objective:
- You will determine the traits of a good observer.
- You will apply these techniques by observing selected objects, record identifying factors, and identify them when mixed with ones containing similar traits.
- You will be able to discuss the role of observation in science.

Materials:

- Pinto Beans
- Small paper bowls
- Notebook paper and pencil

Procedure I:

- Students are to work in groups of 5-7 people
- After groups are assembled, instructor will distribute pinto beans
- This is your personal bean. Examine it very carefully. Notice the pattern of white and tan areas. Examine all other traits (size, shape, etc.) which can help you find your bean later on. Make a small drawing of the bean that matches it as best as you can. **DO NOT MARK THE BEAN IN ANY WAY**.
- After you have examined your bean, and the other members of your lab team have examined theirs, the instructor will collect your team's beans one by one.
- As each bean is collected, it will be placed in a shallow bowl. Each bowl is labeled on the inside bottom with a letter (A, B, C, D, E, and F). A key will be made as to whose bean is in which bowl.
- The instructor will mix up the bowls.
- **WITHOUT REFERENCE TO YOUR DRAWING**, examine the bowls and select what you believe is your personal bean. Note the letter in the bottom of the bowl, but do not make your selection obvious to others.
- Check with the instructor to verify your conclusion. Did you choose your personal bean?

Questions for Reflection

1. Were you successful in locating your BEAN on the first try?__________________

2. Do you think you could locate your bean if placed with ALL students' beans in the class?____________(Let's see….)

3. If you were to place your bean in a bowl of 100 beans would you be able to locate your bean as easily?_________

4. Was there anything about the bean that made it difficult/easy to identify it?

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5. If there had been a dispute about whose bean was whose, what *evidence* would you present to convince your classmates that the bean was indeed yours? (Think about what you did at the beginning of this exercise).____

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Part 2: Observation, Data Gathering and Minimizing Bias

The Importance of Observation
One of the main characteristics of scientists is the ability to carefully observe and record their observations. Copernicus, Newton, and Darwin all based their revolutionary scientific hypotheses on what they noticed by looking at the world around them. Scientists see, hear or otherwise notice what is happening around them and then become curious about *why* it is happening in just that way.

To satisfy that curiosity, the scientist starts by reading and studying what others have done in the past, because scientific knowledge is cumulative. Newton famously remarked, "If I have seen further, it is by standing upon the shoulders of giants." His hypotheses that led to developing his Theory of Motion were based on the work of Copernicus, Kepler, and Galileo, in addition to his own observations. Darwin not only observed and took notes during his voyage on the *Beagle*; he studied the practice of artificial selection by animal breeders and read the works of geologists, economists and other naturalists to form his Theory of Natural Selection.

Science is often a collaborative effort. Darwin consulted with colleagues through letters, wrote extensively in scientific journals so others could read and comment on his work, and carefully read the details of others' observations. Darwin possessed a remarkable ability to integrate seemingly unrelated pieces of information into a coherent pattern, connecting ideas of gradualism from geology with resource limitation and competition from economics and inherited variation from pigeon breeding. Like most scientists, Darwin was dependent on the accurate recording of observations by other scientists. The progress of science over the last several centuries can be directly attributed to scientists ability to "stand on the shoulders" of their intellectual predecessors, relying on other's powers of observation as well as their own.

However, simple observations can be biased for a number of reasons. Sometimes, even when two or more people are looking at the same thing, their perspectives and interpretations of their observations may differ. This is known as ***inter-observer*** bias. Inter-observer bias can be especially problematic when dealing with fossilized remains. An example from hominid evolutionary studies is the differing interpretations of a 24,000 year old skeleton of a young boy found in Europe. Some, but not all of the skeletal features are very robust (similar to the robust species of hominid that lived in Europe during the Ice Age and known as Neanderthals). This has led some anthropologists to conclude that the boy was likely a descendant of

Neanderthal AND Homo sapiens ancestry. Other anthropologists, analyzing the same skeleton say that it simply looks like a more robust Homo sapiens and shows no signs of Neanderthal features, but rather is representative of the wide range of variation we see in modern H. sapiens. Whose observation is "correct?" That may only be solved by DNA analysis, but as of yet, we don't have a conclusive answer.

Another thing that can influence observations is when the background and interests of the observer influence the way the observer perceives information. This is known as ***intra-observer*** bias. This type of bias could stem from an individual's life experience, educational background, philosophical background, or even something as simple as the way they perceive color. Many of you are familiar with the photo of the dress that circulated around the web where some people saw the dress as blue and black and others saw it as white and gold. Same object, same photo, and yet vastly different perceptions.

The important thing then, is to understand and acknowledge the ways in which our observations can be biased so that we can try to minimize error and account for it so that our observations (and results of those observations during testing, experimentation, etc.) are accurate. This exercise is designed to help you understand how these phenomena affect data gathering and observations and how the scientific method attempts to minimize such biases.

DIRECTIONS:

- Each group is to go outside to a place designated by the instructor. All group members should bring this worksheet and a pen or pencil to take notes.

- Once you've arrived in the designated observation point, you will have five minutes in which to observe and gather information about your surroundings. Make notes, *but do not talk*, or share observations with your classmates. Use the space below to record your observations:

- After the five minute observation period, return to class.

- Now, compare your notes/description with those of your fellow group members and answer the questions that follow.

- List the names of students in your group (first names are fine):

2. After sharing and discussing your data with your group, were there any differences in what YOU personally observed and what other group members observed? If so, describe.

3. Was there any *inter-observer bias* (people making same observation interpret the observation differently) in the data collection? Describe below.

4. Did you or any other of your team mates have any *intra-observer* biases (personal background, interests, experiences affecting the observations)? Describe below.

5. Explain how this exercise demonstrates the ***empirical*** nature of science (you'll need to know what empirical means---if you don't, look it up!)

6. One of the goals of the scientific method is to minimize bias by allowing individual investigators to follow an established, consistent set of procedures. Describe the steps in this exercise that attempted to reduce bias among observers (think carefully about the procedures you followed in this exercise).

<u>Part 3:</u> Applying the Scientific Method

The goal of all scientific studies is to help produce reliable and accurate information about the world so that we can make informed decisions based on empirical evidence. This information is applied in many aspects of our lives, whether it is in formulating environmental policy, medical treatments, dietary practices, educational, economic or social policies and practices or conducting further scientific research. For this portion of the lab, work with your group to brainstorm some significant problems we face in our world for which scientific investigation and scientific principles could help explain, understand, and/or solve. List the issues or problems suggested by your group in the space below & be ready to share them with the class.

Part 4: The Nature of Science

Lessons from Pluto

The history of Pluto the (dwarf) planet is not just fascinating, it is also quite useful for understanding how scientific investigation and knowledge proceeds and develops, and in this, provides a valuable lesson in the nature of science.

As we've been learning,

- Science is a system of knowledge about how the world works. It seeks to produce reliable and accurate information about the world.

- Science is *empirical*. This means it is based on the use of our senses, or the extension of our senses, such as through microscopes or telescopes that magnify our vision of natural objects.

- Science is *cumulative*. It builds on previous observations, ideas, experiments, and theories.

- Science is *historical*. Science is also limited in that it can only develop hypotheses and explanations based on the facts, evidence and information we have at any given point in time.

- Science is *limited*. It can only investigate objects and events that can be explored empirically and that are part of the natural, physical world. Any event or phenomena outside this realm is beyond the scope of science. This means some questions/problems simply cannot be answered by science.

- Scientific explanations or theories *can and do change*. Since facts can and do change and new evidence and information is constantly being discovered (partly due to advances in our instruments of investigation, i.e. technology), our explanations or theories should change to reflect this new information as well.

Indeed, this last point is one of the strengths of science---its ability to accommodate new evidence and information. Such discoveries are constantly challenging scientists to "rethink what they thought they knew," and so, some theories will have to be modified while others may need to be rejected entirely based on new findings of tested hypotheses.

One important thing we need to remember is that science is done by humans. Any time humans are involved, there is room for bias and for error because as we know, humans are fallible. Of course, the scientific method attempts to minimize as much of this human bias as possible, but there is no way for humans to ever be completely objective. That's because what lies behind our eyes very much influences what we see before them. The important thing is to recognize how that affects our understanding and interpretations of scientific data.

We also need to be aware that there are some scientists who use scientific information to make conclusions that support their own personal beliefs or agendas. That is, they interpret scientific data to suit their own ends or cause. This is simply bad science. Doing research on the *researchers*, although time consuming, is in many cases, a very worthwhile endeavor. It can give us some background or biographical information about the individuals who are conducting the research, what institutions they represent, and what the source of their funding for research is. All of these factors can influence the kinds of questions they ask, the hypotheses they propose, and the conclusions they make.

In essence, science is like a detective story, a sleuthing adventure, a step-by-step course, a never-ending process that builds on itself, providing answers with ever greater precision. Wrong turns are sometimes taken---and eventually found out---and then there are new hypotheses, new experiments, new formulas, and new theories.

For this part of the lab, we'll be listening to a radio program from National Public Radio (NPR) about planetary astronomer, Mike Brown---the man responsible for Pluto's reclassification as a dwarf planet. As you listen, consider how Brown's discovery & the debate about Pluto's planetary status relates to the nature of science, the scientific method, and scientific theories (or explanations). Also, pay attention to the defining characteristics of scientific explanations or theories (listed above) and how they play out in the story of Pluto.

Instructions: While listening to the NPR segment, take notes on the following:

- What was Mike Brown originally searching for?
- Why was Pluto's planetary status being questioned?
- Why was the discovery of Eris a good thing for helping us to better understand our solar system?

NOTE: PART 4 - Lessons from Pluto will continue at the end of these lab worksheets.

Part 5: **BACK TO SCHOOL: MIDDLE SCHOOL SCIENCE FAIR PROJECTS**

Now you'll be reviewing two science fair projects completed by some middle school students. You are to act as the "judge" of these projects and to assign a grade to each project based on whether or not they used the scientific method properly. Rate the projects using the scale below and complete the comments section.

5 = Very good 4 = good 3 = average 2= not so good 1 = needs improvement

	Project 1: SPROUTING	Project 2: CANDLES
Problem/Question being investigated is clearly stated	5 4 3 2 1	5 4 3 2 1
Information provided is relevant to problem/question	5 4 3 2 1	5 4 3 2 1
Hypothesis is clearly stated	5 4 3 2 1	5 4 3 2 1
Experiment procedures & results are clearly defined	5 4 3 2 1	5 4 3 2 1
Conclusion is supported by experimental results	5 4 3 2 1	5 4 3 2 1
Sources of information for research are identified	5 4 3 2 1	5 4 3 2 1

Based on your review & ratings, describe what you thought was done well in each project or what needed improvement in each project. Make sure to give the project a final grade (A = Excellent, B = Very good, C = Satisfactory, D = Needs Improvement, F = Fail)

Comments or Critiques for Project 1 GRADE:_________

Comments or Critiques for Project 2: GRADE:_________

The Scientific Method - Critical Reading Exercise

Instructions: Read the short articles on the following pages. After reading each article, complete the following:

Article 1

a. Identify the problem

b. What information is given about the problem?

c. What is the hypothesis?

d. How was the hypothesis tested?

e. What was the conclusion?

Article 2

a. Identify the problem

b. What information is given about the problem?

c. What is the hypothesis?

d. How was the hypothesis tested?

e. What was the conclusion?

Article #1

Study Links warmer water to greater levels of mercury in fish

Under the watchful eyes of scientists, a little forage fish that lives off the coast of Maine developed a strangely large appetite.

Killifish are not usually big eaters. But in warmer waters, at temperatures projected for the future by climate scientists, their metabolism---and their appetites---go up, which is not a good thing if there are toxins in their food.

In a lab experiment, researchers adjusted temperatures in tanks, tainted the killifish's food with traces of methylmercury and watched as the fish stored high concentrations of the metal in their tissue.

In a field experiment in nearby salt pools, they observed as killifish in warmer pools ate their natural food and stored metal in even higher concentrations, like some toxic condiment for larger fish that would later prey on them.

The observations was part of a study showing killifish at the bottom of the food chain will probably absorb higher levels of methylmercury in an era of global warming and pass it on to larger predator fish, such as the tuna stacked in shiny little cans in the cupboards of Americans and other people the world over.

Article #2

Playing with head injury slows recovery

Study found mental function also impacted

By Lindsey Tanner, *The Associated Press*

CHICAGO – Continuing to play despite a concussion doubles recovery time for teen athletes and leads to worse short-term mental function than in those immediately removed from action, a study found.

It's billed as the first to compare recovery outcomes for athletes removed from a game or practice compared with those who aren't. The study was small, involving 69 teens treated at a University of Pittsburgh Medical Center concussion clinic, but the results bolster evidence supporting the growing number of return-to-play laws and policies nationwide. The study was published Monday in the journal Pediatrics.

Keeping score

The study involved athletes aged 15 on average from several sports, including football, soccer, ice hockey and basketball who had concussions during a game or practice. Half continued to play and took 44 days on average to recover from symptoms, versus 22 days in those who were immediately sidelined.

Sidelined players reported symptoms immediately, including dizziness, headaches, mental fogginess and fatigue, and were diagnosed with concussions by trainers or team physicians. The others, who continued playing for 19 minutes on average, delayed reporting symptoms and were diagnosed later.

Those who continued to play had worse scores on mental function tests performed eight days after the concussion and 30 days after the concussion. Medical records showed mental function had been similar in all players before their concussions.

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Risky returns

Return-to-play policies are widespread, especially in youth athletics, and they typically recommend sidelining players after a suspected concussion until symptoms resolve. One of the main reasons is to prevent a rare condition called second-impact syndrome---potentially fatal brain swelling or bleeding that can occur when a player still recovering from a concussion gets hit again in the head.

The study results show that a prolonged recovery is another important risk from returning to play too soon---one that "no one had really calculated" until now, said Dr. Allen Sills, a Vanderbilt University neurosurgeon. He was not involved in the research.

Not reported

About 300,000 sports related concussions occur each year nationwide among all ages. In high school athletics, they occur at a rate of almost 3 per 10,000 games or practices.

Evidence suggests up to 50 percent of concussions in teen sports aren't reported. Athletes are sometimes not aware they've experienced a concussion, or they suspect a head injury but continue playing because "they don't want to let their teammates down," said University of Arkansas concussion researcher, R.J. Elbin, the study's lead author.

The results "give us more ammunition" to persuade young athletes to heed the return-to-play advice, Elbin said.

Part 4 – *Lessons from Pluto:* Questions for Reflection on "The Story Of Pluto"

After reading "The Story of Pluto" (on the class webpage), answer the following questions related to the nature of science as illustrated by our changing understanding of the solar system.

1. Science is ***cumulative,*** meaning it builds on the work of others. Percival Lowell predicted the existence of a ninth planet based on his observations of the behavior of Neptune. What scientific principles or laws had already been established, and by whom, that helped him to formulate his hypothesis?

2. When Pluto was first discovered in 1930 the only image scientists had to work with was of a bright spot in the outer region of the solar system, far from the sun. In 1987, an "unexpected" discovery about Pluto was made. First, describe what this discovery was and second, explain how this demonstrates the ***historical*** and ***limited*** nature of science. (NOTE: Please answer BOTH parts of this question)

3. Based on their empirical observations and measurements, astronomers began to notice some differences in Pluto's features as compared to the other planets. Describe Pluto's unique features.

4. As you read, advances in telescope technology & computer programming have changed the way astronomy and particularly, planet hunting is done. Astronomers can now program the telescopes to scan vast regions of the solar system at night & have that data digitally recorded for their review each morning. Can this still be considered ***empirical*** research? Explain your answer.

5. Explain how the discovery of Eris 1) actually advanced the field of astronomy and 2) helped to broaden our understanding of the solar system.

6. What does the "Story of Pluto" tell us about the nature of science and the scientific method? How does this relate to evolutionary theory?