BIO 181 Laboratory Exercise

Name:______________________________

Nature of Science

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The scientific method, as far as it is a method, is nothing more than doing one's damnedest with one's mind, no holds barred. ...This means in particular that no special privileges are accorded to authority or to tradition, that personal prejudices and predilections are carefully guarded against, that one makes continued checks to assure oneself that one is not making mistakes, and that any line of inquiry will be followed that appears at all promising. All of these rules are applicable to any situation in which one has to obtain the right answer, and all of them are only manifestations of intelligence.

–Percy W. Bridgman

Van Leeuwenhoek's microscope and Galileo's telescope took scientists into the realms of the very small and the very distant. With our instruments we obtain images of distant galaxies and probe the nucleus of atoms, measure the distance between stars and the size of an atom. But we can't go there. We can learn about the past from relics and fossils, but we can't go there either.

–Robert Park

1 Introduction

Deoxyribonucleic acid (DNA) is the genetic material in all living things. Biochemists call DNA a ***macromolecule*** because it's very long. If you were to lay out all the DNA in a typical human cell end-to-end, you would have 46 strands that would span about 1 meter. But DNA is also exceedingly thin like an immensely fine strand of hair. Each strand is only about 0.000002 mm (2 millionths of a millimeter, or 2×10^{-6} mm) in diameter. The best light microscopes can resolve objects down to about 0.0002 (2/10,000ths, 2×10^{-4}) mm. So, despite its length, DNA is 100 times too thin to see with a light microscope. More powerful instruments like electron microscopes and others that exploit quantum effects can resolve DNA, but the pictures are fuzzy at best. And yet we know, atom-by-atom, DNA's structure. The discoverers figured it out without ever actually seeing the molecule. Scientists do this sort of thing all the time.

Today's first exercise will give you some experience learning about something you can't interact with directly, which is perhaps the most important aspect of science. On the supply table are a number of black boxes. Each box contains an unknown item. Your job is to determine the physical properties of that item without looking inside the box. This is not a "no right answer" situation. Something is in the box and your job is to figure out what it is or, failing that, determine what it's like—its size, shape, and material at least. Success requires the primary tools of science: observation, experimentation and logic. Curiosity, patience, perseverance and intelligence won't hurt, either.

After that you'll then practice two other important aspects of professional science: peer review and replication. When the scientific method works properly, every observation and experiment must have its design and logic evaluated by other competent scientists. Also, we require that every experiment be replicated by an independent group before results are considered valid. Replication and peer review help eliminate errors of logic, technique and judgement caused by personal bias, politics, greed and other human characteristics that can cloud reality. And that's our goal as scientists—to understand reality and help others do the same.

2 Black Box Procedure

1. With at least one other lab partner, obtain a black box from the supply counter. Boxes are labeled A through F; you may use any available box. *At no point during this exercise or afterwards are you allowed to look inside any sealed box, nor will the instructor tell you what's in them.*

2. Attempt to determine the following properties of the object inside the box:

   (a) The object's weight.

   (b) The material out of which it's made.

   (c) It's dimensions (length, width, height).

   (d) It's general shape.

   Write your answers with supporting evidence in the space provided in the exercises section of this packet.

   NOTE: Rarely will you be able to measure the weight or dimensions of the object exactly; however, you can often provide a range, like "it's between 4 and 6 cm long." Try to be as precise as possible, but be careful not to go beyond what your evidence can support.

3. In the space provided write your suggestion(s) of what's in the box.

4. Exchange boxes and data with another group. Evaluate their conclusions and replicate their findings.

5. Answer the questions about this peer-review and replication procedure in the "Exercises" portion of this packet.

3 Black Box Analysis

3.1 Initial Evaluation

Answer the following questions about the black box you initially evaluated.

1. Which letter box did you evaluate? _______________

2. How much does the object in your box weigh? Explain ***in detail*** the data and logic leading to this conclusion. You may use a separate sheet of paper if necessary.

3. What are the dimensions of the object in your box? Explain ***in detail*** the data and logic leading to this conclusion.

4. Out of what material is the object in your box made? Explain ***in detail*** the data and logic leading to this conclusion.

5. What is the object's general shape? Explain ***in detail*** the data and logic leading to this conclusion.

6. What is your best guess regarding what the object is, and how strongly is this guess supported by the evidence you gathered?

3.2 Peer Review and Replication

Answer the following questions about the *other group's* box and conclusions.

1. Which letter box did the other group evaluate? _______________

2. What is the weakest conclusion of the group you peer reviewed? Explain its weaknesses based on your evaluation of the logic of their arguments and your own experience replicating their results.

3. What is the strongest conclusion of the group you peer reviewed? Again, explain the strengths of this conclusion based on your evaluation of their logic and your experience replicating their results.