UNIT 1: The Nature of Science

"Science is an adventure that people everywhere can take part in, as they have for many centuries." Amer. Assoc. for the Advancement of Science

I. The purpose of scientific inquiry
- A. to understand natural phenomena
- B. to solve problems
- C. to develop a body of knowledge about the world
- D. to develop and apply technology

II. How are philosophy and religion different from science?
- A. Philosophy is broadly defined as the pursuit of <u>wisdom</u> by intellectual means and moral self-discipline. It can also be defined as the system of <u>personal values</u> by which one lives
    1. comprises logic, ethics, aesthetics, metaphysics, and epistemology
    2. includes the investigation of causes and laws underlying reality, including the critique and analysis of fundamental <u>beliefs</u> as they come to be conceptualized and formulated
    3. based on <u>logical reasoning alone</u> rather than empirical methods
    4. the synthesis of all learning presented in university curriculums of science and the liberal arts, except medicine, law, and theology
    5. Thus, philosophy is different in that it is the pursuit of <u>wisdom</u>, by considering many disciplines (including science but also <u>beliefs</u> and <u>ethics</u>), and by logical <u>reasoning alone</u>
- B. Religion is the <u>belief</u> in and acceptance of a <u>supernatural</u> power or powers as a controlling influence for the good in one's life
    1. based on <u>revealed truth</u> (revealed by the supernatural through spiritual leaders)

2. encompasses a large variety of personal or institutionalized systems
3. involves principles, values, causes and rituals pursued with zeal and conscientious devotion
4. Thus religion is different in that it is based on revealed truth, encompasses a variety of beliefs in a supernatural creator or governor, and is a controlling influence on one's life

C. Science is an empirical and rational approach to understanding Nature and solving problems
1. accepts that the world can be understood through observation and by applying reason and logic; that there are fundamental rules which apply to matter and energy, space and time, which make the world understandable.
2. accepts that empirical reality exists, regardless of, and unaffected by, our thoughts and beliefs.
3. based on empirical observation (observable and experimental fact / evidence)
4. explanations must provide testable predictions and must not be contradicted by evidence

D. Philosophy, religion and science are different disciplines, based on different assumptions, and having different goals. But they are not mutually exclusive (to accept one does not require you to reject another)
1. It is appropriate to educate oneself about and utilize any or all of these disciplines
2. All are equally valid in constructing one's personal life view
3. People differ in the extent to which they are influenced by any or all three
4. There are many scientists who practice various religions. Conversely, many religious people accept scientific explanations of the natural world
5. Some matters (ex: religion, ethics and morality) cannot be examined usefully in a scientific way.

6. Just as one must study and reflect on religious texts to correctly learn and practice a religion, if one is to correctly understand or practice science, it is important to understand, and adhere to, its specific empirical and rational rigors. Regardless of our beliefs or philosophies, understanding how philosophy and religion are different from science enables us to be good scientists, by avoiding philosophical and religious bias in our observations, hypotheses and theories

III. Scientific Methodology

Fact: In science, an observation that has been repeatedly confirmed.
Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.
Hypothesis: A testable statement about the natural world that can be used to build more complex inferences and explanations.
Theory: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses, that makes valid predictions, and for which no contrary evidence exists

A. Science is a creative process, involving <u>many different methods</u>, but all share certain characteristics
B. Science is a human endeavor and is thus <u>imperfect</u>. Scientists struggle to eliminate bias and to be <u>skeptical</u> and conservative in their interpretations and explanations
C. **Empirical**
   1. data is <u>based on observations</u> and the body of previously-established **facts**
   2. Facts are culled from **primary sources** (original research), not **secondary sources** (other sources which analyze or restate original primary research).
   3. data must be **<u>valid</u>**
      a. **Internal Validity** – relates to the design and methods of the research. Data must be unbiased, accurate, precise, complete and consistent. Variables must be controlled so that findings are not affected by factors

other than those thought to have caused them. Ex: **double-blind study** with **placebo**

b. **External Validity** - the extent to which you can generalize your findings to a larger group or other contexts. Ex: lab research may not faithfully represent what might happen in the real world.

D. **Hypotheses** (proposed, tentative explanations) must be based on observation and must be testable / falsifiable, either by experimentation or through further observation of Nature. They are NOT merely "educated guesses"

E. Testing of hypotheses can involve experimentation or further observation

F. Analysis of **evidence** (observations and facts which support a conclusion) and testing, and the conclusions based on that analysis, may lead to rejection or revision of a hypothesis, or to its greater acceptance

G. Reporting of results

1. submittal of research to a **professional journal -** different from magazines and books, in that they filter and analyze articles through the process of peer review.
2. **Peer review -** the editors of a journal ask a team of experts in the field to review each submittal for validity and quality before publishing.
   a. review team may send the work back unpublished, with suggestions for improvement.
   b. if a paper is published, other scientists read and discuss it. If there is interest, some may try to duplicate the results. They may design a new experiment or search for additional evidence based on the paper. They may publish their own papers, supporting, disproving or modifying the original hypothesis. When similar investigations give different results, the challenge is to judge whether the differences are trivial or significant, and it often takes further studies to decide.

c. Example: evolution of our understanding about the formation of the Moon – several hypotheses were disproved and rejected while others were modified and accepted by the scientific community

d. example of no peer review: cold fusion

   1. 1989 media announcement: cheap power (heat) generated in a "glass of water"
   2. no peer review
   3. results could not be duplicated
   4. reputations ruined and the cold fusion concept still invokes negative connotations
   5. ironically, many scientists are working on the problem and think it has a future but the technology is quirky – they are fighting lots of skepticism

3. scientists speak and meet at <u>conferences</u> and participate in <u>professional organizations</u> to share information and to set and maintain high standards in the profession
4. One research project alone is not conclusive. Lay people often misinterpret media reports of early research, which may not have yet had a chance to be duplicated and confirmed. It usually takes years of work by many teams before any research is generally accepted by the scientific community.
5. Finally, even though an article has been peer reviewed and published, it may later be subject to significant debate and serious criticism. One question to ask any researcher is "who is funding the research?" Research which is funded solely by private industry, is often considered to be suspect. "The appearance of impropriety" applies when skeptical scientists review professional literature. "Research" funded by "think tanks," which are often glorified propaganda machines, is often neither peer-reviewed nor published in professional journals. Such documents are not considered professional primary research by the scientific community.

H. A **scientific theory** is an overarching explanation of observations and facts that makes valid predictions, and for which not a single exception has been found

1. Because theories provide explanations, they represent the highest level of scientific understanding
2. Theories often model complex processes which are not directly observable in themselves. Examples: electricity theory, germ theory, atomic theory.
3. The greater the number of severe tests a theory has passed, the greater its degree of confirmation and the more reasonable it is to accept it. However, to confirm is not the same as to prove logically or mathematically. No scientific theory can be proved with absolute certainty.
4. If there is more than one valid explanation to a current problem, they are called "multiple hypotheses," not theories (though many, including scientists, may loosely refer to them as "theories"). Once a theory has gained general acceptance in the scientific community, it becomes the single best explanation. Thus, there is normally only one theory to explain particular phenomena. Other testable explanations would be called hypotheses.
5. Common lay definition of theory is very different: *"just one of many speculative ideas"*

I. Some scientific knowledge is very old and yet still valid. But major shifts regularly occur in the scientific view of how the world works. Scientific knowledge is subject to modification as new information challenges prevailing theories and as new theories lead to looking at old observations in a new way. No matter how well one theory fits observations, a new theory might fit them just as well or better.

IV. Why is science important?