

Science as a "Way of Knowing"

Biology 114

Conservation Biology

Part 1: The Assumptions and Methods of Science¹

Introduction: For many, this will be the only science course you take in college. So, besides learning conservation biology, another goal of this course is to learn something about what science is and is not. For instance – why is it that biologists get so upset about teaching "creation science" or "intelligent design" in science classes? Is it because all scientists are atheists or does it have to do with what science is?

High school courses typically do not discuss the foundations of science and thoughtful scientists do not like to leave definitions of science to philosophers and the critics and observers of science. So, here (and in the next couple of sets of notes) is a scientists take on the place of science in human knowledge, on what is and what is not science, and on how science must be practiced. This view owes much to the philosophers of science.

Ways of Knowing: Let's start the semester with a bit of behavioral biology and philosophy. Later we can move to conservation. How do we know anything about the world external to our own minds? You would probably answer that we learn about the world through our senses. But how do we know that what our senses tell us is accurate? In your journey through biology you will learn (if you didn't already know it) that your senses are highly limited and miss a lot of what is going on. They are biased towards some features of the environment and are especially sensitive to and excited by them while they largely or totally ignore other stimuli. For instance, we can only hear a limited range of all the air borne vibrations referred to as sounds. Moreover, our sensory systems do not really present things exactly as they are physically. For instance, your visual system emphasizes contrasting areas. It operates to emphasize the borders of objects. Based on readings from instruments such as light meters, the differences in the intensity of light between an object and its surroundings are smaller than we might expect. Given these small differences in reflected light, one would think that such objects would be hard to distinguish. However, in fact our nervous system often makes them appear very distinct! This is an adaptive distortion created by networks of neural cells in our retinas and further modified in our brains. The lesson here is that what we experience is always an incomplete and is often a somewhat distorted view of our surroundings.

What do we do with this information, beyond the moment-to-moment experience of a floral scent, color pattern, or whatever? All

¹ © 2009 by W. R. Healy and K. N. Prestwich, Department of Biology, College of the Holy Cross. These notes are adapted from a set used in Introductory Biology at Holy Cross.

animals, including humans, have what animal behaviorists often call "**mental toolkits**" which help them recognize, sort, categorize and remember these experiences. The basics of these toolkits are inherited and then they are modified by experience. The amount of modification depends on the particular toolkit. For instance, these interface with other toolkits to produce behavioral responses to particular stimuli. All of the information in the nervous system -- sensory input, memories, and the mental toolkit methods for making sense of the information and taking actions -- is stored as connections between neurons. More correctly, all this information is really represented as a particular pattern of neuronal "firing". Thus, information is stored symbolically -- a particular neuronal firing pattern represents a particular stimulus, memory, or way of making decisions. This is true in all nervous systems.

However, in humans and certain other animals, other symbols are often invented as tags to represent particular firing patterns. In humans, these form the basis of language, and, many would argue, the basis for all of our thoughts and how we understand the world. Let us realize a few things about these symbols that are so important to our thought process. First, they are usually far from precise. Words are to some degree ambiguous; they can mean a number of things. In part, their meaning to different people depends on common experience. To the extent experience is shared, these symbols are likely to have close to the same meanings. The other side of the coin is that words can invoke mental states that are not identical in different individuals. Words create expectations about reality. These expectations can be quite powerful and they can influence our perceptions and thoughts.

Thus, we create complex systems that dictate how we organize or understand what our senses tell us. These are what are often termed "**world views**" ("**zeitgeists**") or "**ways of knowing**". They are the means by which we construct the details of our understanding of how the world works. Examples of worldviews include various religions and philosophies. One of the latter, one that has been particularly useful in guiding thought about how the universe works is called scientific **materialism**. We will discuss it shortly. It forms the basis of the scientific worldview.

In some cases different versions of these worldviews can be incompatible. Fundamentalist religions, to the extent that they espouse special creation over evolution to explain the diversity of the biological world, are largely incompatible with science. On the other hand, religious or philosophical worldviews can be complementary, each with its specialized area of insight. We will discuss this in more detail below.

Science as a Way of Knowing:

Science can be considered one of humanity's greatest achievements based on its impact on our understanding of how the universe operates

and on how it has guided technological innovation. For most of Western intellectual history, however, science existed as a sub-area of philosophy, often referred to as "**experimental philosophy**." Only in the past 300 years or so has science developed into a distinct academic discipline whose fruits can be seen in the spectacular rise of modern technology. Nevertheless, science is rooted in basic assumptions² and in this regard is still similar to philosophy. Furthermore, science can properly answer only a limited number of questions that interest humans, and so it complements rather than replaces philosophy. Because science has the same foundation as philosophy and is more restrictive in scope, it is a mistake to think that scientific knowledge is superior to philosophical knowledge. On the other hand, it is just as much a mistake to hold any theory or system of philosophy above science when it comes to describing the physical universe. Material life -- that which can be sensed and measured -- the subject of ecology, medicine, agriculture and so many other pure and applied fields of biology is part of the physical, observable universe. Science holds a special place in understanding the material world. It is the height of intellectual snobbery to hold that science is mere "technical knowledge" and somehow inferior to other forms of knowledge. And it is just as arrogant for science to claim special importance in the description of things that are not physical (if such do indeed exist).

Let me give a couple of examples here; some of this may be new to you. Take "the mind" -- the sum of thoughts ideas and experiences of an individual. Three different views of the mind would be the scientific view (which would seek to explain the mind based on operation of cells and networks of cells), vitalism (which explains the mind as something attached to a non-material spirit) and a number of philosophies that would explain the mind as something that sits on top of the biological aspects (nerve and sensory cells) where the mind is more than just the function of these cells.

Part 2: A Brief History of the Relationship Between Science and Philosophy

The rise of science can be traced to the pre-Socratic **natural philosophers** of ancient Greece who combined rational thinking, observation and experimentation to explain the mysteries of the cosmos or universe. Their greatest achievement was the assumption that the universe is orderly and knowable and so could be explained in terms of laws rather than the whim of gods. This assumption guided their thinking and is the foundation upon which present scientific investigation is based.

² _An example of an assumption central to science is "for every effect there exists a physical cause" -- in other words, non-measurable (immaterial) agents are not for scientific consideration and are ruled out of science.

However, with **Socrates**, the emphasis in Greek philosophy shifted from explaining the universe to understanding human nature and the good life. **Plato**, a student of Socrates, separated rationalism from empiricism, opted for the former over the latter, and replaced physics with metaphysics. **In so doing, Plato led to the demise of early science.**

Plato's metaphysical thinking, as well as that of his pupil **Aristotle**, came to dominate Western thought until **science was reborn in the 17th century through the efforts of Francis Bacon, Rene Descartes and Francesco Redi** (you do not need to know these names in this course). These three thinkers discovered the power of empirically based **induction, deduction and experimentation** respectively as ways of knowing and so freed the thinking of their day from the bondage of Aristotelian metaphysics and Church dogmatism which were interwoven in what is termed **scholastic philosophy**. As we shall see below, the processes of induction, deduction and experimentation form the backbone of that process of discovery we now call the scientific method.

What are **rationalism, empiricism, metaphysics, dogmatism and dogma**? (If you don't know, please look them up.)

Today, in the minds of many laypersons, science has been elevated to the status of a religion whose priests, the scientists, ply their skills in ways totally unintelligible to the masses. The rift between the two cultures of science and the humanities seems to be widening (a far cry from the days when science and philosophy were one) and must be closed by educated persons if modern society has any hope of surviving and flourishing. It is important that non-scientists temper their optimism for the power of science by appreciating its limitations as a way of knowing and realizing that **science cannot solve all the problems which plague modern society**. As we have already seen in the first class, conservation biology does not look to science for every answer as to how to preserve biodiversity.

As members of a society that relies heavily on science, it is part of your obligation to the community to understand and be able to explain to others what is and what is not science -- and what science can and cannot do.

One of the great advantages of attending a liberal arts college is that you will have the encouragement and opportunity to explore these issues and learn of different perspectives on issues that relate to science and technology. Please take full advantage of them

Part 3: Materialism, the Philosophical Assumption Behind All Science:

The basis of modern science is **materialism**. This term does not refer to the selfish acquisition of material objects. Rather, it is **the philosophical assumption that the entire observable universe has observable causes** -- it springs from **empiricism**. Materialism assumes that there are no immaterial causes to what we can observe or if there are, they are outside of science and belong to some other way or knowing. Therefore, when doing science, we can only utilize material causes when we seek to explain any thing that we observe. To act otherwise is non-science.

Especially with regard to living thing, materialism stands in opposition to another world view – **vitalism**. A materialist believes that all phenomena related to life ultimately have a physical (observable) cause. By contrast, a vitalist believes that at least some of the causes behind the behavior of living things are immaterial and therefore, by definition, are unobservable (although vitalists may argue that the immaterial sometimes controls the actions of the material).

Thus, a vitalist believes that living forms are ultimately "animated" or controlled by immaterial unobservable factors. This is, of course, a very commonly held view. All I would ask you to do is realize that vitalism is a non-scientific view, that is, one that falls outside of science. It may well be correct, but it is not the sort of explanation someone acting as a scientist is allowed to use. It is the job of scientists to push materialistic explanations as far as they can when explaining observable phenomena. It is the job of scientists to be sure that their explanations rest on what is observable. If an individual chooses to believe that other, non-material factors, also matter, that is fine and an honorable and defensible thing. It is just not science.

Much of the controversy between certain religious fundamentalists (some of whom are scientists) and most of the scientific community involves attempts by the former to inject non-material and non-testable explanations into science, and, equally, attempts by some scientists to prove that the views of those who accept non-materialist explanations are incorrect.

Part 3: Definitions of Science

Just what is science and why has it been so spectacularly successful in shaping Western industrial society? The answer to these questions is the focus of interest of a new breed of philosopher, the **philosophers of science**, who analyze what scientists do and attempt to abstract a general set of rules governing scientific inquiry. These individuals are often science's most valuable critics and explainers and it is well worth the time to understand their ideas and maintain dialogue with them. Scientists, for their part, pay little attention to what they are doing in a formal sense and attempt to explain nature and solve the problems they

encounter in their quest for knowledge. Consequently, the nature of science changes as scientists discover new ways to solve problems. There exist a number of conceptions and misconceptions about the nature of science and these will be discussed below. As we shall see **there is no simple answer to the question: What is science?**

1. Science is an organized or systematized body of knowledge. This is a very common definition of science that focuses on the content of science and the factual results of scientific research. It does not, however, distinguish science from non-science, since any logically presented body of thought can be considered science under this definition, e.g., theology was once considered the "queen of the sciences" and the philosophical system of St. Thomas Aquinas was considered to be scientific. A telephone book is a highly organized body of information, but nobody would consider it to be a science text. **Science is not distinguished from non-science by its content.**

2. Science is an authoritative, objective, dispassionate search for absolute truth. This concept of science is **riddled with errors**. First of all, despite the popular appeal of a "scientific demonstration" to sell products on TV or the internet (sports and nutrition quickly come to mind), the validity of which rests solely on the authority of an actor dressed in a white lab coat, scientists routinely reject authority. It is the **empirical evidence** (= observational and measurable phenomena) not the reputation of the investigator, which **decides scientific issues**.

Scientific dogmatism must be rejected as strongly as religious dogmatism in explaining nature, but it exists because scientists are human and not dispassionate in their beliefs. They are just as influenced as everyone else by biased beliefs that spring from accepted **paradigms** (mental constructs which explain how nature operates) and the need to maintain individual prestige. As a result, scientists, like everyone else often lose objectivity. Many of the controversies that have punctuated the history of science were due to the subjective dispositions of scientists unwilling to relinquish their pet ideas in the face of contrary evidence. Scientists, like most everyone, tend to magnify the importance of their work through inappropriate generalization and this often brings them into conflict with other scientists who arrive at a different conclusion.

The **nature vs. nurture controversy** is a good example of how the human aspects of science interfere with progress. Nature vs. nurture broadly looks at the effects of genes and environment in determining an organism's phenotype (all of its structures, processes and behavior). The roles of genetic make-up and environmental experience in determining the **phenotype** come up in many contexts in biology. Here is one example: Ethologists (animal behaviorists) studying so-called instinctive

behavior came to the conclusion that most animal behavior is stereotyped and innate -- they believed it to be "inborn" and due entirely to the actions of genes. They used this worldview to explain nearly all behaviors they observed. However, their conclusion was quite opposite that of behavioral psychologists who studied learning and concluded that behavior was flexible and due to environmental rather than genetic influence. These comparative psychologists tried to explain all behavior as learned and assumed that genetic make-up had not significant role in many if not most behaviors (at least in mammals). As it turned out both were correct and behavior is now known to be influenced by genes and the environment rather than by just one alone. Animal behavior forms a spectrum running from largely instinctive to largely learned responses to the environment. Each school studied one end of the spectrum and attempted to generalize its results. We will consider the nature-nurture controversy broadly as one of the main themes of this course.

Dogmatism and absolute truth: As for the notion that science gets at **absolute truth** -- well, there simply is no notion of absolute truth in science. All ideas in science are subject to revision and so are provisional. For example, the replacement of the Ptolemaic, geocentric universe with the Copernican, heliocentric one, and the conceptual change in geology from stationary to drifting continents, and the replacement of the concept of static, unchanging species with evolution by natural selection are all examples of changes in the way we understand the natural world. They were all achieved rather suddenly in the sense that these new worldviews were announced by single or small groups of scientists and they represented substantial breaks from previous views³. So progress is not necessarily gradual. Moreover, they do not represent the last word -- for example, our views of evolution have been modified since Darwin and Wallace's days to include factors beyond natural selection and Copernicus' view of the solar system with circular orbits by planets was replaced by Kepler's view that orbits were eccentric. Science does make progress understanding reality, but, at any given time, **the ideas of science are subject to change and so do not constitute absolute truth.**

Note: Scientific investigation is driven largely (but not entirely) by what the society of the day deems important and is willing to support, e.g., cancer and AIDS research, not by some quest for ultimate truth.

³ Thomas Kuhn wrote a very influential book entitled *The Structure of Scientific Revolutions* where he showed that science proceeds through relatively long periods where little change in overarching ideas occurs. These are punctuated by periods of scientific revolution. More about this later.

3. Science is what scientists do and the scientific community decides what science is. Although vague, this description of science is probably closest to the truth of what science actually is. Earlier I noted that scientists attempt to solve problems with little attention to what they are doing in a formal sense; it is the philosophers of science who attempt to describe what scientists do. Scientists employ a number of different approaches to problem solving and each specialized branch of science has its own tradition, techniques and outlets for publishing results. Scientific articles are peer-reviewed; hence, scientists themselves determine what is accepted as legitimate science. The essence of science, as viewed by both scientists and philosophers of science, lies in the methodologies followed by scientists rather than in the content of science.

Part 2: Components of scientific methodology

1. Guiding Ideas and the fruits of scientific work

A. Scientific Hypotheses: Hypotheses are tentative explanations of why some pattern in nature occurs. Thus, they are statements that attempt to explain the underlying processes (causes) responsible for patterns in nature (effects). Nobody really knows how people form hypotheses; they result from luck or individual, creative genius. No formula exists for producing them.

The common usage of the term "hypothesis" as a guess or explanation that explains some observation is very close to its meaning in science. However, unlike with common usage, a scientific hypothesis **must have the property that there must be some way (in principle) to show that the hypothesis is false as a result of observation of behavior of the object(s) under study.** Thus, we say that any good scientific hypothesis must be **falsifiable**. The criterion of **falsifiability**, which characterizes scientific hypotheses and provides a basis for distinguishing between scientific and nonscientific hypotheses, was introduced in 1934 by **Sir Karl Popper** (a renowned philosopher of science) in his book, *The Logic of Scientific Discovery*. According to Popper, to be scientific a hypothesis must be tested empirically against nature and accepted only if such testing cannot falsify it. Much of the process of science is finding clever, revealing ways to test hypotheses.

Analogy and the extension of knowledge: Popper's views of hypothesis testing trace partly to Darwin and Wallace's notion of natural selection -- their idea that genotypes contained within individuals are tested by nature and those that work the best (survive the test of nature) continue. Although by no means a perfect analogy, Popper saw hypotheses as something like genotypes and experiments and tests of logical consistency as acting like the environment. According to Popper, the

best hypotheses continue because they are not falsified by experience with nature but just as with a genotype, none is guaranteed permanence as they are repeatedly tested.

Logical consistency and scientific hypotheses: Scientific hypotheses in fact must meet two tests. First they must be logically consistent both internally and with what is believed to be known about nature. Then, they must be tested further against nature (the material world). The hypothesis that God is the creator of nature appears to be definitionally true and logically consistent with the philosophical propositions (assumptions) that every effect has a cause and nature is an effect, not a cause. However, it is not a scientific hypothesis because there is no way of falsifying it through testing. The reason is that ultimately this worldview states that God can act outside of material nature in un-seeable and unknowable (to humans) ways. Take some philosophy and religion while you are here and learn more about this.

B. Scientific Theories: A hypothesis increases in level of certitude if it possesses:

- (i) broad explanatory power and
- (ii) it has survived repeated testing

Eventually, scientists come to refer to such an explanation as a **theory**. The difference between the terms "hypothesis" and "theory" is inexact but refers to the scope of the explanation and the level of certitude attached to it as a consequence of repeated testing. The greater the number of specific predictions which are verified through experiment, the higher is the level of certitude attached to the hypothesis and the more likely it is to be referred to as a theory.

C. Scientific Laws: Scientific laws, on the other hand, are **generalizations about the behavior or operation of nature**. They are based on repeated observations and they usually do not contain a mechanism or explanation for why these patterns occur.

Good examples of scientific laws in biology are

- **the cell theory** -- all organisms are composed of cells;
- **biogenesis** -- all cells come from pre-existing cells;
- **central dogma of molecular biology** -- information moves from genes to the rest of the organism and not vice versa
- **"organic" evolution** -- the appearance and genetic structure of biological populations changes over generational time.

Evolution: members of populations change genetically (and as a result, morphologically) over time.

All of these laws only describe a pattern -- they do not explain these patterns. The explanations (mechanisms) that explain laws

and other broad generalizations are hypotheses and theories. Thus, natural selection and genetic drift are both theories that seek to provide mechanisms to explain evolution.

Use of terms You will see that for various reasons, all of these terms often are misused. For instance, evolution is often termed a theory when it is actually a biological law. Likewise, Darwin and Wallace's theory of natural selection is a theory in the sense that it predicts that a certain process, termed natural selection, is responsible for much of evolution.

One other note -- do not take the sequence of hypothesis → theory as an inevitable progression. Some hypotheses are of such limited scope that we would never consider them scientific theories even though they are well established.

2. Processes of science

a. Observation (Data collection). Many consider the starting point of any scientific investigation to be the collection of observations. These collected observations are termed **data** (plural, datum singular). The random collection of data, however, without any guiding hypothesis is not only tedious, it is most often fruitless and few do it (once again, Popper pointed this out. -- pre-Popper views of science focused on observation as the inevitable, not occasional starting point of the process of science). In fact, data are usually collected to test specific hypotheses, not to formulate them. We will talk more about this later.

b. Observations and Induction: This said, let's start with the less common cases when no prior information about a phenomenon exists. What does one do with a large number of observations? For these to be useable, one creates generalizations by the use of induction. Induction is a type of logical reasoning where the premise(s) support the conclusion but do not ensure it. In science this means that induction is the logical process of extracting generalizations (conclusions) from a set of observations (premises). The conclusion is not ensured because it is always possible that a new observation will be contrary to the previous ones.

- In science, induction is used to make a generalized statement based on a limited number of observations. For example, suppose I trap mice in several different woodland lots and notice that all the mice I have captured are brown. Through induction, I could then argue that all mice are brown.
- Inductive generalizations describe broader patterns in nature. Some inductive generalizations are broad enough and well enough established that we call them scientific laws. However, the vast majority of inductive generalizations are

not termed laws -- they are simply called generalizations for short. For example, there is no brown mouse "law.

- All inductive generalizations beg for hypotheses to explain them.
- Many think that induction must lead to hypothesis construction. It doesn't have to. It does so only because eventually someone wants to explain the generalization in terms of a mechanism or reason for its existence..

c. **Deduction -- the process of arguing from the general to the particular.** Deduction is most commonly used in science to derive predictions based on hypotheses. Recall that hypotheses are tentative explanations of generalizations. Hypotheses can be tested or can be extended to unknown phenomena using deductive reasoning. Thus, if our working hypothesis is that DNA is the hereditary molecule in all living things, then, if we discover a new type of organism we could predict using induction that its hereditary molecule is DNA. Note that once we made this deductive prediction, it now allows us to test further our hypothesis that the hereditary molecule of all living things is DNA.

d. **Predictions.** In science the term prediction means the statement of a fact not evident or known at the time the statement is made, but one that must exist if the hypothesis is true. It is a logical deduction that follows from the hypothesis. An example of a prediction is the statement that, based on the theory that DNA is the hereditary molecule, then any newfound form of life would use DNA as the hereditary molecule. The prediction is the logical consequence of the theory. Moreover, it is a scientific prediction because it is testable (see below).

e. **Tests and Experiments:** The central feature of science is that its hypotheses and their predictions can be falsified through testing. It is the role of the scientist is to generate predictions from hypotheses using the logical process of deduction. Most importantly, good science involves generating predictions that can feasibly be shown to be either true or false.

Karl Popper (see above) effectively introduced the concept of **falsifiability** as being central to hypothesis testing. He stated that it was difficult if not impossible to prove hypotheses. According to Popper, proof exists only in mathematical theorems, not in scientific methodology.

<p>IMPORTANT: Why is it easier to falsify than to prove? For a hypothesis to be <u>proven true</u>, it requires that the predictions of the hypothesis be <u>always</u> in accordance with unbiased observation. However, a single or just a few situations where the hypothesis is not borne out suggest that it is incorrect, at least in part. So, a single false prediction disproves and</p>

forces either modification or total discarding of the hypothesis. It should be evident that even a thousand correct predictions do not prove for all time that a hypothesis is correct. This is part of the basis for the idea that all scientific work is tentative and not absolute (see earlier discussion on absolute truth).

So, modern science generally follows Popper and uses the idea of falsifiability, not the impossible "provability", as the best criterion for deciding whether or not a hypothesis is scientifically useful.

To summarize, **hypotheses that have not been falsified through testing are provisionally, (but not absolutely), accepted**. Such tentative acceptance is the norm because scientific hypotheses still are always capable of falsification and might be falsified in the future. Remember that the discarded theories of the past were accepted as scientific truths in their day!

Falsification and experimentation. An experiment is simply a way of testing hypotheses by finding out if specific predictions are true or false. In a more restricted sense an **experiment is a manipulation of the conditions that result in some phenomenon**, whereas an **observation is simply a witnessing of the phenomenon**. The most effective type of experiment is a **controlled experiment** wherein all factors that can influence a phenomenon are kept constant except one which is allowed to vary. In this way the effect on the phenomenon under study of the variable can be determined precisely and accurately. The controlled experiment is erroneously considered by many to be the hallmark of science, but in actuality it is hypothesis testing (through either **observation or experimentation**) which distinguishes science from non-science.

A Bit More About Hypotheses, Theories and Falsification: What happens when one specific prediction of a theory is falsified? Does this mean that a long accepted explanation of how nature operates must be rejected? The answer is no! The theory will be retained as long as it functions in providing a reasonable interpretation of nature and continues to generate new information by being the guiding light behind research projects. Theories, therefore, are paradigms which:

- explain a significant portion of reality,
- interpret new data and
- generate new information by directing research effort through questions raised by the theory itself.

A theory is not just the explanation of a pattern, it is a paradigm or way of looking at the world; as such, it is exempt from naive falsification, i.e., rejection based on the empirical falsification of one or two of its predictions. Of course, if more and more predictions are falsified as time goes on, the usefulness of the theory diminishes and it

may be replaced by a new theory that provides a better paradigm for interpreting nature.

Theory replacement, according to the philosopher of science **Thomas Kuhn** is the most exciting event in science and the one that accounts for the success of science over the long run. Note again that the replacement of one theory by another *does not necessarily mean gradual progression towards some form of absolute truth. In many instances the new theory doesn't build on the one it replaces, it actually destroys it.* Accepted theories represent the body of current scientific truth and they are the means whereby we make sense out of the world, interpret new information and expand the frontiers of knowledge through research effort.

"Beauty" and Simplicity in Scientific Theories: The Law of Parsimony (Occam's Razor): This "law" is really more of an **assumption**. It states that **when two or more explanations exist for observations, the simplest is always to be preferred** (at least until it shown to be incorrect -- then we go for something more complex). It is based on many observations that suggest that nature can be explained by a series of relatively simple rules.

Study Questions:

1. What are rationalism, empiricism, and metaphysics? Why is a worldview based on metaphysics, vitalism, or rationalism fundamentally non-scientific? Does that mean that these approaches have no use and should be discarded?
2. What are the relationships between empiricism, materialism and experiment?
3. Why must one reject non-materialistic explanations when acting as a scientist?
4. Explain why scientists attempt to disprove rather than prove their hypotheses. Discuss the differences between science and non-science.
5. Discuss the importance of theories to the scientific mode of inquiry and comment on the role of absolute truth and progress in science.
- 6 How do world views influence: observation? Scientific theory?
7. Identify each of the following:
 - natural philosophy
 - materialism
 - paradigm
 - Popper
 - Kuhn
 - falsifiable
 - prediction
 - hypothesis testing
 - controlled experiment
 - experimental and control treatments

- parsimony; Occam's razor
7. Distinguish between each of the following:
- scientific and nonscientific hypotheses
 - hypothesis and theory
 - pattern and process (mechanism)
 - induction and pattern recognition
 - deduction and prediction
 - hypothesis
 - theorist and empiricist