Science as a "Way of Knowing"
The Place of Science[1]

Additional Reading: Campbell, pp. 13 - 19
There will be terms in these notes that you should look up in any good reference book or a good on-line source like Wikipedia. (**http://en.wikipedia.org/**) -- this site is especially useful for philosophical terms and other things that might not be in your textbook.
One other general note -- these notes and the **text** of all others you get from me this semester are searchable -- images and drawings are usually not searchable.

Part 1: Ways of Knowing: Let's start the semester with a bit of behavioral biology and philosophy. *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. Moreover, they do not really present things exactly as they are physically. For instance, your visual system emphasizes contrasting areas. It operates to emphasize the boarders 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 animals, including humans, have what animal behaviorists often call "mental toolkits" which help them recognize, sort, categorize and remember these experiences. 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 is 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 assumptions[2] 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 it would be the scientific (which would seek to explain the main 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 or **natural philosophers** of ancient Greece who combined rational thinking, observation and

[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.

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.

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**. 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, use resources such as those mentioned on the first page of these notes).

Today, in the minds of 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. I will tell you that on this campus and most others, there is a distinct separation in the minds of many faculty and students between "what happens over in the science complex" and their own particular ivory tower. Of course this is not true of everyone but it is something you should expect to run into and to explore. It is important that you understand other views because they are enriching and likewise, because it will allow you to explain science to non-scientists. 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 a budding scientist, it is part of your obligation to the community to be able to forcefully explain what is science and what is not science and what science can and cannot do. It will also enrich your life greatly if you come to understand their unique and valuable perspectives and come to realize why you might reject certain ideas.

Finally, scientists **must come to accept full responsibility for their discoveries** and not wash their hands when their work is used to the detriment of society. Scientists must consider the ethical implications of their work and not undertake research projects that will produce results which society is incapable of handling ethically. 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.

Scientific Materialism: 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. When acting as a scientist we must use frame out actions in materialism. To act otherwise is non-science. It is not wrong to think or act or believe in other explanations that invoke unseen and measurable phenomena if one is working outside of science. However, within science, there is no room for immaterial, unobservable phenomenon. 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. This is a complicated topic and I hope you will talk about it as much as the details of science.

In summary, a materialist would posit that all of life is ultimately explainable in terms of matter and energy whereas, for example, a non-materialist such as a **vitalist** would posit that some aspects of life are beyond matter and energy; are supernatural in the non-pejorative use of the term (i.e., beyond observable nature -- beyond the empirical).

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**.

Broadly defined, I am a zoologist (some who studies animals scientifically). In my lab, and in many other labs, is a sign that guides all of our research "The animal is the authority". What do you think this means?

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 and this will be a central theme in our course. 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 views[3]. 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 Keppler'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. **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

[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.

and philosophers of science, **lies in the methodologies followed by scientists** rather than in the content of science.

Study Questions:

1. What are rationalism, empiricism, and metaphysics? Why is a worldview based on metaphysics or 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. Distinguish between each of the following:
   - rationalism and empiricism
   - hypothesis and theory
   - theorist and empiricist

5. Identify each of the following:
   - mental toolkits
   - natural philosophy
   - Aristotle and Plato (Greek philosophers is not enough!)
   - Materialism
   - paradigm
   - scientific community