What is Science?

Modified from the University of California's Museum of Paleontology UNDERSTANDING SCIENCE WEBSITE http://undsci.berkeley.edu/article/coreofscience_01.

- Science is a way of learning about the **natural world** – what is in it, how it works, and how it formed.
- Science relies on testing ideas by making **observations** to find out whether expectations hold true.
- Accepted scientific ideas are subjected to rigorous testing. As new evidence is acquired and new perspectives emerge these ideas are revised.
- Science is a community endeavor with checks and balances for greater accuracy and understanding.

The Scientific Method

CURIOSITY – A question arises about an event or situation: why and how does this happen?
OBSERVATIONS, MEASUREMENTS – We observe and measure: What is happening? Under what circumstances? Does there appear to be a dependable cause-and –effect relationship at work?
HYPOTHESES – We make educated guesses about what is causing what we are seeing. A good hypothesis can predict future occurrences under similar circumstances.
EXPERIMENTS – We plan controlled experiments to prove or disprove potential cause-and-effect relationships. These tests can happen in nature or the lab and permit manipulating and controlling the conditions under which we make future observations.
BEYOND THE HYPOTHESIS – Patterns emerge. If one or more of the relationships hold and acceptance is widespread, the hypothesis becomes a theory or principle.

BEYOND THE SIMPLIFIED:

- **Scientists engage in many different activities in many different sequences.** Scientific investigations often involve repeating the same steps many times to account for new information and ideas.
- **Science depends on interactions within the scientific community.** Different parts of the process of science may be carried out by different people at different times. Society influences greatly the questions that are researched, and many of the results of scientific investigations become a highly influential part of human culture and civilization.
- **Science relies on creative people thinking outside the box!**
- **Scientific conclusions are always revisable if warranted by the evidence.** Scientific investigations are often ongoing, raising new questions even as old ones are answered.
- **The process of science is iterative.** Science circles back on itself so that useful ideas are built upon and used to learn even more about the natural world. This often means that successive investigations of a topic lead back to the same question, but at deeper and deeper levels.
- **The process of science is not predetermined.** Any point in the process leads to many possible next steps, and where that next step leads could be a surprise.
- **There are many routes into the process**. Research problems and answers come from a variety of inspirations: serendipity (such as being hit on the head by the proverbial apple), concern over a practical problem (such as finding a new treatment for diabetes), a technological development (such as the launch of a more advanced telescope), or plain old poking around: tinkering, brainstorming, making new observations, chatting with colleagues about an idea, or reading.
- **Scientific testing is at the heart of the process.** All ideas are tested with evidence from the natural world — even if that means giving up a favorite hypothesis.
- **Ideas at the cutting edge of research may change rapidly.** In researching new medical procedures or therapies or researching the development of life on earth – making living cells from inorganic materials – scientists test out many possible explanations trying to find the most accurate.
- **The scientific community helps ensure science's accuracy.** Members of the scientific community (such as researchers, technicians, educators, and students) are especially important in generating ideas, scrutinizing ideas, and weighing the evidence for and against them. Through the action of this community, science self-corrects. Note: Authority is NOT a criterion. Just because a scientist has titles or degrees does not mean we must accept their ideas. We apply a healthy does of skepticism to all.

From Hypotheses to Theories and Principles

The process of science works at multiple levels — from the small scale (such as a comparison of the genes of three closely related North American butterfly species) to the large scale (such as half-century-long series of investigations of the idea that geographic isolation of a population can trigger speciation).

HYPOTHESES are proposed explanations for a fairly narrow set of phenomena. These reasoned explanations are not guesses. When scientists formulate new hypotheses, they are usually based on prior experience, scientific background knowledge, preliminary observations, and logic. *Example hypothesis: a particular butterfly evolved a particular trait to deal with its changing environment.*

LAWS OR SCIENTIFIC PRINCIPLES explain events in nature that occur with unvarying uniformity under identical conditions. These principles are arrived at by fact gathering and experimentation. They may have exceptions, and, like other scientific knowledge, may be modified or rejected based on new evidence and perspectives. *Example principle: Geology's principle of superposition, which states that in an undeformed sequence of rock layers, each laid down through natural processes, the oldest layer is at the bottom.*

THEORIES are broad explanations for a wide range of phenomena. They are concise (generally don't have a long list of exceptions and special rules), coherent, systematic, predictive, and broadly applicable. Theories often integrate and generalize many hypotheses and usually are more involved and complicated than a law or principle, with many more areas of doubt and refinement possible. *For example, the theory of natural selection broadly applies to all populations with some form of inheritance, variation, and differential reproductive success — whether that population is composed of alpine butterflies, fruit flies on a tropical island, a new form of life discovered on Mars, or even bits in a computer's memory. This theory helps us understand a wide range of observations (from the rise of antibiotic-resistant bacteria to the physical match between pollinators and their preferred flowers), makes predictions in new situations and has proven itself time and time again in thousands of experiments and observational studies.*

In common usage, the word theory means just a hunch, but in science, a theory is a powerful explanation for a broad set of observations. To be accepted by the scientific community, a theory must be strongly supported by many different lines of evidence. Biological evolution is a theory (it is a well-supported, widely accepted, and powerful explanation for the diversity of life on Earth).

OVER-ARCHING THEORIES are particularly important and reflect broad understandings of a particular part of the natural world. Evolutionary theory, atomic theory, gravity, quantum theory, and plate tectonics are examples of this sort of over-arching theory. These theories have been broadly supported by multiple lines of evidence and help frame our understanding of the world around us. These over-arching theories encompass many subordinate theories and hypotheses. Changes to those smaller theories and hypotheses reflect a refinement (not an overthrow) of the over-arching theory. E*xample over-arching theory: as we learn more about the dynamics of subducting plates in real subduction zones like Japan and Costa Rica, we refine the over-arching theory of Plate Tectonics to reflect that understanding.*