Scientists seek explanations of natural phenomena based on empirical evidence.

Scientific knowledge and understanding accumulate from the interplay of observation and explanation. Scientists gather information by observing the natural world and conducting experiments. They then propose how the systems being studied behave in general, basing their explanations on the data provided through their experiments and other observations. They test their explanations by conducting additional observations and experiments under different conditions. Other scientists confirm the observations independently and carry out additional studies that may lead to more sophisticated explanations and predictions about future observations and experiments. In these ways, scientists continually arrive at more accurate and more comprehensive explanations of particular aspects of nature.

In science, explanations must be based on naturally occurring phenomena. Natural causes are, in principle, reproducible and therefore can be checked independently by others. If explanations are based on purported forces that are outside of nature, scientists have no way of either confirming or disproving those explanations. Any scientific explanation has to be testable — there must be possible observational consequences that could support the idea but also ones that could refute it. Unless a proposed explanation is framed in a way that some observational evidence could potentially count against it, that explanation cannot be subjected to scientific testing.

Because observations and explanations build on each other, science is a cumulative activity. Repeatable observations and experiments generate explanations that describe nature more accurately and comprehensively, and these explanations in turn suggest new observations and experiments that can be used to test and extend the explanation. In this way, the sophistication and scope of scientific explanations improve over time, as subsequent generations of scientists, often using technological innovations, work to correct, refine, and extend the work done by their predecessors.

In science it is not possible to prove with absolute certainty that a given explanation is complete and final. Some of the explanations advanced by scientists turn out to be incorrect when they are tested by further observations or experiments. New instruments may make observations possible that reveal the inadequacy of an existing explanation. New ideas can lead to explanations that reveal the incompleteness or deficiencies of previous explanations. Many scientific ideas that once were accepted are now known to be inaccurate or to apply only within a limited domain.

However, many scientific explanations have been so thoroughly tested that they are very unlikely to change in substantial ways as new observations are made or new experiments are analyzed. These explanations are accepted by scientists as being true and factual descriptions of the natural world. The atomic structure of matter, the genetic basis of heredity, the circulation of blood, gravitation and planetary motion, and the process of biological evolution by natural selection are just a few examples of a very large number of scientific explanations that have been overwhelmingly substantiated.

Science is not the only way of knowing and understanding. But science is a way of knowing that differs from other ways in its dependence on empirical evidence and testable explanations.
The three following words have everyday meanings that differ from the way in which they are used in science. Therefore, it is important for you to recognize and understand the difference.

**Fact:** an observation or event confirmed to such a degree that it would be foolish to withhold provisional consent.  
- In other words, a fact is something that has been observed over and over again so often that it would be “crazy” not to accept it...at least for now.  
- Scientific facts are not absolute. They can change if new evidence suggests that they should.

**Hypothesis:** a proposed explanation of certain “facts” that must be testable in some fashion.  
- Plural: hypotheses  
- Hypotheses are either disproved or regarded as “provisionally true” and submitted to further testing. A hypothesis cannot be “proven” in the everyday sense of the word.

**Theory:** a well-established testable explanation of some aspect of the natural world; the framework within which new hypotheses are formulated and against which new data are evaluated.  
- A scientific theory is not just someone’s “hunch” or “guess.”  
- Theories are the most comprehensive of all scientific ideas and the endpoint of the scientific endeavor.  
- You may someday hear someone say, “I don’t believe in (insert a well-known scientific theory), it’s just a theory.” Here’s what that person is really saying: “I don’t believe in that, it's just a well-established testable explanation of some aspect of the natural world that makes sense of a great variety of scientific observations.” This is not quite what the person probably meant!

**Check Your Understanding**

Based on the information you have just read, which of the following statements are scientific? Circle them.
For the other statements, be prepared to explain why they are not scientific when we discuss this reading in class.

- Walking under a ladder causes bad luck.
- Extraterrestrial beings have visited Earth and are now living among us.
- The number of human chromosomes was once "known" to be 48, but is now considered to be 46.
- With a rod, Moses parted the sea so that his people could cross to the other side.
- Scorpio: be careful with your money today, as it is far too easy for you to waste it on impulse purchases.
- Plants convert sunlight into chemical energy through a process called “photosynthesis.”
- Some animals are carnivorous.
- Living things were once grouped into 2 major groups, then 3, then 4, and now 5, because the criteria used for classifying living things have changed.
- The world was created about 6000 years ago, and no amount of evidence can challenge that fact.
- It was once thought the heart pumped blood out of a large container as an "open system", but now it is known that blood "circulates" in a closed system of blood vessels.
- The relative position of the planets and the stars can have a special, deep significance or meaning that exclusively applies to only you.