Scientific Inquiry

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Concept 1 Scientific Inquiry

- Explain the role of using postulates in science.
- Explain the role of mathematics in science.
- Explain how scientists investigate nature by ensuring their models are able to be proven incorrect (falsifiable) and are tested by many independent researchers.
- Describe the difference between a hypothesis, theory, and law.
- Explain that new theories explain phenomena more accurately than preexisting theories, and such theories are consistent with the correct predictions of previous theories.
- Describe the scientific method.

Vocabulary

Hypothesis
A proposed explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.

Inquiry
An approach to learning that involves a process of exploring the natural or material world, that leads to asking questions and making discoveries in the search for new understandings.

Theory
A statement or set of statements devised to explain a group of observations or phenomena, especially one that has been repeatedly tested or is widely accepted and can be used to make predictions about natural phenomena.

Law
A concise mathematical relationship that always occurs under specific conditions. A law is NOT an explanation, and it is no more or less final than a theory.

Scientific Method
A systematic approach used to investigate the natural world that must make predictions, be testable, based on evidence, and potentially be disproven.

Introduction

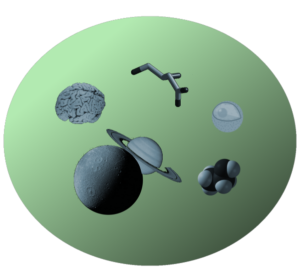

FIGURE 1.1

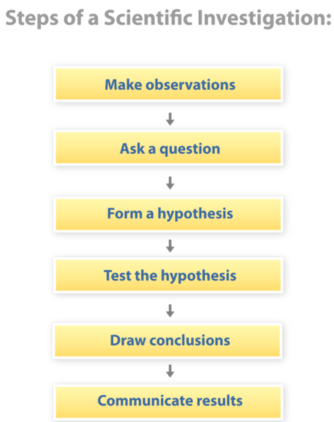

FIGURE 1.2

Many sources present science as a source of absolute truth, but really science is a *process* - not an end result. The scientific process can be approached as a fixed set of steps, such as this:

However, the process can be quite flexible. Scientific explanations are subject to a few requirements, but the process can go in different orders.

- The explantion must be *logically consistent*.
- The explanation must makes *predictions*.
- The predictions must be *testable*.
- The tests must be based on *evidence*.
- The explanation can potentially be *disproven* based on the test results.

Note that the explanation must be able to be *disproven*, but it is never absolutely proven. A scientific explanation is always subject to being revised or disproven by new evidence.

There are a few important clarifications to this definition.

- *There is nothing more solid or final than a* ***theory***.
  - A theory is never formally changed to anything else, no matter how much evidence there is. It becomes harder and harder to disprove with more evidence, but it is never upgraded from a theory to a "scientific fact" or a "scientific law." A scientific "law" means a specific mathematical relationship, which is tested in the same way as a theory and just as open to being disproven at any time.
- *Steps can be skipped as long as the explanation is valid and tested.*
  - As a scientist, you could have a strong hunch before investigating, so you create a hypothesis immediately and then move on to testing it. Alternately, you could devise a series of tests to try out before you have a definite hypothesis.
- *Scientists conduct investigations for a wide variety of reasons.*
  - A scientist can conduct work for any reason, and they are still completely scientific as long as they keep some basic ethics. As a scientist, you could do your work because of the money it would make. Alternately, you could pursue a theory because you like the "beauty" of the explanation. Still further, you could do your work based on religious conviction, following deeply religious scientists like Galileo and Newton. As long as you do not falsify evidence, your reasons are unimportant.
- *Scientists make mistakes, and they report them.*
  - Scientists are never perfect, and even if they follow all proper procedures, sometimes unforeseen circumstances can throw off the results of an experiment. The process of science is not to throw away the

unexpected results, but to keep them, analyze them, and report them. This helps other scientists who might run into the same problem, or even result in new discoveries. It is unethical to throw out odd results unless you know exactly what caused them.

Unethical scientists may alter data to give the results that support what the experiment was intended to show. This could be to enhance their reputation, make more money, or to prove the result that they prefer for personal reasons. That result may stand for years, but in time it will be disproven as other scientists attempt results to confirm or follow up on the false result. Both intentional deception and honest mistakes are eventually discovered.

In order for a result to be taken seriously by the scientific community, researchers must explicitly show how they conducted their work, how the testing was done, and how the data was collected. Presenting their results to their peers allows for feedback and corrections; insights; and errors that may not have occurred to the experimenters.

Development of Ideas Over Time

One example of developing better explanations is in the case of falling objects. From ancient times, scholars believed that heavier objects fall faster. Aristotle, a multi-talented scholar who lived 384-322 BCE, held this interpretation, and for centuries scholars took his word. This idea is based on good experimental evidence, because very light objects like feathers do fall much more slowly than heavy objects like rocks.

However, Galileo Galilei (1564-1642) looked in more detail at the nature of falling objects. He carefully timed marbles as they rolled down a slanted wooden block. He also dropped objects of varying weights. He found that very light objects like feathers were the exception. Heavy objects all fall in about the same time regardless of how heavy they are. Galileo hypothesized that a feather falls slows due to resistance from the air in the way. Heavier objects easily pushed through the air, and thus had very little effect from air resistance.

He hypothesized that in the absence of air, all objects would fall at the same rate. This was confirmed first twenty years after Galileo died by Robert Boyle in 1660, who pumped all the air out of a glass tube and then dropped both a feather and a coin. Centuries later, this confirmation was repeated by astronaut David R. Scott during a live TV broadcast from the Moon on August 2, 1971 - as shown in the following video.

http://www.youtube.com/watch?v=5C5_dOEyAfk

MEDIA

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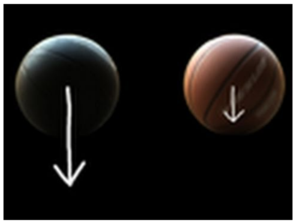
This explanation is more complicated, because it involves two effects: both gravity and air resistance. It can be hard to reconcile these two, especially if you don't know about how they were discovered. Many students learn this only as an unexplained fact that all objects fall at the same rate, without knowing how to relate this to the common case of a feather.

The following is a video of various high school graduates talking about their understanding of falling objects.

http://www.youtube.com/watch?v=_mCC-68LyZM



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Mathematics and Technology

As science has advanced, evidence has gone beyond just what we can see with our eyes. Modern experiments use technology to collect data, and mathematical analysis to reveal patterns within that data.

Mathematics can be used to prove a *scientific law*. As mentioned, a scientific law is no more or less absolute than a theory. Rather, it is a mathematical relation that may or may not have an explanation. For example, you might prove that the weight of water is proportional to how much volume it takes up.