Scientific Laws, Hypotheses, and Theories

by Jerry Wilson

Lay people (or non experts in an area of study - in this case non-scientists) often misinterpret the language used by scientists. And for that reason, they sometimes draw the wrong conclusions as to what the terms used in science mean.

Three such terms that are often used interchangeably are "scientific law," "hypothesis," and "theory."

In layman's terms, if something is said to be "just a theory," it usually means that it is a mere guess, or is unproved. It might even lack credibility. But in scientific terms, a theory implies that something has been proven and is generally accepted as being true.

Here is what each of these terms means to a scientist:

Scientific Law: This is a statement of fact meant to describe, in concise terms, an action or set of actions. It is generally accepted to be true and universal, and can sometimes be expressed in terms of a single mathematical equation. Scientific laws are similar to mathematical postulates. They don't really need any complex external proofs; they are accepted at face value based upon the fact that they have always been observed to be true.

Specifically, scientific laws must be simple, true, universal, and absolute. They represent the cornerstone of scientific discovery, because if a law ever did not apply, then all science based upon that law would collapse.

Some scientific laws, or laws of nature, include the law of gravity, Newton's laws of motion, the laws of thermodynamics, Boyle's law of gases, the law of conservation of mass and energy, and Hook's law of elasticity.

Hypothesis: This is an educated guess based upon observation. It is a rational explanation of a single event or phenomenon based upon what is observed, but which has not been proved. Most hypotheses can be supported or refuted by experimentation or continued observation.

Theory: A theory is more like a scientific law than a hypothesis. A theory is an explanation of a set of related observations or events based upon proven hypotheses and verified multiple times by detached groups of researchers. One scientist cannot create a theory; he can only create a hypothesis.

In general, both a scientific theory and a scientific law are accepted to be true by the scientific community as a whole. Both are used to make predictions of events. Both are used to advance technology.

In fact, some laws, such as the law of gravity, can also be theories when taken more generally. The law of gravity is expressed as a single mathematical expression and is presumed to be true all over the universe and all through time. Without such an assumption, we can do no science based on gravity's effects. But from the law, we derived the theory of gravity which describes how gravity works, what

causes it, and how it behaves. We also use that to develop another theory, Einstein's General Theory of Relativity, in which gravity plays a crucial role. The basic law is intact, but the theory expands it to include various and complex situations involving space and time.

The biggest difference between a law and a theory is that a theory is much more complex and dynamic. A law describes a single action, whereas a theory explains an entire group of related phenomena. It is important to note that while theories can be tweaked, they are seldom, if ever, entirely replaced.

To better understand the differences let's look at the analogy made using a slingshot and an automobile.

A scientific law is like a slingshot. A slingshot has but one moving part--the rubber band. If you put a rock in it and draw it back, the rock will fly out at a predictable speed, depending upon the distance the band is drawn back.

An automobile has many moving parts, all working in unison to perform the chore of transporting someone from one point to another point. An automobile is a complex piece of machinery. Sometimes, improvements are made to one or more component parts. A new set of spark plugs that are composed of a better alloy that can withstand heat better, for example, might replace the existing set. But the function of the automobile as a whole remains unchanged.

A theory is like the automobile. Components of it can be changed or improved upon, without changing the overall truth of the theory as a whole.

Some scientific theories include the theory of evolution, the theory of relativity, the atomic theory, and the quantum theory. All of these theories are well documented and proved beyond reasonable doubt. Yet scientists continue to tinker with the component hypotheses of each theory in an attempt to make them more elegant and concise, or to make them more all-encompassing. Theories can be tweaked, but they are seldom, if ever, entirely replaced.

A theory is developed only through the scientific method, meaning it is the final result of a series of rigorous processes. Note that theories do not become laws. Scientific laws must exist prior to the start of using the scientific method because, as stated earlier, laws are the foundation for all science. Here is an oversimplified example of the development of a scientific theory:

Development of a Simple Theory by the Scientific Method:

- **Start with an observation that evokes a question:** *Broth spoils when I leave it out for a couple of days. Why?*
- **Using logic and previous knowledge, state a possible answer, called a Hypothesis:** *Tiny organisms floating in the air must fall into the broth and start reproducing.*
- **Perform an experiment or Test and collect data:** *After boiling some broth, I divide it into two containers, one covered and one not covered. I place them on the table for two days and see if one spoils. Only the uncovered broth spoiled.*

- **Analyze the data and then publish your findings in a peer-reviewed journal. Publication:** *"Only broth that is exposed to the air after two days tended to spoil. The covered specimen did not."*
- **Other scientists read about your experiment and try to duplicate it. Verification:** *Every scientist who tries your experiment comes up with the same results. So they try other methods to make sure your experiment was measuring what it was supposed to. Again, they get the same results every time.*
- **In time, and if experiments continue to support your hypothesis, it becomes a Theory:** *Microorganisms from the air cause broth to spoil.*

Useful Prediction: If I leave broth open to the air, it will spoil. If I want to keep it from spoiling, I will keep it covered.

Note, however, that although the prediction is useful, the theory does not absolutely *prove* that the next open container of broth will spoil. Thus it is said to be falsifiable. If anyone ever left a cup of broth open for days and it did not spoil, the theory would have to be tweaked or thrown out.