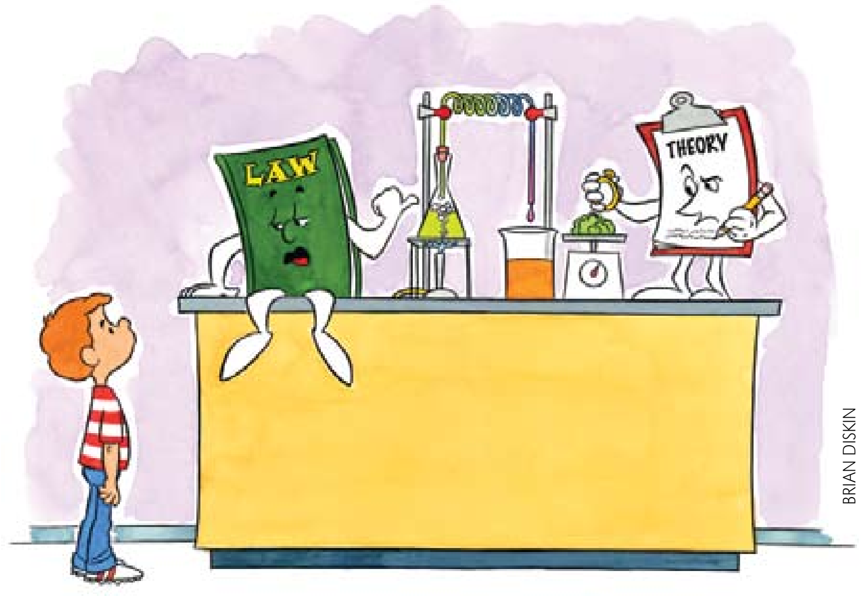
Science 101. Background boosters for elementary teachers

Q: How does a scientific theory become a scientific law?

By Bill Robertson



Look, Kid, ***I*** don't know why. Ask ***him*** to explain it!

A: A theory *doesn't* become a law. End of story, end of this issue of *Science 101*. Just kidding—it's all about the *how* and *why*, and that hasn't been answered. I'd like to step back a bit and address a common misconception that unfortunately permeates science education. See if this sounds familiar: Scientists begin with a *hypothesis*, which is sort of a guess of what might happen. When the scientists investigate the hypothesis, they follow a line of reasoning and eventually formulate a *theory*. Once a theory has been tested thoroughly and is accepted, it becomes a scientific *law*. Nice progression, and not what happens. To understand how scientists proceed in their investigations, it will help to understand each term individually. What's a *hypothesis,* what's a *theory,* and what's a *law?* I'll deal with these in reverse order.

The Law of Laws

To understand what a law is, you just have to look at various laws in science. Boyle's law states that when the temperature of a gas is constant, the pressure of the gas times the volume of the gas is always a constant, regardless of how the pressure and volume change. The law of conservation of mass in chemistry says that the total mass of the things that react together is equal to the total mass of the things that are produced in the reaction. Newton's second law states that the net external force applied to an object is equal to the mass of the object times the acceleration of the object. These things are called *laws* because every time people have tested them, they hold true*.

But let's examine what laws do not tell us. Laws do not explain why things behave the way they do. There is no mechanism involved in the laws. In Boyle's law, for example, we know how pressure and volume are related, but we have no explanation for why one quantity increases or decreases based on the changes in the other quantity. We only know that they increase and decrease according to the law. When we measure the forces applied to an object, the mass of the object, and the acceleration of the object, the quantities obey Newton's second law. That the quantities obey Newton's second law does not explain why the quantities obey Newton's second law. They just do.

So, scientific laws simply explain how things behave. They do not result from theories but are rather

*To be accurate, I have to explain that each law I have mentioned fails to hold true under certain circumstances. Within defined constraints, though, they do hold true. As long as we keep those constraints in mind, we can consider these things to be laws.

descriptions of how the physical world does what it does. Maybe it's the term *law* that makes people think scientific laws have a special place, sort of the ultimate in scientific thought. Not so. Laws are descriptions of what happens and nothing more. That doesn't mean laws are trivial, though. Laws help us develop technologies and develop theories based on the laws. Newton's laws help us figure out how to get a few people to the Moon, even if we don't know why Newton's laws work.

Theories Explained

And with that, let's move on to theories. Theories generally provide mechanisms that explain the things we observe. There is a theory known as the *kinetic theory of gases* that provides a mechanism for understanding Boyle's law. In the kinetic theory of gases, we make various assumptions about how the molecules in a gas act. In the most basic form, we assume that gas molecules run into one another without sticking and that they move about randomly. We assume that the molecules have an average kinetic energy based on the temperature. Those basic assumptions lead to Boyle's law holding true. Because the kinetic theory of gases provides a mechanism rather than just a description of results, it qualifies as a theory. The kinetic theory of gases will never become a law, because that's not what theories become. If a theory is any good, it *explains* a law. The kinetic theory of gases explains Boyle's law, but the theory does not evolve into the law. The highest award for a theory is that it is a good theory, not that it becomes a law.

An Educated Guess?

But what is the role of the hypothesis? For all the space spent in elementary science books discussing hypotheses, you would think this was a really important thing. Hypotheses are important, but maybe a bit overrated. Many books define a hypothesis as an "educated guess" that's based on an understanding of the situation. That's not complete, though. A hypothesis is an educated guess coupled with an explanation for why that guess should come true. For example, two students might guess that a puddle of water outside will disappear overnight. One student might say that this will happen because of evaporation, and the other might say this will happen because the water will soak into the concrete. A true test of these hypotheses should include a test of the explanations as well as what they observe. Now, scientists are always guessing what will happen in a given experiment, expecting certain results and explaining to themselves why they expect those results. Scientists have expectations any time they investigate the real world. If those scientists guess wrong on either what they will observe or the explanation for it, they revise their thinking or redo a procedure. But do scientists write down every hypotheses they have and report the results as part of a final report of research? Probably not, because hypotheses are simply steps that are a normal part of developing understanding of a problem. The truth about how scientists investigate things is that they mess around a whole lot, often without benefit of the statement of a formal hypothesis, and then narrow their focus. Ask someone who currently is doing research in any field of science what his or her hypothesis is, and I'm betting he or she will say, "............ Ummm ... Huh?" Ask that same scientist, "What problem are you working on?" and you'd better sit down and get ready for a lengthy discussion. Finally, do hypotheses become theories? Only in the sense that they contribute to a scientist's understanding of a problem. They are part of the formation of theories, but seldom are they the central kernel from which theories grow.

To summarize, laws in science are a formal way of stating how the world behaves. Laws do not generally provide any kind of mechanism that explains why the law is true. Theories generally provide mechanisms that explain laws as well as explain other observations. While one might use various laws in formulating a theory, that's the extent of the connection. Theories can never become laws, because laws form the body of evidence upon which we base theories. Laws can help with formulating theories, but theories do not develop into laws.

Finally, hypotheses, while a natural part of the scientific process, do not generally evolve into theories. They are an important component of developing theories, but not necessarily the central component.

I'll end with an application of some of these ideas to a contentious issue, which is the ongoing battle between teaching evolution and teaching intelligent design. One of the arguments from the intelligent design crowd is that evolution is "*just* a theory." But a well-developed theory is pretty much the pinnacle of scientific achievement. The phrase "just a theory" might have significance if a theory were the precursor to something better, like maybe a law. Not so, though. The atomic theory and the theory of general relativity, to name two, are among the most solid things we know in science. Of course I'm not putting the theory of evolution on the same level as the theory of general relativity. Too many unexplained things in the former. Still, evolution is a pretty good working theory. And one more thing I just have to add. I have heard too many scientists claim that evolution is a fact, often in retort to the claim that it is *just* a theory. Evolution isn't a fact. Rather than claiming so, I think scientists would be better served to agree that evolution is a theory and then proceed to explain what a theory is—a coherent explanation that undergoes constant testing and often revision over a period of time.

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