

A Gentle Reminder that a Hypothesis is Never Proven Correct, nor is a Theory Ever Proven to Be True

By Jacqueline McLaughlin

Donald French, president of the Society of College Science Teachers, points out in his recent commentary on disclaimers in science textbooks that science is typically taught as a litany of terms and facts using textbooks that do not stress that the concepts presented in them are actually *theories*—the best current explanations supported by experimental evidence that scientists have to offer (2006). We teachers, therefore, have created a huge misconception for students and non-scientists who read and use textbooks. They have come to believe that science is absolute and not open to challenge. Worse still for the scientific community is the fact that, in common speech, *theory* has almost the opposite meaning from its use in the sciences. This change can be seen in modern dictionaries that now define *theory* as a guess or hunch in preference to the scientific definition. In everyday English, a theory is a hunch that a detective comes up with in a murder mystery. It is one of several competing ideas, none of them proved. Fringe theories and conspiracy theories are crazy ideas that are out of the mainstream. New medicines or changes in the tax laws may be good in theory, but

don't always work in practice. Among some scientists, theories are thought to lack solid basis in the facts (Morrison 2005, p. 39).

Yet, the scientific definition of a theory is a logical self-consistent model or framework for describing the behavior of a certain natural phenomenon that is supported by considerable experimental evidence (www.wikipedia.org).

While most scientists try to rely on the dictionary definition of a scientific theory, Thomas Lovejoy, environmental scientist, author, and president of the Heinz Center for Science, Economics and the Environment, says that “theory is used in everyday English to mean hypothesis whereas in science it means something much stronger and just shy of a law (e.g., Second Law of Thermodynamics). Theory in science means a constantly tested explanation of a broad variety of facts and phenomena.”

Richard B. Alley, an eminent scientist at Penn State University known for his work in global warming, states that “in contrast to most dictionary definitions, I believe that theories necessarily involve narrative as well as explanation and prediction. So, you might define a theory as the overarching narrative or ‘world view’ that encompasses and makes sense of the observations and successful predictive tools in a field of study.”

A theory is not a hunch; it is the scientifically grounded way of explain-

ing why or how things happen. For example, “global warming” refers to the observation that worldwide temperatures seem to be increasing. The “theory of global warming” refers to scientific work that attempts to explain how and why this could be happening by measuring various factors such as increased CO₂ emissions in the atmosphere, loss of rain forest productivity in tropical ecosystems, and ice sedimentation in Antarctica and Greenland. “Skeletal muscle contraction” refers to the observation that muscles shorten, as seen using microscopy, when myocytes or sarcomeres are stimulated. The “sliding filament theory of skeletal muscle contraction” refers to the body of scientific experimental evidence that explains how the proteins actin and myosin—with the aid of other proteins like troponin and tropomyosin, essential ions like Ca²⁺, and molecules like ATP—in the sarcomere work to ‘slide’ past one another to shorten the H-zone and I-bands. No hunches here, just solid data from countless published scientific experiments that continue to support the best explanation thus far. These two theories have passed the test of time, as have hundreds others like chemiosmosis as the basis of ATP synthesis, voltage-gated ion channels as the basis of the propagation of an action potential along the membrane of a neuron, and microtubule depolymerization and protein motors at the kinetochores to move chromosomes during anaphase.

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These explanations remain as biological theories and are the concepts that fill biological textbooks. Are you wondering if you should purchase a new edition of your biology textbook? When one truly realizes that science is in a state of perpetual flux, that what's in print today may be outdated tomorrow, this question won't even cross your mind. Again, all of our current understanding of scientific phenomena is theoretical and could be revised in a heartbeat if commendable and repeatable evidence falsifies it and supports a new theory.

Colleagues, it is time to bring honor and dignity back to the 'history of scientific investigation' that has prevailed for centuries. We must act and work together as professional educators to correct the misconceptions that a theory is a hunch, and that science is absolute. As Dr. French pointed out, one way is to have a disclaimer in our textbooks that would make the underpinnings of science explicit—that our explanations are tentative and open to challenge, that what's in our textbooks just happens to be the best theories thus far, and that science is a process. Another way is this: listen to our students and non-scientist community and gently remind them to be careful with their words. This step also requires that we become more cautious with our own words. By using the appropriate words when we speak about research in a public forum, we can correct the misconceptions that science is a done deal, and that a theory is a *hunch*.

So what are the words that we need to keep in mind? The hardest part about understanding scientific theories and hypotheses seems to be this: a hypothesis is never proven correct, nor is a theory ever proven to be true. Words like *prove*, *correct*, and *true* should be removed from our vocabulary completely and immediately.

Recently, I had the honor of judging a regional science fair, the Pennsylvania Junior Academy of Science (PJAS). I also had the honor of taking fifteen of my brightest undergraduate biology majors to this event and having them act as judges. Several of my college students were placed together as judges, but most of them were placed with judges from all over our region—professionals working in industry, academia, and health care. It was a spectacular sight, seeing my students all dressed up and acting like scientists, ready to use the core biological concepts and inquiry-based scientific methodology I had taught them. They were ready and eager to act as role models and mentors, and I was ready to embrace helping them and all the middle school presenters practice their scientific vocabulary. You see, I had judged many science fairs before this one, and knew what was awaiting all of us.

I, along with three other judges, presided over eight of some of the brightest and motivated middle school students I had ever interacted with. Their experiments focused on topics such as the effects of moisture and temperature on fungal growth, the role pH plays on the decomposition of soil, and the inhibitory effects of preservatives on bread mold growth. They were all elegantly prepared experiments that followed the "textbook" scientific method of formulating a question, developing a hypothesis, designing an experiment, determining the variables, presenting and analyzing results, and then interpreting the results. The last step, however, was the only one that needed attention. Most students got to their conclusion section and stated, "My hypothesis is correct because I have proved that..." or even, "My hypothesis is correct because my data

prove..." When they finished their presentations they smiled with pride at having given us, the judges, what they thought was the most important entity in science—positive results that *prove* something.

For the sake of my devotion to real scientific investigation I asked the presenters if they truly felt they had proven their hypothesis. When they replied 'yes' I proceeded to give my speech that no amount of experimental evidence or testing can *prove* a hypothesis beyond a shadow of a doubt. A hypothesis gains credibility from positive data that support it. If they had supplied the scientific world with evidence or new knowledge to support their hypotheses then, with additional supporting evidence from others doing research on the same topic, a theory or an integrated explanation of a number of hypotheses, may emerge. This reminder doesn't fall on deaf ears, as my own students showed me at the end of the day. They rushed to me with glee to tell me that they'd had to explain scientific theory to the middle school students they judged. The lesson for the day was that in science we cannot explain anything with 100% accuracy; our data either support or negate our hypotheses. One is not better than the other since from negative results we can actually learn more.

In our present world, research scientists are fighting to reinforce to the non-scientific world that the "theory of global warming" and the "theory of evolution" (to name two hot-topic theories) are not mere guesses or hunches, but explanations based on reliable data that should be taken seriously. Ideas or hunches that are not grounded in scientific evidence, like intelligent design, should not be associated with the word *theory*. Scientists pride themselves on being able to present data that can stand up to the test of time and, if not,

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can lead us to new discoveries, like a 10th planet in the Kuiper Belt.

I urge all of us to gently remind ourselves and those we mentor that a hypothesis is never proven correct. And that no amount of experimental testing or evidence can prove anything in science. If a scientist's results match his/her prediction, then the hypothesis is supported. This, like the disclaimer in our textbooks, is a start.

Reference

French, D. 2006. Should we allow disclaimers in textbooks? Maybe the right ones. *Journal of College Science Teaching* 35 (5): 54–55.

Morrison, D. 2005. Only a theory? Framing the evolution/creation issue. *Skeptical Inquirer* 29 (6): 37–41.

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