No Scientific Proof

By John Benson

August 2024

1. Introduction

I am not a scientist. I am an electrical engineer. However, I am a member of the American Association for the Advancement of Science (AAAS), and have been for many years. I also faithfully read every weekly AAAS issue of "Science" (although not every article therein – my interests are limited).

The following is a reasonable definition of The Scientific Method:

The principles and empirical processes of discovery and demonstration considered characteristic of or necessary for scientific investigation, generally involving the observation of phenomena, the formulation of a hypothesis concerning the phenomena, experimentation to test the hypothesis, and development of a conclusion that confirms, rejects, or modifies the hypothesis.[1]

If you don't like the above definition, there are several others in reference 1. None of these include the words: "proof," nor "proven." If you look at the history of science you will see that today's "scientifically proven fact" is tomorrow's fiction. Over the years scientists have seen this and avoid the above words.

2. Agreeing Opinions

Throughout the history of science and frequently during the COVID-19 pandemic, the public's trust in science has been undermined when scientists with large public platforms have failed to state strongly enough that their pronouncements are based on science that remains in flux. With the surgeon general's recommendation and the inevitable pushback from Big Tech, the controversy will only intensify. Seeing past the competing agendas will require not only stronger research but a greater care in broadcasting the findings to the public realm.[2]

There are surprisingly few proven facts in science. Instead, scientists often talk about how much evidence there is for their theories. The more evidence, the stronger the theory and the more accepted it becomes.[3]

2.1. Words Matter, But Are Not Proof

In Section 1, where we stated a Scientific Method, the output of that method is a confirmed, rejected or modified hypothesis. However, even the most clearly stated hypothesis that is rigorously confirmed does not prove anything.

Scientists are usually very careful to accumulate lots of evidence and test their theories thoroughly. But the history of science has some key, if rare, examples of evidence misleading enough to bring a whole scientific community to believe something later considered to be radically false.

---

[1] The Free Dictionary, "The Scientific Method," https://www.thefreedictionary.com/Scientifically+proven

[2] H. Holden Thorp, Editor-in-Chief, Science, "Unsettled science on social media," June 28, 2024

[3] Peter Vickers, Associate Professor in Philosophy of Science, Durham University, via The Conversation, June 4, 2018, https://theconversation.com/the-misleading-evidence-that-fooled-scientists-for-decades-95737

A common way scientists gather evidence is to make a prediction / hypothesis about something and see if they're correct. The problem occurs when the prediction is right but the theory they use to make it is wrong. Predictions that seem particularly risky but turn out to be true look like very strong evidence, as Karl Popper and other philosophers of science have often stressed. But history shows us that even very strong evidence can be misleading.

You've heard of our greatest scientific theories: the theory of evolution, the Big Bang theory, the theory of gravity. You've also heard of the concept of a proof, and the claims that certain pieces of evidence prove the validities of these theories. Fossils, genetic inheritance, and DNA prove the theory of evolution. The Hubble expansion of the Universe, the evolution of stars, galaxies, and heavy elements, and the existence of the cosmic microwave background prove the Big Bang theory. And falling objects, GPS clocks, planetary motion, and the deflection of starlight prove the theory of gravity.[4]

Except that's a complete lie. While they provide very strong evidence for those theories, they aren't proof. In fact, when it comes to science, proving anything is an impossibility.

Reality is a complicated place. All we have to guide us, from an empirical point of view, are the quantities we can measure and observe. Even at that, those quantities are only as good as the tools and equipment we use to make those observations and measurements. Distances and sizes are only as good as the measuring sticks you have access to; brightness measurements are only as good as your ability to count and quantify photons; even time itself is only known as well as the clock you have to measure its passage. No matter how good our measurements and observations are, there's a limit to how good they are.

3. Proof vs. Probability

It is often the case that the most fundamental concepts in science are the ones that are the most misunderstood, and that is certainly true with the concept of "proof." Many people accept the misconception that science is capable of providing proof, and I often hear people make claims like, "science has proved X" or "a fact is something that science has proved." In reality, however, science is inherently incapable of proving anything. Upon hearing that, many people then jump to the opposite extreme and claim that since science can't prove anything, it is unreliable and should not be trusted. That position is also incorrect.[5]

The reality is that science deals in probabilities, not proofs. The reasons for that range from the philosophical to the practical, but if you really want to understand the nature of science, then it is very important that you understand the concept of proof. Therefore, I am going to go over some of the reasons why science doesn't prove anything, then I am going to explain why that is actually a good thing and should not make you question the reliability of science. As I will elaborate on, the best way to think about science is that it tells us what is most likely true given the current evidence. As such, it is an extremely useful tool, and it is far better than the alternatives, but it's certainly not perfect.

[4] Ethan Siegel, Forbes, "Scientific Proof Is A Myth," April 14, 2022, https://www.forbes.com/sites/startswithabang/2017/11/22/scientific-proof-is-a-myth/

[5] Fallacy Man, The Logic of Science, "Science doesn't prove anything, and that's a good thing," April 19, 2016, https://thelogicofscience.com/2016/04/19/science-doesnt-prove-anything-and-thats-a-good-thing/

3.1. Definition of "proof"

I think that it is important to define "proof" at the outset. When we say that science can't prove anything, what we mean is that it cannot show anything to be absolutely, certainly, and unequivocally true. For example, we are very, very certain that the earth is orbiting the sun (heliocentrism) but we can never actually be 100% sure that it is. In contrast, mathematics can provide proofs. Mathematics consists of laws, rules, and theorems which are absolutely true. The uncertainty only enters when you apply the laws of math to observations in the physical universe, which in many ways, is all that science is.

Let me illustrate what I mean with the following example:

- *Premise 1: The sum of the angles of any triangle = 180 degrees*
- *Premise 2: For triangle ABC, angle A = 90 degrees*
- *Premise 3: For triangle ABC, angle B = 45 degrees*
- *Conclusion: Therefore, for triangle ABC, angle C = 45 degrees*

In both philosophy and math, we would refer to that as a logical proof. In other words, if those premises are true, then the conclusion must be true. That qualifier is really important though. You can work out the math using variables and demonstrate that for any triangle the sum of the angles must equal 180 degrees, but as soon as you start plugging actual measurements into the formula, you introduce bias and error. In other words, if premises 2 and 3 are true, then we can be absolutely certain that the conclusion is correct, but as I'll explain, we can never actually be absolutely certain about premises 2 and 3, which means that we can never be absolutely certain about the conclusion. Thus, absolute proofs are unattainable in the real world.

3.2. Are we brains in vats? The philosophical problem of proof

The most esoteric reason that science can't prove anything comes from the philosophical arguments about knowledge. You have no doubt heard of these arguments via Descartes' famous statement, "Cogito ergo sum" ("I think, therefore I am"). Descartes was concerned with what we could actually be certain of, and he correctly realized that almost everything that we think we know is based on observations, and observations are notoriously faulty and untrustworthy. We cannot, for example, ever be 100% certain that we are not hallucinating, or, as Descartes argued, that there is not some evil demon projecting a reality onto our senses. Similarly, I have personally had numerous dreams where, in the dream, I contemplated whether or not I was dreaming, and I incorrectly arrived at the conclusion that I was awake. Therefore, I can never be 100% certain that I am not dreaming.

Perhaps the most famous of these arguments is the brain in a vat argument. This is the concept on which the Matrix movies were based, and it argues that we cannot be certain that we actually exist in our perceived physical form and are not actually just brains in vats living is some form of virtual-reality environment.

After considering arguments like these, Descartes realized that the only thing that he could be certain of was that he was thinking, which meant that there must be something doing the thinking, therefore he must exist in some form. That is what is meant by, "I think, therefore I am" (or perhaps more correctly, "I am thinking, therefore I must exist").

I went through all of that to make two important points. First, science is completely dependent on observations, but since we can never be 100% sure that our observations accurately represent reality, we can never be 100% sure of the results that are based on our observations. In other words, even though all of our observations tell us that the moon orbits the earth, we can't actually be certain that the moon and earth even exist and aren't simply part of the Matrix environment.

Second, you should not misconstrue this conceptual uncertainty with a practical uncertainty. I (and the vast majority of philosophers) don't actually think that we are brains in vats or that we are currently dreaming, but we acknowledge that as a possibility which we cannot rule out. In other words, science implicitly relies on the assumption that we are actually in a physical universe, and it would be absurd to make a statement like, "science says that the moon revolves around the earth, but I can't be sure that I am not a brain in a vat, so I am going to reject that science and impose my own view of reality." Similarly, if you show me a triangle and tell me that you measured angle A as 90 degrees and angle B as 45 degrees, I'm going to accept that angle C is 45 degrees unless I have a really good reason not to (like looking at the triangle and seeing that it is asymmetrical). Nevertheless, I acknowledge the possibility that your measurements were inaccurate, that an evil demon is projecting a triangle that doesn't actually exist, etc. Again, I would need actual evidence to convince me that those are happening, but at the same time, I cannot definitively state that they are not.

3.3. Practical Reasons: Inductive Logic

Now that we have the philosophy out of the way, let's talk about the practical reasons why science doesn't prove anything. Even if we could be absolutely certain that we aren't brains in vats, we still could not use science to actually prove anything, and one of the key reasons for this is the types of logic that are used in science. Science involves both ***deductive and inductive logic****, with deductive logic typically being used for specific experiments and testing theories/hypotheses, and inductive logic being used to form general conclusions, hypotheses, and theories. This is important because inductive and deductive logic differ in both the certainty and the scope of their conclusions. Deductive arguments end in a focused conclusion that must be true as long as the premises are true and no logical fallacies have been committed (my triangle example earlier was deductive logic). In contrast, inductive arguments end in a general conclusion that is probably true. Importantly, science is really big on explaining things and making generalizations, because a result that is only applicable to the experiment that produced it is not very useful. Therefore, science relies heavily on inductive logic to form its theories and hypotheses.*

For example, atomic theory states that all matter is made of atoms. We arrived at that general conclusion via numerous observations which consistently showed that matter is made of atoms (i.e., we went from a series of specific observations to the general theory). Now that we have the theory in place, we can test it with deductive logic. We can, for example, take a piece of matter, do an experiment to see if it is made of atoms, and use deductive logic to reach our conclusion about that piece of matter. That is a deductive process, and it is a good way to test a theory (all that it would take to discredit atomic theory is to find one piece of matter that was not made of atoms). Thus, science involves a seamless transition from inductive to deductive logic and vice versa, but because of the inductive steps, the overarching conclusions always have a degree of uncertainty.

3.4. Practical reasons: Statistics

At this point, you may be thinking, "okay, theories and general explanations can't be proved, but since individual experiments often use deductive logic, surely they provide proof." In an ideal world, that would be true, but in reality, it is problematic. Consider the following example from a drug trial.

- *Premise 1: The only difference between the treatment and control groups was the medication that they received*
- *Premise 2: The treatment group did better than the control group*
- *Conclusion: Therefore, the drug worked in this trial*

Can you spot the problem? Don't feel bad if you can't, because it's not obvious. If all of those premises are true, then the conclusion would be true, but the problem is that we can never actually be certain that the premises are true. In fact, premise 1 is almost certainly false. Unless you are working with clones and each of them is treated by an automated computer program and lives in an identical, sterile isolation chamber, there are going to be differences in your groups. You can minimize these by controlling all of the factors that you can, randomizing your samples, and using very large sample sizes, but you can never actually have truly identical samples. So, a properly conducted experiment will have a premise 1 that is as true as possible, but because it is never possible for it to be 100% true, you can never be 100% certain of the conclusion.

The second problem is, of course, that the deductive argument only applies to the specific results of that experiment, and we want to generalize to the entire population (i.e., we want to know if the drug works for most people, rather than simply if it worked for the individuals in our experiment). To do this, we need statistics, because they allow us to gauge how likely it is that our results are representative of the entire population, rather than just being representative of the samples that we collected.

However, statistical tests invariably operate off of probabilities. Indeed, if you read scientific papers, you will never see a statement like, "our experiment proved X." Rather, you'll see things like, "these results suggest X (P = 0.002)" or "our results are consistent with X." I have previously explained what these statistics mean in detail, so I won't do so here, but the point is that essentially all scientific conclusions are based on probabilities of one form or another. For example, classical frequentist statistics use P values which represent the probability of getting an effect that is equal to or greater than the one that you observed if the thing that you are testing actually has no effect. Other probabilities may involve comparing different models and discussing which is the most likely, using prior knowledge to construct a probability, etc. The point is that statistical tests always involve probabilities. To put this another way, statistics can show you that there is only a 0.0000000000000000000000000…1% probability of a result arising by chance, but they can never actually prove that a result is real and representative of the general population.

Final author's comment: At this point I wish to leave a few words from another author, but I can't prove who that author is: *"Lies, damned lies, and statistics" is a phrase describing the persuasive power of statistics to bolster weak arguments.*[6] *In order to make your own guess, go to the article referenced below.*

---

[6] Wikipedia article on "Lies, damned lies, and statistics," https://en.wikipedia.org/wiki/Lies,_damned_lies,_and_statistics