# What is Science?

Science plays a huge rule in our decision-making, at both a personal and a political level. We use it to make decisions about our health, our children’s’ education, our investments, the way we manage our economy, and (for many people) to try to figure out “our place” in the universe around us. However, for obvious reasons, we can’t all be experts on all areas of science, and not all people who claim to be “scientific experts” deserve the title. In the history of philosophy, concerns like this have givenrise to the **problem of demarcation—**the problem of marking off things that really *are* scientific from those that aren’t. Some practical examples of the problem:

* When making decisions about our health or diet, which people or books provide “scientific” knowledge? Which don’t?
* Is there a “science of economics”? If so, what role should it play in politics? And how can we sort out the real experts in economics from the (all too common) financial “wizards” who don’t actually know much?
* What should school children learn about biology and evolution? Physics and the origin of the universe? What does it mean for a theory to be “scientific” anyway?
* Why should I believe that smoking causes cancer? That carbon emissions cause global warming? That vaccines don’t cause autism? That GMOs are safe for human consumption? Why should peer reviewed articles count more than popular websites, TV shows, or the experiences of my friends and I?
* What is the difference between science and religion? Between science and philosophy?

In this lecture, we’ll be taking a look at how two famous philosophers of science—Karl Popper and Thomas Kuhn—tried to answer questions such as these.

## Three Examples of Scientific Theories

In order to get started, we’ll have identify some examples of theories that are (uncontroversially) scientific Most people would consider the following theories to be **scientific** theories:

**Newton’s theory of mechanics and his law of gravity.** Newton described the relationship between *forces, acceleration,* and *mass.* He also described one specific force that he called *gravity.* Newton and his scientific followers used his three laws of mechanics and his law of gravity to make specific predictions about the motions of both heavenly bodies (like the moon, the sun, the planets, and comets) and bodies near the earth (like apples falling off of trees). Even today, these equations are widely used by engineers, architects, and many others.

**Einstein’s theories of special and general relativity.** Einstein claimed that there was an absolute limit to the speed of light, and that a light beam traveling through a vacuum would *always* appear to be traveling at this maximum speed, regardless of how fast (or in what direction) the person trying to measure the light’s speed was moving. In order for the speed of light to be “absolute” in this way, though, it meant things like “the time from event A to event B” or “the distance from point C to point D” could *not* be absolute. He used this theory to predict a number of surprising predictions about the way light would curve around planets and stars, and the effect that sun would have on the orbit of planets like Mercury.

**Darwin’s theory of evolution.** Darwin claimed that all existing organisms were descended from a very small number of original organisms. He claimed that *speciation* (the emergence of different species) occurred for two fundamental reasons: (1) organisms strongly resembled their parents, but differed randomly from them in small ways and (2) organisms that were better fit for their environment were more likely to reproduce than those who were less fit. His theory made specific predictions about the fossil record, the distribution of various species (e.g., remote islands will generally contain lots of unique species), and the similarities between different species.

## Mythology, Religion, and Pseudoscience

Most people would consider the following theories NOT to be scientific theories:

**Religious and mythic claims.** Most cultures have one (or more) popular religious or mythological theories that purport to explain things such as (1) how the world was made, (2) what kind of being/beings were in charge of making the world, and what their motivations were, and (3) what happens to people (and maybe animals) after they die. While these theories differ from scientific theories in a number of respects, one important one concerns the ability to make predictions. Anyone who understands Newton, Einstein, or Darwin can, for example, use this knowledge to make predictions on what will happen in certain sorts of experiments or situations, whether this by the motion of the planets, the bending of light, or the change in cancer cells as a person undergoes chemotherapy. Religion isn’t like this, at least most of the time: there’s no way of carrying out an “experiment” to see the truth of one’s religion.

**Freudian psychoanalysis.** According to Freud, humans have three parts to their minds: the id, the ego, and the superego. Each part of the mind has distinct *beliefs, desires,* and *intentions.* However, we are only aware of the ego and the superego—the id is hidden from our conscious minds. Freud’s claim was that every human action or thought (however “irrational” it seemed) was due to some belief, desire, or intention of these various parts of our minds. Freud wrote a number of essays showing how this theory could be used to explain almost every conceivable type of human behavior—all that one need to do to explain a behavior was to assign the “right” sorts of intentions, desires, and beliefs to the id. One famous example: the id often believes that the same-sex parent (father for boys, mother for gils) is a sexual rival and desires that it be eliminated. Of course, we don’t consciously think this, but Freud claims this is what is really going on.

## Popper’s Proposal: Scientific Theories are Falsifiable

“Bold ideas, unjustified anticipations, and speculative thought, are our only means for interpreting nature: our only organon, our only instrument, for grasping her. And we must hazard them to win our prize. Those among us who are unwilling to expose their ideas to the hazard of refutation do not take part in the scientific game.” (K. Popper, LSD)

Karl Popper (1902-1994) was one of the most influential philosophers of science of the last 100 years. He made significant contributions to debates concerning general scientific methodology and theory choice, the demarcation of science from non-science, the nature of probability and quantum mechanics, and the methodology of the social sciences. In contrast to the widespread view that science involved inductive reasoning (of the sort that Hume raised problems for), Popper thought that science could make do with only “deductive” reasoning (and thus avoid Hume’s problem).

Popper famously argued that a scientific theory was characterized by its “testability,” and in particular by its clear description of way that other scientists might be able to disprove (or “**falsify”**) the proposed theory. He thought this was pretty unique to science, and that it was crucially important, since it explained why and how science (unlike many other areas of human inquiry) could make “progress” of a certain sort. Popper’s proposal has fallen out of favor with many philosophers of science (who still favor the view that science involves induction), but it has remained popular with practicing scientists:

**(Popper’s Demarcation Criteria)** A theory is scientific to the degree that it can be **falsified**. That is, a scientific theory (unlike a non-scientific theory) *clearly describes ways that it could be proven wrong.*

* Science!: Edmund Haley used Newton’s theory to predict that particular comet (“Haley’s Comet”) would appear at a very particular time in a very particular place. If he had been wrong (he wasn’t), this would have been bad news for Newton.
* Not Science!: Many religions predicted that a God (or gods) created the “best of all possible worlds.” However, they do not specify *any possible observation* that would prove this wrong. For example, this does not rule out things like massive natural evils (disease, starvation, etc.). Popper didn’t have any problem with religion; he just thought it wasn’t scientific.

While Popper’s criterion (which he labels D) is simple, he emphasizes several caveats:

1. **It is vague, and that’s OK.** While many theories are clearly scientific and others are clearly not, there is also a large “grey area.” For example, Copernicus claimed that the earth orbited the sun, but failed to make any concrete predictions resulting from this. Many theories start out as “metaphysics” or “non-science” and become science once measuring equipment has been developed. In general, the more “risks” a theory takes (the more ways that it can be “falsified”), the more scientific it is.
2. **Theories are tested (and revised) as a whole.** Newton, Einstein, and Darwin wrote lengthy books describing the ins and outs of their theories. Popper emphasizes that it is the theories as a whole, and not the individual claims within the theories, that are tested. For example, Einstein’s claim that the speed of light had an absolute limit made no sense outside of the rest of his theory about how things worked. Similarly, it is the theory as a whole (and not an individual claim within the theory) that gets falsified.
3. **It’s (sometimes) OK to revise a falsified theory.** If your theory is falsified, it’s OK to revise it and try again. However, you need to make a **legitimate revision** and not an **ad hoc revision**. A legitimate revision produces a *new* theory that makes *new* testable predictions. An ad hoc revision produces a new theory, but does not make new testable predictions.
4. **Just because a theory hasn’t been falsified does not mean that it is true.** Popper notes that Newton’s theory was false, and that Einstein himself thought that his theory would eventually be replaced by a unified field theory. Popper emphasizes that this is OK. What separates science from non-science is not that the former is TRUE and the latter FALSE. Instead, scientific theories take risks—a scientific theory contains a clear claim of the form “If the following thing is observed, you need to reject me, and find a better theory.” According to Popper, this is why science makes *progress*, while non-scientific theories are essentially *static.*
5. **“Creativity” involves bold risk tasking.** Popper emphasizes the importance of being willing to “go it alone” and to come up with a completely new scientific theory in response to an experiment that falsified an old scientific theory. He recognizes that this sort of thinking is not unique to science, but he thinks that it is most valuable when you take a risk of being shown wrong—that is, of having your theory falsified.

## An Alternative View: Thomas Kuhn on Paradigms

“Without commitment to a paradigm there can be no science... the study of paradigms is what prepares a student for membership in a particular scientific community. Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, i.e., for the genesis and continuation of a particular research tradition. ...scientific revolutions are inaugurated by a growing sense that an existing paradigm has ceased to function adequately in the exploration of an aspect of nature.” (T. Kuhn, SSR)

Thomas Kuhn was another famous philosopher of science who worked on the demarcation problem. Like Popper, he was impressed by the ability of science to produce knowledge when compared to other means of human inquiry. He didn’t agree with Popper’s account of why this was, though, because he thought that Popper’s theory really only worked to explain “revolutionary” science (what Popper calls “heroic” science). He didn’t think Popper’s view accurately captures what we calls “normal” science, in which it would be absolutely crazy for someone to give up on theory just because it got one bad experimental result. Here’s Kuhn’s solution:

**Kuhn on Paradigms.** A mature science (unlike pseudoscience or mythology) has a **paradigm** that is shared by all of its scientists. This paradigm consists of a vocabulary, specific testing methods, and a shared sense of what sorts of problems are important. If two scientists share a paradigm, they will agree on the precise import of various experimental results. Science is characterized by things like reproducible experiments, well-understood quantitative or qualitative methods, peer review, and so on.

* Prescientific or nonscientific theories don’t have paradigms. For example, two Freudian psychologists will rarely agree on what specifically is wrong with a patient, and what can be done to treat him or her. In religion, even skilled theologians disagree on what predictions about the future can be deduced from their holy texts. There are also some in-between cases. For example, economists agree on *some* important things, but not nearly as many as biologists or physicists do.
* Scientists with different paradigms (for example, Aristotle and Einstein) cannot really “talk” to one another, since they are concerned with different problems and use different methods, vocabulary, and so on. This doesn’t necessarily mean all paradigms are equally productive—it’s just that we shouldn’t be too surprised when scientists working within different paradigms have a hard time figuring out what on earth the other person’s research project is about. In general, Kuhn thought that scientists rarely changed paradigms, even when the paradigm in question has ceased to work. Instead, in these sorts of circumstances, paradigms mainly change as old scientists die, and their younger replacements adopt the “new” paradigm.
* On Kuhn’s view, scientists almost never entertain the thought that their paradigm is “falsified.” Instead, they assume that something else has gone wrong—e.g., that there has been an error in measurement, that some factual assumption was wrong, or something of the sort. This approach is usually a good one, since it often leads to new discoveries.
* “Creativity” involves problem-solving within a paradigm, and responding to what others are doing within that paradigm. It does NOT involve people outside the paradigm simply making wild, uneducated guesses (so, we shouldn’t be too surprised that engaging in scientific research often involves getting a doctorate). Popper emphasizes the importance of bold risk takers. Kuhn emphasizes that science would never have made any progress if everyone threw away the dominant paradigm at the first sign of trouble. Instead, the paradigm is something like a “tool” that can be used solve difficult problems.

A music analogy: Popper thinks that a “great scientist” is like someone who invents an entirely new genre of music, while non-scientists are basically just people who just sing karaoke, or something of the sort. So, if you’re sick of country, you invent rock; if you’re sick of rock, you invent hip hop, and so on. Kuhn emphasizes that this is pretty unusual, and that most of the great scientists were working *within* paradigms, just as most great musicians were working within their chosen genre of music. Scientists are distinguished from non-scientists by their knowledge of the paradigm (how to play instruments, the basics of song composition, etc.). Importantly, both Kuhn and Popper would strongly resist the idea that simply banging on a drum would count as “great music.”

## REview Questions

1. Whose view of science do you find more convincing—Popper’s or Kuhn’s? Explain and defend your answer.
2. How might Popper and/or Kuhn approach a current debate about science? For example, what might they think about the debate over the teaching of “intelligent design” in public schools? (There are plenty of articles available on this on the web. If you use them, be sure to cite!).