WHAT SEPARATE SCIENCE FROM "PSEUDOSCIENCE?"

In this lesson, we'll be answering the following questions:

1. Why is it important for us to be able to distinguish "genuine" scientific theories from "pseudoscientific" theories?
2. How is this different from the task of distinguishing between theories *within* science?
3. What are some contemporary ideas about how to **demarcate** science from non-science?
4. What are the strengths/weaknesses of these different approaches? To what extent do they converge?

This lecture is the final (!) in a series of five on topics in the history and philosophy of science. However, it should be accessible to newcomers (and, in fact, the material for this lesson is considerably more "practical" and "applied" than material in previous lectures).

A BRIEF RECAP OF WHAT'S COME BEFORE

Before diving into today's topic, it will help to review a few points from earlier classes.

1. In the context of history and philosophy of science, a **theory** is just a collection of claims about the world. Some theories are true, and some are false. We have really, really good reasons to believe some theories (e.g., "Drinking bleach is unhealthy.") decent reasons to believe others (e.g., "drinking too much orange juice is unhealthy"), and positive reasons to disbelieve others (e.g., "drinking tomato juice will make your hair turn red."). A **scientific mosaic** is just the collection of theories (and the methods for evaluating these theories) accepted by the scientific authorities of the day.
2. For this lecture, we'll mostly be interested in theories of the **empirical sciences** (such as physics, biology, medicine, or economics) as opposed to the **formal sciences** (such as mathematics, logic, and computer science). Theories of the empirical sciences are characterized by the **synthetic** claims they make about the world—that is, claims that are NOT logically true/false and which could (conceivably, anyway) turn out either way. For example, "most cats have four legs" is a true synthetic statement, while "most cats have three legs" synthetic statemen
3. Empirical sciences gather evidence—for example, by performing experiments of various types—to confirm or falsify these synthetic claims. In modern science, the **scientific method** nearly always involves something like the following: (a) scientists propose a hypothesis, (b) they deduce predictions from this hypothesis, and (c) they check to see whether these predictions match observations. As a general rule, any hypothesis that proposes a fundamental change to ontology (e.g., it posits the existence of new sorts of entities or forces) is required to make successful *novel* predictions (that is, the hypothesis needs to predict things that current theories can't!).
4. Both individual scientific theories AND the methods by which these theories are tested have changed over time. For example, Aristotle's approach to science was quite different from Newton's, which was in turn quite different from Einstein's. These thinkers (along with the thousands of "working scientists" who followed in their wake) had fundamentally different ideas not just about which theories should be adopted, but ALSO on what sorts of rules/procedures should be used to them.
5. This all being said, scientific progress doesn't seem all that random. In general, scientists will only adopt theories that are justified by their current methods. Similarly, they will only entertain changes in methods when these changes are motivated by underlying changes in theory. In this way, the transition from Aristotle to Newton to Einstein (and beyond) has generally been a slow and gradual one, rather than an abrupt leap from old theories to their replacement.
6. Finally, there is a longstanding debate (going back to the very dawn of science) between **scientific realists,** who think that scientific theories are *attempts to describe the world "as it really is",* and **scientific antirealists,** who think that scientific theories are merely *useful tools* (and thus, it doesn't matter whether they are true or false). Importantly, the vast majority of both scientific realists and scientific anti-realists are generally "pro-science" (that is, they tend to think that science is a good thing for society), and are generally opposed to things like pseudoscience. In fact, one of the debates between scientific realists and scientific anti-realists has been about whose view does a better job of distinguishing between theories that are legitimately "scientific" and those that are not.

WHY RECOGNIZING "SCIENCE" MATTERS

The word *science* gets used in several different ways. Sometimes, it is simply a descriptive term, meant to pick out whatever it is that scientists do (for example, "Oh, my daughter is studying to be a physician. She's had to take a lot of science classes."). In other cases, *science* functions as a **normative** concept meant to distinguish good ideas from those that are bad (for example, "climate change denial is NOT science"). Roughly speaking, historians of science have tended to focus more on the descriptive question (i.e., "As a matter of fact, what sorts of things have been called *science?*"), while philosophers of science have tended to focus on the normative question (i.e., "What theories/approaches *should* be thought of as scientific, and which should not?").

In the end, the debate about "what science is" is NOT primarily a debate about words. It is instead part of a much bigger debate about which ideas/theories we should use to organize our lives and societies, and which theories/ideas we should avoid. So, for example, here are a few of the issues that require us to make distinctions between theories that are "scientific" and theories that are not:

1. Which medical treatments should be recommended by physicians (or dentists, psychiatrists, etc.) as based on "science"? Which drugs should the FDA approve?
2. What sorts of "scientific" evidence should be allowed in courts of law? Should DNA evidence be allowed? Testimony from psychologists? Criminologists?
3. What sorts of theories should children learn in public school? What separates ideas like the theory of evolution via natural selection from "competitors" like intelligent design?
4. What sorts of projects should funding agencies (such as the National Institute of Health) give money to? How can we distinguish promising new "scientific" ideas from non-scientific or pseudo-scientific rivals?
5. How can we (as both individuals and a society) distinguish "legitimate" scientific institutions and ideas from **"pseudo-scientific"** institutions and ideas that merely "pretend" to be science?
6. How can we, as non-specialists, distinguish between theories about which there is genuine scientific disagreement/uncertainty, and those where the "dissenters" have no scientific basis? (For example, there is little *scientific* disagreement about the vaccine-autism link, the reality of climate change, etc.)

The problem of determining what counts as science and what does not is commonly called **"The Problem of Demarcation."** During the early- to mid-twentieth century, this was considered one of the central problems of philosophers and was a major area of research for thinkers such as Rudolph Carnap, Karl Popper, and Thomas Kuhn (more on these thinkers later).

Question: Can you think of any other reasons (besides those mentioned above) why it might be important to know "what science is"?

MYTHOLOGY, METAPHYSICS, RELIGION, AND PSEUDOSCIENCE

To help get a handle on what we'll be talking about, we'll begin with some examples. In contrast to the scientific theories of modern physics, chemistry, and biology, most philosophers of science and logicians would consider the following theories to NOT be scientific theories, even if they might have other legitimate applications:

- **Religious and mythic claims.** Most cultures have numerous 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.
- **Philosophy "metaphysics."** Philosophers regularly have arguments about concepts such as "free will", the rightness or wrongness of various actions (euthanasia, abortions, etc.), the existence of God, or the nature of causation. Many of these theories make no "predictions" of the sort that scientific theories do.
- **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. 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 needs to do to "explain" a behavior was to assign the "right" sorts of intentions, desires, and beliefs to the id (famously, the id often believes that the same-sex is a sexual rival and desires that it be eliminated). The problem? When trying to applying Freudian theory to a particular case, it seems like "anything goes": there is literally *no possible behavior* that a Freudian analyst couldn't chalk up to whacky desire on the part of your id. (Importantly, this does NOT mean that all psychology is like this!).
- **Astrology and Horoscopes.** Many newspapers and websites promise to predict your future based on your "astrological sign." However, the predictions they give are often quite vague. For example, a typical horoscope might predict that you will encounter "conflicts" in your professional or romantic life, or counsel you to expand on your "strength" in choosing your friends. The people who rely on these suffer from a sort of **confirmation bias**—they focus on the things that the horoscope "gets right," without noticing that these are generally the sorts of things that could apply to *everyone.*

Theories that "look" scientific without actually being so are often called **pseudoscience.** Examples might include (certain types of) psychoanalysis, astrology, fad diets, or even widespread views about scientific issues (e.g., denialism regarding vaccine effectiveness, global warming, the cigarette-cancer risk, and so on).

Question: As the above examples show, not all "non-scientific" theories are the same. Some (religion, art) seem to serve different purposes than science, while others (fad diets) seem to compete with science. Finally, some (psychoanalysis?) are ideas that might someday *become* scientific. Can you think of any other categories on non-scientific theories?

SOME IDEAS ABOUT WHAT SCIENCE IS: A VERY BRIEF HISTORY

Until the early late 19th and early 20th century, the distinction between "science" and "non-science" wasn't one that many people had thought much about. Instead, theories about "natural philosophy" (the precursor of modern "science") were generally distinguished from other areas of inquiry (in particular, from areas like theology, philosophy, or history) by adhering to the methods/approaches of the physics of the day:

- Until about 1600, most science in the Christian-Jewish-Islamic "West" was based on **Aristotle's** ideas. Aristotle thought that physical entities (of the type studied by natural science) were combinations of "matter" and form (or **essence)**. Science aimed to uncover these essences, and to give explanations of natural phenomena in terms of these. Natural philosophy adhered to this paradigm. So, "the planets orbit the earth because celestial bodies have essentially circular motion" would be a (very simple) scientific theory. "We know the planets orbit the sun because the Bible says so" would be an example of **revealed religion** (based not on observations of nature but on scripture). Scientific theories could be (and, in fact, often were) about God/religion, but their methods needed to follow Aristotle.
- After the Scientific Revolution of the 1600s, the model of what counted as "science" was based first on the work of **Descartes,** according to which everything needed to be explained **mechanistically—**think of pool balls running into one another. Later scientists adopted **Newton**'s model. Newtonian physics (gravity, in particular, which seemed to operate at a distance) got rid of this requirement. The Newtonian model did require that scientific theories be **deterministic** and **law-governed.** (Basically, the goal of any scientific theory was to identify a *mathematical equation* that accurately and without exception described reality). Starting in the 18th and 19th centuries, attempts were made to formulate new science (in particular, economics) based on the Newtonian model.

These (largely implicit) ideas about "what science is" started to fall apart in the late 19th century, both because they didn't do a good job of explaining how theories outside of physics (biology, psychology, economics) worked and because physics (the "model" of science) itself started to change in remarkable ways. Both Einstein's General Theory of Relativity and early ideas about Quantum Mechanics did not look anything like Newtonian physics. QM in particular did not seem to be deterministic or law-governed.

By the early 20th century, there were lots of other reasons for *caring* about the "definition of science." Science was just a much bigger deal! Universities began hiring much more in the sciences (and much less in areas like theology/philosophy), students began taking their courses, and industry/government increasingly relied on science to help drive technological progress. Alongside this increased visibility for science, however, there were a large variety of ideas that *claimed* to be science but instead seemed to be something else—everything from Freudian psychoanalysis to fad diets to "creation science" to various political ideologies (such as Marxism). It is perhaps unsurprising that many of the earliest attempts to mark the distinction between science and nonscience came in a social context (Germany and Austria of the 1930s) which was simultaneously the center of exciting advances in science and threatening political ideologies that claimed to be "scientific."

Question: In the early 20th century, science was held in very high regard by the educated public (and people regularly went to "public lectures" by scientists). How would you describe the *current* attitude of the general public toward science?

VERIFICATIONISM: SCIENCE AND THE FIVE SENSES

Starting in the late 1920s, a group of German-speaking philosophers, mathematicians, and scientists known as the **logical positivists** (such as **Rudolph Carnap,** who is something like the "father" of modern history and philosophy of science) starting thinking seriously about how "scientific" theories could be distinguished from the "metaphysical" theories of traditional philosophy and theology. One early idea of the positivists was that scientific theories must be **verifiable,** in a way that the "metaphysical" theories of traditional philosophy, religion, or mythology were not. The basic idea was that scientific theories should make claims about things that we can actually see or touch (even if this seeing/touching happened through instruments such as microscopes). That is, in science, we should be able to "verify" whether the claims were true or false. The catchphrase was **"The meaning of a statement is its method of verification."** By contrast, philosophical, religious, or pseudoscientific theories about "God" or "the good" or "free will" or "psychic energy" or "undetectable alien visitors" or "the fundamental nature of reality" seemed to involve things that were, by their very nature, impossible to verify. (And so, claims about these sorts of things ended up being meaningless, much to the chagrin of their defenders!),

Carnap famously describes the idea as follows:

Science is a system of statements based on direct experience, and controlled by experimental verification. Verification in science is not, however, of single statements but of the entire system or a sub-system of such statements. (Carnap, "The Unity of Science")

So, on this view, a scientific theory is essentially a (highly mathematical and abstract) way of describing what we humans should see, hear, touch, and feel. Carnap recognizes that scientific theories might have certain concepts (such as *electrons* or *genes)* that can't be observed in isolation, but he thought the theories from which these concepts were drawn (physics, biology) USED these ideas to make predictions about things we CAN observe (which thus made the theory as a whole verifiable/meaningful).

Problems with Verification. As Carnap and the other logical positivists soon came to recognize, verifications had significant problems. One problem was with the verification principle itself (e.g., about the meaning of a statement being its verification) was itself unverifiable, and, in fact, looked a whole lot like traditional "metaphysics." Even if we ignore this issue, verificationism simply got a lot of science wrong. Science regularly makes universal claims—e.g., "ALL electrons have negative charge"—that are by their nature unverifiable (it's impossible to check all the electrons!). Moreover, there are many, many, many possible "observations" that can be deduced from concepts like electrons (e.g., every claim that somehow involves electricity). Which of these, if any, constitute the "meaning" of the concept *electron?* In the end, Carnap and the positivists abandoned strict verificationism for a modified set of ideas on how observations should affect the *mathematical probability* that we assign to different scientific theories (which helped set the stage for modern **Bayesianism,** a highly influential approach to statistics and machine learning).

Lessons from the Positivists. Outside of philosophy of science, "positivism" often gets a bad name, as it is often associated with attempts to reduce/eliminate any idea that could not be "quantified" or "verified" such as religion, art, etc., or that everything should be replaced by a combination of math, logic, and physics. To a large extent, this misses the point of the positivist's project. They generally had strong political commitments (running the gamut from socialism to libertarianism, but unified by anti-totalitarian themes) and were often quite engaged in religious/artistic debate of the day. They saw their project, with its emphasis on clarity, as an extension of these interests (and it's probably no coincidence that the philosophical and scientific theories associated with the rising fascism of the period were notably *unclear).* Moreover, they were unified by a commitment to scientific "pluralistic" and "tolerance", in the sense that they WANTED to encourage scientists (and philosophers, political leaders, artists, etc.) to explore different (and perhaps, mutually contradictory) ideas. They simply aimed to make sure that those proposing new theories be forced to explain *how the claims of their theories related to things we could actually experience.* This remains an important distinction between "science" and "non-science", though it turns out to be one that is tough to formalize!

A Split in Philosophy. The 1920s and 1930s led to a long-lasting "split" in philosophy between "analytic" philosophers that has continued to this day (and affects areas outside of philosophy). On the "analytic" side of the split were the positivists, who were interested in the use of new mathematical/logical methods, and who saw modern science as the best way of understanding the world. On the "continental" side were thinkers such as Martin Heidegger (of "Being and Time") whose methods were largely "phenomenological" (based on "lived experience") and who placed considerably less faith in science, and much more in art/culture/etc. Political divisions also helped drive/exacerbate this division, especially given Heidegger's ties to the Nazis (many of the positivists were Jewish and/or left-wing, and nearly all fled to the US/UK before 1940).

Question. The "split" in philosophy is also reflected in a broader split in academia between the "sciences" and "humanities", in which each side (on least on occasions) views each other's methods and ideas with distrust. Why do you think this is?

KARL POPPER'S PROPOSAL: SCIENTIFIC THEORIES ARE FALSIFIABLE

Karl Popper (an Austrian-born "associate" of the logical positivists, who saw himself as their main rival) proposed a simple, easy-to-remember criterion for distinguishing between scientific and nonscientific theories. He first proposed it around 1930 and continued to revised it until his death in the 1990s. His approach has proved very popular, especially with practicing scientists:

Popper's Demarcation Criteria. Popper held that 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 a 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 claim wrong. For example, this does not rule out things like massive natural evils (disease, starvation, etc.). Without a clear prediction of the form "If bad thing X happens, then God really doesn't exist" these religious claims don't count as scientific.

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

1. **D 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. **There are (sometimes) legitimate reasons to use non-scientific theories.** Popper argues that most scientific theories started out as pseudoscience, and that there are many domains of human inquiry (including philosophy, logic, and religion) which do NOT make falsifiable claims. Popper's idea about falsification is meant to reflect a broader rule about thinking: when we make claims, we should have in mind *what it would take to convince us that we are wrong.* Popper thinks think many of humanity's worst ideas—religious dictatorships, Fascism, Russian Communism, etc.—were all based on theories defined so that they *couldn't* be proven wrong.
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 taking.** 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.

Popper's basic idea can be summarized as follow: "real" science takes risks by making concrete predictions *that might actually be proven wrong*, while pseudoscience does not. Pseudoscience is marked by a sort of blind acceptance of the theory in question, along with a refusal to subject this theory to any real tests that might show it to be wrong.

Question: One main criticism of Popper's view has been that it can't account for scientific *progress*. That is, Popper says that we *never* have any reason to think that our best, most successful scientific theories are true or accurate, even in part (we can only ever identify false theories, of which there are an infinite number). However, many scientists (and many philosophers of science, including the positivists) have thought that we DO have reason to think that well-tested theories are true/accurate, at least in part. What do you think?

AN ALTERNATIVE VIEW: THOMAS KUHN ON PARADIGMS

Thomas Kuhn was another famous philosopher of science who tried to explain what was "unique" about science. He didn't agree with Popper (or the positivists), 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 captured day-to-day science, in which it would be absolutely crazy for someone to give up on theory just because it got one bad experimental result. His most famous book, *The Structure of Scientific Revolution,* was published by the logical positivists, even as it presented a significant challenge to some of their early views.

Here's Kuhn's solution:

Kuhn's 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 is important. If two scientists share a paradigm, they will agree on how to use the theory to solve problems, how to deal with predictions that don't "turn out," and so on. Learning how to work with a paradigm is a big part of scientific education. Some important points.

- **Prescientific and pseudoscientific 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. Even skilled theologians disagree on what "predictions" about the future can be deduced from their holy texts. No two astrological websites will give you the same horoscope. (And this is all very different from physics, chemistry, or biology, where different textbooks give *identical* results when discussing how to solve the same problems).

- On Kuhn's view, scientists **very rarely 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, or that some factual assumption was wrong.
- **"Creativity" in science involves problem-solving WITHIN a paradigm**. Popper emphasizes the importance of bold risk takers, and "thinking outside the box." Kuhn thinks this is a flawed idea of how science (and even creativity more generally) actually works. In order to actually make any progress, Kuhn thinks that young scientists have to spend *lots* of time learning how the dominant paradigm actually "works." They need to know important equations, concepts, testing methods, problems of current interest, and so on. Kuhn actually argued creative work in many scientific fields requires something like a doctoral-level education. Again, this is very different from pseudoscience: no (reputable) university awards PhDs in astrology, and there is no generally accepted distinction between "skilled" astrologists and unskilled one.

A music analogy: Popper thinks that a "great scientist" is like someone who invents an entirely new genre of music. 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. Both of them would emphasize the not every random collection of sounds deserves to be called music, even if the person making the sounds claims "But I'm a musician!"

QUESTION FOR REVIEW

1. Which of the three approaches we've discussed so far—verificationism, falsification, or "paradigms"—do you think does the best job of answering the question "What is science?"?
2. To what extent do these different approaches "converge"? That is, to what extent are these approaches going to agree on particular questions, such as "Are well-tested vaccines generally safe?" (they all say yes) and "Does astrology work?" (they all want to say no).
3. Is there a way of combining these different approaches? If so, how?