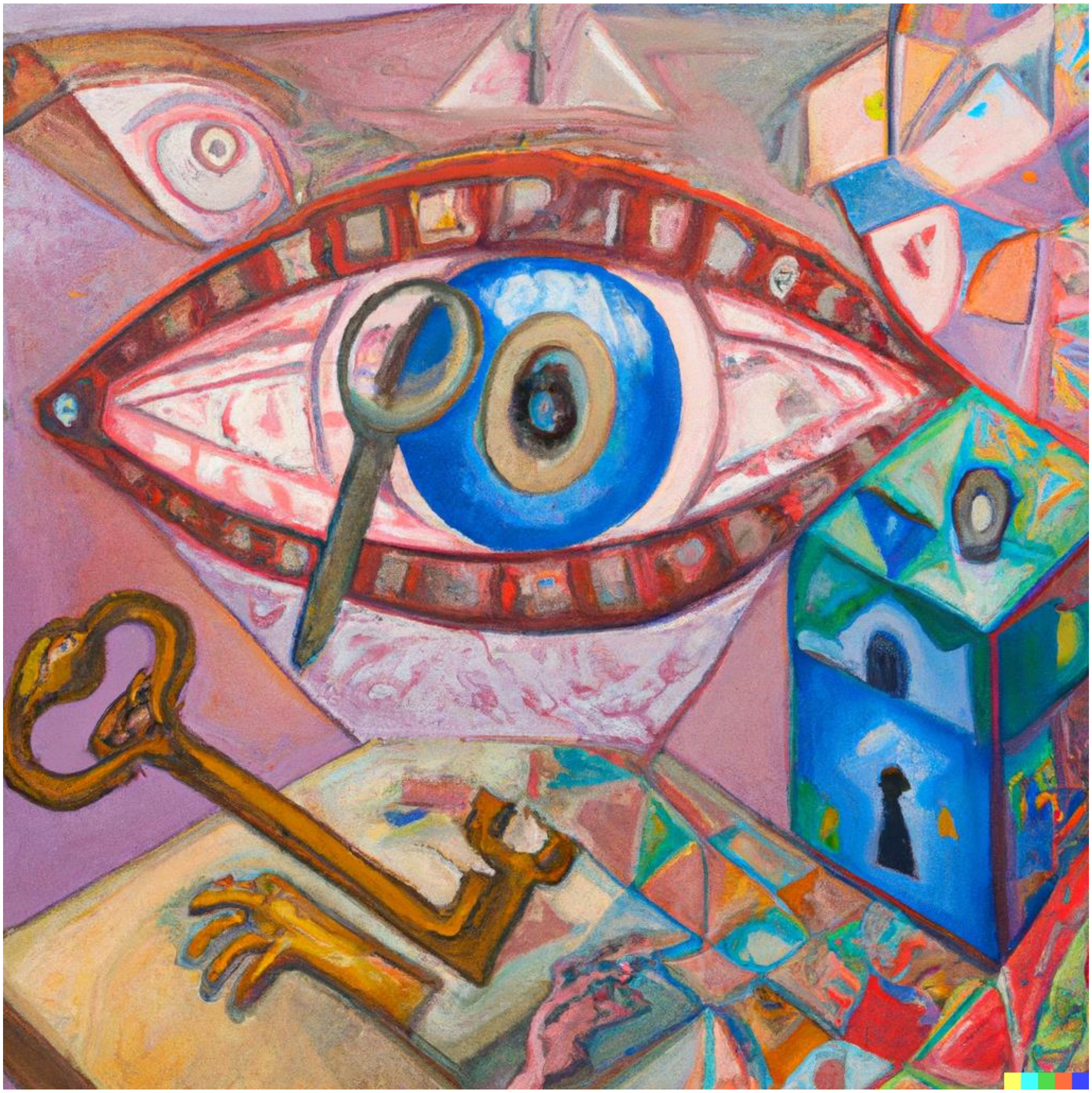
Chapter 8: Philosophy of Science

A Little More Logical |Brendan Shea, PhD (Brendan.Shea@rctc.edu)



1 Contents

2 THOUGHT QUESTIONS

In this chapter, we're going to be examining some "deep" questions about the nature of science. In particular, we'll be looking at a few debates that have long interested both philosophers and scientists. Before starting, what do you think?

1. Are scientific theories better seen as "claims about the way the world *really* is, at a deep level" (or are they rather "useful tools for making predictions and explanations"**?**
2. In general, how can we tell the difference between "legitimate" scientific theories and harmful pseudoscience (that is, theories that "look" or "sound" like science, but which really aren't)?
3. What is the difference between science and other human activities (such as religion, art, etc.)?

3 SHOULD WE BELIEVE OUR BEST SCIENTIFIC THEORIES?

In this section, we'll be taking up some of the central questions in the philosophy of science:

1. What does it mean to be a "realist" about scientific theories? What does it mean to be an "anti-realist"?
2. What's the difference between "accepting" a scientific theory and merely finding it "useful"?
3. What is the "No-Miracle" argument in favor of realism?
4. What is the "Pessimistic Metainduction" argument in favor of anti-realism?

3.1 WHAT IS REALISM? SCIENTIFIC REALISM?

Realism is a difficult term to define, in large part because *many* philosophers (over thousands of years, and from many different traditions) have claimed to be "realists" of some type or other, even while disagreeing rather vehemently about what this has meant. For our purposes here, though, we'll be associating **realism** about a certain domain with the following general beliefs:

1. There is a mind-independent reality that exists outside of us. ("Metaphysical realism").
2. Claims about this domain are "about" this domain. They are true if they accurately describe the mind-independent reality, and false otherwise. ("Semantic realism").
3. We *can* know things about this domain, even if this knowledge might be partial or imperfect ("Epistemic realism").

There are a wide variety of ways in which one can be a realist (and we'll be discussing some of them later). Conversely, **anti-realism** denies at least ONE of the above claims (with different types of anti-realists denying different claims). Anti-realism is often associated with terms such as "pragmatism" or "empiricism".

*Figure 1 According to realism, science is like a "magnifying glass." It allows us discvoer the nature of *real things* we can't see with our senses.*

Most of us are realists about some domains and anti-realists about others. So, a realist about the external world (a pretty weak form of realism) believes that there is *something* outside of my mind, while a realist about ethics believes that ethical truths (like "Nazis are bad") are true *even if people don't agree with them.* A realist about *numbers* believes that numbers exist independently of humans (and that they would have existed even if humans had never been around to "count" things). One could be a realist (or not) about God, ghosts, Santa Claus, the "superego", etc.

The debate between **scientific realism** and **scientific antirealism** is centered around the role the *unobservable entities and forces* play in scientific theories. Nearly every scientific theory (both current and historical) makes claims both about the *observable* world (e.g., "here's what you will see if you do X"), and about the *unobservable world* ("the *reason* you see this is because of force Y"). Examples of claims about the observable world include things such as "planet X will be observed at location X, Y at time T" or "the following measuring instrument will record reading R under conditions C" or even "The life expectancy of patients undergoing treatment T will be X greater than those not getting the treatment". Examples of unobserved entities include everything from quarks and electrons to genes to the process of natural selection to cognitive biases to [choose your favorite ideas from a scientific theory].

In keeping with the general picture of realism given above, scientific realists hold that (1) there is a matter of fact about what unobserved entities/forces are like, (2) our scientific theories should be interpreted as attempts to describe this reality, and (3) scientific methods really do make it possible to *know* something about this reality, even if these claims are partial or imperfect. Anti-realists, by contrast, tend to agree with the first claim (about the underlying reality of the world), but they often disagree with claim 2 (that this is what our scientific theories are really "about") and they almost always disagree with claim 3 (that we could know anything about these entities). For anti-realists, scientific theories involving claims about entities/forces we couldn't possibly observe should NOT be judged on whether they are true or false (in fact, anti-realists will argue they are almost certain to be false). Instead, they should be judged on whether they are *useful*.

Questions: (1) Can you think of a domain that you are a "realist" about? An "anti-realist" about? (2) Based on the initial descriptions of scientific realism and anti-realism, which view do you find more plausible?

3.2 THE DIFFERENCE BETWEEN "ACCEPTING" A THEORY AND FINDING IT "USEFUL"

Another way of thinking of this in terms of **theory acceptance** versus **theory use**. Roughly, we can say that a theory is "accepted" by the scientific community if they believe that is the most accurate description of the world we have at this point. By contrast, we can say that a theory is "used" by a scientific community if they have some practical use for a theory, whether or not they think it is worthy of acceptance. Realists think that scientists can be **justified** in accepting scientific theories involving unobservable entities, at least under conditions (e.g., if we have certain sorts of evidence). By contrast, antirealists think that scientists are *never* justified in accepting these sorts of theories, even though they might be justified in *using* these theories for certain practical purposes.

SCIENTIFIC REALISTS VS SCIENTIFIC ANTI-REALISTS		
Sample claim	**Realists**	**Anti-Realists**
"People with a BMI over 35 have a higher frequency of cardiac events than those with a BMI under 25"	So long as they have adequate evidence, scientists are justified in accepting and using this theory (as they currently do).	Since this theory involves only observable entities (BMI and cardiac events can be defined in terms of *measurements*), they agree with realists. We can both accept and use this theory.
"The gene BRCA is an oncogene—it is a cause of breast cancer."	So long as they have adequate evidence, scientists are justified in accepting and using this theory (as they currently do).	Genes (not to mention "causes"!) can't be directly observed. That being said, measurements (blood tests, etc.) based on theories involving BRCA are highly useful for predicting who will get cancer. So, we should continue using them. However, we are NOT justified in saying that "genes really exist."
"Vaccines cause autism by triggering an unhealthy immune response that inhibits neural development."	This is a claim about unobservable entities. However, it is one that our current evidence strongly suggests is false. Scientists are justified in NOT accepting it.	We shouldn't accept this theory, for the same reason we don't accept any claims involving unobservable processes or entities. However, unlike the BRCA theory, this isn't a *useful* or *helpful* theory, either.
"COVID-19 jumped to humans from acuminate horseshoe bats"	This is a claim about unobservable entities (We can't see viruses! We can see the past!). It's one we are currently **pursuing,** but we don't currently have evidence to accept (or reject) it at this point.	Again, we should NEVER accept theories like this, since they involve claims about unobservable entities (such as viruses). However, it is worth pursuing, because we want to know whether this theory is *useful* (for example, it may be that intervening on bat populations in certain ways will lead to fewer disease symptoms in humans).

Finally, a quick note of caution: nearly all scientists tend to talk *as if* they are realists when they are actually in the process of doing science (that is, they regularly talk about the properties of unobservable entities like electrons, viruses, and genes). However, this doesn't necessarily mean realism is true. First, scientists might be wrong about the "nature" of scientific practice, even if they are perfectly competent practitioners of science. (An analogy: practicing artists don't necessarily have any special insight into questions like "What is art?"). Second, at least some scientists, if pressed on what they are "really" doing, will often retreat to an anti-realist position. (That is, they'll say things like "I don't necessarily *believe* in all of the theories I use in my day-to-day work, but I think they are useful calculating tools).

Questions: The disagreements between scientific realists and antirealists revolve around which scientific theories we can justifiably *accept* as likely to be true. Can you think of other examples (besides those noted above) where realists and anti-realists would (1) agree as to their acceptability and (2) NOT agree as to their acceptability?

3.3 THE "NO MIRACLES" ARGUMENT FOR REALISM

"Realism is not a dirty word. If you wonder why all scientists, philosophers, and ordinary people, with rare exceptions, have been and are unabashed realists, let me tell you why. No scientific conjecture has been more overwhelmingly confirmed. No hypothesis offers a simpler explanation of why the Andromeda galaxy spirals in every photograph, why all electrons are identical, why the laws of physics are the same in Tokyo as in London or on Mars, why they were there before life evolved and will be there if all life perishes, why all persons can close their eyes and feel eight corners, six faces and twelve edges on a cube, and why your bedroom looks the same when you wake up in the morning." (Martin Gardener)

> *Not merely trainee and professional members of the medical profession commit the base-rate fallacy. Even very eminent scientists do, as we have seen. And all the philosophers who use the No-Miracles argument do so as well. (Colin Howson)*

Realists—of whatever stripe—believe that science is aimed at getting things right, and in making true claims about the world. Moreover, they tend to believe that our current best scientific theories really *do* get at least some things right and that these theories are at least "approximately true." Why do they think this? One common reason has been dubbed the **No-Miracle Argument for Realism.** It goes something like this:

1. Modern scientific theories (which include many claims about unobservable entities) do an extremely good job of making accurate predictions about the observable world, especially compared to ancient, pre-scientific theories. Modern science has built iPhones, launched rockets, designed vaccines, etc.
2. If our theories were approximately true, as scientific realism claims that they are, this sort of predictive success is exactly what one would expect.
3. On the other hand, if our theories were wildly false (as anti-realism suggests that they are likely to be), this success is something like a miracle.
4. As a general rule of science, non-miraculous explanations are more likely to be true than miraculous ones.
5. Therefore, realism is more likely to be true than is anti-realism.

This argument attempts to use a form of argument sometimes used within science—sometimes called **Argument to the Best Explanation—**and apply it to science as a whole. The basic idea is that, when one is faced with two competing hypotheses or theories (in this case, realism and anti-realism), one should choose the hypothesis that gives the *best explanation* for the evidence one has. In this, our "evidence" is just the success of science itself!

3.4 THE "PESSIMISTIC METAINDUCTION" ARGUMENT FOR ANTI-REALISM

> *"If rationality consists in believing only what we can reasonably presume to be true, and if we define 'truth' in its classical nonpragmatic sense, then science is (and will forever remain) irrational." (Larry Laudan, Progress and its Problems).*

The No-Miracle Argument for Realism tries to take a common way of reasoning within science—the argument to the best explanation—and apply it to philosophical questions about science. The **Pessimistic Metainduction** does something similar, only on behalf on anti-realism. In particular, it tries to use **inductive** reasoning to show that our available evidence makes it *more likely* that anti-realism is true than is realism. Inductive reasoning involves the use of information about things that we *have* observed to draw conclusions about things that we *haven't* observed. We engage in this sort of reasoning every time we predict the future, reason about causes or effects, or make generalizations from "samples" to "populations." By its nature, inductive reasoning can never have the certainty associated with the **deductive** reasoning of mathematics. However, induction is at the heart of almost everything that scientists do.

With these ideas in mind, here is the structure of the Pessimistic Metainduction:

1. In this past, humans have come up with many, many, many scientific theories containing claims about unobservables. Moreover, many of these theories were **empirically successful** (that is, they made some successful predictions about the observed world).
2. All of these theories have eventually been shown to be false, at least after some time has passed. (E.g., There probably isn't a *single* scientific theory from 100 years ago that we continue to believe in the literal truth of. ALL of these theories have changed in some way).
3. So, our best current scientific theories are highly likely to false, as well.
4. So, we should not "accept" these theories as true (that is, anti-realism is likely to be correct).

The basic picture here is "science as the history of mistakes"—we *know* that no past scientific theory has ever succeeded in "getting everything right". So, why should we expect that our *current* theories get everything correct? It's important to note that anti-realists (such as Larry Laudan, quoted above) generally do NOT take this sort of argument to be "pessimistic" about science in general. They are often very impressed by the empirical/pragmatic success of science and think that it is perfectly rational for scientists to continue to experiment and hypothesize to find more and more useful theories. They simply think it is a mistake to think (as the realist does) that scientific theories are "true" in the way that we usually understand this word.

Question: In what sense is the Pessimistic Metainduction an "inductive" argument? Do you find the realist response successful?

4 WHAT SEPARATE SCIENCE FROM "PSEUDOSCIENCE?"

In everyday life, we often want to make distinction between arguments that are founded in *genuine* "science" versus those that "look" scientific, but really aren't. These so-called **pseudoscientific** claims involve everything from fad diets and astrology to claims of a vaccine-autism link. In this lecture, we'll be looking at how two famous philosophers—Karl Popper and Thomas Kuhn—tried to characterize the difference between "real science" and these other theories.

4.1 Two Examples of Scientific Theories

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 acolytes 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).
- **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.

4.2 Mythology, Religion, and Pseudoscience

In contrast to the theories just mentioned above, 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.
- **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 need 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.
- **Astrology and Horoscopes.** Many newspaper 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.*

4.3 Karl Popper's Proposal: Scientific Theories are Falsifiable

Karl Popper proposed a simple, easy to remember criterion for distinguishing between scientific and nonscientific theories. He first proposed it around 1930, and it has proved very popular, especially 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 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 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.

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.

4.4 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, 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. 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 it 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!"

4.5 Review Questions

1. In your own words, explain how Karl Popper would explain the difference between "science and pseudoscience."
2. In your own words, explain how Thomas Kuhn n the difference between "science and pseudoscience."
3. Give an example of theory/idea that might count as "pseudoscience." See if you apply Popper's or Kuhn's idea to show why this is.

5 A STRANGE CASE OF A PARADIGM SHIFT

[Note: This is a chapter I wrote for a book on "Dr. Strange": (2018) "Paradigm Shift: A 'Strange' Case of a Scientific Revolution." In: W. Irwin and M. White (eds), *Dr. Strange and Philosophy: The Other Book of Forbidden Knowledge. The Blackwell Series in Popular Culture and Philosophy.* (Hoboken: Wiley), 139-150.

The basic idea is that we can use the experiences of Dr. Strange—a fictional medical doctor who acquires magical powers—to understand some of the issues we've been talking about in this chapter, such as the nature of "science." I hope you enjoy the article!]

In the 2016 film *Doctor Strange,* the title character undergoes a radical transition from successful neurosurgeon to highly skilled sorcerer. Unsurprisingly, he finds this transition difficult, in no small part because he thinks that sorcery seems somehow "unscientific." Nevertheless, he eventually comes to adopt sorcery as wholeheartedly as he had embraced medicine. Some of his reasons for making this transition are personal, such as his desire to fix his injured hands and, later, to help others. Strange also displays the same sorts of motivations that might drive any scientist: his intellectual curiosity drives him to understand how the Ancient One cured a paraplegic, and his desire to make a positive difference leads him to push the boundaries of sorcery.

This chapter will examine what Strange's transition can teach us about the nature of scientific inquiry. More specifically, we'll think about when it might make sense for scientists like Dr. Strange to *change* their approach. This will also allow us to explore what it means to practice science more generally. Some of what we learn might be surprising. For example, while it might seem *obvious* to us (and maybe even to Strange) that sorcery can't count as a science, there are reasons for doubting this quick conclusion, at least in the sort of world that Dr. Strange lives in. Finally, we'll consider what all of this means for science in *our* world, where things differ quite significantly.

5.1 BACK WHEN STRANGE WAS NORMAL

Our investigation starts with the ideas of the scientist, historian, and philosopher Thomas Kuhn (1922-1996). In his 1962 book *The Structure of Scientific Revolutions*, Kuhn argued against the widely held view that scientific progress was the result of the application of a universal "scientific method" that assured regular, incremental progress towards the truth.[i] Instead, Kuhn thought that "scientific revolutions" often looked quite a bit like Strange's experience, where scientists refused to change their fundamental ideas about how the world works, or their *paradigms*, until a series of crises forced them to. If and when they finally did change paradigms, they had to undergo their own version of Strange's conversion experience, which required them to relearn exactly what the "world" is.

While Kuhn's examples are chosen from this history of physics, astronomy, and chemistry, his ideas have much broader import. After all, if rival scientific paradigms really are as different as, say, neurosurgery and sorcery, it might seem that the objectivity of science itself is threatened. It's for this reason that the story of Doctor Strange—who has the ability to understand multiple paradigms—is potentially so interesting, even to readers in a world without sorcery.

Kuhn, like Strange, received his initial training in a discipline very different from that which would eventually make him famous. Kuhn earned a doctorate in physics from Harvard University but, in the early years of career, came to feel that many of his best, most original ideas were actually about the history of science. In particular, he thought that many people had wildly inaccurate views of how science had actually worked in the past, which led them to be confused about how it worked in the present.

According to one popular view of science at the time, the *falsificationism* advocated by philosopher of science Karl Popper (1902-1994), scientific theories (as opposed to, say, political theories) were defined by the fact that certain sorts of observations could show them to be wrong, and scientists were the sort of people who were willing to change their minds on the basis of such evidence.[ii] So, for example, Popper would be quite happy with the early picture of Doctor Strange as the heroic, risk-taking neurosurgeon, who was always willing to oppose the received wisdom in an effort to save patients. Most importantly, Popper would note that scientists like Strange are characterized by taking failure seriously and making changes to their theories and methods in response. If a patient dies, Strange would undoubtedly try something different the next time around.

Though Popper's falsificationism remains highly influential, Kuhn argues that it doesn't accurately capture the way "normal science" actually works. By this, Kuhn simply means the ordinary day-to-day activities of the physicists or biologists who are *not* the Newtons, Einsteins, or Darwins of the world. First, Kuhn notes that innovators like Strange are actually pretty rare. The vast majority of practicing scientists spend their lives working on a small, well-defined set of problems—or "puzzles," as Kuhn calls them—that could be answered using the theories and methods they learned through years of rigorous schooling, and which their communities had picked out as worth solving. They rarely propose entirely novel techniques or methods, and certainly don't consider something as outlandish as sorcery, even if they encounter severe problems. Second, absent special circumstances (more on this later), they almost never reject their most fundamental methods, theories, or values, even in the face of numerous, seemingly unsolvable problems (such as the many diseases and conditions that modern medical science hasn't been able to treat or cure). However, in the vast majority of cases, these failures have not caused biological researchers to abandon the basic ways in which they approach problems.

5.2 From Science to Sorcery: How Scientific Revolutions Happens

If Kuhn is right, then Doctor Strange's initial suspicion of sorcery is just what we should expect from a practicing scientist. After all, in normal circumstances, science is all about solving certain sorts of puzzles—identifying new pathogens, developing surgical techniques, designing new drugs, and so on—using all of the skills and knowledge acquired after years of formal education and professional practice. To abandon all of this in favor of some strange new idea, such as manipulating dimensional energy to fight mystical enemies, is almost to abandon science altogether. In fact, Kuhn argues that "mature" sciences like biology and physics weren't even possible until researchers agreed on a shared paradigm that made it possible for them to focus their time and energy on identifying and solving ever more specific sorts of puzzles, as opposed to having to continually make public arguments about which fundamental theories, methods, or values should be adopted.

At certain points in history, however, scientists have changed their paradigms, such as when they adopted the Copernican, sun-centered model of the solar system over the older Ptolemaic, Earth-centered model. In Strange's particular case, this same sort of shift occurs when he abandons his career as a surgeon for one as an aspiring sorcerer. Kuhn spends a great deal of time in *The Structure of Scientific Revolutions* thinking about why and how scientists make such revolutionary changes. He suggests that this process, at least at the level of the individual scientist, is both more mysterious and less prototypically rational, than scientists, historians, and philosophers have often thought.

Kuhn argues that scientific revolutions have their roots in the sorts of "puzzle solving" activity that Doctor Strange engages in as a scientist, which by its nature involves making ever more precise measurements and predictions. Over time, however, these sorts of measurements will reveal anomalies*,* or areas where the existing paradigm's predictions fail, no matter how many tweaks are made. So, for example, while the Earth-centered paradigm in ancient astronomy did surprisingly well for over thousands of years, astronomers eventually found themselves needing to make more and more adjustments, such as positing that the planets moved in ever-more-complex epicycles in their orbits of the earth, just to keep their paradigm in agreement with their increasingly precise observations of the sky.

In the face of such anomalies, scientists are forced to entertain ever more radical ideas, until they reach the very limits of what their current paradigms allow. In Strange's case, this process takes place with extraordinary rapidity, as his quest to heal his injuries leads him first to the frontiers of medicine, then to the miraculously healed Jonathan Pangborn, and finally to the Ancient One and everything she shows him. Until the very end of this process, however, Strange never gives up on the core commitments of his paradigm: that the treatment for his condition will be explicable in terms of human physiology and the biological and physical theories on which this is based.

On Kuhn's view, Strange's reluctance to jump ship is entirely understandable. In fact, Kuhn argues that the mere existence of anomalies—even glaring, important ones—doesn't cause scientists to abandon a paradigm in which they've been trained. Instead, they will abandon such a paradigm only if they are presented with a new paradigm that they can adopt in the old one's place (and they won't always do so then!). Along with offering a solution to the troubling anomalies, this new paradigm needs to make novel predictions and to offer an attractive, elegant picture that leaves plenty of room for future work, in the form of unsolved puzzles. It is only when the Ancient One presents Strange with such an option that he is finally willing to leave his old life behind.

5.3 The Dark Dimension? Why Understanding Is Tougher than It Seems

Much of what we've said so far would fit pretty well with how many scientists, historians, and philosophers have often described the scientific method. Doctor Strange encounters a problem that he can't solve, formulates and tests a number of hypotheses aimed at producing a solution, and finally, finds one that works. Sure, sorcery is a bit different than the sort of scientific theories which work in our world, but that doesn't make Strange's approach any less scientific. For Kuhn, however, this misses the most interesting aspect of the story, which involves the transition between paradigms. When we look back at the history of science (or when the Sorcerer Supreme Strange looks back on his life), we might be tempted to think that the paradigm chosen in the moment of crisis was *obviously* closer to the truth than the old one was, and therefore we've made undeniable forward progress. Kuhn, however, argues that the history of science reveals a much messier process. In many cases, there simply are no clear, "objective" criteria that might allow adherents of one paradigm to rationally persuade adherents of another paradigm to convert and join their cause.

In particular, Kuhn argues that paradigm change is far from the sort of slow, incremental process that one might expect if scientists were simply incorporating new evidence piece-by-piece into their existing paradigms. Instead, new paradigms emerge quite suddenly, and the initial evidence in their favor is often relatively minimal, especially when compared to the historical successes of the old paradigm. The first scientists to adopt a new paradigm do so because they believe that working in the new paradigm will allow them to move forward. However, to adherents of the old paradigm, this often appears as little more than blind faith, especially since the new paradigm almost always involves ideas and methods that are alien to the point of incomprehensibility. (Just think of how Strange's medical school teachers might react if he told them he'd become a sorcerer!) In Kuhn's terms, rival paradigms are *incommensurable*: there is simply no general method for translating the concepts taken from one paradigm into those of another. In a very real sense, scientists who adopt different paradigms literally experience different worlds, which contain very different sorts of things.

Kuhn's claim that paradigms are incommensurable is the most controversial and influential part of his book, but it's also a claim that is easily misunderstood. With this in mind, it will help to look more closely at

Strange's experience. When Strange first encounters the evidence of sorcery, such as Pangborn's cured paraplegia and his own initial experiences with the Ancient One—he reacts with disbelief. He eventually changes his mind, though, when first, he becomes convinced that sorcery really is the best explanation for the anomalies he's observed, and second, he thinks that sorcery will allow him to solve the sorts of problems that interest him (such as his injuries). However, he doesn't commit to becoming a sorcerer until he finally realizes that he can genuinely make a contribution to the field, and help to solve problems that even Mordo and the Ancient One struggle with.

It is at this stage that Strange first encounters the problem of incommensurability. He wants to become a sorcerer, and can perhaps even explain some of the general ideas, such as the existence of other dimensions, that sorcery is based on. However, as it turns out, adopting a scientific paradigm requires more than memorizing lists of formulas. To truly understand things like the nature of dimensional energy, Strange has to master the methods for manipulating this energy, which requires long, tedious practice with simple spells. As it turns out, novice sorcerers—much like novice physicists—can't really understand their theories just by reading explanations of them in textbooks, or listening to wise old physicists or sorcerers talk about them. Instead, they have to learn how these theories are actually applied to standard sorts of problems, which Kuhn calls *exemplars*. The knowledge that Strange gains from this is much more of a "knowledge *how*" rather than a "knowledge *that*"—it is something he learns to do rather than some theory he has memorized.

Kuhn argues that scientists adopting a new paradigm learn to "see" the world in a new way through this process. So, by the conclusion of his training in sorcery, it's not simply that Strange has picked up a few new tricks, and memorized some complex chants and arm gestures. Instead, he finds himself in something like a different world, filled with very different sorts of things than his old world. He is in a world which demands that he respond in very different ways. Moreover, this is something that he will likely find difficult to explain to colleagues. And if Kuhn is correct, Strange shouldn't be too surprised if it proves difficult to convince his old colleagues of the correctness of his new ideas, even if he manages to get the idea across. After all, the sorcery skeptics might argue that contemporary medicine has solved lots of problems, and it would be foolish to let a few anomalies centered around one strange doctor cause them to give it up.

Somewhat surprisingly, Kuhn would also argue that a figure like Strange would be especially well-positioned to make paradigm-shifting advances in his new field of sorcery. Kuhn notes that, historically, most scientific revolutions were driven neither by the oldest, most experienced practitioners in a field, nor amateurs with little or no training. Instead, they were driven largely by people like Strange: newcomers to the field who have received enough training to understand how the paradigm works but who haven't yet become set in their ways. Like Strange, such innovators often come from other scientific disciplines and are often seeking the solutions to problems that the "normal" practitioners of the field had left unexplored.

5.4 PUZZLES ABOUT PARADIGMS

Kuhn, like Popper before him, fundamentally changed the way that many scholars looked at science. Where they once had seen a slow, orderly march toward ever-greater understanding, it now appeared as if scientific revolutions had more in common with political revolutions, or even with religious conversions, than with the dispassionate application of the "scientific method" taught in schools. While such methods have their place to play in normal science, revolutionary science is much closer to Doctor Strange's initial, baffling encounter with the Ancient One. Adopting a new paradigm requires scientists to radically rethink not just their theories and methods, but also their overarching view of what the world is fundamentally like and what their role in this world is.

What does this mean for science in the real world? Should we conclude that the paradigm of sorcery is just as trustworthy as that of medicine, and that they have equal claims to be counted "scientific," for good or ill?

Kuhn's writing is a bit ambiguous on these sorts of questions. When *The Structure of Scientific Revolutions* first came out, many readers took it to be arguing that the revolutionary decision of a scientific community to abandon one paradigm for another was a fundamentally irrational process, driven by very different factors than those relevant to explaining normal science. On this view, the incommensurability between various paradigms prevented any and all comparisons between them that might allow for rational choice. For example, when working as a neurosurgeon, Doctor Strange is perfectly capable of identifying the best surgical techniques to use, and can even explain and defend his choice to interns and colleagues. When he is working as a sorcerer, he can do the same thing when it comes to spells. What he can't do, however, is present a rationally compelling argument to a neurosurgeon that they ought to become a sorcerer, or vice versa.

In later editions of his book, however, Kuhn put a greater emphasis on the existence of more general scientific norms that could be used to judge between paradigms, and on the possibility of "translating" between competing paradigms. In the end, Kuhn thought the scientists themselves were the ones best placed to see how and when it made sense to change paradigms, even if their reasons for doing so couldn't always be made explicit to outsiders. Kuhn even notes the importance of people like Strange—masters of multiple paradigms—in this process, since they can help scientists in rival paradigms understand what exactly their rivals are up to, and what it might mean to adopt their paradigm as one's own. While these translations would always be partial and incomplete—after all, no one but another sorcerer could fully understand Strange's explanation of sorcery—they provide a good starting point, at least to those who come with open minds.

Like most philosophers and historians of science, Kuhn himself offered little advice on how contemporary scientists ought to do their work. However, he did worry that people were too quick to see "paradigms" wherever they looked, and that this caused them to overlook the ways in which mature sciences like physics and chemistry really were different from other human activities. For Kuhn, mastering a paradigm required much more than simply agreeing on a general outlook on life. Instead, a scientific paradigm required a detailed agreements on both what sorts of problems mattered and on the precise manner in which they could be solved. It is only because scientists have these agreements that they can get down to the business of puzzle solving, which makes up their normal work life. Mature science, for Kuhn, was genuinely and fundamentally different from almost everything else humans did.

5.5 After Kuhn, Things Got Stranger

The Structure of Scientific Revolutions was among the most important and influential books on philosophy of science ever published, and it led to major changes in the way many people—philosophers, sociologists, historians, and even scientists themselves—saw science. However, rather than ending the debate about the nature of science, Kuhn's book started a number of new debates. To close, we'll take a brief look at two philosophers of science who followed Kuhn, and we'll consider what they might have to add to our account of Doctor Strange's transition from surgeon to sorcerer.

Some post-Kuhnian philosophers, such as Paul Feyerabend (1924-1994), embraced and expanded upon the idea there were no rational, objective criteria by which one might judge competing scientific theories as better or worse, or even for distinguishing "scientific" theories from religious or mystical ones. Feyerabend's *methodological anarchism* held that, when it came to science, the only rule was "anything goes." After all, he reasoned, once we try to set down rules for excluding certain theories from consideration, we will find that we have ruled out obviously legitimate scientific theories.[iii]

For example, consider how sorcery must have originally appeared to Doctor Strange. It contradicted basic physics; it was based on "primitive" ideas that most people had given up long ago; and sorcerers didn't behave at all like contemporary scientists. They didn't publish their findings, present them at conferences, run randomized controlled trials, and so on. This might seem like more than enough reason to reject sorcery.

However, Feyerabend argues that, if we look closely at the history of science, we'll discover that many scientific theories (such as the sun-centered solar system) started off in much the same way. Because of this, we ought to be very wary of claiming that certain theories just "can't" work, or that we can simply ignore them as possibilities.

If Feyerabend is right, then real-life neurosurgeons and researchers might benefit from some Strange-like openness to ideas from outside of mainstream science. In particular, Feyerabend argues that if science is to continue to progress, scientists must continually be open to the possibility that some very different ideas might be the source of the next medical or scientific advance, no matter how bizarre they might seem now. Moreover, the mere fact that these ideas seem superstitious or mystical is not itself a good enough reason to reject them. Even if the vast majority of these theories are flawed in one way or another, the attempt to grapple with them will help us better understand why and how the theories we do adopt actually work. Feyerabend's ideas have remained quite controversial among both philosophers and scientists. After all, it's one thing to claim that sorcery could be a science in an alternate world like the one Doctor Strange lives in. It's quite another to claim that scientists in the actual world should have to consider sorcery as a serious rival for government funding, or as a possible subject to be included in high school science classes.

In contrast to Kuhn's emphasis on the agreement of the scientific community and Feyerabend's call for methodological anarchism, Imre Lakatos (1922-1974) argued that there were clear, objective criteria for distinguishing between *progressive* and *degenerating* scientific research programs. Interestingly, Lakatos argued that the distinction had to do with how the scientists dealt with failure. Like Kuhn, Lakatos argued that scientists almost never abandon the "hard core" of ideas that made up the heart of their approach to the world. So, the Ancient One doesn't abandon sorcery after one failed spell, and Doctor Christine Palmer doesn't abandon medicine after the death of a patient. Instead, scientists make modifications to the *protective belt* of ideas around their hard core: the Ancient One might try a new pronunciation for a word and Palmer can modify the dose of a drug. Lakatos held that research programs were progressive when these modifications to the protective belt led to new predictions and discoveries. By contrast, a program is degenerating when the modifications to the protective belt are merely defensive maneuvers intended to prevent falsification. That is, in a progressive program, the changes made by the Ancient One and Palmer really should lead to better results, as opposed to simply serving as "excuses" for their failures.

Lakatos emphasized that there was no foolproof way in which philosophers or scientists could determine whether a particular, contemporary scientific research program would make progress in the future. After all, the history of science is full of examples of promising programs that ran into unforeseen problems, as well as of old, abandoned theories finding "new life" in the light of experimental results. Lakatos might not have much advice to give to Doctor Strange, other than to remind him of the importance of keeping a careful, honest record of his successes and failures, both with respect to medicine and to sorcery. However, Lakatos would insist that, when it came for philosophers and historians to tell the story of how Strange came to abandon medicine for sorcery, they should be able to explain why his choice was a rational one, based on objective criteria. Lakatos thought that both Kuhn and Feyerabend, by playing up the sociological and nonrational aspects of the history of science, failed to do just this.

5.6 Of Science, Sorcery, and Philosophy

For Thomas Kuhn and his rivals, the story of a figure like Doctor Strange might have most value when we focus on the contrast between our world and his. Strange provides us with a clear picture of what it would it take for a seemingly outlandish idea like sorcery to become a scientific paradigm. Importantly, Kuhn argues that this would require much, much more than the mere inability of contemporary medical science to solve some problem or other. Instead, we would need to discover, as Strange does, both the existence of significant anomalies within current science and the sorcerous solutions to such anomalies. We would need not only to present a theoretical justification for thinking that spells might work, but develop a rigorous education program for young sorcerers on the precise techniques for various spells. Finally, and most importantly, we would need assurance that the paradigm could be extended to new problems through the use of methodical, puzzle-solving techniques, and that we, like Dr. Strange, could eventually find our ways to new dimensions.

More broadly, one might wonder: Why bother with the philosophy of science at all? After all, many scientists seem to get along quite well without considering such matters, and their work doesn't appear to suffer. However, this sort of quick dismissal misses some important benefits. First, as Kuhn emphasizes, the mere fact that scientists *usually* don't need to worry about philosophical issues hardly means that they never do. After all, when scientists like Doctor Strange find themselves in the midst of a scientific revolution, they have no choice but to consider the big, philosophical questions about reality, knowledge, and the relationship between the two. Second, even for those of us who don't aspire to be scientific revolutionaries, philosophy of science can help demystify the "scientific" approach to the world, even when it comes to theories as magical as those adopted by Doctor Strange.

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[i] Thomas S. Kuhn, *The Structure of Scientific Revolutions: 50th Anniversary Edition*, ed. Ian Hacking (Chicago: University Of Chicago Press, 2012).

[ii] For a short, very readable introduction to the ideas of Popper, Kuhn, and the other philosophers of science we'll be discussing, see Alan F. Chalmers, *What Is This Thing Called Science?*, 4th ed. (Indianapolis: Hackett Publishing, 2013).

[iii] Paul Feyerabend, *Against Method* (London: New Left Books, 1975).