

## *Chapter 3*

# SCIENCE AND PSEUDOSCIENCE

### 3.1 Introduction

Have you ever used a magic eight-ball to answer a question? Maybe you've had a tarot reading done for you or looked up the prediction for your astrology sign. For many, these activities are harmless entertainment. But suppose you believed an Internet ad and bought an ozone generator that was supposed to prevent you from getting COVID, so you ignored the usual advice and caught the disease. Relying on pseudoscience can lead to even worse consequences.

But what exactly sets science apart from these other disciplines? This question often gets called the “demarcation” problem in philosophy of science: How can we distinguish (or demarcate) science from pseudoscience, and for that matter, from other legitimate disciplines?

Let's begin our investigation by first looking at some examples.

#### **QUESTION**

What are some examples of “pseudosciences”?

#### **ANSWER**

A few answers that are likely to emerge are

- astrology (reading the future based on the activity of celestial bodies)
- numerology (predicting the future based on sequences/patterns of numbers)

- creation science (rejecting some modern science, such as evolution and scientific estimates of the age of the Earth and universe, deemed incompatible with certain interpretations of the Bible)
- tarot (using certain kinds of cards to foretell the future)
- mesmerism (attempting to manipulate another living being through a hypothesized force of “animal magnetism” claimed to be possessed by all living beings)
- palm reading (using lines on one’s hands to determine the future)
- Ouija boards (using a board with letters and numbers to try to communicate with the spirits of the deceased)
- tasseography (reading tea leaves in a cup)
- aromatherapy
- homeopathic medicine (trying to cure illnesses based on extreme dilutions of substances purported to have curative properties)
- anti-vax theories (beliefs that all vaccines do more harm than good)
- phrenology (using the shape of the skull as a guide to brain function and personality)
- parapsychology (a massive host of practices including research into the existence of spirits and investigating psychic phenomena)
- a great deal of the stuff advised by Dr. Oz on TV
- clickbait on your computer, advertising miracle cures for everything from baldness to toenail fungus

One thing that’s clear about most (all?) of the things on that list is that they claim to be scientific but aren’t. But we must say more about what makes something unscientific, what criterion (or criteria) can be used to distinguish real science from that which merely claims to be science. Examining such criteria will be the primary concern of this chapter.

First, note that there are many activities that aren’t good science. There is poorly conducted (i.e., bad) science and fraudulent science. There are activities once considered good science but now rejected. There are worthwhile disciplines that aren’t science at all—philosophy, for one!

### 3.2 Why Care About the Difference?

You might be asking yourself some questions at this point: Why bother trying to distinguish science from pseudoscience? Don’t we know which one is which when we see them? Why should we care if astrologers claim that their methods of making predictions are scientific? Let’s take a moment to address these questions.

### 3. SCIENCE AND PSEUDOSCIENCE

Science has a certain authority because when most people hear that a belief is supported by scientific evidence and investigation, they tend to trust that belief—to think it’s true and useful. They’re right. Beliefs backed by science are very likely to be true, though there are false ones. They’re very likely to be useful to us—they have greatly improved quality and length of life by combating disease, for example, and have improved our lives in all sorts of ways.

When a discipline that is not scientific, such as a pseudoscience, claims to be scientific, it inappropriately appeals to the authority and past success of science. The consequences of attributing scientific authority to pseudoscience are sometimes serious. The pseudoscience of phrenology was used to promote racist and sexist ideas about cognitive differences between white people and people of color, as well as between men and women. And while there is little to no scientific evidence supporting homeopathic medicine, people collectively spend billions of dollars every year on homeopathic treatments, sometimes even foregoing more conventional medical treatments with much more scientific support for their efficacy. Being unable to differentiate science from pseudoscience sometimes comes with dire consequences.

#### QUESTIONS

Can you recall any instances from your own experience, or that you’ve heard about from others, in which people suffered negative consequences for taking a pseudoscience seriously? What questions could they have asked to avoid being misled by the pseudoscience?

#### ANSWERS

There are likely to be many answers, but a number of people have been badly misled by the pseudoscientific claims of Scientology, spending thousands of dollars pursuing the fraudulent treatments and processes needed to reach higher levels of the Scientologist organization. It’s debatable whether Scientology should be classified as a religion, a cult, a pseudoscience, or even a business scam, but it certainly seems to claim the authority of science (it practically has “science” in its name!) without being scientific. Initiates to Scientology might have asked about whether the phenomena described by scientology are well supported by empirical evidence from a wide range of studies. Of course, to really determine whether and to what extent something like Scientology is a pseudoscience, we need to turn to examining the criteria that have been used historically to demarcate science from pseudoscience.

### 3.3 Confirmation and Pseudoscience

In chapter 2, we examined the importance of confirming hypotheses with observational evidence. Perhaps this hallmark of scientific inquiry is all we need to differentiate true science from mere pseudoscience.

An example. In the nineteenth century, there was an important debate within the scientific community about whether light exists as a particle or a wave. One key experiment that helped to settle the matter in favor of the wave theory was conducted by French physicist François Arago to test a prediction made by another French scientist, Siméon Denis Poisson. Poisson predicted that, according to the wave theory of light, a point source of light illuminating a circular disk should produce a tiny spot of light in the very center of the shadow of the disk. Poisson's intent was to show that absurdities result from the wave theory—no such spot is normally visible in the shadows of circular objects. But when Arago set up an experiment testing the prediction, the spot (now commonly called the “Arago spot” or “Poisson spot”) appeared, confirming the wave theory.<sup>1</sup> This example demonstrates a crucial, and perhaps distinctive, feature of genuinely scientific theories: They are confirmed by observational evidence. Surely, pseudoscientific astrologers or numerologists cannot claim that their practices are supported by evidence.

Unfortunately, confirmation is often not very hard to come by for the pseudosciences. Consider these examples.

(1) An astrologer says, “Although you’re quite worried about money, you will soon receive a windfall if you work hard.” Later that week, after working a double shift on a busy Friday, you wind up with some serious cash in tips—the astrologer’s prediction was confirmed.

(2) Somebody tells Uncle Fred that a copper bracelet has helped with his arthritis. Fred gets one, and sure enough, his arthritis starts feeling a little better!

(3) A homeopathic remedy for a cough is to take arsenicum album (a solution of arsenic trioxide, so diluted<sup>2</sup> that a dose is unlikely to contain even a single mole-

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1 The spot is not normally visible in the shadows of circular objects because most circular objects aren't illuminated by single, strong, point-sources of light positioned behind the very center of the object.

2 Typically, this dose includes less than 1 part chemical to  $10^{24}$  parts inert substance. That's like putting 14 drops of chemical into the Pacific Ocean. (And stirring.) You can be absolutely sure then that a glassful of Pacific Ocean water contains no molecules of the chemical put in. Advocates of homeopathy agree but claim that the water would then have a “memory” of the chemical having been added. Maybe you remember swimming in the Pacific, but does that ocean remember you? Needless to say, science has been unable to detect any such “memory” in water.

cule of arsenic trioxide). Someone with a cough begins taking it, and a week later, the cough goes away. The homeopathic cure appears to be confirmed.

(4) My doctor says that exposure to sun is a causal factor for skin cancer. But Gwyneth Paltrow said this: “We’re human beings and the sun is the sun—how can it be bad for you? I think we should all get sun and fresh air. I don’t think anything that is natural can be bad for you.”<sup>3</sup> And just look at how beautiful and healthy Gwyneth is! Much better than my doctor. She must be right.

(5) In 1988, Republican presidential hopeful Pat Robertson insisted that his prayers diverted a killer hurricane from his religious broadcasting headquarters in Virginia. He prayed, and then the hurricane turned away.

In each of these cases, experience is used to back up an unscientific hypothesis. We’ll see in future chapters why these confirmations fail to satisfy the rules established by real science. But one thing is clear here: Confirmation has a place in pseudoscience as well as in science. It’s not a useful way to distinguish them.

## 3.4 Falsification

The problem is that if a hypothesis’s predictions turn out right, that doesn’t necessarily show that the hypothesis is true. So the philosopher Karl Popper argued that what science really does is more definite: It tests a hypothesis by identifying possible observations that would show that the hypothesis is *false*. Popper argued thus that science worked by attempting falsification, not verification—by throwing out falsified hypotheses, not by accepting verified hypotheses.

Recall the experimental demonstration of the Arago spot. If that spot didn’t show up, it would show that the wave theory of light was false. This idea gave Popper what he thought were the tools to solve what he called the “demarcation” problem: distinguishing real science from pseudoscience. Thus, some theories are pseudoscientific because no possible observations could falsify them. Popper had in mind disciplines such as Freudian psychoanalysis, which provides a framework for explaining any human behavior. If provided with a behavior and a description of the person and their history, the Freudian can weave together an “explanation” using theoretical terms such as *id*, *ego*, and *superego*. For example, episodes of many antisocial behaviors (such as stealing, assault, or murder) can be explained as being caused by the *id* (the source of our instinctual desires) overpowering the *ego* (the part of us that normally keeps the *id* in check by seeking to satisfy the desires of the *id* in a practical, acceptable way). But there isn’t any possible way

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3 Interview, *Cosmopolitan* (UK), August 2013.

to falsify such an explanation. Freudians can contend that their theory offers the correct explanation without offering any predictions that could be falsified.

Astrology sometimes yields unfalsifiable predictions. Consider its claim that people born at roughly the same time will have a similar life pattern. Could anything ever prove that false? No: not because the claim is really true, but because being born at roughly the same time and having a similar life pattern are very vague descriptions. And because just about any two people can have “life patterns” that are sort of similar in some way or other. Vague assertions like these have almost no possibility of being falsified.

Again, the pseudoscientist Deepak Chopra claims that “quantum healing” is accomplished by the “ability of one mode of consciousness (the mind) to spontaneously correct the mistakes in another mode of consciousness (the body).”<sup>4</sup> What could ever possibly show this to be false? Who could possibly deny what this palm reader says: “You’ve faced some obstacles in your recent past that made you doubt yourself, but if you can commit, you will get what you want.”

When there is unfalsifiability, that is a pretty good sign of a pseudoscience, but many pseudosciences consist of falsifiable statements, just as real sciences do. And, in both sorts of cases, the reaction to a seeming falsification is *not* the immediate rejection of the hypothesis that seems to be falsified by observation—the reaction we saw in the Poisson-spot experiment. It’s rather to hold on to the seemingly falsified theory, and to assume that there’s something unknown bringing about that peculiar, seemingly falsifying observation.

Here’s an example of this reaction from real science: In the early 1800s, the Newtonian theory failed to correctly predict the orbit of the planet Uranus. The planet’s observed orbit differed substantially from the tables of predictions derived using the Newtonian laws of gravity and motion. From a strictly falsificationist perspective, that should have been the end of Newton’s laws. But instead of rejecting the Newtonian theory, scientists set to work trying to determine what led to the failed prediction. One hypothesis was that there was an additional planet further out in the solar system that exerted a gravitational force on Uranus, thus disrupting its orbit from the Newtonian prediction. And they found this planet—Neptune.<sup>5</sup>

This sounds like what pseudosciences also do when confronted by an apparent observational falsification. When astrologers make a prediction that fails to come true, they can always explain away the failure: The subject of the prediction may have given incorrect information about their time and place of birth or omitted other key information needed to make the prediction more accurate, or the prediction may have come true in another way, and the subject simply may not have realized it. Typically, they do not trouble to test these ideas. They simply *explain*

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4 *Quantum Healing* (Bantam Books, 1989), 15, 241.

5 Urbain Le Verrier, a French astronomer, calculated the path and mass of the hypothesized planet and sent his findings to the Berlin Observatory, where Johann Gottfried Galle used Le Verrier’s calculations and a telescope to observe the hypothesized planet.

away these problem cases. A pseudoscientific theory claims all of its successes and none of its failures; “Oh well, there must have been something amiss in that case!” But real science takes apparent falsifications seriously. It will struggle to find testable hypotheses to explain an apparent failure, and to test them. If, at last, these turn out to be false, only then is it time to discard the previous theory. That is why the Neptune reactions were scientific, not pseudoscientific.

A later astronomical investigation was similar to the one described above but instead involved puzzling over observed facts about the orbit of the planet Mercury. As before, scientists hypothesized that there was an unknown additional planet in the vicinity, moving Mercury from the path the old Newtonian physics predicted, but after considerable looking, no such planet could be found. At last, scientists conceded that Newton’s theory, the foundation they had relied on for centuries, had been falsified, and in a major scientific revolution, Einstein’s theory replaced it.

These stories illustrate the difference between real science and pseudoscience. The former takes apparent falsifications seriously, as genuine puzzles that need solving; the latter explains them away. The former finds genuinely falsifiable hypotheses to explain the puzzle cases and tests them. If they turn out to be false, basic scientific theory can be overthrown. This never happens in pseudoscience.

### 3.5 Puzzle-Solving as a Mark of Science

Thomas Kuhn began his academic career as a historian, yet his most famous work, *The Structure of Scientific Revolutions* (1962), is a foundational text in the philosophy of science. In his book, Kuhn investigates the process of theory change in science—the process of how one theory, such as modern chemistry or general relativity, succeeds a prior theory, such as alchemy or Newtonian physics. Kuhn describes science as taking place in two distinct modes: “normal” science and “revolutionary” science. Revolutionary science is much closer to what Popper had in mind with his falsificationist understanding of science: In revolutionary science, new theories come into conflict with established theories, with crucial tests of their competing predictions ending with one theory emerging victorious.<sup>6</sup> For a long time, physicists assumed that light must have a medium to travel through, just as sound waves require a fluid medium such as air to travel through. But no one could figure out how to detect the hypothesized medium for light—the luminiferous (meaning

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6 This is a drastic oversimplification of how theory change works in Kuhn’s account. In fact, Kuhn thinks that it’s quite rare that single “falsification” events or crucial experiments decisively settle the scientific community on one theory or another, and that many other factors contribute to determining which theories are ultimately adopted. Because this chapter focuses on demarcating science from pseudoscience, rather than theory change, we’ll set aside these subtler aspects of Kuhn’s account of theory change. However, we’ll return to this topic in chapter 23.

*light-carrying*) aether. (We mentioned aether above in its role as the stuff that filled interplanetary space, which philosophers/scientists thought could not have been a vacuum.) In the late nineteenth century, Albert Michelson and Edward Morley devised an experiment that would let them detect the effects of the aether (assuming it existed) on how light travels: They ingeniously figured out how to measure the speed of light and compared its speed in the direction the Earth was moving with its speed at right angles to this. In the former direction, light would have been slowed down by the “headwind” of aether. But the speeds came out the same, giving one of the most famous null results in history. (A null result is a result that fails to support a hypothesis.) Despite several efforts on their part and by other scientists, the luminiferous aether was never detected, leading eventually to the claim that we now take for granted: Light waves need no medium. Michelson and Morley’s experiments leading to the rejection of the luminiferous aether theory provide an example of revolutionary science, of one theory being falsified and (after further debate and discussion) rejected by the broader scientific community.

But revolutionary science is rare, according to Kuhn. Most of the time, science operates the way it did when faced with the failed Newtonian prediction of the orbit of Uranus—the anomaly wasn’t used as grounds for rejecting Newtonian physics, but rather as a problem, or puzzle, to be solved by further investigation. Kuhn contends that under normal circumstances, science is constituted by this sort of puzzle-solving activity. There are clear, specific ways, defined by or arising from the scientific theory, for how to approach the puzzle. In the case of the irregular orbit of Uranus, a natural candidate arising from the Newtonian theory that might explain those irregularities is that there is an unknown celestial body exerting a gravitational force on Uranus.

Here we have a promising candidate for distinguishing science from pseudoscience: Science has research problems, or puzzles, to solve. Pseudosciences do not seem to have such puzzles. When a pseudoscience makes a failed prediction, the failure gets explained away and dismissed, rather than researched further with an eye to accommodating missed data or modifying or changing the theory. When an astrologer fails to correctly predict the future, they don’t say, “Oh, let me see if I can figure out what went wrong and amend my method.” Certainly, they may appeal to unknown factors as a way of explaining the failure, but there’s no effort to discover these, and certainly no thought of modifying their basic theory.

Biomedical science isn’t always able to explain or correctly predict the effects of drugs or treatments on every individual for whom they might be prescribed. Put simply, not all medications and treatments work for everyone with the same medical conditions. But a doctor or medical researcher noting that a medication fails in certain instances is quite different from a homeopath responding to the failure of a remedy or an astrologer to a failed prediction. In the context of conventional medicine, there are research paths forward to attempt to investigate and explain why a medication or treatment fails—such as differences in individual biochemistry or in the individual’s environment that impact the effects of a drug or treatment. Those

differences can be explored in studies that might reveal what mechanisms are acting (or failing to act) when the medicine works or doesn't. But when homeopathic remedies fail, there aren't further avenues of research for the homeopath to investigate—the treatment just failed. It's time to try a different one. Because homeopathy is hypothesized to work on abstract principles that cannot be further investigated (such as “like cures like”), homeopaths cannot offer deeper explanations of why the remedy fails or do further research to investigate the effects (or lack thereof) of the remedy. It's just time to try a different remedy, or to further dilute the dosage in hopes that an even smaller quantity of the remedy will produce the desired effect, in accordance with the homeopathic principle that greater dilution produces greater potency. But the key principles of homeopathy (such as “greater dilution produces greater potency”) are never subject to falsification (as they might be in revolutionary science). In over 200 years since the inception of homeopathic medicine, little has changed in terms of its core principles and treatments.

### 3.6 Progress as a Mark of Science

But there are issues with using Kuhn's demarcation criterion of puzzle-solving as well. An example was set aside earlier: what to do about disciplines or theories that were once regarded as scientific but have since been rejected as unscientific or even pseudoscientific? Prior to the beginnings of modern chemistry in the eighteenth century, alchemy reigned as the scholarly method of investigating the properties and interactions of chemical substances. Alchemists, like chemists, investigated the relationships between chemical substances but believed that their investigations had mystical and spiritual dimensions—by purifying metal, one might also learn to purify a soul; by creating a theorized philosopher's stone, one could not only gain the power to transmute one metal into another, but to gain the secrets of eternal life as well. A key episode in the transition from alchemy to chemistry was the rejection of alchemy's phlogiston theory. Phlogiston was an alchemical substance theorized to be responsible for burning. It was supposed to be contained in any object that could be burned, and to be released during the burning. An object that burns easily and is almost completely consumed afterward, such as wood, would be said to be high in phlogiston. An object that is hard or impossible to burn would, according to the theory, have little to no phlogiston. Attributing combustion to the release of phlogiston nicely explained why there is less of something after it burns: It's lost all of its stored phlogiston. But there are always anomalies unexplained by a theory, and one that persistently pestered the phlogiston theory was that some substances (such as magnesium) *gain* weight after burning. Alchemists worked on this puzzle, trying to modify the phlogiston theory to explain such phenomena: They hypothesized that phlogiston was lighter than air or perhaps even had negative weight. But it was still unclear why some substances weigh less after burning.

No satisfactory answer was provided until later in the eighteenth century, when Antoine and Marie-Anne Lavoisier, working together in their laboratory, showed that a measurable quantity of air was required for combustion to occur. Air—or more specifically, the oxygen in air—was the key to combustion, not phlogiston. This discovery led to the modern understanding of combustion as a reduction-oxidation (redox) reaction. Magnesium weighs more after burning because it combines with oxygen in the reaction to form magnesium oxide, a solid at room temperature. By contrast, in the redox reactions that take place when a log is burned, the carbon in the wood combines with oxygen to form carbon dioxide, a gas that floats away, leaving the considerably lighter ashes behind. The oxygen theory could explain both why some materials weigh more after burning and why some weigh less.

The history of the replacement of the alchemical phlogiston theory with our more modern understanding of chemistry presents a problem for puzzle-solving as the mark of science. Both alchemy and chemistry had a puzzle to solve, and both worked on it. According to Kuhn's account, they should both equally count as science. The story of the rejection of phlogiston by crucial experiments appears to be another case of "revolutionary" science at work. The problem is that both phlogiston theory and this business about the philosopher's stone came from the same basic theoretical outlook, but the latter part of the theory seemed to be untouched by the experimental work overthrowing the idea of phlogiston. Alchemy seems to be a rejected science, but it's usually considered nowadays to be a pseudoscience. Someone today claiming to be an alchemist who can transmute lead into gold with a philosopher's stone would likely be regarded not merely as having outdated scientific views, but pseudoscientific ones. So there are grounds to count alchemy both as a genuine, but rejected science, and as a pseudoscience. Which is it? A modification to the Kuhnian view might help us get closer to a criterion that can deal with these subtleties of demarcation.

Let's start by noticing that during the eighteenth century, the alchemical phlogiston theory was indeed trying to solve a puzzle, actively considering new hypotheses and conducting research. But it got stuck on the problem of explaining why some metals (such as magnesium) gained weight when burned and was eventually abandoned. No new discoveries have been made in alchemy; there are no new developments in alchemical research. The part of alchemy that appears to be failed chemical science had, in fact, reached a dead end. Similarly, if someone wants to try their hand at making a philosopher's stone today, they'll be dismayed to know that no one has gotten any closer since the last time someone tried. *That* sounds more like homeopathic medicine or astrology, neither of which, as we noted earlier, has changed in centuries. The stagnating practices of disciplines such as alchemy, homeopathic medicine, and astrology suggest another possible criterion that can perhaps help us distinguish science from both rejected science and pseudoscience.

Imre Lakatos proposed *making progress* as the demarcating factor between science and pseudoscience. According to Lakatos, sciences are divided into "research

programmes,” which consist of three key components: a “hard core” of theory, a “protective belt” of auxiliary hypotheses, and a “heuristic” or problem-solving methodology. The “hard core” of a programme is its essential theories and commitments: Newtonian laws of motion and gravitation, Maxwell’s equations for electricity and magnetism, the two postulates of special relativity. The “protective belt” consists of auxiliary hypotheses that protect the core from refutation by evidence that contradicts the core theories. For example, when Newtonian gravitation and mechanics were found to not correctly predict the orbit of Uranus, rather than jettisoning those core theories, the auxiliary hypothesis that there are seven planets in the solar system could be questioned instead. Finally, the “heuristic” or problem-solving machinery of a research programme consists of methods for investigating anomalies and rendering them coherent with the hard core of the programme. Continuing along with our Newtonian case, one heuristic is that if a celestial body (such as Uranus) is found not to move according to the predicted trajectory, it may be because there is an unknown body exerting a gravitational force upon it. Using Newton’s laws of gravitation and motion, one can try to predict where and how large the unknown body might be based on the deviation of the known celestial body from Newtonian predictions. And indeed, that is precisely what happened when Neptune was discovered.

Programmes make progress—are *progressive*—when they are able to predict new phenomena and solve their research puzzles. Progressive research programmes turn their anomalies into expansions of the core theories’ domains, expanding them with new successful explanations and discoveries, based on the core theory. The Newtonian research programme was progressing with the discovery of Neptune—an anomaly was brought under the explanatory framework of Newtonian theory. By contrast, a degenerating research programme is one in which anomalies that cannot be predicted or explained by the programme continue to pile up. The key anomaly that heralded the rejection of the phlogiston theory was the fact that magnesium weighs more after burning. The phlogiston theory couldn’t offer a satisfactory explanation of the anomaly, while the oxygen theory could.

It’s worth pointing out, based on these examples, that whether a programme is progressing or degenerating is, in part, a matter of context. A single anomaly is rarely enough to tip a programme into degeneration—unless the anomaly has gone unresolved for a long enough time, and there is an alternative programme that neatly resolves the anomaly. When Newtonian physics failed to predict the correct orbit of Uranus, that was a strike against it, but there wasn’t a readily available competitor that could explain the anomaly. So, Newtonian mechanics remained stable as scientists hypothesized the existence of another planet and progressed as various scientists worked on the issue and eventually found its resolution in the discovery of Neptune. By contrast, the anomaly concerning burning metals had gone unresolved for quite some time by the phlogiston theory, though several adherents had attempted to come up with potential explanations, such as hypothesizing that phlogiston is a substance that has negative mass. Importantly, though, there was a

competing theory (the oxygen/combustion theory) that could explain the anomaly. The phlogiston theory degenerated, while the oxygen theory progressed.

The framework of progressive and degenerating research programmes can be used to demarcate science from pseudoscience because pseudosciences often begin as legitimate scientific research programmes that degenerate into pseudoscientific ones. Consider phrenology. Developed by the physician and neurologist Franz Josef Gall in the late eighteenth century, phrenology attempts to infer mental traits and personality characteristics from skull size and shape. Gall believed such inferences could be made based on the idea that functions of the brain are localized to certain areas, or rather, to individual “organs” that compose the brain (just as our other organs compose the rest of our bodies). For example, a region/organ in (what today is called) the parietal lobe of the brain was supposed to determine cautiousness. So, if a person had a bump in the skull over that area, it would indicate a cautious mindset, while an indentation in that same area would indicate recklessness. It’s important to point out that the idea of localized brain function is overall correct—individual areas of the brain are indeed specialized for certain functions. We process visual information with our occipital lobes (which contain the visual cortex), and our ability to make decisions is connected to certain areas in the prefrontal cortex in our frontal lobes. Unfortunately for Gall, brain functions aren’t localized in any way like he believed them to be, and equally importantly, skull shape and size are no help at all in getting information about brain regions. Despite Gall’s efforts to test his hypotheses about which regions corresponded to which personality traits by measuring skulls, he was never able to produce convincing results for most of the scientific community. Later efforts by researchers working toward, and later within, the modern neuroscientific research programme would show associations between brain areas and certain mental capacities, but there was no relation between these and skull shape. As such evidence came to light, and as phrenology consistently failed to correctly predict individual traits, it degenerated into a pseudoscience.

One possible disadvantage of this approach to distinguishing science from pseudoscience is that there’s not a hard-and-fast rule: You can make a case for why a programme is progressing or degenerating, but there’s rarely a clear “tipping point” that everyone will agree on. Certainly, as a programme continues to flourish or flounder, the consensus will become clearer and clearer about whether a discipline counts as a science or pseudoscience. So a programme’s status is tied to its performance, rather than to inherent features of the theories of the program (such as whether they are falsifiable). A further consequence of using progressiveness as the demarcation criterion is that even a severely degenerated, pseudoscientific research programme always has the potential (hypothetically) to turn around and become a progressive, scientific research programme, and vice versa.

The reverse sort of turnaround may account for disciplines that were once considered scientific but are no longer. What happened in these cases may be, on

this account, that such programs were once progressive, but have since degenerated. It is not unreasonable, for a time, to try to turn a degenerating programme into a progressive one, as when alchemists tried to modify the phlogiston theory. But when proponents of a degenerating programme dogmatically adhere to it in spite of multiple, sustained failures without making any real effort or having any credible idea for how to rehabilitate it, the programme becomes pseudoscientific. Programs that degenerate and are abandoned are simply failed or rejected science. Still, using progress as the mark of the scientific does make the following strange situation possible: A discipline might be considered a science because it's making progress, even though one or more of the discipline's hard core of theories later turn out to be false. At the same time, another discipline could be considered a pseudoscience, even though its theories are true, because no one has yet figured out how to make progress (such as designing experiments or making predictions about phenomena we should expect to observe) using those theories.

#### THINK

How could you tell how long to try to rehabilitate a research programme—that is, turn a degenerating programme into a progressive one? How would you know when to give up?

### 3.7 Multi-Criteria Approaches

It's possible that no single criterion will suffice to perfectly discriminate between science and pseudoscience in every single case. Perhaps, then, we need a set of criteria that allow us to make an all-things-considered judgment about whether a discipline counts as a pseudoscience. It might include some (or all) of the previously outlined criteria, and perhaps some new or modified ones, such as the following:

- **Testability:** Some have combined confirmation and falsifiability into a single criterion called “testability.” That is, there should be empirical evidence that confirms or supports genuinely scientific theories or research programmes, and those theories should be testable in the sense that an experiment could conceivably show that the theory or programme is false.
- **Tentativeness:** As we've seen in several earlier examples, many pseudosciences, such as astrology or holistic medicine, don't seem very open to revision. Astrologers and homeopathic healers aren't publishing peer-reviewed articles on their research methods, and they don't take seriously the idea that their disciplines could be fundamentally mistaken about causal relations between, say, people and

stars, or health and ultra-diluted chemicals. But the history of science is a history of overturned theories: Phlogiston gave way to oxygen, the humoral and miasma theories of disease gave way to the germ theory, and Newtonian mechanics gave way to relativistic mechanics. Genuinely scientific theories are willing to accept revision, or even rejection, in the face of contradicting evidence.

The multi-criteria approach is not without complications. Recall that one of the tricky issues with using progress to determine whether a programme counts as pseudoscience is that it's context dependent. In other words, a discipline might count as science at one time and pseudoscience at another (such as the discipline of phrenology). That problem of context dependence reoccurs here. Depending on which criteria you think are the most important, you may disagree with another rational person about whether something counts as a pseudoscience, even though you're using the same set of criteria. For example, if you think tentativeness matters more than progressiveness, you might argue that proponents of the phlogiston theory were willing to revise it in light of contradicting evidence, but never quite found the right way to do it. They were scientific but simply failed. Kuhn's puzzle-solving criterion might render a similar verdict: The phlogiston theory had research puzzles to work on but left too many unsolved before a better alternative sprang up. On the other hand, if you think that progressiveness matters more than tentativeness, the phlogiston theory began degenerating and, at some point, became appropriately classifiable as a pseudoscience.

You might be tempted to conclude that we're no better off than when we started! Every individual criterion we've looked at had some imperfection or problem, and trying to take them all together can lead to reasonable disagreement about what is or isn't a pseudoscience, which is the very problem we're trying to solve. Yes, unfortunately, there's perhaps no single criterion, or set of criteria, that will infallibly lead to clear, correct demarcation between science and pseudoscience in each and every case. But we are better off than when we started—much better off, in fact. We have a set of criteria we can use to articulate our thoughts and argue about what counts as science or pseudoscience. And sometimes, though not always, an all-things-considered assessment of those criteria might render a fairly unanimous verdict as well. Let's return once more to astrology. As we've noted, astrology doesn't really have research puzzles to work on—the basic principles and methods of astrology have remained largely unchanged for centuries, with no one making particular efforts to provide new, “cutting-edge” developments. Despite routinely making false predictions, it refuses to take such falsifications seriously, or else makes predictions that are so vague that they are unfalsifiable. For similar reasons, astrology lacks tentativeness—astrologers aren't considering rejecting any of the basic principles or methods of astrology because of those failures. And combining those many failed or unfalsifiable predictions with the lack of puzzle-solving attempts to improve

astrological methods suggests that astrology is degenerating and has been in a degenerative state for quite some time.<sup>7</sup>

The only criterion that may be said to favor astrology is that it is occasionally confirmed insofar as it sometimes makes correct predictions. But perhaps we've been too unsophisticated in our understanding of confirmation. After all, surely a cough clearing up after taking a homeopathic remedy doesn't count as the same kind of confirmation from a randomized, controlled drug trial in which hundreds or even thousands of subjects are enrolled. And while an astrologer might nail a prediction once in a while, if we looked at the ratio of correct to incorrect predictions, we'd likely notice that the astrologer does no better than chance—that is, random guessing. Modern science makes use of statistical techniques that help ensure that confirmations (and falsifications!) of scientific predictions are significant, and not just flukes of experimental design, measurement errors, or random chance. Perhaps confirmation, in a deeper sense of statistically significant results, isn't as cheap as we thought. Thus, we should spend some time learning and thinking about statistical inference in science. On to the next chapter!

#### QUESTION

Can any of the criteria we've discussed be used to distinguish science from other legitimate academic fields, such as literary studies, history, or philosophy?

#### ANSWER

It's possible but debatable. One criterion you might consider is falsifiability. Some philosophical questions concern entities that are unobservable (such as the existence of God). Thus, the philosophical thesis "God exists" is unfalsifiable—it could be false (or true!), but there's no test that can definitively demonstrate it. The same might go for certain literary interpretations of texts. However, this criterion might not fare as well in distinguishing history from science—some historical theses (such as those about whether a certain event occurred, how it occurred, or who was involved in the event) seem falsifiable, or at least testable to some extent.

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7 A notable attempt was made in the 1950s by Michel Gauquelin to "rehabilitate" astrology in some sense by doing a large-scale astrological study involving thousands of people. He purported to discover a correlation (dubbed "the Mars effect") between the astrological culmination of Mars in the sky at an individual's birth and their athletic ability. This claim was highly disputed for a number of reasons, but most importantly for poor statistical analysis.

### Further Reading

- Kuhn, Thomas. *The Structure of Scientific Revolutions*. 4th ed. University of Chicago Press, 2012. Particularly chapter 4, “Normal Science as Puzzle-Solving.”
- Lakatos, Imre. “Science and Pseudoscience.” In *Conceptions of Inquiry: A Reader*, edited by Stuart Brown, John Fauvel, and Ruth Finnegan. Methuen, 1981, 114–21.
- Popper, Karl. *The Logic of Scientific Discovery*. Routledge, 2005. Particularly chapter 1, sections 4–6.
- Ruse, Michael. “Creation Science Is Not Science.” *Science, Technology, & Human Values* 7, no. 3 (1982): 72–78.