9.4 Scientific Method

When you look at the development of early modern science, it quickly becomes clear that at the heart of the new enterprise was *method*…Philosophical inquiries into new methods for investigation seemed wildly successful, as indeed a raft of new natural and social sciences developed over the following centuries. In another sense, however, they were unsuccessful – if success means finding the one true method. Today there is no single scientific method, and perhaps, as Paul Feyerabend has argued in his book *Against Method* (1975), the only methodological principle that unites all those who call themselves scientists is that they call themselves scientists! The procedures of inquiry among theoretical physicists are different from those among experimental physicists, and the methods of psychology and sociology are different from those of primatology, ornithology, and astronomy. Still, we might for the sake of our purposes here posit a few general, widely shared principles of scientific method that will be useful for critical thinkers to consider.

Causal explanation

…[Often], scientific method attempts to give a causal explanation for some phenomenon (in technical terms usually called the *explanandum* – it's what's "dum" and so needs explanation; see 1.2). To say that a phenomenon is subject to causal explanation is to say that it's part of a *regular order* of causes and effects (see 6.3 and 6.8). That means that whenever the "cause" is in place, the "effect" will always follow and follow in the same, uniform way – unless some other causal system interferes with it. As the philosopher David Lewis argues, a causal relation is such that, all other things being equal, if the cause had not occurred, the effect would not have occurred, at least not precisely as it did occur. So, for example, adding a gram of caesium or any alkali metal to an open cup of water under normal terrestrial conditions will always lead to a kind of explosion with exactly the same amount of energy released each time. (If you've never seen what happens when caesium encounters water, check out an online video. It's pretty spectacular.) A scientific explanation, then, is an account of the cause or causes that produced some outcome – it is to give an *explanans* for an *explanandum*….

Observation

Empirical scientific method is also committed to empiricism, in the sense that scientific claims must be grounded in observation. Not just any observation may count as the sort proper to underwrite scientific claims. The observations with which science is concerned must be the kind any normal human observer can make and that are therefore open to confirmation by others. When the kid in M. Night Shyamalan's 1999 film *The Sixth Sense* says, "I see dead people," he makes a claim that, by itself, cannot be considered a good scientific observation. His unshared personal experience, even if true, isn't enough to count as useful to the procedures of testing employed by science. Unless implications and predictions can be drawn from his perceptions for observations we all can make (for example, the video he plays to the group gathered after the murdered child's funeral), his observations don't quite rise to the level of scientific data.

But when the unobserved or the strictly private and personal does connect with matters of shared observation in regular, law-like ways, it *can* become a topic of scientific investigation. That is to say, science can investigate not only what is *actually* observed but can also make claims about what is *unobserved* and even *unobservable*. In fact, it does so all the time. While ghosts may not meet the conditions for scientific investigation, science does make meaningful claims about magnetic fields and electromagnetic spectra (such as X-rays) that are beyond the range of human observation, such as dark matter. No one today can observe Alexander the Great, microwaves, the beginning of the universe, or the microscopic Higgs boson, and yet claims are commonly made about Alexander's military campaigns and about the big bang, about microwaves, neutrinos and other subatomic particles. That's because claims about those unobservable entities are associated in precise ways with observations that can be currently made and shared…

Verification and falsification

Observation, in short, plays a crucial role in deciding whether or not some claim or *hypothesis* is true. Observations are used scientifically either to "verify" (prove the truth) or "falsify" (prove the falsehood) of a *hypothesis* (see 9.5). Some argue that these terms are too strong because science is always changing and adapting; what is scientifically "true" at one point in time may become "false" at another. Because of the fluid nature of science, some prefer the terms "confirmation" (evidence that a hypothesis is true) and "disconfirmation" (evidence that a hypothesis is false); we can have this sort of evidence regardless of whether the hypothesis is true or false. Either way, in scientific practice, good hypotheses must be crafted so that they are *testable* (see 9.7). There is, however, a logical issue that figures into the practices of both verification and falsification that will be helpful for you to understand when thinking critically about scientific reasoning.

Consider the logic of verification. We might understand verification to work this way: *If the hypothesis is true, then the predicted result of the experiment takes place.*

True hypothesis → Prediction comes about

For example: *if the hypothesis that caesium reacts with water is true, then this piece of caesium explodes when placed in this water*. This seems right given our immediate intuitions about experiments. But if we think of verification this way, it's technically possible for the conditional to be true where the caesium explodes while the hypothesis is nevertheless false…For example, it might be the case that caesium explodes when it is exposed to light refracted by water and not by the water itself. If that were the case, this logic would yield something like a false positive verification. (Again, this is why some prefer the term "confirmation" over "verification," though this still doesn't help us to find the lurking variable until we conduct more experiments.)…

Worries like these have led some to conceive of science as a process of *falsification* rather than verification. Falsification, indeed, works very well for the general and universal claims commonly investigated by science. We can easily falsify the claim that "all light travels at 100m/sec" by conducting a test that shows an exampleof it traveling at another speed. We can falsify the claim that "All swans are white," simply by finding just one black (or non-white) swan…

So, falsification shows us what is false. In this way, as the philosopher of science Karl Popper argues, science works like natural selection in biological evolution, eliminating maladaptive hypotheses through falsification. There's something disappointing about this thought, at least for those who think science finally settles questions. Falsification doesn't prove anything to be *true*. Although we can easily disprove it, we cannot fully prove that "*all* light in space travels at 299,792,458 meters per second" – as modern physics holds. This way of thinking about scientific method renders science methodologically *open* in a sense – which for those who don't require final answers is actually one of the best things about science. Unlike religious dogma, science always stands open for more testing to be done and always allows the possibility that new testing will falsify what has so far passed our scrutiny. Now, in practice, many scientists would say they're engaged with a combination of falsification and verification, accepting the limits of doing so. But in light of the logical complexities of verification and falsification, it seems reasonable to say that to the extent scientific inquiry proves anything, it does so *only in provisional ways*. Even the central idea in physics that nothing travels faster than light has been challenged (albeit still unsuccessfully) by recent experimental findings regarding neutrinos. Those who think that in modern science anything has been proven once and for all just don't understand science….

9.5 Unfalsifiability and Falsification Resistance

Ad hoc hypotheses and the fallacy of unfalsifiability

[T]he fallacy of *unfalsifiability* occurs when an arguer [supplements] his or her definition of a term, concept, or worldview in an *ad hoc* manner in [a way that protects it from falsification]…

Imagine Sarah says to you: "There is an elephant in this room." And you say, I don't see an elephant." Sarah might respond, "Oh, it's an invisible elephant." You could try to say, "Well, I don't smell it; elephants are smelly," but Sarah could simply say, "Invisible elephants don't smell." And you might get up and walk around and say, "Well, I'm walking all around the room, and I don't feel or bump into an elephant." But even then, Sarah, convinced there is an elephant in the room, could say, "You don't understand; it's an *insensible* elephant. But it's there." At this point, you would probably feel exasperated. Sarah has so qualified her "elephant" that there's *no* criterion by which to prove her wrong. Her claim that there's an elephant in the roomis simply unfalsifiable. But, of course, the fact that Sarah can do this doesn't [show she is wrong].

Upon first encountering this fallacy, you might think it isn't fallacious at all. After all, *if there is no way to prove that a claim is false, surely it must be true!* That's a very tempting line of thought. Falsifiability (the capacity for a claim to be falsified) is, as we've seen, an important feature of well-supported claims. We have a better idea of how to support a claim adequately if we know what sort of evidence could *dis*prove it, that is, if we know what to expect if it isn't true. This is clear in empirical cases. We have evidence that the drug ibuprofen reduces pain, but we know what to expect if this were to be false: pain would consistently not diminish even after taking ibuprofen….

Consider another example of unfalsifiability. Imagine Trayvon says, "Senator Jones's policy is the most effective policy to reduce homelessness." We can imagine Sarah challenging Trayvon's claim by presenting data that similar policies have failed to reduce homelessness adequately: "That policy was tried in Dallas, and it didn't work." In response, Trayvon might say, “Well, Dallas has a different demographic; it’s likely to be more effective here.” Sarah might then discover that a similar policy didn’t work in a place with a similar demographic, but Trayvon could respond: “The problem wasn’t the policy; it was the implementation. The state didn’t put enough money in the right place.” We can now begin to suspect that Trayvon isn’t really open to the possibility that the policy is ineffective. He has a tendency to qualify all counterevidence so that it doesn’t affect his opinion of the policy. If he just doesn’t allow that some evidence would falsify his claim about the effectiveness of the policy, he is committing the fallacy of unfalsifiability…

… But there are cases that can seem as though they are being treated as unfalsifiable but aren’t. Consider the hypothetical conversation between Trayvon and Sarah over Senator Jones’s policy to reduce homelessness. Social science research is fraught with difficulties because social situations cannot be replicated in a laboratory. We can always criticize such a study by arguing that the study has a selection bias, or a sampling bias, or that the wrong statistical measurements were used to calculate the results, etc. (see 6.4). Because of this, a researcher can always defend his or her conclusions by noting that those conclusions are valid *given the limitations of social science methodology*. This isn’t quite the same as unfalsifiability, but it is close. Social science researchers still owe us an account of how additional research could confirm or disconfirm their conclusions. Any one study may be problematic, but comparing similar studies with similar information might be informative. Nevertheless, if someone has an easy answer for any particular criticism you have, take the time to ask what sort of evidence would count against the claim at issue.