Chapter 2
Realism Versus Antirealism in Contemporary Philosophy of Science

Abstract The scientific realism/antirealism debate in contemporary philosophy of science is about theoretical knowledge, that is, knowledge that is supposed to be about so-called “unobservables.” This includes theoretical entities, such as neutrinos and genes, as well as theoretical processes, such as natural selection and continental drift. Is theoretical knowledge in science possible? In general, scientific realists tend to think that science can (and does) yield theoretical knowledge, whereas antirealists tend to think that science cannot (and does not) yield theoretical knowledge (that is, knowledge about unobservables). To put it another way, scientific realists tend to argue that we have good reasons to believe that our best scientific theories are approximately true because, if they were not even approximately true, they would not be able to explain and predict natural phenomena with such impressive accuracy. On the other hand, antirealists tend to argue that the impressive success of our best scientific theories does not warrant belief in the approximate truth of our best scientific theories. This is because the history of science is a graveyard of theories that were once successful but were later discarded.

Keywords Antirealism · Approximate truth · Case study · Epistemic dimension (stance or thesis) of scientific realism · Hasty generalization · Metaphysical dimension (stance or thesis) of scientific realism · Observable/unobservable distinction · Scientific realism · Selectivist turn · Semantic dimension (stance or thesis) of scientific realism · Theoretical knowledge

The results of a Pew Research poll from 2015 show that there are big differences of opinion on scientific issues between professional scientists and the general public. For example, 98% of scientists “connected to the American Association for the Advancement of Science (AAAS)” say that humans have evolved over time, whereas only 65% of U.S. adults accept that humans have evolved over time. Likewise, 87% of AAAS scientists say that climate change is mostly due to human activity, but only 50% of U.S. adults accept that climate change is mostly due to human activity. Why are there such big differences of opinion on scientific issues between professional scientists and the general public? Do scientists have good reasons to believe in what their best scientific theories say about evolution and climate change? If so, what are those reasons? And why is the general public
suspicious of these scientific theories? Are there good reasons to suspend belief in what the best scientific theories say about evolution and climate change? If so, what are those reasons? These questions are at the core of the scientific realism/antirealism debate in contemporary philosophy of science.

The scientific realism/antirealism debate in contemporary philosophy of science is primarily about the epistemic status of scientific theories. As Brad Wray (2018, p. 1) puts it, one of the central questions in the contemporary scientific realism/antirealism debate is this: “Do we have adequate grounds for believing that our theories are true or approximately true with respect to what they say about unobservable entities and processes?” That is to say, scientific theories make theoretical claims about the world around us. For example, according to the modern theory of evolution in biology, all living organisms on Earth are related by descent with modification from common ancestors. According to the theory of anthropogenic climate change in climate science, the main cause of global climate change is the greenhouse gases emitted by human activities. Should we believe what these scientific theories say about the world around us? After all, these theories make claims about entities and processes that cannot be observed with the naked eye. For example, the modern theory of evolution in biology makes claims about processes that occur on very large scales and over very long periods of time, such as genetic drift and natural selection, and about very small entities, such as genes and DNA. Such processes and entities cannot be directly observed with the naked eye. Likewise, the theory of anthropogenic climate change in climate science makes claims about processes that occur on very large scales and over very long periods of time, such as infrared energy transfer and the greenhouse effect, and about very small entities, such as photons and electromagnetic waves. Again, such processes and entities cannot be directly observed with the naked eye. Rather, such processes and entities are theoretical posits insofar as they are posited in order to explain natural phenomena that we can observe. In the case of the theory of evolution, for example, the existence of processes like natural selection and entities like genes is postulated to explain biodiversity and speciation, that is, how new species come into being. Likewise, in the case of the theory of anthropogenic climate change in climate science, the existence of processes like the transfer of infrared energy and the heat-trapping properties of greenhouse gases, such as carbon dioxide and methane, is postulated to explain global warming trends. Should we believe in the existence of these processes and entities that cannot be directly observed with the naked eye but rather are postulated in order to explain observed phenomena? This question keeps philosophers of science up at night.2

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1 As Darrell Rowbottom (2019) points out, there is also an axiological dimension to the scientific realism/antirealism debate in contemporary philosophy of science. This axiological dimension is about the goals or aims of science. I will say more about the axiological dimension in Chap. 5 (Sect. 5.5).

2 Johanna Wolff (2019) points out that some philosophers of science prefer to not take sides in the scientific realism/antirealism debate. She calls these philosophers of science “quietists.”
2.1 The Three Dimensions of Scientific Realism

Typically, scientific realists tend to believe in the existence of the entities and processes posited by our best scientific theories. As we will see in Chap. 3, while there are several different positions that fall under the category of scientific realism, broadly speaking, most participants in the scientific realism/antirealism debate in contemporary philosophy of science generally associate scientific realism with one (or more) of the following theses (or stances):

1. The *metaphysical stance* asserts that the world has a definite and mind-independent natural-kind structure.
2. The *semantic stance* takes scientific theories at face-value, seeing them as truth-conditioned descriptions of their intended domain, both observable and unobservable. Hence, they are capable of being true or false. Theoretical assertions are not reducible to claims about the behaviour of observables, nor are they merely instrumental devices for establishing connections between observables. The theoretical terms featuring in theories have putative factual reference. So, if scientific theories are true, the unobservable entities they posit populate the world.
3. The *epistemic stance* regards mature and predictively successful scientific theories as well-confirmed and approximately true of the world. So, the entities posited by them, or, at any rate, entities very similar to those posited, do inhabit the world (Psillos 1999, p. xvii).

As Stathis Psillos and Emma Ruttkamp-Bloem (2017) point out, parties to the scientific realism/antirealism debate in contemporary philosophy of science generally agree “that scientific realism has three dimensions (Psillos 1999) or stances (Chakravartty 2007); a metaphysical, semantic, and an epistemic dimension.”

The metaphysical thesis (or stance or dimension) of scientific realism is supposed to capture the idea that there are things out there in the world for scientists to discover and that those things out there in the world are independent of the human minds that study them. That is to say, when scientists announce that they have made a discovery, they are not merely talking about the figments of their own imaginations. Rather, they are talking about real things that exist in the world, even though those things are unobservable, that is, they cannot be directly observed with the naked eye. For example, when scientists working with the Large Hadron Collider (LHC) in Geneva announced that they had found the elementary particle known as the Higgs boson in 2012, they were not merely making things up. Rather, they were talking about a real thing that exists in nature, even though this real thing, namely, the Higgs boson, is unobservable, that is, it takes sophisticated scientific instruments, such as particle accelerators, colliders, and the like, to detect elementary particles like the Higgs boson. One of the main questions in the scientific realism/antirealism debate in contemporary philosophy of science is when, and under what

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3 Anjan Chakravartty (2007, p. 10) provides a useful classification of realist and antirealist views about science.
circumstances (if any), we are justified in believing that what our best scientific theories say about unobservables (for example, about elementary particles, such as the Higgs boson) is likely true or approximately true.

This last point ties in with the semantic thesis (or stance or dimension) of scientific realism mentioned above. Scientific realists (and even some antirealists, as we will see in Chap. 3) think that scientific theories can be true or false. For example, the theoretical statement “The Higgs boson has no electric charge” is either true or false. Currently, our best theory of elementary particles, which is known as the Standard Model of particle physics, tells us that this theoretical statement is true, that is, that the Higgs boson has no electric charge. Similarly, the theoretical statement “SARS-CoV-2 is the virus that causes COVID-19” is either true or false. Our best current evidence points to this theoretical statement being true, that is, that SARS-CoV-2 is the virus that causes COVID-19. When scientific realists talk about the truth of a theoretical statement, they typically understand it to mean “correspondence with reality” (Psillos 1999, p. 248). That is to say, a theoretical statement is true just in case what it says about reality corresponds with reality. As Howard Sankey (2008, p. 16) puts it, on the so-called correspondence theory of truth, “truth is a relation of correspondence that obtains in virtue of the world in fact being the way that it is said to be.” For example, if the theoretical statement “SARS-CoV-2 is the virus that causes COVID-19” is true, then it is in fact the case that SARS-CoV-2 is the virus that causes COVID-19. If it is not the case that SARS-CoV-2 is the virus that causes COVID-19, then the theoretical statement “SARS-CoV-2 is the virus that causes COVID-19” is false. As we will see in Chap. 3, some antirealists deny this semantic thesis (or stance or dimension) of scientific realism. Instead, they argue that scientific theories should be construed as instruments or tools for prediction, not as statements that have truth values (either true or false).

Of course, if theoretical statements can be either true or false, the question is how do we know that they are true (or false). As mentioned above, this is one of the key questions in the scientific realism/antirealism debate in contemporary philosophy of science. Some scientific realists argue that we sometimes do know (or have good reasons to believe) that our best scientific theories are likely true (or approximately true). Those realists are committed to the epistemic thesis (or stance or dimension) of scientific realism mentioned above. These scientific realists argue that the fact that our best scientific theories make predictions that are borne out by observation and experimentation provides a good reason to believe that our best scientific theories are approximately true. This realist argument will be analyzed and evaluated in Chap. 4 (see Sect. 4.1). On the other hand, some antirealists argue against predictive success being a sign of the (approximate) truth of our best scientific theories on the grounds that the history of science provides examples of theories that were predictively successful (that is, theories that made predictions that were borne out by observation and experimentation), but that were later discarded or abandoned. This antirealist argument will be analyzed and evaluated in Chap. 5 (see Sect. 5.1).

In that respect, we should note the use of the terms ‘approximate’ and ‘approximately’ with respect to the truth of scientific theories as they are used in the epistemic thesis (or stance or dimension) of scientific realism. Most scientific realists
and some antirealists agree that, strictly speaking, scientific theories, even the best ones, are not entirely true. As Anjan Chakravartty (2017) puts it, “it is widely held, not least by realists, that even many of our best scientific theories are likely false, strictly speaking.” The fact that a scientific theory is not entirely true, however, does not necessarily mean that it is completely false. In other words, a scientific theory is not a monolithic whole; it can have some false parts and some true parts. Accordingly, a scientific theory can be said to be approximately true in the sense of being close to the truth to the extent that it has some true parts, but also not fully true to the extent that it has a few false parts as well. As Philip Kitcher (2002, p. 388) puts it, “It doesn’t follow from the fact that a past theory isn’t completely true that every part of that theory is false.”

It should also be noted, however, that explicating the notion of approximate truth is notoriously difficult. Karl Popper’s (1972) attempt to formalize the notion of approximate truth or verisimilitude was shown to be problematic (see, for example, Miller 1974 and Tichý 1974). Other formal approaches, such as the similarity approach (see, for example, Niiniluoto 1998) and the type hierarchy approach (see, for example, Aronson et al. 1994) also suffer from technical problems (see, for example, Psillos 1999). For these reasons, scientific realists have tried to explicate approximate truth in non-formal, qualitative terms (see, for example, Leplin 1981 and Boyd 1990). For example, it has been suggested that \( T_2 \) is more approximately true than its predecessor \( T_1 \) if \( T_1 \) can be described as a “limiting case” of \( T_2 \) (see, for example, Post 1971). But there are problems with these informal approaches as well (Chakravartty 2010). Here, we need not get into the technical details of these formal and informal accounts of approximate truth or verisimilitude. For our present purposes, we can simply follow philosophers of science like Stathis Psillos (1999, p. 278) and work with an “intuitive understanding of approximate truth, or of truth-likeness,” while accepting that “there is no relevant need for a formal introduction of the predicate ‘is approximately true’, or the predicate ‘is truth-like’.” We will return to the notion of approximate truth in Chap. 6, however, where I will offer a definition that fits with the middle ground position I call “Relative Realism.”

As we will see in Chap. 3, positions that fall under the broad category of scientific realism may vary along the metaphysical, semantic, and epistemological dimensions mentioned above. In general, however, scientific realists seek to identify the content of scientific theories that, in their view, warrants belief. As Anjan Chakravartty (2017) puts it, “Scientific realism is a positive epistemic attitude toward the content of our best theories and models, recommending belief in both observable and unobservable aspects of the world described by the sciences.” As we will see in Chap. 3 as well, just like scientific realism, antirealism also comes in different varieties. Nevertheless, it is fair to say that scientific antirealists are generally suspicious of theoretical claims about theoretical posits that cannot be observed directly, that is, “unobservables” or entities, processes, and events that cannot be observed with the naked eye or without the aid of scientific instruments. In that respect, it is important to note that antirealists are not anti-science. They are generally willing to grant that science yields knowledge about the world around us. For example, antirealists would grant that biologists know a great deal about the
different species of plants and animals that inhabit the Earth. What antirealists would question, however, is whether biologists know that the mechanisms of natural selection, genetic drift, and the like, are responsible for the biodiversity observed on planet Earth. Likewise, antirealists would admit that climatologists know a great deal about the atmosphere of the Earth. What antirealists would question, however, is whether climatologists know that the mechanisms of infrared energy transfer, heat-trapping, and the like, are responsible for the warming trends observed on planet Earth.

Generally speaking, then, antirealists tend to distinguish between what is observable and what is unobservable. Anything that can be directly observed with the naked eye counts as observable. This includes things like goats, geysers, and glaciers. Anything that cannot be directly observed with the naked eye, but rather requires the use of scientific instruments, such as telescopes and microscopes, in order to be detected, counts as unobservable. This includes things like gluons, genes, and gravitational waves. As far as the scientific realism/antirealism debate in contemporary philosophy of science is concerned, both scientific realists and antirealists are particularly interested in claims to theoretical knowledge, which are claims about unobservable entities, processes, or events. In other words, the sort of scientific knowledge that is at stake in the scientific realism/antirealism debate in contemporary philosophy of science, then, is theoretical knowledge. For antirealists tend to be suspicious of theoretical knowledge, or knowledge about unobservables, not observational knowledge, or knowledge about observables, in science.

Accordingly, the scientific realism/antirealism debate in contemporary philosophy of science is about theoretical knowledge, that is, knowledge that is supposed to be about theoretical entities, such as neutrinos and genes, as well as theoretical processes, such as natural selection and continental drift. Is theoretical knowledge in science possible? In general, scientific realists tend to argue that science can (and does) yield theoretical knowledge, whereas antirealists tend to argue that science cannot (and does not) yield theoretical knowledge (that is, knowledge of unobservables). To put it another way, scientific realists tend to argue that we have good reasons to believe that our best scientific theories are approximately true because, if they were not even approximately true, they would not be able to explain and predict natural phenomena with such impressive accuracy. On the other hand, antirealists tend to argue that the impressive empirical success of our best scientific theories does not warrant belief in the approximate truth of our best scientific theories. This is because the history of science is a graveyard of theories that were once successful but were later discarded. These arguments will be analyzed and evaluated in Chap. 4 (see Sect. 4.1) and Chap. 5 (see Sect. 5.1), respectively.

Before we begin our survey of key positions and arguments in the scientific realism/antirealism debate in contemporary philosophy of science, it is important to note that the focus of this book is the contemporary debate. As Psillos and Ruttkamp-Bloem (2017, p. 3190) observe, while scientific realism used to include at least three theses: “Theoretical terms refer to unobservable entities; … theories are (approximately) true; and … there is referential continuity in theory change,” contemporary scientific realists tend to be more selective about the content of scientific theories
that they identify as worthy of belief (see also Psillos 2018). That is to say, the scientific realism/antirealism debate used to be dominated by discussions of the notion of convergence on the truth, that is, that “mature theories are converging on the truth because they all are referring to the same things” (Laymon 1984, p. 121, cf. Laudan 1981). Nowadays, however, scientific realists rarely use the notions of convergence on the truth and reference of theoretical terms in general. Instead, they try to be more selective about the parts of scientific theories that warrant a realist commitment in their view. In that respect, the scientific realism/antirealism debate in contemporary philosophy of science has taken what might be called a “selectivist turn” insofar as contemporary scientific realists are more selective about the aspects of science they are willing to be realists about than previous realists were. This selectivist turn has given rise to the following selective realist positions: Explanationist Realism, Entity Realism, and Structural Realism.

Rather than having a realist commitment to the theoretical posits of our best scientific theories in general, explanationist realists recommend limiting one’s realist commitments to those theoretical posits that are responsible for, or best explain, the predictive success of our best scientific theories. Entity realists recommend reserving one’s realist attitudes to those theoretical posits that can be causally manipulated as well as enable efficacious interventions in nature. For structural realists, the parts of our best scientific theories we should be realists about are not theoretical entities, processes, or events per se, but rather the structures posited by such theories. These positions will be discussed in Chap. 3 (see Sects. 3.1, 3.4, and 3.5, respectively).

2.2 “Just Say No” (to Case Studies)

As mentioned in Chap. 1, rather than devoting an entire book to a defense of scientific realism (of some variety or another) or antirealism (of some variety or another) by describing in detail case studies from the history of science that are alleged to support the former or the latter, this book takes an argumentation approach to the scientific realism/antirealism debate in contemporary philosophy of science. In addition to the advantages of this argumentation approach discussed in Chap. 1, this approach also shows why providing detailed descriptions of a few case studies from the history of science is not likely to be a successful argumentative strategy in the contemporary scientific realism/antirealism debate.

As we have seen in Chap. 1 (see Sect. 1.1), a strong argument is an inductive argument whose premises successfully provide probable support for its conclusion.

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4 This is not to say that there is no mention of the notion of reference in the contemporary scientific realism/antirealism debate at all. For example, Paul Needham (2018) discusses whether ‘water’ preserved its extension in chemistry.

5 Milena Ivanova (2013) provides a useful discussion of some of the historical actors in the scientific realism/antirealism debate, such as Pierre Duhem, Henri Poincaré, and Ernst Mach.
In other words, an inductive argument is strong when its premises, if true, make the conclusion more probable or likely to be true. Now, according to the *Oxford English Dictionary*, a case study is “a particular instance of something used or analyzed in order to illustrate a thesis or principle” (emphasis added). In philosophy of science, then, case studies are “particular, detailed descriptions of scientific activity” (Currie 2015, p. 553). The question, then, is this: Can a particular, detailed description of a scientific activity (that is, a case study) provide evidential support (either logically conclusive, as in deductive arguments, or probable, as in inductive arguments) for a thesis or principle in the scientific realism/antirealism debate in philosophy of science? Or, as Michael Bishop and J. D. Trout (2002, p. S204) ask, “How much support does a single case study (or even a number of case studies) provide a general principle about the nature of science?”

Recall from our discussion above that theses and/or principles in the scientific realism/antirealism debate in philosophy of science are supposed to be rather general, not particular. For, as we have seen, scientific realism is generally characterized as an “epistemically positive attitude toward those aspects of theories that are most worthy of epistemic commitment” (Chakravartty 2017). In that respect, scientific realism (of one variety or another) is meant to be a general thesis or “a general principle about the nature of science,” not just a claim about a particular science, a particular scientific theory, or a particular theoretical posit. The problem is that a particular, detailed description of a scientific activity does not provide enough evidential support for a general thesis or a general principle about the nature of science. To see why, suppose that I study in great detail August Kekulé’s discovery of the structure of the benzene molecule. I investigate historical documents as well as his own account of the discovery. Kekulé describes his discovery as follows:

I was sitting, writing at my text-book; but the work did not progress; my thoughts were elsewhere. I turned my chair to the fire and dozed. Again the atoms were gamboling before my eyes. This time the smaller groups kept modestly in the background. My mental eye, rendered more acute by the repeated visions of the kind, could now distinguish larger structures of manifold conformation: long rows, sometimes more closely fitted together; all twining and twisting in snake-like motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning I awoke; and this time also I spent the rest of the night in working out the consequences of the hypothesis (quoted in Rodricks 1992, p. 7).

What I have, then, is a case study, that is, a particular, detailed description of a scientific activity. Now suppose that, based on a very detailed analysis of this particular act of scientific discovery by an individual scientist, I make the following argument that proceeds from this particular case study to a general conclusion:

(P) August Kekulé discovered the ring shape of the benzene molecule while having a vision or a dream of a snake biting its own tail.

Therefore,

(C) Scientific discoveries occur when scientists have visions or dreams.

Now let us follow the decision procedure for the analysis and evaluation of arguments in natural language outlined in Chap. 1 (see Sect. 1.1) in order to find out if this is a good argument. Since we already have the premise and the conclusion in
canonical (or standard) form, we simply need to figure out what type of argument it is supposed to be: deductive or inductive. Is the premise (P) of this argument supposed to provide conclusive or probable support for the conclusion (C)? If premise (P) were supposed to provide logically conclusive support for the conclusion, then it would fail to do so. After all, the fact that Kekulé had a eureka moment while having a dream or a vision does not necessarily mean that scientists in general have eureka moments while they have dreams or visions. Kekulé’s particular act of discovery may simply be atypical. So, if the argument from the Kekulé case study were supposed to be a deductive argument, it would be an invalid argument.

Even if it fails as a deductive argument, the argument from the Kekulé case study could still be a good inductive argument. Is the premise of this argument supposed to provide probable support for the conclusion? In other words, if premise (P) were true, would it make the conclusion more likely to be true as well? Well, not really! Again, Kekulé’s particular act of discovery may simply be an outlier. For all we know, Kekulé’s eureka moment could have been a unique experience as far as scientific discoveries are concerned. The case study itself gives us no reason to believe that Kekulé’s experience is typical of scientific discoveries in general. If Kekulé’s experience is an outlier, and we have no reason to think that it is not, then the Kekulé case study does not make it more likely that scientific discoveries in general follow the same pattern as Kekulé’s discovery of the structure of the benzene molecule. In other words, even if premise (P) were true, as the case study allegedly shows, it would fail to make the conclusion more probable or likely to be true. So, if the argument from the Kekulé case study were supposed to be an inductive argument, it would be a weak argument.

Of course, we could easily turn the argument from the Kekulé case study into a valid argument by adding premises. For example, we could turn it into a valid argument by adding a premise as follows:

(P1) August Kekulé discovered the ring shape of the benzene molecule after having a vision or a dream of a snake biting its own tail.

(P2) All scientists make scientific discoveries in exactly the same way Kekulé made his discovery.

Therefore,

(C) Scientific discoveries occur when scientists have visions or dreams.

With the additional premise (P2), the argument from the Kekulé case study is now a valid argument. For the premises, namely, (P1) and (P2), if true, do provide logically conclusive support for the conclusion. The problem, however, is that we have no reasons to believe that (P2) is true, and the case study provides no such reasons. After all, the case study is about Kekulé in particular; it is not about what all scientists generally do. So, while we can turn the argument from the Kekulé case study into a valid argument quite easily by adding premises, those additional premises would not be supported by the case study itself, and so the revised argument, although valid, could not be said to be a sound argument.
Likewise, we could easily turn the argument from the Kekulé case study into a strong argument by adding premises. For example, we could turn it into a strong argument by adding a premise as follows:

(P1) August Kekulé discovered the ring shape of the benzene molecule after having a vision or a dream of a snake biting its own tail.

(P2) Scientists make scientific discoveries in *pretty much* the same way Kekulé made his discovery.

Therefore,

(C) Scientific discoveries occur when scientists have visions or dreams.

With the additional premise (P2), the argument from the Kekulé case study is now a strong argument. For the premises, namely, (P1) and (P2), if true, provide probable support for the conclusion. The problem, however, is that we have no reasons to believe that (P2) is true, and the case study provides no such reasons. After all, the case study is about Kekulé in particular; it is not about what other scientists typically do. So, while we can turn the argument from the Kekulé case study into a strong argument quite easily by adding premises, those additional premises would not be supported by the case study itself, and so the revised argument, although strong, could not be said to be a cogent argument.

Our evaluation of the argument from the case study of Kekulé’s discovery of the structure of the benzene molecule yields the verdict that it is a fallacious argument. A fallacious argument is an argument whose premises fail to provide either conclusive or probable support for its conclusion. In that sense, invalid and weak arguments are fallacious arguments. Now let us go back to the question we asked prior to considering the Kekulé case study. The question was this: Can a particular, detailed description of a scientific activity (that is, a case study) provide evidential support (either logically conclusive, as in deductive arguments, or probable, as in inductive arguments) for a thesis or principle in the scientific realism/antirealism debate in philosophy of science? Or, as Bishop and Trout (2002, p. S204) ask, “How much support does a single case study (or even a number of case studies) provide a general principle about the nature of science?” The answer is that a particular case or a single case study does not provide enough evidential support (either logically conclusive, as in deductive arguments, or probable, as in inductive arguments) for any general theses or principles about the nature of science. As far as the Kekulé case study is concerned, a particular act of scientific discovery by one scientist does not support any conclusions about acts of scientific discoveries in general. The same can be said about any case study because, case studies from the history of science are, by definition, “*particular*, detailed descriptions of scientific activity” (Currie 2015, p. 553), whereas the conclusions that philosophers of science are typically interested in, especially as far as the contemporary scientific realism/antirealism debate is concerned, are *general* conclusions or “*general principle[s]* about the nature of science” (Bishop and Trout 2002, p. S204). As Joseph Pitt (2001, p. 373) puts it, “if one starts with a case study, it is not clear where to go from there—for it is unreasonable to generalize from one case or even two or three.”
Indeed, most textbooks of logic, reasoning, and argumentation classify generalizing “from one case or even two or three” as fallacious reasoning. For example, according to Patrick Hurley (2006, p. 131), “Hasty generalization is a fallacy that affects inductive reasoning. [...] The fallacy occurs when there is a reasonable likelihood that the sample [or case] is not representative of the group. Such a likelihood may arise if the sample is either too small or not randomly selected.” Likewise, according to Merrilee Salmon (2013, p. 151), to draw general conclusions from “a single vivid case” is a mistake in reasoning, a “fallacy of misleading vividness.” Accordingly, if the particular case of Kekulé’s discovery of the structure of the benzene molecule is not representative of scientific discoveries in general, then generalizing from this case would be an instance of hasty generalization. Since a sample that contains a particular case, such as that of Kekulé’s discovery of the structure of the benzene molecule, is too small (after all, it contains only one case) and not randomly selected, we have reasons to suspect that it is not representative of scientific discoveries in general. Clearly, if the Kekulé case study is not representative of scientific discoveries in general, then it cannot support any general theses or principles about the nature of scientific discoveries.

In the context of the scientific realism/antirealism debate in contemporary philosophy of science, perhaps the most widely discussed case study from the history of science is probably the case of phlogiston. Both scientific realists and antirealists discuss this case study extensively. Antirealists have used it to argue against scientific realism (of some variety or another), whereas scientific realists have used it to argue for scientific realism (of some variety or another). For example, antirealists like Brad Wray (2018, p. 70) claim that “the concept of ‘phlogiston’ has no place in modern chemistry.” For antirealists, phlogiston is an example of a theoretical posit that was postulated to explain a natural phenomenon, namely, combustion, but later turned out not to exist at all. As Wray (2018, p. 70) argues, “‘phlogiston’ was, in one sense, replaced by ‘oxygen’, though the types of substances designated by these terms have very different properties.” For this reason, Wray (2018, p 70) thinks that “Only the most Whig historians of science could claim that oxygen is just phlogiston by another name.”

As one might expect, scientific realists disagree. Indeed, some realists have argued exactly what Wray says would amount to Whiggish history of science, namely, that eighteenth century chemists were using phlogiston-based terminology, such as “dephlogisticated air,” to talk about oxygen. As Miriam Solomon (2001, p. 37) explains:

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6 Ludwig Fahrbach (2011), Seungbae Park (2011), and I (Mizrahi 2013) have made this criticism against the inductive version of the antirealist argument commonly known as the “pessimistic induction” (that is, that it is an inductive generalization from a small and insufficiently diverse sample). This argument is analyzed and evaluated in Chap. 5, Sect. 5.1.

7 For more on the problems with the method of using case studies as evidence for philosophical theses about science, see Mizrahi (2018, 2020).
“Phlogiston” will turn out to have reference at least sometimes because “dephlogisticated air” was successfully--albeit unwittingly--used in a particular set of experimental contexts to refer to oxygen (Kitcher 1993, p. 100). That is, “phlogiston” sometimes refers even though there is no such thing as Priestley’s phlogiston, and even though no phlogiston theorist at the time could say how the term refers. Phlogiston theorists were actually often successfully referring to oxygen when they used the phrase “dephlogisticated air,” although they did not know it (emphasis in original).

Who has the historical facts exactly right--scientific realists or antirealists--is difficult to tell. For our purposes, however, the important point is not historical but rather logical. That is to say, even if antirealists are right in thinking that eighteenth century chemists posited phlogiston to explain combustion, but phlogiston does not exist, no general conclusions about the nature of science would follow from that fact (even if it is a historical fact). In other words, the following antirealist argument is neither a valid nor a strong argument:

(P) Eighteenth century chemists posited the existence of a substance called “phlogiston” to explain combustion, but phlogiston does not really exist.

Therefore,

(C) All (or most of) the theoretical posits of science do not really exist.

As we have seen, a sample of one is too small to draw any general conclusions about the nature of science. As we have also seen, we could easily make this antirealist argument valid (or strong) by adding premises. For example:

(P1) Eighteenth century chemists posited the existence of a substance called “phlogiston” to explain combustion, but phlogiston does not really exist.

(P2) All (or most of) the theoretical posits of science are like phlogiston.

Therefore,

(C) All (or most of) the theoretical posits of science do not really exist.

Now this antirealist argument can be said to be valid (or strong), but it cannot be said to be sound (or cogent). This is because the premise we have added, namely, (P2), is an unsubstantiated premise, and the phlogiston case study gives us no reasons to believe that (P2) is true. For the phlogiston case study is about phlogiston in particular, not about theoretical posits in general.

Likewise, even if scientific realists are right in thinking that eighteenth century chemists used the phrase “dephlogisticated air” to talk about oxygen in combustion, no general conclusions about the nature of science would follow from that fact (even if it is a historical fact). In other words, the following realist argument is neither a valid nor a strong argument:

(P) Although they called it “dephlogisticated air” rather than “oxygen,” eighteenth chemists posited the existence of a substance that really does play a role in combustion.

Therefore,

(C) All (or most of) the theoretical posits of science really do exist.
As we have seen, a sample of one is too small to draw any general conclusions about the nature of science. As we have also seen, we could easily make this realist argument valid (or strong) by adding premises. For example:

(P1) Although they called it “dephlogisticated air” rather than “oxygen,” eighteenth chemists posited the existence of a substance that really does play a role in combustion.

(P2) All (or most of) the theoretical posits of science are like dephlogisticated air.

Therefore,

(C) All (or most of) the theoretical posits of science really do exist.

Now this realist argument can be said to be valid (or strong), but it cannot be said to be sound (or cogent). This is because the premise we have added, namely, (P2), is an unsubstantiated premise, and the phlogiston case study gives us no reasons to believe that (P2) is true. For the phlogiston case study is about phlogiston in particular, not about theoretical posits in general. So, once again, “if one starts with a case study, it is not clear where to go from there—for it is unreasonable to generalize from one case or even two or three” (Pitt 2001, p. 373).

For these reasons, rather than give readers detailed descriptions of a few case studies from the history of science, which are probably a recipe for fallacious arguments, this book takes an argumentation approach to the scientific realism/antirealism debate in contemporary philosophy of science. In Chap. 4, I will analyze and evaluate what I take to be key arguments for scientific realism using the argumentation approach described above. In Chap. 5, I will analyze and evaluate what I take to be key arguments against scientific realism (or for antirealism) using the argumentation approach described above. Before we get to the analyses of what I take to be key positions in debate in Chap. 3, some of these positions are realist positions, broadly speaking, whereas others are antirealist positions, broadly speaking. Finally, in Chap. 6, I will discuss my own brand of scientific realism, namely, Relative Realism. I take Relative Realism to be a middle ground position between scientific realism and antirealism. I have proposed this view for the first time in a paper published in International Studies in the Philosophy of Science in 2013. But I will develop this position in much more detail, as well as advance novel arguments for it, in Chap. 6 of this book.

2.3 Summary

Scientific realism has three dimensions: a metaphysical dimension, a semantic dimension, and an epistemic dimension. The metaphysical thesis (or stance or dimension) of scientific realism is supposed to capture the idea that there are things out there in the world for scientists to discover and that those things out there in the world are independent of the human minds that study them. Antirealists tend to reject this metaphysical stance with respect to the unobservable entities, processes, and events that figure in our best scientific theories. The semantic thesis (or stance
or dimension) of scientific realism is supposed to capture the idea that scientific theories are to be taken literally, which means that they can be either true or false. Some antirealists reject this semantic stance. The epistemic thesis (or stance or dimension) of scientific realism is supposed to capture the idea that there are good reasons to believe that our best scientific theories, in particular, those that are empirically successful, are approximately true. Antirealists tend to reject this epistemic stance with respect to the theoretical claims about unobservable entities, processes, and events that figure in our best scientific theories. Since scientific realists and antirealists aim to argue for and/or against general theses about the nature of science, a case study (or even a few case studies) cannot provide evidential support (either logically conclusive, as in deductive arguments, or probable, as in inductive arguments) for the sort of theses that scientific realists and antirealists argue for and/or against in the scientific realism/antirealism debate in contemporary philosophy of science.

Glossary

**Antirealism** An agnostic or skeptical attitude toward the theoretical posits (that is, unobservables) of scientific theories. Antirealism comes in different varieties, such as Constructive Empiricism (see Chap. 3, Sect. 3.3) and Instrumentalism (see Chap. 3, Sect. 3.2).

**Approximate truth** Closeness to the truth or truthlikeness. To say that a theory is approximately true is to say that it is close to the truth. According to some scientific realists, approximate truth is the aim of science. (See Sect. 2.1).

**Case study** A particular, detailed description of a scientific activity, a scientific practice, or an episode from the history of science. (See Sect. 2.2.)

**Direct observation** Observation with the naked eye, without the use of scientific instruments, such as microscopes and telescopes, as opposed to instrument-aided observation. (See Chap. 3, Sect. 3.3.)

**The epistemic dimension (or stance) of scientific realism** The thesis that our best scientific theories, in particular, those that are empirically successful, are approximately true. (See Sect. 2.1.)

**Fallacious argument** An argument whose premises fail to provide either conclusive or probable support for its conclusion (see also invalid argument and weak argument). (See Sect. 2.2.)

**Hasty generalization** A fallacious inductive argument from a sample that is not representative of the general population that is the subject of the conclusion of the argument (because the sample is too small or cherry-picked rather than randomly selected). (See Sect. 2.2.)

**Instrument-aided observation** Observation by means of scientific instruments, such as microscopes and telescopes, as opposed to direct or naked-eye observation. (See Chap. 3, Sect. 3.3.)
Invalid argument A deductive argument in which the premises purport but fail to provide logically conclusive support for the conclusion. (See Chap. 1, Sect. 1.1.)

The metaphysical dimension (or stance) of scientific realism The thesis that there are things out there in the world for scientists to discover and that those things out there in the world are independent of the human minds that study them. (See Sect. 2.1.)

Scientific realism An epistemically positive attitude toward those aspects of scientific theories that are worthy of belief. Scientific realism comes in different varieties, such as Explanationist Realism (see Chap. 3, Sect. 3.1), Entity Realism (see Chap. 3, Sect. 3.4), Structural Realism (see Chap. 3, Sect. 3.5), and Relative Realism (see Chap. 6, Sect. 6.1).

The semantic dimension (or stance) of scientific realism The thesis that scientific theories are to be taken literally, which means that they can be either true or false. (See Sect. 2.1.)

Weak argument A non-deductive (or inductive) argument in which the premises purport but fail to provide probable support for the conclusion. (See Chap. 1, Sect. 1.1.)

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