Chapter 3
Key Positions in the Contemporary Scientific Realism/Antirealism Debate

Abstract In this chapter, I survey key positions in the scientific realism/antirealism debate in contemporary philosophy of science. The first is a selective realist position, which is known as Explanationist Realism, according to which we should believe only in the indispensable parts of our best scientific theories. Those parts that are considered indispensable, the so-called "working posits" (Kitcher, The advancement of science: Science without legend, objectivity without illusions. Oxford University Press, New York, 1993), are the ones that are responsible for, or best explain, the predictive success of our best scientific theories (Psillos, Scientific realism: how science tracks truth. Routledge, London, 1999). The second is an antirealist position with a long history in philosophy of science (see, for example, Duhem, The aim and structure of physical theory. Princeton University Press, Princeton, NJ. Translated from the French by Philip P. Wiener, 1954/1982), known as Instrumentalism, according to which scientific theories are mere instruments or tools of prediction (Rowbottom, The instrument of science: scientific anti-realism revitalised. Routledge, London, 2019). The third is an influential antirealist position, which is known as Constructive Empiricism and is due to Bas van Fraassen (The scientific image. Oxford University Press, New York, 1980), according to which science aims at empirical adequacy, not truth or approximate truth. The fourth is another influential realist position, which is known as Entity Realism and is due to Ian Hacking (Representing and intervening: introductory topics in the philosophy of natural science. Cambridge University Press, New York, 1983), according to which one is justified in taking a realist stance with respect to entities that can be manipulated and that facilitate interventions in nature (Sankey, Howard, Scientific realism and the rationality of science. Ashgate, Hampshire, 2008). The fifth is another selective realist position, which is known as Structural Realism, according to which we should be realists, not about theoretical entities or processes, but rather about structures (Worrall, Dialectica 43(1–2):99–124, 1989; Ladyman, Stud. Hist. Philos. Sci. A 29(3):409–424, 1998; French, The structure of the world: metaphysics and representation. Oxford University Press, Oxford, 2014).

Keywords Belief/acceptance distinction · Constructive empiricism · Empirical adequacy · Empirical success · Entity realism · Epistemic structural Realism (ESR) · Explanationist Realism (also known as deployment realism) · Instrumentalism · Observation/detection distinction · Ontic structural Realism (OSR) · Predictive success · Structural realism · Working posits/idle parts distinction

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In this chapter, I survey key positions in the scientific realism/antirealism debate in contemporary philosophy of science. The first is a selective realist position, which is known as Explanationist Realism, according to which we should believe only in the indispensable parts of our best scientific theories. Those parts that are considered indispensable, the so-called "working posits" (Kitcher 1993), are the ones that are responsible for, or best explain, the predictive success of our best scientific theories (Psillos 1999). The second is an antirealist position with a long history in philosophy of science (see, for example, Duhem 1954), known as Instrumentalism, according to which scientific theories are mere instruments or tools of prediction (Rowbottom 2019). The third is an influential antirealist position, which is known as Constructive Empiricism and is due to Bas van Fraassen (1980), according to which science aims at empirical adequacy, not truth or approximate truth. The fourth is another influential realist position, which is known as Entity Realism and is due to Ian Hacking (1983), according to which one is justified in taking a realist stance with respect to entities that can be manipulated and that facilitate interventions in nature (Sankey 2008). The fifth is another selective realist position, which is known as Structural Realism, according to which we should be realists, not about theoretical entities or processes, but rather about structures (Worrall 1989; Ladyman 1998; French 2014).

3.1 Explanationist Realism

Both scientific realists and antirealists agree that science is successful. When philosophers of science talk about "the success of science," they usually mean *empirical success*, which includes explanatory and predictive success. That is to say, the best scientific theories are those that explain natural phenomena that would otherwise be mysterious to us and that make predictions that are borne out by observation and experimentation. More specifically, in the context of the scientific realism/antirealism debate in contemporary philosophy of science, the sort of success that is particularly important for both realists and antirealists is predictive success. That is to say, there are scientific theories that make predictions that are borne out by observational and experimental testing. For example, according to Albert Einstein's theory of General Relativity, the fabric of space-time can be distorted or "warped" by the presence of massive objects, such as stars and black holes. This means that, when massive objects, such as neutron stars, move rapidly through space-time, they cause ripples in space-time, in much the same way that stones dropped into a pond produce a ripple effect. Instead of waves in water, however, moving masses like neutron stars produce gravitational waves that ripple across space-time. In other words, Einstein's theory of General Relativity predicts the existence of gravitational waves. Einstein proposed his theory of General Relativity in 1915. Subsequently, the existence of gravitational waves was confirmed indirectly by the discovery of a binary pulsar in 1974 (for which Russell A. Hulse and Joseph H. Taylor, Jr. were awarded the Nobel Prize in Physics in 1993) and directly by the Laser Interferometer

Gravitational-Wave Observatory (LIGO) in 2015 (Abbott et al. 2016). This is quite astonishing: a prediction made by a theory that was proposed at the beginning of the twentieth century is confirmed by experimentation roughly a century later. What could explain this astonishing predictive success of scientific theories like that of Einstein's theory of General Relativity?

Explanationist Realism is the view that realist commitments are warranted with respect to the theoretical posits that are responsible for--or can best explain--the predictive success of our best scientific theories, such as the successful prediction of Einstein's theory of General Relativity. This realist view is based on Stathis Psillos' distinction between the theoretical posits of a scientific theory that are responsible for its predictive success (that is, for the fact that the theory makes predictions that are borne out by observation and experimentation) and those that are not responsible for the predictive success of the theory. As Psillos (1999, pp. 112–113) puts it:

> It is precisely *those theoretical constituents which scientists themselves believe to contribute to the successes of their theories* (and hence to be supported by the evidence) that tend to get retained in theory change. Whereas, the constituents that do not 'carry-over' tend to be those that scientists themselves considered too speculative and unsupported to be taken seriously (emphasis added).[1]

Accordingly, realists of the explanationist stripe argue that we should follow the lead of scientists in believing in the existence of those theoretical posits that contribute to or are responsible for the predictive success of a scientific theory. For example, realists of the explanationist stripe would argue that gravitational waves are one of those theoretical constituents that physicists believe to contribute to the success of Einstein's theory of General Relativity, and are supported by the evidence from the Laser Interferometer Gravitational-Wave Observatory (LIGO) experiments, which uses interferometers to detect the kind of interference patterns that are associated with waves.

Some parties to the scientific realism/antirealism debate in contemporary philosophy of science refer to Explanationist Realism as "Deployment Realism." For example, Timothy Lyons (2016, p. 95) writes:

> According to deployment realism, we can be justified in believing the following meta-hypothesis: *those theoretical constituents that were genuinely deployed in the derivation of novel predictive success are at least approximately true* (emphasis added).[2]

Lyons (2016, p. 95) goes on to point out that the argument for this realist meta-hypothesis is that it would be a miracle if the scientific theories that feature these theoretical constituents that are genuinely deployed in the derivation of novel

[1] Philip Kitcher (1993, p. 149) draws a somewhat similar distinction between "*working posits* (the putative referents of terms that occur in problem-solving schemata) and *presuppositional posits* (those entities that apparently have to exist if the instances of the schemata are to be true)" (emphasis in original).

[2] When philosophers of science talk about "novel predictions," they typically mean a prediction that was not known to be true (or was expected to be true or false) at the time the theory was constructed.

predictions were not even approximately true. For a detailed analysis and evaluation of this argument for scientific realism, commonly known as the "no miracles" argument, see Chap. 4, Sect. 4.1. For now, the important point is that scientific realists do not have to be realists about all the theoretical posits of scientific theories. Instead, realists can be more *selective* about the entities that deserve their realist commitments.

Given this distinction between the "working posits" (that is, those theoretical posits that are responsible for the predictive success of a scientific theory) and "idle parts" (that is, those theoretical posits that do not play any part in explaining the predictive success of a scientific theory) of a scientific theory, realists of the explanationist stripe go on to argue that "it is enough to show that the theoretical laws and mechanisms which generated the successes of past theories have been retained in our current scientific image" (Psillos 1999, p. 108). This allows realists of the explanationist stripe to be optimistic about the progress of science even if many theoretical posits of past scientific theories have been abandoned, as the history of science allegedly shows. (On the pessimistic argument from the history of science, see Chap. 5, Sect. 5.1). The key argument for Explanationist Realism is known as the "miracle" argument or the "no miracles" argument. This argument is analyzed and evaluated in Chap. 4, Sect. 4.1.

3.2 Instrumentalism

As mentioned in Sect. 3.1, there are scientific theories that make predictions that are borne out by experimentation and observation. Some antirealists think that we should focus on the predictive success of scientific theories and stop worrying about whether those theories are likely true or approximately true. In fact, if science is a cognitive tool, then scientific theories should be understood as means to an end. As Darrell Rowbottom (2019, p. 1) puts it, "science is primarily, and should primarily be, an instrument for furthering our practical ends." This is the core tenet of an antirealist position known as Instrumentalism.

Instrumentalism is the view that scientific theories are instruments for attaining practical goals, such as predicting the occurrence of natural phenomena. For example, Pierre Duhem (1954/1982) expresses an instrumentalist view of scientific theories when he says that "A Law of Physics Is, Properly Speaking, neither True nor False" (p. 168) and that "propositions introduced by a theory [...] are neither true nor false; they are only convenient or inconvenient" (p. 334).[3] Understood as convenient or inconvenient instruments, then, rather than as attempts to describe the underlying nature of reality, scientific theories should not be taken literally, as either true or false, but rather instrumentally, as useful or not useful. In that respect,

[3] Milena Ivanova (2013) provides a useful discussion of Duhem and realism about atoms and the atomic theory.

instrumentalists reject the semantic stance (or thesis or dimension) of scientific realism (see Chap. 2, Sect. 2.1).

Accordingly, instrumentalists recommend that we refrain from interpreting theoretical statements literally. For example, we should not take the theoretical statement "SARS-CoV-2 is the virus that causes COVID-19" as a literal statement about an unobservable entity called "the novel coronavirus" or "SARS-CoV-2" that causes infected patients to have symptoms of an infectious disease, such as fever and shortness of breath. Instead, we should treat this theoretical statement as an instrument for explaining and predicting the appearance of symptoms in patients. If it is useful in explaining and predicting the onset of those symptoms, such as fever and shortness of breath, then we are entitled to use this instrument. What matters for instrumentalists is the usefulness of scientific theories as tools for accomplishing practical goals, such as explaining and predicting the occurrence of natural phenomena, not whether they are likely true or approximately true.

Likewise, the theoretical statement "HIV infection is caused by the human immunodeficiency virus" should be taken as neither true nor false, but rather as a convenient or useful tool for explaining and predicting the spread of the chronic condition called Acquired Immunodeficiency Syndrome (AIDS). For instrumentalists, we should not worry about whether pathogenic microorganisms and viruses, such as the Human Immunodeficiency Virus (HIV), are real or not. As long as they serve us in explaining and predicting the spread of infectious diseases, we are entitled to use them as such, that is, as instruments or tools, provided that we are not tempted to say that theoretical statements about such entities are literally true (or literally false). In that respect, Instrumentalism belongs to "an empiricist philosophical tradition" (Rowbottom 2019, p. 1), which gives epistemic priority to direct observation. Since pathogenic microorganisms, such as bacteria and viruses, are unobservable, that is, they cannot be directly observed with the naked eye, we should not commit ourselves to their existence by believing that any theoretical statements about them are literally true (or literally false). Instrumentalism is supported by several antirealist arguments, which are analyzed and evaluated in Chap. 5.

3.3 Constructive Empiricism

Like instrumentalism, another antirealist position that gives epistemic priority to direct observation is known as Constructive Empiricism. As Bas van Fraassen (1980, p. 12) puts it, Constructive Empiricism is the view that "Science aims to give us theories that are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate." For van Fraassen (1980, p. 18), "to accept a theory is (for us) to believe that it is empirically adequate—that what the theory says about what is observable (by us) is true." For constructive empiricists, what counts as "observable" must be directly observable (by us) without the aid of any instruments. As van Fraassen (2001, p. 154) puts it:

> We can *detect* the presence of things and the occurrence of events by means of instruments. But in my book that does not generally count as *observation*. Observation is perception, and perception is something that is possible for us without instruments (emphasis added).

In other words, when scientists use instruments, such as electron microscopes and radio telescopes, they are not *observing* theoretical entities, such as viruses and cosmic radiation, according to constructive empiricists. Rather, scientists are merely *detecting* these things. For example, van Fraassen (2001, p. 158) argues that paramecia, a type of single-celled (or unicellular) microorganisms, can be detected by using microscopes, but they cannot be directly observed.

> The microscope's output can be sent into a scanner which transmits to a computer or projector – then we see the paramecia on the wall or the monitor. *We are having a different sort of experience* then, for we say after only a little urging that we are seeing an image. Nothing about the status of the microscope can follow, it seems to me, from concentration on one of these three experimental arrangements to the exclusion of the others (emphasis added).

If one is inclined to say that one sees an image of an object (for example, a paramecium) through the microscope, van Fraassen (2001, p. 160) argues, then one is no longer simply "gathering information" but rather "postulating" that there is a real object under the microscope. This emphasis on direct observation (as opposed to mere detection) leads constructive empiricists to recommend suspension of belief in any theoretical statements that would commit us to the existence of unobservable entities, processes, or events.

Constructive Empiricism, then, is the view that, when scientists construct theories about natural phenomena, they are not aiming for literally true descriptions of the underlying nature of reality. Rather, they are merely aiming to "save the phenomena," that is, to get the observable facts right. Here is how van Fraassen (1998, p. 213) contrasts Constructive Empiricism with scientific realism:

> Scientific realism and constructive empiricism are, as I understand them, not epistemologies but views of what science is. Both views characterize science as an activity with an aim--a point, a criterion of success--and construe (unqualified) acceptance of science as involving the belief that science meets that criterion. According to scientific realism the aim is truth (literally true theories about what things are like). *Constructive empiricism sees the aim as not truth but empirical adequacy* (emphasis added).

If Constructive Empiricism is the correct view of what science is, then scientists do not (or should not) care whether the theoretical entities they posit to explain observable phenomena are real or not. Rather, scientists only care (or should only care) that the observable predictions derived from those theoretical postulates are accurate.[4] In that respect, constructive empiricists deny the epistemic stance (or thesis or dimension) of scientific realism (see Chap. 2, Sect. 2.1).

[4] In Mizrahi (2014), I argue that Constructive Empiricism is ambiguous between a descriptive reading and a normative reading. On the descriptive interpretation, Constructive Empiricism is the view that scientists *do* aim for empirically adequate theories. On the normative interpretation, Constructive Empiricism is the view that scientists *should* aim for empirically adequate theories.

Unlike instrumentalists, for whom scientific theories should not be understood literally, constructive empiricists do take scientific theories literally, that is, as capable of being true or false. For constructive empiricists, then, scientific theories are not mere instruments, as they are for instrumentalists. Rather, scientific theories consist of statements that can be true or false. However, we should only believe what scientific theories say about observable phenomena, constructive empiricists argue, and withhold belief from what scientific theories say about unobservable entities, processes, and events. For constructive empiricists, to believe what scientific theories say about unobservables is to adopt "beliefs going beyond what science itself involves or requires for its pursuit" (van Fraassen 1998, p. 214). In other words, constructive empiricists argue that there is no need to believe in the unobservable entities, processes, and events of scientific theories in order to make sense of the scientific enterprise. For constructive empiricists, belief in what scientific theories say about observable phenomena, that is, *acceptance* (or the belief that a theory is empirically adequate), is all that is required both to do science and to make sense of science. The main "Positive Argument" for Constructive Empiricism is analyzed and evaluated in Chap. 5, Sect. 5.2.

3.4 Entity Realism

Although the scientific realism/antirealism debate in contemporary philosophy of science is typically construed as a debate concerning the epistemic status of scientific theories (see Chap. 2, Sect. 2.1), this debate can also be understood as a debate concerning the ontological status of the theoretical posits of science. That is to say, instead of asking whether our best scientific theories are likely true or approximately true, or whether we are justified in believing our best scientific theories, we could ask whether the theoretical posits of our best scientific theories are real. (Recall the metaphysical thesis, stance, or dimension discussed in Chap. 2, Sect. 2.1). As Bence Nanay (2019, p. 500) argues, the "debate about theories is very different from, and logically independent of, the debate about unobservable entities."

To illustrate, consider the recent reports that scientists have managed to take a picture of a black hole. In *The New York Times*, the headline of an article announcing the discovery read as follows: "Darkness Visible, Finally: Astronomers Capture First Ever Image of a Black Hole" (Overbye 2019). Now, black holes are theoretical entities insofar as they are unobservable entities whose existence is postulated by scientific theories, specifically, Albert Einstein's theory of General Relativity. According to Einstein's theory of General Relativity, a massive amount of matter can be packed into a tiny region of space such that space-time itself is deformed. This deformity in space-time is known as a black hole. Since the gravitational pull of such a massive amount of matter in a small and dense region of space is so strong, nothing can escape the gravitational pull of a black hole once it passes what is known as the event horizon of a black hole. This means that a black hole does not give off any light, which in turn means that a black hole cannot be observed directly, given that “Eyes are devices for extracting useful information from the light reflected or emitted from objects in the world around us” (Land and Nilsson 2012, p. 23). Now, on April 10, 2019, the scientific journal, *Nature*, reported that the “Event Horizon Telescope’s global network of radio dishes has produced the first-ever direct image of a black hole and its event horizon” (Castelvecchi 2019). This is a bit misleading, however, because what can be seen in that picture is the light at the edge of a black hole, that is, before the light crosses the event horizon. The presence of the black hole itself is then inferred from the fact that there appears to be blackness in the middle of that “photon ring,” as the astronomer Andrea Ghez calls it in the *Nature* article (Castelvecchi 2019, p. 285). Another astronomer, Heino Falcke, makes the same point when he says, “What you’re looking at is a ring of fire created by the deformation of space-time. Light goes around, and looks like a circle” (Castelvecchi 2019, p. 284). This “ring of fire” itself, however, is not a black hole. For, as we have seen, a black hole is a region of space that has a massive amount of mass concentrated in it such that nearby objects cannot escape its gravitational pull. In other words, the picture is not a direct image of a black hole. Nor is it an instance of darkness made visible, as *The New York Times* headline asserts. Rather, it is an image of the *light* around what is supposed to be the event horizon of a black hole.

Accordingly, antirealists would insist that whether black holes exist or not is still an open question, the announcements in *The New York Times* (Overbye 2019) and in *Nature* about “the first-ever direct image of a black hole” (Castelvecchi 2019) notwithstanding. For instance, constructive empiricists might invoke the distinction between *observing* and *detecting* to argue that scientists have detected light around what they think is a black hole, but they have not observed a black hole directly (see Sect. 3.3). Therefore, black holes remain theoretical posits whose existence is inferred from theoretical assumptions rather than directly observed without the aid of scientific instruments. For constructive empiricists, this means that we should not believe that black holes really exist. Instead, we should simply *accept* Einstein’s theory of General Relativity without committing ourselves to the existence of its theoretical posits, such as black holes, gravitational waves, and the like.

Entity Realism is the view that the theoretical entities, processes, and events (that is, unobservables) posited by our best scientific theories are real. As Howard Sankey (2008, p. 43) puts it, “Entity realism is the thesis that the unobservable theoretical entities of science are real.” Bence Nanay (2019, p. 500) agrees with Sankey when he says that, “Realism about entities is the view that unobservable entities that scientific theories postulate really do exist. And, at least according to the proponents of Entity Realism, we can be realist about an unobservable entity a theory postulates without being realist about the theory that postulates it.” One of the key arguments for this view is an argument from the manipulation of theoretical entities, which is based on Ian Hacking’s (1983, p. 23) famous slogan for Entity Realism, “if you can spray them, they are real.” That is to say, if we can do things with the theoretical entities posited by our scientific theories, then we have a good reason to believe that these theoretical entities are real. To use Hacking’s (1983, p. 23) example, we can shoot electrons through a double-slit apparatus using an electron gun. Presumably, we would not be able to do that if electrons did not really exist. Therefore, the fact that we can do things with electrons, such as shooting electrons through a double-slit apparatus using an electron gun, provides a good reason to believe that electrons are real. Similarly, we can combine genetic material from various sources to create recombinant DNA using methods of genetic recombination such as molecular cloning. Presumably, we would not be able to do that if DNA molecules did not really exist. Therefore, the fact that we can do things with DNA, such as combining genetic material from various sources to create recombinant DNA, provides a good reason to believe that DNA molecules are real.

Of course, black holes cannot be manipulated by us. Indeed, as we have seen, antirealists would argue that we cannot even observe black holes directly, let alone manipulate them. Hacking was aware of this. According to Hacking (1989, p. 561), "A black hole is as *theoretical* an entity as could be. Moreover, it is in principle *unobservable*. [...] At best we can *interpret* various phenomena as being due to the existence of black holes" (emphasis added). If, as entity realists argue, we should believe that a theoretical entity is real only if we can manipulate that entity, but black holes cannot be manipulated by us, then it follows that we should not believe that there are such things as black holes. As Hacking (1989, p. 578) puts it, "When we use entities as *tools*, as *instruments of inquiry*, we are entitled to regard them as real. But we cannot do that with the objects of astrophysics" (emphasis added), such as black holes. Therefore, by entity realists' lights, it appears that we are not entitled to regard the theoretical entities of astronomy and astrophysics as real. For Dudley Shapere (1993), this consequence of Entity Realism, namely, that "astronomy is not a natural science at all" (Hacking 1989, p. 577) because its theoretical entities, such as black holes, cannot be manipulated by us, was an absurd consequence of Entity Realism. Shapere interprets Hacking as arguing that "Astronomy cannot interfere with its objects" (Shapere 1993, p. 135), and so it follows that "astronomy is not a natural science at all" (Hacking 1989, p. 577). Shapere (1993, p. 135) argues that "astronomy is a science" and that Hacking is wrong about the "role of experiment in science." On the one hand, for Hacking, astronomy is a natural science only if it is an experimental science (that is, its theoretical entities can be used as tools or instruments of inquiry by us). Since astronomy is not an experimental science (that is, its theoretical entities, such as black holes, cannot be used as tools or instruments of inquiry by us), according to Hacking, it follows that "astronomy is not a natural science at all" (Hacking 1989, p. 577). On the other hand, for Shapere, astronomy is a natural science even if it is not an experimental science. Since "passively observing" can advance scientific knowledge just as much as "interfering actively" can, according to Shapere, it follows that "astronomy is a science" (Shapere 1993, p. 135). As Hilary Putnam would put it, this is a case in which "one philosopher's *modus ponens* is another philosopher's modus *tollens*" (Putnam 1994, p. 280). Aside from Hacking's argument from the manipulation of entities, another key argument for Entity Realism is an argument from corroboration. This argument is analyzed and evaluated in Chap. 4, Sect. 4.4.

3.5 Structural Realism

As we discussed in Chap. 2, the scientific realism/antirealism debate in contemporary philosophy of science has taken what might be called a "selectivist turn." That is to say, contemporary scientific realists are more *selective* about the aspects of science they are willing to be realists about than previous scientific realists were. We have already discussed two selective realist positions: Explanationist Realism (see Sect. 3.1) and Entity Realism (see Sect. 3.4). A third selective realist position in the contemporary scientific realism/antirealism debate is known as Structural Realism. For structural realists, the parts of our best scientific theories that warrant a realist commitment are unobservable *structures*, such as those represented by relations captured in the equations of our best scientific theories, rather than unobservable entities, processes, or events. On this view, we have no good reasons to believe that, say, Isaac Newton discovered real forces in nature, such as the force of gravity. But we do have good reasons to believe that "what Newton really discovered are the relationships between phenomena expressed in the mathematical equations of his theory [for example, his law of gravitation: $F_g = G\frac{M1M2}{r^2}$]"[5] (Worrall 1989, p. 122). For structural realists, "the relations of physical objects have all sorts of knowable properties, [but] the physical objects themselves remain unknown in their *intrinsic nature*" (Russell 1912, pp. 32–34; emphasis added).

The general motivation for this view comes from the role that mathematics plays in science. As Steven French (2014, p. 192) puts it:

> With the mathematization of science it is natural to extend this thesis [that is, the thesis that mathematics describes the structure of a domain] to scientific knowledge and then the latter too comes to be conceived as *structural knowledge* (emphasis added).[6]

Accordingly, structural realists argue that our best scientific theories do give us theoretical knowledge, but that theoretical knowledge is knowledge about *structures*, not entities, processes, or events. After all, if "the universe [...] is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it," as Galileo (1623/1957, pp. 237–238) has argued, then one might think that scientists capture the mathematical structure of the universe in the mathematical equations of their scientific theories. It is in this sense that science can be said to give us structural knowledge of the universe.

More specifically, Structural Realism can be construed as either an epistemological position or an ontological position. Those who construe Structural Realism as an epistemological position subscribe to the view that our best scientific theories give us knowledge about the unobservable structure of the world. This view is known as

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[5] Where G is the gravitational constant, M_1 is the first mass, M_2 is the second mass, and r is the distance between the two masses.

[6] Otávio Bueno (2019) provides a useful discussion of the status of mathematics in OSR.

Epistemic Structural Realism (ESR). Unlike explanationist realists, who think that our best scientific theories give us knowledge about unobservable entities, processes, and events (see Sect. 3.1), epistemic structural realists reserve their realist commitments to unobservable structures only. For example, Augustin-Jean Fresnel's wave theory of light made an extraordinary prediction, namely, that there will be a white spot at the center of the shadow of an opaque disc held in light diverging from a single slit. This was an extraordinary prediction at the time given the dominant understanding of light as corpuscular (that is, made of material particles) rather than wave-like.[7] Despite this predictive success of Fresnel's theory of light, it was later abandoned and replaced by James Clerk Maxwell's electromagnetic theory. Structural realists would argue that Fresnel's theory of light was not completely wrong; it did get something right, not about the *nature* of light, but rather about the *structure* of light. As John Worrall (1989, p. 117) puts it, "it seems right to say that Fresnel completely misidentified the *nature* of light, but nonetheless it is no miracle that his theory enjoyed the empirical predictive success that it did; it is no miracle because Fresnel's theory, as science later saw it, attributed to light the right *structure*" (emphasis in original).

Those who construe Structural Realism as an ontological position subscribe to the view that structures are ontologically basic. That is to say, everything that exists depends on the existence of structures and structures depend on nothing else for their existence. This view is known as Ontic Structural Realism (OSR). As James Ladyman (1998, p. 420) puts it, OSR "means taking structure to be primitive and ontologically subsistent." In that respect, OSR is a metaphysical stance, whereas ESR is an epistemic stance. As we have seen in Chap. 2 (see Sect. 2.1), the epistemic stance of scientific realism is the thesis that "Mature and predictively successful scientific theories are well-confirmed and approximately true. So entities posited by them, or, at any rate entities very similar to those posited, inhabit the world" (Psillos 2006, p. 135). ESR falls under the epistemic dimension of scientific realism, then, since it is the view that the unobservable *structures* posited by our mature and predictively successful scientific theories, or structures very similar to those posited, make up the world.

On the other hand, the metaphysical stance of scientific realism is the thesis that the "world has a definite and mind-independent structure" (Psillos 2006, p. 135). OSR falls under the metaphysical dimension of scientific realism, then, since it is the view that only *structure* is real. As French and Ladyman (2003, p. 37) point out, the motivation behind OSR is to "satisfy the 'mind independence' requirements of realism in general," that is, the metaphysical thesis, stance, or dimension of scientific realism (see Chap. 2, Sect. 2.1) but with respect to unobservable *structures* only, not unobservable entities, processes, or events.[8] Several realist arguments

[7] Alberto Cordero (2011) discusses this example and its implication for the selective (or *divide et impera*) realist strategy in more detail.

[8] Roman Frigg and Ioannis Votsis (2011) provide a comprehensive survey of various positions that fall under the "Structural Realism" label.

support Structural Realism, including the so-called “miracle” argument or “no miracles” argument, which is analyzed and evaluated in Chap. 4, Sect. 4.1.

3.6 Summary

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 scientific realists were. Accordingly, scientific realists of the explanationist stripe reserve their realist commitments to the theoretical posits that are responsible for--or can best explain--the predictive success of our best scientific theories (see Sect. 3.1). Entity realists argue that only those unobservable theoretical entities that can be causally manipulated and that enable efficacious interventions in nature are real (see Sect. 3.4). Structural realists, either of the ontic variety or the epistemic variety, argue that the parts of our best scientific theories that warrant a realist commitment are unobservable structures, such as those represented by relations captured in the equations of our best scientific theories, rather than unobservable entities, processes, or events (see Sect. 3.5). Like scientific realism, antirealism also comes in different varieties. For constructive empiricists, the aim of science is empirical adequacy, not (approximate) truth, and so we should believe what our best scientific theories say about observable phenomena, but we should not believe what they say about unobservables (see Sect. 3.3). For instrumentalists, scientific theories are not to be taken literally, that is, scientific theories are not the sort of things that can be true or false. Rather, scientific theories are merely instruments for attaining practical goals, such as predicting the occurrence of natural phenomena (see Sect. 3.2).

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 Chap. 2, Sect. 2.1).

Constructive Empiricism The view that the aim of science is to construct empirically adequate theories. A theory is empirically adequate when what the theory says about what is observable (by us) is true. (See Chap. 3, Sect. 3.3).

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).

Empirical adequacy The aim of science, according to Constructive Empiricism. To say that a theory is empirically adequate is to say that what the theory says about what is observable (by us) is true. (See Chap. 3, Sect. 3.3).

Empirical success A scientific theory is said to be empirically successful just in case it is both explanatorily successful (that is, it explains natural phenomena that would otherwise be mysterious to us) and predictively successful (that is, it makes predictions that are borne out by observation and experimentation). (See Chap. 3, Sect. 3.1).

Entity Realism The view that the theoretical entities (that is, unobservables) posited by our best scientific theories are real. (See Chap. 3, Sect. 3.4).

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 Chap. 2, Sect. 2.1).

Epistemic Structural Realism (ESR) The view that the best scientific theories give us knowledge about the unobservable structure of the world. (See Chap. 3, Sect. 3.5).

Explanationist Realism The view that realist commitments are warranted with respect to the theoretical posits that are responsible for--or can best explain--the predictive success of our best scientific theories (also known as "Deployment Realism"). (See Chap. 3, Sect. 3.1).

Explanatory success A scientific theory is said to be explanatorily successful just in case it explains natural phenomena that would otherwise be mysterious to us. (See Chap. 3, Sect. 3.1).

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).

Instrumentalism The view that scientific theories are instruments for attaining practical goals, such as predicting the occurrence of natural phenomena. (See Chap. 3, Sect. 3.2).

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 Chap. 2, Sect. 2.1).

Modus ponens A form of argument with a conditional premise, a premise that asserts the antecedent of the conditional premise, and a conclusion that asserts the consequent of the conditional premise. That is, "if *A*, then *B*, *A*; therefore, *B*," where *A* and *B* stand for statements. *Modus ponens* is a valid form of inference, and so an argument in natural language that takes this logical form is valid. On the other hand, the following logical form is invalid: "if *A*, then *B*, *B*; therefore, *A*." It is known as the fallacy of affirming the consequent. (See Chap. 4, Sect. 4.1).

Modus tollens A form of argument with a conditional premise, a premise that denies the consequent of the conditional premise, and a conclusion that denies the antecedent of the conditional premise. That is, "if *A*, then *B*, not *B*; therefore, not *A*," where *A* and *B* stand for statements. *Modus tollens* is a valid form of inference, and so an argument in natural language that takes this logical form is valid. On the other hand, the following logical form is invalid: "if *A*, then *B*, not *A*; therefore, not *B*." It is known as the fallacy of denying the antecedent. (See Chap. 5, Sect. 5.1).

Ontic Structural Realism (OSR) The view that everything that exists depends on the existence of structures and structures depend on nothing else for their existence. (See Chap. 3, Sect. 3.5).

Predictive success A scientific theory is said to be predictively successful just in case it makes predictions that are borne out by observation and experimentation. (See Chap. 3, Sect. 3.1).

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 Chap. 2, Sect. 2.1).

References and Further Readings

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