Essay Review: Scientific Representation and Empiricist Structuralism*

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Bas C. van Fraassen, ***Scientific Representation: Paradoxes of Perspective***. Oxford: Oxford University Press (2008), 408 pp., $50.00 (cloth).

1. Introduction. The publication, in 1980, of van Fraassen's *The Scientific Image* was a major event in the philosophy of science, and not just in retrospect. With that book, van Fraassen breathed new life into empiricism in the philosophy of science following an onslaught of both a renewed scientific realism and historically oriented philosophies of science. In part his success was due to his abandonment of key elements of logical empiricism. One was his replacement of an account of scientific theories grounded in syntax with one grounded in semantics, the 'semantic view of theories'. Another was the replacement of a linguistic distinction between theoretical and observational terms by a distinction between what is and is not humanly observable. Since 1980, van Fraassen has published numerous articles and several substantial books including *Laws and Symmetry* (1989), *Quantum Mechanics: An Empiricist View* (1991), and *The Empirical Stance* (2002). Although, like the latter, *Scientific Representation* began life as a series of lectures, it is far more than that. Indeed, I regard it as the true successor to *The Scientific Image*, an even more mature exposition of an empiricist philosophy of science for a philosophical audience much broader than technical philosophers of science. It is a book rich in historical and contemporary insights which makes even greater breaks with the past than its influential predecessor. And the ever elegant style makes it a joy to read. Finding it impossible to write a systematic review of so rich a book, I will concentrate on what for me is the most significant issue: the relationship between scientific representation and

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empiricist structuralism. In the end, I will question whether the account of representation might not undermine the empiricist version of structuralism.

2. Representation and Perspective. Van Fraassen's most radical break with recent tradition is his account of representation in general, which is thoroughly pragmatic. "I will give pride of place," he says, to "the notion of *use,* the emphasis on the pragmatics rather than syntax or semantics of representation in general" (25). Thus his 'Hauptsatz': "There is no representation except in the sense that some things are used, made, or taken, to represent some things as thus and so" (23). This can't be a definition or a theory of representation since it is obviously circular. His view is that one cannot "define representation or . . . reduce it to something else" (7). One can at most describe some of its major features, "place it in a context where we know our way around" (7).

Pictures and diagrams are prime examples of the kinds of things that are used to represent objects and processes in the world. "To call an object a picture at all is to relate it to use" (25). And, for van Fraassen, use is a rich notion. It includes the idea that there are agents with intentions and goals who do the using. Agents also 'bestow meaning'. "If we were to ask 'What is in a picture?' while taking the picture simply to be the physical object and with no relation to anything that can bestow meaning, the answer would have to be 'Nothing!'" (25). One could say that, for van Fraassen, in representation intention is everything. Thus: "If . . . I draw a graph and present it as representing the rate of bacterial growth under certain circumstances, then by virtue of that very act, what the graph represents is the bacterial growth rate under those conditions—period" (27). It follows that "the very same object or shape can be used to represent different things in different contexts, and in other contexts not represent at all" (27). It also follows that "this conception [of representation] leaves no room for 'representation in nature' in the sense of 'naturally produced' representations that have nothing to do with conscious or cognitive activity or communication" (24). The slogan might well be: No Representation without Representers. Finally, for van Fraassen, scientific representation "has no room for the notion of mental images or mental representations" (24). Science is all about external representational resources.

Van Fraassen also rejects the twentieth-century idea, associated particularly with Nelson Goodman, that resemblance is not important to representation. He claims, rather, that "not all, but certainly many forms of representation do trade on likeness, likeness in some respects, *selective likeness*" (7). Here again, the idea is not to analyze representation in terms of resemblance. Rather, "resemblance comes in, not when we are an-

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swering the question *What is representation?*, but rather then we address *How does this or that representation represent, and how does it succeed?"* (33). Answer: "*By selective resemblance and selective (even systematic) non-resemblance*" (33). And he emphasizes that "the 'selective' in 'selective resemblance' is a delicate, highly nuanced, contextually sensitive qualification" (57). A standard objection against taking resemblance as fundamental for representation is that resemblance is a symmetrical relationship whereas representation is asymmetrical. The introduction of users breaks that symmetry.

The notion of perspective is important because observations (particularly measurements) are, for van Fraassen, perspectival. Like representation, perspective is for van Fraassen, "a cluster concept, with multiple critical hallmarks . . . there being no defining common set of characteristic, only family resemblances among the instances" (59). His paradigm of perspectivity is its use in the visual arts. In Chapter 3 we are treated to a suggestive historical sketch of perspective in the arts and sciences from the Greeks through the fifteenth century and on to the present.

His other main example of perspectivity is cartography. What is in a map? he asks. Here again, "The short answer is 'Nothing!' That is, if we take the physical object by itself, considered entirely without reference to use, to us. . . . *Even relative to the conventions in force in our community or society, for pictorial representation of terrain, there is some information* . . . that *cannot be in the map itself*" (82).

This information is, of course, one's current location in the space mapped. Even if a map has an arrow with the words 'You are here', that is useful only if one knows one is standing where the map has been deliberately located for such use. The same map would be useless if carried around in one's pocket. Using a map requires an 'essential indexical', something of the form "I am here now" (83). "Self-ascription belongs to pragmatics and not to semantics" (82).

The importance of thinking about maps for understanding representation in science is that there is a "*precise and perfect analogy between theory, model, and map*" (80). Of course, "general scientific theories, in their 'official' formulation, are not perspectival descriptions, and their models . . . are generally not perspectival representations" (86). But perspectivity returns as soon as one attempts to apply a model to something in the world, particularly if one is making a measurement. "Spatial measurement is explicitly perspectival, and its deliverances relate to scientific models precisely in the way that visual perspectives relate to physical space" (87).

Van Fraassen devotes two chapters to the topic of measurement as representation. For van Fraassen, what is measured are "physical magnitudes that characterize the objects measured" (142). "Measurement al-

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ways involves a physical interaction between 'object' and 'apparatus'" (143). These interactions satisfy the criterion "that the outcome must represent the target in a certain fashion, selectively resembling it a certain level of abstraction, according to the theory—*it is a representation criterion*" (141). Thus, "measurement is information gathering, a measurement outcome is something that has meaning, is in fact a representation of what is measured, and that point does not reduce to a physical condition" (156). Finally, "a measurement outcome is after all only a representation of the target, and in general does not show what that is like but only what it 'looks like' in that measurement setup" (175–176). "*Measurement is Perspectival"* (176).

3. Appearances and Phenomena. In place of the traditional empiricist dichotomy between theory and observation, in *Scientific Representation* van Fraassen introduces a tripartite distinction: appearance, phenomenon, and theory. By way of introduction, he says, "*phenomena* will be observable entities (objects, events, processes). . . . *Appearances* will be the contents of observation or measurement outcomes" (8). Appearances, therefore, are perspectival. Phenomena are not. Appearances are how the phenomena appear from various perspectives—for example, from different locations or with different instruments.

There is considerable continuity here with van Fraassen's well established views. From individual appearances, 'observations' or 'data' in earlier terms, one constructs models of data, and also more refined "surface models" (166–172), which are elaborations of and extrapolations from data models. These enriched data models may then become models of the phenomena which may in turn be isomorphic with empirical substructures of models belonging to a family of models constituting a theory in the original sense of his version of the semantic view of theories. This picture is well exemplified by Kepler's laws and Newton's model of the solar system. Kepler's laws are surface models constructed from many appearances of several different planets, particularly Mars. They become models of the phenomenon of planetary motion. Then, "under certain simplifying assumptions," these laws are shown to match substructures of a Newtonian model of the motions of the planets. (257)

For further elaboration of the distinction between appearances and phenomena, consider van Fraassen's exemplar of ancient and early modern astronomy (8, 285–288). Recording successive apparent positions of a planet such as Mars against the background of the fixed stars, it appears that Mars occasionally exhibits 'retrograde motion', temporarily moving backward in its orbit before moving forward again. In a Ptolemaic theoretical model with a carefully designed epicycle, the apparent motion corresponds to a phenomenon and is thus directly embeddable into an

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observable feature of the model. In a Copernican theoretical model, on the other hand, the apparent retrograde motion is an appearance only. The phenomenon is a continuous circular motion. However, using the Copernican model, one can explain ('save') the appearances as due to the speed of the Earth in its orbit being greater than that of Mars in its orbit. Mars does not retrogress; relative to Mars, the Earth progresses, giving the appearance from the Earth that Mars is retrogressing. This example well highlights the distinction between appearances and phenomena, but it is philosophically impoverished because the only possible candidates for theoretical unobservables are, problematically, orbits and epicycles.

Given that scientific instruments are designed for human consumption, their outputs, appearances, must ultimately be humanly observable. But for van Fraassen, phenomena also must be "truly humanly observable," so the expression "observable phenomenon" is for him redundant (98). Contrary to tradition, he argues at length that microscopes, telescopes, and so on, do not have to be regarded as providing a 'window' on an otherwise unseen world (Chapter 4). Rather, these instruments can be regarded as creating new observable phenomena. Thus, when looking through a microscope, it only appears as if one is seeing an otherwise unobservable object, say, a paramecium. Rather, what the microscope does is produce a new phenomenon, an image that we theoretically identify as being that of a paramecium. This image is publicly accessible, as is made evident by the possibility of hooking the microscope up to an arrangement that projects the image on a screen for all to see. That image is an observable phenomenon. On his scheme, therefore, it is this image to which biological theory is accountable; not, as any biologist would insist, the appearance and behavior of observed paramecia themselves.

For an alternative view, consider an example from modern astronomy to which van Fraassen indirectly refers (168). During the 1990s, NASA published images produced by the Compton Gamma Ray Observatory. One of four instruments aboard this satellite-based observatory was tuned to detect gamma rays of roughly 0.51 MeV and pointed at the center of the Milky Way. Earlier observations had suggested that there might be particularly interesting gamma ray sources in this energy range. And, indeed, a plume of such sources was recorded protruding at a right angle from one side of the center of the galaxy. Since 0.51 MeV is the energy of each of two gamma rays produced by the annihilation of an electron-positron pair, it was concluded that a plume of positrons is being emitted asymmetrically from the center of the Milky Way. No theoretical explanation for the existence of such a source of positrons was then known.

Van Fraassen also characterizes phenomena as what we use theories to explain (97–101). In ordinary scientific discourse, astronomers would say that, in detecting the plume of positrons being ejected from the center of

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the Milky Way, they had discovered a new phenomenon for which they had no current theoretical explanation. They might also say that this phenomenon first appeared in the images produced by the Compton Observatory. But the primary object of their theoretical investigations is to explain the plume of positrons, not merely the phenomenon appearing on their computer monitors.

Describing the not humanly observable plume of positrons as a phenomenon to be explained is well justified by scientific practice. The existence of electron-positron annihilation is, historically, a theoretically and experimentally well-established physical phenomenon. As van Fraassen would say, it is part of historically 'stable' physics (122). That such annihilation produces a pair of 0.51 MeV gamma rays is also accepted physical knowledge. So the inference that what is ultimately producing the appearance on their computer screens is gamma rays from electron-positron annihilation is well justified. How the positrons are being produced is a question to be investigated, and any proposed theory of stellar formation in the center of galaxies, and so on, will have to provide an explanation of this process. Of course there must also be an account of how the images are produced, but that is more a matter of engineering and computer science than theoretical physics. It requires models of the experiment in addition to models of the fundamental physical processes. In van Fraassen's picture, by contrast, explaining the images, which for him are the observable phenomena, is the goal of theory.

This is not a mere verbal dispute over the use of the word 'phenomenon'. The above example suggests that it is more representative of contemporary scientific practice to think of science as indeed discovering new phenomena, but describing those phenomena in an ever expanding theoretical vocabulary rather than confining descriptions to the realm of the 'truly humanly observable'. Even here, however, van Fraassen does have a reply, though in the context of ordinary rather than scientific language: "In any ordinary way of speaking in is *not* correct to say that we have the *experience of seeing a* . . . paramecium image. In ordinary language the correct report is that we have the experience of seeing a . . . paramecium. As long as ordinary discourse is not filtered through some theory it does not imply that those are objects" (110). But scientific discourse, one would think, is rightly 'filtered through some theory'. So the implication that 'those are objects' should be legitimate.

Van Fraassen's insistence that science is responsible only to what is humanly observable has been the most criticized aspect of his philosophy of science since *The Scientific Image*. His continuing commitment to empiricism comes out clearly when he writes: "If appearances are what appear to us, then, by definition, we never do see beyond the appearances . . . ! This insight, clear enough in Locke and Berkeley, . . . could be

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the slogan for our entire discussion" (99). And remember, appearances, for van Fraassen, are appearances of phenomena. Locke and Berkeley, of course, were sensationalists. For them appearances were of internal, mental entities. Van Fraassen will have no truck with such things. His appearances are public. Nevertheless, they function very much like sense-data. Sense-data are ontologically homogeneous. They have no depth. So they provide a stable epistemological base for all empirical claims. The realm of humanly observable things is not so homogeneous, including as it does everything from a grain of sand to the sun. But it is still a relatively stable base. Ironically, computer technology has turned van Fraassen's scientific phenomena, which now consist mostly of two dimensional computer images, into public analogs of sense data.

At one point he concedes that one might draw a line, for example, at the outputs of electron microscopes rather than optical microscopes. "*The empiricist point is not lost if the line is drawn in a somewhat different way* from the way I draw it. The point would be lost only if no such line drawing was to be considered relevant to our understanding of science" (110). And this point is generalized. In response to the physicist Steven Weinberg's distinction between the 'hard' and 'soft' parts of scientific theories, van Fraassen issues the challenge: "*If you are going to distinguish between a hard and a soft part of science, in some such way, tell us how you draw the line*" (111). The response of a moderate realist such as myself is that no such line drawing is relevant to our understanding of science. My question now is whether van Fraassen has a deeper motivation, beyond a general commitment to empiricism, for drawing a line and for drawing it where he does.

4. Empiricist Structuralism. If there is to be a line drawn for van Fraassen's phenomena, what is on the other side? Structure. Structuralism in the philosophy of science is the view that our theoretical knowledge is knowledge of structure only. Van Fraassen presents his empiricist version of structuralism in two theses:

1. Science represents the empirical phenomena as embeddable in certain *abstract structures* (theoretical models).
2. Those abstract structures are describable only up to structural isomorphism (238).

This represents a major departure from his earlier views. Assuming a standard reference and truth based semantics, his earlier view was that theoretical claims may or may not be true of things referred to, but science can remain agnostic. So, regarding unobservables, he was a semantic realist but an epistemological agnostic. Having abandoned standard semantics for a usage based view of scientific representation, he is free to

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abandon this view as well. Empiricist structuralism is closer to skepticism than agnosticism. It says we cannot theoretically distinguish, for example, vibrations in a diatomic gas molecule from vibrations in electromagnetic radiation such as visible light. Structurally, both are instances of harmonic motion, and that is as far as our theoretical knowledge can go. This remains a serious (I think fatal) objection for scientific realists who would be structuralists, but it is no problem for an empiricist structuralist.

There does remain a major problem for empiricist structuralism which van Fraassen recognizes and faces head on. As he insists: "theoretical models are abstract structures" and "all abstract structures are mathematical structures" (238). This emphasis on abstract mathematical structures fits with his endorsement of "the mathematization of the world picture" which he sees as having culminated in the twentieth century (237). The problem, as he himself presents it, is this: "*How can an abstract entity, such as a mathematical structure, represent something that is not abstract,* something in nature?" (240).

Now, van Fraassen had already dealt at length with a version of this problem earlier in the book under the title 'The Problem of Coordination': "A theory would remain a piece of pure mathematics and not an empirical theory at all if its terms were not linked to measurement procedures. But what is this linkage?" (115). On van Fraassen's telling, Reichenbach set himself the problem of identifying coordinating definitions for length and time "without the use of geometric or kinematic terms" (119). But, asks van Fraassen, "how can such coordinating definitions be meaningfully introduced except in a historical context where there are some prior coordinations already in place? I submit that they cannot" (121). According to van Fraassen, we have no problem understanding what is measured from two perspectives: "from within" the historical process in which measurement procedures are created, and "from above," when there is a stable theory that deals with the measured property (122). In general: "The rules or principles of coordination that can be introduced to define particular sorts of measurement cannot even be formulated *except in a context* where some forms of measurement are already accepted and in place. . . . *There is no presuppositionless* starting point for coordination" (137).

The solution to what might be called "the empirical representation problem for empiricist structuralism" follows similar lines. In his own words: "The *theory to phenomena relation* . . . is an embedding of one mathematical structure in another. For the data model—or more accurately, the surface model—which represents the appearances, is itself a mathematical model" (252). But, "*There is nothing in an abstract structure* ***itself*** *that can determine that it is the* ***relevant*** *data model, to be matched by the theory"* (253). Nevertheless, "A particular data model is relevant because it was constructed on the basis of results gathered in a certain

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way, selected by specific criteria of relevance, on certain occasions, in a practical experimental or observational setting, designed for that purpose" (253). In other words, "the phenomenon, what it is like taken by itself, does not determine which structures are data models for it—that depends on our selective attention to the phenomenon, and our decisions in attending to certain aspects, to represent them in certain ways and to a certain extent" (254). This is indeed, as he describes it, a "sea change" in our thinking about structuralism, inspired by the move to a usage based understanding of scientific representation (254).

My question now is this. Once we have adopted an agent based account of representation, why do we ever need to pass from the physical to the purely mathematical? And in particular, why do we need to make this transition just at the point where we might go beyond the realm of the 'truly humanly observable'? Returning to my earlier example, why cannot our practices be rich enough that we can meaningfully report appearances on a computer monitor as revealing a plume of positrons being ejected from the center of the Milky Way?

To go beyond these rhetorical questions, consider a very simple example of van Fraassen's invoked for a slightly different purpose, a table top. The table top, he says, "*is metrically isomorphic to a Euclidian square*" (249). But that cannot be. No real table has perfectly straight sides or perfect right angle corners. Since the edges are not perfectly sharp, it would require a judgment just where to begin and end a measurement of its width, which would likely not be the same in both directions. What we should say, I think, is that the table top is metrically *similar to* a Euclidian square. Its area is roughly the square of the (average?) length of a side. So we are never dealing with an abstract, mathematical object. Or, to put it in old-fashioned linguistic terms, we never get to an uninterpreted claim about the table. It is always the edge of a table, not the edge of a Euclidian square, with which we are concerned. The language of science is throughout an interpreted language. Or is it? Enter quantum mechanics, stage left.

5. "The Quantum Mechanics Challenge" (297). The suggestion that the language of science is thoroughly physically interpreted is a realist suggestion. It implies that there is no fundamental divide between what is humanly observable and what is not. For contemporary humans, positrons are ontologically (though not epistemologically) on a par with planets. This is not metaphysics, but a realism in practice. "Remember after all that we are not discussing criteria for God's creation, nor for the structure of reality! Our concern is with completeness criteria *for the sciences* in practice, which evolve within the resources humanly available" (297). The completeness criterion in question here is what van Fraassen

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calls "The Appearance from Reality Criterion," roughly, science "*must explain how . . . appearances are produced in reality*" (281). Noting that this completeness condition has been honored since the scientific revolution, he argues that it has now been rejected in scientific practice, that is, practice which includes quantum mechanics.

This is one place the argument of the book becomes a bit technical for those who are not philosophers of physics, but the import is clear. The requirement is that scientific theories explain, in theoretical terms, how particular appearances are produced. For quantum theory, it is not just that what is predicted are probability distributions over a range of possible outcomes. That in itself is not an obstacle for satisfying a liberalized version of the criterion. The question is, "*Does this scientific theory specify, explicitly or implicitly, a process, whether deterministic or stochastic, by which this appearance is produced?*" (299). The answer is No. A theoretical description of any quantum measurement process "does not seem to provide a place for the specific outcome in question" (300). The criterion cannot be fulfilled.

So, in the end, it seems, van Fraassen's insistence on the centrality of the humanly observable and the purely mathematical nature of theoretical structures stems from his conviction that this is how things are in fundamental physics, that is, quantum theory. There are echoes here of Niels Bohr's view that the language of experiments involving quantum phenomena is a classical language, a language of middle-sized objects. And, indeed, van Fraassen's own empiricist interpretation of quantum mechanics has a Bohrian flavor.

Taking quantum theory as a touchstone for the philosophy of science is not an idiosyncratic position. In the first part of the twentieth century, Hans Reichenbach championed the view that the philosophy of science must reflect the major new developments in the physics of that time, especially quantum mechanics. Van Fraassen, Reichenbach's intellectual heir via Carl Hempel and Adolf Grunbaum, endorses this sentiment, saying that "our view of science must be forever modified in the light of this historical episode" (291). We must "appreciate the new key in which the sciences are now composed" (291). Once the appearance from reality criterion has been rejected, "we have the freedom to follow the contemporary abstract structural forms now prevalent in the advanced sciences without the unbearable constraint to satisfy a 'realist' imagination" (267).

There is a threat of irony here. Having argued that the practice of quantum theory shows that the appearance from reality criterion is not a universal constraint on scientific practice, van Fraassen seems to advocate this rejection as itself a universal condition for all of science. His philosophy of science is unrestrained. It is a philosophy of science (or a philosophy of physics?) for all of the sciences. Consider, however, some

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other major contemporary sciences such as evolutionary biology, molecular genetics, or neuroscience. In these sciences, the search for mechanisms behind the behavior of systems is the order of the day. One would be hard pressed to convince neuroscientists that all they really know about neurotransmitters is their mathematical structure, linked by means of the likewise abstract structure of observable phenomena to measurement outcomes (appearances). Indeed, the same would be true of physicists' claims regarding their knowledge of electron/positron annihilation.

Perhaps what is needed is a dose of pluralism in the philosophy of science. So the philosophy of evolutionary theory need not look like the philosophy of quantum mechanics. Of course there would be similarities, the role of some kinds of models being a prime candidate. In reply, it might be argued that, since quantum mechanics is the most fundamental science, dealing as it does with the most fundamental bits of matter, a philosophy of science built around quantum mechanics is fundamental. There is no hint of such reductionist ideas in van Fraassen's text, but it would not be surprising if it were in the background of his thinking.

6. Conclusion. Even at this considerable length, there are many noteworthy points in this powerful and subtle book that have gone unremarked in this review. I doubt that, over the next decade, many such will remain so.

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