Bas C. van Fraassen, *Scientific Representation: Paradoxes of Perspective*, Oxford University Press, 2008.

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The main purpose of this book is to articulate and defend a structuralist approach to contemporary science which is acceptable to an empiricist. van Fraassen's notion of empiricism allows some dissent from the specifics of his own constructive empiricism which insists that the aim of science is empirical adequacy (p. 3).[1] At the heart of van Fraassen's account of structuralism is a view of how scientific representation works. He argues that many versions of structuralism fail because they ignore some of the central aspects of representation in general and so develop a mistaken view of how scientific representation works. For van Fraassen the fact that measurements are themselves representations is crucial to how some scientific theories are given a special role shaping our beliefs and actions. After clarifying what an empiricist structuralism might be, van Fraassen offers a concluding argument against a more ambitious demand for a certain sort of completeness for our scientific theories. Carefully grounded in the relevant history and philosophy of science, and written in an engaging and accessible style, *Scientific Representation* is a major contribution to the topics of representation, measurement and structuralism in the philosophy of science. After outlining van Fraassen's main arguments, I will sound two notes of concern about van Fraassen's proposals.

A central stepping-stone for van Fraassen's own empiricist structuralism is the Bildtheorie or "picture theory" of science associated with Hertz and Boltzmann. The picture theory insists that a scientific theory delivers only pictures of its domain, and that the adequacy of the theory requires only a limited kind of resemblance. In Hertz' formulation, "the necessary consequences of the pictures in thought are always the pictures of the necessary consequences in nature of the things pictured … [and] it is not necessary that they should be in conformity with the things in any other respect whatever" (given at p. 196). To clarify what this might come to Part I of van Fraassen's book considers how representation works in domains like painting and uses this understanding of representation to develop his own proposal for scientific representation. Representation is analysed as a four-place relation: "Z uses X to depict Y as F" (p. 21). In science X is the model, which is a mathematical entity or some concrete entity like a scale model. The model by itself does not represent until some use relates the model to its target Y. But for the use to deliver a genuine scientific representation, the manner in which Y is depicted by X must be pinned down. This is a non-trivial task as both the model and the target have any number of features which might be deemed relevant to the accuracy of the representation. van Fraassen argues that a major feature of how F is fixed in science is the inevitable presence of some level of distortion. This is because the accurate depiction of Y as F seems to systematically require that X be used to inaccurately depict Y in some other respects. One example which van Fraassen develops involves scale models like the scale model of a propeller for a ship (pp. 55-56). Here, as with scientific representation more generally, "useful scaling trades not just on the obvious resemblances in shape but on distortion, both resemblance and non-resemblance being selective in a way dictated by the purpose at hand" (p.

[1] All references are to the book under review.

49). Simply building a geometrically similar but smaller ship will not allow one to accurately represent, for example, the thrust generated as the large ship moves through water. This is because features of the water like its density and viscosity affect smaller propellers differently. Some of these differences can be accounted for by distorting the geometric shape of the scale model or even replacing water with some other fluid.

van Fraassen is equally interested in what agents must be able to do to use a representation. He makes the strong claim that use requires a certain kind of action on the part of the agent. To effectively use a map, one must be able to find where one is on the map. A similar point holds for scientific models: "before we can go on to use that model, to make predictions and build bridges, we must locate ourselves with respect to that model. So apparently we need to have something *in addition* to what science has given us here" (p. 83). This does not deprive the model or science more generally of its objectivity, for van Fraassen insists that an objective description of all the facts can include the claim that an agent is able to use these representations: "It is just that *describing the having of it* is no substitute for *the having*!" (p. 83). What this seems to mean is that having the ability to locate oneself is necessary for the use of scientific representations, but that this ability is not identical to any description which is part of the representations themselves. Similarly, van Fraassen argues, understanding an inscription requires taking the inscription to be written in one of the languages which I am familiar with. The action of taking the inscriptions this way is not identical to any claim expressed in a language I am familiar with.

Part II concerns how measurement relates to the general picture of scientific representation developed in Part I. The problem is approached in terms of the "problem of coordination" which confronted Mach, Schlick and Reichenbach. Reichenbach posed the problem in an especially extreme way as he sought to relate the abstractly given parameters of a physical theory to some measurements without taking for granted any other coordinations. This mistaken "view from nowhere" leads to "an impossible problem" (p. 122). The correct approach is to, as with Mach, recognize that all coordination problems take place within a context where we have already related our abstract theory to some physical magnitudes. One such context is the practice of doing science "*where there were already measuring procedures* for certain other physical magnitudes *taken as given*" (p. 122). Another context is when we look back and consider "*in retrospect*, from within a theory that is already stable and established" (p. 122) how a given coordination problem was solved. Either way, an appreciation of the context where certain things are taken for granted makes the situation amenable to scientific treatment. We can say what the physical correlate of a given measurement procedure is, for example, and distinguish this physical correlate from the "appearance" which is delivered by the measurement, thought of as the content of a representation of some phenomenon. These measurements give rise to both data models and what van Fraassen calls surface models. A surface model moves beyond the relative frequencies provided by a data model by providing "a continuous range of values" (p. 167). By moving to the surface model we find a representation which in the best case scenario can be embedded into a theoretical model, i.e. a model which presents a solution to the equations of the theory (p. 310).

Part III, "Structure and Perspective", considers what implications these lessons about representation and measurement have for structuralism. Following the Bildtheorie's lead, van Fraassen takes structuralism to be a claim about what science represents and so it is not primarily a claim about what we can know, as with epistemic structural realism, or what exists, as with ontic structural realism. The central challenge which structuralism faces is tied to the role of mathematical structures in the theoretical models of our best sciences. Given that "in mathematics no distinction cuts across structural sameness" (p. 208), i.e. isomorphism, how do our theoretical models represent anything beyond mathematics? Or, as van Fraassen puts it later in Part III, "*How can an abstract entity, such as a mathematical structure, represent something that is not abstract*, something in nature?" (p. 240). Simply embedding one mathematical structure in another does not take us outside the domain of pure mathematics. So, the empirical content of our scientific theories is at risk if we approach representation in purely structural terms.

This problem for structuralism is traced through the Bildtheorie controversy and the writings of Russell, Carnap, Weyl, Putnam and David Lewis. van Fraassen is highly critical of the solutions which he finds in Russell, Carnap, Weyl and Lewis for each of them resorted either to some form of illegitimate appeal to subjective experience or to some extravagant metaphysics. For example, in *Analysis of Matter* Russell insists that our knowledge of the physical world is restricted to "what can be expressed by mathematical logic" (given at p. 219). Newman pointed out that this makes our scientific theories more or less trivial as, subject only to some constraints on cardinality, any structural description will be satisfied. Russell's response was to insist that some relations from our experience provide further constraints on the structural description, but van Fraassen complains that Russell's choice requires a dramatic reorganization of science in terms of these relations (p. 223). Even worse, Lewis' metaphysical restriction to "natural" relations is "almost empty" as it not clear how to make "natural" "independently meaningful" (p. 232).

Given the lessons of Part I and Part II it is not surprising that van Fraassen aims to overcome these problems by an appeal to use, context and indexical judgment. At some point in our presentation of our scientific findings we may be charged with ignoring a gap between a mathematical structure and something that is not mathematical. For example, our data model is about some phenomenon like the deer population growth in Princeton (p. 256), "but how does the last structure taken into account relate to what is meant to be the target of all this representing?" (p. 257). van Fraassen's reply is that "at this last step we come to what can only be expressed in indexical judgments" (p. 257). The indexical judgment in this case is that the data model is "adequate to the phenomena as represented, i.e., *as represented by us*" (p. 259). Once we have checked all the relevant ways in which our data model was constructed and addressed all reasonable objections to this scientific procedure, this indexical judgment of adequacy is pragmatically equivalent to the simple claim that the model is adequate to the phenomena. By this van Fraassen means that no agent who asserts one can deny the other. So, on the basis of our situation and our abilities, we are able to relate the data model to the phenomenon. For van Fraassen there is no further story to tell. Science can describe this situation and these abilities, but these descriptions are not identical to being in that situation and having those abilities. These contextual aspects of representation are essential, then, if a viable structuralism is to be defended.

Part IV of the book develops one of the implications of empiricist structuralism and defends it against one sort of objection. As van Fraassen uses the term, "appearances" are the contents of representations of measurements of observable phenomena. Some would require that "*physics must explain how those appearances are produced in reality*" (p. 281). This is a much stronger condition than merely being empirically adequate for empirical adequacy involves only the right kind of embedding between appearances and the models of the theory. This is possible even when there is no explanation or understanding of how the representations in question are produced by the sorts of interactions described by the theory. van Fraassen grants that this test was met by some theories in the past. For example, a Copernican can "explain by means of geometric optics and projective geometry how the visual appearances (content of outcomes of measurements made by astronomers) are produced by reality" (p. 288). But this sort of explanation is absent from quantum mechanics, at least as it is now practiced by scientists. As a result, we should reject this condition and accept that "For unqualified adequacy of the theory, what is required is that the surface models of phenomena fit properly with or into the theoretical models" (p. 305).

The central unresolved issue with van Fraassen's empiricist structuralism is what his appeal to context in the solution of his "problems of perspective" comes to. I would distinguish the weaker claim that an ability is not the same as a description of that ability (p. 83) from the stronger claim that a given indexical proposition is distinct from all the propositions expressed by any scientific theory: "*Is there something that I could know to be the case, and which is not expressed by a proposition that could be part of some scientific theory?* The answer is YES: something expressed only by an indexical proposition" (p. 261). The stronger point seems to link having an ability to knowing an indexical proposition. But here van Fraassen says that even though what these essentially indexical propositions express is a crucial part of any account of representation, this is outside the scope of any scientific theory. As a result, it is not possible to arrive at a scientific theory of representation. This is much less plausible than the mere distinction between an ability and a description of that ability. The weaker claim allows for the possibility of a fully naturalistic theory of how we can think and locate ourselves with respect to our representations, i.e. the abilities which underlie our knowledge of the relevant indexical propositions. While linguistics and cognitive science are not adequate at this stage of science, it is hard to see why what these indexical propositions express would be beyond their scope. It is possible that van Fraassen takes his discussion in Part IV to undermine the demand for this sort of naturalistic completion of a scientific theory of scientific representation, but if this is his intention, then I have failed to follow the argument. It also possible that van Fraassen did not intend to exclude these indexical propositions from the scope of scientific investigation, but then he owes us a clearer account of how our abilities relate to our knowledge of indexical propositions.

A second point of concern is van Fraassen's cavalier attitude towards mathematics and its proper interpretation. One would have thought that a book focused on the key role of mathematical structures in scientific representation would have something to say about what mathematical structures are, or at least a discussion of why the issue is tangential to the aims of the book. Instead, we find remarks like "the statement that there were at time t 500 bacteria in this colony implies the existence of nothing at all beyond the bacteria and the colony" (p. 248). But one who asserts such a statement is also apparently committed to the existence of the number 500. van Fraassen also says "no solutions to a given equation are historically found or constructed for a very long time … though *mathematically* *speaking*, they exist all along" (p. 310, ellipsis in original). Where does the apparent platonism of this claim fit into van Fraassen's empiricism? Perhaps a more determined focus on mathematics and what it brings to scientific representation would offer other alternatives for developing a form of structuralism which has a place for contemporary science and its achievements.