

SCIENTIFIC REPRESENTATION AND NOMINALISM: AN EMPIRICIST VIEW

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Abstract

Can a constructive empiricist make sense of scientific representation? Usually, a scientific model is an abstract entity (e.g., formulated in set theory), and scientific representation is conceptualized as an intentional relation between scientific models and certain aspects of the world. On this conception, since both the models and the representation relation are abstract, a constructive empiricist, who is not committed to the existence of abstract entities, would be unable to invoke these notions to make sense of scientific representation. In this paper, instead of understanding representation as a relation between abstract entities, I focus on the activity of representing, and argue that it provides a way of making sense of representation within the boundaries of empiricism. The activity of representing doesn't deal with abstract entities, but with concrete ones, such as inscriptions, templates, and blueprints. In the end, by examining the practice of representing, rather than an artificially reified product—the representation—the constructive empiricist has the resources to make sense of scientific representation in empiricist terms.

1. Introduction

Constructive empiricists understand scientific practice in terms of the construction of models (van Fraassen 1980). These models represent certain aspects of the world. But how should such models be understood, and how should the notion of representation be characterized? Usually, scientific models are taken to be abstract entities (typically, formulated in set theory), and scientific representation is then understood as a particular (intentional) relation between such models and certain aspects of the world (which, in turn, are also expressed in set-theoretic terms). Since, on this construal, both the models and the representation relation are abstract, a constructive empiricist, who is not committed to the existence of such abstract entities, is unable to invoke these notions to make sense of scientific representation.

In this paper, instead of understanding representation as a certain relation between abstract entities, I focus on the activity of representing, and argue that it

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provides a way of accommodating the notion of (scientific) representation within the boundaries of empiricism. Central to this proposal is sensitivity to the practice of producing and interpreting images, common to both science and the arts. The activity of representing doesn't deal with abstract entities, but with concrete ones, such as inscriptions, templates, and blueprints. It's also guided by coding conventions that shape both the construction and the interpretation of the resulting images—again, a common element to both science and the arts (see van Fraassen 2002, and Sigman and van Fraassen 1993). In the end, by examining the practice of representing, rather than an artificially reified product—the representation—the constructive empiricist has the resources to make sense of scientific representation in empiricist terms.

2. A framework for scientific representation: the activity of representing

The first task consists in developing a framework to examine the notion of representation and the activity of representing. Broadly understood, representation involves three central components: (i) Representation is an *intentional act* relating two objects: the *source* (a certain object or event that is used to represent something) and the *target* (a given object or event that is represented). (ii) Representation also involves a *coding convention*—a certain group of rules that specify what counts as the right *similarity relation* between the source and the target. (iii) Finally, a *mechanism of representation* is also involved. This mechanism establishes how the target is represented: e.g. the target is represented *as* such and such; it also establishes that the target is represented *in virtue of* such and such features of the source. Consider, for instance, the case in which a given model (e.g., a particular graph) is used to represent certain phenomena (say, the average growth of breastfed children). In this case, the source is the graph; the target is the average growth of the children in question; the coding convention indicates that an increase (or a decrease) in the slope of the curve in the graph corresponds to an increase (or a decrease) in the average growth of the children. Suppose now that a continuous line characterizes the graph in question. The children's growth, in this case, is represented *as* continuous *in virtue of* the continuity of the line in the graph.

Bas van Fraassen and Jill Sigman have elegantly presented these features of representation by offering a basic format for representation:

Representation of an object involves producing *another object* which is

intentionally related to the first by a certain *coding convention* which determines what counts as *similar* in the *right way*. (van Fraassen and Sigman 1993, p. 74; italics added.)

As the passage makes it clear, representation is understood as an inherently intentional act that relies crucially on coding conventions to specify in which respects the target and the source are similar. This proposal offers a broad account of representation, independently of the context in which the notion happens to be used.

When we consider the notion of *scientific* representation, however, two additional features need to be taken into account.¹ (a) First, it's important to emphasize that scientific representation is always *perspectival*; it emerges from, and presupposes, a given perspective. That is, a scientific representation is always established from a certain point of view—highlighting a certain standpoint. When we represent a physical system as a Newtonian system, we emphasize certain components of the system; we are adopting a certain perspective in terms of which the system is represented. The representation is informed by the conceptual resources of Newtonian physics, being in general silent about those components that are not identified as relevant from the vantage point of the Newtonian framework. For example, the representation is likely to emphasize features such as the mass, velocity, and acceleration of the objects under study, not saying much (if anything at all) about their color or smell.

However, we need more than the perspective from which the system is represented. We also need to locate ourselves in the model that is used to represent the system. In other words, scientific representation depends on an *indexical feature*. Just as to use a map, we need to identify ourselves with respect to the map, to use a model we also need to identify ourselves with respect to the model. We need to locate ourselves and the situation we are currently experiencing with respect to the resources of the model. As van Fraassen notes:

To use a theory or model, to base predictions on it, we have to locate ourselves with respect to it. We have to be able to say, for example, that the phenomenon *we are presently witnessing* is classified in the theory as oxidizing, or as phlogiston escape, or the like. We have to locate our situation in the theory's logical space, in a way that is similar to our "We are here" with respect to a map. (van Fraassen 2006, p. 31)

In other words, in order to extract the information that the map displays, we need to locate ourselves with respect to the map. This step is crucial: it's only relative to that location that the information provided in the map can be used.

In a similar way, to be able to use a theory or model, we need to locate ourselves with respect to such items. By identifying the phenomenon that we are currently experiencing as something that the theory classifies as such and such, we are then able to use the information provided by the theory to describe the phenomenon. This is an indexical component—where we are with respect to the model—and this component highlights a pragmatic point regarding the use of the model in question.

(b) Second, it's also important to emphasize that scientific representation typically involves *interpretation* (van Fraassen and Sigman 1993). To represent a certain phenomenon *as* such and such, we need to interpret the phenomenon in a certain way—we need to understand and conceptualize it suitably. Given the perspectival nature of scientific representation, interpretation will always be involved. After all, the ability to make sense of the phenomena in terms of the conceptual resources of a theory or model is required. It's in light of the theory that the representation is ultimately established. But in order to do that, the phenomenon needs to be interpreted according to the theory. When Galileo refused to represent the fall of bodies in purely qualitative, Aristotelian terms, and adopted instead a mathematical description of their fall, he changed the interpretation of the phenomena. By shifting the interpretation, Galileo also modified the representation. Falling bodies were represented as satisfying certain mathematical regularities—in terms of a very different framework from the one adopted by the Aristotelians.

So far, I have described representation in general, and scientific representation in particular, as a certain product: an entity that emerges from taking intentionally a certain object as standing for another in a certain way. This way of speaking, however, can be misleading. It invites us to reify the notion of representation. It invites us to think of representation as a certain object. But reification—particularly of abstract entities—is something that empiricists work very hard at avoiding. But can that be avoided here?

I think it can. Consider representation as a derivative notion: representation is what emerges from a certain activity—the activity of representing. What is involved in that activity? The activity involves intentional acts, acts of taking something to stand for something else, given (i) a certain way of conceptualizing the objects in question (a particular interpretation), and (ii) certain coding conventions (that determine the respects in which the objects in question are similar).

If we read carefully the quotation above from van Fraassen and Sigman 1993 on the format for representation, we see that it already indicates that what mat-

ters is the activity of representing. Note how the emphasis lies in the ability of *producing* something intentionally: “Representation of an object”, van Fraassen and Sigman point out, “involves *producing another object* which is intentionally related to the first by a certain coding convention” (1993, p. 74; italics added). What is central here is not an object—the representation—but a certain intentional activity of taking something to stand for something else—the representing. Ultimately, the latter gets the work done rather than the former. And as will become clear shortly, the same emphasis on representing is found when we consider representation in scientific practice.

It might be objected that despite the emphasis on the activity of representing, the empiricist still will be in trouble. After all, some of the objects involved in the activity of representing—e.g. the models that are used in representing the phenomena—are abstract. And being committed to the existence of such abstract entities is something the empiricist is not prepared to do.

Two moves are involved in response. (i) First, when we emphasize that representing is an activity, we emphasize the fact that representing is something *we do*. Clearly, we have no causal access to abstract entities—such entities are not even located in space-time. As a result, it’s unclear how we can invoke such entities in representing, given that we need to exhibit the *source* of representation, the objects (theories or models) in terms of which the representing is implemented. It’s precisely to address this difficulty that representing is understood here as an *activity*. What is exhibited, as the source in representing, is *not* an abstract object. We could never *exhibit* an abstract object, since we can only exhibit things in space-time. Rather, we exhibit *concrete* entities (drawings, blueprints, templates) as the source. These are things we have access to, and thus are able to use as the source in representing. Whether these concrete entities correspond to abstract objects or not is not relevant for representing. We need entities we can *exhibit* in order to implement the representing—which, thus, excludes abstract objects. By focusing on the activity of representing, it becomes clear that all the empiricist needs to accommodate the notion of scientific representation are *concrete* entities.

But perhaps for some representational purposes, not only the source, but also the *content* of the source, becomes relevant. For example, even though we can draw a graph on a piece of paper, and use that drawing as the source of representing, questions may arise as to why a continuous rather than a discrete function was used in the graph. We are now talking about the function that the graph stands for. And when we do that, we cannot reduce that talk to concrete entities. To address this difficulty, a second move is needed.

(ii) The move consists in noting that the empiricist can talk about things she has no reason to believe exist—as all of us do regularly, when we talk about witches, average moms, Newtonian forces, or fictional characters. More than that, the empiricist, just as anyone of us, can quantify over entities she has no reason to believe exist. When Quine (1953) identified the range of bound variables with what exists, he was assigning—and conflating—two very different functions to the existential quantifier. One is the function of indicating that the objects we quantify over with the existential quantifier need not cover the whole domain of discourse, but only some part of it;² the other is the function of indicating that the objects in question do exist (see McGinn 2000 and Azzouni 1997 and 2004). These are very different functions, which are better kept apart.

To distinguish explicitly these two functions, we should use the existential quantifier to indicate only the partial scope that our quantification takes. We then introduce an existence predicate in the language to indicate that the objects talked about do exist. Otherwise, with the Quinean conflation, sentences such as the following come out as contradictory:

(*) Some fictional detectives do not exist.

But, clearly, there is no contradiction here. We are only saying that some fictional objects do not exist. And by distinguishing *quantifier commitment* (the commitment we incur by quantifying over certain objects) and *ontological commitment* (the commitment to the existence of certain entities), (*) can be easily expressed as:

(**) $\exists x(Fx \wedge \neg Ex)$,

where 'E' is the existence predicate, and 'F' stands for the predicate *fictional detective* (see Azzouni 2004). We are now able to express exactly what is needed.

With this distinction in place, the empiricist can talk about the content of sources of representing even when that involves reference to abstract objects. After all, just by talking about abstract objects—such as models, theories, or mathematical entities—or by quantifying over them, the empiricist is not thereby committed to their existence. An additional criterion for existence needs to be met.

Which conditions should the existence predicate satisfy? Of course, this is a large and complex issue, the details of which go well beyond the scope of this paper. For my purposes here, it's enough to provide *sufficient* conditions for us to determine whether certain objects exist. Suppose that we have a *robust* form of

access to some objects (we blink, we move away, and the objects are still there); suppose that we can also *track* these objects (in space and time), and that we can *refine our access* to these objects (say, by getting closer for a better look).³ In this case, there will be typically no controversy about the existence of these objects. In fact, both realists and empiricists can easily agree with *these* sufficient conditions. Some realists may include additional sufficient conditions, such as the theoretical usefulness of positing certain entities. But at this point, the empiricist will part company, and will be agnostic about the existence of things that don't seem to meet the conditions above.

As will become clear, with this framework in place, the empiricist has the resources to make sense of the notion of scientific representation without overstepping the boundaries of empiricism. I'll explore now how the activity of representing plays a significant role in scientific practice, and how the framework above can be used to understand certain aspects of that practice. To make the discussion more concrete, I'll examine a particular, but significant, case of representing: representing via imaging in microscopy.

3. Representing in scientific practice

A sophisticated way of representing certain objects in scientific practice is provided by microscopy. By enhancing selected features of a sample, the microscope allows researchers to study components of that sample that otherwise would not be directly accessible to them. A significant part of the work is to distinguish artifacts of the instrument from genuine features of the sample. Various strategies are employed to this effect: from the use of different methods of sample preparation to the triangulation of the results obtained by a given microscope with other instruments (see, e.g., Hacking 1983).⁴

Once the outcomes of a microscope are obtained, they can be taken to represent the features of the sample that were selected for study. However, whether the representation is *accurate* is an additional issue. For even if the microscope is working properly, it's still possible that, unbeknown to the researchers, it fails to represent some aspects of the sample, or even misrepresents some of them in subtle ways.

As an illustration, I'll consider briefly two cases of representing in microscopy. I'll first examine the use of the transmission electron microscope (TEM) in the identification of ribosomes by George Palade. I'll then discuss the use of the atomic force microscope (AFM) in the identification of surface reconstruction in protein crystals. Both are typical cases of the use of the corresponding micro-

scopes and both involve, as will emerge shortly, significant aspects of representing.

In 1955, George Palade published a paper with the rather cryptic title: “A Small Particulate Component of the Cytoplasm” (Palade 1955). In this paper, Palade describes the new structure he identified at the cytoplasm by a careful and thorough use of the transmission electron microscope (TEM). At this point in the 1950s, the use of TEMs was already well established in biology, and the success of this instrument was, in part, supported by decades of systematic and effective use of optical microscopes in many areas of biology. Despite this success, Palade was very careful in determining what exactly were those “small particulate components” he identified in a number of his micrographs. He first carefully excluded the possibility that they were just artifacts of the method of preparation, by changing the method and determining whether the “small components” were still detected (they were). He then conducted additional research by using a centrifuge, and determined that there were indeed components with different densities in the sample. All of these results strongly supported the conclusion that the “components” were indeed genuine (Palade 1955).

Palade also conjectured in the paper that the “components” were largely composed by ribonucleic acid, but he noted, additional chemical analysis was still needed to determine that. A few years later, the analysis did confirm Palade’s conjecture, and the “particulate components” were called “ribosomes”.

When we consider the micrographs that Palade produced with his TEM, the presence of all those small particles at the cell’s membranes is indeed remarkable. And it was largely based on the TEM images that Palade produced that the biological community very quickly accepted his results.

Do Palade’s micrographs represent ribosomes? Clearly, Palade didn’t simply make up the particular results he obtained with the TEM. He didn’t create the microscopic images out of his own whim. Once the cell sample was suitably prepared,⁵ and the instrument was applied to the sample, which micrograph Palade obtained was not up to him. This independence of the results from Palade’s intentions supports the objectivity of the TEM. In this sense, the micrograph *doesn’t* provide a representation of the ribosome, since there is no particular *intentional* relation involved. However, once the reliability of the TEM is established, *we* can use the micrograph as a representation of ribosomes, since we can take the small particles near the membranes of the cell in the micrograph to stand for the ribosomes. We might be mistaken, of course, in making such identification. And if this turns out to be the case, we can say that a misrepresentation was involved.

In terms of the framework for representation discussed above, a micrograph

can be used as a representing device, where the targets are the ribosomes, and the sources are the corresponding “small particulate components” on the micrograph. There is an indexical feature in the representing process, since in order to interpret the micrograph we need to locate ourselves with respect to it. We need to locate ourselves in relation to the “small particulate components” on the micrograph, so that we are able to identify them, and determine what they stand for. We need to have some evidence to the effect that the “small particulate components” that we are currently experiencing on the micrograph are not just some artifact of the preparation method, but do stand for some significant component of the cell structure. The evidence is unlikely to be conclusive, but if it’s strong enough, it will end up supporting the adequacy of the representation. In this way, the micrograph can be interpreted as representing a novel cellular component—the ribosome. And it’s in virtue of the features that support the adequacy of the representation that we are entitled to take the ribosome as a new component in the cell structure. The mechanism of representation, in this case, involves partial mappings from the micrograph to the sample that preserve the relevant structure—the geometrical configuration, location and distribution of the “small particulate components” on the micrograph (see Bueno 2006).

The TEM is an instrument for the study of the inner structure of the sample. In order to provide a representation of the inner structure of the sample, it may end up damaging the sample’s surface. But if we are interested in studying the surface features of the sample, another type of microscope needs to be used, such as the atomic force microscope (AFM). The central idea of the AFM is that by scanning the surface of the sample, with a tip that is one atom sharp, information about the topography of the sample’s surface can thereby be obtained (Binnig et al. 1986). The movements of the AFM tip are controlled by a cantilever, which gets the tip closer to, or moves it away from, the surface of the sample. The cantilever, in turn, is controlled by a laser beam, which makes the cantilever move up and down. As the tip scans the surface of the sample, it responds to the sample’s topography, and delineates the “contour” of the sample’s surface. And if all goes well, this process will provide information about the geometric configuration of the atoms at the surface of the sample.

The AFM is, of course, a remarkable instrument. Together with the scanning tunneling microscope (STM)—which uses the quantum tunneling effect to establish a “tunneling current” between the tip of the microscope and the sample, thus also obtaining information about the sample’s surface (Binnig and Rohrer 1983)—the AFM is a significant source of information about the surface of various materials in probe microscopy.

In 1999, using the AFM, a group of chemists at the University of Toledo made an important discovery (Li et al. 1999). The group was studying the geometrical configuration of atoms at the surface of protein crystals. They initially obtained information about the samples by a series of repeated measurements of their surfaces using the AFM. The multiple data obtained in this way were then statistically combined to produce an idealized image that offered the average of the various measurements that were made. This image is called the *experimental image*.⁶

Although the resolution of the experimental image is extremely impressive, it's not enough to settle several issues about the geometrical configuration of the atoms at the surface of the sample—in particular, the molecular-packing arrangement. To address this issue, the researchers create a *theoretical image*, in which they introduce (by hand, as it were) their hypotheses about what they take to be the particular atomic configuration at the sample's surface. The two images (the experimental and the theoretical) are then merged together, so that they can be compared. This produces a third, *hybrid image*, containing both the visual information from the experimental image and the hypothetical information from the theoretical image. Once the hybrid image was obtained, it became clear that there was a huge mismatch between the theoretical and the experimental images: the correlation between the two images was 62% (Li et al. 1999). It wasn't strong enough.

The researchers then returned to the theoretical image, and made a novel hypothesis (Li et al. 1999). The phenomenon of surface reconstruction—the difference between the packing arrangement of the surface of the crystal from the arrangement in the crystal interior—was well known in the case of inorganic crystals. The idea is clear: given that the surface molecules have incomplete bonds, and are in contact with the environment, these molecules tend to interact with the latter, thus changing the packing arrangement. However, it was unknown whether that phenomenon was also found in organic crystals—the subject of the investigation by the team. The researchers then changed the theoretical image by incorporating the assumption that surface reconstruction took place. The result was a new theoretical image, which was then compared with the original experimental image, thus obtaining a second hybrid image. The correlation now between the theoretical and the experimental images was 93% (Li et al. 1999)—a much more significant result.

Note how the representing process gets established in this AFM case. First, the target is the particular molecular-packing arrangement at the surface of protein crystals. The source is obtained in stages: from the experimental image,

which provides more reliable, but partial, information about the molecular-packing arrangement, through the theoretical image, which provides more complete, but less reliable, information, to the hybrid image, which provides a combination of the two previous types of images. In each case, the researchers are dealing with *concrete* images, which are perfectly visible—even though they may have been generated by some statistical device. In each case, the researchers need to locate themselves with respect to the image, so that they can extract the relevant information about the molecular-packing arrangement. So, in each case, there is an indexical component in these representations. Moreover, in each case, the representation is established from a certain perspective, providing topographical information from the point of view of the tip of the microscope. And, once again, the mechanism of representation is provided by partial mappings from the various images to the sample that preserve the relevant structure—in particular, the geometrical configuration of the atoms at the sample's surface (Bueno 2006).

Note also that the microscopic images are used as *inferential devices*. Given the poor correlation between the experimental image and the first theoretical image, the researchers drew information from a different domain (that of inorganic crystals) to produce a new theoretical image on the assumption that the phenomenon of surface reconstruction took place. This means that the researchers interpreted the protein crystals *as* going through a surface reconstruction, and made the necessary adjustments to, and drew suitable conclusions from, the theoretical image in light of the new interpretation.

Not surprisingly, microscopic images are often used as exemplars in the domain from which they emerge. They are taken to be typical of a certain group of phenomena, but they are also about a particular kind of sample. These images have both generality and specificity. They are general in that they are supposed to cover a variety of similar types of samples. They are specific in that they represent something particular about the instance of that type. Both features (generality and specificity) emerge from the way these images are constructed, in particular by using statistical techniques in the composition of the experimental data. The generality and specificity of the microscopic images allow researchers to use these images as inferential devices, so that they can generalize the information provided by a particular image to other samples (whether in the same domain or in related ones).

Finally, it's important to note the role played by *coding conventions*. To interpret a microscopic image, it's crucial to be able to identify the coding conventions that are in place—e.g., what do colors, shapes, and brightness in the image stand for? Unless coding conventions are specified, misunderstandings can easily

emerge. It would be a serious mistake to think that if we could shrink ourselves to the size of an atom, and were wandering on the surface of the sample, we would observe exactly the same image as the one produced by the AFM.

4. Representing and nominalism

In the discussion above, it may seem that the empiricist went well beyond empiricism. After all, we were speaking of a variety of unobservable objects: from ribosomes and atoms to mathematical models and statistical devices. But I don't think this happened. As noted above, the empiricist can distinguish quantifier commitment and ontological commitment, and so she can quantify over things without thereby being committed to their existence. This allows the empiricist to follow scientists in their use of statistical techniques and various mathematical models to describe unobservable phenomena, without violating empiricism.

No one can literally see the surface reconstruction of protein crystals at the level represented by an AFM. But the empiricist can still describe the practice of representing that is involved there. The statistical techniques that are used in the construction of the AFM experimental image are devices over which the empiricist quantifies without ontological commitment. And once the relevant images are produced, scientists are dealing with concrete entities—micrographs, blueprints, and templates—whose ontological status poses no problem for the empiricist.⁷

In this way, the practice of representing meshes naturally with the distinction between quantifier and ontological commitment. It's in virtue of the fact that representing ultimately invokes concrete devices, such as micrographs, that we can motivate why there's no need for a commitment to the existence of abstract objects, such as models or structures, to make sense of that practice.

These remarks also highlight an important connection between representation and idealization, in particular the fact that scientific representation often involves idealization. This becomes especially clear in the case of the AFM experimental image, which is idealized in many ways. It doesn't provide complete information about the sample's surface, but only partial information is available. And it doesn't settle the issue of the particular molecular-packing arrangement at the surface of the sample, but only a sketch is provided. In turn, the information offered by the theoretical image, despite being more complete than the one given by the experimental image, is not fully reliable. The theoretical image, then, is also idealized in that the additional information it generates need not correspond to the actual state of the sample. A trade-off is involved.

5. Conclusion

Representation via imaging in microscopy illustrates how an empiricist can make sense of the notion of representation. In the end, there's no need to reify the notion of representation. We should rather understand a certain *activity*: the activity of *representing* a certain class of phenomena by using the outputs of the microscope. The data, images, models, and blueprints that are generated via the microscopes are all *concrete*, even though they may rely on various mathematical devices. But these mathematical devices should not be reified either, since the empiricist can quantify over entities she has no reason to believe that exist. Moreover, mathematical devices (such as statistical techniques) are useful only when interpreted in a physically significant way, so the work of interpretation relies on empirical information.

As we also saw, representation by imaging in microscopy is perspectival. We have to locate ourselves with respect to the images (recall the case of the AFM images). But, when we do that, we need to be careful not to bring inadequate coding conventions and misinterpret the images.

Moreover, representation by microscopic imaging also crucially depends on interpretation, and on ways of making sense of the information provided by the instrument. A change in interpretation may change substantially the content of what is experienced in the images (recall the phenomenon of surface reconstruction using the AFM).

Finally, a mechanism of representation is provided in microscopic imaging by establishing certain *partial mappings* between the image and the sample. The mappings are only *partial* since not everything in the sample is selected for representation in the image, and even the selected items are typically not represented in every detail (there are limits to the resolution of each image).

In this way, by understanding the activity of representing, and resisting the temptation of using a reified notion of representation, the empiricist is able to make sense of scientific representation without leaving the boundaries of empiricism.⁸

References

- Azzouni, J. 1997. Applied Mathematics, Existential Commitment and the Quine-Putnam Indispensability Thesis. *Philosophia Mathematica* 5: 193–209.
- . 2004. *Deflating Existential Consequence: A Case for Nominalism*. New York: Oxford University Press.

- Berg-Hildebrand, A. & Suhm, C. (eds.) 2006. *Bas C. van Fraassen: The Fortunes of Empiricism*. Frankfurt: Ontos Verlag.
- Binnig, G.; Quate, C.; and Gerber, Ch. 1986. Atomic Force Microscope. *Physical Review Letters* **56**: 930–3.
- Binnig, G. & Rohrer, H. 1983. Scanning Tunneling Microscopy. *Surface Science* **126**: 236–44.
- Bueno, O. 2006. Representation at the Nanoscale. *Philosophy of Science* **73**: 617–28.
- Hacking, I. 1983. *Representing and Intervening*. Cambridge: Cambridge University Press.
- Levine, G. (ed.) 1993. *Realism and Representation*. Madison: University of Wisconsin Press.
- Li, H.; Perozzo, M. A.; Konnert, J. H.; Nadarajah, A.; Pusey, M. L. 1999. Determining the Molecular-Packing Arrangements on Protein Crystal Faces by Atomic Force Microscopy. *Acta Crystallographica* **D55**: 1023–35.
- McGinn, C. 2000 *Logical Properties*. Oxford: Clarendon Press.
- Palade, G. 1955. A Small Particulate Component of the Cytoplasm. *Journal of Biophysical and Biochemical Cytology* **1**: 59–79.
- Quine, W. V. 1953. *From a Logical Point of View*. Cambridge, Mass.: Harvard University Press.
- Sigman, J. & van Fraassen, B. 1993. Interpretation in Science and in the Arts. In Levine 1993, pp. 73–99.
- van Fraassen, B. C. 1980. *The Scientific Image*. Oxford: Clarendon Press.
- . 2002. *The Empirical Stance*. New Haven: Yale University Press.
- . 2006. Weyl's Paradox: The Distance Between Structure and Perspective. In Berg-Hildebrand and Suhm 2006, pp. 13–34.
- Wilson, C. 1995. *The Invisible World*. Princeton: Princeton University Press.

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Resumo

É possível a um empirista construtivo interpretar a representação científica? Em geral, um modelo científico é uma entidade abstrata (por exemplo, formulada numa teoria de conjuntos), e a representação científica é concebida como

uma relação intencional entre modelos científicos e determinados aspectos do mundo. Nesse concepção, dado que tanto os modelos como a relação de representação são abstratos, um empirista construtivo, que não se compromete com a existência de entidades abstratas, seria incapaz de empregar tais noções para dar sentido à representação em ciência. Nesse artigo, em vez de compreender representação como uma relação entre entidades abstratas, enfatizo a atividade de representar, e argumento que esta última proporciona uma forma de interpretar representação dentro dos limites do empirismo. A atividade de representar não lida com entidades abstratas, mas com objetos concretos, tais como inscrições, moldes, e esquemas. Ao final, examinando-se a prática de representar em vez de um produto artificialmente reificado — a representação — o empirista construtivo possui os recursos para dar conta da representação científica em termos empiristas.

Palavras-chave

Representação científica, nominalismo, empirismo construtivo, microscopia, imagens científicas, Bas van Fraassen.

Notes

¹ Although these features are also relevant for representation in general, they are particularly significant for scientific representation.

² In contrast, with the universal quantifier, the whole domain of discourse is covered.

³ According to Azzouni, if conditions of this sort are met, we have a *thick epistemic access* to the objects in question (see Azzouni 2004). Being a realist, Azzouni doesn't draw the empiricist conclusions from these conditions that I do.

⁴ Of course, for the empiricist, even after all of this process is concluded, the issue as to whether the unobservable objects that are represented by a microscope exist or not has not quite been settled yet. After all, the criterion of existence still needs to be met.

⁵ And here, as noted, considerable care goes into ensuring that the method of preparation does not generate the results—the latter are invariant under transformations of the preparation method.

⁶ It's interesting to note that, in their construction of the experimental image—which, as we saw, depicts the averages of multiple measurements—the AFM researchers continued a long-standing tradition in microscopy, stemming from Hooke's original presentation of his observations with the optical microscope. Instead of simply reproducing the results of individual observations, Hooke drew images that were meant to capture the average features of the many samples under study (see Wilson 1995). A significant difference in

the practice, from Hooke's work to the use of AFMs, is the introduction of computer software to produce the averages involved in experimental images.

⁷ The empiricist could adopt an alternative, slightly less general, strategy. She could use a constructive logic, and take the mathematical constructions that are invoked in the formulation of the relevant mathematical models to be just idealized, concrete constructions. Since these constructions are no longer taken to be mind independent and abstract, they are within the bounds of empiricism. The significant restriction of this strategy is that there may not be enough mathematical structures to accommodate all that is needed in science. So, this move may be ultimately limited in scope.

⁸ My thanks go to Anjan Chakravartty, Newton da Costa, Steven French, Michel Ghins, Peter Luykx, and Bas van Fraassen for helpful discussions.