A Journal for the History and Philosophy of Science
Spontaneous Generations

Truth-bearers or Truth-makers?

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Source: *Spontaneous Generations: A Journal for the History and Philosophy of Science*, Vol. 6, No. 1 (2012) 142-147.

Published by: The University of Toronto
DOI: 10.4245/sponge.v6i1.17357

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Published online at jps.library.utoronto.ca/index.php/SpontaneousGenerations
ISSN 1913 0465

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Truth-bearers or Truth-makers?[*,†]

Laura Perini[‡]

One way visual representations might function in scientific reasoning is to convey content that is true or false, analogous to making a claim. An alternative way that visual representations might function is as an object that may make statements true or false, but is not itself true or false, analogous to a scientific model. In this paper I evaluate the most recent and extended defense of this latter position and show that the case study involved does not in fact support the view that the diagrams discussed function as truth-makers rather than truth bearers.

Do scientific visual representations bear truth or merely make statements true? In a prior work I argued that visual representations can bear truth (Perini 2005). I thought it was important to demonstrate this capacity in order to convince philosophers that visual representations play crucial roles in scientific reasoning. Scientists use visual representations to convey evidence and present conclusions in research publications: visual representations seem to be playing roles analogous to premises and conclusions in an argument. The main critical response to my view has not been dispute over the claim that visual representations can bear truth; instead there have been efforts to show that there is reason to doubt that the capacity to bear truth is relevant to understanding what visual representations contribute to science. Meynell (2008) suggests broadly that any analysis that directs our attention to truth will somehow lead us astray. I disagree: the kind of analysis involved in showing that pictures can bear truth has yielded important insights, including results that show that prevailing intuitions about pictures are wrong (Perini 2010). Goodwin (2009) presents a more specific response, arguing that visual representations in science function in roles that do not depend on their capacity to bear truth, acting sometimes like descriptive names and sometimes like models. This suggestion is well worth exploring, since scientists use a great variety of images, across a significant range of contexts (below I discuss one type of

* Thanks to Megan Delehanty for helpful input on this project.

† Received 14 August 2012.

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image that does not usually function to "express a claim," as Goodwin 2009, 374 puts it). The alternative that Goodwin advances in his analysis of how visual representations contribute to scientific reasoning is that visual representations function like scientific models.[1] Goodwin draws on Ronald Giere's view that visual representations are of the same representational type as models. In discussing maps, Giere claims that they are "physical objects, for example, a piece of paper with colored lines and spaces on it. It does not, therefore, make sense to ask whether a map is true or false" (Giere 2006). Giere is an advocate of the semantic view of scientific theories and, from that perspective, the claim that visual representations function in the same way as scientific models has the advantage of bringing scientific images within the purview of a high-level account of scientific knowledge.

According to the semantic view, scientific knowledge is embodied in models, which make statements true, but are not themselves true or false. The semantic view can be cashed out in alternative ways; some authors have logical models in mind, others work with more broad and intuitive views about models. Thomson-Jones (2006) argues that these alternatives can be understood as different views about the sense in which a model is a truth maker. The first perspective involves a very strong form of truth-making where models provide an interpretation for a formal language as well as a universe of discourse in which statements (so interpreted) are true or false. The second involves truth-making in a weaker sense, a view which Thomson-Jones refers to as "description-fitting." On this view, scientific models are objects that play representational roles and natural language statements about the models may be true or false, but the models don't provide an interpretation of that language in the way that logical models do for the formal language associated with a logical model. Giere and Goodwin are talking about models in this second sense: a scientific model is an object, about which certain claims are true and others false, depending on whether or not the model fits the description conveyed by the claim. Goodwin is explicit that, in reasoning with a model, a modeler draws inferences about the model as an object and then infers facts about the relevant part of the world from there.

I would like to explore further the idea that visual representations in science function as truth-makers, but not as truth-bearers. It is trivially true that any visual representation will make some claims true; each will fit a correct description of its visible form. The question is: will analyzing scientific visual representations as the kinds of things that can be true or false generally be inappropriate? The key issue here is the extent to which we can understand

[1] Goodwin argues that some chemical diagrams function like descriptive names, on the grounds that they carry the same information conveyed by IUPAC formula names—information about the atoms and bonds in a chemical compound. Goodwin does not show that they play the role of names in actual scientific reasoning.

the role of scientific visual representations in the way that Giere and Goodwin articulate: as objects, rather than as analogous to representations that convey propositional content, like sentences.

Goodwin aims to show that visual representations do not mainly function as truth-bearing representations in scientific reasoning. He discusses several diagrams of chemical formulas to support this position, working with a case study from organic chemistry in which an important result depended on comparison of the possible structures of two chemical isomers—compounds that have the same atomic components, but whose atoms are arranged in different bonding configurations from one another. The isomers both consist of a six-carbon ring with methyl groups attached to the first and third carbon atoms of the ring. In the *trans* isomer one of the groups is positioned above the ring, and one below; in the *cis* isomer both of these carbon groups are on the same side of the ring. Experimental work has shown that these isomers have different boiling points and also that, for similar compounds, the more stable isomer has the lower boiling point. The *cis* isomer has both of the bulky methyl groups on the same side of the carbon ring, and so it was thought that it would involve greater steric hindrance than the *trans* isomer, so the first hypothesis was that the *trans* isomer would be the more stable of the two. However, work with three-dimensional models of the isomers led to the opposite conclusion. Goodwin describes how moving the parts of the models of each isomer allowed for the observation of effects that influence the overall structure and that this allowed for inferences about the relative chemical stability of each isomer. First, the model of the *cis* isomer was put into configurations in which the parts of the model corresponding to methyl groups stayed quite far apart from both each other and from hydrogen atoms attached to the ring. A similar configuration could not be achieved by manipulating the model of the *trans* isomer. The next step was to draw inferences about the part of the world the model represented: because the isomers share structural features with the respective models, the scientists could infer that the *cis* isomer is the more stable of the two and thus the one with the lower boiling point.

Goodwin focuses on the use of models and on the importance of manipulating those material objects and observing the results. He concludes that the model's primary role in scientific reasoning is to function as an object that certain statements are true about, rather than functioning as a representation that is playing a role analogous to the linguistic expression of a claim. For Goodwin, the fact that the model is an object that shares properties with its referent is key; he concludes that the role of the model is to be a truth-maker, not a truth-bearer.

Goodwin's thesis that diagrams function as truth-makers rather than truth-bearers depends on their functioning in the same way as the models in his case study. Do they? Goodwin presents a pair of diagrams in a figure which labels them as the lowest energy configuration of the *cis* and *trans* forms, respectively (see Goodwin 2009, Figure 3, second row). These diagrams represent the volumes of ring-attached components of the isomers with broken circles. The diagrams are not standing in "as objects" in the way that models do. Goodwin describes three-dimensional models whose parts can be rotated in space. They can be used to discover the conformation with the least crowding among parts of the model. That discovery, along with the assumption that the structure of each model resembles one of the isomers and the connection to chemical theory (the effect of steric hindrance on the stability of a compound), supports the conclusion that the *cis* isomer will be more stable than the *trans* isomer. However, that is the reasoning that can be accomplished with models with movable parts. All the diagrams Goodwin discusses are static markings on a flat surface. The positions of their parts can't be manipulated. The viewer can imagine a three-dimensional object after viewing the diagram, and then imagine what that three-dimensional object would look like if its parts were rotated. Then they could use the same reasoning that was applied to their observations of the actual three-dimensional models after they were manipulated. So it seems possible that diagrams could be used to achieve the same discovery that models facilitated. However, this does not show that the diagram is functioning like the model. If this is how the diagrams are used, then some model-based reasoning is involved, but the diagram itself is not functioning in the same way as the model in that reasoning process; instead, the imagined compound functions like the model.

The diagrams that Goodwin claims function like models actually work to support the conclusion about the relative stability of the two isomers because they represent the particular structure of each isomer. Those diagrams are presented with captions labeling each as the lowest energy configuration. This is in sharp contrast with the reasoning involved with the model, in which one manipulates the model and concludes, based on observing alternative conformations, which isomer has the lowest energy. In the diagram, large and small dashed circles are used to convey information about the relative volumes occupied by hydrogen atoms and methyl groups. There is nothing about this case that indicates that these diagrams are not functioning to make a claim about the structures of the isomers; were we to discover that hydrogen occupies a larger volume than a methyl group, I believe it would be appropriate to judge the diagram inaccurate or false. Goodwin's discussion of models has raised an important suggestion about how visual representations might function in science, but he has not shown that diagrams function like objects rather than as claim-making representations in this particular case.

As I mentioned above, there are circumstances in which scientific images are used like objects in the sense Goodwin claims—where it's their capacity to make certain statements true rather than a capacity to bear truth that matters in scientific reasoning. For example, when scientists investigate protein structure they often use images produced by the interaction between a protein crystal and X-rays. The crystal diffracts the rays, which interfere or reinforce one another, producing a complex pattern of spots. There is little to no visually accessible resemblance between the spot pattern and the shape of the protein. To derive information about protein structure from the diffraction pattern, scientists measure the location and intensities of spots. That yields numerical representations of the form of the image, which are then subjected to extensive analysis in order to generate a model of the protein structure (see Perini 2012).

However the fact that in some circumstances scientists use images in ways that are best described as using the image as an object (or description-fitter), doesn't imply that most scientific images are used in this way. For example, understanding diagrams that are presented as conclusions as such offers a way to understand the reasoning scientists present that is consistent with scientists' concerns. Authors worry about whether they are correct or not, whether or not their conclusion is conveyed through an equation, a statement, or a diagram. Referees evaluate whether such conclusions are adequately supported by the evidence. When evidence is presented in diagrammatic format, referees evaluate whether it adequately supports the conclusion of the paper.[2] In the context of research articles and talks, visual representations frequently do seem to play the role of making claims, rather than being presented as objects that merely make other representations true.

I would like to end by emphasizing that we are at a preliminary stage in understanding how visual representations contribute to the growth of scientific knowledge and that it is valuable to explore a variety of kinds of roles that they might play and a variety of issues that might be relevant to understanding how they play those roles. At a recent seminar on visualization in biology Robert Skipper (2012) noted that whether or not the image is an idealization or an abstraction may be important for understanding why the image is used and the reasoning involved. Evaluation in terms of accuracy and precision is often more apt than whether a visual representation is true or false. Finally, the variety of both images and their contexts of use in science provides good reasons to investigate their use in roles that have little or nothing to do with a capacity to bear truth. For all these projects, close attention to images in their context of use is crucial to expanding our understanding of how they are involved in scientific reasoning.

[2] For discussion of a case where one diagram is presented as evidence for another, see L. Perini, Diagrams in Biology, *Knowledge Engineering Review* (Forthcoming).

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