Notes

1 Models and Representation

1. Giere's account is often described as a version of the 'semantic view' of theories. Other versions of the semantic view take models to be set-theoretical structures (Suppes, 1960) or trajectories through phase-space (van Fraassen, 1980). These accounts aim to give a formal analysis of the structure of theories and the notions of model they employ are rather different from those we are concerned with here. For helpful discussions of this issue, see Godfrey-Smith (2006) and Thomson-Jones (2007, 2010).
2. See also Godfrey-Smith (2006) and Hughes (1997).
3. The terminology I use here is similar to that in Friend (2007).
4. Variations of this point may be found in Frigg (2006), Hughes (1997) and Suárez (2003), although each draws rather different lessons from it.
5. This problem is also raised by Suárez (2003) and Callender and Cohen (2006).
6. Of course, this is not to claim that realism in modelling is the same as realism in painting.
7. Notice that the question is not whether the salt shaker could be a model-representation under *any* circumstances, but whether it is a model-representation in the particular circumstances that Callender and Cohen describe, in which we simply stipulate that it represents Madagascar. As we will see in Chapter 3, in other circumstances the salt shaker might be used as a model-representation. But doing so requires more than the act of stipulation described by Callender and Cohen.

2 What Models Are

1. The suggestion that Walton's theory may be applied in the context of scientific modelling has also been made by Anouk Barberousse and Pascal Ludwig (2000, 2009) and Roman Frigg (2010a, 2010b). I consider Frigg's account in detail in Section 2.4.2. The issues addressed by Barberousse and Ludwig are rather different from those that concern us here.
2. This definition is intended to distinguish the world of the representation from that of the games individuals play with it. When we read a novel, Walton claims, we not only imagine the events it narrates, we often imagine that we ourselves hear or read about those events. But we are not a character in the novel (1990, p. 60). I will say more about participation in games with scientific models in Chapter 5.

3. Of course, Walton's analysis of discourse about fictional characters is far from universally accepted. Friend (2007) gives a very helpful review of this debate.
4. In fact, Walton's theory does not demand that the speaker actually engage in pretence. When we say 'St Paul's is damaged' we might specify the relevant kind of pretence without exemplifying it (Walton, 1990, p. 404).
5. And, in fact, Frigg's analysis of model-systems differs from Walton's analysis of fiction at a number of points, and sometimes seems at odds with antirealism. For example, he writes that 'the attribution of certain concrete properties to models ... is explained as it being fictional that the model-system possess these properties' (2010b, p. 116; see also 2010a, p. 261). To say that it is fictional that the model-system possesses certain properties, however, is to say that we are to imagine that the model-system possesses those properties. This would seem to conflict with antirealism: we cannot imagine things about model-systems if there are none.
6. My arguments in this section are similar to those in Thomson-Jones (2007, section 4).

3 How Models Represent

1. In stressing the role of propositions, the make-believe account is similar to that offered by Daniela Bailer-Jones (2003). Bailer-Jones describes the relationship between models and propositions as one of nonlogical 'entailment' (2003, p. 60). Critics have objected that this notion of entailment remains obscure (e.g., Callender and Cohen, 2006, p. 70). The make-believe account explains the link between models and propositions: models, together with principles of generation, make propositions fictional.
2. Notice that I do not deny that scientists sometimes talk about the accuracy of models in terms of similarities between model-systems and the world, or that it may be useful to do so. In my view, however, such talk should not be taken literally, but instead understood according to the interpretation I offered in Chapter 2 (Section 2.3.3.2).
3. Note that *Sim* is not endorsed by Giere (2004, 2010), who instead stresses the role played by the scientists using a model. In this respect, the view expressed in this section is similar to Giere's. I offer a critique of Giere's account in Toon (forthcoming).
4. I am grateful to Martin Thomson-Jones for encouraging me to stress this point more clearly.
5. Of course, one response to this might be to adopt a version of the indirect fictions view of theoretical modelling considered in Section 1.2.3. I say why I do not think this would be a good route to take in Section 2.4.
6. 'D.D.I.' stands for 'denotation, demonstration and interpretation'. According to Hughes, these combine in the following way: 'Elements of the physical world are denoted by elements of the model; the model

possesses an internal dynamic that allows us to demonstrate theoretical conclusions; these in turn need to be interpreted if we are to make predictions' (Hughes, 1997, p. S325).
7. The phrase 'deferral strategy' is taken from Thomson-Jones (2007).
8. Callender and Cohen also attempt to defer the problem posed by models without actual objects, observing that 'the worry arises for all species of representation – not just scientific representation – and there is no reason to suspect that whatever ultimately explains representations of unicorns and golden mountains won't work for representation of phlogiston and the ether' (2006, pp. 80–1). There is an important difference between Callender and Cohen's deferral strategy and my own, however. Callender and Cohen simply express a hope that a solution to the problem for other forms of representation may be applied to scientific models. They tentatively suggest a 'Humean strategy', which provides a relational theory for 'atomic' representations and explains representations without actual objects as constructed as 'compounds' of other representations. But they do not show whether this can be applied to scientific models, or whether their account would remain intact if it were. This amounts simply to deferring the problem for scientific representation itself. By contrast, the make-believe account *reduces* the problem for scientific representation to the more general problem for imagination.

4 Carbon in Cardboard

1. It is worth noting that Ramberg's analysis focuses on chemists in Germany (see Ramberg, 2003, p. 8).
2. Van't Hoff's templates might thus be seen as an ingenious attempt to circumvent the 'Latourian' problem of the immobility of three-dimensional models compared to flat inscriptions (see, for example, Latour, 1990).
3. The notion of iconic representations is, of course, put under considerable pressure by Goodman (1976).

5 Playing with Molecules

1. In looking to practice to inform our understanding of models, my study therefore follows work by Daniela Bailer-Jones (2002, 2009), although my methodology is rather different. While Bailer-Jones's study used interviews to determine scientists' views on various aspects of modelling, mine was based on observations of the way that models were used and, in particular, of how this practice was explained to novices.
2. For three-dimensional models in general, see de Chadarevian and Hopwood (2004). Laszlo (2000) offers a chemist's perspective on the relationship between molecular models and toys.
3. These model sets are manufactured by Spiring Enterprises Ltd., Gillmans Industrial Estate, Natts Lane, Billingshurst, West Sussex, England.

4. MDL Chime is a product of Accelrys, Inc., 10188 Telesis Court, Suite 100, San Diego, CA 92121, USA. It is available at http://www.symyx.com/downloads/downloadable/.
5. For criticism of Walton's account of depiction see, for example, Schier (1986).
6. Of course, there are many puzzles one could raise in this regard, just as there are regarding the visual depiction of molecules. For example, isn't it fictional that we cannot touch molecules? Once again, it seems that the threat of contradiction does not prevent us from engaging in such imaginings.
7. However, there are some molecular modelling computer programs being developed that allow for tactile engagement. See Francoeur and Segal (2004).
8. For make-believe and pretence in children's games see, for example, Leslie (1987), Singer and Singer (1990), Sheikh and Shaffer (1979), Weisberg and Bloom (2009) and Wyman et al. (2009).
9. See, in particular, the papers collected in de Chadarevian and Hopwood (2004).
10. This includes, for example, the relative ease with which computer models allow the user to build models of large molecules and their ability to simulate more complex interactions between atoms within a molecule.

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