Chapter 8: Models, Fiction and the Imagination

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Abstract

Science and fiction seem to lie at opposite ends of the cognitive-epistemic spectrum. The former is typically seen as the study of hard, real-world facts in a rigorous manner. The latter is treated as an instrument of play and recreation, dealing in figments of the imagination. Initial appearances notwithstanding, several central features of scientific modeling in fact suggest a close connection with the imagination and recent philosophers have developed detailed accounts of models that treat them, in one way or another, as akin to fictions. This chapter will critically discuss the fictions approach as an epistemology of scientific modeling.

Introduction

Science and fiction seem to lie at opposite ends of the cognitive-epistemic spectrum. The former is typically seen as the study of hard, real-world facts in a rigorous manner. The latter is treated as an instrument of play and recreation, dealing in figments of the imagination. Initial appearances notwithstanding, several central features of scientific modeling in fact suggest a close connection with the imagination and recent philosophers have developed detailed accounts of models that treat them, in one way or another, as akin to fictions. This chapter will critically discuss the fictions approach. The chapter first motivates the appeal to fiction (section 2); then looks at several ways of developing the basic idea that models are a form of fiction (section 3); and finally considers how models, understood in a fiction-based way, can play the epistemic roles they are typically thought to play, namely as tools of scientific reasoning, representation and explanation (section 4.) The final section provides a summary and points to some directions for further development and expansion.

Motivating the models-as-fictions view

A central feature of modeling is idealization: the introduction of false assumptions – e.g. concerning infinite populations, point masses and perfectly rational agents – to facilitate analysis and understanding (Jones, 2005; Levy, 2021). These are concrete seeming entities but they are not ones that we can encounter in any spatiotemporal location or that can be studied by empirical methods; they are posits. It is natural to regard such posits as imaginary, and this is often how they are referred to within scientific discourse. Another way to put this, to quote Godfrey-Smith (2006, 734-5), is that “we might say that model systems are often treated as "imagined concrete things" – things that are imaginary or hypothetical, but which would be concrete if they were real.” In this, models appear not unlike the persons, places and events populating novels, films and other fictions – Holmes, Middle Earth, The War of the Worlds etc. Thus, a central motivation for treating models as fictions is their shared imagined, concrete-hypothetical character.

Several related features of the practice of modeling strengthen this line of thinking. For one thing, modelers often describe models in a way that is not unlike the introduction and development of a fictional setup. Consider this example, drawn from chapter 19 of Richard Feynman's celebrated *Lectures on Physics*, which discusses centers of mass. Early on, Feynmann explains how to calculate the center of mass of a compound object:

"Suppose that we imagine an object to be made of two pieces, A and B. Then the center of mass of the whole object can be calculated as follows. First, find the center of mass of piece A, and then of piece B. Also, find the total mass of each piece, M_A and M_B. Then consider a new problem, in which a point mass M_A is at the center of mass of object A, and another point mass M_B is at the center of mass of object B. The center of mass of these two point masses is then the center of mass of the whole object."

This little text has the look and feel of a (very) short story, not to mention the fact that Feynman begins by asking us to use our imaginations. Such examples can be multiplied.[1] This too suggests a kinship between modeling and fictionalizing.

A further aspect of similarity involves the presence of an internal/external distinction. In a fiction, it is natural to distinguish what is the case "in" or "according to" the fiction from what is true *simpliciter*. According to Thomas Mann's The Magic Mountain, a young shipbuilder named Hans Castrop goes to visit his ailing cousin at a sanitorium near the Alpine resort town of Davos, Switzerland, and ends up staying for seven years. That this is true "in" Magic Mountain is settled by the text of the novel. Whether such a place actually existed is a different question, to be settled "outside" the novel – most straightforwardly by visiting Davos (at least around the time of the novel's writing – i.e. 1924.)[2]

A final, more theoretical, consideration motivating appeals to fiction is the thought that this will allow one to use resources from the philosophy of fiction. There is a fairly rich tradition of philosophical discussion about fiction, including its representational and ontological aspects. As we shall see in next section, several ideas from this area have been utilized in accounts of modeling.

How ideas about fiction and the imagination have been imported into the discussion of modeling will be examined in more detail below. But before that, two preliminary points to clarify these notions and the use to which they will be put to here, should be discussed. First, the term 'fiction' is sometimes used to indicate that a statement or narrative are false ("the story he told us was a complete fiction."). But fictions can contain true propositions, and more generally there is no contrast between fictionality and truth. This is clearest in cases of fictions that are extensively grounded in fact, like historical novels, where much of the fiction's content may be factually accurate. But even in many "ordinary" fictions much of what is depicted – including mundane facts such as names of places as well as more subtle aspects of culture and society – may well be factually accurate.[3] Thus, the fictional is not fundamentally opposed to the factual. That said, the fictional is, as should be obvious, not necessarily anchored in the factual. Fictions contain many statements that are not true of any part or aspect of the real world – invented persons, places and events. More fundamentally, fiction-making isn't based in truth in the way factual description normally is, or is expected to be. In producing a fiction, either in a literary context or in a scientific (modeling) context, one

is not attempting to describe reality, at least not in the first instance, and the success of the product – the fiction – isn't to be assessed, at least not in the first instance, in terms of factual accuracy.

The second point concerns the relevant notion of imagination, which can be understood in thinner and thicker ways. In a thin sense, to imagine is to merely entertain, to take under consideration without presuming truth. In this sense, we imagine whenever we perform hypothetical reasoning. But in a richer sense, to imagine is to "see in the mind's eye". In this sense, imagining involves a special psychological capacity, a kind of offline sensory experience. Philosophers have differed on which of these senses is important in the context of modeling (Frigg and Salis 2020) and on its epistemic significance more broadly (Kinberg and Levy 2022). It could be argued that the significance of appeals to the imagination is diminished if it is confined to the thin sense. But since some authors discussed in this chapter would disagree, this is not presumed in what follows. Only the thin sense of imagination will be at play.

One final remark is in order, before moving on to consider fiction-based accounts in more detail. While the idea that models can be understood in terms of fiction has gained some popularity, with more than a few authors arguing for it and developing it, significant dissent has been voiced as well. A moderate criticism, presented by Adrian Currie (2017) is that a fiction-based view is insufficiently general. Currie gives examples from engineering and argues that the fictions approach does not capture them well. Gregory Currie (2016) has made a more far-reaching critique, suggesting that the appeal to fiction is philosophically unilluminating. He is unimpressed, in particular, by the idea that models and fictions are alike in terms of the internal/external distinction. Perhaps the harshest critic of the appeal to fiction is one of the forefathers of the modeling literature, namely Ronald Giere (2009). He holds that models function differently from fictions, in society and culture. Moreover, he worries that the assimilation of models to fiction might provide fodder for anti-scientific forces such as the Intelligent Design movement.

These objections should be taken seriously, and may at the very least point to limitations of and problems with the fictions view of models. But they do not seem to nullify the appeal of the view, certainly not to the point where we should avoid looking into it in further detail. So the chapter turns to that next.

Developing the models-as-fictions view

Models and the imagination. The idea that models are akin to (or perhaps a species of) fiction can be developed along various interrelated dimensions. One such dimension concerns the relationship between a model, construed fictionally, and the imagination. Suppose we accept that modeling, in some of its phases at least, is constituted by a use of the imagination. What exactly is the nature of the imaginative exercise in question and how does it relate to the way we engage our imagination when consuming fiction? This is relevant not merely to understanding the relationship between models and fiction. It is also central to understanding what determines a fiction's content, and what makes claims regarding it correct or incorrect (note that the notion of 'true' is not used here deliberately, as per the remarks about truth and fictionality made above).

Almost everyone in the philosophy of fiction agrees that we engage with novels, films and other central forms of fiction by means of our imagination. Fleshing out the connection to fiction has been key to most views of the semantics of fiction, but this can be done in several ways. Two will be discussed, as they seem to illustrate not only the similarities but also the potential differences between models and fiction. A first move is to distinguish actual from prescribed uses of the imagination. What makes something a fiction could be, on the one hand, that people actually use their imaginations when consuming it. Or it might be that they ought to use their imaginations when consuming it. A central insight due to Walton (1990) and Currie (1990), now endorsed by most philosophers of fiction, is that fictionality has a normative element to it. It is about what we should to imagine when encountering a novel or a painting. While it seems true that people often do in fact use their imaginations when reading a novel or watching a film, that is not what makes it a fiction, and not what determines its fictional content. It is the fact that we *should* respond to it a certain way: by employing the imagination (and not, as in the case of non-fictional work, by believing its content.)

But what determines *what* we should imagine when consuming fiction? A simple answer is: the fictional work at issue, be it a novel, a painting, a play. But this simple answer calls for elaboration: how does the work determine what we ought to imagine? At least two sorts of views can be outlined. An 'intentionalist' outlook holds that when, say, we read a novel, we are supposed to imagine what its author intends for us to imagine. And to the extent that we have succeeded in doing so, we have correctly grasped the fiction's content, can make correct statements about its content etc. Stated in this simple form, this view seems implausible, but several writers about fiction have developed it in ways that overcome its apparent simplemindedness (Currie 1990; Stock 2017). Without entering into details, we can note that on such a view, fictions are seen as a form of communication, inasmuch as the reader (the consumer, more broadly), is engaged in interpreting the words (or splotches of paint etc.) of the author. It is for this basic reason that such a view is not well suited to account for models. Modeling is, of course, a human activity, and does involve communications – among modelers, for instance – but a model is not fundamentally a vehicle of interaction between people. Moreover, while the intentions of a modeler (i.e. someone who originates a model) may matter in some contexts, they do not in general determine what the model is about. For this reason, while intentionalism may be a plausible view of fiction it is not suitable for an account of models.

An alternative to intentionalism is the make-believe view due to Kendall Walton (1990), an influential account of fiction and artistic representation. On this view, a fiction is a regimented, "grown up" version of children's pretend play. A game, in this analysis, involves two key elements: a prop, which is a concrete real-world object; and a set of rules – Walton calls them 'principles of generation' – which specify what the game's participants are to imagine given the prop's properties. To use an example from Walton, in a game of "spot the bear", the prop might be a tree stump and principles of generation might say, for instance that when seeing a stump, one is to imagine encountering a bear, that the stump's color should determine how one is to imagine the color of the bear's fur and so on. The extension to fiction is straightforward: a novel or a painting is a prop, which together with principles of generation mandates that certain propositions are 'fictional', namely *to be imagined*. Given the text of Thomas Mann's Magic Mountain, it is fictional, i.e. one is to imagine, that Hans

Castrop visits his ailing cousin at a sanitarium near Davos. That is, given the novel's text and the relevant principles of generation, this is a correct (in Walton's terms 'fictional') claim in the game of Magic Mountain. A further distinction made by Walton is significant here: some claims in a game are primary, i.e. they are explicitly specified in the work of fiction. That the hero's name is Hans Castrop, for instance. Other claims are implied, that is, they are inferable from the primary claims, given principles of generation (as well as features of the context.) For instance, it is implied, but never stated explicitly, in Magic Mountain that Hans Castrop is killed on the battlefields of WWI. Indeed, for Walton most of a fiction's content is implied, since only a small portion of what is to be imagined when, say, reading a novel, is explicitly stated in it.

Walton's view is much more readily applied to modeling than intentionalism. We can regard a model's equations (or even a verbal description of the model) as a prop that, given suitable (scientific) principles of generation, implies what the model's content is. The primary truths are those propositions that are explicitly specified in the equations or text, and the implied propositions are those that follow from them, given principles of inference from logic, mathematics and the relevant scientific discipline. Several authors have adopted such a view of modeling (e.g. Frigg 2010; Toon 2010; Levy 2015.) Notice that it suggests that the contents of the model are not dependent on the modeler, or her intentions. They are a matter of accepted principles of generation that (we may suppose) are part of the practice of the relevant scientific community. Moreover, while some such principles may be general, applying across many or all scientific disciplines – perhaps basic principle of logic and mathematics – others may be specific to a given area or modeling tradition.

Direct versus indirect

The next point concerns the manner in which models relate to their targets, i.e. the things (systems, phenomena) in the world that we intend to study by means of modeling. Suppose one introduces a model as follows: "imagine an ideal pendulum with length l and period p." We may call this a *model specification*. What is the status of such a specification – what is it about? And how does the specified model relate to its target in the world? Two sorts of answers are possible: a direct and an indirect approach. Let's start with the latter.

It may be easiest and most natural to understand the indirect approach by thinking first of a concrete actual model – such as a stick-and-wire model of a molecule or the San Francisco Bay Model developed by the US Army Corps of Engineers (Weisberg 2013, Chap. 1). In these sorts of cases scientists construct an object – a concrete, actual one, that is – so as to serve as a simple and accessible surrogate for the system they are ultimately interested in. They study this system for a while, figuring out (if successful) how the model behaves under various circumstances. They then apply the lessons to a target, transferring their finding about the model to the system they are ultimately interested in (the chemical, the bay, etc.) This process is indirect in a straightforward manner: to study the actual bay, one first studies a surrogate. The indirect approach to modeling can be seen as a generalization of this, to include models that are not concrete (which is to say, most models). It should be noted that the indirect approach need not be coupled to a fictionalist attitude to models. Indeed, one of its central advocates, Michael Weisberg, has been explicitly skeptical of the connection

between models and fiction (2013, Chap. 4). But others have developed an indirect fictionalist outlook, and this will be our focus here.

On the indirect approach, fictionally construed, the modeling process involves two "things", corresponding to the two phases of a model-based investigation: *a fictional model system* and a real-world *target system*. While the second of these is fairly straightforward, ontologically speaking, the first is puzzling: what is a fictional model system? Does it genuinely exist and if so, what does its existence consist in? Here too philosophers of science have looked to discussions of fiction for guidance. One option is to view the model as a possible entity. In the context of fiction, this view was developed by David Lewis (1978).[4] It has some initial attraction since it seems that at least many literary fictions describe a possible world, a way the (actual) world might be. It might initially seem that such a view is even more attractive as a view of fictional models. Recall the phrase used by Godfrey-Smith: models appear to be objects which "would be concrete if they were real". Isn't this near enough to saying that models are possibilia? Perhaps (although this is not Godfrey-Smith's view – see his 2020 for discussion). Be that as it may, the possibilia view has not garnered much support. One reason for this is that there are well-known cases of models that depict impossible states of affairs (Thomson-Jones, 2010).[5] A more basic reason is that many philosophers of science are wary of the metaphysical commitments of such a view (Levy 2015). They do not think acknowledging possibilia is a price worth paying for an account of modeling.

Might models be construed not as concrete hypotheticals but as abstract objects? Some have suggested so. Weisberg identified models with mathematical structures (2006, 2013) – although it is not clear that he intends this as an ontological claim. Recently, Thomson-Jones (2020) and Thomasson (2020) have suggested that models be understood as abstract artifacts. Based in Thomasson's previous work on social ontology and the metaphysics of fiction, this approach has it that models are "thin" abstract objects. They are generated – or, more precisely, modelers bring them into being – in the course of scientific modeling but have no more reality to them than is needed to serve as loci of reference and property attribution. They are 'hypostasized' objects that serve the purpose of coordinating our talk of models. This kind of view is ontologically economical (unlike modal realism about models). Thomasson and Thomson-Jones argue that there are real similarities between models and fictions inasmuch as both are created systems, and that the artifactual approach captures this. But there are concerns about this approach too. Perhaps the most serious of these is that abstract artifacts do not play a genuine cognitive role (Godfrey-Smith 2020): they are too thin to constrain the practice of modeling, and are of doubtful explanatory significance (Frigg 2022, Chap. 14 provides further discussion.)

So much for the indirect approach. It is fair to say that it sits well with modeling practice, but generates an ontological puzzle that is not easy to resolve. To the extent that one is troubled by this puzzle, one might at this point opt for a direct approach to modeling. On such an approach, there is no model system that stands apart from the target and can be explored independently of it. Both Toon (2012) and Levy (2015) develop such an approach. Relying on Walton's make-believe approach to modeling, they suggest that it allows one to view models as ways of thinking about real-world target, and no more.[6] Levy and Toon argue for this approach primarily on grounds of ontological parsimony: the direct approach does not

need to view models as entities in any substantive sense. They merely involve imaginative descriptions of real-world systems.

Toon develops the direct view as a straightforward application of Walton's general ideas about fiction. He thinks that model specifications can serve the role of Waltonian props, with the rest of the account largely parallel to how Walton views fiction in general. Levy's account is a variant of this general strategy, which relies on Walton's notion of a prop-oriented make-believe – the idea, in essence, is that we can play a game of make-believe in which our interest is geared at a real-world system. Thus (to use an example from Walton 1993) suppose you ask a person where in Italy the town of Crotone is and they reply "on the arch of the Italian boot." Here, you are enjoined to imagine Italy as a boot as a means for informing you of the location of Crotone. Applying this to models, the idea would be that we imagine certain systems as different than they in fact are so as to highlight certain properties, make evident certain processes, ease certain inferences about them, etc.

As can be seen, the direct approach is ontologically parsimonious. It recognizes only actual target systems, and creative descriptions of them. Some have argued that this parsimoniousness is also a source of trouble. Frigg and Nguyen (2016) think that some cases of idealization cannot be accommodated within a direct approach. They also argue that the direct approach cannot handle cases in which models have either generalized targets, or no apparent target (see also Salis 2021). If this is so then the direct approach seems doomed, since many models have generalized or non-existent targets, and idealization is central to the practice of modeling. But this topic is still being debated, and the jury is out on whether the direct approach can overcome these difficulties.

Before moving on, two recent accounts should be mentioned. In sense, these views aim for the best of both worlds – both to neatly capture the practice as the indirect approach does, and to remain as ontologically lean as the direct approach. The first view is expounded in Frigg and Nguyen (2016). These authors offer an elaborate account of model-based representation which is not fully recapped here (although one of its elements is examined in section 4, when discussing keys.) They too employ Walton's make-believe approach, but do so while aiming to remain ontologically neutral. As they put it at one point: "Game-driven make-believe can be seen as a way to refer to, or even create, a Meinongian fictional entity (Priest 2011), as a method to create an abstract artefact of the kind Thomasson (1999) describes, or simply as inducing mental content in those who play the game." (2016, 27). In the present context, this claim to ontological neutrality cannot be assessed in detail. The main worry about it is that it may cause trouble when we come to account for model-target comparisons (which will be discussed more fully in section 4), inasmuch as such comparisons may pose constraints on the ontology of modeling. Frigg and Nguyen are somewhat terse in their treatment of comparative statements, seeming to suggest that they are less important than some authors hold.

A second best-of-both-worlds attempt is due to Fiora Salis. She has recently proposed an approach that incorporates elements of both the direct and indirect views. Salis' suggestion is that models be seen as complex objects: "According to [this] view, model M is a complex object constituted by model description D and content C, so that M = [D, C]." She adds that "From an ontological point of view, the model is analogous to a literary work of fiction; the model description is analogous to the text of a fictional story (the prop that prescribes

imagining certain f-truths); and the model content is analogous to the content of a fictional story… (2021, 729). She goes on to argue that the model's content (the C in the above formula) is no more than the contents of a mental file, having no further, "heavy duty" reality. While this suggestion seems to do a better job with cases of generalized and/or non-existent targets, it arguably faces a version of the criticism leveled by Godfrey-Smith at the abstract artifacts view: can mental files explain the uses to which models are put, in the course of model exploration? Salis does not address this point directly, and she may well have a response. Given the difficulties of both the direct and the indirect approaches, her third option seems promising, and at any rate well worth further development.

Knowledge of models

A further set of questions that arises for a view of models as fictions is epistemological. Here we can divide the terrain in two: knowledge of the model itself will be discussed in this section. The next section will discuss issues relating to knowledge of the world outside the model, as it were, under the heading of 'exportation'.

If a model is a fiction then investigating the model is akin to figuring out the content of a fictional scenario. But this leads to a concern: why think there is a definite, discoverable content to fictions? Doesn't the fictions approach portray model the investigation as a much less systematic and objective affair than it is (and should be)?

A basic response to this worry can be obtained by appealing, yet again, to the work of Kendal Walton. Recall the distinction drawn above, in connection with Walton's framework, between primary and implied fictional statements. The former are explicitly stated in the fictional text (or expressed in a non-verbal way, if the fiction isn't literary) whereas the latter are implicit, to be inferred from the explicit ones. If a model is to be construed along these lines, then clearly much of what constitutes modeling is a matter of figuring out what the implied propositions are: what follows from the model's explicitly specified elements. Thus, if we model some system as an ideal pendulum, the bulk of our work would be to solve the pendulum equation for the relevant values, i.e. to figure out what the mathematical expressions (given an interpretation, and given values for variables, boundary conditions etc.,) imply.

Walton's framework supplies a general answer to the question of what governs these implications: it is the relevant principles of generation. Such principles *just are* principles for inferring fictional statements, either from props or (more importantly) from primary propositions. Whether such principles exist for artistic fiction can be disputed: arguably, in literary fiction there simply is no determinate implied content (Levy, 2020). But it is fairly clear that they exist in scientific contexts. Some of the relevant principles are general, including principles of mathematics and logic, while others are domain specific, i.e. particular to this or that scientific field. But this seems to be as far as we can go within a general discussion of models: the notion of principles of generation supplies an answer to the question of how knowledge of fictional models works in principle, but it also suggests that beyond basic principles of mathematics and logic, there will not be a general account of how model content is determined.

Before moving on to questions about exportation, one final issue pertaining to knowledge of models, to which relatively little attention has been paid in the literature so far, should be mentioned: the role of the imagination. Early on, thinner and thicker senses of the imagination were distinguished. The first is closely related to hypothetical reasoning, while the latter involves a sensory-like component. Which kind of imagination is involved in the exploration of a model? Weisberg (2013, Chap. 4) assumes that it is the richer sense, and on this basis voices concerns about the fictions view of models – he worries that some common elements of models (such as probabilistic ensembles) cannot be imagined (in the rich sense of imagining, that is.) Frigg and Salis (2020) argue, to the contrary, that a thin notion of imagination suffices. This allows the view to avert concerns such as Weisberg's. A worry about a view like Frigg and Salis's, however, is that it dilutes the role of the imagination, and consequently of imagination-based views of fiction. These and related issues have not been hashed out in much detail as yet, and remain largely open.

From models to targets

The final set of issues to be discussed is perhaps the most important, as it concerns the very purpose of modeling, namely learning about the world. While a modeling project often involves an extensive phase in which the model is explored, that is typically done in the service, ultimately, of using the information gathered from the model to predict, understand and explain some real-world set of targets. Several philosophical issues arise in this context, from relatively general questions pertaining to realism versus anti-realism to more specific questions concerning the manner in which model-based knowledge is exported to worldly targets. These are tackled in order.

First, do models, understood as fictions, generate special problems for a realist standpoint?[7] Here realism is understood as a view both about science's goals – seeking true descriptions of phenomena and their underpinnings and as a statement about its results – science sometimes succeeds in producing true descriptions of phenomena and their underpinnings. It might at first seem that the fictional perspective on models does indeed general problems, for isn't the claim that a model is a fiction tantamount to saying that it does not accurately describe reality?

But this is too quick. First, recall that the fact that modeling often involves idealization – making false assumptions in order to simply and facilitate model analysis – was part of *the motivation* for the fictions view. It is not as if treating a model as a fiction *adds* further tension with realism. Another point made earlier concerns the relation between fictionality and truth: it is not one of opposition but of independence. Fictions needn't, but certainly can, contain true propositions. Indeed, a fiction can – and many artistic fictions arguably do – aim at truth. That is, a fiction can, by presenting the world in fictional way, try and sometimes succeed, in telling us a larger (or simply different) truth about the world. This is the equally, if not more, the case in science as it is in art. Thus, the mere fact that a model is seen as a fiction does not entail that it cannot also tell us true things about its targets.

That said, the fictions view does remind us that one central argument for realism – the No Miracles Argument (NMA) – may have limited applicability in the context of model-based science. Briefly put, the NMA is an argument that states that since the best explanation

for the success of science is that its underlying theories are (at least approximately) correct, we should accept that it is (at least approximately) correct. This argument is seen by many as realism's "master argument" (Musgrave, 1988; Psillos, 2003). The NMA takes the form of an inference to the best explanation – it suggests that since truth (or approximate truth) is the best explanation of the success of scientific theories, we should believe that at least many of these theories are true (or approximately so). But, like in any case of inference to the best explanation, we cannot use such an inference rule to reach a conclusion that we know, in advance, to be untrue. It may well be that the conspiracy theory according to which the CIA is behind the assassination of JFK, is very attractive in terms of sheer explanatory "loveliness" (Lipton, 2003.) But we have independent information confirming the falsehood of this theory, and so we cannot move from its explanatory prowess to its truth. In the case of modeling the situation is, in a sense, even more extreme: we know that central elements of the model are idealizations. That is, we know them to be false. So we cannot use model-based explanations in an IBE, at least not without extreme care.[8] Thus, by focusing our attention on idealizations as the fictions view of models does, it helps us see the limitations of an argument such as the NMA. This isn't an in-principle blow to realism, but it does limit its relevance – or at least the relevance of its master argument – in many real-life cases.

But realism, as a broad philosophical question, is not the only or even perhaps the main question on the agenda, when learning from models is at issue. A more immediate set of questions concerns *how* models inform us about their targets. In asking such a question we of course presume, at least provisionally, that models do indeed inform us about targets. There is room for further distinctions in this context: we can ask whether and how models allow us to make predictions, how they enter into explanations and so on. But this direction won't be examined here further. Instead, two broad sorts of answers to the "how models inform" question, will be addressed: one based on similarity relations, the other based on the concept of a key.

The notion that we learn from a model about its target by means of, and to the extent that, it is similar to its target, need not be associated with a fictions view of models and is fact embraced and developed by authors who explicitly oppose the fictions view. But it sits well with a view on which models are concrete hypothetical systems, to return to Godfrey-Smith's locution. On this kind of view models and targets may share certain properties, or at least have a degree of resemblance in their properties. The ideal pendulum's length may be similar to a real pendulum's; the rate of predation of a model population may resemble the rate at which a real population is preyed upon, etc.

A similarity account of model-target relations merits further elaboration. For one, it should spell out an account of similarity and of the kinds of similarities that are relevant in the assessment of model-target relations. The philosopher who has done the most to articulate such an account appears to be Michael Weisberg (2013, Chap. 8)[9]. Weisberg explicitly distinguishes similarity with respect to the target's *attributes* in contrast to an underlying similarity of *mechanisms.* He then offers an account in terms of feature-matching, inspired by the seminal work of psychologist Amos Tversky (1977). Whether Weisberg's account succeeds in part or in whole is not an issue that will be discussed here (see Parker, 2015). But surely some such account is needed if claims about model-target similarities are to be illuminating.

A similarity account of model-target relations should also be seen in light of the discussion of the previous section, concerning model ontology. A simple and straightforward understanding of similarity says, roughly speaking, that two things are similar insofar as they share properties. Obviously, for an object to share a property with some other object, it must have that property. But recall that at least some versions of the fictions view of models contend that the model is a "mere" fiction, and not an object at all. It is unclear whether and how such a view is consistent with a similarity-based account of model-target relations.

A second, more abstract approach to model-target relations has been developed by Roman Frigg, partly in collaboration with James Nguyen (2010, 2022; Frigg and Nguyen, 2016, 2018). A crucial element in their approach is the notion of a key, namely a mapping from properties of the model to properties of the target. A key tells one how properties of the model translate into properties of the target. In this sense it is tells one how to "read" the model inasmuch as one wants to learn from it about the target. A key can utilize relations of similarity – it can map the size of an element in the model to the size of a corresponding element of the target – but similarity need have no role. A key can map size onto, say, location relative to some point of reference. All that is required is a consistent, one-to-one mapping between relevant elements of the model and elements of interest in the target.

An advantage of the appeal to keys is that it can be applied very widely. As previously indicated, keys can rely on similarity relations but need not. In this sense the keys approach is a generalization of the similarity approach. This approach is, as noted, rather abstract. Keys are mappings, and the specific mapping used will vary by context. This means that much of the "action" concerning how models represent targets will depend on the relevant key, a matter which varies as a function of the area of science, and indeed the type of model being used. Frigg and Nguyen probably view this as an advantage of their view. Others may take such generality to deprive the view of some of its explanatory power, relative to a more concrete approach such as Weisberg's. It is possible, perhaps ironically in view of his rejection of it, that Weisberg's view is a better match to the fictions view of modeling, relative to Frigg and Nguyen's more abstract approach. But these issues are yet to be debated at greater length and developed further, as is the broader issue of model-target relations.

Summary and open questions

The fictions view of modeling is motivated by features of the practice and embodies the thought that a focus on the role of the imagination can illuminate modeling. We have seen that such a view can be fleshed out along several dimensions, with choice points for each of them. Questions arise about the semantics, metaphysics and epistemology of models, understood as fictions.

Kendal Walton's make-believe account of fiction has been central to the development of the fictions view. It plays a role in accounting for the semantics of models-as-fictions, inasmuch as modeling differs from artistic practices such as literary fiction (where an intentionalist view is at least a plausible candidate.) Walton's account is also central to the metaphysics of fictions, since some philosophers take it to permit an attractive anti-realist stance toward models. This is so especially if the Waltonian framework is combined with an indirect view of modeling that many take to be true to modeling practice.

Finally, we have seen two sorts of accounts of the manner in which the results of model exploration can be exported to the target. One of these, the similarity-based account, is more closely connected with the motivations for the fictions account, but raises semantic and ontological concerns. The other, Frigg and Nguyen's keys approach, is more abstract and more general, but its fit with the fictions approach may be somewhat less tight.

The fictions approach is still a live area of research in which several questions remain under active debate, and several avenues for development remain untrodden. The chapter has tried to indicate these throughout. Here, in closing, two areas outside of philosophy of science, with which fruitful connections can be made, will be highlighted. The first concerns the ontology of modeling – as noted in discussing this, beyond the direct and indirect approach, several recent authors have offered what may be regarded as intermediate stances, and the prospects of these are yet to be fully determined. Here it is notable that there is a large literature in metaphysics concerning fiction, as well as related questions (such as social ontology; see surveys in: Epstein, 2021; Kroon and Voltolini, 2018, 2019). Contact between the literature on modeling and this larger body of work in metaphysics has, to date, been relatively minimal. Another area with which the fictions view can make contact is the large (and increasing) literature on the imagination (Kind and Kung, 2016; Badura and Kind, 2021). In particular, much of the recent writing on epistemic aspects of the imagination – whether and how can imagining play a role in justifying belief? How does this relates to other forms of justification and knowledge acquisition? What role do different forms of imagining play in this process? Since modeling is a central epistemic practice within science, and since the fictions approach tightly connects it to the use of the imagination, it seems likely this is an area with which potentially fruitful contact can be made.

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[1] The collection edited by Suarez (2009) contains many examples. See especially the chapters by Morrison, Teller and Winsberg.

[2] In fact, there was indeed a *Schatzalp Sanatorium* near Davos. So the statement "There exists a sanitorium near Davos" is true (or was, at the time, since it was converted to a hotel in the 1950s.)

[3] In this sense, the current discussion departs from ideas familiar from Vaihinger (1925, in which the "philosophy of as if" is explicitly linked to claims that are untrue of, often even in conflict with, reality. (on linking Vahinger to modern treatments of fiction, and to its role in science, see Fine 1993)

[4] To be precise, Lewis provides a possible worlds semantics for fictional statements. He does not, in his 1978, tie this to an ontological stance on possible worlds. But since Lewis is well-known for his modal realism, many understand him as offering, indirectly, a view of the metaphysics of fiction, as well.

[5] Lewis, in his 1978 paper, considered the parallel problem for fictions and offered some solutions. But these solutions have been criticized (Byrne, 1993) and in any event it is not clear that they can be transferred as is to the context of modeling.

[6] It should be noted, however, that Walton's approach, in and of itself, is neutral as between the direct and indirect views, and more generally is compatible with a variety if takes on the ontology of fictions.

[7] These issues are discussed at greater length in Levy (2018).

[8] It may be that some kernel of truth to a model-based explanation, and that the explanation's success supports an inference to said kernel (a view such as Strevens' – see his 2008, Chap. 4 – may allow such a move). But moving from the model to the supposed kernel is likely to be a delicate inferential process.
[9] It should be recalled, however, that Weisberg is a critic of the fictions view of models. He regards his account of model-target similarity as independent of such a view.