Modelling with words: Narrative and natural selection

Dominic K. Dimech

Author email: dominic.dimech@sydney.edu.au

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1. Introduction

Contemporary philosophy of modelling emerged as a departure from debates over what constitutes a scientific theory, in which the term "model" referred to a formal semantic object (a "partial interpretation" in Braithwaite, 1962; Nagel, 1961. See also Lloyd, 1988; Suppes, 1962; van Frassen, 1980). Philosophers of science now speak of the *practice* of scientific modelling, and Godfrey-Smith (2006) – representative of this practice-based tradition – defines models as, "idealized structures that we use to represent the world, via resemblance relations" (2006, pp. 725-726). Models are now understood as things that scientists spend their time building, analysing, and modifying in light of their results. Even though not all science involves models, a lot of scientific practice does encompass modelling, and they are particularly ubiquitous in the biological sciences (see Winther, 2006). The need for a departure from the old, formal sense of "model" was prompted by concerns that philosophical debates about theory did not make reference to, and were thus irrelevant to, real-world scientific practice (see Cartwright et al., 1995; Morgan & Morrison, 1999; Odenbaugh, 2008).

Recent studies of models in science, however, still identify a pretty narrow range of things that can count as models. Michael Weisberg, in *Simulation and Similarity: Using Models to Understand the World* (2013), argues that purported model types, such as verbal, diagrammatic, and pictorial, are to be excluded from an account of modelling on the grounds that we can account for such things as model descriptions. Weisberg does not define "descriptions" precisely but gives a series of examples and indicates that they refer to models and make them present in contexts in which, for whatever reason, the model itself cannot be present (2013, pp. 31-39). Weisberg would want his distinction between models and model descriptions to reflect the practical reality of science, and this would happen if scientists only ever use verbal structures to refer to some more important thing that is doing the heavy work.

Here I argue that we ought to recognise verbal models in a philosophical account of modelling because verbal structures do indeed have the capacity for robust scientific work. Previous studies have explored the role that verbal structures can play in science (Huneman, 2011; Lennox, 1991; O'Hara, 1988; Richards, 1992; Winther, 2006; Winther, 2011), but this defence of the capacity of verbal structures against a reductive argument like Weisberg's is original. Here I analyse parts of Charles Darwin's *On the Origin of Species* (1859/1964) (henceforth, the *Origin*) and show that Darwin used models in the form of invented, idealized narratives to display how the process of natural selection works.

Getting the right typology in a philosophical account of models is important because it determines from the outset the examples that will be looked at when investigating other philosophical questions about models. A broad implication of the argument here is that the description/model distinction is a weak device for reducing the number of types of models we recognise. This, consequently, lends reason to suggest that other model types that are excluded, such as diagrammatic and pictorial, could be models. In fact Winther (2006, p. 447) has argued that developmental biology, a subject area he explicitly points to as containing verbal models, also contains diagrammatic models (see also Sheredos et al., 2013). Godfrey-Smith (2006, p. 732) also claims that one prime example of a work of evolutionary modelling, Maynard Smith & Szathmáry's *The Major Transitions in Evolution* (1995) involves many models that are not mathematical. It is clear that some models in that book are given in diagrammatic form, such as a model of the Oklo reactor (1995, pp. 18-20), and the stochastic corrector model of gene replication (1995, pp. 55-58). In general, the philosophy of modelling still needs to capture the full diversity of practices that involve models.

In the next section I run through the core ideas behind contemporary philosophy of modelling. This sets the scene for the rest of the paper and provides a frame of reference for me to argue that verbal structures should indeed count as models. In Section 3, I proceed to go over Darwin's central claim in the *Origin* and then present his examples of verbal models. In Section 4, I address some objections about whether verbal models really represent a distinct category, and I conclude in Section 5 by summarising my argument and restating the general lesson that can be gleaned from it about how we decide what should or should not count as a model.

2. Models in science

Weisberg (2007) defines modelling by contrasting it with *abstract direct representation* (ADR). Modelling is a way of doing science in which an independent structure is used as a proxy to study some target phenomenon that is beyond direct investigation for some practical reason. ADR does not involve such intermediate structures but does involve making general claims and being selective about which features to represent and which to ignore. Unique to modelling is a methodological step of comparison, of determining in what respects the studied object is similar to the target (Weisberg, 2007, p. 223). Modelling, like ADR, involves idealization, and for Weisberg this involves, "a departure from complete, veridical representation […] In other words, a model is idealized with respect to its target when it fails to represent some important aspects of the target" (2013, 98). Godfrey-Smith (2009a, p. 48) more narrowly defines idealization as *fictionalizing*, that is, as representing things falsely, as opposed to just leaving truths out. Each of the examples I will look at from Darwin involve at least some fictionalizing and are therefore idealized according to even Godfrey-Smith's narrower sense. Darwin does bring in empirical facts in some of his examples, but in all the cases I pick out, Darwin is not attempting to describe what is really the case.

The upshot of modelling is that it makes possible the study of phenomena that would otherwise be too complex or beyond grasp for some other reason. A particular application of modelling is especially relevant here – that of using models to study general phenomena. Evolutionary scientists are not just interested in how this or that species evolved, but how the process of natural selection in general comes about. Scientists can theorize about general phenomena via ADR, but representing such phenomena in distinct structures is the work of modelling. In what follows, we will see that Darwin's invented scenarios of natural selection are not supposed to be about any particular cases but they capture what is common to all cases by representing only what is salient (see also Weisberg, 2013, 114-121).

Weisberg is sympathetic to the point that in the past theorists were too narrowly focused on mathematical models and cites Winther (2006) as a source of agreement on this (Weisberg, 2013, p. 15). Unlike Winther, however, Weisberg does not recognise verbal models, instead countenancing only physical, mathematical, and computational models (2013, p. 7). Weisberg relies on the distinction between models and model descriptions for his rejection of verbal models, as he insists that the types of objects used as descriptions varies more widely than the types of things that are actually models (2013, p. 17). A mathematical model, like the Lotka-Volterra predator-prey model, can be described using formulas, using graphs, or diagrams, and these all may vary in levels of detail (see Weisberg, 2013, pp. 31-39). By way of example, Weisberg shows how Shepard & Metzler's (1971) purported verbal model of mental image rotation can be seen as a mere description of a computational model. If elaborated on, Weisberg tells us, the words in that model would be replaced with, "a lot of mechanistic detail of the sort that visual input *V* triggers mental mechanism *M*, which is processed by *P*, and gives output *O*" (2013, p. 18). This way of proceeding, however, involves a significant lacuna. It might be the case that we can think of the putative verbal model as a description of a hidden computational model, but Weisberg needs a reason why we ought to reject the existence of verbal models altogether and not just believe that verbal models can sometimes be transformed into computational ones.

3. Narratives in the *Origin*

3.1 Principles of Natural Selection

In order to make lucid what is being modelled in Darwin's scenarios, I will first provide a brief summary of the basic ideas behind Darwin's fundamental thesis in the *Origin*. Contemporary summaries of the theory of evolution by natural selection identify three principles that capture what is necessary to it. Godfrey-Smith (2009b, p. 18) cites Levins & Lewontin (1985) for the standard summary. Note that the following is mere abstraction, since there is not yet a further, proxy structure that these principles are represented in:

> 1. Individuals within a species vary in physiology, morphology, and behavior: the principle of variation.
> 2. Offspring resemble their parents on the average more than they resemble unrelated individuals: the principle of heredity.
> 3. Different variants leave different numbers of offspring: the principle of differential fitness.
>
> (Levins & Lewontin, 1985, 76)

Of course, Darwin did not understand his own theory in these terms, but we can identify the relevant corresponding parts in the text of *Origin*. In the following quotation, I have put a number just before each principle is referred to, even though the resulting numbering is out of order:

> Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occurred, that [1] other variations useful in some way to each being in the great and complex battle of life, should sometimes occur in the course of thousands of generations? If such do occur, can we doubt (remembering that many more individuals are born than can possibly survive) that [3] individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating [2] their kind? On the other hand, we may feel sure that any variation

> in the least degree injurious would be rigidly destroyed. This preservation of favourable variations and the rejection of injurious variations, I call Natural Selection.
>
> (Darwin, 1859/1964, pp. 80-81)

Heredity and fitness are presented closely together in the above. In one sentence, Darwin identifies that some individuals procreate more than others and that they procreate their own kind. Fitness and heredity are distinct principles though, since the fact that some individuals procreate more than others is due to the relative advantage they have, but a separate principle ensures that offspring tend to resemble their parents. Anyway, the important thing is that Darwin makes the move of inventing scenarios that model how these core principles of natural selection come together. Narratives in science do, of course, appear as non-models, such as when scientists recount particular cases of evolution (see O'Hara, 1988, pp. 144-146). The narratives that I present below, however, are proxies intended for representing the general phenomenon of natural selection.

3.2 Darwin's Models

In Chapter IV of the *Origin,* in a section titled "Illustrations of the action of Natural Selection" (1859/1964, 90-96), Darwin sets out to show how a few biological principles come together to produce the all-important result of a change in species over time. I present and explain four examples here, labelled (A)-(D), and I claim these are verbal models.

In the first case, Darwin shows how some individuals would enjoy an advantage over others by specifying a change in a shared environment. Such a move puts the principles of variation and fitness on display, since we see *one* type of variant with the ability to thrive under change in a way that others do not. Darwin presents an imagined wolf population and then specifies a change in the environment that affects the way the wolves hunt prey. Darwin only gives as much detail as he needs in order to reveal the general causal process at work:

> Model (A)
> In order to make it clear how, as I believe, natural selection acts, I must beg permission to give one or two imaginary illustrations. Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey, a deer for instance, had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the wolf is hardest pressed for food. I can under such circumstances see no reason to doubt that the swiftest and slimmest wolves would have the best chance of surviving, and so be preserved or selected - provided always that they retain strength to master their prey at this or at some other

> period of the year, when they might be compelled to prey on other animals. I can see no more reason to doubt this, than that man can improve the fleetness of his greyhounds by careful and methodical selection, or by that unconscious selection which results from each man trying to keep the best dogs without any thought of modifying the breed.
>
> (Darwin, 1859/1964, pp. 90-91)

Due to the "change in the country", at the dire time when wolves are hardest pressed for food, swifter wolves have an advantage in hunting prey. In virtue of their increased ability to survive, those wolves are given greater opportunity to reproduce and have their own kind preserved in future generations. Darwin compares this natural case of selection to artificial selection, which he previously discussed in Chapter I ("Variation Under Domestication"). Darwin is selective about what to include in this fictionalized scenario.

Darwin then describes a slightly different way in which fitness can arise and bring about change in a species. This time, rather than a change occurring and affecting some pre-existing variant, an individual creature is simply born with a novel advantage:

> Model (B)
>
> Even without any change in the proportional numbers of the animals on which our wolf preyed, a cub might be born with an innate tendency to pursue certain kinds of prey. Nor can this be thought very improbable […] Now, if any slight innate change of habit or of structure benefited an individual wolf, it would have the best chance of surviving and leaving offspring. Some of its young would probably inherit the same habits or structure, and by the repetition of this process, a new variety might be formed which would either supplant or coexist with the parent-form of wolf. Or, again, the wolves inhabiting a mountainous district, and those frequenting the lowlands, would naturally be forced to hunt different prey; and from the continued preservation of the individuals best fitted for the two sites, two varieties might slowly be formed.
>
> (Darwin, 1859/1964, p. 91)

Like in the previous scenario, what is important here is that the factors that bring about natural selection are on display. By presenting one invented narrative, Darwin puts on display the causal factors that bring about the natural selection of species in general.

Next, Darwin shifts focus to a different scenario depicting natural selection that involves the intercrossing of varieties of flowers. Darwin begins with a simple enough imaginary premise, which is that the nectar juice from flowers is excreted by the inner bases of their petals. The consequence of this is that insects seeking juice are dusted with pollen and inadvertently transfer pollen between flowers. From this, Darwin concludes that those flowers that are most often crossed will gain an advantage. Darwin began this section of the *Origin* prefacing that he would look at "one or two" imaginary illustrations and I take it that, despite some empirical detail being woven in, this is the second one (1859/1964, p. 90).[1] Moreover, in model (D) we will also see that Darwin refers to the nectar-feeding insects illustration as "imaginary". This shows that these cases involves fictionalizing and therefore idealization even in Godfrey-Smith's (2009a, p. 48) sense:

> Model (C)
> Let us now take a more complex case. Certain plants excrete a sweet juice […] This juice, though small in quantity, is greedily sought by insects. *Let us now suppose* a little sweet juice or nectar to be excreted by the inner bases of the petals of a flower. In this case insects in seeking the nectar would get dusted with pollen, and would certainly often transport the pollen from one flower to the stigma of another flower. The flowers of two distinct individuals of the same species would thus get crossed; and the act of crossing, we have good reason to believe […] would produce very vigorous seedlings, which consequently would have the best chance of flourishing and surviving. Some of these seedlings would probably inherit the nectar-excreting power. Those individual flowers which had the largest glands or nectaries, and which excreted most nectar, would be oftenest visited by insects, and would be oftenest crossed; and so in the long-run would gain the upper hand. Those flowers, also, which had their stamens and pistils placed, in relation to the size and habits of the particular insects which visited them, so as to favour in any degree the transportal of their pollen from flower to flower, would likewise be favoured or selected.
>
> (Darwin, 1859/1964, pp. 91-92. Added italics)

That intercrossing brings advantages to individuals is an observation that Darwin elaborates on later (1859/1964, pp. 96-109). In the scenario, there are a few different ways that Darwin considers a flower might receive such advantages. Some flowers just produce more nectar than others, and some flowers ease the efforts of insects seeking nectar by their stamens or pistils. The take-away message is that we see the effects of natural selection at work in anything that makes insects more likely to seek the nectar of certain flowers.

After a brief digression into the separation of sexes, Darwin returns to the same broad scenario but shifts focus to how insects would gain advantages:

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[1] Individuating the examples here as four models is for illustrative purposes. We may equally consider that there are just two models that have different parts that are each worth going through.

> Model (D)
>
> Let us now turn to the nectar-feeding insects *in our imaginary case*: we may suppose the plant of which we have been slowly increasing the nectar by continued selection, to be a common plant; and that certain insects depended in part on its nectar for food. I could give many facts, showing how anxious bees are to save time; for instance, their habit of cutting holes and sucking the nectar at the bases of certain flowers, which they can, with a very little more trouble, enter by the mouth. Bearing such facts in mind, I can see no reason to doubt that an accidental deviation in the size and form of the body, or in the curvature and length of the proboscis, &c., far too slight to be appreciated by us, might profit a bee or other insect, so that an individual so characterised would be able to obtain its food more quickly, and so have a better chance of living and leaving descendants. Its descendants would probably inherit a tendency to a similar slight deviation of structure.
>
> (Darwin, 1859/1964, p. 94. Added italics)

This case is similar to model (B) insofar as an "accidental deviation" gives rise to an advantage. The significance of all these examples is that they fit nowhere in a typology of models like Weisberg's. What makes them instances of modelling is that there is some identifiable, idealized structure that performs the role of telling us about the general phenomenon of evolution by natural selection. The examples make clear that Darwin was not merely talking abstractly about natural selection; he was not making anything like a Lewontin-style summary. Darwin created imaginary illustrations that displayed how the causal factors most relevant to natural selection interact to produce change over time. The only difference between Darwin's representations and many examples of models in contemporary biology is that Darwin used only words in his scenarios. It should not matter, though, whether the structure uses numbers, or is something physically built, or is produced using words; the scientific work that it does should be enough for it to count as a model.

4. Objections

The argument so far has been that Darwin modelled natural selection using verbal scenarios and that this is representative of the work that verbal structures can do in science. A potential worry about the argument, though, might be that using words to bring a model into existence is not the same as having a model that is verbal in nature. Many kinds of models may be described using words, and since that is the case it might seem that more needs to be done.

In response to this, I would highlight that Darwin had some models and that these are verbal *and nothing else*. That is, they are structures that are actually being used as models and they cannot be explained away as mathematical, computational, or anything else. The causal factors underpinning evolution by natural selection are not mathematical principles, and so we cannot simply say that Darwin's scenarios are mathematical structures presented in verbal form. Causal factors can sometimes be modelled mathematically and sometimes verbally. To illustrate this point, consider what Weisberg tells us about Craig Reynolds' (1987) *boid*s (bird-oids) model. Reynolds' model involves three basic flocking rules that are supposed to explain how birds flock without a master controller. Boids models, Weisberg tells us, were originally developed for computer animators to produce realistic bird populations (2013, p. 120). The principles are:

> 1. Collision Avoidance: avoid collisions with nearby flockmates.
> 2. Velocity Matching: attempt to match velocity with nearby flockmates.
> 3. Flock Centering: attempt to stay close to nearby flockmates.
>
> (Reynolds, 1987, p. 28).

These rules represent the bare mechanism which may then be converted in a model (Weisberg 2013, 120). Weisberg, of course, thinks that there will be some mathematics involved along the way of this conversion process. What we agree on is that the rules themselves do not model anything, but once the rules are represented in some further structure that is used as an intermediary to study the world, then we have a model on our hands. But this is just what is going on in the cases of evolution by natural selection that I have presented here, since we have abstract principles applied in a separate structure that serves the purpose of representing a general phenomenon.

One might wonder whether verbal models are always hiding a non-mathematical but still *computational* model. If all computational models were also mathematical, then by showing some model was not mathematical we would thereby show that is not computational either. In *Simulation and Similarity*, Weisberg suggests precisely that computational models are a special kind of mathematical model. Responding to the suggestion that his own three-way typology could be reduced to two by subsuming computational models under mathematical models, Weisberg says that there is nothing about the ontology of the models that would block such a move: "ontologically they are not distinct types of models, [but] they function differently in practice and have different representational capacities, so they should be given their own categories" (2013, p. 20). The difference is a practical one: mathematical models derive explanatory power from relationships among variables, what he also calls "the mathematical structure", and computational models derive explanatory power from algorithms (2013, p. 20). Weisberg's main example of a computational model, Thomas Schelling's (1978) model of population segregation, involves mathematical detail (see Weisberg, 2013, pp. 13-14).

There might be a case to be made, though, that computational models are distinct from mathematical models, and Weisberg seems at least open to this possibility when he speaks of a computation as a bare "procedure" (2013, p. 18). But even if this is the case, it does not settle the issue. For we have seen that the mere possibility of explaining away the existence of verbal models is not the same as providing a reason why we ought to. Anyone who would push the argument that verbal models should always be subsumed as non-mathematical computations has this task to deal with. What is clear is that any way of accounting for the cases I have presented here from Darwin would involve some revision of the view offered in *Simulation and Similarity*, which is a recent and influential book on the philosophy of modelling. As I have presented them, we have every reason to think those cases are verbal models that present the causal principles behind evolution by natural selection.

5. Conclusion

In this paper I have argued for the recognition of verbal models in a philosophical account of the practice of scientific modelling. I proceeded by showing examples of verbal models of natural selection from Darwin's *Origin*. I have specifically opposed Weisberg's (2013) suggestion that verbal models can be explained away as mere descriptions of other types of models. Verbal models are not the only ones that Weisberg wishes to do away with; as indicated in Section 1, putative diagrammatic and pictorial models are given the same treatment. The general lesson enunciated at the start I will now repeat: what matters for determining whether types of objects are models or not is whether scientists use such objects as idealized intermediaries to study the world. The question of whether certain types of objects have the capacity to do robust scientific work is best answered by looking directly to practice. This prioritisation of practice is what motivated the contemporary development of a philosophy of modelling that was not bound up with accounts of scientific theory, and this paper has appealed to this fundamental guiding motive.

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