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NARRATIVE AND MODELS

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1. Narrative and models: good companionships[1]

It may be taken for granted by some commentators on science that models are scientific objects and narratives are humanist constructions. But in many respects, models and narratives function as good companions and, in some aspects and some cases, narratives are constitutive in the core of models. Before getting into this agenda of companionship, some preliminary remarks are needed.

First, Models are understood here as objects designed by scientists to help them investigate some part, or some characteristics and behaviours, of their science's phenomena that they do not fully understand, and cannot access directly or consistently.[2] These model-objects are *representations of* how they think their phenomena behave and may be in mathematical, statistical, graphical, or diagrammatic formats (or perhaps even in verbal accounts, though they are mostly non-linguistic entities). They may even be real living objects, specially chosen to be *representatives of* biological life *for* certain purposes such as the use of the model organism: fruit flies for genetics, the lab mice used in medical science, or the lab rats of psychology.[3] But the important point here is their function: models—in construction and usage—provide scientists with *a means of enquiry into* the theoretical and conceptual accounts they have of the world, and *with* the model into the real world.[4]

Second, there are multiple definitions of what a narrative is in narrative theory, probably many more than the different notions of a model within the sciences and offered by philosophers of science. The most basic, and very helpful, way to think about narratives in science is that they provide an account of how things are related together (see Morgan 2017). Narrativising could involve relating events over time, across space, between social groups, or within individual behaviour, and so forth. It is important that a narrative is always *more* than a chronicle (a simple ordering of events), but how much more and what is involved is rather open, so the definition is focussed, but still relatively unrestricted.[5] An important point about using this definition is that narrative-making does not just place things into an order (e.g. according to their time sequence or spatial arrangements) but configures them: it brings together more or less disparate elements into an account that indicates or makes claims about, their relationships, and in this way 'makes sense' of the scientific phenomena

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of interest. That is, narrativising (or narrative-making) provides *a sense-making technology* for scientists (see Morgan 2022).[6]

Finally, the discussion here will *not* be concerned with the rhetoric of the sciences: namely, the important ways in which the use of expressive forms—e.g. clever metaphors in literary analysis, elegance in mathematical proofs, good design in diagrams—matter to the way ideas are presented and understood. This is a perfectly good agenda, for rhetoric is never 'mere' and always matters; but is not the issue here. Rather, the agenda is concerned with how narratives and models work together in various ways in scientific work. Two main and very different sources of examples: the natural historical sciences, and the more technically oriented social sciences (particularly economics), are used here to explore and explain the relationships between models and narratives, that is, to see how *models as a means of enquiry*, and *narrative as a sense-making technology* collaborate in certain sites of science and in certain of their practices. The companionships of models and narratives are discussed first for situations where narrative is constitutive in a science's theoretical explanatory framework and appears so in its models. The discussion then turns to other reasons and other ways in which narrative is involved in the construction and usage of scientific models.

2. Where narratives are constitutive in science and its models

2.1 Narratives in the core of models

In certain sites in the sciences, narrative is constitutive in the core of the scientific account, not just in sense-making descriptions but often in reasoning and explanation (see Olmos 2022). This is pretty obviously so in the natural historical sciences, where accounts of how the natural world changes over time seem 'almost naturally' to take a narrative form—as we can see at several levels in evolutionary biology. At the most all-encompassing theoretical level, the general theory of biological evolution has a narrative structure telling of the adaptation of species to their environment, or the role of random mutations, or of both. When applied at a broad level, that narrative structure is used in giving an account of, or explaining, how major groups of living things in the world developed over time: e.g. plants, fish, mammals, insects. Then, that narrative structure remains similar in discussing more specific individual evolutionary changes—for explaining, for example, how some kinds of fish became flat fish, and even down to the most particular level, such as the turbot. Thus, narrative is constitutive in such accounts of evolution that run from the most general to the most particular. At all levels, these scientists make sense of and explain what happened by telling narrative accounts, and this close relation between narrative and explanation can be found throughout the natural historical sciences of evolutionary biology, geology, palaeontology, cosmology, and so forth.

Where do models fit into these natural-historical scientific narratives? In general, there is no one standard way that models fit into a science; different sciences use models in different places and for different purposes, wherever scientists have found them useful in doing science. In the natural historical sciences, these differences are illustrated by three specific examples of the ways narrative and models come together and fit into the levels of evolutionary biology arguments as suggested above.

First, at the general level of evolutionary change, two major theorists of the 1920s—Sewall Wright and Ronald A. Fisher—produced competing accounts of the main drivers of evolutionary change. According to Rosales' analysis (2017, 7), they agreed on the mathematical elements but held different narrative accounts of the evolutionary processes. Fisher's narrative privileged 'natural selection as the driving force'; Wright's narrative involved 'drift, migration and selection'. The point was that they used these different qualitative narratives to integrate their mathematical elements together. Otto and Rosales (2020) argue that both narratives and mathematics have played key roles in the development of evolutionary theorising, that they are interactive, and, going further, that maths may be embedded in the narratives rather than be the main carriers of theory.

At the second level in this evolutionary biology domain, modelling can be found in the ubiquitous use of 'phylogenetic tree' diagrams representing the evolution of species, making sense of their evolutionary changes over time and space, and placing them into relationships with each other just as genealogical kin diagrams do. Starting with Darwin's famous 'tree of life' diagram, these 'trees' are found not just in museums and children's books but in serious scientific work tracking the evolutionary development of the phenomena of our natural world. For example, such a tree diagram tracing the evolutionary spread of marsupials (the kangaroo family) from South America to Australasia over time offers a similar structure of narrative history as found in our own human-family kinship diagrams (see Kranke 2022). They chart the narrative of both generational descent and spread, and they can be found in a variety of vertical and horizontal forms. These tree diagrams are not habitually thought of as 'models', but, as with many other diagrammatic devices in other fields, they function as just such representations, i.e. as shorthand, artefactual accounts, that express knowledge claims about relationships in a non-linguistic way, and notably here with a narrative structure. According to Priest, such tree diagrams form the 'scaffolding' for explanation in the field in which narrative remains constitutive (see Priest, 2018; and his entry XI in *Narrative Science Anthology II*).

The third and most particular level of evolutionary narrative might also be depicted with diagrammatic modelling to unravel the possible order of adaptation of some fish to become flat fish (see Beatty 2022). Although it is known that flounders (the generic term for flat fish) began their evolutionary lives upright, their evolutionary narrative from living their lives vertically to living lives horizontally is not known. The possibilities of such paths of adaptation can be modelled as a branching tree sequence to suggest alternative 'back stories', e.g. that first these fish had become bottom layers, then their fins had become side flaps, and finally their eyes had moved over the top. But in the absence of the relevant fossil record, any other order seems just as plausible. Each possible pathway or ordering in the branching tree betokens a narrative account created from following different adaptation routes along the branches of the tree.

This narrative 'following' process (which could be done backwards or forwards), is also used with the tree diagrams in the social sciences of psychology and economics to model sequences of decision-making in human life—for example, in the use of 'game theory' in economics and in political science. These diagrammatic models also have similarities with the chemical reaction diagrams depicting possible routes to a successful synthesis in chemistry, showing not adaptive evolutionary moves nor human decision processes, but narrating the possible processes of chemical reactions in the formation of complex molecules. For example, Paskins (2022) shows two chemical syntheses 'equations' for a particular molecule: tropinone. One from the early 20th century offers a narrative 'recipe', telling scientists how to make that molecule, while a more recent one from the early 21st century is understood to represent the relevant chemical reaction processes that occur in such a synthesis.[7] This example also nicely illustrates the useful distinction delineated by Meunier (2022) between the 'research narrative' of the scientist's research work, and the 'narrative of nature': namely what is thought to happen in the natural process.

It is perhaps worthwhile to draw out the related implications of this broad argument. One aspect is the relationship between historical and philosophical notions of explanation. In the natural historical sciences: laws, concepts, and theories address fundamental changes over time using a narrative structure, and in this sense, narratives are constitutive in the core of scientific accounts and so in their explanations of their phenomena. To get closer to explaining and understanding the details of historical changes in the world, scientists in those fields need to adopt and adapt such narratives to more particular levels. In contrast, then, to the normal divide drawn in philosophy—that scientific explanations rely on laws or on causal mechanisms that hold generally while historical explanations can only be about particulars—the claim here is rather different. Rather, these narratives of evolution, from their most general down to their most particular level (of the turbot), remain as much scientific narratives as historical narratives for they depend on, or they embed, or they are driven by, the general scientific laws or the mechanisms envisaged in their discipline and so remain narratives of adaptive evolution or random mutation, or both.

This raises the question: How do these natural scientific laws and causal mechanisms appear in such narratives and models of the natural historical sciences? Hopkins (2022) argues of the equivalent base-level geological laws that the forces of deposition and erosion tightly constrain the narratives of geological change, though the policing by these laws may perhaps remain hidden; the laws lurk in the narratives rather than being found explicit. This lurking is indeed how they appear in the models and accompanying narrative texts in Hopkins' examples of the narratives and diagrams/models that appear in geology.[8]

This suggests the following reflection on a certain useful similarity in the relation of the base theories/laws/mechanisms/concepts of a scientific field and both its models and its narratives. A model is not a scientific law, or general theory, or a concept, but institutes some aspect of these into its representational qualities. The same can be said of the narratives of a science. How might this similarity of character of models and narratives be understood? The main message of the 'models as mediators' account (Morrison and Morgan 1999) was to point out that models do not sit neatly as a sandwich filling between laws/theories and empirical evidence, but rather that they are independent representational objects, artefacts designed (or chosen, as in model organisms) to embed elements of those theories and a field's realities in such a way that the model can be used to explore both realms. That is, they are not simply derivative copies of either laws or world descriptions. In this respect, scientific narratives are like scientific models, they take some relevant elements of the scientific laws/theories of their field into their constructed accounts. This is how narratives fit onto, or into, scientists' explanatory accounts, making use of their sciences' concepts, ideas, framings, and so forth in more generic, or more particular, accounts of how things happen.

In this framing then, models and narratives, can *both* be understood as representations used by scientists: they have much the same qualities, and have similarities in status, with respect to the sciences' explanatory frameworks and phenomena. Regardless of how models are fashioned and framed, they always provide thinner, smaller, and less comprehensive accounts of the phenomena of the world than the world itself, by definition and purpose; and they are usually accounts in a different medium from the phenomena they model. The narrative accounts of science have very similar characteristics.

2.2 Narrative motivations vs narrative at the core

While narratives come in 'almost naturally' in the natural historical sciences because of their general commitment to understanding how the natural world changes, there are other sciences where narrative has a less obvious or less secure relationship to a main thesis of a field and their depictions in models. Consider the account that economists make of peoples' decision-making behaviour when they make choices. In that account, consumers are assumed to make decisions that 'maximise their utility', and they do so by preferring more to less, and by making their preference choices consistent amongst several goods. These economists' axioms about utility (that is, the values humans associate with the outcomes of the decisions they make) translate neatly into a mathematical description that can be applied to many (every?) decision(s). But that base-level account of model man's choices is rather thin, empty even. It has descriptive content and may offer predictive outcomes, but it lacks, within the model itself, the agency of decision-making. Narratives may be told by scientists about such human actors' decision-making to give reasons for the scientists' choices for the depictions in their model, yet those presumed narratives may not be recognised within the model. The general question here is whether the narratives are constitutive of the model or merely give an account of such motivations, whose rationality hinges on something else than those narratives. We can examine this in the history of how economists modelled this 'choosing' problem.

When a group of economists in the late 19th century began their utility theorising, they motivated their accounts by telling lots of small stories, imagining how people (including themselves) thought through their choices, and how they made valuations and decisions based on their preferences. These various forward-looking motivational accounts about how people would behave were used in justifying the particular details of three different versions of these theories, expressed in three different model forms: mathematical, graphical, and tabular (laid out in Morgan 2020, 248), but it is notable that the human actors' stories were not really built into the models, rather they were verbal accompaniments to motivate and explain, *ex ante*, the behavioural habits and rules that lay behind the economists' choice of model representation. The human actors' stories were not represented in the models themselves.

By the early 20th century, economists had mostly given up these initial attempts to link decision-making back to psychology, and so, no longer relied on these back stories about how people think about their preferences to 'explain' their choices. One of these three models, developed from Jevons' original geometrical and algebraic representations of 1871, grabbed the mainstream, and his theory of choices was developed into a more general mathematical model account of rational economic man's behaviour by the mid-20th century with little narrative accompaniment (see Morgan, 2006 for a fuller account).

A few decades later, that mathematical model was found to lack traction when applied in laboratory and field experimental work (where people behaved unexpectedly with respect to the theory) and in less than straightforward set-ups (where outcomes were uncertain). These findings produced a set of patches onto the basic theory, and thence into a proliferation of versions of that basic model. Significantly, each of these late 20th century versions of the basic model was again motivated by 'small stories' told by the economists about people's behaviour, but this time *post hoc* to make sense of those experimental findings about how people acted in those situations or reasoned about the valuations and decisions they made. People were understood to have made their decisions by thinking forwards about 'prospects', or by thinking backwards about 'regret' (and so forth) in their decision-making. These narrativised accounts by economists after the events (rather than in the earlier 19th century stories of motivations beforehand) of how and why people had made the decisions they made created extensions or versions of the original theory model. It is again difficult to see exactly how far these more focussed narratives became constitutive into the model, but they were a critical input into the fashioning of the new generation of models.

A well-used model where a sense-making narrative seems to be more central within the model was offered by Hirschman (1970) who was interested in characterising the situation that prompted the three-way choice decision that people made in organisations between exiting a situation they found uncomfortable, or expressing their disquiet ('whistle-blowing'), or staying and keeping quiet. This 'exit, voice or loyalty' decision model grew out of an anecdote, a small story he told of a puzzling experience he had in Nigeria about their railway system. Working away to make sense of his puzzle, he came up with this multipurpose model that could be applied in lots of circumstances: to a firm in an industry, a person in an organisation, a country in a trade alliance, that is, to any individual unit in a larger set facing this three-way choice. Because the model situation was more complex, and the possibilities of various options needed more content, the narrative connections became more central in the model. And because this model situation is a generic kind of situation (i.e. neither completely particular, nor completely general), the model-narrative works as a generic tool for exploring many different situations: that is, narrative sense-making in the model could be applied regardless of the relative details of the person, situation, and choice descriptions.

And, more recently, two sets of commentators have argued that such narratives of decision-making are more than devices for economists in explaining how people make choices before or after the event, but must actually be constitutive within these models because narrative reasoning is constitutive in human decision-making processes (as indeed, seems consistent with the experimental and field evidence mentioned above). That is, narrative is not part of the scientific rationale offered by the scientist in supporting the use of such a model, but rather the model must embed narrative processes because narrative is constitutive of human reasoning. Thus, Tuckett and Nikolic (2017) draw on *cognitive* psychology to show how people make decisions in situations of radical uncertainty to develop an account that relies on narrative reasoning on the part of those people. Bianchi and Patalano (2017) draw on *developmental* psychology to explain how people reason from their current situation to the outcome they hope to reach by creating narratives linking those situations. Both accounts depend on narrative being a core element of human reasoning in decision-making and so, they argue, should be constitutive (even if not fully identifiable) in economists' models of people's decision-making.

3. Narrative in constructing and using models

3.1 Narrative configuring in making models

Although model-making varies across time and subject fields, and histories and philosophies of science may throw up other different kinds of relationships of models with narratives, there are useful comparisons to be drawn that give insight into their relationships. As suggested above, both narratives and models can be understood as forms of scientific representation: representations of how scientists think the world is and how it works. But it is also worth noticing that the *nouns* of narratives and models are the outcome of different practices of scientific reasoning that can be described in the *verbs* of narrativising (or narrative sense-making) and model-making (or modelling). So, the relationship between narrativising as a sense-making activity and the narratives that result parallel those of model-making and the models that result. Such modelling and narrativising practices may also be connected or conjoint. This relationship is most evident when models are the outcome of sense-making processes that involve 'narrativising' an account of their phenomena of interest (as occurred in the exit-voice-loyalty economic choice example above).

Narrative sense-making (the verb) can be found in constructing both theoretical models and empirical models: narrative sense-making may inform, drive, or be more or less strongly instantiated into the relational representations that form either kind of model. In the 1920s and 1930s, for example, economists were deeply concerned with understanding the relatively new phenomena of 'the business cycle'. Some were dealing with the evidential trails of business cycle data in fashioning empirical models while others, at the same time, were creating nascent theoretical models of how an economy as a whole (the 'macro-economy') might generate such cycles. Jan Tinbergen was one of the special group of economists who worked on both kinds of modelling and used narrative sense-making in both. At the former site, he used narrative-making in configuring sets of different statistical data trails of the economic-cycle phenomena to fit together into an empirical model. At the latter site, he constructed theoretical, aggregate-level, models out of a variety of elements relying on narrative-making to configure the causal relations of the cycle to provide both for their cyclical dynamics and their variabilities. Marcel Boumans (1999) used this historical example to motivate his account of model-making as a practice that picks out and integrates a set of ingredients to produce a model (a kind of lego project that then relied on mathematical moulding to configure the parts to fit together). He pointed out how economists' meta-narrative about how the aggregate economic system worked involved them not only pulling together a narrative of causal chain parts but also drawing in a small narrative that functioned as a key ingredient in this theoretical modelling of the cycle.[9] This little narrative—of a child hitting a rocking horse—instantiated the dynamic role of randomness into the mathematical model. Thus, narrative sense-making was important in creating both Tinbergen's mathematical model structure and his statistical-econometric model.

The natural historical sciences offer especially instructive examples of how narrative-making may be integral in model formation. Those concerned with understanding the extinction of the dinosaurs have suggested two alternative models, with different associated narrative forms, applied to the same data (see Huss 2022). For one group of scientists, that particular extinction is understood as just one of many similar such events in a recurring pattern of such mass extinctions, to be pinned down by revealing a cyclical pattern (of 26 million years' periodicity) in the long data series of the timing of mass extinction events. Their narrative is rather thin for it is descriptive rather than explanatory, though speculation suggests a regular 'cause' narrated in the events of cosmology (which might then contribute to explanatory reasoning with the model). For another group of scientists, that particular extinction—of the dinosaurs—is understood as one amongst the set of different such cases, each of which has its own set of causes. The challenge for the latter is to make sense out of a messy evidential domain and configure the set of causes into a model with data that would support a narrative explanation for that one event.

3.2 Narrative in the mediating role: sense-checking the model

The above examples relied on narrativising (sense-making) in configuring sets of elements to help create viable structures and pinpoint relevant relationships in a model. But narratives are at least as important in providing a sense-checking device for models once they are in usage as a means of enquiry. In this context of a collaborative account of models and narratives, how models are used might be at least as important and interesting as how they are made, and particularly how scientists reason with narrative in using their models and what they learn from that usage. In the 'models as mediators' account (Morgan and Morrison 1999), models mediate between theories and the world, having reference to them both and being able to mediate between them by being partially of them both. Mari and Giordani (2014) re-describe these mediating possibilities when they suggest that a 'model is used both as a theoretical tool for interpreting our concepts and as an operational tool for studying the corresponding portion of the world' (83).[10]

One important place where these mediating possibilities are used together is in exploring models through conducting simulations, where narratives associated with the simulations provide a means of potentially exploring both the theoretical qualities and possible empirical validity of models, and so offer a form of double quality control for scientists in working with models. How does this work? In this 'what happens if' reasoning, the model can be simulated and the resulting narratives of this explorative usage provide one of the criteria scientists use to validate their models, and so inform what scientists take to be a 'good' model for their purposes. This narrative usage enables the scientist to enquire into the theoretical world of the model, to suggest domains where it might be usefully applied (a kind of 'applied theory') or into the applicability of the model to the world, either in rather general form or in closer fit to the kinds of phenomena experienced in the world. These narrative 'tests' of validity are qualitative: concerned with *kinds* of outcomes (rather than quantitative in the sense of dealing with domains of uncertainty or error as associated with statistical kinds of testing regimes) and so provide a kind of quality control testing. This is how the theoretical tool and operational tool of mediating using narratives can be seen working together, as in the next two cases.

As a tool of theoretical investigation, this exploratory reasoning mode of model-generated narratives is used to see what kinds of outcomes might be possible, plausible, or implausible according to the model. For example, a mathematical model seen to embody a particular theory might be run either informally in a kind of thought experiment, or via a computer simulation with different starting values, or with different parameter values, according to different assumptions about the world depicted in the model. These exploratory/ reasoning modes effectively use the model to 'tell' narratives about the possible paths and outcomes of events, or the predicted outcomes of these models under various settings. One early example is given by the first, hand-cranked simulation of a very small mathematical model of the aggregate economy in 1939 by economist Paul Samuelson. He 'ran' his model for a few nominal 'years' forwards to see how the patterns changed by choosing different parameter values in the model. Each 'run' produced a sequence of model outcomes that provided paths over nominal units of time. Sometimes these narrative paths were rather plausible, with outcomes that were not too big, not too small, and with regular cycles. In other words, they seemed to make sense in terms of being consistent with observed variability in the economy. Other parameter sets produced implausible outcomes: economies that expanded towards infinity within a small number of iterations, other runs that showed no effects, and others that created expanding cycles. Samuelson concluded that almost anything can happen in the world depicted in the model: the 'model-world' of his theorising (see Morgan 2012 for a full analysis). His simulation narratives offered insight into the models' theoretical pretensions but had less to say about the qualities of the real world that the model might be compatible with, and indeed, they were not intended to have this kind of representational verisimilitude. Nevertheless, negative information is often as useful as positive in showing where and when a model is useful to 'explore' a particular phenomenon. Narrative explorations are a way of showing the limitations of the theory that the model is designed to capture, and/or in application to things in the world. What these narrative explorations do is to suggest to the scientist what it cannot be applied to, which might be as important as telling what it might apply to, both in developing the conceptual or theoretical domain of the model and in suggesting constraints on that model's usefulness in the empirical domain.

Another example, from the natural science domain, is found in the model-based, computer simulation of snowflakes (see Wise 2017). Snowflake formation can be modelled with a relatively simple mathematical model based on water droplets falling through the atmosphere with changing temperatures at different elevations. Each of these simulations charts out an individual snowflake's life history, a narrative told through the successive changes in that snowflake's shape and size. As this simple theoretical model simulation process goes on, the computer generates simulated snowflakes into a surprisingly different set of visual shapes, not at all the kind of standard six-sided shapes that were long presumed by scientists (and still cherished by children drawing them at Xmas). This might suggest a rejection of the model on implausibility grounds, but, surprisingly, these outcomes from the simple mathematical model are consistent with the observed evidence of snowflakes: which come in a huge variety of shapes. That is, in simulations, this simple model created highly varied, but empirically valid, outcomes in snowflake shapes equivalent to those seen arriving on the ground—each one separately narrated by the mathematical model simulation.

Samuelson's macro-economic model was also very simple in terms of the structure of the mathematical model, and it too generated a variety of different narrative outcomes, but unlike the snowflakes case, only some of these were empirically plausible. In contrast to these simple model scenarios, Beck (2014) rightly argues that one could not tell narratives with simulations from climate science models because the latter are just too complex to be able to understand the processes in any kind of narrative format. That is, he might argue, as an operational tool for models in climate science, narrative exploration just does not work. That may well be, and the large-scale macro-economic models developed in the 1960s would probably be equally problematic in simulation checks in the theoretical domain. And since the macro-economy is a large open system subject to shocks (as in climate science), empirical sense-checking using narratives would also probably be equally unrewarding. So, it is important to distinguish between a small-scale, simple core model (as in Samuelson's model), and a large-scale more detailed and complex overall model. These will be quite different objects, used differently, and narrative exploration might not be feasible or helpful with a large-scale or complex model in any science (not just climate science). There are probably no obvious or easy general statements about the relations between the simplicity/complexity of a scientific model and the associated variability of the narratives associated with model simulations and with their empirical referents.

Yet, as implied already, for some circumstances this exploratory aspect of model narratives can provide a kind of quality control tool: Does this model provide sensible narratives when you ask a sensible question (either in the context of theorising or in empirical domains)? If it does not, ummmm! In the philosophy of science framing, this use of narrative as a quality indicator for the model is thinly characterised and might seem extremely non-rigorous. But in the context of a scientific community, it may look much more reasonable. For any given community of expert knowledge, a verdict that something makes sense, or makes nonsense, is likely quite a good criterion, for it is about the extent to which this model-narrative knowledge matches up with all the other elements of knowledge these scientists hold (theoretical and empirical) about the phenomena in their domain, a 'coherence' quality not to be underrated (see Currie and Sterelny 2017). And this plausibility facet overlaps with the explanatory services offered by such narratives with or without models. The narratives, by reasoning through the linkages depicted in the model, proffer answers to scientists' questions about how their model-world works, and so offer explanatory possibilities. This quality of the model-narrative nexus reappears again next.

3.3 Narrative closure, opening, and transfer

A third focus for the models-narrative collaboration comes in adopting the notion of 'closure' from narrative theory into scientific uses of narrative. The classic example of closure is found in detective novels, where narrative sense-making requires that by the end of the story, there should be no bits of knowledge left out or leftover or that do not fit the narrative, otherwise the narrative is not closed satisfactorily. An equivalent reasonable quality test for models might suggest that a model is complete for the task at issue if all bits thought to be important are fitted together, there are no essential holes in the account, and anything not considered relevant is omitted.[11] These ideas of closure are not so well formed in philosophy of science discussions of models, but they make a strong appearance in narrative theory and might be applied to the use of narrative in collaboration with models as another aspect of sense-making with models and associated modes of assessing model quality.[12]

One case investigated by Biddle (2023) was the problem of modelling disequilibria in agricultural markets, such as what happens with the introduction of hybrid corn, or the use of fertiliser. Economists' models of markets typically focus on the equilibrium conditions and outcomes in a model, but how this equilibrium comes about over time, and what moves were involved in agricultural markets, were not easily or well modelled. These gaps in the model became very evident when it was applied to the data and evidence of particular markets for particular times. In some of the early days of such empirical modelling, economists sought out farmers and market participants to hear their narrative accounts of what happened in these markets, and in particular how they adjusted their behaviour, and how fast they adapted when things in the market changed. The economists used these narrative inputs to fill the information gap, and so plug the holes in the model with relevant adjustment factors so that it could make sense of the phenomena under study. This is reminiscent of Rosales' account of the evolutionary biology mathematical modelling gap (discussed above), which had to be closed with narrative.

Tinbergen's macro-models (also discussed above) also used the idea of closure. He wanted to develop macro-models that could be used in policymaking. The original models (theoretical and econometric or statistical) involved not just closure of the equation system (where everything that needed explanations had an explanatory equation), but also closure in the sense of enabling all the equations to hold simultaneously in the system. This was essential, for it was difficult to use the model to figure out policy actions unless the whole model was 'closed': all the inter-relations within the model need to be tied up; otherwise, the narratives told in using the model would have loose ends and the policy analysis would fail.

These narrative notions of closure parallel the literature on legal case narratives, which require that all evidence is taken into account and that the evidence fits together in a consistent way, and so forth (see MacCormick 2005). Going further, Campbell (1975), argued that in case study work, when one piece of evidence fails to fit an account that has been built up from lots of different elements, the account—effectively a case narrative—is 'infirmed' (in contrast to 'confirmed'). These closure notions of narrative seem to reflect Tinbergen's ideas about working with mathematical models, and perhaps the failures of such 'closure' are best, or most easily, revealed in failures in the narrative accounts that might be told with the model.

Sometimes narratives play a role not in model closure, but in opening models up. Sharon Crasnow (2017; 2022) details how political scientists open up their statistical models that come from a set of data on political phenomena by going into narrative 'process-tracing' for a few particular individual cases chosen from the data set. Here narrative comes in, not to 'test' the model statistically, but to test in another sense: namely, to explore alternative hypotheses and bring evidence and explanation together in a very different way than with the use of statistics. Such process tracing of political events to tell viable narrative accounts is designed to provide causal stories and perhaps reveal causal mechanisms. For example, the 'democratic peace hypothesis', when tested with statistics, suggests that democracies don't go to war with each other. But: 'How does the democratic peace hypothesis work in practice? What is the process by which war is avoided?' These questions cannot easily be answered in statistical models but can be in case work, taking individual cases and filling in the account; which is in turn dependent on narrative-making as the tool for guiding the analysis, joining up disparate pieces of information at different times to answer the questions and so make sense of that case. For example, Crasnow (2017) examines political scientists' investigation of the Fashoda Incident, when French and Anglo-Egyptian forces came to a standoff over the boundaries of their colonial power in Africa in 1898. Process tracing involved narrative sense-making at the evidential level, but working through conceptual categories and ideas of the political science field to understand why the two forces did not go to war.

This use of narrative in opening up models, rather than closure, may actually be rather common in science. Regardless of how scientists get to their models (and of the accounts philosophers give to these processes), there is an important moment when scientists seek to go on from their theoretical models to try to make them fit the materials from the world. Narratives emerge in the process of using the model to speak directly about particular situations, cases and contexts in the world (as in the example above). For some philosophers of science, this is called model application, for others it might be termed de-idealisation (Knuuttila and Morgan 2019), but the process of making the model fit a particular world is much the same, and narratives are a significantly useful tool in doing so.

Looking at the histories of particular models, it has often been found easier to incorporate additional elements to the base model rather than go back to start anew, and narrative can play a key role here. Much modelling work involves the application of an existing model, with some revisions, to another problem in the field, often motivated by a narrative rationale for such application. This might be especially true of model transfers between fields. For example, Quack and Herfeld (2023) trace how the problem of understanding political coalitions involved the transfer of game-theoretic models from economics into political science, where that transfer depended on narratives (both thinner and thicker) of empirical cases to justify the relevance and fit of the model transfer. To what extent this transfer relies on the fact that stories may be constituted in the core of game theory (in the narrative 'rules of the game', see Morgan 2007b) is one interesting question here. Another might be to look for the role of narrative in arguably the most famous historical transfer of game theory—from mathematics and social sciences into evolutionary biology models. As in the process tracing of Crasnow's example (above), narrative emerges as an indispensable companion to model work, not just in historical moments, but as part of everyday practice found in a variety of sites in the sciences.

4. Conclusion

Both model-making and narrative-making are part of the creative practices of science. Model-making and -using offer means of *enquiry into both theories and the phenomena* of the world that the theory is about. Narrative-making and -using offer ways of *making sense of those phenomena* by configuring disparate elements together and exploring their implications. Narratives provide inputs to model creation: they are sometimes constitutive in the scientific laws/theories/mechanisms embedded in the model; they sometimes feature as connectors or closers in model-making. They are often used and developed to explore the models' possibilities; to help develop models in a field; and as suggestive quality controllers with associated criteria (that is, complementary to formal testing devices). Narratives are not models, and models are not narratives, but in usage, they have similarities as representational devices, and in explanation and reasoning about scientific phenomena. They have synergies of practice which create many areas of collaboration for scientists using them together: they function as good companions.

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Notes

1 This account of narrative draws on research undertaken for the Narrative Science Project at LSE: www.narrative-science.org/ and references many of the book chapters of Morgan et al (2022) and *Anthology* resources of that project; and before that for Morgan and Wise (2017).
2 This account is sometimes called the 'artefactual' account of models (see Knuuttila 2011), but much of what is argued here might be just as relevant for other understandings of the nature and role of models in science.
3 For the distinction on how models represent, see Morgan (2007a); for an extensive account of model organisms, see Ankeny and Leonelli (2020).

4 This focus on the role/function of models as a means of enquiry comes from the 'models as mediators' account (Morgan and Morrison, 1999).
5 For example, definitions within literary theory and narratology may require many more conditions: e.g., a 'beginning, middle, and end'; a 'change of state between beginning and end'; the 'role of human agency'; etc.
6 This account of narratives as 'a general purpose technology' for sense-making in science draws on the many workshops, projects, and collaborators involved in the ERC project referenced above in note 1.
7 Further narrative examples from the chemistry of making things can be found in extracts and commentaries by Mat Paskins in *Narrative Science Anthology II* (entries XIX and XXVI) on recipe narratives; and by Sabine Baier in *Anthology I* (entry VIII) on narratives as a navigation tool.
8 See Hopkins 2022, and *Narrative Science Anthology II*, XXVII and XXVIII.
9 A parallel small story usage in physics is given in Hartmann's (1999) account of the development of the 'MIT Bag model'.
10 An alternative framing that makes use of the 'stories' element is suggested by Cartwright (2010) who suggests that models are 'fables' in their relation to scientific laws but 'parables' in relation to the empirical world.
11 These qualities can be framed in philosophy of science as equivalent to fulfilling the full set of *ceteris paribus* conditions on a model (see Boumans and Morgan 2001) but are rarely portrayed as a critical test of model completeness.
12 See Hajek (2022) on narrative closure in science; and Carroll (2007) which engages with both philosophy and narrative on the issue of closure; see also Anand (2023) and Morgan and Stapleford (2023).

References

Anand, Ibanca. 2023. "Resisting Narrative Closure: The Comparative and Historical Imagination of Evsey Domar." In Morgan and Stapleford, 497–522.

Ankeny, Rachel and Sabina Leonelli. 2020. *Model Organisms*. Cambridge: Cambridge University Press.

Beatty, John. 2022. "Narrative Solutions to a Common Evolutionary Problem." In Morgan, Hajek and Berry, 405–423.

Beck, M. Bruce. 2014. "Handling Uncertainty in Environmental Models at the Science-Policy-Society Interfaces." In *Error and Uncertainty in Scientific Practice*, edited by Marcel Boumans Giora Hon and Arthur C. Petersen, 97–136. London: Pickering & Chatto.

Bianchi, Marina, and Roberta Patalano. 2017. *Storytelling and Choice*. Rounded Globe: https://roundedglobe.com/books/1dd3bc40-0775-4182-87a1-d20e0529076f/Storytelling%20and%20Choice/

Biddle, Jeff. 2023. "Narratives and Empirical Strategies in Zvi Griliches Early Research." In Morgan and Stapleford. 447–470.

Boumans, Marcel. 1999. "Built in Justification." In *Models as Mediators*, edited by Mary S. Morgan and Margaret Morrison, 66–96. Cambridge: Cambridge University Press.

Boumans, Marcel and Mary S. Morgan. 2001 "*Ceteris Paribus* Conditions: Materiality and the Application of Economic Theories." *Journal of Economic Methodology* 8(1): 11–26.

Campbell, Donald T. 1975. "'Degrees of Freedom' and the Case Study." *Comparative Political Studies* 8(2): 178–193.

Carroll, Noël. 2007. "Narrative Closure." *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition* 135(1): 1–15.

Cartwright, Nancy. 2010. "Models: Parables v Fables." In *Beyond Mimesis and Convention: Representation in Art and Science*, edited by Roman Frigg and Matthew Hunter, 19–31. New York: Springer.

Crasnow, Sharon L. 2017. "Process Tracing in Political Science: What's the Story?" *Studies in History and Philosophy of Science* 62(April): 6–13.

———. 2022. "Process Tracing and Narrative Science." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 229–245. Cambridge: Cambridge University Press.

Currie, Adrian and Kim Sterelny. 2017. "In Defence of Story-Telling." *Studies in History and Philosophy of Science*. 62(April): 14–21.
Hajek, Kim M. 2022. "What Is Narrative in Narrative Science? The Narrative Science Approach." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 31–57. Cambridge: Cambridge University Press.
Hartmann, Stephan. 1999. "Models and Stories in Hadron Physics." In *Models as Mediators*, edited by Mary S. Morgan and Margaret Morrison, 326–346. Cambridge: Cambridge University Press.
Hirschman, Albert O. 1970. *Exit, Voice, and Loyalty*. Cambridge, MA: Harvard University Press.
Hopkins, Andrew. 2022. "The Narrative Nature of Geology and the Rewriting of the Stac Fada Story." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 82–103. Cambridge: Cambridge University Press.
Huss, John E. 2022. "Mass Extinctions and Narratives of Recurrence." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 61–81. Cambridge: Cambridge University Press.
Knuuttila, Tarja. 2011. "Modelling and Representing: An Artefactual Approach to Model-based Representation." *Studies in History and Philosophy of Science* 42(2): 262–271.
Knuuttila, Tarja and Mary S. Morgan. 2019. "Deidealization: No Easy Reversals." *Philosophy of Science* 86(4): 641–661.
Kranke, Nina. 2022. "The Trees' Tale: Filigreed Phylogenetic Trees and Integrated Narratives." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 206–226. Cambridge: Cambridge University Press.
MacCormick, Neil. 2005. *Rhetoric and the Rule of Law: A Theory of Legal Reasoning*. Oxford: Oxford University Press.
Mari, Luca and Alessandro Giordani. 2014. "Modelling Measurement: Error and Uncertainty." In *Error and Uncertainty in Scientific Practice*, Marcel Boumans, Giora Hon and Arthur C. Petersen, 79–96. London: Pickering & Chatto.
Meunier, Robert. 2022. "Research Narratives and Narratives of Nature in Scientific Articles: How Scientists Familiarize Their Communities with New Approaches and Epistemic Objects." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 247–266. Cambridge: Cambridge University Press.
Morgan, Mary S. 2001. "Models, Stories and the Economic World." *Journal of Economic Methodology* 8(3): 361–384; Reprinted in *Fact and Fiction in Economics* (2002) edited by Uskali Mäki (Cambridge University Press, 178–201) [Research Memorandum in History and Methodology of Economics, University of Amsterdam, 1999].
———. 2006. "Economic Man as Model Man: Ideal Types, Idealization and Caricatures." *Journal of the History of Economic Thought*, 28:1–27.
———. 2007a. "Reflections on Exemplary Narratives, Cases, and Model Organisms." In *Science Without Laws: Model Systems, Cases, Exemplary Narratives*, edited by Angela Creager, M. Norton Wise, and Elizabeth Lunbeck, 264–274. Duke University Press.
———. 2007b. "The Curious Case of the Prisoner's Dilemma: Model Situation? Exemplary Narrative?" In *Science Without Laws: Model Systems, Cases, Exemplary Narratives*, edited by Angela Creager, M. Norton Wise, and Elizabeth Lunbeck, 157–185. Duke University Press.
———. 2012. *The World in the Model*. Cambridge: Cambridge University Press.
———. 2017. "Narrative Ordering and Explanation." *Studies in History and Philosophy of Science*, 62: 86–97.
———. 2020. "Inducing Visibility and Visual Deduction." *East Asian Science, Technology and Society*, Special Issue 14: 22552.
———. 2022. "Narrative: A General Purpose Technology for Science." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 3–30. Cambridge: Cambridge University Press.
Morgan, Mary S. and Margaret Morrison, eds. 1999. *Models as Mediators*. Cambridge: Cambridge University Press, *Ideas in Context* Series.
Morgan, Mary S. and Thomas A. Stapleford. 2023. "Narrative in Economics: A New Turn on the Past." In *Narrative in Economics: Historical Experiences. History of Political Economy*, edited by Mary S. Morgan and Thomas A Stapleford, 395–422. Duke University Press.

Morgan, Mary S. and M. Norton Wise. 2017. "Narrative Science and Narrative Knowing: Introduction to Special Issue on Narrative Science." In *Narratives in Science*. Special Issue of *Studies in History and Philosophy of Science* Vol 62, edited by Mary S. Morgan and M. Norton Wise, 1–5. Elsevier Ltd.

Morrison, Margaret and Mary S. Morgan. 1999. "Models as Mediating Instruments." In *Models as Mediators*, edited by Mary S. Morgan and Margaret Morrison, 10–37. Cambridge: Cambridge University Press.

Narrative Science Anthologies I and *II* at https://www.narrative-science.org/anthology-of-narrative-science.html

Olmos, Paula. 2022. "Just-So What?" In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 424–444. Cambridge: Cambridge University Press.

Otto, Sarah P. and Alirio Rosales. 2020. "Theory in the Service of Narratives in Evolution and Ecology." *The American Naturalist* 195(2): 290–299.

Paskins, Mat. 2022. "Thick and Thin Chemical Narratives." In *Narrative Science: Reasoning, Representing and Knowing since 1800*, edited by Mary S. Morgan, Kim M. Hajek, and Dominic J. Berry, 267–286. Cambridge: Cambridge University Press.

Priest, Greg. 2018. Diagramming Evolution: The case of Darwin's Trees." *Endeavour* 42(2–3):157–171.

Quack, Alexandra and Catherine Herfeld. 2023. "The Role of Narratives in Transferring Rational Choice Models into Political Science." In *Narrative in Economics: Historical Experiences*. *History of Political Economy*, edited by Mary S. Morgan and Thomas A Stapleford, 549–576. Duke University Press.

Rosales, Alirio. 2017. "Theories that Narrate the World: Ronald A Fisher's Mass Selection and Sewall Wright's Shifting Balance." In *Narratives in Science*. Special Issue of *Studies in History and Philosophy of Science* Vol 62, edited by Mary S. Morgan and M. Norton Wise, 1–5. Elsevier Ltd.

Tuckett, David and M. Nikolic. 2017. "The Role of Conviction in Decision-making under Radical Uncertainty." *Theory & Psychology* 27(4): 501–503.

Wise, Norton M. 2017. "On the Narrative Form of Simulations." In *Narratives in Science*. Special Issue of *Studies in History and Philosophy of Science* Vol 62, edited by Mary S. Morgan and M. Norton Wise, 74–85. Elsevier Ltd.