1 Narrative: A General-Purpose Technology for Science

*Mary S. Morgan**

Abstract
Narrative is ubiquitous in the sciences. Whilst it might be hidden, evident only from its traces, it can be found regularly in scientists' accounts of their research, and of the natural, human and social worlds they study. Investigating the functions of narrative, it becomes clear that narrative-making provides scientists with a means of making sense of the materials in their field, that narrative provides a means of representing that knowledge and that narrative may even provide the site for scientific reasoning and knowledge claims. Narrative emerges as a 'general-purpose technology', used in many different forms in different sites of science, enabling scientists to figure out and to express their scientific knowledge. Understanding scientists' use of narrative in this way suggests that narrative functions as a bridge between the interventionist practices of science and the knowledge gained from those practices.

1.1 Introduction

Scholars of scientific life see it filled with experiments, models, theories, descriptions, observations, categories, etc. It is equally full of narratives. Yet

* The Narrative Science Project was funded by the European Research Council under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 694732), whose activities are reported in great detail on the project website: www.narrative-science.org/. This chapter – especially in footnotes – refers to a number of resources on that site, particularly the reports of our workshops, and the entries in our two *Anthologies* (*Anthology I* 2019 and *Anthology II* 2022). This project grew out of an earlier collaboration with Norton Wise that resulted in a special issue (see Morgan and Wise 2017) and I am grateful for Norton's 'wise' advice throughout this current project, including on this chapter. Special thanks for their help with this chapter go to Roy Weintraub, Sarah Dillon, Tarja Knuuttila, Claudia Cristalli, William Twining, Martina King and Brian Hurwitz; to the team of postdocs on the project and the wider team of authors in this book for all they have taught me, and especially to Kim Hajek and Dominic Berry for their incredible hard work on this book.

https://doi.org/10.1017/9781009004329.002 Published online by Cambridge University Press

the levels at which narratives work, and the kinds of things that scientists come to understand through the activities of developing their narratives, are not easily described in terms of any specific ambitions or functions. Narratives themselves may be understood as a broad class of 'epistemic genre', to use the label that Pomata (2014) developed, essential to the representation of scientific knowledge.[1] But narrative is more than just a means of representing such knowledge; rather, prior to such representations, narrative-making plays a wider role in the sciences as a means of sense-making. In contrast with Crombie's (1988) historically situated categorization of ways of doing science, an account developed further in Hacking's (1992) philosophical analysis, narrative-making is not mainly about how scientists investigate the world but rather about how they make sense out of those investigations. Narrative-making does not satisfy epistemic questions and worries in the way the interventionist and observational modes of doing science described by Hacking (and others) – such as experimenting, category making, statistical work and case-making – can do. Narrative-making and -using, by contrast, are more closely aligned with ontological questions, or, rather, scientists' claims in their 'narratives of nature' are ontological claims about the way the world is and works. The role of narratives piggybacks onto the epistemology of those other, more interventionist modes of practising science. So, while narrative usage may overlap in places with Pomata's notion of 'epistemic genres' and can be an accompaniment to Hacking's modes of doing science – narrative-making and -using fulfil other distinct roles for scientists, roles that need separate recognition.

Narrative emerges from this volume as having three functions for scientists: narrative-making operates as a means of making sense of their puzzling phenomena; it provides a means of representing that scientific knowledge; and it provides resources for reasoning about those phenomena. These three functions are related: it is because scientists often make sense of their world by making narratives that they then use those narratives to represent what they believe they know, and thence to reason with them. I propose we think of narrative as a 'technology of sense-making' that enables scientists to bridge between their interventionist activities of exploring the world and their knowledge claims about the world, that is, between their epistemic and

[1] Pomata (2014) labelled certain kinds of texts in science 'epistemic genres' in contrast with the genres recognized in literature. As she argued (in a historical account of changes in medical reporting), an epistemic genre: develops 'in tandem with scientific practices'; is 'deliberately cognitive in purpose'; is linked 'to the practice of knowledge-making'; and has a 'primary goal' of 'the production of knowledge'. These have certain parallels in the claims made in this chapter about the roles of narrative in science, but the functions I attribute to narrative-making have greater agency in *doing* science.

ontological realms. To label narrative a technology may seem rather strange, but we are in some interesting company here. The philosopher John Dewey argued that the notion of technology was not just about how to make things in the economy, but equally attributable to the abstract and intangible work of enquiry and deliberation involving cognitive work – just as we find for narrative in science.[2] His contemporary, the sociologist-economist Thorstein Veblen, insisted on the priority of the human element in designing, making and using a technology. While narrative-making, -using, and -reasoning start with the scientist and their community, it is worth remarking that narrative also embeds its own technical elements and attributes. These three separate but related functions of narrative, broadly understood as a technology of sense-making for scientists, may be recognized in the chapters of this book by observing whether narrative is being used as a noun, verb or adjective.

All those nouns of scientific practice – experiments, models, theories, descriptions, observations, categories – hide actions and activities: experimenting, modelling, theorizing, describing, observing, categorizing. Other elements that scientists use don't immediately convert between nouns and verbs – data has to be given its own multiple verbs ('to gather, clean, assemble and prepare'), just as laws have 'to be discovered or made'. Narrative is akin to laws and data: easily understood and effective as a noun, its scope as an activity is not quite so obvious; yet appreciating that scope is critical for understanding the broader role of narrative as a technology for scientists. The quintessential feature of narrative is that it shows how things relate together, so that constructing a narrative account in science involves figuring out how the elements of a phenomenon are related to each other. This is why narrative-making and -using are conceived here as a technology, one that enables scientists to make sense of their phenomena.

These basic usages of narrative in *noun* and *verb* forms are important, of course, but they might be still awkward, and limited, if we want to go one step further and conceive of narrative as flourishing in the knowledge-claiming activity of the sciences. In this respect, the adjectival form is more immediately useful: so, 'narrative account' and 'narrative description' might both be taken for granted. And, while 'narrative inference', 'narrative argument' and 'narrative explanation' might initially sound strange (even perhaps contradictory), it will turn out that we need these terms, for the narrative form does overlap in usage into these scientific activities of reasoning and knowledge-making. Thus, narrative as an *adjective* works as an attribute of a certain form of reasoning: giving a satisfactory narrative

[2] I thank Teru Miyake for drawing my attention to Dewey's insight, best followed in Hickman (2001).

https://doi.org/10.1017/9781009004329.002 Published online by Cambridge University Press

account may go beyond sense-making into the kinds of reasoning associated with inference and explanation.

None of these uses of the term narrative – in noun, verb or adjectival forms – should be problematic if we can find ways to appreciate the active work that narrative does in our sciences, particularly if we can figure out its features and its functions, just as we have for data and laws. These grammatical labels give clues, but only clues, to the ways in which scientists develop, create and use narratives in their various fields, for various purposes and in conjunction with various other forms of scientific representation and knowledge-making activities. These language terminologies need to be filled in with examples and hardened through analyses to reveal the active work we attribute to narrative in science, and so to appreciate how narrative operates as a technology for scientists in doing science.

There are, of course, many commentaries about narrative in other domains, especially in the fields of literature, narratology and legal studies. Narrative scholars from the domain of literature typically focus on the narrative as text: its plots, its structure, temporal and spatial organization, its eventfulness and cognitive function, as well as its rhetorical and aesthetic components, and terms of affect. Narratologists tend to focus on the narrators, readers, what constructions narratives follow, and their requirements for narrative tellability. It is fair to say that with few notable exceptions, neither group focuses especially on connections of narrative with knowledge-making.[3] So, in an important chapter, Kim Hajek explores what is narrative about ‘narrative science’, and thus extends the relevant intersections of those fields with our agenda (Chapter 2). Discussions in the field of law about narrative range over matters of rhetoric and affect, but have an equal interest in the putting together of evidence, and the role of ‘theory’ – meaning both the hypothesis about what happened in a particular case, but also the concepts from law that need to be taken into account.[4] As such, these latter interests fit closest to those of this chapter. But rather than work comparatively with this legal literature I treat narrative in science on its own terms – in order to examine how it makes itself ‘at home’ in the scientific knowledge environment.

[3] Dear (1991) is a notable early work in the field (on which more later in section 1.6). Of four current books that overlap with our agenda to treat narrative in science seriously: Fludernik and Ryan (2020) attends to narratives in factual spheres (while our focus is on narratives in science, which are often, or not only, about ‘facts’); Carrier, Mertens and Reinhardt (2021) are concerned with the contrasts and intersections of narratives and comparison in science; Dillon and Craig (2021) analyse how narrative can be used alongside scientific evidence in the public domain on account of the cognitive value of narratives; and Kindt and King (forthcoming) focus on narrative knowledge-making from a sample of ancient to modern texts.

[4] See, especially, Nicolson ((2019): chap. 7); Twining ((2002): chaps. 13–14); Twining ((2006): chaps. 9–13). Thanks to William Twining for introducing me to this literature and discussing it with me.

Narrative is a broad, expansive term (with many definitions in narrative theory), and the challenge has been to develop an analysis which is insightful for scientists' creation and use of narrative. Our research shows narrative to be an enabling, general-purpose technology, widely used by scientists within their own different communities to fulfil certain functions in their scientific work – even when they don't use the word or recognize that label for their activity. It is important to note the limits of this claim: narratives are not found in all aspects of all sciences. Rather, they fulfil certain kinds of function with some regularity in some sciences, or some sites of science, and in conjunction with some methods of doing science. By tracing this (sometimes hidden) narrative activity, and its locations, we can understand both what is different and what is generic in these usages in different sites, and so develop an understanding of narrative in the domains of science.

1.2 Narratives of the Field

The first challenge we address in this book is to see and locate the narratives that appear in our sciences. The most obvious narratives found in science may be those wrap-up accounts in publications resulting from the activities of scientists. In modern science, these are usually impersonal narratives,[5] cut down to the essential actions that scientists tell of how they went about their research: their 'research narratives'. Less recognizable, but still apparent, as Robert Meunier argues (Chapter 12), are their 'narratives of nature': the narratives – 'as if told' by natural, human and social life – that those scientists have tried to reveal, recover and make sensible. And, as he points out, scientists' research narratives often twine in symbiosis around their narratives of nature.[6] This has fruitful consequences: the researcher–author, in guiding the scientist–reader along the path of their activities, enables the latter to gain practical familiarity with the former's narratives of nature, particularly with any new elements and concept set in use.

A broader category of narratives can be found that seek to define and lay boundaries to new approaches for a whole field, or maybe to delineate a new interstitial field. These field-making narratives might be more or less reticent in their agenda. Grand ones are epitomized in the self-proclaimed narratives of those seeking to automate and computerize the whole of mathematics. Stephanie Dick (Chapter 15) discusses two such competing self-narratives in

[5] The significant exception is anthropology, where the scientist must be personally present in their narratives, and attend to the narrative text they create, to signal professional credibility (see entry on Geertz, *Anthology II*).

[6] These 'research narratives' and 'narratives of nature' are often openly related in medicine and management sciences, where scientists and their subject participants recount, and often share, their expert and experiential knowledge via narratives.

late twentieth-century American mathematics: one group sought to reformulate all mathematical knowledge into one single form, and the other to enable all mathematicians to contribute elements in their own format.[7] Their politics of control vs. pluralism were explicit. Other field narratives may be more opaque, evident only in their alignments and commitments, to be discovered by an outside reader, as Dominic Berry (Chapter 16) does in looking at how 'synthetic biologists' positioned themselves between engineering and biology in defining and growing their own field. He uses longue durée changes in history writing – from chronicles through genealogies to narratives – to argue his case. These are important categories. Chronicles report events solely based on their place in a time sequence without paying attention to any relationships between those events; *genealogies* focus on the 'family' (broadly construed) relationships between the events or objects; *narratives* provide an account of the relationships between events or objects (whether or not these relationships are tied together in a time sequence or by family connections). Among narratologists, there is a widespread view that a chronicle does not count as a proper narrative because the relational content is absent, while genealogies are just a subset form of narratives. Anne Teather (Chapter 6) adopts the same categories to show how new technologies of dating in archaeology have effectively changed narrative practices in that field. Whereas archaeologists used to tell *genealogical* accounts to frame the periods of prehistory (e.g., the Neolithic period), more recent technologies of investigation have created the more limited *chronologies* or *chronicles*.

Certainly, the narratives of nature – narratives of how the world is and how it works (whether it be the natural, human or social world) – are sometimes much harder to see than these research and field-making narratives. Narratives of nature are more likely to be found implicated with, or inside, other accounts of scientific activity. Like those sherds and trenches of Teather's archaeological sites, these traces of narrative point to the scientific activities that created them, and from which we must reconstruct the power that narrative-making and narrative-using have in such spheres.

1.3 Narrative: A Means of Scientific Representation

The core function of what narrative does is to bring and bind elements in a subject field together. Narrative-making in the sciences can be found in theorizing, in creating an adequate description of empirical materials or in marrying them to each other in ways that embed ideas and concepts,

[7] This chapter originated in our project workshop on narrative in mathematics. See workshop on mathematics on project website: www.narrative-science.org/events-narrative-science-project-workshops.html.

that is, in activities of sense-making and knowledge-making (examined in sections 1.4 and 1.5). Since the narratives that result from these activities express, or make evident, these connections between elements in a scientific domain, narratives can be treated as a form of scientific representation akin to other forms of representation. What are the characteristic aspects of such representations, and the implications of this way of understanding the role of narratives in science?

First, narrative representations found in science may appear as free-standing or separate pieces of verbal text – in ordinary or natural language. They might be embedded in visual representations (drawn into schemas such as diagrams of mechanisms or detailed representations of empirical matters in graphs), or even expressed in the completely formal languages of abstraction and mathematics. Wise (Chapter 22) contrasts the possibilities of natural and formal languages, and the extent to which they do different kinds of work, and say different things, and thus why narratives in the two forms are not simple translations or transpositions of each other. Depending on the science in question, the narrative form of representation will be more or less formalized, more or less abstract, and may have more or less dimensionality of elements compared to other representational forms of diagrams, equations and so forth. But, whatever their form and language, it is typically the case that they are 'community narratives', to be understood without further explanation or accompanying text only by those in the expert community who use them. Mat Paskins (Chapter 13) translates/explains, for us lay-readers, the 'chemese' of chemical reaction diagrams depicting the synthesis of particular molecules. He points out that early twentieth-century versions told a different narrative from early twenty-first-century versions of essentially the same representation: in early years, the 'equation' expressed the sequence of steps taken to synthesize a certain chemical, but in later years, such diagrams came to narrate the chemical reactions that took place. The 'cartoon' narrative shown in Andrew Hopkins's chapter (Chapter 4) relates what happens in a meteorite impact as material explodes, flows out and gradually builds up deposits on the ground. This requires, for the lay reader, a lengthy verbal narrative that lets us follow the combinations of interacting processes and outcomes from these geological events.[8] In other cases, indirect representations of nature (such as mathematical models) are manipulated to show the narratives implicit in visual schematic representations. We find such narratives in the computer visualizations from simulating snowflake growth and the processes of chemical reactions, as shown by Wise (2017); the latter offers an alternative free-standing, time-stepped,

[8] Another great example is found in Hopkins's analysis of three different geological diagrams depicting different theories and dimensions of the formation of the continents over long geological time (in *Anthology II*).

https://doi.org/10.1017/9781009004329.002 Published online by Cambridge University Press

visualization of the chemical reaction 'equations' found in Paskins's paper (Chapter 13). Such narratives give clues to the density of knowledge that typically lies behind formal language representations.

Second, more often than free-standing independent forms, textual narratives are strongly co-dependent with other forms of scientific representation, such as charts, graphs, drawings, maps, matrices, models, formulae and so forth. Such textual narrative accompaniments might well be an essential part of the identity of those representations, whether of the evidential diagrams in graphs or of the theory-based representations found in models. The classic well-known example is Darwin's pictorial 'tree of life', which – when read alongside textual information – offers a shorthand depiction showing how evolving species branch, or die out, or survive. It is a kind of genealogy – but a conceptual tree not a report of observations. Greg Priest describes this as a 'scaffold' on which we as readers can stand to 'create narratives that enable us to understand' Darwin's account of natural evolution.[9] The infamous 'prisoner's dilemma' model from economics (which was soon transferred to other social-science and biological domains) consists of a mathematical matrix, a set of inequality conditions on those numbers, and a narrative text of the possible behaviours of the 'prisoners' given the 'dilemma' of their situation (termed by economists, 'the rules of the game'). The narrative is an essential element in identifying the game and differentiating it from others that may look similar, for the matrix and inequalities are both insufficient (see Morgan 2007). Combinations of text and drawings (keyed with numbers to each other) are found as essential partners in communicating narrative accounts of metamorphic changes in the insect world (from egg to caterpillar, larva to butterfly), as seen in Mary Terrall's (2017) discussion of eighteenth-century accounts of this phenomenon. Such matching media of visual and text narratives, in which neither is primary but each depends on the other, are also used to explore possibilities of hypothetical events as we see, for example, in D'Onofrio's account of eighteenth-century generals re-running historical battles according to geometrical lines (in *Anthology II*).

There is often a kind of bonding here, rather than co-dependency, of forms and functions. Narratives embedded in formal languages and visual representations often provide a highly efficient rendering of the materials of events. The phylogenetic trees of the evolution of the kangaroo and other marsupials discussed by Nina Kranke (Chapter 10) express a travel saga that charts their geographical and biological evolution over time and space as the species evolved while members of its ancestral population 'journeyed' from South America to Australia. As she shows us, such 'trees' exist in multiple formats – showing in succinct ways, but with distinctly different variants,

[9] See Priest's extract from Darwin, and his commentary, *Anthology II*.

the narratives of different kinds of family trees or genealogies. Some of these are for professional audiences, some for museums; some are plain, some 'filigreed'; some read upwards, some downwards, some sideways. There is no one convention despite the related kinds of narratives that are told by these related kinds of trees. There is surely a family tree of such trees, a genealogy of trees, going forward in evolutionary biology from Darwin's tree of life, and going back in time in a long tradition of drawing human dynastic trees.

This complementarity, and bonding, of narratives alongside and inside alternative representations show how narratives fulfil their representing functions in the sciences and how narratives do the kind of representing work they do. These kinds of co-dependency also suggest there are *no* strong reasons to privilege narratives as a text form when narratives can find their primary expression in other forms of representation. Narratives in the visual, schematic or even mathematical forms of representation may perform by *showing* as much as by *telling*; they are designed to be 'seen' by others in the same community of scientists who know how to 'read' them. For example, Martina Merz (2011) recounts how readers of a scientific paper in a particular field of physics will automatically follow the diagrams that are arranged in a clockwise fashion at the beginning of the paper – these 'show not tell' the research narrative of the salient activities, and readers follow that visual narrative before bothering to read the text of the paper. In some cases, nature's entities show their own narratives directly. Devin Griffiths (Chapter 7) tells how the Darwins set up plants so that their roots traced out their own growth narratives in scientific experiments. Starting from these visual autobiographies, Darwin constructed narratives at three different genre (i.e., generic) levels: 'micro-narratives' of individual plant life, the 'novella' of the life history of plants and the saga of biological evolution.

In sum, I argue two points: first, that narratives (like models, diagrams, equations, graphs, etc.) can be understood as a mode of representing scientific things (ideas, theories, processes, evidential records, relations, etc.); and second, that such narrative forms are quite likely to hybridize or be co-dependent with, or even entirely embedded within, those other media of scientific representation.

1.4 Narrativizing: A Means of Sense-Making

Narratives in science are not given by God, or by some other external authority, but designed and made by scientists in their research communities. Attention has to be given to the ways that they create narratives as a means of sense-making – to the active work of narrative formation in the practices of scientists, especially with respect to their narratives of nature.

There are two points here:

1. I take it that the quintessential function of narratives of nature in science lies in making, or unravelling and remaking, connections between things. The world presents many puzzles and scientists seeking to understand their phenomena in their 'narratives of nature' have to figure out how that part of their world works, and to give an account of how the bits of it fit together that makes sense. And, like other ways of making other kinds of scientific representation (such as models, schemas, diagrams, tables and category descriptions), narratives have to be developed, tried out, calibrated against other information, reconfigured and re-thought-out to fit the materials that need to be understood. I have in mind something like 'narrativizing' – which has the primary and distinctive aim of 'bringing and binding' together the heterogeneous elements associated with the phenomena in a field.
2. Following this, I ask: what relational 'grids' and scaffolds do scientists use to build their narratives? This is *not* a question about the structure of the final narrative (whether it has to have a beginning, middle and end with a change of state (see Carrier, Mertens and Reinhardt 2021), nor whether it is primarily 'tellable' in terms of sufficiently interesting events (see Ryan 1986), nor on its 'affect' and how it facilities multiple connections (see Jajdelska, Chapter 18). Rather – this is a question about the basic dimensions of relations that scientists use in building or creating or supporting their narratives; it is about the lines of relationship on which narrativizing goes on.

First: what happens in narrativizing? The basic role of narrative and its special function for scientists is to put diverse materials into relation with each other through time, or across space, or through other conceptual dimensions (such as classes in society, or elements in an ecology) in order to form a coherent account of a phenomenon. Narrativizing is a way for scientists to organize their bits of scientific knowledge to create sense out of their relations. Narrativizing serves to join things up, glue them together, express them in conjunction, triangulate, splice/integrate them together (and so forth). Yet, the need to clarify relations between things means that narrativizing sometimes means scientists have to sort things out so that their interrelations can be seen more clearly.

One term that captures the challenge that scientists face when they make narratives – explicitly or implicitly – to help them order and relate the separate elements of their scientific knowledge into coherent accounts is *configuring*. This term comes from Mink (1970 and 1978), writing about the philosophy of history, but he remained opaque about the processes involved. Two other terms, discussed in Morgan (2017), offer recipes with more content for science narrativizing. *Colligating* comes from William Whewell, who used it to refer to the process of fitting together, under an idea, items primarily from the empirical domains of science (see Cristalli 2019; Kuukkanen 2015; and Swedberg 2018). *Juxtaposing* was the other term I used then – to refer to the activity of pulling together separate elements known about a phenomenon, but that did not initially make sense together. Narrativizing, constructing a narrative, was a way to make sense of them and resolve initial puzzlement. (This followed a lead from Paul Roth (1989), again for philosophy of history, rather than for science.) Both recipes offer the possibility for creating wider narrative-based understanding or even explanations (as we will see in section 1.5). I want to press the use of Whewell's terminology of colligation for two reasons. First as a process (in verb form), colligating involves *bringing* elements together and *binding them together* just as narrative-making does; the outcome (its noun form) is equally appealing, for a narrative can be understood as a colligation. (A little care is needed here: while narrative-making in science can be understood as a process of colligating (the verb), not all colligations (nouns) necessarily come from narrative-making; for example, the elements brought together could be similar things, bound together in creating a category.)[10] Second, with these two insights of bringing and binding, it is easy to see how the process of colligation can cover the many varied ways in which scientists use narrative to bring together all sorts of different kinds of elements: empirical elements, theoretical arguments and speculative claims. These practices of colligation vary from site to site, and from science to science. Thus configuring elements into a narrative that explores a time-based, path-dependent system in nineteenth-century biology mobilizes a different mode of ordering and relating, both from the juxtaposing narratives of mid-twentieth century case studies in sociology and from the 'how possibly' puzzle narratives of modern mathematical and computer-based simulation.

These examples take us to the second point: how does this narrativizing go on? We find two main sense-making strategies, two main relational 'grids' for colligating: one based on taking a possible network of relationships as the main device for ordering materials, the other by ordering elements along space or time lines. 'Grids' are not to be understood as rigid measuring rods, but rather as a shorthand way to express the main domain upon which the process of colligation – the ordering and relating, the bringing and binding together of elements – happen. These different kinds of grid are not straightforward in use, and often they are used conjointly, because the materials that need to be knitted together in science narratives are not going to be simple connections between elements as if lined up along an individual piece of string, whether that string is a time or space string or a causal path string.

[10] See particularly Wise (2021), who outlines the importance of colligating for understanding the role of narrative in science; and chapter 6 of Kuukkanen (2015), which discusses colligating in the context of history, and explicitly refers to categorizing in that context.

A 'cat's cradle' offers an analogy for narrative-making for the first, causal/associational, version (a term offered in Anne Teather's chapter). It is a net made from one joined-up piece of string that can be fashioned into several different network patterns. Each network pattern will be different, for it uses the same elements of the string arranged in different ways. Each network pattern can be understood as depicting a set of relationships; the nodes and spokes of the elements may denote an ambiguous relationship, or be causal in a mechanistic kind of way, or they may indicate a much looser association. Indeed, the benefit of colligating or narrativizing on a network grid is that the resulting narrative can be opaque about the exact nature of those relations; it can allow knowledge to be uncertain; it can allow for multiple perspectives; it can enable complexity to be maintained; and it can embrace context where the cut between content and context is unclear.

Time-line and spatial relations *seem* to offer simpler grids for narrativizing. But, in practice, scientists don't rest content with creating narratives just by moving along a chronological time-line or arranging items across a spatial grid. Their use of time is not straightforward: they might use relative or absolute time; will cut time up into different units; work backwards and forwards over time, etc. And while time-based accounts in sciences may find narrative necessary, it is important to remember that time-based relations are neither a necessity for narrative, nor sufficient in themselves.[11] Of course, things happen in time, and across space, but these may not be the domains in which relationships matter. And even where either time or space may be understood as the dominant dimension for observing change (as in fields such as geology, palaeontology, evolutionary biology and parts of anthropology, sociology and social science history), there is rarely any simple time or space sequencing of events. And often, these two major kinds of grids – relational and spatio-temporal – will mix together in the narrative and will interact. Sometimes, the time–space line enables the scientist to infer subject-matter connections, at other times the subject-matter connections enable the scientist to infer the time or space relations.

It perhaps helps to draw some comparisons. The main feature of the narrative form – that it fits elements together and reveals the connections between them – contrasts with other forms and modes of making and expressing scientific knowledge. The comparison here is particularly with those activities that list

[11] Here is where the narrative science experience moves apart from the narratological assumptions, in which time relationships are *usually* taken as essential. See Morgan (2017) for the argument that time ordering is a subset of narrative ordering; and see Hajek's chapter for consideration of this temporal assumption (Chapter 2). Many of these issues were discussed in our project workshop on 'Temporality in Scientific Narratives'. See workshop on temporality on project website: www.narrative-science.org/events-narrative-science-project-workshops.html.

or rank elements of knowledge, those focused on activities of separating out similarities and differences between things, and the consequent listing, labelling and describing of such taxa and types. A list of fossil remains, or the table of chemical elements, or the species of natural history, organize or 'order' our knowledge according to weights, or categories.[12] They produce nuggets of knowledge, orderings of knowledge, families of like and dislike things, and whole classification systems.

So, on the one hand, the configuring and colligating of narrative-making sit in contrast to the *making of tables and categories*: the former stitching together relations between things, the latter separating out different kinds of things according to their particular characteristics. On the other hand, those alternative forms of ordering and expressing scientific knowledge are also, like narrative, more than description, for they too are a means of organizing and representing our knowledge. Both narrative-making and category-making develop our scientific knowledge and facilitate our expression of our knowledge about the world rather than being primarily technologies of intervention in the world. And, as usual, there is a caveat: the sense-making quality of narratives (the attempt to find narratives of nature) can also work *co-dependently* with those other contrasting activities and forms in science (category-making, case-making, statistical thinking and so forth). Narrative ordering and relating do not always substitute, or replace, but may complement other modes of developing knowledge in science. Narrative-making is one potential element, often an essential one, in a multifaceted network of practices that enables scientists to develop ideas and accounts of their domains.

1.4.1 Joining Things Up

The two main relational grids of narrative-making in science, as suggested above, are the spatial- or time-line and the relationship net. Narratives are widely accepted to provide the kind of glue that helps us to 'follow' a set of events through time, or across space. Free-standing, time- or space-sequenced narrative representations are found most readily in the historical sciences – natural and human/social – for these deal in matters of time and space *and* where such dimensions of ordering really matter.

Where time and/or space does matter, scales, measures of time and space, and ways of dating and locating events, may be critical to the kind of narrative made. John Huss (Chapter 3) analyses the competing narratives of the set of major mass extinctions in the natural history domain. The mass extinctions in

[12] It is significant here that at one of the first narrative science workshops, Lorraine Daston presented an account of lists for our consideration (the work of Jack Goody) as the comparator for narrative.

https://doi.org/10.1017/9781009004329.002 Published online by Cambridge University Press

species evident in the fossil records were recorded in graphs which then had to be 'explained' by the palaeontologists – either by a narrative of a periodic event (that might possibly have an unknown astronomical cause) that repeats every 26 million years, or by individual causal narrative accounts for each individual episode. Either way, periodic or individual causes, there was a desire for 'narrative closure', the satisfaction of closing the evidential/explanatory gap between the time charts of those visual artefactual fragments of fossils and understanding the causes of the timing of these enormous events. Narrative-making here required getting a satisfactory, plausible and convincing – i.e., narratively closed – alignment of evidential remains with major events, whatever the ultimate explanation might be.

In sites such as evolutionary biology, archaeology and geology, evidential requirements from both time and space typically create narrative density and narrative complexity, as found, for example, in Anne Teather's account of narrative changes in recent archaeology. Previously, the recognition of familial relations between artefacts and their spatial distribution were used to determine the *relative time datings* of cultures, transitions and migrations, and so determine the *genealogical* periods of prehistory (the bronze age, the Neolithic period, etc.). Now, the more recent methods of dating the *absolute age* of archaeological remains (by technologies of tree ring and radio-carbon dating) determine time relations, namely the *chronologies* of those civilizations, and so have changed the nature of explanations in that field.

Narrativizing (or narrative-making) in science often relies on a kind of 'tellability' that stems, as in Ryan's analysis of 'embedded narratives' in literature, from the intersections and inter-relations of characters that prompt the events or actions that happen. That is, time and space may not be the dominant dimensions needed to follow the sequence or set of events; other relationship factors may be much more important. For example, Morgan (2017) gives an account of the narrative-making habits of social anthropologists working in American cities, where the relationships between a street gang with the police, with the political machine, and with rival gangs are all drawn through the use of narrative accounts. In such contexts where existing social/class relationships are primary, time or space as a grid has almost no value. Narrative-making does especially well in enabling accounts where causal claims contain contingency, doubt and choices, as in John Beatty's discussion of the tellability requirements for evolutionary change where the order of events is not well evidenced in a time sequence, even though they must have happened in time (2017 and Chapter 20 in this volume).

The intersection of time–space and relationship grids becomes clearer in the notion of 'process tracing', an activity discussed by Sharon Crasnow (Chapter 11) and found in many scientific fields, which involves tracing the evidence of certain relationships (in processes and between events) through time and space and other dimensions, and putting them together into a narrative account. A closely detailed narrative following political changes may be the only way to open out a full understanding of a political science phenomenon which had previously only been accounted for in a spare theorizing or model format, as she argued in studying how political scientists unravelled cases of interactions between democracies to substantiate their ‘democratic peace hypothesis’ (see Crasnow, 2017). We can see in such process tracing how narrative-making actually depends on both kinds of grid relationality – time–space relations and causal relations. It seems in her cases that it is the causal links between events which enable the process to be traced through the time–space events, rather than the other way around. By contrast, in Huss’s mass-extinction events, the time domain is the predominant medium for tracing causes.

Relational grids sometimes function more like bridges in joining up other dimensions. For example, the genetic history in Kranke’s chapter involves following materials that bridge different levels of both time and space in the processes of evolution (Chapter 10). A narrative bridge might provide the link that joins over other gaps, such as it did between different accounts of evolution by R. A. Fisher and Sewall Wright, accounts which nevertheless shared the same mathematical formulation (Rosales 2017). A bridge could offer a methodological joining up, where the research life of the scientist and their narrative of nature intersect in a joint account by the scientist, as Griffiths’s chapter shows for the Darwin family’s investigations into plant growth (Chapter 7). A narrative bridge could be a vehicle for familiarizing the community with the research done, by overcoming the mismatch between actual research events and the given record of events (as in Meunier’s account). Or it could be the way that scientists place their own particular bit of research into a longer or wider research trajectory through ‘narrative positioning’ (see Berry’s 2019 working paper, published in 2021).

1.4.2 Sorting Things Out to Join Them Up

It is one of the paradoxes of narrativizing that it sometimes only succeeds in joining things up by first sorting things out, perhaps in order to join them up in a different order or set of relations than they first appear. The world presents phenomena in puzzling and myriad forms. For example, the massive data sets that come from modern earthquakes have to be sorted out and re-aligned before they can be joined up into any narrative. As Teru Miyake’s account (Chapter 5) of the Tohoku earthquake of 2011 tells us, each measuring instrument at each geographical point produces a data series that tells its own individual story, scaled second by second. These need to be colligated: they need to be sorted out, juxtaposed, aligned and somehow melded back together to produce an integrated full narrative of that quake. Miyake shows how the visual representations of such earthquake data enable the scientists to sort and depict the complexity of an earthquake in narratives that require one to follow time evidence at different geographical points. Narrative-making does the work of both filtering and unifying these multiple records of nature. This is a time–space-rich narrative, in which absolute time matters absolutely, but its narrative focus may be less evident than in Huss's mass-extinction case because it is so strictly controlled by the technical scientific language of the field. At the same time, in both Miyake's account of earthquake science, and Andrew Hopkins's of geology, their analyses show us how narrative sense-making works underground, within and through professional accounts.

Such categorizing, sorting out and putting back together could involve a set of more heterogeneous observations, coming in different forms from different observers in different places, contributing diverse information in the empirical domain. Here the technology of colligating is more like jigsaw-making – where grids of time or space or cause are each separately insufficient, as we see in Lukas Engelmann's 'plague narratives' from the late nineteenth-century (Chapter 14). As in all pandemic diseases, there are many elements that matter, and have to be sorted out for each local account of the causes of the spread of the disease. Here, space and time may be at least as important as the multitude of possible causes that might be 'traced' and blamed for such disease transmission. This points us to how narrative-making proves a useful way to deal with complex phenomena that don't divide well, don't separate well and don't simplify or abstract easily but that have multiple elements and agencies. Just as narrative is good for following the connection of events through time, across space and through causal relations, narratives are good for taking all the elements into account without trying to separate them out on the grounds that they don't exist as separate independent elements – and the scientists' problem is to understand their interactions. That this entanglement problem can be 'solved' through narrative-making is well shown by examples in anthropology (e.g., Geertz, and du Bois, in *Anthology II*). Narrative-making is even at home where there are conflicting accounts of a phenomenon, which are resolved by understanding how these conflicts are inherent in the phenomena rather than in the scientists' understanding, as in Hajek's examples of multiple personality and memory confusion.[13]

1.4.3 Narrative Levels

There is one other important dimension in narrativizing – almost perhaps the first decision for the scientist: what is the focus of the narrative gaze; at what

[13] See in *Anthology I* and Hajek (2020) and also Morgan's 'juxtaposing' account (2017).

level of interest is the scientific phenomenon; and where is the narrative perspective? The relevant 'level'[14] may range from narratives about small atoms to the whole universe, from the single individual's preferences to the market economy, from the smallest ant to the planet's ecology. Scientists' narrative-making is a reflection of these interests and decisions. We remarked earlier how Darwin constructed micro-, meso- and macro- narratives of plant life. Teather's account shows how narrative-making works on two different levels in archaeology – at the broad epoch level of the bronze age or iron age, and at the small local level of the shape of flints to create fires, and in between in the styles of causeways. So we can think of narrative-making in that field as a process of erecting scaffolds on the basis of time-datings, relative or absolute, and then using these to understand both big cultural shifts and, equally important, really specific cultural habits.

Narrative-making can operate under a kind of umbrella for understanding a general approach within a science, or even across sciences: thus narratives of complexity theory, of catastrophe theory, and so forth. Mathematicians (as we have seen) sometimes like to frame their fields in broad and deep terms – a grand narrative of 'everything' that should fit under an approach or new form of theorizing (Dick, Chapter 15).

At the other end of the scale are 'nutshell narratives'. Some of these are 'anecdotes' that capture telling examples in very particular short narratives that point to something atypical, extraordinary, unusual or exemplary.[15] They are based on individualized observations and circulate just because they pick up things that don't seem to fit together. Such juxtapositions are critical, for it is this detection of oddity that sets up the 'epistemic switch' that makes the scientist think anew about something. In one of Hurwitz's cases (Chapter 17), it is the sudden recognition that a baby being observed is 'well' which surprises the medic. In another switch, it is from 'seeing' something as just a technical fault in a lung X-ray to the removal of a bike-spoke left from a long-ago accident to the patient! In Meunier and Böhert (*Anthology II*), it is the anecdotes of dogs learning to exchange small coins for buns at the baker's door that creates new reflections about the natures of animals vs humans. Hurwitz's epistemic switches are also ontological ones.

Anecdotes come from surprising observations, but other 'small stories' come from the scientist's imagination to prompt theory-making. Stephan Hartmann (1999) tells how a small imaginative story used to launch the 'MIT Bag model' lay behind certain theoretical developments in hadron physics. Marcel Boumans (1999) tells how the little story of a child hitting a rocking horse at

[14] This term narrative 'level' is not to imply the same usage as in literary studies.
[15] See workshop on Anecdotes on project website: www.narrative-science.org/events-narrative-science-project-workshops.html.

random intervals with random force motivated a new model of the business cycle in the 1930s. Both of these come from metaphors that were then extended and explored through narrative – a feature discussed by Gillian Beer (1983) in a literary examination of 'Darwin's plots'. In these two cases of narrative prompts to scientific model-building, the metaphor-narratives in natural language are extended into theories expressed in formal language (again, see Wise, Chapter 22).

1.5 Narrative Reasoning and Knowledge-Making

So far, we have examined the ways in which narrative provides a means, an enabling technology, for scientists to make sense of their investigations, rather than being a means of those investigations. Yet, we have also seen that narrative-making is not a passive part of science, nor an add on at the end of work, but rather (as noted by Meunier) that scientists' research narratives are symbiotic with their narratives of nature. Our cases in this volume suggest a more ambitious claim, namely that such narrative-making and -using activate scientific understanding and explanation. Narratives appear in chains and forms of reasoning associated with direct knowledge claims, which can best be expressed in terms of 'narrative argument', 'narrative explanation' and 'narrative inference'. Once again, we see that these narrative usages do not provide a competitive path to other modes of scientific reasoning and knowledge claims, but a complementary one.

1.5.1 Narrative Inference

Narrative-making and -using act as go-betweens in inferential domains – offering the means to join together, or mediate between, theories/laws and speculations on the one hand, and data, facts and specific empirical elements on the other. Drawing inferences implies a thesis of some kind that the evidence is asked to speak to; it involves making the connection from evidence to thesis. But this is rarely (perhaps never) entirely rule-bound in any science. Rather, drawing inferences involves some leaps of commitment because the evidence rarely speaks clearly, or uniformly, or exactly, and often has gaps in the chain. Constructing plausible narratives here can play a bridging role to help scientists draw and express such inferences, sometimes preliminary ones that prompt the next step, or search for further evidence.[16]

Most often narrative comes into play in inference where the evidence is heterogeneous; and where qualitative or quantitative observations need to be

[16] Morgan (2021) explores the notion of narrative inference further in the context of economists' attempts to pin down the behaviour of economic cycles.

joined up. Elizabeth Haines (Chapter 9) argues that narrative-formation offers a critical resource for picking out bits of heterogeneous evidence, fitting them together and drawing inferences from them, and constitutes a ‘reticulate practice’. As an example, she discusses how a scientist might go about picking out particulars from a crowded field of vision – for instance, in contexts such as the photographic evidence of terrains in order to figure out what is salient and what not in a problem of intelligence-gathering. Debjani Bhattacharyya (Chapter 8) gives an account of two sites of narrative inference. One, offering a similar kind of reticulate practice, is the legal site where the various records of shipwrecks during cyclones in the Indian Ocean – as told by captains and pilots, in ships’ logs and weather reports – are spliced into narratives that draw such evidence together to determine ‘the main cause’, and so apportion blame. Inferences depend here on the consideration of several different narrative accounts, each of which may point to a different cause.[17] On the other side, narrative works to aggregate cases: she tells how taking the evidence from many such storms created the meteorological science of cyclones. This new scientific understanding of the behaviour of cyclonic winds and storms was then used to create ‘storm cards’ which contained little ‘recipe narratives’ telling how ships’ captains should steer their ships when they found themselves in such a cyclone.

Such inferential judgements and arguments may look informal and squashy, and of course such narratives may only be partially informative. But all inference has an element of informal connections to be made. Even statistical inference, which may be strongly supported by statistical rules and criteria, needs subject-matter analysis in order to make sensible claims to answer scientists’ questions. We see this in Lukas Engelmann’s plague narratives. Different narrative accounts of past and current episodes of plague and its treatment based on varied sources of observation were essential to make sensible inferences from facts on the ground. Equally for the scientists seeking inferences about the causes and pattern of mass extinctions. The point here is that knowing about the statistical characteristics of plague does not give automatic entry into knowing about the statistical characteristics of fossil records – the subject matter is so different that simple rules of statistical inference have limited grip; subject matter knowledge, sometimes in narrative form, is needed to draw informative inferences.

Narrative inference may be said to have its own set of criteria for inference. Following the legal literature,[18] one might reasonably argue that the requirements for narrative inference lie in consistency (taking account of all the individual bits of evidence) and coherence (fitting all the elements together in

17 This was one of a set of examples discussed at our Project Workshop on polyphonic narratives. See workshop on polyphony on project website: www.narrative-science.org/events-narrative-science-project-workshops.html.

18 See MacCormick (2005) for these criteria, discussed in Morgan (2017).

https://doi.org/10.1017/9781009004329.002 Published online by Cambridge University Press

a way that makes sense in the context). For legal cases, there is an additional requirement of 'agency' (e.g., of those committing a crime), which might be translated for narrative science in terms of an adequacy/plausibility and perhaps an implicit or explicit agency in the relational claims used in the inference. Surely the most formal inferential rules for ordering and categorizing, and so transforming heterogeneous evidence into a consistent and plausible narrative, is proposed in legal scholarship: namely the Wigmore Chart method, which is designed to take into account the conjunctions among the individually separate pieces of evidence that need to be combined into legal narrative accounts.[19] It is not clear that lawyers follow such strict methods of evidence colligation, but for scientists, it is clear that the use of narratives in a scientific field comes with its own generic criteria for assessing plausibility. Andrew Hopkins recounts how geologists attempting to account for a particular rock formation in Scotland inferred, on the basis of deposited material, that the cause must have been volcanic and told a story of geological formation based on that cause. Some years later, finding a different kind of deposit, the narrative changed to blame the fall of a meteorite. In neither case was there obvious evidence of that particular cause in the presence of a volcanic vent or meteorite crater! In both changes of inference – one might argue – some crucial evidence of the 'agency', or cause, was missing when these specific event narrative accounts were constructed against an ongoing background narrative in geology of more gradual causes of erosion and deposition.

1.5.2 Narrative Argument

Narrative argument features in our volume where narratives are involved in making arguments about causes, and about sequences, and about causal sequences – for in practical terms, single causes are hard to come by in science. The philosophical literature arguing about causes is long-standing and wide-ranging. Narrative does not solve those arguments in any principled way. Once again it helps to return to the purpose of narrative – relational sense-making. If, long ago, the adult fish species was upright and then became flat, what evolutionary causal sequence could possibly account for this change (Beatty's paper, Chapter 20)? (And if that fish species still now begins juvenile life in upright form, and becomes flat only in adulthood, how does this work?) Simple adaptionist stories of efficiency or optimality don't work very sensibly – the argument does not grip. 'Back-stories' are needed to make sense of the adaptations, and of their order, but such arguments may still not be definitive, and it is an open question how far the narrative sequence needs to go back in

[19] See discussions of Wigmore Charts and their usage in Twining (2006) and Nicolson (2019).

order to make an explanation that counts as satisfactory with no questions left over.

Strangely, and despite assumptions among some narrative scholars that time is integral to narrative understanding, a given temporal sequence may be consistent with very different sets of adaptations in evolution, or very different causal relations, because, as Jajdelska (Chapter 18) makes clear, narratives have their own power to invest perceptions of causality. The aesthetic details of a narrative matter to our perception and acceptance of such causal claims as being plausible, such that the narrative must be 'performative' in this kind of sense. Jajdelska's argument is paralleled in legal analyses of narrative accounts. This is obvious in court rooms, where the performative aspect of narrative is associated with a degree of rhetoric, but much more interesting for science is that the *order* in which elements of evidence are introduced into the legal narrative affects the degree of acceptance of the narrative conclusion, just as, probably, happened in those colonial courtroom narratives of shipwrecks during cyclones.

The textual details of narratives are not just performative, but, like the diagrams and schema discussed earlier, they also embed important signals of community expertise. Line Andersen (Chapter 19) analyses how mathematicians read mathematical proofs in terms of 'scripts', a literary term denoting slim chunks of text that provide shorthand access to a set/sequence of taken-for-granted background elements for the reader of fictional or everyday factual narratives. For mathematicians, such a script can point to a set of mathematical elements that would be habitual at that point in a proof (a set of proof steps in the background, very different from the kind of 'back-story' argument Beatty tells about going back in time). They can best be construed as the denser argument behind the shorthand maths, or the thickness of activity behind the 'chemese' found in Paskins's paper (Chapter 13). As Andersen argues, mathematicians reading a proof expect to see standard habitual moves shorthanded into these 'scripts'; they are accepted by the expert community without expanding them. But gaps in a series of such scripts, or unusual linking moves between them, alert the community to some strange move in the proof argument – a narrative gap to which they must pay attention.

1.5.3 Narrative Explanation

Traditional arguments from philosophers of history portray narrative as offering an explanation for a particular set of events. By contrast, almost in direct opposition, the traditional philosophy of science position was to understand scientific explanation as both general and valid only if it were 'covered' by 'laws' as a kind of umbrella. We can see the contrast between these two notions of explanation most vividly in Huss's account of mass extinctions. The periodic narrative 'explained' (according to philosophy) mass extinctions as a regular pattern driven by law-based behaviour elsewhere in the system and was contrasted to the 'historical narrative explanation' given for each particular historical case of mass extinction in terms of the reasons why each one happened.

More recently, philosophers of science have settled on a looser or more generous account that portrays explanations as answers to 'why?' (and perhaps 'how?') questions, but still with a presumption that scientific explanation involves a high degree of generality in its scope (although the strict 'law-based' account is now regarded as old-fashioned).[20] If we concentrate on how scientists do explain things in narrative forms, we can recognize elements of all these recipes for explanation, sometimes used at the same time.

As we have already seen, scientific narratives often embed causes for things to have happened, that is, they answer 'why' questions – so, on that definition, they are readily set up to provide explanatory accounts. Especially this applies to narratives using relational networks, for, as Olmos (Chapter 21) points out, narratives that make sense of relations (causal, associational, etc.) will double as reason-givers in persuading the reader/listener of the knowledge claims embedded in the narrative. This may account for why narrative modes of 'reason-giving explanation' work more easily than general law-based accounts in some sciences. But Olmos goes further in claiming that 'law-dependent explanations' using time relations invoke narrative as soon as they are examined and unpacked in a way that shows how those 'laws' account for real particular events. Thus, taken as an argument form, such narratives of particular events embed law-type explanations.

Olmos's analysis offers us a framework for understanding narrative explanation more broadly, for we can recognize that there are a number of ways in which narrative accounts in the sciences answer 'why' questions while making use of 'generic' claims (claims relevant for a class of phenomena) without a full-blown appeal to 'laws' (this is particularly so in mechanism-type explanations). Following Olmos's point, we can find this conjunction happening first in the considerable gap between giving more general explanations and finding the particular ones that might be needed for any specific scientific problem, and to recognize how this gap may be filled by the narrative form. Why is this so common? The 'laws' of science are in many cases 'straw men' – they are supposed to provide umbrella explanations but often do not organize scientific materials very well – they lie at too general a level to connect immediately or practically with many of the scientific problems studied. For example,

[20] This new account is restrictive in another way, for it is most often understood to involve offering answers that require causes, and especially a specific causal 'mechanism' (a high requirement for many scientific contexts).

https://doi.org/10.1017/9781009004329.002 Published online by Cambridge University Press

scientists from several disciplines with different perspectives have general knowledge about pandemics, but for answering questions about any particular disease-class pandemic, they need to fit together knowledge about the genetic form of a virus, its transmission and medical treatment, and the social behavioural responses that might be relevant to control or eradicate it. As Engelmann's paper shows, despite widespread generic-level knowledge of the plague, all explanations in his late nineteenth-century cases had to be made local, so each area narrative was relevant to particular causes, transmission, controls and effects of the plague in that context (Chapter 14).

Another conjunction of the two bases for explanation – question-answering with an appeal to the generic level in some form – also works in reverse. It starts with narrative explanations of particulars, but then generates accounts that have more general claims. Thus, in Bhattacharyya's paper (Chapter 8), we see how, studying and aggregating the narrative accounts of many examples of cyclones, her 'hero' Piddington was able to infer the stable characteristics of the behaviour of cyclonic winds, and so set out how ships' captains should behave in such storms. An alternative mode of extending particular narratives to the generic level was explored in Morgan's (2017) account of how puzzles thrown up by the juxtaposition of evidence were resolved to answer an important 'why' question. The particular case evidence showed firms exited a failing industry in the 'wrong' order, according to the theory. The narrative account answered that puzzling 'why' question with a narrative of reasons that could be (and was) extended by the community of scientists to 'explain' a set of similar cases in similar circumstances.[21]

More often, the narratives of scientific particulars don't pretend to offer generality, or extend to a more general level, but they rarely work without some generic element (including, at the limit, the use of, or appeal to, general scientific 'laws'). My earlier account of narrative explanation (Morgan 2017) showed how narratives use conceptual elements from a science to bring together a set of examples under one conceptual roof. Cristalli (2019) has urged that such colligation is the basis for a wider notion of narrative explanation, one consistent with both philosophy of science and philosophy of history. The engineering narratives of particular accident reports rely on general claims and knowledge of the behaviour of materials and people,[22] just as the legal narratives of particular cases are set within a framework that uses the general concepts and claims of the legal system. The narratives of ant-lions catching

[21] The critical point for narrative science is that the explanation was exported beyond the original case to other cases; for philosophy of history, that puzzle-solving explanation works for the particular case (Roth 1989), but there remained an open problem of how that argument could be extended to science (on which, see Morgan 2017, and references therein).

[22] See the reports of the NS Workshop on 'expert narratives'. See project website: www.narrative-science.org/events-narrative-science-project-workshops.html.

their prey (Terrall 2017) can be understood as particular instantiations of a more generic predator–prey account. The narratives of marsupial evolution told by Kranke provide particular accounts of general versions of genetic evolution. Félida's narrative of multiple personality is a one-off case, but can be used for broader understandings of such cases (Hajek 2020). These all rely on some kinds of generic or conceptual framing in the narrative accounts. Specific causes can also fit easily and well with laws in a narrative account as they do in geology, where the laws might be said to lurk or police, rather than be specifically determinate (Hopkins, *Anthology I*). The appeal to a general or generic level, or the use of the conceptual level, is found somewhere in most scientific narratives – in fact, it is difficult to conceive of a narrative in science that does not do so.[23] This characteristic of narrative explanation (like the other answers given here for how narrative arguments extend their reach), does not start from an appeal to something general in the nature of historical or philosophical explanation, but looks to the practices of how scientists do reason with narrative to make their knowledge stick together with theoretical and conceptual materials and so speak beyond particulars to (some) more general kinds of knowledge.

1.6 Conclusion

Narratives are made by people, perhaps mainly for enjoyment, perhaps for enlightenment, but also in the sciences for far more utilitarian purposes; thus my labelling them an enabling, sense-making, technology for scientists. I propose we go further than this, and think of narrative as a 'general-purpose technology' (GPT). This term comes from economists and economic historians who have focused on the *use* of a technology and its histories (rather than its invention or how it is reproduced), and on two particular attributes of such technologies, both of interest for this account of narrative as a general-purpose technology for science.[24] First, GPTs are, as the term suggests, technologies with usage that is both generic in its main purpose, but gradually expands across a range of unexpected sites, fulfilling that main function in different ways, and becoming co-dependent with other technologies in the process. Steam power, electricity and computing all offer supreme examples of such GPTs: each has a general-purpose use but is harnessed in different ways for

[23] As before, narratives, as a form of representation in science, may well share this characteristic with other more abstract forms of scientific representation, such as models and schemas, which also embed more general conceptual claims. Even tables and graphs have concept-based labels and headings that point to generic content.

[24] The notion of general-purpose technologies was labelled in a working paper of 1992, published in 1995, by Bresnahan and Trajtenberg, following work, especially of Rosenberg (1982), on the historical development of technological interdependencies.

different specific purposes, just as narrative is harnessed across the sciences. Second, and less obviously, those scholars have noted the important role of users, and user-innovation, in the spread and development of those technologies into those multiple sites, and charted how those innovations created changes in economic and social life. For scientific life, our chapters have analysed the multiple and varied usages of narrative and shown how its general purpose of sense-making can be traced into narrative representation, reasoning and knowledge claims.

Of course, narrative is not a new technology, nor invented by scientists just for their use! It would be equally unhelpful to argue that narrative was introduced into science in a particular era, and that it became a revolutionizing GPT as it spread through the sciences in the way that steam power, electricity or the computer did for our everyday lives. Not at all. I am not claiming, nor did our project suppose, that narrative was introduced into science in the way that historians of science have argued 'the experimental method' was. Arguably, we could treat that 'method' as another possible GPT: historians have tracked how it came into the sciences in the early modern period, taking over the means of investigation and mantle of experiential knowledge, and gradually morphed into the method of controlled laboratory experimentation on the one hand, and field experiments on the other. It has now appeared under many guises (in computer simulations, in medical randomized trials, in thought experiments with models, etc.) and has grown into conjunction with other modes of investigation such as statistical methods and modelling – two other modes of doing science we might also label GPTs – to create the kinds of hybrid modes that characterize modern scientific practices.

In contrast to the laboratory experiment, narrative was surely always in science, and narrative-making and -using in science is a human activity, and so could easily become a social habit in new environments. Thus it surely has a history. Neither this chapter (nor our book) offers any serious history of the place of narrative in the sciences, although we can see a number of points salient for investigating that history of the changing roles, sites and manifestations of narrative.[25] And we can suggest the kinds of materials that would be involved. For example, Dear (1991) points to the use of narratives of individual experience in reports of actual and thought experiments in the English tradition of the seventeenth century. Holmes (1991), in response, compares that tradition with French scholars' narrative modes, which aggregated several experiments at once and which melded their experimental accounts with arguments about the nature of the materials. This is the kind

[25] This book sadly does not offer any kind of meta-history of narrative in science equivalent to the history of 'ways of knowing and working' (Pickstone 2011), nor the earlier multi-volumed account by Crombie (1994).

of historical point when, for a particular site of science, narrative turns from being an epistemic genre (using Pomata's terminology) into a technology that goes beyond simple reporting into something like narrative inference (while still relying on particular modes of intervention and reasoning, to use Hacking's and Crombie's ideas). Another hinge point in this historical account of narrative in science might be the one noted by Terrall (2017) in the eighteenth century, when natural historians turned from pictures, narrative texts, or one plus the other, to keying the text to the pictures. Perhaps this is one of the moments when narrative became diagrammatic? These brief remarks suggest that whereas narratives in science may have been found largely as textual free-standing accounts in earlier centuries, the production and usage of narratives appear to have become increasingly intertwined with, and adopted into, other modes of doing science and making scientific knowledge over the last two centuries. In doing so, narratives and narrative-making may have changed in form, but perhaps not changed in their fundamental knowledge-making functions.

Those three GPTs of economic life – steam, electricity and computing – are called so not just because of their flexibility in use, but because they have infiltrated the ways we humans do things in ways which add power to, and expand, our human resources. Narrative, and narrative-making, have expanded or enlivened our human abilities and intelligence as scientists – just as different modes of doing science and different epistemic genres of scientific representation have done. For narrative – as we have suggested – the general purpose that makes narrative as a technology so useful to scientists in doing science lies in narrative's sense-making possibilities: the power of narrative is to colligate elements together under conceptual frames to make sense of the phenomena that exist in the world.

References

Anthology I: Case Book of Narrative Science (2019). Edited by M. Paskins and Mary S. Morgan. London: London School of Economics and Political Science. www.narrative-science.org/anthology-of-narrative-science.html.

Anthology II: Case Book of Narrative Science (2022). Edited by A. Hopkins, Mary S. Morgan and M. Paskins. London: London School of Economics and Political Science. www.narrative-science.org/resources-narrative-science-project.html.

Beatty, J. (2017). 'Narrative Possibility and Narrative Explanation'. *Studies in History and Philosophy of Science Part A* 62: 31–41.

Beer, G. (1983). *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction*. Cambridge: Cambridge University Press.

Berry, Dominic J. (2019). 'Narrative Positioning'. Economic History Working Papers, 001. Narrative Science Series, Economic History Department, London School of Economics and Political Science.

(2021). 'Narrative and Epistemic Positioning: The Case of the Dandelion Pilot'. In Z. Pirtle, D. Tomblin and G. Madhaven, eds. *Engineering and Philosophy: Reimagining Technology and Social Progress*. Cham: Springer, 123–139.

Boumans, M. (1999). 'Built-In Justification'. In Mary S. Morgan and Margaret Morrison, eds. *Models as Mediators*. Cambridge: Cambridge University Press, 66–96.

Bresnahan, T. F., and M. Trajtenberg (1995). 'General Purpose Technologies "Engines of Growth?"' *Journal of Econometrics* 65.1: 83–108.

Carrier, M., R. Mertens and C. Reinhardt, eds. (2021). *Narratives and Comparisons: Adversaries or Allies in Understanding Science?* Bielefeld: Bielefeld University Press, 29–61.

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

Cristalli, C. (2019). 'Narrative Explanations in Integrated History and Philosophy of Science'. In E. Herring, K. M. Jones, K. S. Kiprijanov and L. M. Sellars, eds. *The Past, Present, and Future of Integrated History and Philosophy of Science*. Abingdon: Routledge.

Crombie, A. C. (1988). 'Designed in the Mind: Western Visions of Science, Nature and Humankind'. *History of Science* 26: 1–12.

(1994). *Styles of Scientific Thinking in the European Tradition: The History of Argument and Explanation Especially in the Mathematical and Biomedical Sciences and Arts*. 3 vols. London: Duckworth.

Dear, P. (1991). 'Narratives, Anecdotes, and Experiments: Turning Experience into Science in the Seventeenth Century'. In P. Dear, ed. *The Literary Structure of Scientific Argument*. Philadelphia: University of Pennsylvania Press, 135–163.

Dillon, S., and C. Craig (2021). *Storylistening: Narrative Evidence and Public Reasoning*. London: Routledge.

Fludernik, M., and M.-L. Ryan, eds. (2020). *Narrative Factuality: A Handbook*. Berlin: De Gruyter.

Hacking, I. (1992). '"Style" for Historians and Philosophers'. *Studies in the History and Philosophy of Science A* 23.1: 1–20.

Hartmann, S. (1999). 'Models and Stories in Hadron Physics'. In Mary S. Morgan and M. Morrison, eds. *Models as Mediators*. Cambridge: Cambridge University Press, 326–346.

Hajek, K. (2020). 'Periodical Amnesia and *Dédoublement* in Case-Reasoning: Writing Psychological Cases in Late 19th-Century France'. *History of the Human Sciences* 33.3–4: 95–110.

Hickman, L. A. (2001). *Philosophical Tools for Technological Culture: Putting Pragmatism to Work*. Bloomington: Indiana University Press.

Holmes, F. L. (1991). 'Argument and Narrative in Scientific Writing'. In P. Dear, ed. *The Literary Structure of Scientific Argument*. Philadelphia: University of Pennsylvania Press, 164–181.

Kindt, T., and M. King, eds. (2022). *Narrative Structure and Narrative Knowing in Science and Medicine*. (forthcoming).

Kuukkanen, J.-M. (2015). *Postnarrativist Philosophy of Historiography*. Basingstoke: Palgrave Macmillan.

MacCormick, N. (2005). *Rhetoric and the Rule of Law: A Theory of Legal Reasoning*. Oxford: Oxford University Press.

Merz, M. (2011). 'Designed for Travel: Communicating Facts through Images'. In P. Howlett and Mary S. Morgan, eds. *How Well Do Facts Travel? The Dissemination of Reliable Knowledge*. Cambridge: Cambridge University Press, 349–375.

Mink, L. (1970). 'History and Fiction as Modes of Comprehension'. *New Literary History* 1.3: 541–558.

(1978). 'Narrative Form as a Cognitive Instrument'. In R. H. Canary and H. Kozicki, eds. *The Writing of History: Literary Form and Historical Understanding*. Madison: University of Wisconsin Press, 129–149.

Morgan, Mary S. (2007). 'The Curious Case of the Prisoner's Dilemma: Model Situation? Exemplary Narrative?' In A. Creager, M. Norton Wise and E. Lunbeck, eds. *Science without Laws: Model Systems, Cases, Exemplary Narratives*. Durham, NC: Duke University Press, 157–185.

(2017). 'Narrative Ordering and Explanation'. *Studies in History and Philosophy of Science Part A* 62: 86–97.

(2021). 'Narrative Inference With and Without Statistics: Making Sense of Economic Cycles with Malthus and Kondratiev'. *History of Political Economy* 53(S1): 113–138.

Morgan, Mary S., and M. Norton Wise (2017). 'Narrative Science and Narrative Knowing: Introduction to Special Issue on Narrative Science'. *Studies in History and Philosophy of Science Part A* 62: 1–5.

Nicolson, D. (2019). *Evidence and Proof in Scotland*. Edinburgh: Edinburgh University Press.

Pomata, G. (2014). 'The Medical Case Narrative: Distant Reading of an Epistemic Genre'. *Literature and Medicine* 32.1: 1–23.

Pickstone, J. V. (2011). 'A Brief Introduction to Ways of Knowing and Ways of Working'. *History of Science* 49: 235–245.

Rosales, A. (2017). 'Theories that Narrate the World: Ronald A. Fisher's Mass Selection and Sewall Wright's Shifting Balance'. *Studies in History and Philosophy of Science Part A* 62: 22–30.

Rosenberg, N. (1982). *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press.

Roth, P. A. (1989). 'How Narratives Explain'. *Social Research* 56.2: 449–478.

Ryan, M.-L. (1986). 'Embedded Narratives and Tellability'. *Style* 20.3: 319–340.

Swedberg, R. (2018). 'Colligation'. In H. Leiulfsrud and P. Sohlberg, eds. *Concepts in Action*. Leiden: Brill, 63–78.

Terrall, M. (2017). 'Narrative and Natural History in the Eighteenth Century'. *Studies in History and Philosophy of Science Part A* 62: 51–64.

Twining, W. (2002). *The Great Juristic Bazaar: Jurists' Texts and Lawyers' Stories*. Aldershot: Dartmouth Publishing.

(2006). *Rethinking Evidence*. 2nd edn. Cambridge: Cambridge University Press.

Wise, M. Norton (2017). 'On the Narrative Form of Simulations'. *Studies in History and Philosophy of Science Part A* 62: 74–85.

(2021). 'Does Narrative Matter? Engendering Belief in Electromagnetic Theory'. In M. Carrier, R. Mertens and C. Reinhardt, eds. *Narratives and Comparisons: Adversaries or Allies in Understanding Science?* Bielefeld: Bielefeld University Press, 29–61.