RICHARD WALSH

The Narration of Scientific Facts

If there is a meaningful concept of scientific fact, it is one that cuts across the more careful standard distinction between scientific observation and scientific theory. That is, there are both empirical scientific facts (water at a pressure of one atmosphere boils at 100 degrees centigrade) and principled general scientific facts (cell theory describes the fundamental structure of living organisms). Both observations and theories may come to be regarded as factual within a scientific community; the sense of 'fact' that applies, though, is not only more rigorous but also more skeptical than factuality as ordinarily understood. To call a fact 'scientific' is not exactly to say that it is a more absolute fact (as common usage implies), but rather that it is a more accountable fact. The rigorous aspect of this accountability is secured by the methodical standards of science: theories must be testable, and be extensively tested; particular observations must meet the criteria of established practice in the relevant field and hence be, at least in principle, reproducible. The skepticism that attaches to the notion of fact in science is just the flip side of the accountability. Scientific theories have to be falsifiable to be testable, and their legitimacy is not a matter of confirmation, strictly speaking, but of demonstrated robustness in the face of efforts at falsification. As the Popperian doctrine of falsificationism has it, scientific facts are not ultimately confirmed, so much as tested beyond reasonable doubt (2002 [1959]).

There are pragmatic dimensions to such factuality: theories are accountable within the scope of their applicability, within certain degrees of approximation, and within the limits of the questions they answer, and these considerations are contingent upon the current agenda of research in the relevant fields. A robust theory is one that is too well tested to be worth further testing, but that criterion is relative to a given state of the science. Scientific facts, then, are part of the discourse of knowledge, and there is an irreducible conceptual gap between facts in that sense and the states of affairs with which they are concerned.

This point is similarly applicable at the level of scientific observations. They are factual to the extent that they are independent of the circumstan-

https://doi.org/10.1515/9783110486278-028

tial variables of a particular act of observation, a criterion of objectivity secured by the accountability of observation to standards of in-principle reproducibility. Yet 'objectivity' here clearly cannot mean independence from the human perspective as such. Observations do not present the reality or state of affairs itself, but the phenomenon as registered by our senses or their technological extensions, our instruments; this is inherent in the status of observations as knowledge. Empiricism is founded upon the evidential basis of knowledge, but its practice is also framed by the contingencies of currently prevailing systems of knowledge. Theories must hang together; observations, and methods of observation, must be consistent. Science is above all systematic, which means (counterintuitively) that precisely to the extent that it is cumulative, it privileges a coherence theory rather than correspondence theory of truth (see → II.2 Bartmann, → II.1 Klauk).[1] Note that to say so is not to opt for philosophical idealism rather than realism; unlike the former, both coherence and correspondence theories of truth are (in their scientific manifestations) finally accountable to empirical data. Both concern the relation of knowledge to reality, but whereas correspondence theories conceive this relation atomistically, point by point, coherence theories conceive of it holistically, as the adequacy of a domain of knowledge to its object. This premium upon coherence is confirmed, not refuted, by the fact that scientific paradigms are occasionally superseded by more inclusive or more finely granular explanatory frameworks.

Factuality, as a property of discourses, does not apply simply to what is, but rather to what can be truly said about what is. Truth, being necessarily couched within terms of some conceptual framework, is implicated in considerations of form; and narrative form is a case in point, one that is both ubiquitously invoked and deeply problematic. Scientific facts come into relation with narrative for two kinds of reason, one having to do with explanation, the other with communication. The former is the privileged use of narrative in science education, while the latter is dominant in science communication, though of course both modes are invoked in both contexts. My distinction here, despite the apparent compatibility of explanation and communication, is actually an antithetical one. The choice between these two uses of narrative involves two alternative premises about its function: narrative explanation assumes that the form and logic of narrative are adequate to the scientific facts under consideration; whereas narrative communication assumes that narrative form and logic are intelli-

1 For a philosophical overview of the history of scientific method, see Gower (1997); on the systematic nature of science, see Hoyningen-Huene (2013).

gible to the intended audience, graspable in a way not afforded by the facts themselves (that is, non-narrative articulations of factuality: laws, statistics, systemic distributions of data, formulae, etc.). The value of narrative explanation, then, depends upon the congruence between narrative form and the facts; the value of narrative communication depends upon the difference between them.

In broad theoretical terms, the incompatibility between narrative and scientific knowledge is a familiar idea. It is the premise of Jean-François Lyotard's argument in *The Postmodern Condition*, which characterizes the postmodern crisis of delegitimation as a result of the way science has defined its own authority and integrity in opposition to narrative knowledge, only to find that the project of science itself rests upon metanarratives that must themselves fall within the scope of its skepticism, or its "incredulity" towards narrative (1984 [1979], xxiv; also see → III.11 Borrelli). The impossibility of an objective narrative of facts has also been played out in Hayden White's critique of historiography (1987), which argues that narrative history can never be just the exposition of historical fact because narrative is intrinsically evaluative discourse, and the sources of its value system are not the empirical world of historical events but the discursive forms (the genres, tropes, and archetypes) of cultural narratives (see → III.4 Jaeger). Despite the occasional rhetorical excesses of these theorists, however, such considerations do not conflate narrative in general with fiction. These are issues native to the discourses of narrative factuality.

While the qualities of narrative as cultural discourse do have some purchase upon the pursuit of scientific knowledge, narrative is more relevant (though no less problematic) when taken as fundamentally a mode of cognition.[2] The convergence between narratology and cognitive science has increasingly located the roots of narrative sense-making in embodied cognitive behavior, a full account of which would need to encompass evolutionary and developmental parameters as well as cultural contexts. Narrative cognition is the form in which we grasp process, and so conceive of temporality; it has an irreducible relation to what it means to make sense of these things. Nonetheless, it does not require much reflection to see that it is not the only way of conceptualizing time and process, since other conceptual frameworks have currency within certain fields of inquiry, and indeed in general cultural discourse. There are systems models and probabilistic models of process; tensed models of time that situate the past

2 A succinct definition of narrative cognition, avoiding presupposition of everything that is consequent upon thinking narratively, would be "the semiotic articulation of linear temporal sequence" (Walsh 2018, 12).

and future relative to a changing 'now' (or 'A-series' time, in philosophical parlance, in contrast with the spatialized timeline of 'B-series' or calendric time); as well as four-dimensional conceptions of time, among others.[3] Such ideas can be intuitive as well as intellectual, but their intelligibility nonetheless remains, more or less overtly, in dialogue with a narrative mode of understanding. Narrative is the elemental form on which we draw whenever something happens, to the extent that to make sense of events, in basic cognitive terms, is just to grasp them together as a narrative.

Yet narrative form is not neutral or transparent to phenomena: it establishes hierarchies of salience and axes of relation, as any sense-making activity must, and these have tendentious features at a far more fundamental level than the narrative qualities that were of concern to Lyotard and White. It is not just that our narrative understanding is conditioned by the familiar devices and templates we have assimilated from dominant cultural forms of narrative; the bare possibility of narrative form itself entails significant and prejudicial epistemological commitments. Narrativity, in this cognitive context, is best regarded as the name for those effects intrinsic to thinking narratively, rather than as a measure of the extent to which a given discourse possesses the qualities of a narrative. So, perhaps the most elemental feature of narrative cognition is its anthropocentrism, which is manifest in the human scale of its reference frame and its projection of literal or figurative experientiality upon any subject matter whatever, in forms ranging from the implicit attribution of agency to full-blown anthropomorphism. Anthropocentrism of some kind is inherent to the meaningfulness of any human cognitive construct, but it is also bound up with the contingencies of our evolutionary past in intellectually constraining ways. But the distinctive logic of narrative is not only a product of the circumstantial criteria of competitive advantage in a state of nature, it is also reflexively self-confirming: every individual narrative is intelligible as an instance of a narrative pattern that is itself an abstraction from narrative instances. This reciprocity between the particular and the general is intrinsic to narrative meaning, but the consequent hermeneutic circle necessarily constrains the empiricism of narrative cognition. For example, narrative's privileging of sequential relations as a sense-making principle not only obscures other kinds of process, but also relies upon irreducibly implicit

3 On the incompatibility between systemic and narrative models of process, see Stepney and Walsh (2018). On the variety of possible conceptions of time (not all of which are decisively aligned with, or incompatible with, narrative understanding), see Markosian (2016). For a helpful discussion of time in philosophy, see the first chapter of Currie (2007).

connective principles, most obviously our innate model of causal inference. These effects arise from the conceptual primacy of form in narrative cognition, and while the successful imposition of such form is the condition for narrative understanding, it is not just limiting but actually debilitating when attempting to understand processes that are remote from the ordinary experience of an intelligent social animal. Yet challenges of this sort are necessarily presented by, for example, the sciences of the very large or small, the very fast or slow, or just the systemically complex.[4]

Narrative's affordances and limitations impinge upon the narration of scientific facts at the level of theory and at that of observation, and both cases foreground the tension between narrative's explanatory and communicative functions. So, the task when articulating scientific theories is typically both to exemplify, and to do so in terms that are assimilable to a human experiential frame of reference. Two classic examples of such narratives are the 'twin paradox,' as an illustration of the principle of time dilation consequent upon the special theory of relativity; and 'Schrödinger's cat,' as a thought experiment concerned with the Copenhagen interpretation of quantum mechanics.

A partial version of the problem that became known as the twin paradox was set out by Einstein, using clocks, in his 1905 paper introducing special relativity, "On the Electrodynamics of Moving Bodies" (1989 [1905]); the twins themselves were introduced by Paul Langevin in 1911, although Einstein had already implicitly done so by referring to identically constituted living organisms in a 1911 lecture elaborating upon his earlier account.[5] Briefly told, the story of the twins is this: one twin goes on a long journey through space at near light speed, while the other remains on earth; the traveling twin returns to find the earth-bound twin is now significantly older.[6] The age difference is due to time dilation, a theoretical (and empirically testable) consequence of special relativity; a clock traveling at speed relative to another clock runs more slowly, and the greater the relative speed, the more pronounced the effect. The apparent paradox is that, if motion is relative, both twins are traveling at speed relative to each

4 For a more thorough discussion of the range of implications to be drawn from a definition of narrative in cognitive terms, see Walsh (2018).

5 A succinct and accessible exposition and resolution of the twin paradox is Lasky (2006); a thorough discussion of the pedagogical challenges of explaining the paradox is given in Shuler (2014); the history of Einstein's own engagements with the problem is given by Pesic (2003).

6 Note that here and subsequently my concern is with the bare narrative form of my examples, not the extent to which they exhibit the qualities we associate with novelistic fiction.

other, and so time should pass more slowly for each relative to the other. Why do the two effects not cancel each other out?

My purpose is not to be detained by the charm of the twin paradox, much less by the physics that explains it, but to note the ways in which narrative interacts with scientific theory here. Einstein's resort to a narrative example in the first place had expository motives; it made the abstruse mathematics of special relativity concrete and specific, and so made some of its consequences tangible and particular. The example's mutation from clocks to twins is a predictable anthropocentric consolidation of its narrativity, serving both to express time dilation as an experiential reality rather than a mathematical abstraction, and to make it significant on a human scale. At the same time, it is precisely this narrative move that foregrounds the more disconcerting and fantastical aspects of the idea. The story of the twins is in one sense a literal extrapolation of the implications of time dilation, but it is the human scale of this presentation that requires the appeal to near light-speed space travel (to produce time dilation effects of a perceptible magnitude), and so introduces an element of science fiction. By accommodating human scale in one respect, the example exceeds it in another, and shades from narrative explanation into a form of narrative communication that emphasizes the exoticism of the theory.

Einstein himself drew attention to this rhetorical shift in his own 1911 elaboration upon the story, describing it as presenting "the thing at its funniest" (Pesic 2003, 586). The story is no longer offering direct access to the theory, so much as providing the vehicle for an imaginative leap. In this guise, the narration of scientific facts works less as an instance of direct factuality than as a form with some of the qualities of parable, the figurative projection of one story onto another (Turner 1996). A parable is cast in terms accessible to understanding in ways that the target domain is not; all narrative presentation of theory has this character in a sense, being a projection of the concrete or particular onto the abstract or general. Since its explanatory power depends upon difference, however, it also greatly increases the potential for inappropriate inferences, and misinterpretation. The 'paradoxical' quality of the twin paradox is itself an instance of such mistaken inference, the root of which is not the issue of scale, but the bare fact of narrative's anthropocentric perspectivalism. Attempts to disentangle the example from paradox have taken a surprising variety of directions, all of them struggling to reconcile the mathematical theoretical framework with narrative form, which both makes it accessible and resists it. In essence the apparent asymmetry between the experiences of the two twins is explained by the fact that the space traveling twin's out-and-back journey necessarily involves a change of inertial frame of reference that does not apply to the earth-bound twin. The irreducible relativity of inertial

frames of reference is at the heart of special relativity; there is no absolute temporality, no absolute present, and so the axis of simultaneity between the two twins need not correspond to equivalent elapsed time. Yet the story of the twins, as a story, inherently posits the third-person frame of reference of the narration itself, and so continues to insinuate an absolute space-time in defiance of the main point of the narrative. In a more abstract sense, the function of parable itself, which is to conceptually synthesize discrete frames of reference, is what dooms the narrative to misrepresentation.

Erwin Schrödinger (1980 [1935]) had different motives for his recourse to narrative in the case of Schrödinger's cat, and the contrast offers an illuminating comparison with the twin paradox. Briefly, this thought experiment involves placing a cat in a sealed box, along with a Geiger counter rigged to release poisonous gas when it detects the decay of a single atom of radioactive material – an event which has an equal probability of occurring or not occurring in the course of an hour. After one hour the box is opened, to reveal either a live or dead cat, but until that point its fate is indeterminate. In accordance with the Copenhagen interpretation of quantum mechanics, one would say that until it is observed it is both alive and dead. Narrative has a mixed role in Schrödinger's thought experiment, just as it does in the twin paradox. On the one hand, it offers a literal extension of the idea of quantum superposition to macro-scale events; on the other hand, it serves as a *reductio ad absurdum* of the Copenhagen interpretation, in the form of a parable about the role it attributes to observation in the collapse of the wave function.

In Einstein's case, then, the narrative was intended to be expository for a general audience, and the appearance of paradox was an unfortunate effect of presenting the theory in narrative form. Schrödinger's technical scientific paper did not require narrative exposition; in this case the narrative was introduced as a refutation of the theory (or rather, of certain interpretations of the theory), and its paradoxical quality is very much the point. Although Schrödinger offered no definite alternative reading of his own wave function equation, he (like Einstein) was a scientific realist; his refusal to countenance the idea of a cat that is simultaneously dead and alive is a refusal to accept that reality has no definite form independent of observation. Yet his appeal to the macro-scale coherence of narrative itself takes the limits of human cognition to define what is to count as definite form.

Schrödinger's story has had an extensive afterlife not only in scientific debate but also in general culture, including many readings that run entirely counter to his own point, and the range of these responses has been explored in detail by Marie-Laure Ryan (2011). They can be broadly charac-

terized, though, in terms of the different ways they seize upon aspects of the narrative presentation. Responses that focus upon the story's extension of quantum effects to the macro-scale have tended to look for principled limits to the scope of superposition, or to pursue issues that remain implicit in Schrödinger's version, such as what counts as observation. They take the anthropocentric scale of narrative as too coarse-grained to capture quantum reality, or they take the narrative to be problematic just because it is incomplete. Responses that treat the story primarily as a parable, on the other hand, have much more freely affirmed its paradoxical qualities, as figurative expressions of concepts beyond the remit of narrative, whether because it says too much (with respect to the radically discontinuous logic of quantum physics), or too little (with respect to the supra-narrative excess of many-worlds ontologies).

The case of Schrödinger's cat also broaches the question of the relation between observation and theory; between the two distinct frames within which scientific factuality can apply. Theories are built upon observations, and the regularities revealed by observations, but observation is never innocent of theory; without some theoretical frame of reference, observations are meaningless. This reciprocity between observation and theory is echoed in the way narrative meaning depends upon a reciprocal relation between the particulars of a given narrative and the abstract model of narrative form – that is, its logic of sequentiality and the manifold corollaries of that logic. Narrative is itself a theory-laden form of explanation, though it is theory-like in a largely unexamined way.

I can now turn to an example of the narrative representation of observations as scientific facts, keeping in mind not only the principled reciprocity between scientific theory and observation, but also the analogous reciprocity between narrative particulars and narrative form. My example accentuates the reversal from top-down to bottom-up conception implied in the move from theory to observation, and declines a long way from the heady intellectual realms of special relativity and quantum mechanics. It is a recent piece of research published in the *Proceedings of the Royal Society*, and picked up by the BBC and other media channels, titled "The Roles of Impact and Inertia in the Failure of a Shoelace Knot." The paper's account of knot failure, as presented in the published abstract, is as follows:

First, the repeated impact of the shoe on the floor during walking serves to loosen the knot. Then, the whipping motions of the free ends of the laces caused by the leg swing produce slipping of the laces. This leads to eventual runaway untangling of the knot. (Daily-Diamond et al. 2017, 1)

This rather bland summary in narrative form presents the results of experimental observations, taken with a high-speed camera, of the laced

shoes of subjects on treadmills – as well as a number of control experiments.

There are both communicative and explanatory considerations in play in this example. The research is engaged with applied knot theory and has possible implications in other contexts, including surgical sutures, but its choice of subject clearly has an appeal to the general public in mind. It did indeed secure take up in the news media, but not as an effective exercise in science communication; instead, it slotted into a well-established stereotype of the wasteful irrelevance of science. A comment in response to the BBC online coverage is representative: "I find it unbelievable that (presumably) highly educated scientists are spending their time on these petty questions. Any fool can tell you that if you walk about, the movement of your feet will loosen laces" (BBC News 2017). This is a typical science communication dilemma: the narrative presentation of research is intended to maximize its accessibility, but mutates into banality. The problem is aggravated in this case by the fact that sequential narrative form tends to obscure the main finding of the research, which is the combination of two distinct mechanisms in a cyclical positive feedback loop. The researchers do gesture towards this feature in the narrative presentation of their findings to the media ("avalanche effect"; "catastrophic failure"); but like the word "runaway" in the quote above, these efforts inevitably generate comic overtones in relation to the subject of shoelaces.[7]

Even as explanation, then, the function of narrative here is problematic. Despite the simplicity of the object of inquiry, an all-too-readily narratable event, and the apparent compatibility between the bottom-up empiricism of observation and a narrative presentation of facts, the scientific interest eludes narrative articulation. The reason is not circumstantial but intrinsic to the findings, which indicate that a systemic rather than sequential modeling of the process is required, in order to express the reciprocal interaction of mechanisms involved in the emergent effect of unraveling; that is to say, the facts are recalcitrant to the logic of narrative representation.

But the problem goes beyond the circumstances of these particular observations, and raises the question of what it is to be explanatory. On the one hand, if narrative form is a feature of the *explanans* rather than of the *explanandum*, of the mode of cognition rather than the cognized reality, it is hard to see how it can be explanatory by virtue of being narrative (Klauk 2016). On the other hand, causal inference (and therefore causal

7 Nicholson Baker's extended meditations on shoelace wear and shoelace knots in *The Mezzanine* conclude with a long footnote comically surveying extant research on the subject (1988, 129–131). Thanks to Marie-Laure Ryan for this reference.

explanation, surely the most paradigmatic form of explanation) is hard to disentangle from narrative cognition. Causal inference is another name for the conceptual leap necessary to the formal grasping together of every act of narrative cognition; it is the archetypal implicit relation constituting narrative wholes. Causal explanation, then, cannot be reduced to the invocation of covering laws, as in the deductive-nomological model of explanation; it is bound up with narrative cognition. This is not to say that causality is a projection of human subjectivity, but only that our conceptual relationship to it is mediated, and constrained, by our dependence upon narrative. Narrative factuality is the application of an innate theoretical paradigm, and is explanatory, not by virtue of reference to states of affairs, but just to the extent that it is itself pragmatically grounded and so continuous with empiricism, if a restricted mode of it.[8]

The narrative explanation of scientific facts, from the most abstruse theories to the most elementary observations, is a necessary but compromising effort to make the specific affordances of a basic cognitive resource adequate to the full scope of scientific inquiry. Such compromise leaves unresolved a range of problems concerning narrative explanation and communication, according to context; the former is at a premium in education, for example, while the latter dominates science communication in the public sphere. In an educational context there is some plausibility to the hypothesis that narrative modes of representation not only enhance interest and understanding by virtue of their accessibility, but also more effectively take root in memory. But narrative explanation also tends, by privileging relatability, to minimize the intellectual exposure to the unfamiliar (in the subject matter and in the mode of explanation) that we might reasonably consider essential to education itself (Norris et al. 2005). In a science communication context, especially in mass media, these considerations are to a large extent superseded by the way the rhetoric of narrative factuality becomes entangled with the tendentiousness of news values and the ethics of persuasion, both of which are fundamental motives behind the near-ubiquitous recourse to narrative presentation of science for non-specialist audiences (Dahlstrom 2014). It is not just that the cognitive accessibility of narrative's human scale becomes increasingly problematic for phenomena that diverge from that scale; but also that the affective power of narrative form itself becomes a problem. David Velleman has argued that the force of narrative "explanation" has to do with the emotional nature of the grasping together of narrative wholes, and the sense of resolution they

8 For a 'manipulationist' view of causal explanation grounded in pragmatics and counterfactual intervention, see Woodward (2004).

offer: "Having sorted out its feelings toward events, the audience mistakenly feels that it has sorted out the events themselves: it mistakes emotional closure for intellectual closure" (2003, 20). It is true that critical self-consciousness about narrative can help guard against such tendencies, but repudiating narrative form is not always a constructive move; it can all too easily serve to reject explanation itself, and devalue the project of science. Even as we recognize the need to regard narrative with suspicion, we continue to depend upon it.

References

Baker, Nicholson. *The Mezzanine*. New York: Grove Press, 1988.

BBC News. "Mystery of Why Shoelaces Come Undone Unravelled by Science." 12 April 2017. http://www.bbc.co.uk/news/science-environment-39573642 (15 May 2017).

Currie, Mark. *About Time: Narrative, Fiction and the Philosophy of Time*. Edinburgh: Edinburgh University Press, 2007.

Dahlstrom, Michael F. "Using Narratives and Storytelling to Communicate Science with Nonexpert Audiences." *Proceedings of the National Academy of Sciences* 111.suppl. 4 (2014): 13614–13620.

Daily-Diamond, Christopher A., Christine E. Gregg and Oliver M. O'Reilly. "The Roles of Impact and Inertia in the Failure of a Shoelace Knot." *Proceedings of the Royal Society A* 473 (2017): 1–16. http://dx.doi.org/10.1098/rspa.2016.0770. (5 July 2018).

Einstein, Albert. "On the Electrodynamics of Moving Bodies." [1905] *The Collected Papers of Albert Einstein, Vol. 2*. Ed. John Stachel. Princeton, NJ: Princeton University Press, 1989. 304–395.

Gower, Barry. *Scientific Method: A Historical and Philosophical Introduction*. London: Routledge, 1997.

Hoyningen-Huene, Paul. *Systematicity: The Nature of Science*. Oxford: Oxford University Press, 2013.

Klauk, Tobias. "Is There Such a Thing as Narrative Explanation?" *Journal of Literary Theory* 10.1 (2016): 110–138.

Lasky, Ronald C. "Time and the Twin Paradox." *Scientific American Special Edition* 16.1 (2006): 20–23.

Lyotard, Jean-François. *The Postmodern Condition: A Report on Knowledge*. [1979] Trans. Geoff Bennington and Brian Massumi. Manchester: Manchester University Press, 1984.

Markosian, Ned. "Time." *The Stanford Encyclopedia of Philosophy*. https://plato.stanford.edu/archives/fall2016/entries/time/. Ed. Edward N. Zalta. Stanford: Stanford University, 2016 (15 May 2017).

Norris, Stephen P., Sandra M. Guilbert, Martha L. Smith, Shahram Hakimelahi and Linda M. Phillips. "A Theoretical Framework for Narrative Explanation in Science." *Science Education* 89 (2005): 535–563.

Pesic, Peter. "Einstein and the Twin Paradox." *European Journal of Physics* 24.6 (2003): 585–590.

Popper, Karl R. *The Logic of Scientific Discovery*. [1959] London: Routledge, 2002.

Ryan, Marie-Laure. "Narrative/Science Entanglements: On the Thousand and One Literary Lives of Schrödinger's Cat." *Narrative* 19.2 (2011): 171–186.

Schrödinger, Erwin. "The Present Situation in Quantum Mechanics." [1935] Trans. John D. Trimmer. *Proceedings of the American Philosophical Society* 124.5 (1980): 323–338.
Shuler, Robert L. Jr. "The Twins Clock Paradox: History and Perspectives." *Journal of Modern Physics* 5 (2014): 1062–1078.
Stepney, Susan and Richard Walsh. Eds. *Narrating Complexity*. London: Springer, 2018.
Turner, Mark. *The Literary Mind: The Origins of Thought and Language*. Oxford: Oxford University Press, 1996.
Velleman, J. David. "Narrative Explanation." *The Philosophical Review* 112.1 (2003): 1–25.
Walsh, Richard. "Narrative Theory for Complexity Scientists." *Narrating Complexity*. Eds. Susan Stepney and Richard Walsh. London: Springer, 2018. 11–25.
White, Hayden. *The Content of the Form: Narrative Discourse and Historical Representation*. Baltimore: Johns Hopkins University Press, 1987.
Woodward, James. *Making Things Happen: A Theory of Causal Explanation*. Oxford: Oxford University Press, 2004.