A Theoretical Framework for Narrative Explanation in Science

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ABSTRACT: This paper deals with a number of conceptual and theoretical issues that underlie the proposal to employ narrative explanations in science education: What is narrative? What is explanation? and What is narrative explanation? In answering these questions, we develop a framework of narrative elements and characteristics of narrative explanations. Two possible examples of narrative explanation are presented and examined in light of the framework. This examination brings to light various conceptual and empirical questions related to the examples and to the larger issue of the use of examples like them in science instruction. The value of the framework lies partly in its power to point to such questions. The questions can guide a program of theoretical and empirical research into the psychological reality of the narrative form of explanation, the existence of narrative explanations in science, the use of narrative explanations in science teaching, and the nature and extent of the narrative effect upon which proposals for the use of narrative often are justified. © 2005 Wiley Periodicals, Inc. *Sci Ed* **89:**535–563, 2005

INTRODUCTION

Narrative is a centerpiece of literary studies. For decades narrative also has had a prominent place in educational studies, both as a focus of research methodology and of instructional content. Attracted by the educational benefits narratives are presumed to promote, many scholars have argued for greater use of narratives in science education. For example, motivated by the assumed power of narrative as a communicative device, Conant (1947) embedded scientific explanations in the context of historical case studies that narrated the social milieu and personal lives of scientists. Conant did not treat scientific explanations themselves as narratives, but cast the pursuit and development of explanations within story lines "to assist the student in recapturing the experience of those who once participated in exciting events in scientific history" (Nash, 1950, p. 3). Conant's usage is similar to one found in Norris (1992), which supported telling a more accurate story of the practical reasoning involved in science as a way to counteract the widespread stereotyping

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and distortion of science. Solomon (2002) also recommended historical stories about science, not only to increase student motivation and enjoyment, but also for several other important purposes such as the facilitation of ethical discussion. Harré (1986), who sees science not primarily as a static body of knowledge but rather as a dynamic engagement of people within a community, drew upon another source of story in science, namely, the communal practice of science. Myers (1990) saw narratives of scientific discoveries in the interpretations of findings originally reported in journal articles: The articles themselves are reports of logical sequences of experiments, compared to subsequent interpretations of the research that tend to be more narrative in their form. Smolin (1997) aimed to capitalize upon a presumed motivational advantage in the use of the narrative form: "nonscientists, who—not sharing the conventions of formal scientific monologue—can relate more easily to a personal story than to a ritualized display of impersonality" (pp. 6, 7). Meyer (2000) seems similarly motivated in attempting to address "the estrangement of females from science" (p. 78) by encouraging greater participation with natural phenomena and by exposing students to the first level of scientific description through story telling (cf., Brickhouse, Lowery, & Schultz, 2000). As a final example, in *Beyond 2000*, Millar and Osborne (1998) propose that science education "make greater use of one of the world's most powerful and pervasive ways of communicating ideas—the narrative form" (p. 2013). They argue that such narratives in science can prove useful in "communicating ideas, and in making ideas coherent, memorable, and meaningful" (p. 2013). Narratives, they claim, emphasize interrelated sets of ideas. In contrast, science education too often focuses on ideas in isolation, and consequently obscures the major themes at the core of the science.

Our focus is on the explanatory role of narratives. This concern is narrower than many of those above. Our aim is to help science educators study and test the wide array of proposals for using narrative explanations in science education by providing a comprehensive framework for distinguishing such explanations from others. Barring the ability to make such distinctions, it is impossible to conduct research that examines the assumptions, claims, and conjectures that have been made about narrative explanations.

Although we acknowledge that many empirical issues require resolution before a comprehensive understanding of narrative explanation is possible, it is the theoretical that shall be our primary concern for this paper. We examine a number of conceptual and theoretical issues that remain unresolved, and usually unexamined, in all the thinking on the use of narrative explanation in science education. Our interest derives from several sources. First, we believe there may be merit to using narrative explanation in science education that can be articulated more completely once a conceptual foundation is more fully established. Second, the value of all of these proposals rests on the existence of a *narrative effect* that enhances memory, interest, and understanding. We shall speak to this effect and raise several important questions related to it. The theoretical framework outlined in this paper will assist in evaluating critically research designed to determine the substance and extent of that effect. Third, as implied above, the science education community needs a theory of narrative explanations to identify where they exist in science, to do research on them, and to create them for curricular purposes if this seems warranted.

We shall proceed as follows. First, we shall provide answers to the three questions already posed: What is narrative? What is explanation? and What is narrative explanation? Any theory of narrative explanation must provide answers to these questions in order to be able to assess the narrative credentials of alleged examples as well as to judge the validity of any proposal to use narrative explanation in science teaching and to test its usefulness. We shall offer as the core of our framework a set of eight *narrative elements* that we propose as defining features of narratives and a set of distinguishing characteristics of narrative explanations. We hope that the framework will prove useful to research on identifying and possibly creating narrative explanations in science and studying their effects. Second, we shall speak briefly to the empirical research on the narrative effect and use our theoretical framework to suggest other research that is needed. Third, using the theoretical framework, we shall examine two candidates for narrative explanation, one from the Millar and Osborne document and one from a science trade book. We shall show that the framework would suggest very different interpretations of the narrative credentials of these examples. This contrast enables us to frame a number of empirical questions that must be addressed before the value of such examples for science instruction can be established. Finally, we draw some implications for science education should a proposal to introduce more narrative explanations into the curriculum be taken seriously.

In order to understand precisely where our interest lies, it is critical to distinguish between explanations intrinsic to the discipline of science and those that are extrinsic. An explanation intrinsic to science is one that explains some natural phenomenon and is part of the body of scientific knowledge. The theory of universal gravitation, plate tectonic theory, and evolutionary theory provide explanations intrinsic to science. An explanation extrinsic to science is one that explains something about science, and is thus outside the body of scientific knowledge itself. Examples of extrinsic explanations include those of how the discovery of the neutrino was made, of how scientific knowledge moved away from vitalism over time, and of the motivations and trials of Galileo surrounding the publication of his *Dialogue*. Conant, to give one example, provided such extrinsic explanations in his case histories. Our discussion of narrative explanation will apply to both of these categories of explanations, and thus can be of guidance to science educators dealing with either type. However, we shall focus our attention on intrinsic explanations, because there is a significant question surrounding the existence of intrinsic explanations in narrative form. There are many examples of extrinsic narrative explanations, so there is no dispute over their existence. The dispute with extrinsic narrative explanations, where it exists at all, is over their effects on science learning. If the question of the existence of narrative explanations intrinsic to science could be settled, then this would mark an important theoretical advance. The development of a theoretical framework for recognizing such explanations is the crucial first step needed at this time.

Another issue that needs to be addressed is the importance of developing a framework for narrative explanations. Clearly, a theory of narrative is not needed to create fine narratives, because we possessed an enormous body of them before narratology existed. Also, because there are indisputed cases of narrative, much important research on narrative can be done without an articulated theory of narrative characteristics. However, perhaps more so in science than in other fields, it is unlikely that the alleged narrative explanations we find are going to fall into the category of clear-cut cases. If they are not clear cut, then we will require a means of making deliberate decisions about their status. Only then, will we be able to interpret the results of any studies using them and be in a position to adjudicate the merit of narrative inclusion in science.

WHAT IS NARRATIVE?

Not surprisingly, a very common source of discussions of narrative, including attempts to define this form of discourse, is the literature related to the analysis of works of fiction. In addition, narrative has been examined by philosophers of history in order to explore whether history relies on narrative to explain the past. We also strove to locate and emphasize works that refer to narrative in science. Using these vast bodies of work, we have attempted to forge an accurate and comprehensive theoretical position that takes into account as much as possible the points of consensus, of which there are several. In so doing, we have not incorporated the findings of other bodies of work that treat the questions from an empirical perspective, dealing with such issues as what texts ordinary readers judge to be narrative and what features are used by the readers to distinguish narrative from nonnarrative. We cannot assume that answers to what is narrative from the theoretical domain will map directly or even easily onto answers from the empirical domain. We understand, however, that both perspectives will be needed for a comprehensive understanding of narrative.

Within the theoretical perspective, one statement in particular has been repeatedly referenced in literary discussions on narrative, and can serve to frame our discussion: "We might conceive of narrative discourse most minimally and most generally as verbal acts consisting of *someone telling someone that something happened*" (Herrnstein Smith, 1981, p. 228). In this statement are found references to a narrator (someone telling), a narratee (someone receiving, whom, because we are concerned primarily with written stories, we shall call the "reader"), events (something that happened), and past time. We shall consider each of these narrative elements, and also describe important narrative features highlighted by other theorists: narrative appetite, structure, agency, and purpose.

Something Happened (Event-Tokens)

There is widespread agreement that narrative requires, at its most basic, an account of a sequence of events (Berger, 1997; Cobley, 2001; Cohen & Shires, 1988; Tambling, 1991; van Peer & Chatman, 2001). However, a simple recitation of a series of events does not constitute narrative. A list of events, ordered in chronological sequence, is referred to as an *annal* (White, 1981). Here is an example:

411 BC	Aristophanes wrote *Lysistrata*
1066	William I, the Conqueror, was crowned King of England
1854	Oscar Wilde was born
1927	Babe Ruth hit 60 home runs
1932	Vitamin D was discovered
1949	Newfoundland and Labrador became the 10th Canadian province

If a list of events is about a unified subject, "we arrive at a somewhat more complex structure than the annal which has been called the 'chronicle"' (Carroll, 2001, p. 25). Here is an example:

ca. 500 BC	Leucippus advanced a theory of atomism
1704	Newton proposed a mechanical universe with small solid masses in motion
1803	Dalton proposed a "modern atomic theory"
1897	Thomson announced his discovery of electrons
1911	Rutherford first proposed the nucleus concept
1913	Bohr published "On the Constitution of Atoms and Molecules"
1930	Schrödinger introduced wave mechanics

Danto (1985), a philosopher of history, noted that chroniclers who write at roughly the same time as the events they are describing, "pretend to no knowledge not really available to contemporaries of the events designated" (p. 354). Thus, chroniclers recording events as they happen cannot know the significance of what they are recounting, because they are unable to consider it in the light of what follows. Myers' (1990) observation that the process of scientific discovery "cannot be located in the papers to which it is usually traced" (p. 104) is similar in its point. That is, authors of scientific papers are often chroniclers, outlining, particularly in the methods and results sections, what they did (e.g., we adapted . . . , we inserted . . . , we designated . . . , we prepared . . . , we examined . . . , we observed . . . , we found . . .). In addition, in interpreting their data, scientists are able to make comparisons only to work done previously to theirs. And, although they may surmise that their work has significance, it is not possible to assign it pivotal or seminal status at the time of writing. However, articles in journals like *Nature* and *Science* can integrate the "discovery event into larger narratives" (Myers, 1990, p. 104), accounts where the significance of the discovery can be made much more obvious. The same is true of narrators who know the future course that events will take (it is, after all, their story), and who can use this knowledge to attribute significance to the events they are recounting or to insinuate significance into them in order to keep readers in suspense.

In addition to a sequence of events about a unified subject, a narrative requires that the events be connected so that individual events can be seen in the perspective of the others. Richardson (1990), commenting on Bruner's (1986) differentiation between logico-scientific and narrative modes of thinking, explains that while the logico-scientific mode "looks for universal truth conditions . . . the narrative mode looks for particular connections between events" (p. 118). Although narrative does not require that an earlier event causally necessitate a later event, Carroll (2001) observes that the earlier event in a narrative connection must be "*at least* a necessary or indispensable contribution . . . for the occurrence of the relevant later event in the narrative complex" (p. 28). Martin (1986) notes that in narrative, "The earliest events recounted take on their meaning and act as causes *only* because of the later ones. Whereas most sciences involve prediction, narrative involves 'retrodiction.' It is the end of the temporal series—how things eventually turned out—that determines which event began it: we know it was a beginning because of the end" (p. 74). Thus, meaning in history, fiction, and biography (and, if narrative is intrinsic to it, sometimes in science) is developed by going back in time from a known effect to find its causes (Cleland, 2002). Polkinghorne (1988) comments that narrative is "a meaning structure that organizes events and human actions into a whole, thereby attributing significance to individual actions and events according to their effect on the whole" (p. 18).

For example, Dickens's *Hard Times* opens with Mr. Gradgrind's speech on the importance of facts, namely that nothing but facts are ever of any service to reasoning animals. In the subsequent chapters, readers are introduced to students in Mr. Gradgrind's class, to the "little pitchers . . . ready to have imperial gallons of facts poured into them until they were full to the brim" (1996, pp. 41–42). Although this approach to life has an effect on all the children exposed to it, the effect varies depending on the unique combination of events experienced by each character. While both Thomas and Louisa, two of Mr. Gradgrind's "model" students, had "been lectured at from their tenderest years" (p. 48) to ensure their allegiance to facts and the elimination of any inclination toward Fancy, their individual personalities and reactions to events render them very different people by the end of the book. Because Thomas and Louisa initially are portrayed as similar children, in order to understand why and how they became so different, readers need to look back at earlier events once the fact of their dissimilarity becomes apparent.

This is consistent with Martin's (1986) assertion, because the earlier events in Dickens' narrative do not allow the reader to predict what will ultimately happen. However, as the story unfolds, as the number of associated events increases, readers can begin to perceive and understand the interconnection among those events and grasp how what is happening to characters is a result of what came before. Narrative, thus, is formed through contingencies as well as causally necessitating events. That is, narrative accounts interconnect both events of nearly certain consequences and events that, when first encountered, have highly unpredictable outcomes. The latter, the contingent events, are those that gain meaning retrodictively. And, although contingent events are a key element in understanding narrative, we will defer an elaboration of this topic until our discussion of narrative explanation.

The idea of events leading to changes of state is also central to narrative: “An event, bringing a change of state, is the most fundamental requirement in narrative” (Toolan, 1988, p. 90). Here we return to the concept of narrative being an account of a sequence of events, but with an added emphasis on events that “delineate a process of change, the transformation of one event into another” (Cohen & Shires, 1988, p. 53). Miller, too, listed change as a basic element of narrative: “There must be, first of all, an initial situation, a sequence leading to a change or reversal of that situation, and a revelation made possible by the reversal of situation” (1995, p. 75). Additionally, Lodge (1986) reminds us that although narrative is concerned with “change in a given state of affairs . . . . It must have a point, and it must have some kind of unity” (p. 142).

Someone Telling (Narrator)

For Scholes and Kellogg (1966), a narrative requires no more and no less than a teller and a tale. Similarly, Bal (1985), in her somewhat circular definition of narrative, states, “A narrative text is a text in which an agent relates a narrative” (p. 5). Toolan (1988), in describing the narrator as the necessary source of narrative, adds that this holds true “no matter how backgrounded or remote or ‘invisible”’ (p. 5) that narrator remains. No narrator—no story, because it is the narrator who takes what is simply a sequence of events before the telling and fashions it into a whole having meaning. To do this, narrators must determine the point (Lodge, 1986) and the purpose of the story to be told. Subsequent to this, narrators must choose events they perceive as developing that predetermined point and purpose. Further, to create suspense and anticipation, narrators deliberately choose the sequence in which events will be told (Genette, 1980). All of this construction involves interpretation: in the narrator’s recollection or imagination of what happened, selection from among those recollections, and recitation choices for their particular audiences (Hawthorn, 1985).

Unsurprisingly, narratologists (e.g., Bal, 1985; O’Neill, 1994; Tambling, 1991) argue that the way a narrator tells a story strongly affects the narrative quality of that story. That is, the narrator’s choice of what to tell and how to tell it affects the degree to which the other someone (the reader or listener) becomes engaged with the story. Nearly everyone has experienced how a good storyteller can take a set of seemingly humdrum events and weave them into an engrossing narrative. Contrariwise, we have seen that even a good story in the hands of a less-skilled narrator can appear humdrum. The contrast is evident in the following two passages introducing Isaac Newton to the reader. Both contain accurate listings of events related to Newton’s life. The second, however, opens up issues and questions in a way the first does not. The difference is in the telling, because, presumably, both authors had access to most of the same facts. The difference is also in the authors’ purposes. The first author was writing a manual, a sourcebook on experimental physics. The second was writing a biography.

1. Isaac Newton was born in Woolsthorpe, Lincolnshire, on December 25, 1642. He was a posthumous child. His father, also named Isaac, was the owner of the little manor of Woolsthorpe. When Newton reached his majority, he inherited this estate, and remained in possession of the manorial rights until his death. (Magie, 1963, p. 30)
2. Isaac Newton said he had seen farther by standing on the shoulders of giants, but he did not believe it. He was born into a world of darkness, obscurity, and magic; led a strangely pure and obsessive life, lacking parents, lovers, and friends; quarreled bitterly with great men who crossed his path; veered at least once to the brink of madness; cloaked his work in secrecy; and yet discovered more of the essential core of human knowledge than anyone before or after. (Gleick, 2003, p. 3)

Narrative Appetite (Wanting to Know What Happened)

In order for a narrative discourse to flourish, both parties (the narrator and the reader) have to find engagement in this social transaction interesting enough to prevail over competing activities. Thus, stories must not only be accounts of events, but accounts of events that someone cares to know more about; we must want to know what happened if we are to continue reading or listening. Lodge (1986) refers to this desire to learn more about what happened as "narrative appetite."

As Cobley (2001) writes, "narrative has the potential to be thoroughly captivating" (pp. 9–10). Similarly, Miller (1981) refers to the "latent potentialities" to be found in narrative, potentialities that incite narrative appetite through "instances of disequilibrium, suspense, and general insufficiency" (p. ix). Martin (1986) declares that readers are led to want to know what happens next through the tensions and reversals of situations found in narrative. Prince (1995) stresses that narrative text is characterized by actions that have "logically unpredictable antecedents or consequences" (p. 80) and that these foster an appetite for more. Further, MacIntyre (1981) emphasizes that it is crucial that at any given point in a narrative the reader or listener not know what will happen next. It is this not knowing, but having a sense of a range of possibilities that Carroll (2001) claims creates the anticipation that is necessary for narrative comprehension. This anticipation, based on expectations of possible actions or events happening, is constrained by earlier events in the story. That is, only certain anticipations are created. The expectations created are, in turn, based on knowledge of the world, of the conventions of the narrative genre, and of the thought and actions probable in the culture in which the narrative is situated. All of these—suspense, reversals, unpredictability within cultural bounds—are means for sustaining interest in the story, that is, for maintaining narrative appetite. After reading only the first nine lines of Gleick's biography of Newton, we want to know in what ways Newton was strangely pure and obsessive, with which great men he bitterly quarreled, what drove him to madness and to a desire for secrecy, and, if he was so secretive, why we know of his work and what we might not know of it. The stage is set for much that is to follow. The reader is hooked with the contradictions between the image of Newton as a great scientist and "chief architect of the modern world" and someone from whom, because of his personality, we might withdraw.

Time (The Past)

The expectation that narrative not only tell a story, but "do so *interestingly*" (O'Neill, 1994, p. 4), compels narrators to select ways to tell stories that will entice their audiences to want to know what happens. One means at their disposal is the manipulation of time. Time is considered a central defining element of narrative. In Scholes's (1981) view, only a "time-thing" can be narrated, events "connected by subject matter and related by time" (p. 205). Ricoeur (1984), author of a three-volume book entitled *Time and Narrative*, adds a human dimension to this time discussion by claiming that narrative portrays the temporal character of human experience. Tambling (1991), explaining Ricouer's phrase, "time becomes human," suggests that narrative gives substance to events that might otherwise remain abstract, thereby allowing readers to understand what has happened and, further, to use this understanding as a way of conceptualizing and acting in the present. Magie and Gleick made quite different decisions about how to manipulate time in their prose. Whereas Magie began at the beginning of Newton's life, telling us first his place and date of birth, Gleick told us first of an event that took place well into Newton's adult life. These different choices make a difference to how readers are engaged by the text.

Not only is time considered fundamental to narrative, but the consensus view is that "narratives concern the past" (Martin, 1986, p. 74). In Herrnstein Smith's (1981) definition, with which we started this discussion, narrative is “someone telling someone that something *happened* [italics added]” (p. 228). That is, narrative events, either actually or imaginatively, occur prior to their telling. Moffett (1983) also emphasized that narrative discourse is concerned with what happened. He adds, “The essence of story is once upon a time. Once. Unique and unrepeatable events—not ‘recurring’ events, as in science” (p. 121). Moffett’s observation about the nature of science will be discussed in more detail later in this paper.

Structure

Narrative, we have shown, is a narrator’s recounting of “events structured in time” (van Peer & Chatman, 2001). The elements of both time and structure are associated in many descriptions of narrative. Chatman (1981) writes that a salient feature of narrative is its “double time structuring” (p. 118). He explains that narratives combine the time sequence of plot events with “discourse-time,” the sequence in which the narrator orders the story. “What is fundamental to narrative,” Chatman writes, “is that these two time orders are independent” (p. 118). Narrators are able to manipulate order and duration of events and make use of techniques like flashbacks, flash forwards, and foreshadowing to achieve a desired effect (Genette, 1980). Chatman contrasts this treatment of time with that in nonnarrative texts where “discourse-time is irrelevant” (p. 118) and logical or chronological ordering takes precedence.

Many analyses of narrative are variations on the traditional beginning-middle-end structure of stories (e.g., Gudmundsdottir, 1995; Roth, 1989; Scholes, 1981). Bal (1985) proposes that three phases are to be distinguished in every story: the possibility, the event, and the result or conclusion. Miller (1995) describes narratives as comprising an initial situation, followed by a sequence leading to a change or reversal of that situation, and ending with a revelation made possible by the reversal of situation. Similarly, van Peer and Chatman (2001) write that narratives “typically start with imbalances that protagonists attempt to redress. Usually these attempts lead to complications, setbacks, crises, and ultimately to success or failure” (p. 2). Thus, Gleick in his first nine lines refers to imbalances that would confront Newton throughout his life. Egan (1986) refers to the rhythm found in narrative, explaining that stories “set up an expectation at the beginning, this is elaborated or complicated in the middle, and is satisfied in the end. Stories are tied beginning to end by their satisfying the expectation set up in the beginning” (p. 24). All of these descriptions recognize the significance of structure in the creation and comprehension of narrative.

Iser (1980) was interested in the element of “connectability” that structures different texts. Connectability, he maintained, must be “strictly observed in expository texts where an argument is to be developed or information is to be conveyed” (p. 183). In such texts, the writer aims for a precise interpretation where a “multiplicity of possible meanings must be constantly narrowed down” (p. 185). In contrast, such strict connectability is replaced in fictional narrative by “blanks,” by vacancies and shifts that release possibilities and mobilize readers’ imaginations, thereby maintaining interest as well as opening the text to the possibility of multiple interpretations.

Agency

Although not all narrative analysts insist that agents or characters (human or otherwise) are an essential feature of narrative, for many, narrative “at its simplest . . . displays a group of characters who live in a given place as time passes” (Ireland, 200l, p. 26). Statements by Bal (1985) and Cohen and Shires (1988) exemplify common views expressed about the role that characters or agents play in narrative. According to Cohen and Shires, narrative events "require some agency of action: characters" (p. 69). Bal explains that a story is "a series of logically and chronologically related events that are caused or experienced by actors" (p. 5) and that these actors need not be human. Actors and agents normally introduce an ethical element into narrative, because they must take responsibility for the effects of their actions. Abbott (2002) advocates substituting "entity" for "character." Although admitting that "entity" may seem cold and abstract, he argues that because a narrative may concern "the story of an atom, say, or an experiment involving the interaction of chemical elements, or the history of shifting landmasses, or the evolution of planetary systems, it would seem strained to continue to speak of characters" (p. 17). Thus, Abbott does not demand agency for there to be narrative.

McEwan and Egan (1995) stress that narrative is valuable in that it forms "a framework within which our discourse about human thought and possibility evolve . . . . [functioning] to make our actions intelligible to ourselves as well as to others" (p. xiii). Here, again, there is a focus on the human features of narrative. In his examination of narrative, Bruner has consistently depicted this genre as dealing "with the vicissitudes of human intentions" (1986, p. 16) and being composed of "happenings involving human beings as characters or actors" (1990, p. 43). Polkinghorne (1988) states that narratives work "to draw together human actions and the events that affect human beings and not relationships among inanimate objects" (p. 6). In addition, Mattingly (1991) differentiated narrative from nonnarrative accounts on the basis of the focus on people: "Narrative descriptions highlighted the role that particular actors play in shaping the project component. In the non-narrative account no actors were identified" (p. 242).

Purpose

Although it has been alleged that the main purpose of narrative is to entertain (Weaver & Kintsch, 1991), this is a narrower description than that ascribed to this genre by many philosophers of narrative. For example, Coles (1989) writes that stories are constructed to help us understand the world we live in: to help "comprehend the life that is in me and around me" (p. 189). Tilley (1992), taking what might be considered a constructivist stand, argues that it is through narrative that we are able to "accommodate the new within that which is familiar to us" (p. 150). In these descriptions of purpose, narrative can be interpreted as helping us better understand the natural as well as the human world.

Similarly to those emphasizing the human-centeredness of narrative, numerous writers tie narrative purpose closely to advancing an understanding of human actions and feelings. This can be seen in Witherall's (1995) statement that "stories enable us to imagine and feel the experience of others" (p. 41) and MacIntyre's observation that stories help us understand "how others respond to us and how our responses to them are apt to be construed" (1981, p. 201).

Phelen (1996), who views narrative as having a strong rhetorical dimension, emphasizes that narrative has "the purpose of communicating knowledge, feelings, values and beliefs" (p. 18). This is a broad definition, indeed, as it encompasses both knowledge and emotions and the intention to persuade or influence others.

Someone Receiving (Reader)

We now come to the second someone in Herrnstein Smith's (1981) definition of narrative, the recipient of the story. Just as the telling of a story is an interpretive act for the narrator, the reception of that story requires interpretation by its reader. Emphasizing this role, Cobley (2001) calls the reader of a story the interpreting agent. Martin (1986) writes that the reader produces meaning; meaning is not found merely by decoding text. Instead, a reader employs a number of different processes and activities, such as inferring, construing, projecting, hypothesizing, imagining, and anticipating (Herrnstein Smith, 1981), to make meaning. Because reading for meaning requires effort, a reader must be sufficiently interested in what is happening and in what might happen next to continue to engage in the reading act. Knowledge of genre, form and rhythms, and reading processes constructed during previous reading experiences help readers navigate new text (Bakhtin/Medvedev, 1991; Cohen & Shires, 1988). Because readers draw on genre knowledge when reading, Toolan remarks that "narrative depends on the addressee *seeing it* as narrative" (1988, p. 7). Genre knowledge helps readers anticipate and interpret text and helps shape their perspective on events and their focus on what is likely to be significant and salient in a particular text (Toolan, 1988). It will, in addition, suggest whether they should approach the text analytically, affectively, or both (Rosenblatt, 1991). It is, thus, through active engagement with text that a reader constructs meaning (Norris & Phillips, 1994). If the reader recognizes a text as narrative, it will be read through a "narrative lens," with the clarity of that lens sharpened by knowledge and attitudes formed from previous exposure to stories. If a reader judges a text to be telling a story, he or she will approach it with a set of anticipations and expectations distinct from those that would be held if the text were judged to be expository or argumentative.

Section Summary and Discussion

Table 1 contains a concise overview of the key points made in this section. There are eight narrative elements identified. We do not take these elements to make up a set of necessary and sufficient conditions for narratives. Rather, we would say that a piece of prose is narrative to the extent that it features these elements. That is, there are degrees of narrativity. The question remains whether some elements are more important than others. We speculate that there is a hierarchy of importance. The narrator, narrative appetite, structure, purpose, and reader seem to be of secondary importance in determining degree of narrativity. Although these elements are important, we can imagine narratives in which these elements are represented poorly or not at all. For example, lack of narrative appetite does not mean there is no story. It perhaps signals a story poorly told, but there can be a story nevertheless. Of primary importance, we believe, are the existence of event-tokens, past time, and agency: particular occurrences involving particular actors in the past and over time. Having said this, we are very interested in examining any examples of prose such as Abbott (2002) imagines that contain entities incapable of willed behavior in place of agents. For example, he imagines the story of a planet being struck out of its orbit by an immense asteroid. Because the planet and the asteroid are insentient objects incapable of willed action, it is not proper to speak of them as agents. It is crucial to our enterprise here, however, to know whether genuine stories can be created with such entities taking the place of agents. Abbott also imagines the story of an atom, and Primo Levi's memoir (1984, pp. 224–233) contains one of the better known attempts at such a story. Levi relates what happened to a fictional carbon atom from the time of its release from limestone (perhaps from the Dolomite Mountains in northern Italy) in 1940: its eight-year airborne trip as part of a molecule of carbon dioxide, its capture by the leaf of a grape vine, its entry into wine and its becoming part of a sugar molecule, its being ingested by a human being, and finally its being respired attached to two new atoms of oxygen. Levi's account has some of the elements of narratives. It names events, has a narrator, and whets the reader's curiosity about what will happen next in the movement of the carbon atom. Of course, the atom is not alive, and hence has no motives, feelings, or life prospects. We find that this lack of agency dulls the sense of narrative considerably.

TABLE 1 Narrative Elements and Their Meanings

Narrative Element	Meaning
Event-tokens	• particular occurrences involving particular actors at a particular place and time (event-tokens, see footnote 1 in the What Is Narrative Explanation? section) • are chronologically related • involve a unified subject and are interconnected • later events seen as significant in light of earlier events • lead to changes of state
Narrator	• the agent relating a narrative (foregrounded or backgrounded) • determines the point and purpose of the story to be told • selects events and the sequence in which they are told • fashions a sequences of events into a significant whole
Narrative appetite	• desire created in readers and listeners to know what will happen • based on a range of possibilities that creates anticipation and suspense
Past time	• narratives concern the past • narrators can manipulate time in relating narratives
Structure	• narratives typically start with imbalances, introduce complications, and end in success or failure • narratives are structured around two independent time sequences—the sequence of plot events and the sequence in which the events are related • narratives are tied together by satisfying expectations that are established previously
Agency	• actors cause and experience events in narratives • actors are responsible for their actions • narratives involve human beings or other moral agents
Purpose	• to help us better understand the natural world and humans' place in it • to help us imagine and feel the experience of others
Reader	• the reader must interpret the text as a narrative in order to approach it with appropriate expectations and anticipations

No scientific explanation is carried by Levi's account, although a number of scientific processes are referenced. Nevertheless, Levi's effort represents one that is worth considering and studying in any attempt to write narrative explanations, because its borderline nature raises an interesting question: Would texts such as Levi's show a significant narrative effect on memory, interest, and comprehension, or must the texts display more narrative elements to have this effect? We know of no empirical research that addresses such a question. However, such research is crucial to evaluating proposals to use narrative explanations in science, because it is likely that many of the texts created for such a purpose would be hybrids, either because they contained mixtures of purely narrative and purely nonnarrative text or because they contained text that does not fall clearly into any category.

WHAT IS EXPLANATION?

No doubt, the fundamental nature of the concept of explanation is part of the reason it has proved so difficult to explicate in terms of ideas we grasp better. This difficulty has not prevented people from trying, but it is fair to say that we still do not possess a fully satisfactory account of explanation. Although many ideas have provided some insight, even the best are beset by known flaws. Much of the difficulty is knowing where to start, a problem we face here. A number of theorists have thought that explanation is, at its most basic, an act intended to make something clear, understandable, or intelligible (Brewer, Chinn, & Samarapungavan, 2000; Danto, 1985; Kim, 1995). Almost anything can be the object of an explanation so conceived: a word, a poem, a facial expression, an act of violence, a streak of light in the sky. Passmore (1965), in his examination of explanation in everyday life, in science, and in history, concluded that although explanations are called for and offered under a wide variety of circumstances, in each instance an explanation sets out to resolve a puzzlement. And because we are puzzled by many different things, explanations serve a number of different functions, most often assigning, developing, or expanding meaning; offering a justification; providing a description; or giving a causal account. These functions of explanation provide a way into this difficult topic.

First, explanations offered to questions such as "What is exaptation?" or "What is Popper's thesis in *The Logic of Scientific Discovery*?" attempt to clarify and make understandable by interpreting a term, proposition, or treatise. That is, the explanation assigns, develops or expands meaning. A second type of puzzlement is addressed by explanations that offer a justification. For example, if asked why we set up an experiment with a plastic tubing instead of a glass column, we might reply that the tubing was the cheaper, the more readily available at the time, and adequate to the task. Or, if asked why we do not support the funding of a research proposal, we might argue that the objectives are vague and the methodology is inappropriate. In explanations used to justify, there must be appeal as above to norms, standards, or values. A third type of puzzlement may be resolved with a descriptive explanation. Kepler's two laws of planetary motion are of this type, in that they describe *what* was happening in contrast to *why* it was happening (Simon, 2000). They describe the shape of the planetary revolutions and how the planets' motions around the sun are related to time. The fourth type of explanation offers a causal account—exemplified by Newton's explanation of why the planets revolve around the sun. In his explanation, Newton introduced a mechanism—gravitational force—that caused, not just described, the revolution of planets.

In addition to function, explanations have been distinguished by their type, which complicates matters because function and type overlap in various ways. A type of explanation that has been examined and debated extensively is the one that most concerns us here, namely, scientific explanation. Salmon (1989) affixed a 23-page bibliography to a review of the major works written on scientific explanation between 1942 and 1989. The debate and discussion have continued. For much of the 20th century, the debate centered on the structure of scientific explanations as signaled by Nagel's influential book of 1961. In that work, Nagel differentiated four different patterns of scientific explanation: deductive, probabilistic, functional, and genetic. Although each of these has been the subject of lengthy analysis and debate, we shall restrict ourselves to a brief description of each in order to suggest the dimensions of what is perceived to be essential in a scientific explanation.

The first of these, the deductive model, is also referred to as the deductive-nomological model (D-N) or the covering law model. Although deductive arguments have been analyzed since antiquity, contemporary deliberation on this type of scientific explanation is widely referenced to a 1948 seminal paper by Hempel and Oppenheim (e.g., McErlean, 2000; Salmon, 1989; Sintonen, 1984). Indeed, Salmon (1989) refers to this work as "The Fountainhead," and in the same volume Kitcher (1989, p. 410) refers to it as "the pioneering article" and says that "the main contemporary approaches to explanation attempt to incorporate what they see as Hempelian insights." According to Hempel and Oppenheim (1948, p. 136), "The question '*Why* does the phenomenon happen?' is construed as meaning 'according to what general laws, and by virtue of what antecedent conditions does the phenomenon occur?"' Hempel and Oppenheim posited that what is being explained must be logically deducible from the antecedent conditions and the general laws. This type of explanation they labeled causal and the explanations themselves were deductive arguments. That is, for Hempel and Oppenheim, causal explanations for particular facts are provided when empirical regularities (general laws) connect a particular set of antecedent conditions with the occurrence of the particular event. In this respect, their model can be traced to Hume's notion of causation as constant conjunction (Hume, 1748/1955), a lineage they recognize in speaking about cause "in the sense that there are certain empirical regularities . . . which imply that whenever conditions of the kind indicated . . . occur, an event of the kind described . . . will take place" (1948, p. 139). As an example of explanation according to this model, consider the question, "Why did the cannonball travel 2000 ft before hitting the earth?" The explanation appeals to general laws: (a) The vertical distance traveled by a freely falling body close to the earth and starting from rest is given by $s_{\mathrm{v}} = \frac{1}{2}gt^2$; (b) The horizontal distance traveled by an object moving with constant velocity is given by $s_{\mathrm{h}} = vt$; (c) The horizontal velocity of an object is independent of its vertical velocity. It also appeals to antecedent conditions, such as: (d) The cannon was aimed horizontally at a position 64 ft above the earth; (e) The muzzle velocity of the cannonball was 1000 ft/s; and (f) $g = 32$ ft/s^2. You can see that the distance of 2000 ft is deducible from these six premises, and because of that we know why the cannonball traveled that distance.

Rescher (1962) argued that if scientific explanation was confined to deductive argument from general laws, many modern scientific discussions would be defined as "outside the pale of *explanations proper*" (p. 50). Rescher and others (e.g., Reichenbach, 1971; Salmon, 1971), and after 1948 even Hempel (1966), stressed that the concept of scientific explanation needed to be extended to include explanations based on statistical probability. As McErlan (2000) states, "while deductive arguments have universal laws which necessitate their conclusions, the conclusion of an inductive argument is not guaranteed, it is at best rendered highly probable" (p. 20). According to Salmon (1989), the most important development in the second of his *Four Decades of Scientific Explanation* was the explicit study and advancement of models of statistical explanation. In statistical explanation, an event is explained by showing that its occurrence is highly probable on the basis of given facts and known statistically general laws.

There have been other, more significant critiques of the D-N view. One critique, and this was known to Hempel, is that functional explanations do not fit the D-N pattern nor the probabilistic refinements to it. Functional explanations, the third pattern in Nagel's list, are closely associated with questions in biology and studies of human affairs (Nagel, 1961). Here the puzzlement concerns the purpose or function of something: Why do Os have P? (Kitcher, 1989, p. 417). Examples of questions requiring a functional explanation include: Why do deciduous trees have leaves that drop in the fall? Why do snakes have skins that shed? and Why do humans have kidneys? In answering any of these questions, attention must be paid to consequences, ends, functions, and purposes.

Consider an example discussed by Salmon (1989). We seek an explanation for why jackrabbits living in hot climates have such large ears. The functional explanation is that the ears serve as radiators of excess body heat. The problem for the D-N model in accounting for this explanation is that there is no general law as required by that model that can be used in a derivation of the fact that jackrabbits have large ears. The possible candidates, such as that mammals living in hot regions have large ears, are simply not true generally.

An additional critique comes from historians who insist there is a narrative or genetic explanation that relates the story leading up to the event to be explained. Scriven championed this critique and others of the D-N model in a series of papers (1959, 1962, 1963). The classic example that Scriven used concerns the mayor who contracted paresis. In the example Scriven constructs, he believes we can explain the mayor's contracting paresis by pointing out that he previously had syphilis that was left untreated. The problem for the D-N model in accounting for this explanation is that there is only a low probability of contracting paresis from untreated syphilis. Therefore, there is no possibility of constructing the general law required of the model and the low probability of the connection between syphilis and paresis challenges even the probabilistic refinements to the model, which depend upon the existence of high probabilities.

Nagel considered the distinctiveness of genetic explanations debatable, because he thought it likely they were "by and large probabilistic" (1961, p. 26). As he explained, "the task of genetic explanations is to set out the sequence of major events through which some earlier system has been transformed into a later one. The explanatory premises of such explanations will therefore necessarily contain a large number of singular statements about past events in the system under inquiry" (p. 25). He noted that because not every past event is mentioned, those events that are included must be selected "on the basis of assumptions (frequently tacit ones) as to what sorts of events are causally relevant to the development of the system" (p. 25). Salmon (1989) also refers to genetic explanations and describes them as narrative. Such explanations, he wrote, consist in "telling the story leading up to the event to be explained. Since the mere recital of just any set of preceding occurrences may have no explanatory value whatever, the narrative must involve events that are causally relevant to the explanandum [what is being explained] if it is to serve as an explanation" (p. 32).

A final problem with the D-N model that we shall mention is that it does not respect the asymmetry of the explanatory relation. If A explains B, then, unless we are dealing with the special case of a feedback loop, B does not explain A. We can explain the length of a shadow by the length of the flagpole that casts it and the angle of the sun. However, we cannot explain the length of the flagpole by the length of the shadow and the angle of the sun (although we could infer it). The D-N model cannot block this type of unwanted explanation, primarily because it is based upon a constant conjunction view of causation. However, as Kitcher (1989) has pointed out, the resolution to this problem depends upon having an adequate view of causation, and causation is no more tractable an issue than explanation.

A contemporary alternative to the D-N view designed to avoid such critiques, an alternative with acknowledged debt to its D-N predecessor, is Kitcher's (1989) explanatory unification view. According to this view, the value of explanations resides in their enabling us to unify and to organize knowledge. Scientific knowledge is unified to the extent that our explanations fit the phenomena into a general worldview with few independent assumptions. In contrast to the D-N view and other causal accounts of explanation, which allow explanations to be assessed individually, the explanatory unification view requires that explanations be assessed against the "explanatory store" (Kitcher, 1989, pp. 436–437) available at the time. Kitcher's view finds much of its motivation in the work of Friedman (1974) who maintained that a theory of explanations must tell us how they yield understanding. Understanding increases, he claimed, as the number of facts we have to take as brute is reduced. Scientific knowledge is thus unified to the extent that we can derive the largest number of facts from the smallest number of assumptions. That is, the same assumptions are used again and again to derive different facts (Kitcher, 1989, p. 434). In its focus on derivation, this view, like its D-N predecessor, is deductive.

Another contemporary alternative responds to the pragmatic intuitions in Scriven's critiques of the D-N view. So often in practice, Scriven showed, we are prepared to accept (his way of signaling the involvement of pragmatics) as explanations statements that have no chance of being fitted within a deductive argument. The most prominent champion of the pragmatics of explanation is van Fraassen (1980). According to his view, an explanation is an answer to a question, specifically to a why-question. In addition to the pragmatic element introduced by viewing explanations as speech acts in this manner, van Fraassen developed pragmatic theories of questions and of answers. His theory of questions shows that questions must be interpreted in context, making their meanings pragmatic. He asks us to consider the question, “Why P_k?” P_k states the fact to be explained, for example, “Birch trees lose their leaves in the fall.” Central to van Fraassen’s view is that the question admits of many interpretations depending upon the context. Two constraints are required to narrow the field of possibilities. First, we need to know the contrast class, X. If the question means, (a) “Why do *birch* trees (as opposed to other types) lose their leaves in the fall?, X = {pine, spruce, fir, cedar, ...}. If the question means, (b) “why do *birch* trees (similar to other types) lose their leaves in the fall”, X = {maple, oak, beech, ash, sycamore, . . . }. Alternatively, if X = {spring, summer, winter}, then the question is being interpreted as asking why the loss of leaves occurs in the fall as opposed to some other season. Other contrast classes are possible. The second constraint on interpretation comes from the relevance relation, R. What is the relation between the fact to be explained, P_k, and the contrast class, X, that the answer to the question, A, must provide? Under interpretation (b), the relevance relation might be that all these trees fall into the class *deciduous*. Under interpretation (a), the relevance relation might be causal: if deciduous trees did not lose their leaves when ground water was frozen, they would lose much more water than coniferous trees and risk death. So, in answer to, “Why P_k?”, van Fraassen supplies the answer: “P_k in contrast to (the rest of) X, because A” (1980, p. 143).

Table 2 contains an overview of the functions and types of explanations discussed in this section. As we have said, function and type are not always clearly separable. For example, justification sometimes appeals to causes; deductive-nomological explanation is meant to be causal, although it adopts a view of causation at odds with those who advocate a more mechanistic view; at least Kitcher’s meaning of the explanatory unification view relies upon deduction to provide the ideal form of explanation. The entries reveal the broad set of meanings attached to the concept of explanation.

WHAT IS NARRATIVE EXPLANATION?

In 1961 Goudge proposed that when one aims to make unique, nonrecurrent evolutionary events intelligible, “recourse must be had to historical or ‘narrative’ explanations. The situation does not permit of being treated systematically in terms of general laws” (pp. 70–71). This stand was disputed by those who held that all good scientific explanations necessarily contain reference, at least implicitly, to at least one general law (e.g., Ruse, 1971, 1975; Hull, 1974). Deductive-nomological explanations still held great appeal at the time. We have seen Scriven’s challenge to the D-N model is that frequently we explain particular events or conditions, not by providing a deductive argument from general laws and other events and conditions, but by simply pointing to other events and conditions. Specific events, as we have seen, are the elemental core of narrative. Hempel (1965, pp. 359–364) tried to accommodate Scriven’s objection within his D-N framework by dealing with pragmatic aspects of the explanatory situation. His conclusion is telling: “An explanation may well be put into the form of a sequential narrative, but it will explain only if it at least tacitly presupposes certain nomic connections between the different stages cited” (p. 362). According to Hempel, pointing to the mayor’s untreated syphilis does not explain his paresis unless also we assume a causal lawlike connection between the two. This intuition of Hempel’s is difficult to deny and has bedeviled most attempts to improve upon his D-N model despite its known flaws, and complicates the development of a coherent notion of narrative explanation.

TABLE 2 Explanations and Their Characteristics

Explanatory Function or Type	Characteristics
Interpretive explanation	• clarifies meaning • defines terms, propositions, treatises • assigns, develops, or expands meaning
Justificatory explanation	• explains by justifying why something was done • provides reasons for acting • appeals to norms, standards, or values • may appeal to causes as reasons for acting
Descriptive explanation	• explains by describing a process or structure
Causal explanation	• explains by citing a cause for events or laws • events may include human actions • many scientific explanations are causal
Deductive-nomological explanation	• explains particular facts or general laws by deriving the facts or laws from general laws and other facts • must include at least one universal law • basic structure is a deductive argument • causation interpreted as Humean constant conjunction
Statistical explanation	• explains facts by showing them to be highly probable • basic structure is an inductive argument • must include at least one statistically general law • causation typically is not implied
Functional explanation	• explains a fact by indicating its function
Explanatory unification	• explains phenomena by fitting them into a general worldview • aims to derive largest number of facts from smallest number of assumptions • views ideal explanation as deductive
Pragmatic explanation	• explains by answering why questions • questions are asked and answers are given in a context • contexts enable determination of appropriate contrast classes and relevance relations
Narrative explanation	• explains an event by narrating the events leading up to its occurrence • cites unique events as explanatory of other unique events • posits some events as causes of others • seeks unification (but does not supply deductive tightness) by showing how the event to be explained is one of an intelligible series of events • rarely supports predictions, but rather relies upon retrodiction to indicate how the present is a consequence of the past

If you can explain an event, according to the D-N view, then the explanation (including knowledge of the initial conditions) would have allowed you to predict it. Turning to the cannonball example once more, it can been seen that on the basis of the general laws and the antecedent conditions that explain why the cannonball traveled 2000 ft, it could have been predicted that the cannonball would travel 2000 ft before hitting the earth. However, in some scientific fields it is not possible to assume such symmetry. As Roqué (1988) wrote, "Explanation was possible, according to modern science, because phenomena were (assumed to be) atemporal . . . or that their future behavior was independent of the previous history of the system" (p. 249). She adds that in classical near equilibrium thermodynamics, one can argue that structures exhibit time but no history: "unlike structures explicable by means of classical thermodynamics, structures that are created under non-equilibrium conditions . . . . are irreducibly historical structures in the sense that their future behavior is *not independent* of their past . . . . [so] these *not only exhibit time but also history* . . . . *Within* each stable state, then, the deductive-nomological model works nicely; between states . . . one is left with *ex post facto* narrative" (p. 250). Predictability, as we have seen, is also not a feature of narrative. Rather, the norm is retrodiction, whereby what happens in the present is understood as a consequence of what has come before.

In her examination of the differences between historical and experimental science, Cleland (2002) states that "Hypotheses of prototypical historical science [among which she lists paleontology, archaeology, geology, astronomy, biology, and astrophysics] differ from those of classical experimental science insofar as they are concerned with event-tokens instead of regularities among event-types.[1] This helps to explain the narrative character of many historical explanations. The complexity of the causal conditions and the length of the causal chain (connecting the cause to its current traces) bury the regularities in a welter of contingencies" (p. 480).

As mentioned earlier, the presence of contingent events is a narrative feature that adds unpredictability and, thus, suspense to a text—that whets the narrative appetite. For science, Goudge (1961) wrote: "The presence of many contingent, contributory conditions in [a temporal] sequence makes it idle to hope that the statements constituting the explanatory pattern can be organized deductively, or even, perhaps, axiomatically" (p. 74), although one committed to the D-N view such as Hempel would certainly maintain that such organization must be possible, at least in principle, for there to be any explanation. Instead, Goudge maintained that just as historians produce a coherent narrative of events in order to make the sequence of events intelligible as a relatively independent whole, "In a similar way the explanatory pattern we are considering forms a coherent or connected narrative which represents a number of possible events in an intelligible sequence. Hence the pattern is appropriately called a 'narrative explanation"' (p. 75). Similarly, Roqué writes: "Narrative is not a mere temporal listing of discrete events; that is mere chronology, a linear sequence of atomistic, separate facts. In true narrative the telling of the tale explains by interweaving sequential but overlapping threads such that a temporal pattern, the *meaning* that has flowed throughout the unique sequence of events and has bound them into a whole, emerges" (p. 251).

In all these statements, it is important to note the view that narrative is important when one needs to explain unique events, "unique and unrepeatable events—not recurring events" as Moffett (1983) stated. He seemed to assume, however, that none of science is characterized by attention to unique and unrepeatable events. This assumption is in error. Morson (1994) uses the writings of Stephen Jay Gould in his discussion of narrative in science, asserting, "Laws of motion allow us to retrodict and to predict with equal certainty . . . But that is not true of evolution . . . For Gould, evolution is truly a historical science in the sense that contingency, unrepeatable facts and unpredictable details play an important part" (p. 245). "Why did Bighorn sheep evolve in the North American Rocky Mountains?" seems to be a question calling for a narrative account. The event is a result of an innumerable sequence of

[1] Generally, the type-token distinction is between a category and a member of that category: between *dog* and Spot, the dog next door. The distinction can be generalized to events—between *people saying "hello" to people* and President George W. Bush saying "hello" to Prime Minister Silvio Berlusconi on the occasion of President Bush's visit to Italy in July 2003—and to linguistic expressions—between the word *next* and the particular use of that word found in the previous sentence. Now that we have made this distinction, it can be seen that the events that make up narratives are event-tokens.

historical events, some of the more important of which could be listed. The emergence of Bighorn sheep could hardly have been predicted, though, even if the relevant facts leading to their evolution could have been isolated in advance.

Goudge, Cleland, and Roqué also assume that there are areas of science concerned with explaining the unique and particular. Therefore, one might surmise that narrative explanations or explanatory stories do have a place in science, albeit one limited to fields where it is necessary to detail a set of unique, contingently and causally linked events in order to make a particular event or phenomenon clear, understandable, or intelligible. So, we need a distinction between scientific fields in which particular events are intrinsic to the science, versus those in which they are not. We do not aim to supply a complete categorization here, but return yet again to the cannonball example. Explaining what happened to a *particular* cannonball is not intrinsic to the project of physics. Rather, it is an application of general physical laws to a particular context. That particular itself is uninteresting to physicists as physicists, because, having explained *any* particular they have put in place an explanation for any other token of the type. There is no new physics involved in the application of general laws.

By way of contrast, consider fields in which the particular has intrinsic interest. In those fields, questions such as the following are germane to the discipline and answering them marks an advance in the science: How was the Earth's moon formed? Is there life on Mars, and, if so, from where did it come? Why did the Neanderthals who lived in what is now Spain become extinct? How were the Italian dolomites formed? How did the dinosaurs whose fossilized remains are now found in Alberta meet their deaths? If narrative explanations are demanded ever in science, it is questions such as these that seem to come closest to demanding them. The question remains whether narrative explanations are provided in response.

Narrative explanations naturally must take on features both of narratives and of explanations. From what we have seen, the narrative elements of event-tokens and past time seem to be central. From the explanation side, it seems that narrative explanations are causal, but not deductive-nomological. Whether they are D-N in principle is an issue we believe is unresolved, but in practice they clearly are not deductive arguments. The other feature that seems prominent in narrative explanation is their unifying power. In this regard, they seem related to Kitcher's explanatory unification model. The final entry in Table 2 summarizes these characteristics of narrative explanations.

THE SCIENTIFIC STANDING OF THE NARRATIVE EFFECT

Many proposals for the use of narrative in science education rest on the presumption of a narrative effect. Such an effect is desirable educationally, in that it means improved memory for content, enhanced interest in learning, and greater comprehension of what is learned. The theoretical model outlined in this paper presupposes no such effect, but neither does it rule it out. Clearly, however, the status of the narrative effect is important to our agenda, and, as it happens, we believe the empirical evidence provides moderate support for a claim that there is such a thing as a narrative effect in a very broad and general sense. For example, there is research showing that narrative passages are read faster, comprehended better, and tend to be more absorbing than expository passages and perhaps than other genres as well (Graesser, 1981). Other research has suggested that a good narrative can increase the plausibility and persuasiveness of information presented (Voss, Wiley, & Sandak, 1999), a finding that would be important for science education, which places considerable emphasis on information. It has also been found that narrative passages positively affect memory (Graesser, 1981; Graesser et al., 1980) and that readers apply themselves more when reading narrative compared to expository prose (Zabrucky & Moore, 1999).

An explanation sometimes offered for such findings is that the actions and events in narrative are interpreted by readers as more concrete and more easily and closely organized by causal relationships than the organizational structures found in expository and argumentative prose. Of course, not all narratives show these effects over all expository and argumentative texts in all contexts. Many factors seem to be at work, including the fact that many texts are not purely one or the other type. For example, a narrative may have elements of description, an argument may contain a narrative, and so on.

Expository and argumentative texts *tend* to be more difficult than narrative texts for several reasons. Expository texts tend to have greater vocabulary load and propositional density. There tends to be less familiarity with the wide variety of possible expository and argumentative structures than with narrative structures. However, some of these factors are not necessarily tied to genre. For example, there exist both easy expository pieces with very few unfamiliar words and few propositions and very difficult narratives with many unfamiliar words and high propositional density. In such a comparison, the expository piece would likely be comprehended and recalled more easily. Also, there is the argument that positive narrative effects are not due to narrative itself, but to the fact that narrative is the genre that is used primarily for teaching reading and that school students are seldom taught how to interpret other genres (Graesser, Golding, & Long, 1991).

In order to establish confidently a narrative effect, we would need experiments that vary just the texts, comparing pure narrative and pure expository with the same content and difficulty while keeping all other text variables as well as reader, activity, and context variables controlled. Aside from the fact that such an experiment would be virtually impossible to implement, the finding of a narrative effect in this controlled situation could not be expected to hold in uncontrolled contexts where all the other text, reader, activity and context variables would immediately come into play. Any of these variables could override the genre variable so that the effect is no longer observed. Thus, a single genre variable is unlikely to account for the ease or difficulty of any particular piece of prose in educational contexts.

This being said, it is a ubiquitous observation that students find expository texts (e.g., content area textbooks) more difficult to read with comprehension than narrative texts, and reasons for this phenomenon have been noted by a number of people over the years. For example, Sáenz and Fuchs (2002) outline factors that contribute to difficulty with expository reading:

> Empirical evidence indicates that for most students, expository reading poses a greater challenge than does narrative reading . . . For secondary students, the effects of expository reading are wide and varying . . . Although many factors may contribute to the difficulty students experience with expository reading, the four most commonly cited are text structure, conceptual density and familiarity, vocabulary knowledge, and prior knowledge. (pp. 31–33)

Arguments such as these are fairly commonplace. For example, Alvermann and Boothby (1982) remarked:

> Educators commonly believe that upper elementary students find expository material (e.g., content area texts) more difficult to comprehend than narrative, story-like material. Empirical studies . . . generally have supported this belief. Teachers' explanations of why children find content area materials more difficult have pointed to such factors as students' lack of experience in dealing with expository structure, their unfamiliarity with the vocabulary or content, and their inability to process the heavy concept load. (p. 298)

Because many such statements and summaries are found in the literature, and because there is no strong body of opposing arguments, it seems fairly well accepted that, in general, expository texts are more difficult to read than narrative texts.

Some have argued that narrative has a privileged status in the cognitive system for a variety of reasons (Graesser, Golding, & Long, 1991; Graesser, Olde, & Klettke, 2002; Herman, 2003). Some of these arguments seem quite persuasive. There is appeal to the view that narratives are easier to comprehend, because the most basic elements of narratives are germane aspects of all human experience. We are all *agents* with *purposes* of some sort whose lives inevitably consist of a series of *events* situated in *time*. This being the case, and these being the fundamental properties of narratives, it is not a large leap to the notion that the "narrative" experience of our lives would make narratives in general easier to comprehend or recall than the content of some expository texts, which may be much less related to life experience.

Despite such claims for a narrative effect, there actually has not been much research done that directly compares narrative to other text types. We have on file almost 200 articles related to the study of narrative. Of these, 45 are experiments. Of the experiments, 26 included both narrative and expository texts as independent variables. Any one of these studies is, in itself, rather inconsequential. However, 13 of the experiments provided clear evidence to support the narrative effect, and 7 experiments provided evidence that was not so clear but was supportive. In 3 experiments, expository texts were found to have the advantage, once notably. In the notable study favoring expository text, the same passages were used as one of Graesser's much cited studies in favor of narratives. We interpret this level of evidence supporting a narrative effect as moderate. It suggests to us that frequently other essential variables in the reading process had a stronger effect than the text variable of genre. We are thinking of reader variables such as prior knowledge, interest, motivation, purpose for reading, reading proficiency, and strategy use, and activity variables such as discussion, summarization, multiple-choice questions, and cued recall. The fact that a narrative effect has not been produced more than 50% of the time in controlled conditions leads us to expect an even lower likelihood of the effect in the uncontrolled conditions of school science teaching.

TWO POSSIBLE EXAMPLES OF NARRATIVE EXPLANATION

We now are ready to use the narrative elements detailed in Table 1 and the descriptors of narrative explanation in Table 2 to test the narrative credentials of two examples of prose. The prominence of Millar's and Osborne's (1998) document in the United Kingdom and beyond warrants our attention to it. They put forward two examples as explanatory stories to illustrate this form of science writing, one about the Earth and its place in the solar system and the other about the particle model of matter. From their discussion, it seems clear that they are thinking about explanations intrinsic to science. We will examine *The Particle Model of Chemical Reactions*. We take the second example from a lengthy passage in a science trade book (Ward, 1997). The book is subtitled, *Why the Ice Age Mammals Disappeared*, and provides an extended account over 10 chapters of that explanation. Ward employs a mixture of genres, sometimes presenting an argument from evidence for a scientific conclusion, sometimes providing an expository account of natural phenomena occurring during the late Mesozoic period, and at other times launching into extended fictional narratives.

The Particle Model

The Particle Model of Chemical Reactions in its entirety is as follows:

> Imagine being able to 'peek inside' matter. Then you would 'see' that matter is made of tiny particles of less than 100 different types. These particles, called atoms, move about, arranging or re-arranging themselves in patterns or sticking together to make new, more complex particles. Alternatively, complex particles can be broken up into their constituent atoms.
>
> Seen at this level, breaking a brick tears particles apart from each other, as links between the particles are broken. Water evaporating is a few particles breaking free of the large collection in the puddle to move freely in the air above. Salt dissolving is charged particles breaking free from the surface of the crystal of salt, dispersing themselves amongst the particles of water. Iron rusting is particles from the air (oxygen, water) bumping into the particles of iron and combining to make a new bigger particle. Polythene is made when particles of ethene, whizzing freely around, join up in long chains when they bump into one another. Big complex particles (enzymes) act on others by being the right shape to help other particles come together and combine. Some of the particles are made of a single nucleus surrounded by electrons. If you looked around, you would find only 92 stable kinds, differing from each other by the positive charge on the nucleus (from 1 to 92) and their weight. Helium particles, for instance, would be four times as heavy as those of hydrogen. Each particle would be surrounded by an equal number of negative electrons so that any atom is electrically neutral. The electrons are arranged in a characteristic pattern, and the pattern repeats itself so that certain atoms have similar behaviour and fall into natural families. This pattern also decides which kinds of atoms any atom would readily stick to.
>
> When atoms join together in clusters they are called molecules. When atoms combine, the electron arrangement changes giving the new molecule totally different properties. So sodium (a highly reactive metal) can combine with chlorine (a highly reactive and poisonous gas) to make sodium chloride (common salt which we eat). This is how atoms and molecules make the huge number of different materials that there are—the many 'chemical compounds'. So when atoms break apart and regroup, a 'chemical change' has occurred and the new substance is different from its constituent parts. (Millar & Osborne, 1998, pp. 2014–2015).

This piece of writing is explanatory in two senses of the term: it is an effort to make what is obscure to students intelligible to them; and it provides an elementary causal account of a number of phenomena, including evaporation, dissolution, rusting, and the formation of common compounds. In this latter role, the explanation is intrinsic to science. But is it narrative? We first see that the question seeking an explanation, "What is the particle model of chemical reactions?", does not contain the focus on particularity and uniqueness of events associated with narrative in our model. We also note that the text does not name a single event-token. It does contain descriptions of conditional events and events with other modal qualifiers: "Then you would see . . . "; "If you looked around . . . "; "So sodium . . . can combine with chlorine . . . ." It does name event-types: " . . . breaking a brick tears particles apart from each other . . . "; "Salt dissolving is charged particles breaking free from the surface of the crystal of salt."

The passage does have a narrator. The narrator is unknown and impersonal, but there is someone asking us to imagine things and suggesting what we might see if we did. However, the narrator is quite peripheral to the passage and does not play the role of manipulating the order of events that can be so crucial to narration.

What about narrative appetite? Rather than open and nonlinear, the text is closed and linear. The narrator does not create points of ambiguity in the text in order to invite the reader to see multiple possible futures and to provoke the reader into a state of curiosity, suspense, and tenseness. Largely, this is because the text does not invite wonderment about what happens next. There is no before and after in this text, because time, another narrative element, is absent. What is being described is timeless.

Is there a narrative structure? Is there agency and purpose? Narrative structure is not present largely because there is no plot time to manipulate in the narrating. There is no beginning, middle, ending; no complications and resolutions; no imbalances, successes, or failures. There are no agents in this passage; nobody who is causing and experiencing events. There is nobody to be responsible for anything. Clearly, the text is designed for the purpose of helping the reader understand the natural world. However, the text is not about how human beings relate to that world.

Finally, how is the reader likely to interpret this text? We cannot tell with certainty from our model, which is theoretical. However, due to the lack of most narrative elements, and given the tenuousness of the narrative effect even in experimental studies, we predict that it would not be interpreted as a narrative or as narrative explanation. More likely, it would be interpreted as descriptive prose, offering an exposition of why certain event-types occur, and, consequently, would be unlikely to have the positive effects on memory, interpretation, and comprehension attributed to narratives. Of course, these predictions depend for their success on our theoretical model having picked out the elements crucial to readers for identifying narrative.

The Ice Age Mammals

The excerpts below are from a four-page section that provides a fictional account on the demise of the dinosaurs by focusing on the area of the Earth that is now Texas.

> The herd of duckbills lowed to one another as the first hints of dawn began to paint the eastern sky with the faint promise of daybreak. The low coastal swampland was already alive with the calls of birds, but calls somehow dissonant and anxious, as if predators were approaching, though none could be seen or smelled. To the west, still black with night, the full moon was beginning to set; to the south, however, a bright star blazed forth, with a long phosphorescent tail extending across half the night sky. It had been in the sky for many nights, growing larger and brighter with each reappearance. Among the vertebrate and invertebrate fliers that depended on the moon for navigation, this new beacon scrambled all the visual neurons; nowhere in the intricately coded DNA of the birds, insects, pterosaurs, and pterodactyls was there any information about a second moon in the sky; it troubled them at a deep, intracellular level. Seaward, in the warm reefal ocean, the combination of approaching day, a full moon, and the new celestial light meant extra food for the piscine swimmers and shelled ammonite predators as they hunted crabs and shrimp in the coralline cities.
>
> The dinosaur herd was completely awake now and starting to feed on the rich low vegetation . . . . The bright head of the comet could be seen to descend slowly into the south and finally disappear below the horizon, to be followed some seconds later by the orange glow of a second dawn.
>
> From the southern horizon a thin but brilliant bar of white light shot upward into the sky, the first proclamation of the end of an era and the beginning of a new one. Molten rock from the impact created this beam of light as rock from the comet and the impact site were intermixed and blasted into the thin pillar of vacuum created by the comet's fall to earth. The dinosaur herd was still oblivious; southern lightshows were irrelevant to brains programmed to seek food, avoid predators, and propagate. But the great flocks of birds paid heed, falling silent as the second dawn unfolded. The thin pencil of light began to change color, become more diffuse, and widen; from its base, tiny specks of light fanned outward in all directions. What sounded like distant thunder now silenced the dinosaurs as well, and all turned to the south as a bass rumble intensified. A low cloud appeared in the south, moving

> toward the herd. The dinosaurs turned in fear as the shock wave approached and then passed in speeding seismic fury, emptying the trees of birds, creating great flocks of screaming avian and reptilian flyers in the rapidly brightening sky. The now-terrified dinosaurs rushed in all directions, oblivious to the silence that once more filled the landscape, oblivious as well to the orange cloud creeping upward from the southern horizon . . . .
>
> Swamps and lakes and especially the sea's edge became last refuges of the great Mesozoic fauna. The survivors crowded the shorelines of the once and future seaway beneath the cosmic barrage, explosions now blasting great clots of burning forest as the meteors rained inward. And through that inferno a new noise manifested itself, a great roar coming from out to sea as a huge new mountain range appeared in the direction of the retreating ocean, a mountain range growing larger every moment, a black mountain reflecting the angry red of the burning land, a mountain now a kilometer high, a mountain formed from the angry sea, the largest wave in the history of the world . . . . In Texas nothing survived. Nothing. (Ward, 1997, pp. 63–66)

This passage very closely matches the set of narrative elements in Table 1. First, it names event after event. They are event-tokens and they happened in the past. There is a narrator standing outside of the events and relating them to the reader in a sequence that roughly matches the sequence of plot events. Where there are simultaneous events, the narrator chose which to relate first, allowing the reader to compare, for example, the initial obliviousness of the dinosaurs with the initial alertness of the flocks of birds. Narrative appetite is whetted in part by the pace and order of the narration. For example, in a section not quoted, the narrator takes considerable time to describe what was occurring as the sea receded, which enhances anticipation about what this event foreshadowed. But narrative appetite is whetted even earlier in the description of the bird calls as "somehow dissonant and anxious." "Why so?" the reader is prompted to ask. There is also consciousness that, although it does not rise to the level of agency, frequently reflects the responses of humans in similar terrifying situations: the initial obliviousness of the dinosaurs, the paying heed and falling silent of the flocks of birds, the dinosaurs turning to face the south in fear and then in terror, the creatures capable of swimming seeking refuge in the sea, the land creatures fleeing the blazing forest, and so on. Regarding purpose, it is difficult to read this passage without imagining what it must have been like to be there. Perhaps this was one of the author's purposes, to help human beings better understand the natural world, to realize that when animals face such cataclysmic events they experience similar sensations to humans.

In addition, the text is explanatory. It fits most closely with the models of genetic and historical explanation discussed previously. The story sets out a sequence of events "through which some earlier system has been transformed into a later one" (Nagel, 1961, p. 25) and tells "the story leading up to the event to be explained" (Salmon, 1989, p. 32). The event being explained, the extinction of the dinosaurs, also fits into the set of "unique, non-recurrent evolutionary events" mentioned by Goudge (1961, pp. 70–71) as calling for historical or narrative explanations and fits with Cleland's (2002) idea that "the hypotheses of prototypical historical science . . . are concerned with event-tokens" (p. 480).

This example contains many of the narrative elements we have described in our model. Also, the explanation is intrinsic to science. As such, it suggests that it is possible to construct narrative explanations that are part of the substantive content of science itself, and not merely explanations about science. Under the sorts of carefully controlled experimental situations where a narrative effect has been found, we predict that readers would interpret this passage as narrative and use that schema to form expectations and anticipations for the text. We also predict that under such conditions the passage would have the positive effects on memory, interest, and comprehension frequently associated with narrative. However, as noted earlier, these predictions from our model must be subjected to empirical test.

DISCUSSION AND IMPLICATIONS

Our investigation was prompted by claims about narrative prose and its expected positive role in science education. As we have shown, the expectations have at least some plausibility. Although some evidence tends to support the use of narrative in science education, more needs to be considered. The research comparing narrative to other genres suffers from design problems due to failure to control relevant variables. It is very difficult, for example, to construct comparable narrative and expository passages that are alike in all respects except that they are in different genres. The genres invite different topics, word choices, and sentence structures and it might be these, and not the genres themselves, that are leading to differences in readers' responses. In addition, other studies (e.g., Phillips, 2002) conclude that although narrative appears easier than expository text for students to comprehend, the difference is small. Even more to the point, Phillips found that the inferential interpretation ability of students is weak no matter what the genre. Therefore, once we venture past rote learning, literal interpretation of texts, and locating information, students will require additional literacy competence and the instruction that fosters it no matter what the genre.

Having said all of this, we believe the role of narrative in science education needs to be explored more completely. We started this exploration with a focus on narrative explanations intrinsic to science. We provided a detailed theoretical analysis of narrative prose, indicating its hypothesized crucial elements. If the narrative effect hypothesis has any substance, then it might be the presence of some or all of these elements that produces the effects on memory, comprehension, and interpretation that we all desire. However, scientific explanations typically are not characterized by event-tokens, past time, and agency, the elements we have posited as being of primary importance in narrative text. We have shown that narrative explanations are possible in science, but that they are likely to be found in particular contexts, namely, those involving the explanation of unique and nonrecurring events. Since scientific work is often concerned with general and recurring events, narrative is unlikely to be found frequently or to be appropriate to the task. We have therefore begun a search for examples of narrative explanations in areas of science that are most likely to deal with unique events, one of which we have reported. We know from this example that it is possible to create an elaborate narrative explanation that is intrinsic to one area of science. Additionally, we predicted that this text would demonstrate the narrative effects sought.

In order to make narrative explanations a significant part of the science curriculum, a number of things would have to happen. First, a more extensive catalogue of narrative explanations is needed in order to provide a basis for curriculum. Second, if more than a very few narrative explanations are to be included in the curriculum, then topics that traditionally have been a minor part of the curriculum will have to be given a more prominent place. There would be more emphasis on the historical, so-called "softer," sciences, less emphasis on what is general and universal, and more emphasis on particulars that are of scientific interest.

We have been concerned specifically with the nature and use of narrative explanations but there may well be reasons to use narratives in science education that have little to do with scientific explanation. As we noted at the very beginning of this paper, narratives may be used to introduce content and inspire interest in scientific investigation, which would lead to more involvement with scientific texts. The potential many and various roles of narrative in science education need to be further explicated and better understood. The science education community must take these matters seriously, because alterations in the science curriculum to include more narrative could have effects other than the positive ones on memory, comprehension, and interest contemplated. One possible additional effect might be the attraction of more females into science, because of a greater interest in narrative on behalf of females (OECD, 2000). We remain skeptical of this result, however, both because it is not clear that it is the genre of the text that deters females from entering science (or some sciences) as frequently as they might, and it is not certain that females are more attracted to narration than they might be to exposition and argumentation. An alternative possible effect might be the attraction of greater numbers of individuals into science, both males and females. This might occur as a result of less emphasis on more basic sciences, such as physics and chemistry which tend to be universal in their theories and laws, and more on the historical sciences. Like narrative, if this is true of narrative, the historical sciences might be easier for most individuals to remember, interpret, and comprehend. More narration might go some way toward altering the image of science as impersonal, atemporal, and ahistorical, which characteristics appear off-putting at least for some people.

At this point, we wish to add some notes of caution and also to suggest a partial agenda for future research. We must be wary of any proposal that appears to make a direct connection between theory and practice or research and practice. Imagine a line of reasoning that goes like this: Research indicates that narratives are easier to comprehend and recall and more engaging than expository pieces in general. Therefore, if we put scientific material into narrative form, this practice will facilitate comprehension of and engagement with scientific content.

One problem with this line of reasoning is the apparent assumption of a direct and transparent relationship between basic research and educational practice. This assumption is almost never warranted (Norris, 2000). Regarding the use of narrative explanations in science, there are a number of concerns. First, the two examples we have considered suggest that attempts to construct narrative explanations in science would result in hybrids that contain some elements of narrative. Very little is known about the use of such hybrid texts in learning. Because these are not true narratives, it is possible that much of the benefit associated with narratives would not materialize. True narratives, for example, tend to evoke aesthetic and affective responses, which presumably aid comprehension and recall in ways that are not well understood. Would hybrids do this? If they do not, it is unlikely that the use of narrative explanations would yield the desired benefits.

A second problem has to do with limiting students' exposure to the types of text they will encounter in real life and in specialized fields of study. Existing research indicates that exposure to text types leads to knowledge of genre and enhances ability to comprehend and learn from various forms of writing (Dymock, 1999). There is additional evidence that narrative forms already dominate school reading experiences (Venezky, 2000). If narrative is easier to comprehend and remember, and most of students' reading instruction utilizes narratives, how will they learn to cope with expository and argumentative text types? By a twist of reasoning, any evidence for a narrative effect or the prominence of narrative in life or school experience provides a powerful argument for providing more experience with and instruction in expository and argumentative text, because these are the types of text that students will have experienced the least and with which they will find the most difficulty. Under these considerations, more, not less, experience and instruction with such texts seems justified.

With these concerns in mind, we close with a few suggested questions for future research, and with a comment.

1. What are the implications of any narrative effect for teaching science? We need to better understand and more closely explicate the issues surrounding this question in order to grasp the possible roles of narrative in science education.
2. What features of narrative prove through empirical research to be most crucial, and how do they operate? The answers to these questions are needed in order to learn

whether there might be positive narrative effects from texts that have only some of the features of pure narrative. Are there degrees of narrativity associated with degrees of narrative effectiveness? We suggest that our list of narrative elements can help guide empirical research into this question.

3. In addition to the possibly beneficial effects of using narrative explanations intrinsic to science, are there positive effects that accrue from the use of narrative explanations extrinsic to science as has been suggested going back many decades?

Our comment: After extensive searching, we remain skeptical of finding much narrative in primary scientific sources, even when those sources are in the historical sciences. Our conjecture is that the narrative genre is not sufficiently attuned to the requirement that scientific writing be cautious, circumspect, and tentative. We have found these characteristics to be as prominent in the examples of historical science that we have examined as they are in the more basic sciences. It is clear that genres other than narrative are predominant in science and this prevalence perhaps should be reflected in science curriculum. Exposition and argumentation are adopted for good reason in science—they not only effectively carry the reasoning that connects scientific methods and data to conclusions; they also carry the precision of description demanded for replication, test, and critique; and they carry the disposition of tentativeness and the policy of circumspection required by all honest scientific work. Concomitantly, the role of narrative in scientific explanation is limited whenever science aims for generality and is not interested in the particular, which is frequent. Therefore, however important a role the use of narrative might play in science education, students must still be taught to interpret and critique exposition and argumentation. There is greater need for improvement in teaching students how to read well these genres than there is for including more narration.

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