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Chapter 12

Effective Explanation of Uncertain and Complex Science

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Years ago, forest fires were always bad. Currently, prescribed burning is a standard practice in forestry.

Years ago, swamps were wastelands. Now, environmental scientists say these wetlands are "nature's kidneys" because they cleanse polluted water, allow floodwaters to recede peacefully, and provide habitat for important flora and fauna.

Several years ago, we were told that salt was bad for our health. A recent TV documentary said the health risk of high salt intake has been substantially overstated and that high salt intake is harmful only to those with specific health ailments (Neufeldt, 1997).

Audiences for mass media science routinely receive these conflicting reports. They learn to talk about wetlands, hormones, toxic chemicals, and ozone layers, although exactly what these concepts mean and what the conflicting reports about them are saying is often unclear. Uncertainty about the validity and meaning of scientific claims is pervasive in science news.

Journalists routinely manage uncertainties. They learn to frame conflicting claims as certain types of stories, and they identify ways of researching unfamiliar subjects quickly (see chap. 2, in this volume). As experts in the arts of uncertainty management, they do not need a review of communication fundamentals, but they can use "step back" opportunities. Just as professional athletes benefit from coaching, so too can those who report and write scinews benefit from learning about text features that help audiences consider conflicting information and understand complex ideas.

This chapter provides that sort of "step back" opportunity. Organized as a discussion of myths, this chapter first debunks the myth that science is a collection of facts that scientists spot and journalists convey. To critique this myth, the chapter discusses ways in which scientific knowledge and everyday knowledge differ, and then explains the implications of these differences for reporting science news. A key implication is that audiences are poorly served when scientific findings are reported without some account of the reasoning that led to them. Frequently, the finding and the reasoning are intertwined.

The second myth concerns balance in science news. Sometimes science news is reported with an announcement of findings, a statement from someone who agrees with the findings, and another from someone who disagrees. This approach suggests that those agreeing and those disagreeing have equally valid perspectives. Because science works by consensual puzzle-solving, this is rarely the case. The chapter explains why and offers an alternative way to report science news objectively.

The third myth says that jargon and lengthy sentences are the principal obstacles to making science news clear. Instead, there are other, harder to detect, but more important barriers to comprehending science. Three are identified along with research-supported ways of overcoming them.

MYTH #1: SCIENCE IS A COLLECTION OF FACTS THAT SCIENTISTS SPOT. JOURNALISTS CONVEY THESE FACTS THROUGH NEWS STORIES SO NEWS AUDIENCES CAN APPLY THEM TO THEIR LIVES

Like all myths, this one has some appeal. Most people encounter science through textbooks, and textbook science is typically a presentation of established scientific knowledge (Trachtman, 1989). Because a good deal of textbook science has been tested for decades or even centuries, it has the status of fact. Yet, this myth suggests that news about the findings of recent studies also constitutes facts and that news stories reporting these facts must be correct. Furthermore, it says that reporters simply convey scientific findings and provide a range of comments about them.

One way of questioning this myth is to analyze its impact in different situations. First, consider a reporter covering a city council meeting. The meeting is an event that reporters, editors, and news audiences can verify. Many have some way of judging the council news to determine if it makes sense. In sharp contrast, imagine that a respected local scientist calls a TV station to report seeing a UFO above Main Street. Reporters receiving this call have many ways to check it out, just as they do the city council story. They can talk with passersby to see if they saw anything unusual downtown. They can contact the scientists' colleagues to see whether they can corroborate the UFO sighting. They can interview family and friends of the UFO-spotting scientist to inquire about his mental health, and so forth. However, if this story is aired or published, there is one aspect of it that will probably not be reported—an aspect that is difficult for journalists and news audiences to assess. The scientist who believes he has identified a UFO has likely used special reasoning processes to reach his conclusion, as startling as it might be. Although these out of the ordinary patterns of thought might be attributable to mental instability, they are also the stuff of scientific discovery. Even though these reasoning processes are hard to explain, they are part of the story. The news is not simply that something occurred. The news is the range of questions, uncertainties, and interpretations the reporter, scientists, and other rational observers would use to identify and frame this event.

In one sense, scientific claims are always like this hypothetical scientist's claim that a UFO is hovering over downtown. Scientific claims refer to events in the world that may be both real and creations of a particular kind of human reasoning. The specialized reasoning needed to make scientific discoveries is frequently not reported in news stories because it is unfamiliar and hard to understand. Yet, reporting a scientific discovery without at least some of the reasoning that led to it is like reporting a baseball game's final score without an account of the game. The score is meaningful only to fans. For science news to be meaningful, enjoyable, and accountable to wide audiences, journalists need to package stories in ways that help people realize that the fundamental rule in considering them is not "true, unless good reasons suggest otherwise." The rule for judging science news should be "important, if true" (Sandman, 1986, p. 1).

In the 19th century, astronomers discovered Uranus, the seventh planet from the sun. About the same time, they spotted some round, blurry images in interstellar space that looked like Uranus. Astronomers named these round images *planetary nebulae* because they looked like planets and they were nebulous, or hazy. In 1997, astronomers using the Hubble Space telescope were able to see these fuzzy images more clearly. Scientists now say that planetary nebulae are not planets, they are not nebulous, and they are not always round.

News reports in late 1997 told of a scientist nearly falling off his chair when he saw Hubble's pictures of planetary nebulae (Wilford, 1997). Hubble's photos revealed these blobs to be neither blobs nor planets, but the gaseous emissions of dying stars burning away in shapes ranging from pinwheels to butterflies (Edmonds, 1997).

The difference of a century shows the integral connection between scientific facts or discoveries and the reasoning that leads to them. As the misleadingly named planetary nebulae show, scientific findings are partly "out there" and partly a function of currently available scientific tools and reasoning. As noted earlier, to report only findings, facts, or discoveries is similar to reporting sport scores without describing the corresponding games. Ideally, good sports coverage helps people to enjoy, vicariously participate in, and even check the accuracy of a game story. Similarly, coverage of science news should help audiences be scientist-like in the ways in which they respond to science news. A good science news story should help audiences learn to test or question scientific claims. Ideally, it feeds an audience's appetite for increasingly better explanations by giving people some basis for questioning or considering scientific claims—rather than frustrating them with unsupported claims that warrant only blind faith or unreflective cynicism.

Scientific Knowledge and Everyday Knowledge

Journalists who understand the differences between scientific knowledge and everyday knowledge can help their audiences think scientifically. Social scientists Reif and Larkin (1991) summarized these differences well. According to these authors, scientific knowledge and everyday knowledge vary because the goals of science and everyday life differ. People's goals for living are, roughly, to lead satisfying lives. Explaining confusing phenomena and predicting future events are important only in so far as they contribute to the general goal of having a satisfying life. Consequently, the criteria for explanation and prediction in everyday life are not stringent. For example, if you routinely park a car on steep hills, it is useful to predict that applying the parking brake will reduce your risk of injury. Yet, for everyday life, few people need the laws of physics to understand what will happen if they fail to exercise this caution.

In contrast, for scientists, explanation of natural and social phenomena is the principal goal. Consequently, the definitions, claims, words, and inferences used to explain and predict must be exceptionally precise and careful. Furthermore, because more refined, more precise, better explanation is always possible, no phenomenon, no matter how thoroughly studied, is ever fully explained

or understood. In this sense, all scientific knowledge is uncertain. In addition, and more surprising from the perspective of everyday life, discovery is not the principal goal of science. Galileo discovered the sparks near Jupiter with his telescope, but his capacity to hypothesize that these sparks of light were probably moons was an integral part of his finding. Instead of facts being "out there" for collection, science is the process of building increasingly better ways of explaining reality through the testing of claims (Burleson, 1979; Kinneavy, 1971; Kuhn, 1962; Toulmin, 1972; Whedbee, 1993). In support of this view, Reif and Larkin (1991) cited physicist William Bragg, who said, "The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them" (p. 739).

REVISION OF MYTH #1: SCIENCE IS A PUZZLE-SOLVING PROCESS DESIGNED TO PRODUCE BETTER EXPLANATIONS OF REALITY. WHEN JOURNALISTS REPORT SCIENCE NEWS, THEY SHOULD HELP AUDIENCES PARTICIPATE IN THIS PUZZLE-SOLVING BY REPORTING SOME OF THE REASONING THAT SUPPORTS OR QUESTIONS THE FINDINGS

For audiences to gain the most from science writing, journalists need to assist them in learning to "play" the game of demanding increasingly better explanations and increasingly more evidence for any claim. As Reif and Larkin noted, audiences are capable of learning very precise rules for reasoning when they understand that these rules are needed. For example, people learn the precise rules needed to play board games or to balance their checkbooks. Just as journalists assist audiences in understanding and evaluating unfamiliar sporting events, so too do they need to assist audiences in understanding and evaluating scientific claims.

Unfortunately, reporting scientific findings with little evidence of their merit has become a frequent practice. Pellechia (1997) sampled 30 years of newspaper science stories. She found that stories often omitted information on how scientific studies were conducted. An Associated Press (1997) story seemed to illustrate Pellechia's finding:

> NEW YORK (AP)—A derivative of vitamin A reversed emphysema-like abnormalities in the lungs of rats, suggesting a possible lead for a treatment. . . .

> "This is the first time that anyone has identified a means of reversing emphysema," said Dr. Claude Lenfant, director of the National Heart, Lung, and Blood Institute.
>
> But Lenfant, whose institute paid for part of the work, said in a statement that much more basic research is needed "before we can even begin to think about applying this to humans." (p. 4)

This story summarizes a study published in *Nature*, a scientific journal. The Associated Press reporter was careful to note the study's funding source and to include a caution about overgeneralizing the finding in rats to humans. Yet, another essential step may not have been taken. Readers need evidence if they are to make their own judgments, and they need writers to teach them how to evaluate the evidence. When they are not given evidence, audiences have no guidance on what to think if conflicting findings are reported 6 months from now. In its current version, this emphysema story is about as meaningless as the UFO-spotted-downtown story. A claim is made, but the reasoning behind the claim is missing. Audiences need that missing part of the story if they are to understand why that claim survived rigorous testing—or if it did.

Suggestions for Journalists

To help audiences think about science news, journalists should find out:

- What evidence, reasoning, or testing supports a finding.
- What "bugs," frustrates, or impresses scientists about their finding.
- What parts of the puzzle remain unsolved.
- What the best objections are from respected others.
- What has to happen before the finding is viewed as established knowledge.
- What people can do to learn more.

MYTH #2: CONFLICTING FINDINGS AND OPINIONS IN SCIENCE NEWS CAN BE REPORTED THE SAME WAY DISAGREEMENT IN ANY OTHER FORM OF NEWS IS REPORTED

In everyday life, we are often interested in public opinion on questions of value and policy. The range of opinion on immigration or taxation is important partly because decisions on these policies will be influenced by our votes. However, scientific knowledge or consensus is not built by elections or opinion polls. It is built through the testing of claims in scientific journals, conferences, and daily discussion. So, when journalists strive for balance in reporting, they cannot simply give audiences a report that "one scientist says it is and another says it is not." Instead, to achieve balance and accuracy in science news reporting, journalists need to let the public know whether an explanation is widely shared in the scientific community, the bases for its support or lack of support, and some of the better critiques of this position.

REVISION OF MYTH #2: BECAUSE SCIENTIFIC PUZZLE-SOLVING WORKS BY TESTING CLAIMS AND BUILDING CONSENSUAL SUPPORT FOR ONE EXPLANATION OVER OTHERS, NEWS AUDIENCES NEED TO KNOW HOW WIDELY A SCIENTIST'S OPINION IS SHARED BY OTHER SCIENTISTS

Global warming is an issue that illustrates the importance of reporting the extent of scientific support for claims. This climatic phenomenon refers to an average increase in global temperature caused by increasing amounts of greenhouse gases (Hammitt, 1995). Currently, there is widespread scientific agreement that amounts of atmospheric greenhouse gases have increased over the last several centuries. Evidence of these increases may be found in such phenomena as fossilized plants and tree ring records. These entities provide indicators of changing atmospheric gas content (Williams, 1992, p. 197). In contrast, however, there is considerable disagreement among scientists about the long-range physical, social, and economic impacts of these increases.

Ideally, a balanced story on global warming would let audiences know which claims in this complex puzzle are supported by scientific consensus and which are not. A story that cited one scientist who said greenhouse gases have increased since the 1600s and another scientist who said they had not would be balanced in the classic sense, but it also would be extremely inaccurate and misleading. Reporters are more likely to achieve balance, accuracy, and objectivity in covering science news if they let audiences know how widely key claims are supported by most scientists. The puzzle-solving orientation of science means that groups of scientists continually try to find consistent ways of viewing, testing, and solving core problems. That is, they work within paradigms. The trick in science reporting is to indicate broad support for claims that have survived rigorous testing but still help audiences see that currently accepted perspectives are the best working hypotheses.

Although mass media reports may tend to underestimate the amount of scientific consensus on certain claims, in some cases there may be, in fact, relatively little consensus. News audiences have become accustomed to conflicting answers on questions about the merit of fat and sugar. Unfortunately, research suggests that, rather than helping audiences cope with complex issues, stories that present conflicting information sometimes breed confusion or cynicism (Qian & Alvermann, 1995; Rukavina & Daneman, 1996; Schommer, 1990). Reflecting the public's frustration, Greenfield (1984) wrote, "By now the public suspects that what is banned today is likely to be given intravenously tomorrow" (p. 80).

Such cynicism is sometimes warranted. But, because science is an unending quest for better explanations and because the phenomena it attempts to explain are complex, a great deal of science news involves inconsistent information. Interestingly, a recent line of work suggests that the ways writers frame or package science news may assist audiences in interpreting conflicting findings (e.g., Qian & Alvermann, 1995; Rukavina & Daneman, 1996). In brief, this research shows that when writers cast scientific information as a puzzle or a dilemma, where there is no single answer, some individuals are better able to comprehend it. Specifically, Rukavina and Daneman (1996) found that labeling conflicting accounts as an unsolved puzzle with two possible answers and then discussing the strengths and weaknesses of each answer significantly improved comprehension of these ideas among many high school and college students. In contrast, students who received the same information in texts that presented the two theories successively were less likely to understand the theories or even note that they conflicted.

Journalists are not always able to frame scientific findings as a puzzle. Sometimes science news gives results from only one study. However, the puzzle frame is appropriate when several studies present mixed results. For example, a 1997 story begins, "The quandary faced by millions of American women of whether to enter menopause with or without hormone replacement therapy is likely to be exacerbated by a new set of studies published this week" (Bowman, 1997, p. A2). The story's next two paragraphs briefly summarize two research reports: a *New England Journal of Medicine* study that says hormone therapy may increase risk of breast cancer and a *Neurology* study that says this hormone therapy may reduce risk of Alzheimer's. The story then describes these studies and includes a recommendation that women consult their physicians to determine the best choices for them. If Rukavina and

Daneman (1996) are right, audiences' abilities to reason about science news such as this may be improved by the reporter's lead paragraph labeling the situation as a quandary to which there are few simple answers. Without this story frame, some readers may infer that a fatalistic or cynical view of postmenopausal options is the only possible perspective. The puzzle format may increase awareness of other choices.

Suggestions for Journalists

To provide balance, accuracy, and objectivity in science news, reporters should:

- Learn if a claim is widely supported by scientists.
- Find out if the scientists being interviewed endorse this consensus.
- Ask whether there are important variants on the consensus view.
- Frame conflicting findings as puzzles, noting the strengths and weaknesses of key puzzle-solving efforts.

MYTH #3: JARGON AND LONG SENTENCES ARE THE CHIEF OBSTACLES TO UNDERSTANDING SCIENCE NEWS

Intuitively, we know that unfamiliar words and long sentences are often hard to understand. Research supports these intuitions. For example, Hayes (1992) operationalized *lexical difficulty* as relative frequency of word usage. He demonstrated that scholarly articles in journals such as *Science*, *Nature*, and *Cell* are among the most lexically difficult forms of discourse, whereas mothers' talk to 3-year-olds and farmers' talk to cows are among the least lexically taxing. Numerous other readability studies, in which *readability* is defined in terms of word and sentence length, have come to similar conclusions (e.g., Klare, 1963).

However, there are important limitations to readability research. First, it offers a very narrow depiction of possible sources of confusion. Readability research assumes that the only sources of difficulty in comprehending complex ideas are the length and familiarity of words and sentences (Shuy & Larkin, 1978). Although this set of obstacles is important, audiences find many ideas difficult to comprehend, even when they are expressed in the simplest and most familiar words (e.g., the idea that the Earth is weightless is hard to understand).

Furthermore, studies show that if writers try to simply shorten sentences by excising transitional words and phrases, they may occasionally make their texts less—rather than more—understandable (Davison, 1984; Duffy, 1985). Transitional words and phrases may illuminate links between key points; these links, in turn, help audiences build mental models of complex phenomena. So, ironically, a text with multisyllabic words and long sentences may be more understandable than one with short sentences and a seventh-grade reading level—if the ideas it expresses seem intuitively plausible.

A third problem with readability research is that it is atheoretical. Grade levels for readability are simply correlations between indexes of word and sentence length in reading passages and the likelihood that students in various grade levels can answer questions on these passages correctly. It is unlikely that word and sentence length are the only factors affecting student comprehension.

REVISION OF MYTH #3: THERE ARE MANY OBSTACLES TO UNDERSTANDING SCIENCE NEWS

When it comes to excising jargon and making sentences clear, journalists have considerable support from textbooks, computerized aids, and editors. Yet, science writers and journalists have far less assistance in anticipating their audience's conceptual confusion. This may be one reason why Long (1995) found that science news stories devoted only 10% or less of their content to explaining complexities.

One way to think about likely sources of conceptual confusion is to review research on these phenomena. According to research, scientific ideas may be misunderstood in three principal ways. The first source of confusion occurs when familiar terms are used in unfamiliar ways. In everyday life, the word *force* may be associated with movement that requires effort, such as pushing or shoving; for scientists, however, this term typically refers to Newtonian force, which has nothing to do with effort. In everyday parlance, *hormones* are often considered artificial, excessive, or unnecessary substances; however, in scientific contexts, the term *hormones* may refer to essential substances found in all cells, both plant and animal.

The second source of conceptual confusion concerns structures or processes that must be envisioned or mentally modeled at new levels of precision or abstractness. Instead of simply referring to digestion, scientists might need to envision these processes in great detail to learn, for example, why stomachs do not digest their own linings. Similarly, a scientist considering a traffic accident might want to envision it abstractly in terms of an equation: Force equals mass times acceleration (F = MA). Journalists may have to help audiences to picture these entities in these new ways.

A third source of conceptual confusion lies with notions difficult to understand because they are counterintuitive. For instance, the ideas that the Earth is weightless, that forest fires can be good for forests (Patterson, 1992), or that plants naturally produce carcinogens and pesticides (Ames, Magaw, & Gold, 1987) are each supported by many scientists. Nevertheless, these ideas seem implausible to many people.

Scholars in a variety of fields have explored these obstacles to understanding science, identifying text features effective at overcoming each. I refer to people's efforts to minimize these difficulties as certain types of explanation (e.g., Rowan, 1988, 1992, 1995). These include elucidating explanations, which establish the meaning and use of terms; quasi-scientific explanations, which help audiences see the outlines of complex scientific phenomena; and transformative explanations, which help audiences understand counterintuitive scientific ideas.

Elucidating Explanations

Elucidating explanations are designed to help people understand the meaning and use of a term. The name *elucidating* is used because this sort of discourse clarifies meanings. Research in instructional design and linguistics shows that when people are struggling to understand the meaning of a term; they are in fact struggling to distinguish a concept's essential meaning from its associated meaning. So, good elucidating explanations focus attention on this distinction. Specifically, good elucidating explanations contain a typical instance of the concept, a definition that lists each of the concept's essential features, an array of varied examples and nonexamples (nonexamples are instances likely to be mistaken for examples), and opportunities to practice distinguishing examples from nonexamples (Merrill & Tennyson, 1977; Tennyson & Cocchiarella, 1986).

Because good elucidating explanations include sets of varying examples and nonexamples as well as definitions, they are more effective at emphasizing a concept's critical features than definitions alone. That is, concept mastery is more likely when people practice considering ways in which certain examples embody each critical feature of meaning and certain nonexamples do not.

Typically, elucidating explanations begin with definitions or examples. Yet, sometimes, they first help audiences recognize a concept's unessential meanings.

Journalists make this move when the name of a concept is misleading. For example, in a special section for *The Quill*, a journalism magazine, Hammitt (1995) noted that the term *global warming* is misleading. As he wrote, "Global warming is not likely to produce a uniform warming of the Earth's surface. . . . Some regions may even experience cooler than average temperatures" (p. 3). Similarly, writers discussing dietary fiber frequently say that not all dietary fiber is fibrous or stringy.

Second, good elucidating explanations list all of a concept's essential meanings. Wetlands are not simply any patches of moist soil. There are many legal definitions, but typically wetland is distinguished by permanent or periodic soil saturation, creating anaerobic conditions and distinctive vegetation that grows in water ("Federal manual," 1989). Because wetlands may be protected from farming or development by law, some people have become alarmed when *wetness* and *land* were viewed erroneously as the only defining criteria for wetlands.

A third feature of a good elucidating explanation is an array of varied examples. Intuition tells writers to give an example of a confusing concept, but research suggests that the best elucidating explanations offer many examples that illustrate the concept's essential meaning in differing ways (Merrill & Tennyson, 1977, p. xx). This effort to illustrate a concept's essential features in multiple guises minimizes the likelihood that a random feature of some single example will be interpreted as essential. *The Washington Post* writer Lawrence G. Prouix (1996) does a good job of offering a range of varied examples in a story on what counts as dietary fiber:

> Much of fiber is chemically similar to starch, but its atoms are so arranged that our stomach enzymes cannot break it down. It comes in two types, insoluble and soluble, and plant foods are the source of both. Insolubles, such as cellulose, fit the popular sawdust-like image of fiber (think of wheat bran). They absorb water and add bulk to the stool but pass out of the body unchanged. . . . Soluble fibers are softer things, including gums and pectin; apples and oats are good sources. (p. D2)

This passage is a good elucidating explanation because it offers varied examples of fiber (from the sawdust-like to the "softer things" like oats). The text might be even clearer if it explicitly defined *dietary fiber* and offered an even wider range of examples. One definition says dietary fiber is "plant cellular material resistant to digestion by human beings" (Slavin, 1987, p. 1164). Audiences are sometimes surprised to learn that french fries count as fiber and that "the fiber content of canned vegetables may be higher than that of fresh vegetables because browning reactions may occur with cooking" and "the browning products are [a kind of fiber called] . . . lignin" (p. 1167). Ideally, the wider the range of examples writers can offer, the clearer the essential features of a concept become. In this case, differing examples help readers understand the array of fiber sources.

A final important step of an elucidating explanation is discussion of nonexamples. Research shows that audiences can make important distinctions when they are offered apparent examples that nonetheless are erroneous illustrations of the concept (Merrill & Tennyson, 1977; Tennyson, Woolley, & Merrill, 1972). For example, Prouix (1996) could further help audiences recognize fiber by discussing a nonexample: tough meat. Tough meat is fibrous or string-like, but it is not an instance of dietary fiber because it is not plant material. Providing this nonexample would be one more way to clarify the essential versus the associated meanings of this concept.

Quasi-scientific Explanations

The second type of explanation is the quasi-scientific. This type helps audiences envision main points, key structures, or critical connections in complex phenomena. For instance, quasi-scientific explanations help audiences understand hard-to-picture phenomena, such as how the Pathfinder spacecraft relayed Mars images to Earth or why butterfly wings dissipate heat effectively. I use the term "quasi-scientific" for this type of explanation because it is similar to the sort of explanation scientists produce for one another. That is, scientists aim to represent some aspect of reality; journalists make these scientific accounts widely accessible partly through use of graphic aids, textual highlighting, and figurative language.

Picturing the Complex. Science news is often difficult to understand because it describes hard-to-picture structures or processes. Good quasi-scientific explanations overcome this obstacle by helping audiences to construct mental models of the intricate or abstract. Research shows that texts characterized by features suggesting the structure of to-be-learned material help audiences not only to understand such information, but also to use it. These text features include signaling devices, such as titles, previews, headings, bullet points, topic sentences, and transitions; and figurative language, such as organizing analogies (e.g., "Wetlands are nature's kidneys: They filter impurities") and graphic aids such as drawings, models, and animation. Overall, studies show that texts and videos enhanced by these features are better understood and applied than is the same information without them (Gentner, 1988; Gilbert &

Osborne, 1980; Loman & Mayer, 1983; Mayer, 1983; Mayer & Anderson, 1992; Mayer & Sims, 1994; McDaniel & Donnelly, 1996; Rukavina & Daneman, 1996).

For example, Mayer, Bove, Bryman, Mars, and Tapangco (1996) gave randomized groups of college students materials explaining how lightning strikes. One group of students received a text account accompanied by captioned cartoons that highlighted key steps in the process (e.g., particles in a cloud and on the Earth become oppositely charged; opposites attract; lightning strikes if a "leader"—an antenna, a tree—facilitates the particles' attraction. See Fig. 12.1). The other group of students read a text account without the captioned cartoons. The researchers found that those who had the captioned cartoons, plus the text, were better able to use their new knowledge to solve problems than were those who were given the text only. For instance, the text-plus-captions group was better able to describe conditions under which lightning would not strike than were their counterparts.

Good quasi-scientific explanations minimize distracting detail. That is, if the key challenge involved in understanding some intricate structure or process is its envisionment, then material that distracts people from building rough mental outlines is likely to hinder comprehension. In the lightning study, Mayer et al. (1996) found that those students who received an additional 550 words of text along with their captioned cartoons did not do as well on measures of comprehension and problem solving as the group that received the captioned cartoons plus text without the unnecessary words.

Good explainers often sense an audience's need for mental models. Effective teachers preview a lecture's main points. Similarly, scientists being interviewed may search for pencil and paper to draw, for example, the structure of some enzyme. They may also offer an analogy that captures the gist of the science they are trying to explain. In a news story on a new memory drug, for example, reporter Robert S. Boyd (1996) quoted a scientist who provided a particularly vivid comparison:

> "In summer, a forest is full and thick. In winter, you can see clear through the trees. Unfortunately, that's what your brain looks like with age," [Dr. Gary Lynch] said. "As the number of healthy brain cells shrinks, ampakines [the new drug] increase the ability of the remaining neurons to communicate with each other," Lynch explained. (p. A2)

An Associated Press version of this story appeared in a local paper without the seasonal analogy (Recer, 1996). Without it, the story seemed less effective at explaining this source of memory loss and its treatment.

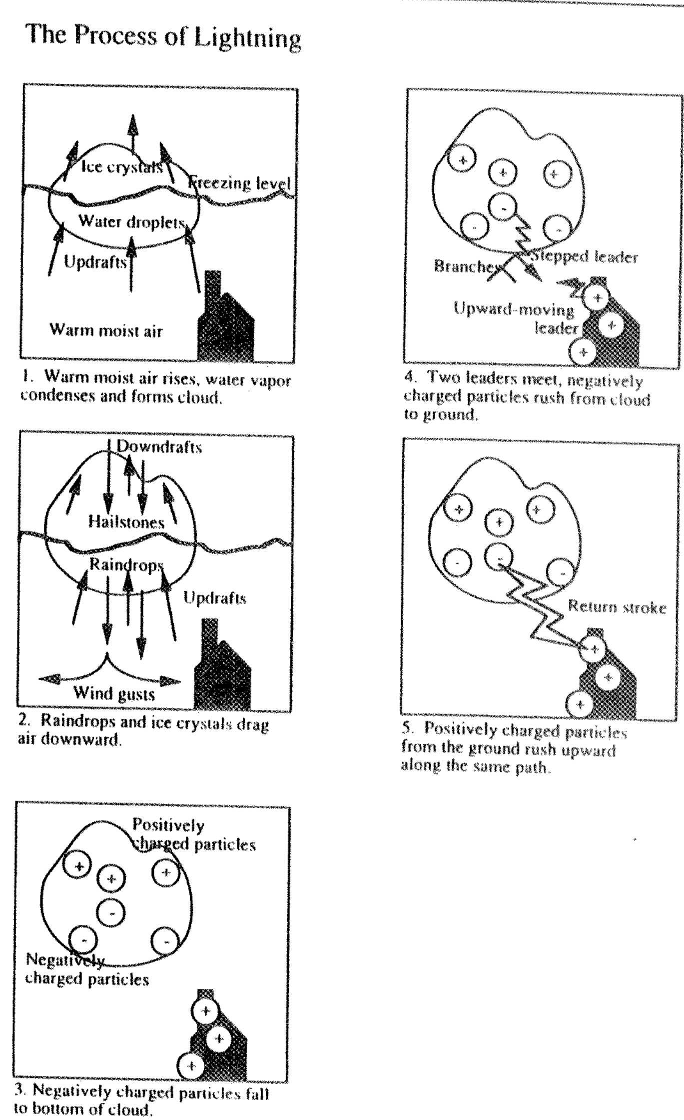

FIG. 12.1. A captioned set of diagrams or cartoon used by Mayer et al. (1996) to explain how lightning works. Students who saw this illustration understood how lightning works better than those who read a text account but saw no illustration. Copyright 1996 by the American Psychological Association. Reprinted with permission.

Conflicting scientific findings may be considered a special kind of confusing, hard-to-picture structure. Rukavina and Daneman (1996) argued that this explains why readers are more likely to understand conflicting theories when those theories are introduced as differing approaches to an unsolved puzzle, for which there are two possible answers, than when conflicting research is presented without this frame. The puzzle label suggests a way to organize and consider what may otherwise be viewed as senseless information.

Transformative Explanations

Transformative explanations help audiences understand ideas that are difficult to comprehend because they are counterintuitive. That is, some scientific notions can be expressed with simple words and are easy to envision, but they are still profoundly difficult to understand. For instance, people struggle to understand how forest fires could possibly be good for forests, how the Earth could be weightless, or why going outdoors without a jacket is not the cause of head colds. In these cases, powerful nonscientific, or lay, theories are the principal source of confusion. Research in science education shows that transformative explanations help audiences recognize, test, and overcome lay theories. Transformative explanations are so named because they assist audiences not only in recognizing an implicit lay theory, but also in understanding its strengths and limitations, in fathoming the reasons scientists endorse the counterintuitive explanation, and in transforming the lay theory into science-based information that can be comprehended and accepted.

Scholars have explored lay theorizing in detail, for it particularly blocks people's mastery of Newtonian principles and scientific accounts of familiar phenomena such as weight, light, or disease (e.g., Alvermann, Smith, & Readance, 1985; Anderson & Smith, 1984; diSessa, 1982; Guzetti, Snyder, Glass, & Gamas, 1993; M. G. Hewson, & P. W. Hewson, 1983; P. W. Hewson, & M. G. Hewson, 1984). Fortunately, it is possible to predict the contexts in which lay theories are most likely to develop. People develop lay theories about very familiar aspects of life that have great import. Lay theories explain weather, accidents, gender relations, nutrition, and so forth. For example, powerful lay theories may tell people that bad air is the cause of a disease or a glider's crash. Lay notions erroneously assure people that everything natural is good or that infants riding in cars are just as safe in a parent's arms as they are in a car seat.

Lay theories are difficult to overcome for several reasons. First, they are often tacit or unspoken, although they still guide thought and action (e.g., Rowan, 1991). People who memorized force equals mass times acceleration may be surprised when they learn a train traveling only 10 miles an hour can cause a horrific accident. Their unspoken lay theory says that impact or force is a function of speed. Third, lay theories often exist side by side with their more orthodox scientific counterparts (Anderson & Smith, 1984). As in the train example, everyday experiences may seem to support the lay notion that slowness equals "lightness." To reconsider a lay notion, people must sometimes be surprised into awareness of the discrepancy between a lay theory and its more accepted scientific counterpart. Media coverage of an accident caused by a slow train may be the impetus creating this surprise. Good reporting can take advantage of such opportunities and help people rethink the connections among mass, acceleration, and force.

Researchers have identified message features that help audiences recognize and reflect on lay theories. In general, good transformative explanations treat audiences like scientists, and scientists do not give up their theories until they have compelling reasons to do so. Similarly, people do not give up lay notions simply because someone says they are wrong. Specifically, good transformative explanations help audiences overcome lay theories when they state the lay theory, acknowledge its apparent merit, create dissatisfaction with it, and show how a more orthodox notion better explains the phenomenon in question (Alvermann et al., 1985; Anderson & Smith, 1984; Guzzetti et al., 1993; Hashweh, 1988; Hewson, & Hewson, 1983; Hewson, & Hewson, 1984; Kuhn, 1989; Schommer, 1990; Shymansky & Kyle, 1988).

Transformative Explanations in the Mass Media. A good example of transformative explanation appeared when *The New York Times* covered the devastating Hamptons fire in 1995. In one story, reporter Andrew Revkin (1995) effectively explained the counterintuitive idea that a policy of controlled burning might have prevented these fires. In the story, he alluded to the lay theory that "forest fires must be bad for forests" and explained its inadequacy:

> For several years, environmental experts had been warning that the forests, which have evolved in a natural cycle that includes frequent fires, need to be burned in a planned pattern to avoid disastrous wild blazes.
>
> But, unlike Southern California where fire—both wild and managed—is almost an annual rite, Long Island has not seen a vast blaze in more than two generations, said Bruce Lund, director of preserves for the conservancy.
>
> Controlled burning has been successful for years in other areas with pine barrens, including a preserve in Albany, . . . foresters say.

> The shrubs' waxy leaves, the resin-rich pine branches, and the dense mats of twigs and other litter typical of such barrens form one of the most combustible forest types in the country, said Dr. William Patterson, a professor of forestry at the University of Massachusetts.
>
> "That's the unique thing about pine barrens," Dr. Patterson said. "So much can burn so fast that it's very hard to react. Once it starts, often the only thing to do is to get out of the way." (p. A25)

Revkin's story does a good job of explaining a practice that may seem absurd to New York residents unfamiliar with controlled burning. Furthermore, his story is well-researched, clear, and thought-provoking. The story acknowledges the understandability of the lay viewpoint, suggests its inadequacy, and then explains the greater range of situations accounted for by the expert view. It contains all of the attributes of a good transformative explanation, with one exception: The story does not explicitly state the lay theory to be critiqued or debunked. Presumably, the unstated lay theory is, "Forest fires are always bad for forests," or "If open flames are harmful to people and animals, they must be harmful to trees." By explicitly stating these lay views and then critiquing them directly, Revkin's story might be even more effective.

Transformative explanation can also be used in weather news. For example, a woman and two children recently sought shelter in an electrical storm underneath a tree. Lightning struck the tree, and all three were killed when the tree fell on them. During a TV news show, Indianapolis meteorologist Paul Poteet (WTHR-TV, 1997) commented on the story, noting that although trees seem to be safe havens in storms, they are anything but safe. In fact, although it seems unlikely, Poteet told viewers, if you are caught outside in an electrical storm, an open field is the better place to be. Poteet's explanation in this context was probably informative to many. He did an effective job of acknowledging the understandability of the lay theory and then presenting the expert view. Ideally, he also could have explained why standing under a tree is dangerous in a storm. (As Fig. 12.1 shows, trees can act as leaders, facilitating the attraction of negatively charged cloud particles to positively charged particles on the ground, and drawing a lightning strike.)

Because they work by surprising people into rethinking some of their most unquestioned notions, transformative explanations are often fascinating to audiences. In a sense, this chapter functions as a transformative explanation as it tries to reframe some fundamental notions in journalism. The challenge in transformative explanation is to explain scholarly or scientific notions compellingly, while acknowledging that they are nonetheless open to critique.

Suggestions for Journalists

Three major sources of conceptual confusion can mar audiences' comprehension of science news. To explain complex scientific information, journalists should determine the most likely sources of confusion presented by a story and then take steps to minimize these difficulties. Specifically, when reporting, interviewing, and writing, journalists should:

- Identify familiar terms being used in specialized ways and distinguish their essential from associated meanings.
- Use diagrams, analogies, or previews, and frame conflicting findings as puzzles to help audiences mentally model complicated subject matter.
- Explain counterintuitive scientific notions by identifying lay theories that make them seem implausible, acknowledging the understandability of lay views, demonstrating the lay views' limitations, and illustrating the greater adequacy of the orthodox scientific theories.

SUMMARY OF GUIDELINES

To help audiences think like scientists about science news, journalists should find out:

- What evidence, reasoning, or testing supports a finding.
- What bugs, frustrates, or impresses scientists about their finding.
- What parts of the puzzle remain unsolved.
- What are the best objections.
- What has to happen before the finding is viewed as established knowledge.
- What people can do to learn more.

To provide balance and accuracy in science news, reporters should:

- Learn whether a claim is widely supported by scientists.
- Find out if scientists being interviewed endorse this consensus.
- Ask whether there are important variants on the consensus view.
- Frame conflicting findings as puzzles, noting the strengths and weaknesses of key puzzle-solving efforts.

To understand and explain complex scientific information, journalists should:

- Identify familiar terms used in specialized ways and distinguish their essential from associated meanings.

- Use diagrams, analogies, and previews to help audiences mentally model complicated subject matter.
- Explain counterintuitive scientific notions by:
  - Identifying lay theories that make them seem implausible.
  - Acknowledging the understandability of lay views.
  - Demonstrating the lay views' limitations and the greater adequacy of the orthodox scientific theories.

CONCLUSION

This chapter began by promising a step back opportunity for writers. After reading it, a writer may wonder whether science news involves so much stepping back that one is likely to fall attempting it. Reporting information that can never be certain is intimidating. To make it less so, this chapter provided some coaching. Although this chapter emphasizes ways in which science news is distinct from other types, in many ways, reporting science is similar to covering any real, uncertain, and complex event. Research shows that most adults find science news fascinating and learn the bulk of what they know about contemporary science from the mass media (Atwater, 1988; Durant, Evans, & Thomas, 1989; Nunn, 1979). Journalists have the challenging job of helping audiences locate science news they can use, while still appreciating that today's best answer to an important puzzle may be overturned by tomorrow's better approach. In a sense, perhaps the best test of science reporting is the extent to which it helps audiences be like ethologist Konrad Lorenz: confident enough to enjoy learning from science news, but sophisticated enough to understand his point that "truth in science can be defined as the working hypothesis best suited to open the way to the next better one" (Reif & Larkin, 1991, p. 739).

ACKNOWLEDGMENTS

Several people helped me think about, find examples for, and improve this chapter. Thanks go to the editors of this volume—Sharon Friedman, Sharon Dunwoody, and Carol L. Rogers—as well as Brant Burleson, Kathy Campbell, Christopher Dowden, Michael Rowan, and Karen Whedbee. Any errors that remain are mine.

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