WRITING IN THE SCIENCES

Exploring Conventions of Scientific Discourse

Third Edition (2010) Open Access Version

Ann M. Penrose

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INFORMATION FOR 3E OPEN ACCESS VERSION USERS

We are pleased to offer the 2010 edition of *Writing in the Sciences* on Parlor Press's website as a free resource for students, instructors and other scientist-writers. This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits users to share the material with proper attribution under specified terms. This open access version is intended for educational and personal use only, not for commercial use or resale in any form. This PDF book can be downloaded as a single PDF. Instructors are encouraged to use it as a primary text, or with other primary texts or supplemental materials.

The text has been adapted for open access publication as described below.

- In order to make the book available free of charge, it was necessary to remove copyrighted materials that had appeared in the 3e as examples for discussion and analysis. Many of these are journal articles that you should be able to access from their original publishers via your university library. However, the real value of *Writing in the Sciences* lies in what it helps you learn about communication in your own disciplines and research communities. We encourage you to apply the principles in Ch. 1-8 to analyzing new articles from your own disciplines and journals.

- We have been able to retain all the sample proposal documents that appeared in the 3e print version, in Chapters 10-13; these unpublished proposals are not otherwise available. The scientists who authored these documents have generously agreed to their publication in this Open Access Version of *Writing in the Sciences* under the Creative Commons license. We are grateful for their support and continue to applaud the collegiality of scientists.

- The transition from print text to online text required adjustments in page formatting and numbering. The Table of Contents, and the Index, have been revised to reflect the new page numbers of this Open Access Version, making these crucial locating tools completely operational and useful. (But please note that the occasional intertextual page references embedded in the manuscript itself do not match the page numbers of the Open Access Version; we have replaced these non-referential page numbers with xxx.)

- As with any published text, URLs and other textual references in Parts 1 and 2 are likely to have changed since the 3e appeared, but many of them work or get you to updated and/or related webpages as of the time of the completion of this Open Access Version of *WITS* (July 2020). *We have updated as indicated the URLs (accessed June 2020) offered as "Additional Resources" in Part 3* (the research cases, Chapters 9-13).

Aside from these logistical matters, the 3e Open Access Version is a reproduction of the 3e print text published in 2010. Our thanks to Dr. David Blakesley/Parlor Press for hosting this ebook.

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Chiba N, Veldhuyzen van Zanten SJO, Sinclair P, Ferguson RA, Escobedo S, Grace E. 2002. Treating *Helicobacter pylori* infection in primary care patients with uninvestigated dyspepsia: the Canadian adult dyspepsia empiric treatment—*Helicobacter pylori* positive (CADET-*Hp*) randomised controlled trial. *British Medical Journal.* 187

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PREFACE: *WITS 3E* (2010) *OPEN ACCESS VERSION*

As noted above, we are pleased to offer the 3rd edition of *Writing in the Sciences* online as a resource for students, instructors and other scientist-writers. This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits users to share the material with proper attribution under specified terms. Please review those terms before downloading, using, or sharing this text.

The 3rd edition of *Writing in the Sciences* was published in 2010. The text has been a valuable resource for science writing courses across the US since its first edition in 1998 and has had international adoptions as well. Publication was suspended in 2014 when the publisher discontinued its technical communication series.

We've recently succeeded in recovering the rights to the text and are now in a position to make it available as a free resource under a restricted Creative Commons License on Parlor Press's ebook repository. In fact, what is new about this text is that it is *free* and also *readily available online!*

Thus, please note that although this version has a 2020 CC license, the print text was published in 2010 and the content of the book has not been updated. The text *has* been adapted for open access publication as described above in "Information for 3e Open Access Users."

The original Preface, below, details the purpose and methods of our rhetorical approach to exploring conventions of scientific discourse. We encourage you to continue these explorations within your own research communities.

A special thank you to Myers (Addy) Enlow, Steve's research assistant at Clemson University, for her help in the formatting and conversion of the 2010 text, as well as the development of a much-needed new cover.

We especially wish to express our gratitude to Dr. David Blakesley for offering to host this textbook on the Parlor Press ebook repository as a free text, free of charge; his career-long dedication to the development and public dissemination of knowledge is recognized and truly appreciated. We are of course indebted to Creative Commons for the licensing tools that enable open sharing of intellectual work.

We remain indebted to the students, instructors, scientists, and other supporters who have sustained this work through multiple editions and publication venues.

ANN M. PENROSE
STEVEN B. KATZ
JULY 2020

PREFACE: 3E PRINT VERSION (2010)

The third edition of *Writing in the Sciences* has developed during a time of great change in communication processes generally. Indeed, the concept of "writing" itself is in many ways being redefined and expanded. Though the central forums for scientific communication and their basic features remain fairly stable, the availability and widespread acceptance of online media have enabled the development of new visual and verbal representations, expanded the range of audiences scientists can reach, and attenuated the time lag between making a discovery and making it public. Thus, the need for understanding communication processes and conventions in science has never been greater. This edition explores these new developments and their influence on the basic communication practices that sustain progress in the sciences.

New to This Edition

- A new Chapter 2 explores technologies in scientific communication, examining media scientists use to communicate with each other and with the public. Other chapters have also been revised to consider effects of digital media on specific genres and conventions of science.

- The new Chapter 2 also introduces new analyses and recent scholarship on visual literacy, issues that inform the rest of the text as well.

- The research cases in Part 3 have been revised and expanded, now encompassing a broader range of environmental research fields and offering an expanded array of sample texts designed for public audiences.

- These additions include a new case on global climate change (new Chapter 13), which focuses on environmental effects of Hurricane Katrina in the United States and offers opportunities to examine science in the context of public debate. In addition to updated introductions, each case chapter contains a list of additional online resources.

- A second new case on the popular Kepler supernova research in astrophysics (new Chapter 12) preserves the second edition's inclusion of a theoretical research case but also includes coverage in the public domain to enable analysis of how technical science can be made accessible to non-specialists.

- The book has been reorganized into three parts to highlight general principles and issues that ground the text's treatment of specific genres and forums in science: Part 1: Principles and Purposes of Scientific Communication; Part 2: Exploring Conventions of Scientific

Communication; and Part 3: Sample Research Cases. The chapters on the social, technological, and ethical dimensions now begin and frame discussion. This rearrangement clarifies the organization of the text while solidifying the social-rhetorical approach applied in later chapters.

- All chapters have been revised to incorporate recent scholarship on scientific communication.
- All chapters include newly researched and updated examples of scientific discovery and communication.
- All chapters include newly researched and updated editorial guidelines, calls for conference proposals, RfPs, and other sample materials illustrating the communication infrastructure in a range of research fields.

Purpose and Approach

Writing in the Sciences is intended as a resource for scientists and technical communicators and is designed as a primary text for upper division and graduate courses in scientific writing. It is also well suited as a supplemental text for courses in the sciences that seek to provide explicit support for writing. Material in the text has been field tested in our own classes over the past 20 years and at other institutions around the country and abroad.

The book presents a rhetorical, multidisciplinary approach to teaching the major genres of writing for science and research: research reports and reviews, grant proposals, conference presentations, and a variety of forms of public communication. We introduce general rhetorical concepts and analytical tools to help students recognize the conventions used by scientists in their own fields and use these conventions effectively. Our approach is descriptive rather than prescriptive—the goal is to teach students to recognize distinctive features of common genres by examining how, why, and for whom such texts are created by scientists.

These features are illustrated in the research cases in Part 3, which include documents addressing a range of audiences for scientific research and illustrating consequent differences in substance, focus, arrangement, style, and other rhetorical dimensions. Examples are drawn from a variety of research disciplines, enabling students to recognize practices in their own fields, as well as to compare these practices to those of other disciplinary communities. Such comparisons provide the opportunity for instructor and student to identify and investigate common conventions in science, examine variations across fields, recognize relationships between the nature of inquiry in a discipline and the logic and form of the discipline's written and spoken texts, and explore the social and ethical dimensions of these communication practices. The new cases

in this third edition both preserve and enhance one of the most distinctive features of earlier editions: our emphasis on exploring actual rhetorical practices in actual research communities. Multiple exercises and activities are provided in each chapter, and chapters can be used in any order.

Acknowledgments

Once again we cite physicist Jasper Memory's remark that the ability to work and play well with others may be as important a trait for budding scientists as good grades in math (Memory 2003). Our research into the nature of communication in science supports this observation, and our experience in writing this book continues to confirm it. We could not have completed this project without the help of many others. We are greatly indebted to the scientists who graciously provided the sample texts and research stories on which much of this text is built: especially physicist Steve Reynolds and botanist JoAnn Burkholder from North Carolina State University. We express our appreciation to archeologist John Hale of the University of Louisville and ecologist Jeffery Chambers of Tulane University for granting permission to reproduce their work, and we are grateful to Barry Marshall and Robin Warren for their compelling research example; their accomplishments have helped us illustrate many critical features of scientific discourse. We also thank George Hess of the Department of Forestry and Environmental Resources at NC State, Gary Blank of NC State's College of Natural Resources, and biophysicist Carl Blackman of the EPA's National Health and Environmental Effects Research Laboratory, for their time, materials, and expertise. The willingness of these researchers to share their work with us illustrates what we consider the most valuable dimension of science: the ethic of collaboration and sharing.

Previous editions of this book were adopted by science writing instructors in a variety of courses and fields across the United States, many of whom have offered comments and suggestions that have shaped the new edition. We would like to thank the reviewers who commented on the second edition in preparation for the third: Jenny C. Smith, University of Tennessee at Chattanooga; David Kellogg, Northeastern University; Pamela Demory, University of California, Davis; Jonathan Buehl, The Ohio State University; Anne Zanzucchi, University of California, Merced. In addition to the authors, many other instructors at North Carolina State University and Clemson University have used the text in advanced writing courses required of their science majors. In particular, Jamie Larsen and Christian Casper at NC State provided valuable feedback and new insights for this third edition, as did biological scientist Lesly Temesvari and science communication instructor John Dinolfo at Clemson University. We also thank Carolyn Miller, our long-time mentor and colleague, for her constant attention to things rhetorical and scientific.

. . . .

Once again, we have been fortunate to recruit a superb support system. In this third edition we have been ably assisted by scientific communication researcher Christina D'Elia at Clemson, whose technical expertise has enhanced our work in innumerable ways and whose long hours working with Katz made possible the actual writing and typing of text during the summer of 2008; and Daun Daemon, professional editor and award-winning lecturer at NC State, who has taught and practiced scientific communication for many years. We are grateful for their skill and their enthusiasm for this project. In addition to the logistical support they've provided, they have contributed some of the book's best examples and resources. They follow in the footsteps of Trish Watson, our invaluable assistant on the first edition.

We are continually sustained by and indebted to our spouses, David Brooks and Alison Katz, whose patience and understanding seem truly without limit.

And finally, we reiterate our thanks to our science writing students, past, present, and future, who are both observers and participants in scientific discourse.

ANN M. PENROSE
STEVEN B. KATZ

About the Authors

Ann M. Penrose is Professor of English at North Carolina State University, where she teaches courses in academic and scientific writing, composition theory and pedagogy, and empirical research methods. Her work has appeared in *Written Communication, College Composition and Communication, and Research in the Teaching of English*. [Emerita 2019]

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PART 1

Principles and Purposes of Scientific Communication

CHAPTER

1

Science as a Social Enterprise

1.1 THE SHAPING OF KNOWLEDGE IN SCIENCE

We begin this introductory chapter with the case of a young scientist who made a revolutionary discovery. In September, 1983, Barry Marshall, an unknown internist at Australia's Royal Perth Hospital, presented his and pathologist Robin Warren's findings at the Second International Workshop on *Campylobacter* infections in Brussels. They had already published separate, technical "letters" together in the *Lancet* (Warren and Marshall 1983). In these letters they reported the presence of bacteria (later classified as *Helicobacter pylori [H. pylori]*) in the stomach lining of patients with gastritis. Following the presentation of their joint paper at this international conference, Marshall stood before doctors, researchers, and specialists in microbiology, gastroenterology, and infectious diseases. In response to a question from one of the experts, Marshall declared that he believed this bacterium was the cause of all stomach ulcer disease and that chronic ulcer recurrence could be eradicated in most, if not all, patients with a treatment of common antibiotics and bismuth such as Pepto Bismol (Chazin 1993; Monmaney 1993).

Marshall and Warren's theory that ulcers were the result of bacterial infection in the stomach lining was greeted with both intense interest and skepticism by experts in the field. After all, the claim that *anything* could live in the intensely acidic environment of the stomach was as unbelievable as it was revolutionary. If the claim were true, the implications for ulcer sufferers—and as Marshall himself later noted (2005b), for the major drug companies manufacturing acid blocker treatments—would be substantial. Although experts in the field were polite and respectful in the professional journals, they later told the popular press that when Marshall first presented the theory, they thought he was "brash" (SerVaas 1994, p 62), "a madman" (Chazin 1993, p 122), "a medical heretic" (Monmaney 1993, p 65), "a crazy guy saying crazy things" (Monmaney 1993, p 66). The experts were intrigued, however, and the problem was important enough to demand attention, as evidenced by letters and editorials in scientific journals devoted to gastroenterology and internal medicine.

Marshall and Warren started a revolution in the field of gastroenterology (Carey 1992). By 1993, more than 1500 studies around the world had lent support to Marshall's theory (Monmaney 1993). In a major shift in policy in February, 1994, a panel of the National Institutes of Health released a consensus statement in which it accepted that there is a relationship between *H. pylori* and ulcer disease and recommended that antibiotics be used in the treatment of stomach ulcers where the bacterium is present (NIH 1994). In April, 1996, based on Marshall and Warren's findings, the FDA approved the first drug specifically designed for treating ulcers. A sure sign of the acceptance of the theory, several books, including a handbook, have been published on the nature, identification, and manipulation of new species of *H. pylori* and their physical and genetic structure (Harris and Misiewicz 1996; Clayton and Mobley 1997; Heatley 1999; Mobley et al. 2001). Marshall himself edited a collection of firsthand accounts, spanning almost a century, of discoveries of *H. pylori* worldwide (Marshall 2002). And one of Marshall's most outspoken critics, David Graham, edits *Helicobacter*, a journal devoted exclusively to the subject. Dr. Marshall later was tenured at the University of Virginia School of Medicine, established and directs the Helicobacter Foundation, and runs a lab at the University of Western Australia. The testing for *H. pylori* and its treatment have been extended to the investigation of common dyspepsia (e.g., Chiba et al. 2002). Methods for more accurately and easily detecting the presence of *H. pylori*, such as a breath test for *urease*, continue to be developed (e.g., Alimenterics 1999; Harvard Medical School 2007; WebMD.com 2008 [see the Additional Resource for Chapter 9]). The *British Medical Journal*'s first Masterclass for General Practitioners was on the procedures for diagnosing and treating *H. pylori* infection (Shah 2007).

In 2005, Marshall and Warren won the Nobel Prize in Medicine. Yet, it had taken more than a decade for their theory to be accepted. And most of the development and support came from other physicians and scientists. Although Marshall had continued to publish technical letters, abstracts, reports, and some retrospective studies, he had great difficulty getting his clinical research published and felt his message about ulcer treatment was not being heeded (Chazin 1993; Marshall 2005d). The decade following his presentation in Brussels was a period of trial and tribulation for him.

Why was there such negative reaction to Marshall's presentation in Brussels? Despite all the positive editorials by scientists expressing interest in the theory and the subsequent research and confirmation of the claim, why did Marshall have difficulty getting his research published? Why wasn't his theory immediately embraced, as he, the press, and the public thought it should have been? A close examination of the answers to these questions can provide insight into the role of communication in the creation of scientific knowledge.

Certainly, part of the answer has to do with the somewhat shaky nature of Marshall's methods—with his science itself. In 1982, Warren, the Royal Perth pathologist, had observed the presence of the bacterium in the stomach and showed Marshall the pathology slides. Together they studied 100 patients suffering from peptic ulcers and found that *H. pylori* was present in 87 percent of the cases. This was the study they presented in Brussels and later published as a research article in the *Lancet* in 1984 (Marshall and Warren 1984). But by his own accounts (Marshall 2005a) and those of experts such as David Graham, chief of gastroenterology at Houston's Veterans Affairs Medical Center, Marshall was "not the greatest researcher of all time" (Chazin 1993, p 123). One scientific editorial pointed to the 1984 Marshall and Warren study in the *Lancet* as "well planned" (Lancet 1984, p 1337), but in 1988 Marshall's large-scale study was rejected by the *New England Journal of Medicine* as "inconclusive" (Chazin 1993, p 123). Other editorials in scientific journals criticized the validity of his methods and conclusions (see Lam 1989), and Marshall admitted to the press that he was more interested in curing patients than in developing adequate methods and conducting large clinical experiments needed to support his claim; he had hoped that clinical success with patients would be enough to convince his colleagues (Chazin 1993). Thus, Marshall was faced with the problem that to some degree all

scientists, not just the lucky ones who wind up doing important research, face in their career: How do you get other scientists to listen to you?

To gain the acceptance he thought his theory deserved, Marshall did something that most scientists would—and should—never do. Unable to convince his colleagues that *H. pylori* caused stomach ulcers, in 1984 Marshall created a potent mixture containing the bacteria and drank it, inducing a case of acute gastritis in himself (Marshall et al. 1985). As Marshall explains in his Nobel Prize lecture, "I felt that there was an urgency to solve this dilemma and do the experiment. The only person in the world at that time who could make an informed consent about the risk of drinking Helicobacter was me. So I had be to in my own experiment . . . " (Marshall 2005d). As he also points out in his Nobel lecture, he had at least the implicit cooperation of others, notably the lab chief who grew the precise strain and strength of bacteria for the mixture, and the endoscopists, one of whom was Warren. But at the time, Marshall's methods were seen not only as unorthodox but also as potentially dangerous. Although Marshall's experimenting on himself led to further research, the incident made his critics even more skeptical of his professionalism and less accepting of his theory (Morris et al. 1991; Carey 1992).

Another reason Marshall's theory wasn't readily accepted had to do with the prevailing assumptions about, and treatment of, gastrointestinal diseases. Warren and Marshall were not the first to observe bacteria in conjunction with gastric inflammation. Medical researchers as far back as the late 1800s had reported and even published images of bacteria living in the stomach lining (Blaser 1987; Marshall 2002). But these findings had been dismissed either as contaminants introduced during biopsy or as unrelated agents existing near ulcers; because of the presence of hydrochloric acid, gastroenterologists assumed that the stomach was "a sterile organ" (Warren and Marshall 1983, p 1273). As Monmaney reported, "Marshall's theory challenged widely held and seemingly unassailable notions about the cause of ulcers. No physical ailment has ever been more closely tied to psychological turbulence" (1993, p 64). Traditionally, ulcers had been attributed to weak stomach linings and/or to an increase in stomach acids caused by emotional trauma, tension, nervousness, or modern life itself. In his published Nobel Prize lecture, Marshall was unequivocal: "I realized then that the medical understanding of ulcer disease was akin to a religion. No amount of logical reasoning could budge what people knew in their hearts to be true. Ulcers were caused by stress, bad diet, smoking, alcohol, and susceptible genes. A bacterial cause was preposterous" (2005c, p 267).

The contrast between the initial response to Marshall's hypothesis and the subsequent success of his theory suggests several important points about how knowledge is shaped in science and the importance of communication in that process. We will highlight these briefly here by way of introduction and then will examine them in more depth in this chapter and throughout this book as you begin to explore them in your own field.

- Scientific experimentation and knowledge are governed by tacit beliefs and assumptions about what is factual, valid, and acceptable; these beliefs and assumptions are "social" in nature.
- Communication is central to the growth of scientific knowledge in each discipline, and thus to the advancement of science itself.
- Persuasion is an integral part of scientific communication; it includes the use of sound arguments and an appropriate style of presentation, as well as acceptable scientific theories, methods, and data.
- As social enterprises, scientific fields are also to some degree governed by explicit conventions about how and what to communicate, conventions that professional scientists expect each other to follow; failure to follow these can result in a failure to communicate and thus can hamper the advancement of scientific knowledge.
- Collaboration and cooperation both within and across disciplines and professions are essential to the development of scientific theories, research, and knowledge. As you will

learn in your exploration of communication in your field, collaboration and cooperation are central to research and to the actual writing of research papers and proposals. Scientific knowledge is built and shared through collaboration and cooperation.

1.2 THE SOCIAL NATURE OF SCIENCE

As you will see when you explore your own field, science is a social enterprise. In one sense, this means that science is a part of the larger society in which it is situated. Science is shaped by the values of the dominant culture in which scientists participate and live, sharing many of its assumptions, goals, biases, and problems (NAS 1995; Lyne 1998). Conversely, science also exerts a powerful influence on society. Think about decisions you've made recently concerning such practical things as medical treatment, diet, energy and fuel consumption, and weather. Indeed, at a deep level, our very way of thinking about the world is rooted in current scientific practices and beliefs.

Our primary focus here, however, is on the social nature of the activity within scientific communities and related settings, rather than on the general social context in which these communities are embedded; the challenges and implications of communicating science in the public realm will be considered in Chapters 3 and 8. Scientists in a discipline constitute a *community* in which knowledge is built, is validated, and has meaning. Warren needed Marshall's clinical knowledge to understand how the bacterium he was observing was related to gastric symptoms (Chazin 1993; Warren 2005a,b). Marshall needed Warren in order to understand the biology of the bacterium he was observing in his patients (Marshall 2005a,c,d). And both Marshall and Warren relied on prior research to guide their own, and needed other scientists and the NIH to further test, validate, accept, and extend their work in theory and practice. In providing healthcare to their patients, physicians applying this research needed the pharmaceutical industry to develop tests and treatments for *H. pylori*, and the drug companies required FDA oversight and approval. We saw earlier that this can be a slow process. Like any society, scientific communities operate by a system of assumptions and beliefs that govern the perception and understanding of phenomena, the methods used, the research that is conducted, and the kinds of conclusions that can be drawn and treatments developed.

Before reading further, try the classic "nine-dot problem" presented in Figure 1.1. In the next five minutes, connect all the dots below with only four straight lines and without lifting your pencil from the page. If you have done this problem before, do what Einstein did—a *Gedanken* (thought) experiment: connect all the dots with only one line; there are several ways of doing this.

Often the difficulty is that the solution cannot be found within your current cognitive framework; your assumptions about the problem, the experimental and cultural context in which you are working, and your expectations about the solution all influence your perception. Thus, according to Kuhn (1996), finding the solution involves something like a "gestalt" switch, where you see the problem in a new context, a context that allows you to find the solution.

FIGURE 1.1 Nine Dot Problem (Adams 1976).

Notice that solving the nine-dot problem involves going outside the conceptual space you perceived and believed to be a square. The perception that dots form lines is, of course, one of the basic principles of geometry, which defines a *line* as the track made by a moving point, and so in some sense this perception is based on a social belief or convention. But the belief that the solution must fall within the square created from the dots prevents the perception of the easy solution. To solve the nine-dot problem, you must "violate" or ignore conventional beliefs and assumptions. This is what leading gastroenterologists had to do to accept Marshall's theory that stomach ulcers are caused by bacteria rather than by stress.

The important point here is that assumptions and beliefs influence scientists' perception of phenomena. In *The Structure of Scientific Revolutions,* Thomas Kuhn (1996) calls these sets of assumptions in science *paradigms*. Paradigms are learned tacitly through observation and imitation of scientists and practitioners in the field (Polanyi 1958); and they are learned explicitly through education, textbooks, and specific practices (Kuhn 1996). Thus, some of the assumptions in paradigms are only implicit or subconscious, and some are explicit in the form of rules and accompanying examples. In his Nobel lecture, Marshall explicitly refers to paradigms governing medical perception when he and Warren announced their theory, and in the years following: "Our results were rejected because they were outside the current paradigm" (Marshall 2005d). As students of science, you are currently engaged in learning the paradigms of your fields. As we will explore in this book, paradigms include conventions, assumptions, and rules about communication in science as well.

Paradigms constrain thinking, as illustrated in the nine-dot problem. Yet, at the same time, paradigms provide the support and context for discovery. Without the background of the square created by the pattern of the dots, there would be no clear way to connect the dots, nothing to break out of, no problem to solve. In the case of *H. pylori,* the discoveries that had been made—and the assumptions, examples, and knowledge about bacteria and about ulcers that already existed in the field—provided both the scaffolding and the backdrop against which to discover

the connection between the bacterium and gastritis. Although Warren, Marshall's co-worker, stated that the discovery of the ulcer bacteria "was something that came out of the blue," he also admitted he "happened to be there at the right time, because of the improvements in gastroenterology in the seventies" (Monmaney 1993, p 68). Warren, in his Nobel lecture, says his role in this discovery wasn't brilliance, and it wasn't accident: "I think I was the right person at the right time, with the right interests, who would do more than just look at it and forget it" (Warren 2005b). We observe here that the discovery by an individual scientist that takes place outside the dominant paradigm nevertheless depends on that paradigm for the perception of it. Without paradigms, we would notice nothing at all. As a set of assumptions, conventions, and examples, the prevailing paradigm in a field helps define the problems in that field, specify methods that are allowed to solve the problem, and predict what results can be expected.

This is not to deny the role of the individual scientist's perception and judgment (cf. Ziman 2000). Some assumptions in science are personal, subjective, and even aesthetic (the scientific values of simplicity and elegance, for example, are aesthetic). The National Academy of Sciences calls attention to this dimension of science:

> Researchers continually have to make difficult decisions about how to do their work and how to present that work to others. Scientists have a large body of knowledge that they can use in making these decisions. Yet much of this knowledge is not the product of scientific investigation, but instead involves value-laden judgments, personal desires, and even a researcher's personality and style. (1989, p 1)

In general practice, this subjective dimension is balanced by social paradigms. Paradigms as social mechanisms act as a check on personal judgment and individual error, and so they make science as we know it possible (Merton 1973a; NAS 1995; White 2001). In fact, what is personal, private, and subjective must be validated socially by the community of scientists to count as "objective" scientific knowledge. Thus, while paradigms that operate in a particular discipline tend to influence perception and constrain scientific research and thought, they also serve to correct and enhance it.

Sometimes, as in the case of Drs. Marshall and Warren, the individual scientist or group of scientists opposing a dominant paradigm in their field turn out to be right. When other scientists begin to shift their beliefs and assumptions and work on the problems created by the new theory, the field undergoes a paradigm shift—what Kuhn calls a "scientific revolution" (1996). Marshall himself calls the paradigm shift in gastroenterology "a revolution" (Marshall 2005d). Scientific revolutions, such as the one that resulted in the shift from Ptolemaic to Copernican astronomy, or from the belief that the earth is flat to the belief that the earth is round, are very well-known paradigm shifts. Other scientific debates in contemporary society that may involve conflicting paradigms include the discussion of whether evolution proceeds gradually or by leaps (gradualism versus punctuated equilibrium); whether the universe is expanding and contracting or is a steady-state universe; and the cause of dinosaur extinction (volcanic activity and/or global climate change versus meteor storm). Can you think of any debates that may involve conflicting paradigms in your field?

In these special instances of revolutionary or extraordinary science, as in normal science, scientific knowledge must be validated by the community of scientists (e.g., see Toulmin et al. 1984; Kuhn 1996; Good 2000). As we will discuss next, communication is essential to that process and thus is central to science itself.

EXERCISE 1.1

Working in a group of students from your field, brainstorm about a theory that has been accepted by your discipline. Prepare to discuss what you know about its history: previous theories to

explain the phenomenon, the personalities of the scientists involved, the debates surrounding the newer theory, and the evidence that made it acceptable or unacceptable in your field. Does the acceptance of the theory constitute a paradigm shift (i.e., a scientific revolution), or a working out of previously held assumptions or research?

1.3 THE CENTRALITY OF COMMUNICATION IN SCIENCE

The centrality of communication in science? To the casual observer, the phrase may seem somewhat nonsensical if not patently false. After all, what matters in science is the science itself—hypotheses, research methods, results. Certainly, these are fundamental to good science. Yet, without the communication of those hypotheses, methods, and results to other scientists, no science would be possible. Scientists in and across fields would not be able to share or build knowledge on the results of other scientists. Science would become a private, redundant, and ultimately futile endeavor.

Some external factors exert enormous pressure on scientists *not* to share. Scientists who work for industry or for government agencies, for instance, often find there are restrictions on what they can talk about. But scientists generally agree that secrecy is bad for science (NAS 1989, 1995; see Huizenga 1992). One of the fundamental principles of science is free and open communication. The National Academy of Sciences puts it bluntly: "If scientists were prevented from communicating with each other, scientific progress would grind to a halt" (1989, p 10).

Barry Marshall's sharing of his theory prompted a rethinking of the field of gastritis research, ulcer treatment, and the curing of patients. His presentation in Brussels did "arouse much interest" (*Lancet* 1984, p 1336), and the desire and necessity to check out his theory propelled scientists in the fields of microbiology, gastroenterology, and internal medicine into a flurry of research. Hundreds of articles investigating the existence, nature, classification, detection, and treatment of *H. pylori* followed, eventually lending support to Marshall's contention.

For the National Academy of Sciences, communication is the engine that drives the "social mechanism" of science (NAS 1989, p 10). And as communication scholar William White puts it, "[C]onceptual innovation is both a fundamental scientific activity and essentially a communication phenomenon" (2001, p 290). We have already noted that the communication of hypotheses, research methods, and results—in journals, at conferences, over email—is essential for the growth of science. *Sharing ideas is essential to the evolution of every scientific field.* In this sense, it is communication that binds any discipline into a community, which makes science social. Language is the basis of any society. Without language, there could be no communication, no cooperation, no concerted research effort that we note in the investigation of *H. pylori* and other scientific endeavors.

Indeed, communication in science is so important that *the credit for a scientific discovery is awarded not to the scientist who discovers a phenomenon, but to the scientist who publishes its discovery first.* (Actually, even more telling, it is the date the paper is received by the journal that determines historical priority.) This is another way in which communication, and writing itself, is central to the conduct of science. Credit can be awarded only to the scientist(s) who write up their findings—and who write first! As astrophysicist Donald Clayton (2007) discusses, Hoyle's early equation for nucleosynthesis in young stars has been "underappreciated in comparison with later works . . . . [H]e did not put to paper the equation he envisioned and described verbally. Had he done so, unambiguous scientific visibility of his achievement would have followed more easily" (p 1876–1877).

The practice of attributing originality to the scientist whose paper first reaches the offices of the journal, along with the promise of quick turnaround time for publication and support by the institution and/or journal in disputes concerning the ownership of ideas and discoveries, was begun by the Royal Society of London in the 17th century. By protecting the rights of the author,

the Royal Society hoped to ensure open communication and the sharing of ideas in science by alleviating the (real) fear among scientists that their ideas or results would be stolen by others. The National Academy of Sciences cites the example of Isaac Newton, who wrote in Latin anagrams so his findings could be on record but not publicly available (NAS 1989). Marshall and Warren were not the first to observe the presence of *H. pylori* in the stomach, but they were the first to recognize and write about its role in gastritis, and their joint letters to the *Lancet* thus mark the historical point of discovery of that phenomenon (Warren and Marshall 1983; Marshall 2005a).

Since historical priority is awarded to the scientist(s) whose manuscript reaches a publication first, scientists who do original work and want that work recognized and used by the field must write and publish as quickly as possible. Warren and Marshall presumably felt this need, for they, like many other scientists, submitted initial reports of their important discovery in the form of brief technical letters or preliminary notes rather than as fully elaborated research reports. (The Watson and Crick letter in *Nature* about the double-helix structure of DNA is a famous example of this genre.) Speed of publication is necessary not only because of the rapid advance of the field but also because of scientists' need to ensure their claim of originality (Merton 1973b; see Miller and Halloran 1993).

Thus, while scientific journals protect the science that is submitted and published, the necessary speed of publication in most sciences also creates competition: "researchers who refrain from publishing risk losing credit to someone else who publishes first" (NAS 1989, p 9). It is a matter of historical fact that eminent scientists such as Darwin, Watson and Crick, and others were pressured *to write up* and publish their results to beat the competition. Darwin didn't want to write at all, and only did so when he heard that Alfred Russell Wallace was about to publish a theory of evolution (Campbell 1975); Watson and Crick were hotly competing with another lab to be the first to announce the structure of DNA (Watson 1968; Halloran 1984). As you will read in Chapter 2, technology has only sped up the process of publication as well as response, which also has begun to affect communication conventions in multiple ways. Learning to write quickly and well is important in science.

There are other, less obvious but absolutely crucial ways in which communication has come to play a key role in science. The processes of writing and submitting papers, of giving presentations, and of writing grant proposals in a real sense *define the nature and activity of the field and the state of knowledge within it.* The acceptance or rejection of conference abstracts, scientific papers, and grant proposals by conference organizers, journals, funding agencies, as well as by peers, becomes a vehicle not only for the dissemination but also for the control of scientific research. As the National Academy of Sciences states, "At each stage, researchers must submit their work to be examined by others with the hope that it will be accepted. This process of public, systematic skepticism is critical in science" (1989, p 10).

Peer review is the primary mechanism through which such gatekeeping is accomplished. In addition to the dissemination of scientific research, it is the function of research journals to ensure "quality control" by deciding what is acceptable to publish in the field. These decisions are typically accomplished via a "peer-review" system in which journal editors send the manuscripts they receive from researchers to other experts working in the same field for evaluation. After soliciting evaluations on a given manuscript from several such experts, an editor uses their assessment to make a decision about whether the paper merits publication in the journal. (Authors also receive the comments of the reviewers, which influence subsequent revisions.) Through the process of peer review, journal editors and reviewers determine what gets published and thus influence what scientists read and, to some extent, what scientists work on (Bazerman 1983; NAS 1989; Rowland 1997; Relman 1999). (Warren notes that disbelieving reviewers delayed the publication of their first paper in the *Lancet* [Warren 2005a, p 302]. Marshall's three-year clinical study did not pass peer review because it was inconclusive [Chazin 1993], but his smaller studies and technical notes were allowed into print.) Similarly, research

funds are typically allocated using a peer-review process. Funding agencies such as the National Science Foundation, the Department of Energy, and the National Institutes of Health evaluate proposals or requests for funding by assigning them to appropriate groups of experts for peer review; then, based on those recommendations, the funding agency decides which studies to fund, thus again determining what kind of research can proceed in the field (Myers 1985; Seiken 1992). (We consider related ethical issues in Chapter 3, and discuss mechanisms of peer review in more detail in Chapters 4, 6, and 7.)

Most scientists believe that peer review, as the social system of checks and balances that works against personal bias and ensures quality control, is at the heart of good science. Scientists therefore take this system of checks and balances very seriously and believe that violating or circumventing it makes for risky science. One of the ways the system can be circumvented is by releasing scientific studies or results to the public prior to peer review and publication in professional journals; this prior release has been dubbed "pre-publication" (Ingelfinger 1977). Except for presentations at scientific meetings and conferences (Angell and Kassirer 1991), journal editors become concerned when scientific results are released prematurely or independently of scientific publication. The National Academy of Sciences summarizes this concern:

> Bypassing the standard routes of validation can short-circuit the self-correcting mechanisms of science. Scientists who release their results directly to the public—for example, through a press conference called to announce a discovery—risk adverse reactions later if their results are shown to be mistaken or are misinterpreted by the media or the public. (1989, p 10)

It is because of this gatekeeping function of the peer-review process, the need and desire to control the flow of information and ensure "quality control," that email and Internet discussion lists, which in the past have had fewer quality control mechanisms in place, are a concern for professional scientific organizations (NAS 1995). However, as we will see in Chapter 2, some of the parameters of "pre-publication" are evolving with the advent of new technological media.

These traditional gatekeeping mechanisms, and the entire consensus process by which theories and results are verified and accepted as knowledge in the scientific community, depend on the fair, accurate assessment of research. *Papers must be written in a way that makes the science accessible, testable, and acceptable* to journal editors and other colleagues in the field. As proposed many years ago by philosopher of science Karl Popper (1959) and is still widely believed, a scientific hypothesis or theory must be susceptible to falsification in order to be verified; that is, a hypothesis or theory must be wholly testable (as opposed to tested) before it can be accepted by the scientific community as a valid hypothesis or theory (but cf. Ziman, who argues that in reality there are too many hypotheses to all be tested [2000]). One way in which findings are tested is through replication, in which scientists in a later study repeat or build on the methods and results of an earlier one. The practice of replication as standard procedure was recommended at the beginning of modern science by Francis Bacon to address the untrustworthiness of the senses and mind in interpreting what we see, playing tricks with our perception and understanding of reality (Bacon 1605).

In addition, *the development of knowledge in science depends on the willingness and ability of scientists to share information after publication.* Research reports must provide enough information for readers to evaluate the plausibility and rigor of the researchers' theory, methods, and results; but scientists can't and don't include every detail of their experiments in their reports (Berkenkotter and Huckin 1995). Researchers must be willing to make further details available to others working in the field. This is especially important when you consider that scientists cannot be present at each other's observations and experiments. Rather, scientists must rely on how observations and experimental results are presented in writing. Here again we see the

centrality of writing and communication in science. As Popper (1959) pointed out, the statements contained in a research report come to embody and represent the science itself. Hypotheses, theories, experiments, and results are primarily presented, obtained, and critiqued through publication (Latour [1979] 1986; Bazerman 1988; Winsor 1993; White 2001).

EXERCISE 1.2

1. Carefully read the summary contained in Figure 1.2. Describe the sequence of events. Now think about the discussion in this chapter. Based on the information given here, why do you think Pons and Fleischmann did what they did? Explain the reaction of the scientific community. What principles of science were involved? What principles of scientific communication did Pons and Fleischmann violate? Were they justified in doing so? Can you think of a scenario in which scientists would be justified in doing so?
2. Now compare the story of Pons and Fleischmann with that of Marshall and Warren. What are the similarities between these two cases? What are the differences? Do you think the differences between these two cases have anything to do with the eventual acceptance of Marshall and Warren's theory, or with the rejection of Pons and Fleischmann's? Explain. Why do some scientists still argue in favor of cold fusion and seek to duplicate the results that Pons and Fleischmann said they achieved? What should Pons and Fleischmann (or Marshall) have done differently? Why?

On March 23, 1989, at a Salt Lake City press conference called by the University of Utah, two electrochemists, Dr. B. Stanley Pons (University of Utah) and Dr. Martin Fleischmann (University of Southampton, England) announced to the world that they had achieved cold fusion. They claimed that their electrolysis experiment produced four times the amount of energy required to run the experiment—not by the tremendous heating and smashing and splitting of atoms (fission), but by bringing together positively charged atomic (deuterium) nuclei at normal room temperatures (fusion). The benefits of their method of achieving cold fusion would be that deuterium is available in seawater and produces much less dangerous radioactivity, and thus that the process would not require nuclear reactor facilities. Pons and Fleischmann, both chemists, thought they had made a major breakthrough in nuclear physics, where research into the possibility of cold fusion had been going on for years without much hope of success; they thought their breakthrough would benefit the entire world (Crease and Samios 1989; Maddox 1989). A flurry of experiments followed, with major research labs around the world (MIT, Cal Tech, Harwell in Britain, for example) diverting attention and money to cold fusion projects.

On March 24, the day after Pons and Fleischmann's press conference, *Nature* received a paper by a team of physicists, led by Stephen E. Jones, working on cold fusion at Brigham Young University. This paper made much more modest claims about cold fusion. Pons and Fleischmann apparently had a prearranged agreement with Jones, made at a March 6 meeting between the scientists and the presidents of their respective universities, to submit their papers simultaneously to *Nature* on March 24 (Huizenga 1992). However, on March 11, unknown to Jones, Pons and Fleischmann submitted a paper to the *Journal of Electroanalytical Chemistry* (Fleischmann and Pons 1989); the revised version was received on March 22, the day before the press conference on March 23, and appeared in the *Journal of Electroanalytical Chemistry* on April 10, 1989. The paper had been faxed around the world so many times that only the words "Confidential—Do Not Copy" were legible (Huizenga 1992, p 24). This paper was later followed by the publication of extensive corrections, called "errata," including the omission of the third author, Marvin Hawkins. Contrary to what was widely believed and reported in the press, Pons and Fleischmann never submitted a paper to *Nature* (Huizenga 1992). On April 26, 1989, the University of Utah asked for $5 million from the Utah state legislature, and Pons and Fleischmann appeared before the U.S. Congress to ask for an additional $25 million immediately (and $125 million later) for a Cold Fusion Institute to continue their research. The paper by Jones et al. (1989) was published in *Nature* on April 27. At the American Physical Society meeting in Baltimore on May 1 and 2, other groups reported negative results from cold fusion experiments, and at the American Electrochemical Society meeting in Los Angeles on May 8, Fleischmann reported flaws in some of Pons's and his original results. On May 18, the first full-fledged critique of Fleischmann and Pons's

paper appeared in *Nature.* Petrasso et al. (1989a) criticized the research on the grounds that it lacked adequate controls and that the equipment may have been miscalibrated, and attributed the reports of energy production and other by-products to those errors. Even though it was "only" a "preliminary" or "technical note," many scientists thought that Fleischmann and Pons's paper should have been revised again before being published. As Huizenga comments:

> When the paper was finally available for examination by an anxious scientific community, most readers were shocked by the blatant errors, curious lack of important experimental detail and other obvious deficiencies and inconsistencies. David Bailey, a physicist at the University of Toronto, said the paper was "unbelievably sloppy." He was quoted as saying, "If you got a paper like that from an undergraduate, you would give it an F." (1992, p 24)

Scientists also complained that there wasn't enough information in the paper for others to replicate the experiment. Pons and Fleischmann refused to answer criticisms directly or to provide crucial details of their experiment (Petrasso et al. 1989b; Huizenga 1992). As reported by *The New York Times:*

> Drs. Pons and Fleischmann offered little help to the unfortunates struggling to repeat their work; they declined to provide details of their techniques and refused to send samples of their equipment to laboratories for analysis . . . . When someone claimed that it was not possible to produce cold fusion, the two Utah [sic] scientists would add more instructions. As Robert Park, head of the Washington office of the American Physical Society, remarked, "Anytime someone did the experiment with no results they would say, 'You didn't do the experiment right,' and offer up another tidbit." (Crease and Samios 1989, p 3D)

When asked for more information, Pons and Fleischmann claimed "that they preferred to press on with more urgent work rather than stop to handle the reviewers' criticisms" (Crease and Samios 1989, p 3D).

As researchers failed in their attempts to test or reproduce Fleischmann and Pons's results, many of the big laboratories terminated their expensive cold fusion experiments. By early July, a special advisory panel to the Department of Energy, co-chaired by John Huizenga, had recommended against awarding special funds for cold fusion research. In 1996, a judge ruled against Pons and Fleischmann in a libel suit they had brought against an Italian journalist who had reviewed their work in a book on scientific fraud. In his decision, the judge ruled that the journalist's review was justified, citing "important opposition from the scientific community, not just against the theory of the research and the way the experiments were conducted, but also the way the data were divulged and the conclusions reached about the future direction of research" (Abbott 1996). For many scientists, subsequent research, including a paper published by Pons and Fleischmann in 1993 (Pons and Fleischmann 1993), added little to what was already known (Amato 1993; Dagani 1993). The field split between "believers" and "nonbelievers," both of whom continue to try to convince each other of their positions (Dagani 1993; Greenland 1994). In 2004, DOE established a second committee to evaluate research in cold fusion, and once again arrived at the conclusion that the evidence wasn't persuasive enough to warrant federal funding of this research program. "While significant progress has been made in the sophistication of calorimeters since the review of this subject in 1989, the conclusions reached by the reviewers today are similar to those found in the 1989 review" (DOE 2004, p. 5).

Despite the lack of funding from DOE, cold fusion research continues and has some advocates. The U.S. Navy's Space and Naval Warfare (SPAWAR) Systems Center in San Diego remains understandably interested in this technology and the development of this potential fuel source (Van Noorden 2007). At the Cold Fusion session of the American Physical Society (APS) Meeting in March 2006, thirteen papers sponsored by the Naval Research Laboratory were delivered (see Chubb 2006). Research also continues in industry and some governments, as well as groups of scientists (Feder 2005). An "invited symposium" on cold fusion was featured at the 2007 American Chemical Society's (ACS) conference (Van Noorden 2007). In 2008, India, having abandoned cold fusion research for sixteen years, began revising its effort again after the former chairman of the Indian Atomic Energy Commission recommended reviewing the research program (Jayaraman 2008; Srinivasan 2008). Authors, complaining about a lack of funding, continue to research and publish on this controversial subject (see Anderson 2007; Szpak et al. 2007). Pons and Fleischmann and their supporters continue to stand by the discovery and to work on cold fusion (see Moore 2000; Van Noorden 2007). But most scientists continue to be skeptical about

claims of excess power produced from low-energy nuclear reactions and critical of poorly documented experiments and the unrepeatability of results (DOE 2004). A website of ongoing research has been developed and is available online (see http://www.std.com/~mica/cftrefs.html).

FIGURE 1.2 Chronology of communication events in cold fusion. Among other sources, we are indebted to Huizenga (1992) for the basis of the chronology here.

1.4 THE ROLE OF PERSUASION IN SCIENTIFIC COMMUNICATION

We have already discussed the importance of sharing information in science. But facts do not speak for themselves. Rather, facts are interpreted and presented as evidence in scientific arguments contained, for example, in research reports, conference presentations, or grant proposals. In the two cases we have examined, that of Marshall and Warren and that of Pons and Fleischmann, the initial failure to gain acceptance for a theory can be directly attributed to a failure to convince colleagues of the validity of the work. The problem is not only a matter of methods and data; it is also a matter of the accessibility, quality, and presentation of evidence—the persuasiveness and style of the argument made.

Neither Marshall and Warren nor Pons and Fleischmann did a particularly good job of persuading their colleagues. In the end, Marshall's critics were persuaded by the results of other researchers, made possible in part because Marshall and Warren provided enough information to make their theory testable; Pons and Fleischmann apparently did not. While Marshall and Warren's theory has revolutionized the field of gastroenterology, Pons and Fleischmann's theory is still hotly disputed, as is their professional credibility.

Persuasion is central to scientific communication. Persuasion tends to be a dirty word in our culture, and a tricky subject in science, which traditionally prides itself on objectivity. But in addition to acceptance by editors and reviewers associated with journals and funding agencies, the work of scientists must ultimately be accepted by the scientific community at large. As mentioned previously, science consists of those findings that have survived the scrutiny of the community and the test of time. Individual findings take on the status of scientific knowledge as they are accepted by more and more members of the field. Thus, the process of building scientific knowledge is best described not through individual facts, but through the achievement of consensus about what counts as fact (Kuhn 1996; Good 2000).

And this consensus is created through scientific argument (Prelli 1989; Lyne 1998; Ziman 2000). In the cases of Marshall and Warren and of Pons and Fleischmann, we get a glimpse of the importance of persuasion, argumentation, and debate in the construction of scientific knowledge. In later chapters you will explore this dimension of science in your own field. To briefly illustrate the role of argumentation in science here, let's return to the case of Barry Marshall. In the exchange of technical letters in the *Lancet* that followed Warren and Marshall's initial announcement in their joint letters, scientists focused not only on methods and data, but also on proving or disproving the validity of Marshall's argument. Debate raged not so much about data, but about reasoning from the data. Veldhuyzen van Zanten et al. (1988), Lam (1989), Marshall et al. (1989), Loffeld et al. (1989), Bell (1991), and others commented on Marshall and Warren's logic, evidence, classification, terminology, beliefs, and judgment. In most cases, it was the *reasoning* of the scientists—and thus the persuasiveness of their argument—that was being called into question. Commenting on a 1989 paper by the Marshall team, Walter Peterson (1989, p 509) pointed to "a number of problems *with this paper* that compel me to urge that *its recommendations* not be accepted" (emphasis ours). Once published, the letters themselves became the object of critique.

Persuasion is created not only by the logic of arguments but also by presentation and style (Myers 1985; Montgomery 1996; Fahnestock 1999). Earlier, we said Marshall had trouble getting people to listen to him because of the way he answered questions at the conference in Brussels. Certainly, a part of the problem was Marshall's position as a young internist speaking before seasoned experts in gastroenterology, an outsider working against the dominant assumptions in the field. Marshall himself admitted to the press that the odds were stacked against him. But critiques by his colleagues in the popular press indicated that they were skeptical not only because of his youth and casual appearance but also because of how he presented himself. Beyond one's past "reputation," the persona one projects through language—what Aristotle called *ethos*, the persuasive character of the speaker or writer created in and through language—can be understood to operate in scientific communication as well (see Halloran 1984; Miller and Halloran 1993; Constantinides 2001). Although the contents of his conference paper may have been appropriately qualified and cautious, Marshall struck listeners as brash and reckless because of his presentation style and the way he answered questions:

> Unschooled at such presentations and filled with boyish eagerness, he refused to respond to questions in the measured, cautious manner of most researchers. Asked whether he thought the bacteria were responsible for some ulcer disease, Marshall replied, "No, I think they're responsible for *all* ulcer disease." Such blanket statements, backed only by small studies and anecdotal case histories, alarmed many researchers. (Chazin 1993, p 121–122)

Pons and Fleischmann too, were criticized for overstating their claims. Physicist Stephen Jones, on the other hand, made more modest claims in his report in *Nature*, and so he was more believable. As *The New York Times* reported, Jones's "colleagues took him seriously not because he was one of their own, nor even because he showed up at all the important meetings to defend his work. Rather, it was because his work betrayed an awareness of potential pitfalls" (Crease and Samios 1989, p 3D). As we will see in subsequent chapters, that awareness is reflected not only in what is said, but also in how it is said. Sociological research has shown that the kinds of arguments and styles employed in formal scientific communication often differ from those in informal settings. Much gets said in the lab that would not be said in more formal forums such as the research report or grant proposal. In formal communication, scientists employ a style that subordinates their personal preferences and professional allegiances (Merton 1973a; see Couture 1993). Regardless of the validity of his claims, Marshall's enthusiasm seemed inappropriate in this formal context. Even Walter Peterson, one of Marshall's most staunch opponents, says, "We scientists should have looked beyond Barry's evangelical patina and not dismissed him out of hand" (Chazin 1993, p 124). Of course, the Nobel Prize vindicated Marshall and Warren—but as Marshall humorously points out in his Nobel Prize speech (2005a), Nobel Prizes are not easy to come by, and most scientists don't receive them. So the question is: Can most scientists look beyond style of argument, appearance, and delivery when this is how science is presented?

The reaction of scientists to Marshall's and to Pons and Fleischmann's presentations of their research illustrates the central role of argument and style in scientific communication. To be persuasive, scientists must make the claims of their research believable in the context of the previous research and the existing paradigm of the field; and they must present these arguments in professional forums and styles that are acceptable in the scientific community.

1.5 SCIENTIFIC COMMUNICATION AND CONVENTION

As illustrated by the preceding discussion, the forums and styles a scientist chooses can make a difference in how well the results of his or her research are heard and understood. The

conferences you attend and in which you participate, the publications to which you submit your work, the funding agencies to which you apply, even the institutions for which you work—all can make a difference in how well your research is received and whether it is used by other scientists.

As you will discover in working through subsequent chapters, different types or genres of writing follow different implicit and explicit "conventions"—that is, different organizational, evidentiary, and stylistic patterns that have come to characterize that genre's use in a particular community. Understanding what these conventions are and how to use them to demonstrate the nature and significance of your research to other scientists in your field is one of the things that distinguishes a professional scientist from a student scientist.

As we join a research community, we gradually acquire knowledge of the ways in which that community develops and communicates knowledge. This happens naturally, and usually without conscious effort, as we read papers written by other researchers, attend conferences, and talk informally with new colleagues in the classroom, the field, the development lab, or other research workplace. We are gradually *socialized* into the communication patterns the community has adopted. (We will discuss ethical issues related to this process in Chapter 3.)

You have probably already started thinking as a biologist or soil scientist or wildlife researcher. If you've taken a course or two or have pursued a personal interest in the field, the socialization process has begun. Not only have you begun developing *content knowledge*—the principles, concepts, and terminology that members of the field take for granted; but you've also begun to acquire *procedural knowledge*—knowledge of how to do things in this research area: how to solve problems, how to test hypotheses, how to use the basic methods of your field, and how to communicate your concerns, questions, and findings to others in the community. The more familiar you become with the ways of thinking, speaking, and writing in your field, the easier it is for you to quickly understand written texts, to grasp important concepts and recognize issues that matter to the field, and to contribute to written and spoken conversations—that is, to participate in the development of new knowledge.

Your content and procedural knowledge develop together, though not necessarily at the same rate, and are mutually reinforcing. You can't write like a physicist if you don't know anything about physics. And you cannot acquire knowledge of physics if you're not able to read the texts written by physicists, apply the experimental procedures and theorems that physicists have developed, and communicate with others in the field about your questions and your developing understanding. Thus, the process of socialization involves learning the subject matter of your particular branch of science and also learning how to reason and communicate as a member of your research community. In Chapter 4 you will take a close look at reports published in research journals in your field. You'll be looking at how the authors of those reports have introduced the problem motivating their research, how they've described their methods and results, and how they've explained and defended the conclusions they've drawn. Our emphasis on exploring such forms of scientific discourse is grounded in the assumption that this knowledge is both generative and constraining (Carpenter & Krest 2001). In studying the genres of a discipline, students entering that discipline learn *what* can be said as well as *how*, and they also learn what is *not* said in particular forms or forums.

For example, when science is "written up" in a typical research report, it is not presented to the scientific community as a personal narrative or story of "what happened" in the actual order that it happened. Although the report may include a chronological description of methods, this description is embedded in a broader argument in which a claim or hypothesis is supported or refuted. Thus, several scholars have pointed out that the traditional report does not accurately represent the processes of scientific research (Medawar 1964; Bazerman 1988; Gross 1990; Ziman 2000), which might include emotions, beliefs, intuition, mistakes, missteps, accidents, serendipity, and other "non-scientific" factors (see Holton 1973; Kuhn 1996; Feyerabend 1978; NAS 1989, 1995; Harris 2005). In his Nobel Prize lecture, Robin Warren (2005b) settles on

serendipity as perhaps the most accurate term to describe his part of the discovery. The Delphic oracle (Chapter 11) also illustrates how science initially may be "rooted in serendipity, hard work, and productive dreaming" (Broad 2002, p D1). Two ground faults—one of them exposed by a widening of the road to accommodate the need for tourist buses to turn around!—were first discovered at the Delphi site by Jelle Zeilinga de Boer, a geologist hired by the Greek government to determine the geological conditions for constructing nuclear reactors in the area (Broad 2002). When De Boer discussed his puzzling finding over a bottle of wine in Portugal with archeologist John Hale, the two hypothesized that, contrary to accepted belief in their respective fields, these fissures may have been the source of the gas that inspired the Delphi priestesses' prophetic pronouncements and visions. None of this was included in their published report, however (compare Broad 2002, p D1, and De Boer, Hale, and Chanton 2001 [both in Chapter 11]).

In writing a report, the creative process of scientific imagination and discovery is reconceptualized along the empirical and mathematical lines of the argument needed to justify the science to a particular scientific community (see Carnap 1950; Holton 1973; cf. Feyerabend 1978; Fuller 2000; Ziman 2000). The four-part structure of the conventional research report (introduction, methods, results, discussion) requires the writer to begin not with the first step in the experiment but with an argument for the significance of the research question. Personal narrative does play a role in science; it is often employed to communicate science to general audiences (see Katz 1992a; Jorgensen-Earp and Jorgensen 2002; Samson 2006), particularly in general-interest magazines and television programs, and often in email, where discussions are more informal. We will explore this important dimension of science in Chapter 8. But in a formal research report in most fields, the narrative form probably would be considered inappropriate in convincing other scientists of the validity of research and might actually undermine that attempt. As you continue to read and study research reports in your field, you'll become more sensitive to the distinctive ways in which scientists in your research community persuade each other that their questions are important, their methods sound, and their results carefully interpreted.

It is important for students contemplating becoming professional scientists to know the conventions of their fields, to understand the underlying assumptions and attitudes that give rise to those conventions, and to understand how to work within them in order to be heard. Theoretically, the more you know about the community you want to join and about the socialization process itself, the easier your initiation into the community will be. Thus, you can simply let the socialization process take its course, or you can actively seek out the distinctive patterns of communication and interaction that characterize your field. The discussion and activities in this book are intended to help you recognize the communication patterns that have developed in the scientific community you are joining.

1.6 THE ROLE OF COLLABORATION IN SCIENTIFIC COMMUNICATION

One of the most striking features that becomes evident when examining scientific communication is its collaborative nature. Science itself tends to be more collaborative than work in some other fields "because of the specialization and sophistication of modern research methods," and "the increased emphasis on interdisciplinary research being prompted by funding agencies" (Macrina 2000, p 157, 158). Given this trend, the role of communication becomes even more important. (In our citing of scientific research in this book, note the number of times "et al.," designating multiple authorship, has been used; even the shorter technical letters to the editor are often written collectively or represent a group of scientists.) The discovery of the role of *H. pylori* in the development of stomach ulcers clearly has a collaborative history. Marshall drew heavily on earlier studies to support his claim that there is a connection between bacteria and ulcers by showing that bacteria in the stomach lining already had been noted but had been overlooked as a cause of ulcers; Marshall and Warren wrote joint letters and a research report together to argue this claim (see Chapter 9); finally, other scientists validated, confirmed, and extended Marshall

and Warren's research and began testing and developing treatment. The creation of scientific knowledge is truly a collaborative process.

In the Marshall and Warren case, we see how scientific progress involves collaboration within the discipline of gastroenterology. In addition to in-field work, collaboration increasingly occurs across disciplines. A good example of this kind of interdisciplinary collaboration can be found in the case we present in Chapter 11 on the Delphic oracle. In this research, an archeologist, a geologist, a chemist, and a clinical toxicologist eventually teamed up to work on a theory that the legendary trances and visions and occasionally violent frenzies of the prophesying priestesses at the Temple of Apollo at Delphi were caused by vapors that rose from a subterranean fault beneath the temple floor. First postulated by writers in antiquity, this theory was virtually dismissed in the early 20th century by archeologists and geologists who first excavated the site and found no large faults or volcanic activity in the region (Spiller et al. 2002). What is of particular interest in this case is that collaboration occurred not only across the boundaries of disciplines, but across the geography of time as well. This diverse team of scientists relied not only on each other, but also on the evidence provided by the testimony of another group of diverse authors: ancient Greek and Latin philosophers, historians, poets, orators, geographers, travel writers, and biographers (Spiller et al. 2002, p 190), particularly Plutarch (see De Boer et al. 2001; also see Plutarch in the Additional Resources, Chapter 11). The keen observations and reports of these ancient writers provided not only the questions that guided the hypothesis of the team of contemporary researchers, but also some compelling evidence (e.g., see De Boer et al. 2001, p 710). Also drawing on ancient literature as well as modern science is the refutation of the "ethylene-intoxication hypothesis," by Foster (a philosopher) and Lehoux (a classicist). In their 2007 article, published in *Clinical Toxicology*, we see that collaboration again crosses what C.P. Snow once called "the Two-Cultures"—the humanities and the sciences—thus dissolving another artificial boundary.

Another example of the collaboration of scientists, who together can truly be said to be attempting to cross the vastness of time and space, is the range of experts working on the Kepler supernova project. The range of expertise represented on this team, as detailed in the final paragraph of the Reynolds et al. proposal in Chapter 12, clearly illustrates that collaboration is necessary for the development of theory and the conduct of research in contemporary science. This is especially true in "big science" projects. Based on the roles designated at the end of the Reynolds et al.'s Chandra Satellite Observatory proposal, imagine the range of expertise and professions involved in the construction, deployment, repair, and maintenance of the Hubble Space Telescope, and in the continuous processing and publishing of images from it. Or the number of scientists and engineers from a variety of countries involved in the construction of the International Space Station. Or the Human Genome Project! In physics, biomedicine, and other fields, the effect of collaboration is vividly illustrated by the growing (and problematic) number of authors appearing on articles (McDonald 1995; CBE Task Force on Authorship 2000).

John Ziman (1968) has called the schools of thought that emerge when researchers regularly work and/or publish with each other "invisible colleges." But not all collaborations have to be large, and sometimes the professional interaction can be quite varied. Thomas Edison relied on an array of lab assistants and workers in all sectors of society (including the press) to develop and promote his inventions, especially electric power and light (see Bazerman 1999). Uglow (2002) describes the close and productive friendship of James Watt (inventor of the steam engine), Erasmus Darwin (Charles's grandfather and a physician and evolutionary theorist in his own right), potter Josiah Wedgwood, and chemist Joseph Priestly, who together created an informal "society" to share ideas and provide mutual support. As a result of this alliance, for example, Wedgwood sculpted the ceramic equipment Priestly needed to eliminate contamination in his work on gases. In all of these examples we see the benefits of multiple skills and perspectives that scientists from different fields can bring to an exploration or problem.

And although perhaps less obviously than in the case of the Delphic oracle, the use of historical research occurs in other fields as well. For example, note how Marshall's letter in the *Lancet* (page 231) situates his study of bacteria in the stomach lining in the context of prior research going back more than half a century, and how he uses that history to build a case for the significance of his own findings. (This is one of the purposes of Marshall's 2002 book as well.) In his Nobel Prize lecture, Marshall makes a point of discussing the importance of prior research in his ability not only to form a hypothesis, but even to see the phenomenon! (2005d). In recognizing the role history can play in scientific collaboration, we also more clearly see the "situatedness" of collaborative research. A research program develops in a specific time and place. History, politics, economics, and culture all influence the shape of science, just as science influences each of them (e.g., see Bazerman 1983, 1999; Lewontin 1993; Lyne 1998; Fuller 2000; Shea 2008). To begin to test the feasibility of their hypothesis, De Boer and Hale had to request that the Greek government allow their team to take samples from this ancient site (see pages 324–325). For the Greek government and the Greek state, this is not exactly a context-free request: throughout its history, and often without permission, explorers and collectors from other countries have carried away pieces of ancient Greece. (This controversy can be perused in the websites we have listed in the Chapter 12, Additional Resources.) This is yet another kind of collaboration, between scientists and governments—in this case, a foreign government. Just as specific research projects are planned and carried out in the context of a paradigm and fields, science as a social enterprise is always situated. History is ongoing and contemporaneous.

This brief overview of collaboration illustrates several important features of the conduct of scientific research: that professional scientists help each other with both the thinking and the writing of science; that readers as well as authors can come from a variety of fields, countries, and even times; and that readers, whether peer reviewers or other professionals, also influence scientific communication (see Gragson and Selzer 1993). Science is truly a social enterprise.

Activities and Assignments

1. In Chapter 9 (pages xxx-xxx) we have reprinted the original letters Marshall and Warren sent jointly to *Lancet*, in which they announced their discovery of *H. pylori*. Write a one- to two-page analysis in which you compare and contrast Warren's letter with Marshall's. Which arguments are similar and which are different? Do you detect any difference in emphases and purpose between them? How do the letters build on each other? Why do you think Warren and Marshall decided to submit these letters together?
2. To demonstrate the value of collaboration as a means of generating ideas and discovering insights, do the NASA simulation exercise in Figure 1.3.
3. Write a one-page introduction to the "business" of your field for outsiders who are unfamiliar with that branch of science. What do botanists (or soil scientists or organic chemists) do? Where do they work? What do they study? What kinds of questions do they ask? What kinds of methods do they use? Why is their research important? Who uses the results of this research? Who is affected by the results?

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FIGURE 1.3 NASA simulation exercise. Adapted from Hall (1971).

4. This multipart activity involves creating and possibly presenting a profile of communication patterns in your research field. The purpose of this activity is to have you further explore the major organs and structures in your own field, and how they function. Your instructor will let you know which parts of this activity to complete.

A. Interview a member of your research community to learn the kinds of writing, reading, speaking, and listening he or she does in professional life. A good way to elicit this kind of information is to ask your interviewee to describe a typical day or couple of days in the lab or office: With whom did he or she talk? What meetings did he or she attend? In what professional reading or writing activities did she or he engage, in either print or electronic formats (e.g., recording data, writing notes, drafting part of a report or proposal, revising an article, reading or skimming journal articles or abstracts, reviewing manuscripts or proposals, participating in online discussions)? Your interview subject also should be able to help you identify the major research journals, professional conferences, funding agencies, online forums, and databases in your field. If you are working with a group, decide together on an appropriate interview subject, develop a set of questions, and arrange for one or more members of the group to conduct the interview. Feel free to interview more than one person, particularly if your group includes students from different subfields. Your instructor may ask you to summarize your findings for the class in an oral presentation, or to present them in writing, as described below.

B. Use the research you've conducted in Activity 4A as the basis for an oral or written profile of communication patterns in your research community. Your goal is to describe the distinctive practices that have developed in your community. Include the names of the most important journals, professional associations, funding agencies, and websites as examples, but also focus more broadly on how, why, and with whom scientists in your field communicate. Include written, spoken, and digital channels of communication. Tell your readers what kinds of knowledge or information are exchanged via the various channels, to whom that information is directed or from whom it is received, and what form it must take in each case.

Your profile should be directed toward readers who are not familiar with your particular field of study. Begin the presentation or paper with a brief introduction to the field (as described in Activity 4A) to give readers some idea of the type of research that is carried out in this field. Then go on to describe the channels of communication that have developed to facilitate this research.

C. As an alternative or addition to the written profile, draw a comprehensive map of your field. Your map should identify the major journals, associations, and funding agencies that are active in your field and illustrate specific interrelationships among them.

D. In groups, exchange your written or graphic profiles with other students in the class. (If profiles were presented orally, use your notes from the oral presentations.) Ideally, each member of the group should represent a different research field or subfield. After all members of the group have read the set of profiles, develop a list of similarities and differences across fields. Prepare a brief group presentation for the class in which you compare and contrast the conventional ways of communicating in this set of research fields. For example, consider whether scientists in these fields ask similar or different types of questions, whether their objects of study are similar or different in significant ways, and whether and how their methods differ. Determine whether differences in research goals or methods have led to different patterns of communication in these communities. For example, you might examine the importance of conferences versus publications in different fields, print versus digital publication, the amount of interaction researchers in each area have with outside audiences, the amount of collaborative work in each field and the mechanisms for supporting that work, and so forth.

CHAPTER

2

Exploring Technology in Scientific Communication

2.1 SCIENCE AND TECHNOLOGY

The interrelationship of science and technology has a long history. The ancient Greeks regarded science as a higher form of knowledge (*episteme*), and technology as a craft (*techne*) (see Toulmin and Goodfield 1962; Stiegler 1998). Thus, for a long time, technology was considered "a handmaiden" of science. In *The Structure of Scientific Revolutions*, Thomas Kuhn talks about technology as the concluding stage of a science, the application of a science being its natural "end" (Kuhn 1996). In a reversal of fortune, with the rise of the Industrial Revolution, technology became a driving force in science as well as culture. In fact, following the scientific revolution of the seventeenth century, technology played decisive roles in the development of the sciences (see Gillispie 1960; Toulmin and Goodfield 1962). As technology became more powerful it came to be considered another form of knowledge in its own right, equal if not superior to science (see Skolimowski 1966; Stiegler 1998), and in the 1960s even a kind of consciousness of the world (Habermas 1970; Heidegger 1977; Miller 1978). Most scholars now agree that science and technology work in tandem in the discovery or creation of new knowledge, as well as its propagation (e.g., see Bazerman 1999): science is essential for the development of technology (e.g., Markoff 2008b), and developments in technology are essential for the growth of science (e.g., Eisend 2002).

When we think of technology in science it's natural to think of the tools or methods with which scientific work gets done. From molecular probes for detecting microscopic organisms to satellite observatories exploring the reaches of space, new technologies are continually changing how, and therefore what, scientists can see. Similarly, in choosing one communication technology instead of another—say, in posting videos of conference presentations online instead of distributing print abstracts—scientists and their associations significantly alter what can be communicated and who can see or hear it.

As we'll explore in the next sections, advances in technologies of communication have affected science in profound ways, influencing interaction among research teams, the speed

with which findings are communicated, the processes through which scientific work is evaluated and responded to, the audiences that can be reached, even the shape and content of what is communicated. Our focus in this chapter is not on the development of technologies for scientific research but on the developing technologies through which scientific work is advanced and made public. As we'll see, these two categories are not necessarily distinct. In contemporary science, technology provides a primary basis for both research and communication, and constitutes the material conditions in which both take place.

2.2 TECHNOLOGY AND COLLABORATION IN SCIENCE

The basic knowledge-sharing processes of science are continually shaped by the technologies available. Digital technologies and the Internet have provided scientists, along with everyone else, with multiple easily accessed tools for interacting with one another. Researchers no longer need to rely on face-to-face meetings or the exchange of letters and manuscripts or synchronic phone contact in order to communicate with colleagues. Email, instant messaging, tele- or video-conferencing technologies, and webinars (seminars conducted via the web) offer instantaneous contact for members of research teams across geographical distance. With the availability of asynchronous media such as listservs, discussion boards, blogs, online social networks, and (again) email, it's no longer necessary for all participants in a conversation to be physically or even virtually present—or even awake at the same time for that matter—for communication to proceed in a timely fashion.

As we saw in Chapter 1, the advance of science is intimately dependent on such communication. Digital tools clearly offer new efficiencies and can play a critical role in supporting collaborative processes, especially as research teams in many domains grow larger and more geographically dispersed. Indeed, digital technologies permit these expansions. It is important to note, however, that new material capabilities do not necessarily make collaboration easier or more productive. Communications researchers have observed that online collaboration, in which efforts are distributed over time and sometimes via different media, may be challenging to coordinate and thus may require collaborative strategies different from those used by groups who can meet face to face.

For example, Swarts's (2004) observations of collaborations in a business setting suggest that although technologies such as MS Word's Track Changes enable multiple authors to work efficiently on the same text, in order to do so productively these co-authors must have a shared sense of the goals of the project, similar expectations for the form and content of the written text, a common understanding of how labor will be distributed within the group, and so forth—all of which will need to be established and negotiated through other means. In other words, the tracking and commenting tools provide a means for collaborating but not the motivation or shared knowledge or group dynamic necessary to ensure success. Although more synchronous, the same no doubt applies to collaborative documents created using wikis, in which all authors can see the document as it is being revised in real time. Google Talk combines instant messaging with voice-over, which could be developed into an effective means of simultaneously communicating about and collaborating on a document. But in any of these scenarios, technology is part of a much larger picture, situated in a dynamic social context. These dynamics constitute an intriguing area for research as digital technologies continue to develop and as science continues to rely on them to support its collaborative practices.

Digital technologies offer new ways for scientists to interact with their broader disciplinary communities as well. The professional societies and associations that serve as formal networks for members of a research field typically use the Internet to provide a central forum for such interaction. Through its website, a professional association can provide continually updated information about meetings and events, grant opportunities, journals and publications, even job openings. Websites also serve a critical function as a repository for a group's policies, position statements, codes of conduct, and other documents that define and

maintain the community. For example, the American Astronomical Society's website (www.aas.org) provides its 6500 members with access to meeting programs, career services, teaching resources, and information about awards and prizes, as well as position statements endorsed by the Society on such issues as NASA's budget and the protection of radio frequencies used for astronomical research (AAS 2008a).

Beyond these housekeeping and archival functions, many associations use their websites to announce new research findings, typically with links to published articles or abstracts, and sometimes with accompanying conference podcasts or other media. Some websites offer subscription feeds to alert members automatically when announcements on pertinent topics are posted. The American Society for Microbiology (www.asm.org), for example, posts "Journal Tipsheets" (links to articles published in the association's journals), provides news feeds by subscription, and offers several categories of electronic alerts (e-alerts) that members can select to receive notification of publications and announcements in areas they request (ASM 2008a).

Increasingly, scientific associations also sponsor or link to more interactive forums, such as listservs, discussion boards, and blogs. The American Astronomical Society hosts a public policy blog at its site, and members of the American Society for Microbiology can sign up for a variety of listservs in addition to the e-alerts noted above. EcoTone is the official blog of the Ecological Society of America (ESA 2008a), intended to complement ECOLOG-L, a popular electronic bulletin board begun in 1992. In introducing their blog in 2006, ESA president Alan Covich stated that "[e]cologists need independent and creative electronic communication" and predicted that the ESA blog would "grow rapidly as a meeting place to explore emerging views about ecology and related environmental sciences" (Covich 2006).

Independent blogs and social networking sites offer additional mechanisms for networking, particularly for scientists who want to reach audiences beyond the professional community. These freely available technological tools make it possible for researchers and interested others to find each other quickly as new interests emerge, without relying on the infrastructure of a disciplinary association. As we'll discuss in the next section, some scientists use blogs as forums for response to published research, representing an emerging form of post-publication review. Whether sponsored by associations or initiated by individuals, interactive media such as blogs and listservs function as virtual meeting spaces for members of scientific communities, not only making it easier for scientists to stay abreast of the latest developments in their fields but also providing opportunities to participate in the development of new knowledge.

The web also plays an important role in the development of the informal "invisible colleges" (Ziman 1968) we discussed in Chapter 1. In fact, the new technologies not only facilitate but also constitute "invisible electronic colleges." For example, the Open Science Grid (2008), "a national distributed computing grid for data-intensive research" (http://www.opensciencegrid.org/), as well as the TeraGrid (2008), "an open scientific discovery infrastructure combining leadership class resources at eleven partner sites to create an integrated, persistent computational resource" (http://www.teragrid.org/about/), are large-scale research collectives that depend on web technologies to facilitate the collaborative use of computing resources. The mission of the Internet2 (2008), a member-based, systems approach to the development of a new, second Internet constituted by a worldwide community of researchers, is "to conduct science, to engage in research, to educate, and to bring diverse communities together in rich new ways" (http://www.internet2.edu/pastshowcases.cfm#494).

The Internet has also enabled the establishment of numerous online repositories for certifying and sharing data within particular fields. The Federation of Ecological Societies of the Americas established a Joint Working Group on Data Sharing and Archiving in 2004 to explore possible collaborative resources (ESA 2008c), and other disciplinary resources are well established. Nature Publishing Group has created interactive databases or "gateway" tools to provide access to resources for neuroscience and genomic research, among other areas (Clarke 2007). Researchers submitting their work to the journal Science are required to deposit data

sets (such as DNA or protein sequences) in approved databases before their work can be published. *Science* "supports the efforts of databases that aggregate published data for the use of the scientific community" (AAAS 2008b), a practice that underscores the value placed on making knowledge accessible and testable in science. In sum, digital technologies have significantly expanded opportunities for the collaborative interactions essential to the advance of scientific knowledge.

EXERCISE 2.1

Visit the website for a professional research association in your field. What technological tools does the site use? How would you describe the social functions of these tools: e.g., housekeeping, archival, knowledge-generating, community-building? What other functions do you discern?

2.3 TECHNOLOGY AND PUBLICATION IN SCIENCE

Despite, and in the midst of, this explosion of informal communication forums, publication in peer-reviewed journals remains the primary mechanism for the recognition, documentation, and distribution of new findings in science. Formal publication still plays a central role in establishing the credibility of a finding and of a researcher. In practical terms, digital technologies have changed the way authors submit research reports to journals, the way those reports are sent out for review, and the way authors are informed of editorial decisions and comments of reviewers. Although some question whether email leads to a "paperless" office, there is little doubt that email is replacing "snail mail" in the submission process, becoming a preferred method of submitting research reports to journals and corresponding with editors. Email is quicker and more efficient even at short distances, to say nothing of global communication (Copher et al., 2002). Many journals now feature submission links and author guidelines on their websites. After being contacted by editors via email, potential reviewers also often work through an automated reviewing process hosted by a central submission hub (sometimes operated as a business serving many client journals). Proposals to most large funding agencies (for example, the National Institutes of Health) are now submitted online as well. The National Science Foundation features a "fast-track" submission process which, as its name implies, is meant to speed up the submission-review process and facilitate communication.

Beyond these logistical improvements, scientific journal publishing is changing dramatically in the digital world. Electronic journals began appearing in the late 1980s, and print journal publishers began offering electronic versions and online access to their journals soon thereafter (Mackenzie Owen 2007). Often these dual-media journals (e.g., the *New England Journal of Medicine*) don't merely "republish" what appeared in print, but take advantage of the versatility of the electronic medium to publish additional features, such as news items pertinent to the research community, additional editorials, or titles of articles accepted for publication in future issues. The hard-copy journal received through the mail and shelved in the university library, when it exists at all, is increasingly embedded in a complex array of interwoven media, including digital texts, the journal's website, online commenting forums, and new databases and archival sites that support information exchange across traditional disciplinary and professional boundaries.

The most significant changes these technologies have wrought have been not in the substance of scientific articles but in their modes of delivery and thus their availability. Perhaps most obviously, the digitization of research texts has made them available for efficient electronic searching. In Chapter 5 we'll explore some of the many search tools that have developed to help scientists, students, and others find research quickly in the digital "intertext." In conjunction with this capability the Internet also has facilitated the important development of

"open access" publishing, which moves beyond the subscription model of print and early e-journals to offer unrestricted access to journal articles to users around the world. One prominent open source effort, PubMed Central (www.pubmedcentral.nih.gov), was established by the National Library of Medicine for NIH in 2000 as a "free digital archive of biomedical and life sciences journal literature" that "aims to fill the role of a world class library in the digital age" (PubMed Central 2008). Once a manuscript has been accepted for publication by a peer-reviewed journal, authors are encouraged to deposit the article in the PubMed Central archive to advance the goal of building this comprehensive repository of science. In April 2008, NIH took the further step of making PubMed submission mandatory for scientists whose research is funded by NIH (NIH/OER 2008).

In addition to serving as repositories for research published elsewhere, some open access publishers also support the establishment of new electronic journals. The non-profit Public Library of Science (PLoS 2008) publishes seven online journals and is managed by an organization of scientists who want to make the "world's science and medical literature a freely available public resource" (http://www.plos.org/). Independent publisher BioMed Central (http://www.biomedcentral.com/) currently hosts a digital portfolio of 187 journals. Their website provides a useful description of the problems that open access publishers seek to solve:

> The traditional business model for scientific publishers relies on restricting access to published research, in order to recoup the costs of the publication process. This restriction of access to published research prevents full use being made of digital technologies, and is contrary to the interests of authors, funders and the scientific community as a whole. The traditional subscription-based model is also becoming increasingly unsustainable, as increasing amounts of research [are] being published whilst library budgets remain static. (BioMed Central 2008)

One of the earliest open access resources, "arXiv.org," was started by Paul Ginsparg at the Los Alamos National Laboratory in 1991, not only to archive and disseminate print journals, but also to create e-journals and publish articles on high-energy physics in electronic-only form (Ginsparg 1994). In cooperation with the National Science Digital Library and sponsored by NSF since 2003, arXiv was later expanded into an "e-print archive mirror" (National Science Digital Library 2008). It is hosted by Cornell University and now houses e-prints in a multitude of areas of physics, as well as many subdisciplines in mathematics, computer science, quantitative biology, and statistics (http://arxiv.org/). In 2002, Ginsparg, who is a Professor of Physics at Cornell University, was named a fellow of the John D. and Catherine T. MacArthur Foundation for his pioneering work in the dissemination of scientific knowledge (MacArthur Fellows 2002).

Both dual media and "e-only" journals have been heralded as a boon to developing nations that traditionally have not had easy (or in some cases any) access to cutting-edge research (Samarajiva 1990; WHO 2000). In 2003, in an effort to address the critical need for access to scientific information in the developing world, the Food and Agriculture Organization of the United Nations (FAO), launched the digital library AGORA in conjunction with nine major scientific publishers. AGORA (Access to Global Online Research in Agriculture)[1] has amassed a collection of over 1200 journals in agriculture, environmental science, and related fields, and offers free or low-cost access to institutions in specified low-income nations (FAO 2008).

Proponents of e-journals as *the primary vehicle* for scientific research point out that e-journals publish scientific advances faster and more easily, cost less to produce, and afford greater access to scientists around the world than do print publications (Harnad 1997). Some scientists even believe that by publishing and reaching more scientists, e-journals in particular

1 "Agora" is the Greek word for "meeting place"; in Greece, it was the center of Athens.

will help "break down social barriers between central and peripheral scientists and thereby . . . increase the size of 'invisible colleges'" (Matzat 1998).

At the same time, there is some concern that e-journals will have fewer quality controls built in because of the emphasis on speed and availability of publication, and so might undermine the checks and balances of the traditional peer-review system (Rowland 1997; Relman 1999).[2] These questions have been noted as the major obstacle to the quicker adoption of e-journals (Harnad 1997). However, more and more scientists are coming to believe that if rigorous quality control and the permanence of articles in e-journals are ensured, the benefits of electronic publication will outweigh the disadvantages (Harnad 1997). We will discuss the ethical dimension of these issues further in Chapter 3.

In addition to the broader access afforded by the Internet, moving journals online has enabled changes in other fundamental aspects of journal publishing. Though the basic form of the research report has changed little in the digital age, publishing online allows authors to embed links to cited research and other resources and also to provide additional information that print journals would not have room for. For example, a one-page "Brevia" article in *Science* by Jeffrey Chambers and colleagues (reproduced in Chapter 13) was accompanied online by eight pages of supporting material, including methods details, tables, and additional references. The expanded "space" available on the web may in effect be reversing the trend in print journals toward shorter manuscripts, driven by the costs of print production.

Online technologies offer advantages in terms of time as well as space. Inherent in all scientific work is a certain sense of urgency: the sooner new knowledge is discovered, the sooner it can be examined, verified, applied, and extended. A high priority is therefore placed on sharing knowledge quickly, a need that some print journals have responded to by creating abbreviated report genres and offering expedited review for particularly important or time-sensitive research. (See, for example, Marshall and Warren's announcement of their discovery of ulcer-causing bacteria in joint letters to the *Lancet*, reprinted in Chapter 9.) We'll discuss these express genres in more detail in Chapter 4, but our point here is that the move to the web has created additional "advance publication" mechanisms to ensure the timely announcement of new findings. For example, on May 18, 2008, *Nature Geoscience* posted a research letter by Knutson et al. on their study of effects of climate change on hurricane frequency (included in Chapter 13). Though the letter would not officially publish until June 2, online readers were able to see the text, as well as 15 pages of supplemental figures and videos, two weeks earlier via this journal's Advance Online Publication (AOP) process. Similarly, Reynolds et al.'s report on the Kepler supernova was published in *The Astrophysical Journal* in October 2007, but the full article was available to online readers at arXiv.org the preceding August. Though new technologies can do little to speed up the time-consuming process of peer review (aside from facilitating the exchange of manuscripts among authors, editors, and reviewers [Clarke 2007]), advance online publications offer clear benefits in terms of production time.

Quick publication benefits the scientists who make the discovery as well, for in addition to making knowledge quickly and widely available, advance publication mechanisms certify a discovery's originators and put them on the record quickly, thus assuring scientists of instant recognition of their work. In this and other respects, online publishing represents a further evolution of the practice begun by the Royal Society in the 17th century to encourage sharing of research by ensuring that scientists would receive credit for their work.

Some scientists take advantage of new media capabilities to play an active role in alerting prospective readers to their work. At the SciVee website (http://www.scivee.tv/), for example, researchers can post "pubcasts" to accompany their published articles. In these 5–10-minute videos, a scientist speaks directly to potential readers, introducing his or her work and providing a link to the published paper. SciVee (2008), whose sponsors include PLoS and NSF,

2 Okerson and O'Donnell (1995) reproduce an online debate about these issues—ironically, in book form.

has introduced this service as a way for readers to find out more about an article than they could from reading an abstract, and also as a way to facilitate discussion among researchers, using the site's commentary and blogging features. Whether such practices will become the norm in science is an open question; some are skeptical that scientists will be willing to invest this extra time in promoting their work (Mackenzie Owen 2007). But the wide support for open access resources indicates a strong interest within the scientific community in exploring ways to reach and engage wider audiences.

Online commenting and response features offer new venues for what Casper (2008) calls "post-publication review," another dimension of scientific publishing that has been significantly influenced by technology. Print journals provide limited forums for responding to published research; some publish commentaries or letters to the editor in response to previous articles (the Marshall and Warren announcements in *Lancet*, for example, generated a number of letters from other scientists, published in subsequent issues). As we'll discuss in Chapter 5, research review articles also provide opportunities to evaluate and comment on previous work (Casper 2008), though at a considerable remove. Electronic media, in contrast, enable response that is immediate, interactive, and potentially permanent. In a study of two such forums, "e-letters" in *Science*'s online edition and commentary in the open access journal PLoS ONE (Public Library of Science), Casper (2008) points out that the commentary in these forums, once posted, becomes electronically attached to the original article and thus appears with it whenever the article is subsequently accessed.

Even more popular at present are personal blogs and other independent forums for commenting on scientific and other work. *SEED* magazine hosts some 70 science-themed blogs at scienceblogs.com. Situated in the public domain, bloggers and their audiences may include readers outside the formal professional communities and range widely in the types of commentary they offer, including but not limited to responses to recent peer-reviewed publications. These interactive tools facilitate informal conversation within the research community but also enable researchers to reach and hear from interested readers who may not be professional scientists, as we'll explore further below. In sum, scientists and journal publishers are using the reach of new media to expand the audience or reach of their work.

EXERCISE 2.2

Visit the Open Students blogging site at http://www.openstudents.org/. Sponsored by the Scholarly Publishing and Academic Resources Coalition (SPARC), this student activist group seeks to "chang[e] the way research is disseminated." Browse this site to get a sense of what the open access movement is all about. What changes are being sought? Why? What changes have already been made? Is there an interest in this movement within your field? What is the nature of that interest? Does your area of research pose particular challenges or goals for open access?

2.4 TECHNOLOGY AND THE PUBLIC AUDIENCE FOR SCIENCE

The presence of the public online has enabled an unprecedented degree of communication between scientists and outside audiences. Scientists have long been committed to informing the public about their work, not only to share and apply their knowledge in "the real world" but also to educate new scientists and to maintain political and financial support for science. We'll explore the social and ethical mandates driving this interest in Chapter 3, and strategies for conveying technical information to non-specialists in Chapter 8, but our interest here is in how new technologies have interacted with this goal. In short, the Internet has made it easier for scientists to reach the public, and perhaps an even more significant change, for the public to access scientific knowledge and resources.

A quick glance at the website of a federal research agency such as the National Science Foundation or the Department of Energy reveals the extensive effort devoted to making the site interesting and informative for a wide range of audiences. See, for example, NSF's homepage in Figure 2.1, which features press releases available to the general public in its prominent "Latest News" section, as well as links to resources for educators, information for news media, podcasts describing recent NSF-funded discoveries for the general public, and other features addressing audiences with varying degrees of scientific expertise. Such sites function in part as public relations vehicles for the agency, informing interested members of the public about how NSF is spending federal dollars and what scientific discoveries those investments have led to. (NSF highlights the public's role in these discoveries in introducing their "Discovery Files" podcasts: "Federally sponsored research—brought to you, by you!" [NSF 2007b].) NSF's stated goal for its website is to "provide accurate, unbiased information about NSF programs and activities to the widest possible audience" (NSF 2007a).

Many professional associations embrace similar missions, providing resources at their websites for the general public as well as their own membership of professional scientists. The Public Affairs Office of the Ecological Society of America, for example, "works to infuse ecological knowledge into environmental decision-making, convey ecological science to the media and the general public, and to provide services to the ecological community" (ESA 2008b). ESA's homepage serves as a portal to podcasts, the EcoTone blog mentioned earlier, and a range of other materials designed for a general readership. An extensive literature in communication studies has begun to examine how scientists learn to communicate with such varied audiences—for example, how conservation researchers balance their dual roles as scientists and environmental advocates (e.g., see Lindeman 2007). Indeed, as scientists become more visible and accessible to the public via new technologies, they may need to develop new skills for explaining and defending their work in the socio-political arena (Ziman 2000), issues we'll explore further in Chapter 3.

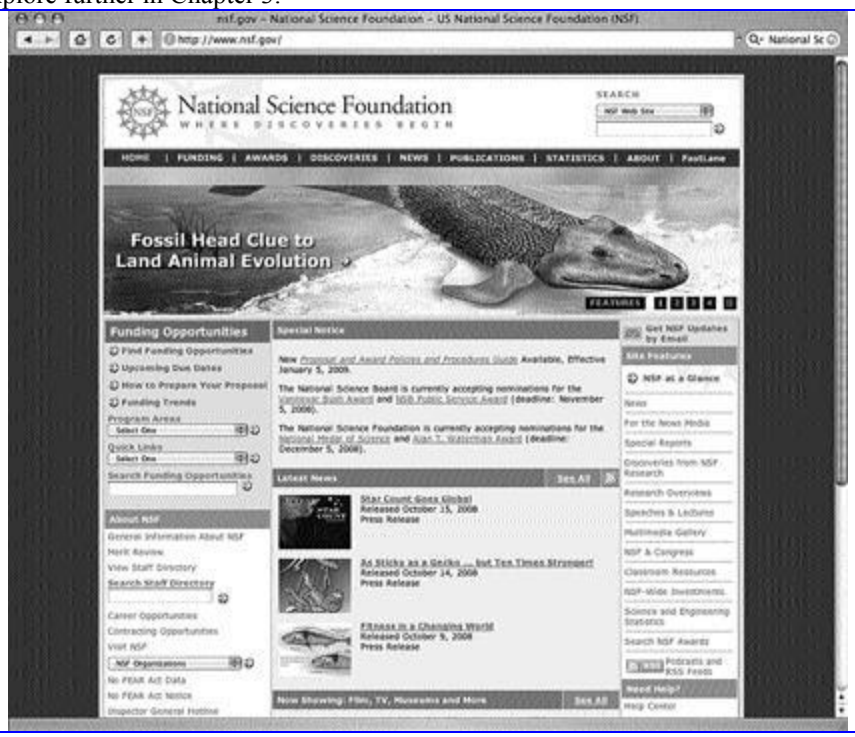

FIGURE 2.1 National Science Foundation Homepage: http://www.nsf.gov/. [Accessed 2008 Jul 1] (Visit the page online for a better view of the interactive features and multiple audiences addressed by this website.)

Though ESA's advocacy agenda may be more prominent than some other groups, most scientific associations see themselves as public educators and have taken ample advantage of new media to reach interested audiences. To a large extent, the communication of science to the public is shaped by the technologies the public uses. NASA's Chandra Observer team, for example, created a Chandra Facebook page in response to popular demand and also has a presence on MySpace, sponsors a blog, posts podcasts of Chandra images to YouTube, and offers podcasts for downloading to MP3 players, among other media tools (see http://chandra.harvard.edu/new.html). Groups wanting to reach the public must go where the public is. Just as newspapers and broadcast networks have established multimedia web resources in response to the changing habits of their readership, so scientists and research agencies have followed the public into the cyberspaces they frequent.

These digital forums are not simply promotional vehicles for these agencies but may also be used for important informational purposes, for example in disseminating health and safety information. The Internet has become an important medium for the dissemination of safety policies and emergency information, reports on government activities, and guidance to citizens seeking expert advice on issues affecting their communities. The states of North Carolina and Maryland, for example, use the web to convey cautionary information about *Pfiesteria* outbreaks for residents who live and work in affected areas in those states. The EPA provides a similar resource at the federal level. (See the Additional Resources in Chapter 10 for these and other public information documents on the web.)

This extensive online outreach has spawned its own service infrastructure to help readers and writers navigate the vast amount of information now available on the web. One such service, Science.gov, is a search engine developed by an alliance of 13 federal agencies to "[help] citizens sort through the government's reservoirs of research and return results most likely to meet individual needs" (Science.gov Alliance 2008). For research organizations that generate scientific information and want to reach public audiences, the American Association for the Advancement of Science (AAAS) operates EurekAlert!, an online news service that "provides a central place through which universities, medical centers, journals, government agencies, corporations and other organizations engaged in research can bring their news to the media" (AAAS 2008a). Research agencies also have needed to develop elaborate protocols governing the release of scientific announcements in various media. NASA, for example, will normally disseminate interesting Chandra satellite images via website or listserv, but if the image is judged to be a significant finding of importance to the general public, it will also be announced in a formal electronic press release and in non-Internet media such as a televised press conference or NASA-Select TV (Chandra X-ray Center 2006). (It is interesting that NASA adds TV to the mix for urgent news, perhaps because, unlike the web, television does not rely on user initiative to locate information.) With more ways to reach the public, communicators have more decisions to make. In short, the sheer volume of information and variety of media available have given rise to new tools for navigating these resources and the decisions they entail.

In considering these ubiquitous digital forums, it is important to recognize that the virtue of expanded reach raises the critical question of who has access. Government agencies that post health and safety information must of course be cognizant of the need to provide information through other means for those who don't have ready access to the Internet or to the ever-changing media tools deployed there. Some question whether the Internet really has the democratizing influence with which it is often credited (Selfe 1999), for an individual's access to information online is clearly dependent on factors such as the presence of computers in the home, physical disabilities affecting the ability to process visual or audio information, language differences, and the challenges of cross-cultural communication, to name a few. Beyond the immediate and practical question of public safety is the larger issue of access to knowledge in a democracy—issues we'll explore in Chapter 3. Theoretically, digital technologies enable easier

access to knowledge for scientists, health workers, and citizens in the developing world, as noted previously, but such access relies on decisions made by scientists and publishers to join networks such as AGORA and post their materials in open forums. Digital technologies facilitate but cannot guarantee access to information. Like the technologies themselves, access is embedded in a complex set of social conditions and actions.

EXERCISE 2.3

As a student in the sciences, you have access to many "insider" sources in your research field. But you are also part of the public audience for science. Where do you come across information about scientific discoveries and applications in fields outside your own? In particular, how do you discover knowledge about science when you aren't looking for it? What scientific topics are most prevalent in the various media you are regularly exposed to? (In addition to online media, consider print, broadcast, and face-to-face communication.) Do you tend to come across information about the environment or about medical advances, for example, via some media more often than others? Compare your observations with others to see if there are trends emerging in how scientific knowledge reaches the public.

2.5 TECHNOLOGY'S MATERIAL ADVANTAGES

We have been looking at how digital technologies have transformed basic knowledge-making and knowledge-sharing practices in science. Here we want to highlight some of the physical or material capabilities of new media that have supported these changes. If we reflect on the various communication practices described thus far, we can identify a number of material conditions that recent technological developments have altered. How are new digital technologies different from previous forms of communication? In what material ways do new media constitute "progress" in scientific communication?

- Speed/Timeliness. As we've seen, the instant availability of information on the Internet provides for early release of critical scientific findings, expedites collaboration among researchers, and is a critical factor contributing to the success of e-journals and dual-media journals. Even traditional print publication processes benefit from the quick exchange of manuscripts among authors, editors, and reviewers afforded by email and online manuscript submission sites.
- Space and Storage. Though many journal publishers still prescribe length limitations even for materials they publish online (Mackenzie Owen 2007), the web provides essentially unlimited space for publishing scientific findings; data storage and record-keeping; shared databases, archives, and other repositories; and educational and informational resources. Simply put, digital technologies expand the amount of information that can be easily preserved.
- Availability. As important as the capacity to store information is the ability to retrieve it. As described above, the web's global reach represents a dramatic departure from print technologies, potentially enabling instant communication and access to resources across time and distance. Although fraught with ethical, economic, and political tensions that we'll explore in Chapter 3, this technological feature plays a critical role in the social agenda of making scientific knowledge broadly available.
- Intertextuality. We take hypertextual links for granted when we browse and read online, but consider how different our online reading processes are from our reading of print texts. When reading online we can not only "skip around" within the text but jump to other texts and resources, and from those to still others. Though this capability presents challenges for readers (e.g., in keeping track of authorship and relationships among

linked materials) as well as web designers (who must create meaningful links, navigation bars, and menus), the technological innovation of hypertext enables communicators to not only post their knowledge but connect it quite literally to the existing knowledge base within the matrix that is the World Wide Web.

- Searchability. Print libraries have of course long offered indexes and other tools for sorting through their collections, but as those collections increasingly become digitized, they not only become more readily accessed but more easily searched. From general search engines like Google and Yahoo to domain-specific tools like Pub Med Central and Science.gov to the local search engines within individual journals and websites, the Internet provides powerful tools to help researchers and others navigate the sea of information now digitally available.
- Malleability. Wikipedia and other interactive repositories that embrace knowledge as communal and evolving are made possible on the web because online texts can be continually updated and amended. The fact that digital texts are infinitely changeable has important practical advantages for scientific publishing as well, enabling journals to publish updates and correct errors as they are discovered (by linking subsequent corrections or "errata" to the original text) and to include later commentary and response to an article as part of the permanent record. In challenging the immutability of the written artifact, digital technologies help maintain the accuracy and currency of the formal scientific record.
- Adaptability. New typesetting programs such as LaTeX (2008) illustrate the flexibility and tailorability of digital tools. Increasingly popular in fields such as mathematics and statistics that rely heavily on numerical expressions, LaTeX is a free manuscript preparation system designed to address the special formatting requirements of technical prose. For example, the program is intended to facilitate the incorporation of tables and figures into page design and renders mathematical expressions more easily than traditional word processors like MSWord (Roberts 2005). Though some advocates perceive LaTeX as separating content from style in that it relieves authors of the responsibility of formatting their text (Roberts 2005), such tools demonstrate that content and style are intimately intertwined. In choosing a particular formatting program an author is adopting a set of representations appropriate to the nature of his or her research. The software that is habitually used in a particular field or workplace—e.g., Word, LaTeX, Excel, Power Point—encodes conventional practices of that community. In learning to use these tools, as with other visual and verbal conventions, new members are learning concepts and relationships important to the field (see, for example, Winsor 2001).
- Interactivity. The Internet's speed and availability features create an interactive environment unparalleled in the print world. Email, listservs, discussion boards, blogs, commenting forums, wikis, web conferences, and other Web 2.0 developments facilitate interaction within the scientific community, open up opportunities for input from those outside the professional community, and also encourage (sometimes require) scientists to be responsive to the broader society in which they are situated.
- Visualization and other forms of representation. Lastly, perhaps the most distinctive characteristic of digital media as a group is the variety of representational forms they support. As we will explore in the next section, digital technologies enable authors to represent knowledge in ways that are difficult, expensive, and in some cases impossible to reproduce in print. Color, motion, and sound are natural elements of the online universe, opening up new possibilities for representing scientific knowledge within and beyond the scientific community.

In concluding this quick survey, we note that these and other material conditions of communication influence more than the spread of knowledge in science but also the ways in which individuals process and learn from scientific texts. The interactive innovations of Web 2.0 focus our attention quite naturally on social factors: who has access to knowledge, who contributes to it, how stable or malleable it is, how quickly and broadly it is dispersed. But digital tools also influence how we process text as readers and writers (Charney 1994; Haas 1996). Our comprehension and use of information begins with how we apprehend it physically: what we see on the page or screen, what we must keep in memory or store externally, how easily we can move from place to place in a document or across a network. Even the introduction of basic word processors, for example, affected how some writers planned and revised their texts (Haas and Hayes 1986). The technologies we've been discussing here present new challenges in organizing and managing sources; integrating visual, verbal, and audio information; and keeping information current over time, among many other concerns. Research has begun on how these material factors interact with the social conditions and contexts in which scientific communication takes place (IText Working Group 2001) and will continue as science and technology evolve.

EXERCISE 2.4

Choose one new digital medium to examine more closely. What advantages does this medium offer over others? What can and can't be communicated via this technology? What are this medium's liabilities (practical, ethical, political)?

2.6 TECHNOLOGY AND THE VISUAL DIMENSION OF SCIENCE

It is easy to see the way television, word processors, email, instant messaging, websites, blogs, wikis, Webinars, listservs, discussion boards, online social networks, virtual realities, animation, and other digital media (as well as printed material) all depend on the visual technology of pages, monitors, screens, and other forms of electronic display. But in relation to science, technology—including visual technology—takes on specific functions. In a sense, technology in science moves beyond concerns of hardware and software to concerns about the way specific technologies provide material conditions for the development and communication of science.

The use of visual technology to develop and enhance scientific knowledge has a long history, of course. Taking the field of medicine as just one instance, from the time of the ancient Greeks to the Middle Ages, physicians had limited access to the interior workings of the body, and treated ailments externally through the skin or orifices. The limitation was the result of the lack of knowledge or the unavailability of technology yet to be invented. But it was also the result of social and religious taboos about penetrating the sacred temple of the flesh—taboos whose removal had profound implications for how we subsequently view and treat the human body (see Benthien 2002). The 15th century saw the acceptance and growth of the field of anatomy; physicians and "barber-surgeons" conducted public dissections of corpses—usually of prisoners—in open amphitheatres packed with spectators as well as students (Bakhtin 1984). The medical "gaze" into the human body widened and deepened with the rise of Newtonian empiricism in the 17th and 18th centuries, with further cultural implications for the perception of the body (cf. Foucault 1977). That "gaze" has only increased in precision and power with the development of other visualizing technologies: the microscope, the X-ray, the ultrasound, the MRI, the CT-Scan, PET-Scans. Today, extensions of video technology in cameo, including angiography, arthroscopy, catheterization, endoscopy, fluoroscopy, and laparoscopy, have made possible the microscopy of areas of the body previously difficult or impossible to access except by cutting (Dinolfo 2008).

In fact, it is hard to "see" how progress in medicine and other scientific fields would be possible without the development of visual technologies. Published in the late 1800s, Charles Darwin's *The Expression of the Emotions in Man and Animals* was the first science book in English to use photographs (see Ekman 1998, p xvi; Prodger 1998). Darwin used these photographs not only to study the nature and evolution of emotional expression, but also to illustrate his observations and principles to his colleagues and the reading public whose assent was necessary for the wider acceptance of his theories. The growth of visual technology in the field of medicine also has been well documented as well as critiqued by scholars. For example, Lisa Cartwright, whose book *Screening the Body* (1995) traces the development of visual culture in medicine, explores the use of "cinema" technologies to study the external movement of the body, the internal structure of the body, and eventually the microscopic interior of the body (see also Lury 1998, esp. 156–183). John Dinolfo (2008) also discusses the history of photography and later "moving images" in the development of medicine and surgery; the use of these technologies grew rapidly in the decades after World War II, and more so with the advent of new film and video technologies in the second half of the 20th century.

And the development and dissemination of visual technology continues unabated: "Arguably, the greatest advance in video distribution has been the evolution and expansion of the Internet. Today, webcasting offers dramatically new possibilities for global receipt of video programs and reports" (Dinolfo 2008, p 187). Miniature cameras in medical research, diagnosis, and treatment discussed above all depend on digital technology. So do large-scale scientific and telecommunications efforts using new visual media on the Internet. For example, the Open Science Grid, TeraGrid, and Internet2 research collaboratives described earlier all depend on large-scale applications and use of visual web technologies that are changing the way research is conducted in the fields involved. And without leaving their wireless digital devices, residents and non-residents of Second Life were able as avatars to attend the Health & Science Communications Association (HeSCA) and Association of Biomedical Communications Directors (ABCD) conference in June, 2008, to listen to the keynote address given by Randall Moss of the American Cancer Society's Futuring and Innovation Center at (http://www.hesca.org/meeting/featured.php#moss).

As we discussed in Section 2.2, new as well as older forms of collaboration, so essential to scientific progress, are facilitated and made possible by technology—including visual technologies. Let's return to Darwin for a moment. Describing the collaboration between photographer Oscar Rejlander and Darwin, Prodger says: "Darwin . . . had long struggled to find photographs suitable for inclusion in *Expression*. Rejlander provided a wealth of useful photographic images . . . the enthusiasm and imagination with which [Rejlander] embraced Darwin's project transformed the content of the book, and in turn revolutionized the way in which scientists study human behaviour" (1998, p. 399). Other photographers and engravers also contributed not only illustrations, but to the development of the content of the book, and thus to the science (Prodger 1998). A similar contemporary example of the role of visual technology in collaboration is contained in the case study in Chapter 9 of this book: Warren needed a clinician to interpret his slides, and Marshall "needed a project"—i.e., he needed visual case evidence to found a theory that then could be tested clinically (Warren 2005b; Marshall 2005d).

Other examples, contained in Chapters 12 and 13 of this book, illustrate the importance of visual technology in the collaborative development of scientific knowledge. In an example involving collaboration between scientists and a federal agency overseeing large-scale, expensive, and complicated visual technology in space, Reynolds and his colleagues reply to NASA's Call for Proposals (CfP) with a proposal to use the *Chandra* satellite observatory to examine the cosmic history of the Kepler supernova. (Parts of both the CfP and the proposal are contained in Chapter 13.) A study of the relationship between the intensity and frequency of hurricanes and global warming, by Thomas Knutson and his colleagues in NASA's

Geophysical Fluid Dynamics Laboratory, relies heavily on visual global climate models based on satellite imagery and computer simulations, as well as other forms of telemetry (see Knutson et al., 2008, in Chapter 13). In an example involving visual communication across universities and disciplines as well as "remote sensing image analysis" (also contained in Chapter 13), Jeffrey Chambers and George Hurtt examine the relationship between deforestation in the Southeast caused by hurricanes and global climate change. Through these "visualizations" of data, they "develop scenarios" and "test empirical relationships and model predictions" (Chambers and Hurtt 2006).

Many scholars have noted the importance of teaching in the development of scientific knowledge. Visual technologies also play a central role in the teaching of science. In scientific classrooms as well as conferences, Smart Boards, PowerPoint presentations, LCD projectors, wireless laptops, and Smart phones have replaced the blackboard, the white board, the slide projector, and the 8- and 16-mm film, the mainframe, and the PDA. Laser scanning and fluorescent microscopy are used to study cell biology; and computer-assisted simulations, mapping, and modeling are used in teaching and research in fields ranging from architecture and archeology to biology and chemistry to meteorology and physics. Investigating the centrality of visualization in the study of cell biology, Dinolfo et al. (2007) found that visuals are used to train students to "'see' at the cellular level" and thus socialize them in the field (p 395). Video—including the animation of surgical procedures—is also used in Continuing Medical Education (CME) and in "Grand Rounds," in which the videos are distributed to medical teaching hospitals and universities by Medline Plus and OR-Live. (Dinolfo 2008). And as Randall Moss states in "Healthcare Informatives in the Metaverse":

> As interest in the 3-D virtual community programs grow, and the technological abilities of our population increase, it is reasonable to predict that medical information delivery will leverage higher technology in the coming years. Cell phones as diagnostic tools, virtual worlds as health education centers, and patient centered information delivery channels available on mobile devices, e-mails, and even bio-implants [sic]. Information delivery and information gathering will make a marked difference in the overall health and [potential] wellness of our population. All of these advents will be possible with the structural advent of the Metaverse: the three dimensional overlay of information technology that will allow us to have extended information about things and events. (http://www.hesca.org/meeting/featured.php#moss)

Of course, new visual technologies—particularly the Internet—also play a crucial role in the communication of science to wider audiences, including the general public. Printed visual documents such as photographs, blueprints, and drawings; physical show-and-tell objects, models, and maps; and radio and television programs and commercials have been supplemented and in some cases subsumed by the webshots and podcasts contained or linked from scientific websites. You-Tube, social networking sites, and computer animation on the Internet allow the public greater access to scientific knowledge; through visual as well as auditory channels, these technologies also allow the public greater participation in and sensory experience of scientific knowledge. On You-Tube, the public can learn about "The Inner Life of a Cell" in a video by Biovisions (2008) at Harvard University (http://www.youtube.com/ watch?v=THKXy _YOK_w), and watch other animated videos by "Dnatube" (2008), a "scientific video site," about cell processes, protein synthesis, and the origin of life (http:// www.youtube.com/watch?v =aIMGS0cSoFI). At the NASA website (see the Additional Resources for Chapter 12), the public can watch space-walks, view downloaded images from the latest lander on Mars, or interact with other stargazers through NASA weblogs. Google Earth, Google Moon, and Google Mars provide real (but not real time) adjustable satellite maps of these stellar bodies.

Google Sky (2008), a collaboration between Google and "astronomers at some of the largest observatories in the world," invites Internet viewers to bring the universe not only into their living room but via wireless browsers or Smart Phones right into their hands (http://www.google.co.uk/sky/about.html). In the Additional Resources for Chapter 13, note the effective use of podcasts that don't merely report but also visually demonstrate the research of scientists studying the effect of deforestation on global climate change.

In fact, visual technologies provide a material basis for science by making non-visible phenomena visible to scientists and non-scientists alike. Visual technologies make the miniscule and the infinitely vast—both invisible to the naked eye—not only present and palpable to the senses but also subject to replication and further experimentation by other scientists. In cell biology, for example, video-enhanced microscopy is employed to visualize cells that are then reproduced and analyzed in specialized journals like *Cell* and the *Journal of Cell Biology*, and in more generalized scientific journals like *Science* and *Nature*. These images, found in print and online, "constitute an evolving archive of cell visualizations . . . used to generate close-up views of cells that were not obtainable with previous technology" (Dinolfo 2008, p 196, 198). Even in specialized journals like the *Journal of Cell Biology*, online articles contain links to video clips and 3D representations of cell structures and processes that are now available to all.

In effect, these images of cells constitute a growing bank of biological knowledge, facilitated and made possible by visual technologies in the laboratory as well as the web. Indeed, these visual technologies are a kind of language of science. From the discovery of the double helix in the mid-20th century, scientists and non-scientists alike have thought of DNA as a code, and referred to it as the "language of life" (e.g., Watson and Crick 1953; Beadle and Beadle 1966; Watson 1968; Gross 1990; Lewontin 1993; Niehoff 2005; Shea 2008). The study of the language of DNA is in fact a highly visual process: DNA profiling and analysis isn't necessarily based on numerical data, but on the location and visual display of the actual strands in gel electrophoresis. (The human genome itself is complex code represented on an enormous map.) Likewise, Gilbert and Mulkay illustrate that molecular models in chemistry are abstract representations of the molecules rather than portraits of them; these models provide chemists with the explanatory power necessary to develop, understand, and share non-visual phenomena in their field—models that make up the "language" of chemistry (see Gilbert and Mulkay 1984). In high energy and quantum physics, physicists use electron microscopes, spectrometers, atomic accelerators, bubble chambers (where subatomic particles or waves are spotted or tracked), and supercolliders to smash and parse the invisible units of matter into visible units of language (see Latour and Woolgar 1979).

Scholars in a number of fields have been studying the actual "language" of visual communication. As Kostelnick and Hassett discuss, just as writing "is regulated by the rules of grammar, syntax, and usage," visual communication is governed by "conventional codes," but currently these are learned informally and through social interaction (2003, p 32). Although Kostelnick and Hassett suggest that visual communication does not have formalized rules and grammar, they point out that "[t]o function as a language, visual language must embody codes that normalize its practices among both the designers who deploy it and the readers who interpret it" (Kostelnick and Hassett 2003, p 1). These codes in effect constitute a grammar of visual communication. Thus it is that "[w]e interpret design with our accumulated knowledge of conventional forms...and we draw on these experiences to interpret new forms that we encounter" (Kostelnick and Hassett 2003, p 12). In *Reading Images: Grammar of Visual Design*, Gunther Kress and Theo van Leeunwen (1996) go several steps further in arguing that visual design is rightly to be regarded as a language. Based on semiotics—the study of signs and meaning—they explore the way visual design elements and structures such as framing, perspective, shape, color, composition, texture, and the like can be regarded as a formal grammar of visual communication. The ability to read, create, and critique these forms in a

variety of media, including writing, is generally now what is referred to by the terms *visual literacy* or *digital literacy*.

Whether or not one accepts that the elements of visual communication constitute a language, there is little doubt about the enormous role visual technologies play not only in scientific research and communication, but in scientific argumentation as well. Darwin knew this, as illustrated by his placement of engravings and photographs in his book (Prodger 1998). The importance of visual arguments also applies to more recent technologies, such as digital video. In "Seeing and Re-viewing the Human Body: Reflections on the Rhetoric of Medical Videography," Dinolfo explains that medical videography "is rhetorical in its use of speech, gesture, scripts, sounds, and images to discover, inform, instruct, persuade, argue, and otherwise graphically convey complex lines of discussion, argumentation, and analysis"; he adds that these technologies "are revealing what might be called a *primal rhetoric* of the human body—what the body is expressing biologically and precognitively in health and wellness or in trauma and disease" (Dinolfo 2008, p 183–184).

In our case documents (Chapters 9–13), we can see that visual technologies and visual communication serve a number of rhetorical functions. Just as visual technologies constitute a language of thinking for multiple scientific audiences, visual technologies constitute key parts of scientific arguments. For example, Marshall and Warren's rediscovery of *H. pylori* in the stomach lining of ulcer patients depended on light microscopy and silver staining of slides to externalize and thus make visible something existing invisibly in the interior of the human body.

In the case of *Pfiesteria*, Burkholder et al. use scanning electron micrographs to visualize the stages of *Pfiesteria piscimorte;* they worked to confirm these images with laboratory bioassays (Burkholder et al. 2005). In their proposal, Burkholder and Rublee used gel electrophoresis to visually "map" the DNA of *Pfiesteria* and identify it as a new organism as an essential part of their overall argument for funding of their research (Burkholder and Rublee 1994). (In Burkholder et al.'s 2005 article, note the careful attention to media specification and measurements in the caption of the DGGE [density gradient gel electrophoresis] image in Fig. 1 [p xxx], as opposed to the simpler presentation of the image in the Burkholder and Rublee proposal, which was addressed to the more general audience that evaluates proposals [p xxx].)

In the case of the Kepler supernova, you also might have noticed the repetition of the image (a typecasting X-ray portrait) of the supernova, which creates a visual and thematic unity across a variety of documents, spanning proposal and article, press release and website (see Fahnestock 1999). In the Reynolds et al. proposal, the authors used a high-pass filtered version of the X-ray portrait to see previously invisible spatial structures (see p xxx). In fact, the argument for their proposal is based on their need for the visual capabilities of the observatory to conduct research that is "uniquely possible with a sufficiently long *Chandra* observation" (Reynolds et al. 2005, p xxx). In addition, visual technology and communication are used to adapt content to different audiences. In the Katrina case, two documents from NPR and from NASA, both intended for a wider audience, use a colorized satellite image to show live (in green) and dead or damaged (in red) trees before and after Katrina (color not reproduced here; for a color version, see the URLS on p xxx and p xxx). But we also see an expert version of these images in the Chambers et al. piece, showing "quantitative measure of disturbance intensity"—"pre- to post-hurricane change in the NPV [non-photosynthetic vegetation] fraction (ΔNPV) on a Landsat 5 subset for the Pearl River basin" (p xxx).

A variety of uses of the visual technologies on the Internet can be seen in the Additional Resources at the end of each case, which are URLs that link to multimedia sites. Note the number of media attached to the Nobel Prize website, which features podcasts, PDFs, and PowerPoint slides from Marshall and Warren's Nobel lectures and acceptance speeches. In the Delphic oracle case, we include websites used by the BBC and by the Hellenic Ministry of Culture to advance their respective positions in an ongoing argument—and perhaps persuade

the public—regarding the removal of the Parthenon marbles from the Acropolis by Sir Elgin in the 19th century. NASA's versatile and highly developed use of web technology includes podcasts for kids, launch information, updates on the construction of the International Space Station, imagery from Mars, and observations from the *Chandra* satellite that bring photographs from outer space to webspace.

The use of visual technology in scientific research and communication is by no means ornamental or cursory. Since Bacon's call in the 17th century for a science grounded in the observation of nature, modern science is highly inductive and empirical, and in Western culture at least, empiricism itself is primarily visual (as opposed to auditory or tactile, for instance [cf. Katz 1996]). In ways that Bacon could never have envisioned, the inherently visual dimension of modern science is both extended and enhanced by continuous developments in technology. Visual technologies are deeply embedded in the sciences; and the sciences are highly dependent on technology. We will explore visual communication in particular genres in subsequent chapters of this book. We conclude this section by noting that like technology generally, visual technology is crucial in providing the material conditions for scientific knowledge.

EXERCISE 2.5

In Chapter 11, we have presented documents related to the theory that the ancient priestesses at the temple at Delphi may have been intoxicated by ethylene gas fumes rising from the floor. Look at the photographs and line drawings in these documents. Why have the authors chosen to represent the phenomena they are studying with these types of visual aids? What aspect of their arguments do these photographs and line drawings "portray"? Is their placement in the text significant? Would you have done something similar or different?

EXERCISE 2.6

In your field, what role does visual communication play in the construction of scientific arguments? Find a print or electronic document that contains one or more visuals and describe how that visual contributes to the overall argument of the piece. Why have the authors used it? Is it central to their purpose, or merely ornamental? How are intended audiences meant to use or relate to it?

2.7 TECHNOLOGY AND PARADIGMS

In Section 2.6, we saw the way visual technologies, like technology generally, can constitute the material basis of scientific research and communication. In a real sense, then, technology can be considered a way of seeing—literally and figuratively, as a screen or a window on or through which we observe different parts of nature (see Burke 1966)—particularly those parts of nature to which we don't have easy, immediate, or direct access except through technology. We therefore tend to think of technology and new media as expanding research and communication possibilities—of making things visible or accessible that weren't before. And of course, as we can see from the many successes of technology and science, this is true. But as Bolter and Gromala (2003) argue, technological windows are not transparent. Rather, technological media themselves can shape the way we perceive and think about phenomena (see Skolimowski 1966; Miller 1978; Scott et al., 2006). Think of the problem of the electron microscope as described by Heisenberg (1958), which enables the observation of subatomic particles—or waves, but not both—while simultaneously affecting that phenomenon as it's being observed.

As we discussed at length in Chapter 1, paradigms enable some kinds of thinking while hindering others, thus shaping what is acceptable in a scientific field. Technically speaking, technology as defined by Kuhn constitutes only a part of a scientific paradigm—laboratory equipment, machines, and apparatus such as high-tech microscopes and computers. To that list we may now add email, the Internet, blogs, Smart phones, etc. Given the role of technology in shaping perception and social processes in science, and in constituting the material contexts in which scientific work is accomplished, technologies themselves may be usefully thought of as paradigms in a more restricted sense than Kuhn meant (cf. Hayles 1999; Harris 2005). This is just as true for communication technology as for technology generally. For if, as we have discussed in Chapter 1, communication is central to the development of scientific knowledge, it is in and through communication technology that theories and data are first discussed and debated, credit eventually awarded, and scientific consensus finally achieved.

Do new media, such as electronic publication, really shape the content of science? Preliminary research on other technological forms of communication would seem to indicate that to some degree this might be the case. We have seen the way technology increases efficiency (in researching, drafting, and revising manuscripts), speed (of submission, peer review publication, response), and thus productivity (the depth and amount of work that can be done). Generally speaking, these three values can be regarded as the goals of any technology, including information technology (cf. Moses and Katz 2006). But the effect of the technology as paradigm may go further than that. Jason Swarts has conducted extensive research on the use of PDAs (personal digital assistants) in the field of veterinary medicine and education. Swarts (2006) explored how newer communication technologies such as the PDA removed forms of communication in veterinary medicine from their specific contexts. Swarts found that to accommodate the technology, a reduction of the "resource rich" environment (p 174) was necessary but did not completely destroy the original information structures. However, students using PDAs in their research on small animal medicine and anesthesia rotation had to adapt resources, content, and presentations to the new technological form. Swarts and VanNorman (2008) investigated the use of PDAs by fourth-year veterinary students at North Carolina State University. What they found was that students didn't use these handheld devices as high-tech calendars or clocks or calculators or notepads (as they were originally designed to be used). Rather, despite the limitations of the hardware noted by the authors (e.g., notoriously small screens), the PDAs helped students in their "mobile, information-centric" work, which consisted of composing texts, videos, and images for PDA delivery while "making the rounds" (Swarts 2006). Swarts has subsequently been exploring the way texts accommodated to technologies mediate knowledge environments and organizational relationships, reshaping both research and communication (e.g., Swarts 2008a; cf. Eisenberg 2008).

Another communication technology that has been studied is PowerPoint technology, which is widely used by scientists for making presentations—even Nobel Prize lectures! (See Warren 2005b; Marshall 2005d; listed in the Additional Resources for Chapter 9.) In a well-known critique, *The Cognitive Style of Power Point*, Edward Tufte (2003) demonstrates the way that the technological form of the slides themselves negatively affects not only the content of the presentation, but how listeners think about the content as well. Noting the limited space and low resolution of slide technology (compared with a 35mm slide) and the default bulleted list style, Tufte criticizes the slides for their lack of content, which is often little more than bulleted points, generalized phrases, and slogans, and for their overuse of headings, logos, and clip art that fill the rest of the space. The presentation that results, says Tufte, focuses attention on the technology and slide form that shapes and dominates the presentation, rather than on the content of or the audience for the presentation. Worse, citing the *Harvard Business Review*, Tufte argues that the bulleted outline form and limited space of the slides limit content and also encourage "a foreshortening of evidence and thought" (p 4)—to arguments that are little more than a series of items whose real critical or causal relationships are unspecified and imprecisely

presented as hierarchical, sequential, or simply similar, no matter what the content (p 5). Thus, narratives, arguments, and data are broken into fragments that are spread across many slides and presented in rapid temporal succession, further reconfiguring content and argument (p 4). Following the *Harvard Business Review*, Tufte further notes that the bulleted PowerPoint format now frequently appears in written reports as well, with similar cognitive effects.

Tufte's book created a large debate on the ATTW (Association for Teachers of Technical Writing) listserv about the value and disadvantages of PowerPoint technology, and its effects on thinking and communication (http:// cms.english.ttu.edu/attw). Our purpose here is not to criticize PowerPoint, but rather to suggest how new technological forms as paradigms can affect content. We will discuss some ethical implications of Tufte's criticism in the next chapter, as well as some recommendations for more effectively using PowerPoint and other forms of oral presentation in the sciences in Chapter 6.

Other scholars are examining the role of new forms of communication technology as genres—specific communication forms that recur to meet the needs of particular situations (see Miller and Shephard's study of weblogs [weblog, accessed 2008 Jun 15]). John Dinolfo (2008) calls medical video "a unique electronic genre for medical discourse, clinical instruction, and patient education with implications for TV broadcasting and Internet webcasting" (p 199). In fact, as habitual modes of perceiving and thinking, technological genres may possess paradigmatic qualities as well. As a genre, "medical video holds potential for becoming . . . a way to re-view and re-know the human body in health and illness. The video camera—and, by extension, the Internet, where much video is now transmitted—may be thought of as an illuminating eye, seeing, recalling, and revealing clinical facts and interpretations" (p 186). As paradigmatic, technological genres not only shape communication, but scientific perception and thought as well.

As Tufte points out, as a mode of seeing, specific technologies, like other visual aids that we will discuss throughout this book, possess particular features that make their forms useful for some kinds of audiences and purposes of communication, but not others. For example, medical videos on DVD or the Internet are useful not only for off-site visual training in procedures, but also as a visual archive of those procedures (Dinolfo 2008). The activities in this chapter will ask you to think about communication technologies used in your field, and the advantages and disadvantages of each in relation to the rhetorical situation.

But perhaps the most complex dimension of technological forms of communication is the rapid development or shifts in technological paradigms, which bring about rapid changes in intellectual "environments" (see Stiegler 1998). As technologies change, so do specific parts of a science situated in them. Knowledgeable in their fields, scientists are quick to utilize new technologies in their work. In his Nobel lecture, for instance, Marshall remarks that he knew that the treatment of *H. pylori* would never catch on unless a less cumbersome and less painful method than endoscopy were developed (2005b): blood tests and then the even simpler "breath test" (Shah 2007). Scientists are often directly involved in the development of technologies in their field, as Rublee et al.'s 2005 review of detection methods for *Pfiesteria piscicida* reveals (see Chapter 10). Many other instances of the paradigmatic relationship between developments in science and in technology can be found in Part 3 of this book.

The relationship between old and new technologies themselves is multifaceted. New technologies may replace older technologies. There is little doubt, for example, that bulky reference books, such as encyclopedias, are being replaced on the Internet by powerful search engines and online tools (see Cohen 2008). There is much debate about the fate of printed books, but even Amazon's "wireless reading device," Kindle, probably will not replace all books or journals in the sciences, which will continue to exist in different forms on multiple platforms. More usually, new technologies absorb and/or transform older technologies without necessarily eliminating them. Lohr (2008) argues that older media able to adapt to new technological and business environments survive. Just as television did not supplant radio, or

DVDs the movie theatre, science programs on the Internet may not replace television. One of Reynolds et al.'s major arguments in their proposal to use the *Chandra* satellite observatory is that prior technology, XMM-Newton (http://xmm.esac.esa.int/), while capturing certain features of the Kepler supernova, was not able to resolve its spatial structure (Reynolds et al. 2005, in Chapter 12). In this case, the new technology, they argue, was needed to supplement the older one.

Thus, new technologies may lead to scientific revolutions, or they may be part of what Kuhn calls normal science. With the invention of video (which is less expensive and requires less technology than 6, 16, or 35mm film), some radio and television broadcasts on science and other subjects have been incorporated into podcasts, which are then placed on the Internet to be played or downloaded into other devices developed for that purpose. As we saw in Section 2.6, there is little doubt that some programs, like Harvard's Biovisions, are migrating to the Internet. Programs like these, designed and produced solely for webplay, are changing the way the programs are conceived and written, while the "inexpensive broadband access" and unfettered viewing schedule are restructuring the way the programs are financed and broadcast (see Caruso 2007). One important lesson for us here is that different technologies serve different purposes. Podcasts tend to be shorter, for instance. (A 30-plus-minute podcast, such as Marshall's Nobel lecture, has buffering problems.) As with PowerPoint, we see how the medium may be altering the form and content of these programs: short videoclips are available anytime to a specific yet geographically wider audience (perhaps even more so than even cable television programs).

In some cases, the old and new forms not only exist simultaneously, but also point to each other (as when scientific print journals contain URLs, or electronic forums link to PDFs). Some new media rely on re-creating older media, and like radio programs turned into podcasts (see the NPR podcast on Chamber's work in the Additional Resources for Chapter 13), or television programs turned into streaming video feeds, one technology is nested in another. New technologies of visualization make it possible to preserve, recycle, and/or reinvent old media as new media, such as the medieval medical treatises in the National Medical Library's "Turning the Pages Online" collection, whose individual original pages can be turned, viewed, and or read (if you speak Latin or French, as well as English), and which selectively feature voice-over background explanations, a magnifier or built-in rollover dialogue boxes explicating particular parts of the page, as well as a print option (http://archive.nlm.nih.gov/proj/ttp/ books.htm).

Old and new technologies also are (re)combined to fulfill different or multiple functions. Thus, the technologies themselves take on different functions. For example, in addition to their traditional roles of teaching and demonstrating, medical videos are now being used to record patients' personal narratives (Dinolfo 2008). In this sense, these videos incorporate some of the original function of weblogs, as reported by Miller and Shepherd (2008), in making personal reaction public (but note that the ability to record responses to weblogs is lost in the video medium). In another example that combines two networking forums, the American Institute for Biological Sciences (2008) has a social networking webpage that contains a separate link to its group on Facebook (http://www.aibs.org/ online-social-networking/).

In fact, perhaps the major point of this section is that technological paradigms change scientific research and collaboration. For example, Jason Swarts argued that PDAs were not simply recording devices in veterinary science training, but actually fundamentally changed the information and indeed the practice of the students using them (2006; 2008a). As Swarts notes,

> The PDA started to pass out of favor as a suitable technology for supporting mobile work. Instead, it is being replaced by smaller laptops and other portable devices that operate more like computers than personal organizers . . . The PDA bridged a gap

> between paper-based personal information management technologies and the generation of mobile devices that we are now starting to use. (Swarts, 2008b)

Again, these changes in technology may result not only in a different form or shape of information, but also in fundamental changes in the information, and thus in the knowledge and practice of science. Other scholars have studied the impact of newer forms of technology on communication conventions. Focusing on email, Moses and Katz (2006) investigate the ways in which the form and ideology of email encourage a "freer," more informal style of writing (e.g., incomplete sentences, lack of capitalization, punctuation, alternate spellings, and the use of abbreviations and emoticons) and thus blur the distinction between leisure and work. As already noted in this chapter, scientists use email, listservs, discussion boards, and websites to correspond quickly with each other, with editors and publishers, and sometimes with the public. In Chapter 1 we also saw how leaving an equation out of a paper cost Hoyle credit for his work (Clayton 2007). Given that email technology and form may facilitate if not encourage quick informal messages, how much more likely are mistakes when the medium of communication is instant and worldwide?

Technology will increasingly constitute new research and communication paradigms. Perhaps more than any time in history, students as well as professional scientists are having to negotiate these quickly changing paradigms. In part, this is a matter of understanding what styles are appropriate in a given medium for specific situations. But it also will be a matter of understanding the new technologies as paradigms. How will the function and values of media forms affect communication conventions, principles, and practices in the sciences? The complexity and speed of technological innovation in the sciences presents unique rhetorical challenges for scientific communicators. We conclude this chapter with an overview of some of these challenges.

EXERCISE 2.7

Find an example of an email that you would consider inappropriate for the circumstances in which it was sent. What (do you suppose) was the motive for or the response to the email? Why? What specific features made it inappropriate? What would you have done differently? Revise that email.

2.8 TECHNOLOGY AND THE RHETORICAL CHALLENGE OF COMMUNICATING SCIENCE

In an intriguing study of carpentry and other blue-collar trades, Rose (2004) observes that tools (hammer, router, jigsaw) can be viewed as embodying solutions to recognized practical problems. Applied with appropriate knowledge and skill by an experienced craftsperson, tools perform necessary tasks in the physical world. The successful use of a given tool thus requires expert knowledge of both task and tool: an understanding of the problem to be solved, an understanding of the tool's capabilities, and the ability and judgment to adapt the tool to the task at hand and use it purposefully in context. In this final section we consider the demands that new communication technologies make on the writers and readers (and viewers and listeners) who use them. Given the social and material conditions we've reviewed in this chapter, what kinds of knowledge and skill are required to communicate successfully via new media?

It may seem obvious that the scientist author needs a broader set of skills in the digital age. The multimedia capabilities of the web have dramatically expanded the representational options available and thus the range of forms to be learned. As with other scientific technologies, the communication tools important to specific disciplines are continually

evolving; both new and experienced scientists must continually update their skills accordingly. It's also important to recognize that while visual and audio information may ease communication for some audiences (consider how visual images might ease communication across languages, for example), these media present new challenges to readers and writers with hearing or visual impairments or physical disabilities that affect keyboard use. Technological developments such as screen readers and voice recognition systems have the potential to significantly expand accessibility, but these advances do not relieve authors of responsibility for considering accessibility issues in designing their own materials and choosing forums in which to post them. The expanded international audience foregrounds the need for knowledge of cross-cultural communication patterns as well.

In many research fields, the expanding public audience for science—or perhaps more accurately, scientists' expanding ability to reach this audience—places a high priority on understanding how to adapt technical information for non-specialists and also on how to discuss science in civic and political contexts. As we've discussed, many scientists are not accustomed to defending their work or advocating for action in the public arena (Ziman 2000); researchers in fields with prominent advocacy missions may need new communication skills to achieve their goals. But whether advocating or informing, the scientist author's relationship to his or her audience is potentially altered when communicating via new media. Distance and reach are increased on the web and, paradoxically, immediacy and "presence" are increased as well. Technology enables communication across much longer distances, and at the same time makes it seem as if there's no distance at all. The *ethos* a scientists projects via a pubcast or even a professional webpage may be considerably different from that conveyed in a journal publication, an added consideration for scientist-communicators as the face of science becomes more personal.

Contrary to popular belief, digital technologies require knowledge and judgment on the part of readers and viewers as well. We've noted the logistical challenges of navigating and keeping track of information online. In addition, though sophisticated online search tools simplify and expedite the task of searching, the sheer volume of information—and the variety of sources from which information is drawn—pose new challenges for readers, who must assess the validity of what they find and also "recontextualize" information from disparate sources to create a coherent understanding for the purpose at hand (cf. Bazerman et al. 2003). In significant ways, the digital universe places more, not less, responsibility on the reader.

In sum, new technologies bring material advantages but pose new practical and ethical challenges for communicators as well. In Chapter 3 we'll explore some of these ethical questions, including questions of authorship and ownership, quality control, and access. New media no doubt will continue to emerge and reshape the landscape of scientific communication. As access to technologies increases within and across research fields, new communication channels will become navigable. Their purposes and audiences will gradually become defined, as will the other conventions governing their use. Students entering your research field a decade from now will no doubt find an even more complex set of communication channels to negotiate.

Activities and Assignments

1. Interview two or three members of your research field about the impact of technology in that community. Ten years ago, what was the most important type of technology in this field? Since that time, what technological developments have been especially valuable to researchers in your field? List as many as you and your interviewees can think of. Then go back over the list and identify those developments that have to do with communication, including, for example, technologies for communicating with other scientists, for storing and sharing data, for accessing and reading other research, for creating documents and presentations, and for reaching audiences beyond the scientific community. Write a profile of the "technological life" of your research community. Describe how

technological developments have affected the way research is conceived, conducted, interpreted, and shared in your field.

2. Map your own technology networks and history. What communication tools do you rely on in daily life, to interact with friends, family, fellow students, co-workers, instructors, employers, and others? Do you use the same or different tools to participate in these different groups? How did you learn to use these tools? How have these technologies changed in the past decade or so? How have these technological changes affected you? How do you expect these technologies to change in the future?

3. Listen to Elizabeth Shogren's National Public Radio report, "Trees Lost to Katrina May Present Climate Challenge": http://www.npr.org/templates/story/story.php?storyId=17814049 (or another report at this site). The website provides a print story transcript as well the podcast. Turn off your screen and listen without the text as you would to a radio broadcast. What kinds of *visual* information are conveyed in this audio story, and how does Shogren create these images without the aid of a shared visual text? What strategies does she use to compensate? What does the radio broadcast allow Shogren to convey that she wouldn't be able to communicate in a print article? Prepare a report of your analysis for written or oral presentation. Your instructor may ask you to compare your results with other students' observations about this or other audio texts.

4. Select an online scientific text intended for a public audience. (You'll find plenty of options through the websites listed as Additional Resources in Chapters 9–13.) Propose a plan for communicating the information in this text to the same target audience, but without the Internet. Can you do it? How would you do it?

CHAPTER

3

Considering Ethics in Scientific Communication

> Society's confidence in and support of research rest in large part on public trust in the integrity of individual researchers and their supporting institutions . . . . It is therefore incumbent on all scientists and scientific institutions to create and nurture a research environment that promotes high ethical standards, contributes to ongoing professional development, and preserves public confidence in the scientific enterprise. (Committee on Assessing Integrity in Research Environments [CAIRE] et al., 2002, p 33)

3.1 COMMUNICATION ETHICS IN SOCIAL CONTEXTS

As members of society, scientists are influenced by the dominant values of the culture in which they live, such as truth, justice, freedom, progress, happiness. As societies in themselves, scientific disciplines also are governed by conventions, both written and unwritten, which come to constitute standards and principles of professional conduct and practice. That is, the conventions of your field constitute (or imply) a system of ethics. Finally, like everyone else, scientists find themselves in "the global market"; scientific research and practice is increasingly conducted on "a world stage"—a stage made much smaller and more immediate by electronic communication. As you explore the communication practices in your field, you will learn about some of the conventions that shape your discipline. As you become a member of your discipline, it also is important that you understand the ethical dimension of these conventions in these different social contexts, and some of their implications for you as a scientist.

Scientists usually learn professional ethics informally by observing how other scientists behave. But as the National Academy of Sciences wrote: "science has become so complex and so closely intertwined with society's needs that a more formal introduction to research ethics and

the responsibilities that these commitments imply is also needed . . . " (1995, Preface). While informal observation is still a primary venue for learning ethics, efforts to formally integrate the teaching of ethics into science curricula across the country that began in the early 1980s have greatly expanded in the 21st century (see Benditt 1995; Sweeting 1999[1]; DuMez 2000; Macrina 2000; CAIRE et al. 2002; ORI 2005b). For example, at the level of research universities, the Collaborative Institutional Training Initiative [CITI] provides extensive ethical training and testing in all areas of scientific research and authorship for member Institutional Review Boards (IRBs). (IRBs [they may have different names at different universities] must review and approve research proposals according to accepted ethical standards when the plans involve research with human or animal subjects, and monitor the compliance of the researchers with those approved protocols [CITI 2008].)

On the national level, a collaborative effort was launched at the turn of the century by the U.S. Department of Health and Human Services's Office of Research Integrity (ORI 2006b), in association with the non-profit National Academies (Institute of Medicine, the National Academy of Sciences, the National Academy of Engineering, and the National Research Council). At the request of and with funding from the Department of Health and Human Services (DHHS), the National Academies's Committee on Assessing Integrity in Research Environments, in conjunction with other organizations in the National Academies, began by articulating core values and behaviors associated with scientific integrity, listed in Figure 3.1. As you examine this list, notice how many of these core values pertain to issues of communication. Because the conduct of science includes the ways in which scientists share their results and interact with others in and beyond their research communities, communication practices are a central focus of efforts to examine and foster scientific integrity. CAIRE et al. set out not only to develop a rigorous program of defining, teaching, and promoting scientific integrity, but also to develop more formal procedures of collecting, measuring, and evaluating data on integrity in science education and research (CAIRE et al. 2002). Their report, "Integrity in Scientific Research: Creating an Environment that Promotes Responsible Conduct" (2002), represents an early step in the effort to formally identify, track, and study scientific integrity for the National Academies.

Another significant source not only of funding but also of values for scientists in the United States is the National Science Foundation (NSF). Like ORI, NSF is concerned with scientific ethics and the integrity of scientific research and communication, has invested in studies on these issues, and as CAIRE et al. (2002) reported, awarded grants for projects such as "Openness, Secrecy, Authorship, and Intellectual Property"; "Sharing Research Data: An Examination of Practices"; "Dynamic Issues in Scientific Integrity: Collaborative Research"; and "Historical Perspectives on Scientific Authorship" (p 24). NSF also has funded studies in ethics education, such as "Responsible Conduct of Research in Science and Engineering Education: Moral Motivation and Ethical Sensitivity in Multi-National Graduate Students" (Bowler et al. 2008), and the "University of Michigan Comprehensive Ethics Training Program in Basic and Social Sciences and Engineering" (Barald et al. 2008). We will touch on many of these ethical issues in this chapter as we conclude Part I of this book, and reflect on the ethical dimension of the communication conventions that you will read about in Part II of this book. At the end of this chapter we will discuss the ethical implications of the socialization process you are now engaged in as a new member of the scientific community.

[1] Dr. Linda Sweeting (2000) and her students continue to compile a comprehensive and annotated list of ethical topics linked to bibliographies and webpages of sources, available at: http://pages.towson.edu/ladon/ethics/ethicbib.htm. We are indebted to this bibliography for several of the referenced sources in this chapter.

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FIGURE 3.1 "Integrity in Research" from CAIRE et al. (2002, p 5).

Since scientific disciplines are participants in the larger society in which they are situated, it stands to reason that scientists would face some of the same ethical issues in communication faced by society at large. Occasionally we read in the press about incidents of misconduct in scientific communication. For example, we read about Dr. Roger Poisson, who falsified and misrepresented data in a seminal report on breast cancer treatment on which major research and health recommendations had been based (Taubes 1995); about W. Bezwoda, who fabricated data involving cancer treatment in South Africa (Hagmann 2000); about Sarvamangala Devi, an assistant researcher who discovered a vaccine that could be used in the treatment of AIDS patients, who charged that she was being denied credit for her discovery by senior scientists at the National Institutes of Health because of her gender and ethnic background (E. Marshall 1995); about the scandal in the Department of Oncology at the University of Freiburg Medical Center in Germany, where hematologist Frieldhelm Herrmann and colleagues were accused of falsifying or manipulating the data of numerous research reports, prompting *Nature* to state that there are serious flaws in the infrastructure of German science (AAAS 2000); and about the fabrication of stem cell research data by Woo Suk Hwang, at Seoul National University, that "eliminated from the record one of the field's most promising therapeutic advances—patient-specific stem cell lines," a crisis that science ethicist Jonathan Moreno at the University of Virginia has called "'the greatest conduct disaster in microbiology,' [which] may swing the debate over embryonic stem cells" (Beardsley 2006).[2] We also read about a scientist at Purdue University, Rusi P. Taleyarkhan, whose 2002 paper claiming he had achieved cold fusion employing a well known technique of sound waves to collapse bubbles to release energy (Maugh 2008) was published in *Science* over the objections of several reviewers; unlike Pons and

[2] For continuously updated investigations by the ORI into scientific misconduct, see https://ori.hhs.gov/content/case_summary (cited 2020 June 27).

Fleischman, Taleyarkhan was actually found to have fabricated data by claiming his findings had been independently verified by a post-doc when he had been "heavily involved in the work," and to have listed another researcher "who had not been directly involved in the research" as a co-author of the follow-up study (Strickland 2008). For his part, "Taleyarkhan accused his critics of conflict of interest, jealousy and other motives. He filed a defamation lawsuit this year accusing two Purdue professors of trying to destroy him and his reputation" (*Newsweek* 2008).

And so we also read about charges of bias in the gatekeeping and educational institutions of science themselves. We read about how NIH stopped its funding for a controversial conference examining the relationship between genetics and crime after protest from black leaders (Associated Press 1992); about the possible misuse of data from an unpublished article submitted to a journal by researchers at Cistron Biotechnology, by peer reviewers from a competing drug company, Immunex Corporation (E. Marshall 1996a), ending with an out-of-court settlement that established neither guilt nor the legality of the confidentiality of peer review (Marshall 1996b); and about the disruption if not devastation of the careers of doctoral students in genetics at the University of Wisconsin after they were compelled to report questionable data and practices in grant applications and published articles by their professor, Elizabeth Goodwin (Couzin 2006). We read about investigations into elitism and bias against women, minorities, and the disabled in science and its educational institutions (Mervis 2000; Rowe 2008; Tierney 2008); and about continuing problems of under-representation, prejudiced evaluation, and suppression in science and industry based on gender (Horn 1998; Jacobs and Storck 2000; Science 2000a;)—even in the National Academy of Sciences itself (Angier 1992; cf. NSF's ADVANCE program (DeAro 2008), designed to help women scientists and engineers at key points in their careers [NSF 2007a]). Questions regarding the representation and tracking of foreign scientists and science students were debated even before the terrorist attacks on the U.S. mainland on September 11, 2001 (see Heylin 2000; Lawler 2000a, 2000b).

Given issues and charges like these, U.S. science would appear susceptible to the same ethical shortcomings as American society at large. As science ethicist Francis Macrina succinctly puts it: Both the DHHS and the NSF definitions clearly forbid "fabrication, falsification, and plagiarism. This is commonly referred to as the FFP core. Fabrication means making up results; falsification means tampering with results; and plagiarism means passing off another's ideas as your own. In other words, in science as in life, it is wrong to lie, cheat, or steal" (2000, p 11).

In fact, today the scientific community is a microcosm of the world. The reaction of scientific communities around the globe to unethical conduct by or against scientists in individual countries not only reflects a concern for the ethical infrastructures of nations; it also reflects the internationalization of ethics in the community of science. The accessibility of research and interaction of researchers through electronic communication has only sped up the internationalization of science. As science becomes more international, the actions of one scientist, or organization or government, affect scientists everywhere. For example, the internationalization of ethical concern in science is reflected in the establishment of the Scholars at Risk Network to help persecuted scientists outside the United States (AAAS 2000). It also is reflected in the call by the French national agency of scientific research, L'Institut de Recherche pour le Développement, for an international code of ethics (AAAS 2000). The ORI (2008a) website of the U.S. Department of Health and Human Services features an International section in which they have assembled for U.S. scientists links to various international and national ethics "activities," to misconduct cases in other countries, and to ethical and regulatory codes from nations around the world. NSF offers international ethics training (Bowler et al. 2008).

We shortly will discuss the effect of the Internet and technology generally on copyright as well as ethics. But we will mention here that because the Internet has helped science outgrow national boundaries, there has been a longstanding call for the revision of international treaties to address such ethical and legal issues as ownership and copyright (Liedes 1997). In 2007, Peter K. Yu issued a comprehensive report developing an international concept of intellectual property

within the framework of human rights issues. In 2008, the CEO of the American Association for the Advancement of Science, Alan I. Leshner, along with other leaders of science policy, called on the U.S. Congress to renew sustained efforts to use scientific collaboration as an essential instrument in improving diplomatic relations, even with countries where normal relationships are strained or don't exist (AAAS 2008d). Just as political economies are globally interdependent, in today's world there is an increasing awareness that the validity and quality of work done by scientists in one country affect the perception and quality of science—and indeed the quality of life—everywhere.

As this quick overview indicates, scientists working in research environments are subject to pressure from a variety of social, economic, and political forces. By all accounts, the pressure is mounting: The very success and "affluence" of science (Hoshiko 1991, p 11)—and the enormous pressures to compete for dwindling funds, publication, prizes, promotions, prestigious labs and equipment, research assistants, students, and media attention—seem to be changing the ethical environment in which science is conducted (Cohen 1995; Macrina 2000; CAIRE et al. 2002; Martinson et al., 2005). In Figure 3.2 we have reprinted CAIRE et al.'s graphic depiction of these "environmental influences." For institutions as well as individual scientists, maintaining scientific integrity is a matter of negotiating these influences, including the pressure to publish in order to maintain employment and enhance professional reputation; the need to tailor research agendas to the interests of funding agencies; and the constraints imposed by journal editors, professional societies, and governmental regulation on what, and how, research is presented to the scientific community.

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FIGURE 3.2 External factors influencing the research environment. CAIRE et al. (2002, p 8).

Also see revised figure at: https://www.academia.edu/35909041/_Lines_and_Fields_of_Ethical_Force_in_Scientific_Authorship_The_Legitimacy_and_Power_of_the_Office_of_Research_Integrity_with_C._Claiborne_Linvill_2_files_See_a_revised_Abstract_under_More_Information_, p 55 (Cited 2020 June 28).

3.2 ETHICAL MECHANISMS IN SCIENCE

Because of alleged and reported cases of misconduct in the United States, there is strong political pressure for congressional oversight of science—a pressure that scientists have consistently resisted, insisting that they can monitor themselves (Koshland 1989; Hoshiko 1991; CAIRE et al. 2002; Wells 2008). A three-year study by the Gallup Organization for the ORI of the types and frequency of scientific misconduct in biomedical research funded by NIH states: "Scientists

believe that the best way to detect and prevent research misconduct is through close supervision of research work and place this responsibility on the principal investigator." Along with other recommendations concerning collegial and institutional "review, audit, and quality control procedures," they add: "Scientists also endorse open communication as a way to detect research misconduct" (Wells 2008, p 32). Most scientists "have experienced or know first-hand some cases of misconduct" (Hoshiko 1991, p 11)—a conclusion also supported by the ORI-sponsored Gallup study (Wells 2008). In 1989, *Science* editor Daniel Koshland Jr. estimated that in three million research articles published over the prior ten years, only about a dozen major cases of fraud had been reported. In 2000, an evaluation involving two hundred scientists by the DHHS Office of Research Integrity reported only one case of fraud out of ten thousand studies per year (ORI 2000). In 2008, the Gallup study for ORI, which focused on the core issues of fabrication, falsification, and plagiarism (FFP) covering the period 1998–2004, found "approximately three per 100" incidents of scientific misconduct (Wells 2008, p 42). From these statistics, it might appear that misconduct in scientific research is rising.

Indeed, the Gallup study was based on ORI's 2005 definition of ethical violations in science that excludes a host of minor infractions (we will discuss this definition further in the next section). While acknowledging the limitations of their own as well as previous studies of misconduct in science due to the difficulty of researching the subject, and the probable under-reporting of infractions, the Gallup study concludes: "We see that while potential research misconduct is a rare event . . . it is not as rare as most scientists believe it to be" (Wells 2008, p 42), an opinion shared by Martinson et al. (2005), who attempted to measure *all* types of scientific misconduct that fall outside ORI's narrower definition of FFP. As we can see under "Other behaviors" in Figure 3.3, Martinson et al. found that "*lesser*" infractions occurred more frequently for both beginning and mid-career scientists than the "Top ten behaviors."[3]

Although it is still widely believed that the number of incidents of scientific misconduct is relatively low, the scientific community in general and specific disciplines in particular have instituted measures to counteract potential unethical conduct. In addition to "institutional" oversight such as ORI, NSF, AAAS, and NAS, scientific journals have had in place the system of checks and balances we discussed in Chapter 1, based on peer review and credit by publication, to guard against bias and fraud in science.[4]

[3] The "Top ten behaviors" represent those considered sanctionable by ethics compliance officers. The authors speculate that one of several reasons for the higher percentage of mid-career scientists may have to do with fear by younger scientists of reporting misconduct, and that these percentages as a whole may be conservative based on under-reporting (Martinson et al. 2005). The Gallup study (Wells 2008) also criticizes earlier studies of misconduct on these and other grounds.

[4] For samples of editorial statements on these and other ethical issues, see the guidelines published by the International Committee of Medical Journal Editors (ICMJE 2007) at http://www.icmje.org, or those developed by the American Society of Civil Engineers (ASCE 2008) at http://pubs.asce.org/editors/journal/generalresource/ethicalstandards.htm.

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FIGURE 3.3 Reported Acts of Misconduct in Science. Martinson et al. (2005, p 737).

Also see summary of results at:
https://www.academia.edu/35909041/_Lines_and_Fields_of_Ethical_Force_in_Scientific_Authorship_The_Legitimacy_and_Power_of_the_Office_of_Research_Integrity_with_C._Claiborne_Linvill_2_files_See_a_revised_Abstract_under_More_Information_, p 44 (Cited 2020 June 28).

It is generally assumed that all parties involved in the peer-review system—authors, editors, and reviewers—will conduct themselves ethically: that work will be evaluated fairly and their authorship will be recognized; that editors will assign reviewers impartially, keep all information about submitted research confidential, and recuse themselves from decisions pertaining to manuscripts in which they are co-authors or have a vested interest; that peer reviewers will review without bias, maintain confidentiality, and reveal potential conflicts of interest before agreeing to review a manuscript. Some scientists doubt that the above principles based on fairness and skepticism can be reliably sustained, given the sheer number of people involved in the peer-review process and the many sources of pressure that might potentially undermine ethical behavior, and over the years have questioned the efficacy of these internal gatekeeping mechanisms (Hoshiko 1991; Roy 1993; Dagani 1995; Hojat et al. 2003). This is particularly the case in light of the possibilities of more open and interactive e-publications. In fact, some of the early arguments for the wider acceptance of electronic publication in science have had to do with reforming the peer-review system of journals (e.g., Odlyzko 1995; Brody 1996; Harnad 1997; Smith 1997; Delmothe and Smith 1999). A few of those scientists have called for the replacement of the traditional peer-review system with one based on trust in individual scientific authors, the number of papers previously published (Dagani 1995), and/or, as Ginsparg believes, the opinion of scientific readers, who can and will determine what is good themselves (*Cornell News* 2002). The latter, what we might call "peer review by social consensus," is made possible by the Internet. Ginsparg's arXiv.org, discussed in Chapter 2, also may depend on the high degree of familiarity and trust that develops in a smaller field, such as exists in high-energy physics (Fry 2003). However, this assumption is being tested by the expansion of the content of arXiv.org to other fields beyond high-energy physics.

But even proponents of electronic publication in science generally acknowledge the importance of a system of checks and balances that since the 17th century has been designed to protect the rights of individual scientists, maintain the integrity of research, enhance the reputation of scientific institutions, and preserve the public trust in science (NAS 1995; Harnad 1997; Day 1999). There also has been a concerted effort to reform the peer-review systems of major funding agencies such as NIH and NSF (see Friedlander and Bessette 2002; DHHS 2008), and revised and expanded guidelines for many scientific organizations are now readily available online.

The ethical standards articulated by journal editors and funding agencies reflect the historical values of scientific research itself—"honesty, skepticism, fairness, collegiality, openness" (NAS 1995, p 21), or what Jacob Bronowski (1965) called the "Habit of Truth." Scientists' respect for these shared values is perhaps the ultimate safeguard against misconduct in science. Because scientific communities are themselves social groups, the behavior of scientists also is strongly influenced by the opinion of their peers, with shame being a major deterrent of misconduct (Cohen 1995; cf. Ball 2008). Even an allegation of misconduct in science can be damaging to a scientist's career (Macrina 2000; ORI 2005b). As Hoshiko notes, "A scientist's most valuable possession is his or her reputation, which, once lost—whether deservedly or not—may be virtually impossible to regain" (1991, p 11).

EXERCISE 3.1

Obtain a copy of the research policies or guidelines for your department, lab, university, or professional association, or look at the special concerns addressed in a funding agency's RFP or the editorial guidelines for a journal in your field. What kinds of ethical issues are raised in these guidelines? Categorize these issues (e.g., humane treatment of subjects, misrepresenting data, authorship, sexual harassment). What do these categories tell you about the focus of ethical concern in your field?

3.3 THE ETHICS OF AUTHORSHIP

These general values of honesty, skepticism, fairness, collegiality, and openness imply distinct responsibilities for authors as well. In the prior section, we mentioned the narrower definition of scientific misconduct adopted by ORI in 2005 (ORI 2005a). Except for plagiarism, FFP excludes many authorship issues, which we also see in Figure 3.3. Following the policy recommendation of the Office of Science and Technology Policy (OSTP 2000) and the practice of the Public Health Service (ORI 2005b) in 2005 the ORI adopted and codified into law a stricter definition of scientific misconduct as "fabrication, falsification, and plagiarism (FFP) in proposing, performing, or reviewing research, or in reporting research results" (ORI 2005a). Citing the problem of attributing credit in multiple-authored projects in "big science" discussed in Chapter 1, the American Physical Society had adopted this definition in 2002 (Overbye 2002). The University of Pittsburgh further extended this definition of scientific misconduct in the case of Gerald Schatten, who worked with Dr. Hwang, mentioned in the previous section, by classifying authorship issues as "scientific misbehavior" (Holden 2006).

One of ORI's explicit intents in adopting this narrower definition of scientific misconduct was to exclude "authorship or credit disputes" in its investigation of misconduct (DHHS 2005, p 28377). But the exclusion of authorship and credit in investigating misconduct in no way diminishes the importance of the ethics of authorship in science, for ultimately the whole enterprise of science depends on collegiality and trust. Building on the report by CAIRE (CAIRE et al. 2002), Martinson et al. (2005) demonstrate in their study of scientific misconduct that ethical problems in science go well beyond FFP, and that authorship and credit issues are significant: "our evidence suggests that mundane regular misbehaviors present greater threats to

the scientific enterprise than those caused by high-profile misconduct cases such as fraud" (p 737). Furthermore, the narrower ORI definition of misconduct includes plagiarism as a core violation: "As a general working definition, ORI considers plagiarism to include both the theft or misappropriation of intellectual property and the substantial unattributed textual copying of another's work" (ORI 2006a). Devoting an entire chapter to the wider ethical issues of authorship, the Council of Science Editors lists four kinds of plagiarism, as delineated by the American Medical Association (CSE 2006). These four definitions are shown in Figure 3.4. Finally, funding agencies (eg., NSF 2008f), research institutions, as well as scientific journals remain strong advocates for the ethics of authorship and credit.

Journal editors often articulate ethical guidelines for authorship quite explicitly. As we can see in Figure 3.5, the editors of *Gastroenterology,* for example, include research *and publication* misconduct in their definition of what constitutes "a serious breach of ethics," and begin their Instructions to Authors with a section on ethics and authorship. As these guidelines illustrate, misconduct in *scientific communication* includes not only falsification and plagiarism, but also duplicate publication and questions concerning the improper allocation of credit. Related to the concern about acknowledging the work of others are scientists' concerns about allocating credit appropriately among members of the research team itself. In a standard research report, review, or grant proposal, for example, credit is allocated in three places: the list of authors, the acknowledgments, and the citations. Each of these indicates a particular relationship of scientists to the report, review, or proposal. Citations, obviously, refer to published (and occasionally unpublished) work outside the present study that create the context for the new work. Acknowledgments are expressions of appreciation for funding, support, equipment, or other contributions to the research, such as technical assistance (the help of a statistician, for example). The Ethics section of the *Gastroenterology* guidelines (Figure 3.5) stresses the value of honesty by requiring authors to sign a responsibility statement certifying that the submitted manuscript is the work of the specific authors listed, that it does not contain intentional error, and does not plagiarize the work of others.

1) Direct Plagiarism: Verbatim lifting of passage without enclosing the borrowed material in quotation marks and crediting the original author.

2) Mosaic: Borrowing the ideas and opinions from an original source and a few verbatim works or phrases without crediting the original author. …

3) Paraphrase: Restating a phrase or passage, providing the same meaning but in different form without attribution to the original author.

4) Insufficient acknowledgment: Noting the original source of only part of what is borrowed or failing to cite the source material in such a way that a reader will [not] know what is original and what is borrowed.

FIGURE 3.4 Four Types of Plagiarism. Council of Science Editors (CSE 2006, p 10).

The question of who should be listed as an author (to say nothing of in what order) can be complicated. For example, in some fields, it has become the trend to credit a large group of people for a single publication! In fact, the problem of the soaring number of authors has become so vast that a number of scientists dubbed this "author inflation" and called for reforms in the system (see Garfield 1995; McDonald 1995; Schwitters 1996). The Council of Science Editors (formerly CBE) created a task force to investigate the problem and recommend possible solutions (CBE Task Force on Authorship 2000). Many journal publishers have or are being urged to develop written policies concerning authorship and the allocation of credit (AAAS 2000; Scheetz 2000; Martinson et al. 2005), and a push has been on to make these policies more complete and uniform for publications featuring interdisciplinary collaboration, as well as for e-journals (DuMez 2000). Care in assigning responsibility in multiple authorship is evident in a note to the online version of Burkholder et al.'s 2005 *Proceedings of the National Academy of Sciences* article (the article is contained in Chapter 10; the note is reproduced in Figure 3.6).

According to Macrina (2000), "Authorship encompasses two fundamental principles: contribution and responsibility. An author must make a significant intellectual or practical contribution to the work reported in the paper. With such authorship goes the responsibility for the content of the paper" (p 59–60). The editors of the *Annals of Internal Medicine* make this point succinctly: "Authorship means accountability" (*Annals* 2002). In addition to certifying their role in the research, authors also are required to certify that they have followed appropriate standards for the ethical conduct of the research itself, as we also will discuss in the context of research proposals in Chapter 7, and they must declare any financial relationship they may have with companies whose products are involved in or affected by the research. *Gastroenterology*'s ethics guidelines in Figure 3.5 also make it clear that authors are expected to respect the journal's right to exclusive publication and copyright, thus preserving the journal's as well as the authors' claim of ownership. The prohibition against duplicate publication reflects the community's concern that all published research be original. In sum, the integrity of the journal publication process clearly depends on the integrity of individual authors.

2008 printed version of "Guidelines on ethics and authorship from *Gastroenterology* Instructions to Authors" deleted. The latest on "Ethic Standards" under "Instructions to Authors" is available for free at: https://www.gastrojournal.org/article/S0016-5085(16)34543-7/fulltext#secsectitle0165 (cited 2020 June 29).

FIGURE 3.5 Guidelines on ethics and authorship from *Gastroenterology* Instructions to Authors (*Gastroenterology* 2008).

Author contributions: J.M.B., A.S.G., P.D.M., J.M.L., K.J.C., A.J.L., H.G.M., N.J.D., S.C.C., J.W.K., and P.A.R. designed research; A.S.G., P.D.M., J.M.L., K.J.C., N.J.D., J.W.K., and S.L.M. performed research; J.W.K. contributed new reagents/analytic tools; J.M.B., A.S.G., P.D.M., J.M.L., K.J.C., A.J.L., J.S.R., H.G.M., N.J.D., S.C.C., J.W.K., and P.A.R. analyzed data; and J.M.B., A.S.G., P.D.M., J.M.L., K.J.C., A.J.L., and H.G.M. wrote the paper.

FIGURE 3.6 Author Contributions posted with the online version of Burkholder et al. (2005).

At the same time as scientists and editors grapple with the issue of the ever-larger number of authors and the proper allocation of credit, the cost of doing science rises, and research budgets for scientific projects not related to national defense shrink. The need to obtain funding and attract other researchers and students, and hence more funding, increases the pressure for individual scientists to seek publication that will advance their careers (Cohen 1995; Macrina 2000; Martinson et al. 2005). This may mean competing to publish in more prestigious journals, to work with well-known scientists, or to be the primary author of important research. These two trends—toward increased collaboration and increased competition—are often in opposition to each other (CAIRE et al. 2002). Even collaborating co-authors may find themselves in competition with each other. Until their Nobel Prize speeches, it was not well know that Marshall and Warren delayed publication for two months while they wrestled with the order of their names on a joint publication in the *Lancet*—an issue finally decided by David Sharpe, the editor of the journal, "who suggested we [Marshall and Warren] write two separate letters detailing Robin's initial findings in the first and our joint work in the second" (Marshall 2005c). Sometimes the human drive for personal recognition and the increased pressure for funding work against the "ethic of collaboration" that is at the heart of science. Some observers of the Pons and Fleischmann case described in Chapter 1 ascribe their "fall from grace" to just such a conflict (e.g., Crease and Samios 1989; Close 1992). Whether the conflict between collaboration and competition is a major contributing factor in the cold fusion debacle or not, scientists in all fields must continuously negotiate this very real tension between "the ethic of collaboration and the drive for glory" (Benditt 1995, p 1705).

EXERCISE 3.2

Read the following case study, "A Case of Plagiarism" (NAS 1995, p 18), about a student who finds she has committed plagiarism; then consider the questions that the National Academy of Sciences asks. In addition to answering these questions, think about why NAS asks these particular questions; that is, what ethical questions does NAS want you to focus on in the case? Are there some mitigating circumstances here, and if so, what are they?

> May is a second-year graduate student preparing the written portion of her qualifying exam. She incorporates whole sentences and paragraphs verbatim from several published papers. She does not use quotation marks, but the sources are suggested by statements like "(see . . . for more details)." The faculty on the qualifying exam committee note inconsistencies in the writing styles of different paragraphs of the text and check the sources, uncovering May's plagiarism.
>
> After discussion with the faculty, May's plagiarism is brought to the attention of the dean of the graduate school, whose responsibility it is to review such incidents. The graduate school regulations state that "plagiarism, that is, the failure in a dissertation, essay, or other written exercise to acknowledge ideas, research or language taken from others" is specifically prohibited. The dean expels May from the program with the stipulation that she can reapply for the next academic year.

1. Is plagiarism like this a common practice?
2. Are there circumstances that should have led to May's being forgiven for plagiarizing?
3. Should May be allowed to reapply to the program?

EXERCISE 3.3

Read the following two scenarios from Macrina (2000, p 66, 69), and prepare for class discussion your answers to the questions posed at the end of each scenario. For each case, also speculate about why events might have unfolded as they did. What are the practical and ethical ramifications of those possibilities for scientific publication?

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3.4 SCIENTIFIC COMMUNICATION AS MORAL RESPONSIBILITY

An ethical issue related to the allocation of credit is the sharing of information. If science is a social enterprise, the sharing of information becomes in effect a moral imperative for scientists. The CAIRE et al. report on "Integrity in Scientific Research" makes this clear: "Collegiality in scientific interactions, including communications and sharing resources requires that investigators report findings to the scientific community in a full, open, and timely manner" (2002, p 37). At the same time, we've just underscored the highly competitive nature of science. Thus, the drive for personal recognition that sometimes works against the ethic of collaboration also may work against the ethic of sharing. Hoshiko noted, "Competition fosters self-protection and inhibits collegiality among investigators" (1991, p 11). In addition, conflicts between the need for scientists to cooperate and the need to "protect" one's findings can be complicated by the requirements of the privacy of study participants, corporate secrecy, national security, competition between labs or universities, and even personal animosities.

The conflict between the open sharing of scientific results obtained in research universities and the proprietary nature of results obtained in industry can be particularly apparent when the researchers in science and industry are working on the same problem, as they often are (see Narin et al. 1997), or when a university study is funded by industry, and the stakes—be they scientific, social, or monetary—are high. For instance, in 2000, *Science* reported a case in which Immune Response Corporation attempted to stop the publication of an immune system booster study by James Kahn at the University of Southern California; Kahn's study indicated the company's drug was not effective in inhibiting the progression of HIV. Immune Response Corporation demanded that Kahn and his fellow researchers include the company's own data, which they claimed indicated more positive effects of the drug for a small subset of people, and that the company review revisions prior to publication. "The researchers refused" (Morton 2000, p 1063).

A significant case of competition in recent memory between public and private sectors of scientific society was the competition between the National Genome Research Institute, a federally funded project led by Dr. Francis Collins, and Celera Genomics, a public exchange corporation led by Dr. J. Craig Venter. The heated competition to be the first to map the human genome has erupted on several occasions into arguments about technique and technology, government versus corporate sponsorship, the shared public versus the competitive proprietary nature of gene data, and the ultimate "ownership" of the research—the right to profit from the human genome itself (*Science* 2000b). Eliot Marshall (2000a), a Deputy News Editor for *Science,* noted that despite their appearance together onstage for a tribute by President Bill Clinton on June 26, 2000, to celebrate a major milestone in the mapping of the human genome, the personal animosity between these two leading researchers was obvious. In 2000, *Science* waived its standard requirement that DNA data be deposited in a public database in order to publish Celera's genome research, which the journal considered of primary importance to the scientific community; as a result, the National Genome Research Institute announced it would no longer publish their results in *Science* (Schultz 2000; E. Marshall 2000b). Scientists frequently wrestle with these types of ethical decisions, for which there is often no clear answer. In fact, Jacob (2003) argues that with the dominance of industry in our society and its closer relationship to universities than ever before, scientific knowledge itself is being turned into a commercial "product," that the process of commoditization is global, and that it affects the perception and thinking of faculty and students alike (also see Rae-Dupree 2008). This argument is concretely supported by the frequent use of public science by industry to develop and patent technology (Narin et al. 1997).

Many scientists believe that generosity and openness, as opposed to competition, are in the long run rewarded in science (Cohen 1995). Nevertheless, the social ethics of science are in a constant state of tension with the individualistic ethics of science. We saw in Chapter 1 how in the case of Pons and Fleischmann, competition and the rush to publicize undercut peer review (Huizenga 1992). "The need for skeptical review of scientific results is one reason why free and open communication is so important in science," says the National Academy of Sciences (1995, p 12). But this social mechanism, designed to maintain professional standards and foster the sharing of information, can work against the individual scientist's drive for priority and credit that is a major incentive in scientific research (NAS 1995; Macrina 2000).

One source of sought-after credit is publication in the most prestigious journals. Arguments in favor of electronic publication have often pointed to the speed and openness of this medium (e.g., Harnad and Hey 1995; Smith 1997). As we discussed in Chapter 2, and as Frankel reports, "Electronic publishing presents a new and exciting prospect for science and its patrons . . . . It allows for virtually instantaneous feedback and commentary . . . . and the size of the audience it can reach efficiently expanded well beyond the readership of paper-based journals. Electronic publishing also offers more powerful and creative ways for exhibiting and illustrating research findings than is possible in print publications" (2002, p 22). One concern that emerged early in the development of e-journals was that, because of some of the advantages listed above, and the fact that they are less expensive to produce, e-journals would drive out more expensive print journals. The fear was that this trend would reduce competition, resulting in a decrease in the number of journals overall, and that electronic journals would be less likely to be peer reviewed and thus less prestigious. While increasing the sharing of information, the net effect of more open and interactive publication in e-journals would have been to undermine one of the major incentives in science: individual advancement (e.g., Butler and Wadman 1999; Hogan 1999).

However, this does not appear to have happened, at least partially because of the retention of print journal conventions. Hojat et al. (2003) argue that because most journals still do not allow the simultaneous submission of manuscripts to multiple journals, an initial screening process should be instituted on editorial boards so that manuscripts not suitable to the journal or funding agency could be filtered out and returned to authors immediately. MacKenzie Owen (2007) also notes the reproduction of paper publishing features and conventions, such as space limitations, that are carried over into electronic forums, and seems to be more skeptical about the electronic revolution in scientific publication. In fact, MacKenzie Owen argues that the e-journal in sciences actually has already failed, and has been replaced by open access sites (like arXiv.org). But many prestigious journals are embracing electronic media and publishing their journals online; as noted in Chapter 2, many if not most medical journals, for example, now produce e-publications ahead of print (see PubMed).

Even with the advent of pre-publication on the web, scientists are entitled to a "period of privacy," especially in the early stages of research (NAS 1995, p 10). But during peer review or after the conference presentation or publication, scientists have a responsibility to share results openly, honestly, and accurately. Perhaps a reflection of the electronic openness of our age, arguments for electronic publication sometimes also cite as advantages the possibility of more interaction in the pre-publication stage "in which most of the cognitive work is done" (Harnad 1990, p 342). For example, Reynolds et al. (2005, p 6), in their proposal to NASA requesting the use of the *Chandra* satellite to observe Kepler's supernova remnant, waived the one-year "proprietary data" period guaranteed by NASA's CXO Research Program (2007, p 13), which, according to the NASA call for proposals, is "customary for observations intended to benefit the general community" (Chandra X-ray Center 2007, p 43). However, unlike the generosity exhibited by the Reynolds team, pride, competitiveness, the desire for originality, the fear of being scooped, the need for professional advancement (and the research funds that go with it), the pressure for secrecy from corporations or government, and, in a few cases, the profit motive, all potentially can work against the open, interactive nature of electronic communication, just as

they work against the ethic of sharing. The complexity of these issues for scientists is best summed up in the CAIRE et al. report:

> Because science is a cumulative, interconnected, and competitive enterprise, with tensions among the various societies in which research is conducted, now more than ever researchers must balance collaboration and collegiality with competition and secrecy. (CAIRE et al. 2002, p 25.)

Ways to better handle some of these ethical conflicts—through improvements in science education, further articulation of policy by funding agencies and professional societies, instructions to authors, and more rigorous evaluation and monitoring—are continuously being developed (see Hoshiko 1991; NAS 1995; Scheetz 2000; CAIRE et al. 2002; ORI 2005; Wells 2008).

EXERCISE 3.4

Read Chiba et al. (2002) in Chapter 9. Note the affiliation of each author. Also note the acknowledgment section at the end of the report, particularly the source of the funding for this project and the statement of competing interests.

Identify possible competing interests in this report. Do you think this study is impartial? Why or why not? Is the risk of bias in research in industry similar to or different from risks in other scientific settings? What safeguards are in place to protect the research from bias in industry? Are they similar to those in place to protect research in other scientific settings? In your opinion, are these safeguards adequate?

EXERCISE 3.5

In light of this discussion of competing ethics within science, review a case of possible malfeasance in science about which you know. List the competing ethical factors in this case. Write a paragraph defending the scientists' actions; then write a paragraph criticizing them. Different groups may be assigned parts of this exercise in preparation for the kind of ethical debate scientists, science educators, and policy makers have been engaging in (Benditt 1995). Does this ethical examination of conflicts of interest in science give you a better understanding of the motives or increased sympathy for the action of the scientists? Why or why not?

3.5 ETHICAL "COSTS" OF COMMUNICATION TECHNOLOGY

As we can infer from the discussion about electronic publication above, one way scientists attempt to handle ethical conflicts and facilitate communication is through the development of new technologies. Ironically, however, these new technologies themselves may introduce further ethical complications and become a potential obstacle to scientific communication. In Chapter 2 we examined the benefits of new communication technologies in the sciences; in this section, we will examine some ethical "costs" of these technologies.

As we discussed in Chapter 2, more and more researchers have come to believe that electronic communication is making scientific information more quickly and readily available to an ever-widening community of scientists, helping them keep up with the latest advances in their fields and facilitating the interaction of researchers throughout the world while reducing the astronomical cost of paper publication (Samarajiva 1990; Odlyzko 1995; Matzat 1998; WHO 2000; Frankel 2002). Indeed, some scientists believe that electronic publication will help break down geographical or social barriers, especially for so-called developing countries, leading to a global democratization of scientific knowledge. However, the question arises: do these new

technologies also create inequities and privilege in access—recreating or exacerbating in the digital domain the tension between those with and without resources, access to libraries, equipment, and research funding?

Certainly, electronic publishing has increased availability of scientific knowledge—at least for some people. But some scholars have begun to question the assumption of access, and the myth of the electronic democracy of the Internet that grows from it. First and foremost, the new technology requires computers, access to the Internet, and increasingly sophisticated software programs and equipment. We suggested in Chapter 2 that technologies themselves can become paradigms. In a real sense, new technology is necessary to "see" the phenomenon—and to communicate it. And as paradigms, media make their own requirements and demands. For example, Moses and Katz (2006) question the "illusion of freedom" of email, arguing that the technological medium—and the technology itself—impose invisible "technical" rules and constraints (e.g., at a basic level, all emails are in memo format; email encourages an informal writing style, the use of abbreviations, and icons to convey emotions). As we suggested in Chapter 2, much as it did with traditional modes of publication, science is developing a reliance on new media to make science possible.

But new media require more than technology, and even more than money. Technologies are situated in a site of social, economic, cultural, and political forces. Investigating the "digital divide" both in the United States and abroad, DiMaggio et al. (2004) suggest that the Internet may "reproduce," or reinforce social, cultural, and economic inequities (p 38). Rather than focusing solely on the technology of the Internet as a causative agent of social change, they point to communication infrastructure as well as economic development as highly determinate. As they state, "Patterns of inequality are likely to reflect such changing factors as public connection availability, private subscription price, services available, and the technology necessary to access them effectively, as well as the diffusion of knowledge and the evolution of informal technical-support networks" (DiMaggio et al. 2004, p 39). They also report that most computers are in developed countries, and that only a fraction of the world's population has access to the Internet, though that fraction is growing. They conclude that not enough studies have been conducted on the medium to assess whether Internet use is erasing the "digital divide" (p 50).

In addition to these more obvious "costs," there are other, perhaps hidden economic and political forces in the online industry that may shape future Internet access and use in ways that work against the ideal of open access to scientific communication and knowledge. For instance, because of the shift to the World Wide Web of television and other entertainment and news media, there are plans under serious consideration—termed "inevitable" by online service providers—to impose a fee structure beyond monthly service charges based on volume of bandwidth use. The costs for this "buffet of Internet Access" for "heavy users" of the Internet (Stelter, 2008, p 1) could become increasingly prohibitive. Of course, heavy users include scientists and public alike, both in the United States and abroad. Thus, an "á la carte" menu may restrict the freer flow of science that the Internet ideally enables (Stelter 2008, p 1). In addition, "Critics of the bandwidth limits say that metering and capping network use could hold back the inevitable convergence of television, computers, and the Internet" (Stelter 2008, p 21), thus stultifying the growth of communication technology in science through the merging of technologies that we discussed in Chapter 2.

Further, various entrepreneurial attempts are underway to develop wireless web networks in which specific subscribers would share their connections with other subscribers to "allow ubiquitous, global access while traveling for business or pleasure" (Markoff 2008a, p 1). Web services like this, however, would require a redesign of the Internet, "top-down, highly structured approaches that will cost billions of dollars to build and may close a door on some of the architectural openness that led to the rapid growth of the Internet" (Markoff 2008a, p 8). Needless to say, the curtailment or elimination of the architectural openness of the Internet that has allowed it to grow unfettered could have unforeseen and perhaps deleterious effects on the development

of scientific communication, especially globally. Government regulations, as well as any kind of "postal fees" on the Internet, could have similar results.

Some "intellectual costs" of electronic publication in scientific communication may already be evident. A study by James Evans at the University of Chicago found that, despite the increasing archive of articles online, the use of the Internet in scientific research and publication may be resulting in narrower pools of citations, limited to newer publications online—"an effect that may lead to easier consensus and less active debate in academia" (Couzin 2008, p 329). It is probably too soon to determine with any certainty the effect of the Internet on scientific discovery and the process of writing.

Another cost of electronic publication in scientific communication involves the effects of digital publication on notions of copyright, ownership, and authorship, which have been central to the scientific enterprise. To begin with, contrary to popular belief, most authors do not legally own their work once it is published; when a manuscript is accepted for publication, the author usually is required to sell various "rights" to the journal. These copyrights determine legal ownership and thus distribution and reprinting of the work. They might be First American Rights, for instance, although they generally include all International Rights.[5] As we hinted at earlier in this chapter, international copyright is still governed by a seeming hodge-podge of national copyright laws, and not generally addressed in international treaties. The need to address issues of international copyright has become even more urgent not only with the advent of the "information age," but also with the explosion of electronic publication. However, the Internet has called into question the concept of copyright itself.

In an AAAS study, Frankel (2002) examines the relationship between copyright, patents, trademarks, and trade secrets, and how their relationship is changing on the Internet. For Frankel, copyright and patent laws are digitally interchanged, for instance, "when a patented process is involved in the performance of a digital work subject to copyright, or when a patent covers the methods used for accessing or structuring data" (2002). Think here not only of the publication of journal articles on the web, but also of the biology podcasts of cell division, or the scientific conference on cancer that could be attended through Second Life. As Frankel notes, "Existing copyright law governing distribution of scientific research . . . may become increasingly difficult to apply because of technological advances in methods of structuring, managing, processing, and providing access to information in various digital formats" (2002a). Of particular concern in this discussion of the "cost" of technology is that the need to protect the rights of owners of the work, and the desire to expand access to the work via digital media, are in conflict if not incompatible.

Elkin-Koren (2004) asserts that intellectual property law rather than copyright law is becoming the legal mechanism by which knowledge is produced and disseminated on the Internet. She distinguishes between two opposing models that have emerged in the law: "the traditional property rule created by centralized institutions"; and "the emerging regime of standard contracts, namely, of rules generated via private ordering" (p 252). According to Elkin-Koren, the latter concept, of private ordering, makes "access to informational products contingent on accepting terms of a license" (p 252). Indeed, a quick survey of online publications reveals that scientific information is not always free, or if it is, access is limited. Even if they are not completely subscription based, many journals are in fact governed by "private ordering": legally controlled, limited access granted, sometimes for a specified time by a standardized contract. Of course, some journals, like *The Journal of Applied Ecology,* use the Internet to release published issues after a specified time, making them then freely available online (*J. Applied Ecology* 2008).

Frankel concludes that it will be a while before copyright law catches up with scientific publication in the digital world, and that the creation, distribution, and reproduction of these publications in electronic communities blurs the distinction "between public and private rights .

[5] For a good overview of basic copyright law and procedures as it applies to scientific publication, see CSE (2006), p 21–35.

. . . The legal infrastructure emerging from the computing and telecommunications revolution creates uncertainty for scientists and other stakeholders" (2002). Indeed, electronic publication not only affects copyright, but perhaps our notion of ownership and "authorship" itself. Tharon Howard remarks: "[T]he use of online computer conferences, electronic discussion groups, hypertexts, multimedia presentations, groupware, and other computer technologies aimed at enhancing and promoting collaboration, are all seriously challenging the popular, romantic view that an author owns his or her text" (2004, p 398). The possibilities of collaboration, file-sharing, easy access, social networks, cultural "commons," instantaneous dissemination, and wide distribution that the Internet technologically enables raise conflicts concerning ownership, authorship, and costs. As with other ethical conflicts in scientific communication, there is a built-in tension here too: authors—even scientific authors—publish to make a profit (see Howard 2004, p 402). As we pointed out in Chapter 2, the same applies to publications, and the organizations that sponsor them. If they do not earn a profit, who will pay for publication? If all scientific knowledge is shared, how will scientists "own their own work"? Despite the much-vaunted death of the author, these basic economic facts driving copyright, authorship, ownership, and credit via publication since the 17th century are unlikely to change in the foreseeable future.

Many issues regarding republication and distribution on the World Wide Web are yet to be resolved. But the ethical tension that Frankel notes between public and private rights—between sharing vs. proprietary rights, for instance—seem to extend and be stretched into new dimensions by innovations in communication technology. In the digital world, the problem noted by Huizinga (in Figure 1.2) of Pons and Fleischmann's paper being faxed around the world so many times it was no longer legible is multiplied endlessly, but unlike the fax, there is no loss of clarity! The law can't keep up; but ethics must. Scientists are becoming increasingly aware of the legal, social, economic, cultural, and political costs of new communication technologies that now shape their disciplines, and of their new responsibilities. There is much hope that technology will enable easier access for developing countries; but technology alone does not initiate such outreach. Such efforts will require action on the part of scientists, and their publications and organizations. In designing websites and other access platforms, scientists have a moral obligation to become aware of and responsive to issues of different technological capabilities, and access strategies of international audiences. While English is currently the *de facto* language of science (Jaffe 2003), scientists need to work toward improving technologies by using principles of international communication popular in technical communication (see Kostelnick 1995; Perkins 1999) but not generally considered in science.

The same issues apply to adapting scientific information via technology for the disabled. New types of information (both visual and audio, static and active) as well as voice recognition and other automatic translation software are available to help scientists adhere to the Americans with Disabilities Act (ADA). But scientists also need to be aware of ADA design principles, such as those posted in the American Public Health Association's "Accessibility Guide" at http://www.apha.org/meetings/access/. As a student, it will be important for you to become familiar with digital forms of communication common in your field, but also to understand the social, political, economic, and legal implications of those forms, and to learn the attitudes of professional scientists toward them.

EXERCISE 3.6

Examine the websites of associations in your field. Are there any sets of special accommodation guidelines offered by these associations? What are the guidelines? Which associations offer these guidelines? Why? How do the special guidelines account for different audiences? How is the information changed by these accommodations? Are there any special provisions for conference

presentations or journal manuscript preparation? Without new technologies, how visible were the needs addressed in the special guidelines? How were the needs previously accommodated or addressed?

3.6 SCIENTIFIC COMMUNICATION AND PUBLIC COMMUNICATION: AN ETHICAL CONFLICT?

The ethical tension between public and private rights that Frankel notes are created by electronic publication also affects the public's need and right to know. In part because of the increasing presence of and access to science on the Internet, scientists increasingly consider the needs of general public audiences as well. We will discuss in Chapter 8 why scientists have an obligation to communicate with the public and why the public has both a need and a right to know what is going on in science. Sometimes, as perhaps in the case of Pons and Fleischmann, the need for peer review and the need or desire to share information with the public come into conflict as well. This can become an ethical dilemma for the scientist. While there are strong incentives to keep research secret until publication, some of the same factors may provide motivation to release results to the public before peer review and publication—both positive factors such as the desire to respond to urgent social need and the technological capability to communicate quickly, and negative factors such as competition, pride, and the desire for credit and fame.

Despite technological innovation and digital communication, there is also still a stigma in scientific journals attached to "reprinting" material that has already been "pre-published" in the popular press, as in the case of Pons and Fleischmann. The problem of pre-publication also applies to the Internet (sometimes including email, listservs, discussion boards, weblogs, podcasts, etc.) where information tends to be exchanged more freely. Most editors will refuse papers that have been published elsewhere. Some publishers, like the American Chemical Society (ACS 2006), will withdraw papers that have been previously pre-printed on the web.[6] In other cases, however, editors have been willing to reconsider the injunction against an early press conference or web release prior to scientific publication, or forgo the embargo against publication of a study that has been released to the press (Roy 1993), especially if the research is urgent or important enough to warrant its early release (Maddox 1989; CBE 1995).

In the announcement of the Kepler supernova remnant, the subject of Chapter 12 of this book, Reynolds et al. reported their findings in a poster presentation at the January 2007 meeting of the American Astronomical Society, and at a NASA-sponsored press conference. NASA itself released the *Chandra* photo on its website, noting the forthcoming publication of results in the *Astrophysical Journal.* According to Reynolds (2008), the timing of the announcement by NASA had nothing to do with embargos, and everything to do with juggling professional and personal variables (conference trips, NASA's launch of the Gamma Ray Large Area Space Telescope [GLAST], the schedule of NASA's graphic artist). In this instance, it was the authors who asked *The Astrophysical Journal* and the *Monthly Notices of the Royal Astronomical Society* to delay publication of the photo until after NASA published the photo; both journals published the photo on their websites the day after NASA did (Reynolds 2008). Perhaps in this case more than any other, then, we see the future effect of web technology on "pre-publication," and the increasingly complex interrelations of print and electronic publication in professional vs. public communication. In this case, peer review of the importance of the research took place *prior* to publication; often the vetting by the field does not take place until after publication in professional journals—too late for the unfortunate scientists who have released their results too soon, or the public that is misinformed and confused. As with most ethical issues, tension exists

[6] Cited 2008 June 21; the ethical guidelines for the American Chemical Society are available at http://pubs.acs.org/ethics/index.html.

in scientific communication—in this case, between the obligation to monitor itself and the obligation to inform society.

It is not only the system of scientific checks and balances or the injunction against prior publication that prevents scientists from communicating with the public. Sometimes interaction with the public is impeded by the requirement of political or corporate secrecy. This sets up another ethical dilemma. The conflict between the need for secrecy in science and the public's right to know is not unlike the (unresolvable?) legal conflict over the need for national security versus the First Amendment right of free speech (e.g., former government officials are prevented from publishing what they know about classified government activity—even illegal activity—until the information has passed through government review). In fact, questions concerning secrecy versus the public's right to know have become further complicated and particularly acute following the 2001 terrorist attack on the U.S. mainland. Research, especially in sciences and technologies related to the development and/or detection of nuclear, chemical, or biological weapons, and those connected with surveillance, is perhaps more tightly interwoven with national security and thus secrecy than ever before—so much so that the lack of cooperation and coordination even among the government agencies can compromise communication with the public during times of emergency (see Helsoot 2005). Scientists working on projects involving "homeland security," whose purpose it is to coordinate different agencies, are legally bound to secrecy.

But at the same time scientists realize that good science requires open science, and open science is international. Neal Lane, Assistant to President George W. Bush for Science and Technology and Director of the Office of Science and Technology Policy, suggested that to balance these conflicting needs, the federal government must trust scientists themselves to handle and maintain security (Lane 2001). Sometimes, scientific and other information is kept from the public for legitimate security reasons. But sometimes information is kept from the public for reasons other than legitimate ones. The problem is, how do we, the public, know? Politicians have been known to "spin" or distort the data of a scientific study, or even to change it, for economic or political purposes. In at least some of these cases, the press has uncovered government misconduct and has reported it.

This conflict has taken on a new dimension in the debate over global climate change. In 1989, Philip Shabecoff (1989) revealed that the White House's Office of Management and Budget (OMB) under President George H. W. Bush had changed the text of a scientific report on global warming, which was to be delivered to the Senate subcommittee on Science, Technology, and Space by the director of NASA's Goddard Institute for Space Studies. The wording and conclusion of the report were substantially altered to soften projections and thus justify the administration's tempered approach to international policy on the greenhouse effect. What outraged scientists and congressional members was that the OMB, a political office, not only misrepresented a scientist's conclusions, but actually tampered with his words. As widely reported in the press, the section of the 2003 Environmental Protection Agency report identifying global warming as a threat was completely deleted after the administration of President George W. Bush removed and/or changed the language of the study by the National Academy of Sciences (see Sierra Club 2003). Even after a dire United Nations report (Rosenthal 2007), the political debate over global climate change continues. As can be seen in the Chapter 13 documents, the connection between Hurricane Katrina and global climate change is a point of contention as well. It is clear, as Ziman succinctly states, that "The debate over climate change . . . is now so deeply implanted in the womb of politics that it cannot really avoid developing in conformity to the principles of that social environment, rather than those of the scientific world where it was conceived" (Ziman 2000, p 188).

The requirement of secrecy can raise serious ethical and political questions about the power to control scientific information. On what grounds should information be kept from the public? What kind of information should be kept from the public, and under what circumstances? Perhaps

most important, who in a democracy will make these decisions? Scientific experts? The government? The Pentagon? The CIA? Executives of corporations? Average citizens? The press? Finally, how will these decisions be made? How much does the public need to know to make these decisions, and how can security simultaneously be maintained? To whom does the scientist ultimately owe allegiance? These are all vexing questions in our democratic society, and there are no clear answers.

Unfortunately, history also contains some extreme cases where those in power have used science for immoral ends. Katz (1992b, 1993) has examined what can happen when political, economic, or corporate expediency is allowed to subvert the interests of science: he argues that when "the ethic of expediency" becomes the only goal of science or technology—becomes the value in science that overrides all other human values, as it did in Nazi Germany (or the former Soviet Union)—scientific communication can become an ethical weapon that can be used by the unscrupulous *against* society. As the National Academy of Sciences points out, the result is invariably a deterioration of science itself (see NAS 1995, p 7). The painfully ambiguous situation of the atomic physicist Werner Heisenberg, who elected to remain in Germany during the Nazi years to protect science from Hitler, Heisenberg argued,[7] is poignantly illustrated in the play *Copenhagen* (Frayn 2000), an exploration of the enormous ethical and human dilemmas that this scientist faced in his lifetime.

Fortunately, most of us probably never will have to face such extreme ethical situations. But in cases involving governmental or corporate misconduct, the scientist may be called upon to communicate in another way: to "blow the whistle." This presents another ethical dilemma in scientific communication. Scientists are often hesitant to act because of uncertainty about the appearance of wrongdoing, or from fear of reprisal. But according to the National Academy of Sciences, "someone who has witnessed misconduct [in science] has an unmistakable obligation to act" (1995, p 18). One of the major conclusions of the Gallup study conducted for ORI is that "the most effective way to increase the probability that suspected research misconduct would be reported is by providing protection for whistle-blowers and permitting anonymous allegations" (Wells 2008, p 43–44). *How* to act is often a pressing question. When do you "tell," and whom? Scientists may wish to seek advice from friends, colleagues, or supervisors before they act (see NAS 1995). Aside from the employees at Enron and World.com, a spectacular example of whistleblowing has been the allegations in the media by former top scientists of tobacco companies that their employers, contrary to their sworn statements, studied the addictive process of nicotine and deliberately manipulated its levels in cigarettes. Although whistleblowing has been most often associated with private industry, events related to the flawed federal response to Hurricane Katrina itself, as well as the issue of climate change, show that the issue is present in the government as well. Science exists in a political landscape. No matter what your politics are, the world has become an ethically complex place. As CAIRE et al.'s report on research integrity demonstrates, it is not only the scientific domain, but also the political world that scientists must now negotiate as a part of their normal environment (CAIRE et al. 2002; cf. Martinson et al. 2005).

EXERCISE 3.7

The following case study is from the Report from the 1994 Annual Meeting of the Council of Biology Editors (CBE 1995, p 14), at which editors of scientific publications were asked to respond to different scenarios concerning the "pre-publication release of information." This two-part scenario was addressed to Richard Horton, editor of the *Lancet.* What are the ethical issues

[7] See Heisenberg 1971, esp. p 165–179.

involved? What information do you need in order to make a decision? How do you think Horton responded to each scenario, and why?

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EXERCISE 3.8

Can you think of other scientists in history who have had to make momentous ethical decisions? Name them, identify the circumstances and issues they faced, and describe the possible consequences of their options and action. Outline the ethical guidelines they seemed to follow in making their decision(s). What can we learn about the relationship between science, ethics, and life from these extraordinary cases?

EXERCISE 3.9

Find out whether there are specific policies, safeguards, and procedures for communicating ethical violations in your department, lab, university, or discipline. What kinds of ethical misconduct are covered by these policies? Note any specifics about the procedure, such as to whom you are to communicate misconduct, time periods for reporting, protection from reprisals, processes of adjudicating charges, and results of possible outcomes. In your opinion, are these policies, safeguards, and procedures adequate? Why or why not?

3.7 SCIENTIFIC STYLE AND SOCIAL RESPONSIBILITY: A TWO-WAY CHANNEL

Throughout this book we will explore how scientific knowledge is constructed in and through the social process of communication. Because scientific knowledge is a social construction, scientists have a social and moral responsibility for the knowledge they create. In the traditional view of science as a dispassionate description of truth, scientists did not have a responsibility for their discoveries: what they discovered was simply "there"; the job of the scientist was to objectively observe and report the "facts." In the traditional view of science, it is up to others in society to decide how to use science and how to deal with the consequences of the "facts" discovered by scientists. Facts are not simply there but are construed by scientists based on the paradigms and values within which scientists work. In *Science and Human Values* (1965), Jacob Bronowski, chemist and man of letters, argued that scientific "facts" are concepts that organize appearances into laws. Thus, for Bronowski, science and ethics are not different because both are "systems of concepts" that are tested in experience (p 40). "When judgment is recognized as a scientific tool, it is easier to see how science can be influenced by values," says the National Academy of Sciences; "values cannot—and should not—be separated from science. The desire to do good work is a human value. So is the conviction that standards of honesty and objectivity need to be maintained" (1995, p 6). Both the desire and value of good work is evident in the history of Dr. Marshall's clinical work on peptic ulcer disease (see Chapter 9, especially his Nobel Prize lecture, which can be listened to and viewed through the link in the Additional Resources).

In the contemporary view of science, scientists participate in the construction of "reality" through the process of communication (Brummett 1976; NAS 1989; Ziman 2000). Whether it be an idea, a theory, an observation, a measurement, a method, a discovery, an invention, or an experiment, scientists help shape the beliefs and concepts of a culture and so bear responsibility for those beliefs and concepts. Throughout this book we will explore how argumentation and persuasion are integral to the construction of scientific knowledge. Thus, scientists also have a

moral obligation to create and use scientific arguments responsibly, by employing theories, methods, logic, and data acceptable in the field as well as to society at large (CAIRE et al. 2002).

In constructing responsible arguments, we need to carefully consider not only *what* we say but *how* we say it, for style has an ethical dimension as well. Take the traditional use of passive voice in science as a case in point. Passive voice has the effect of de-emphasizing the individual scientist or lab in favor of an *ethos* of neutrality and objectivity. Thus, the sentence "We collected the samples" becomes "The samples were collected" in passive construction. The effect of this style is that the agent, the human being conducting the experiment, is no longer apparent. This is not usually a problem. As we will discuss in Chapter 4, for example, the AIP Style Manual (1990) recommends the use of passive voice in some method descriptions where the agent is not important. Passive voice is used conventionally in many forums; using it appropriately is part of learning how to speak as a professional scientist. But the use of passive voice can become an ethical problem when it is used to hide responsibility, as sometimes happens when information is released to the public: "In the 1960s, the CIA tested LSD on civilians" can become "In the 1960s, LSD was tested on civilians."

In Chapter 8 we will touch on the fact that miscommunication played decisive roles in the *Challenger* explosion, in the disarray that followed the Three Mile Island meltdown, in failed attempts to site radioactive waste facilities around the country, and in the Katrina debacle; in that chapter our focus will be on scientists' ability to understand and appeal to audiences outside their discipline. Here our focus is on the ethical role of style in these catastrophes; *how* something is said can become as much of an issue as what is said in scientific and technological accidents. On January 28, 1986, as a horrified nation watched the space shuttle *Challenger* explode, NASA's media spokesperson announced: "A major malfunction has occurred." Many found the *ethos* of objectivity, of nonresponsibility, of calm scientific detachment—created by abstraction and jargon—inappropriate if not offensive because it ran counter to the way people actually felt; the perception was reinforced when this style was continued by NASA officials in press conferences throughout the day (Havelock 1986), creating an impression of callousness that was difficult for NASA to overcome. NASA did not make this public relations mistake again when in February 2003 the *Columbia* disintegrated minutes before landing. Where public health, safety, and/or trust are at stake, and the accountability of science is put to the test, scientists must recognize and take pains to avoid even the appearance of evasiveness that can be created by style. A quick look at NASA's website (Additional Resources, Chapter 12) reveals that they have learned to communicate with the public well.

This issue of how one says things, style, applies not only to verbal, but also to visual communication. In *Visual Explanations,* Edward Tufte (1997) argues that the Challenger explosion was at least in part due to the improper visual display of data on O-ring performance—to Tufte akin to concealing information. The same content visually presently differently can have a drastically different meaning. Tufte suggests that if NASA scientists had used their tables to demonstrate causality, rather than just a glut of data, the outcome of the meeting between the engineers and NASA officials might have been quite different. In fact, most people consider tables and graphs as windowpanes that provide a clear, objective outlook onto the world. Bolter and Gromala (2005) argue that this view is a result of the "myth of transparency." The simplicity and falsity of this view of visual communication is exposed not only by tragic historical events such as the *Challenger* explosion, but also by different interpretations reflecting changing attitudes over time of visual "texts" presented in digital media (see Wysocki 2004).

The use of scientific style by others in society, like the use of scientific findings, also can create an ethical problem for scientists. Public officials may not have adequate knowledge of the science; they also may not have complete control of their style, as Katz (2001) demonstrates in an analysis of a speech given by former Secretary of Agriculture Dan Glickman. At a press conference about the benefits of biotechnology, Glickman's language was full of hidden negative words and metaphors. For example, he referred to recent developments in biotechnology as "the

tip of the biotechnology iceberg" (Glickman 1999, paragraph 7). After the sinking of the Titanic, the iceberg metaphor is problematic, hinting that bigger problems lie beneath the surface; these kinds of stylistic choices create a negative tone that permeates much of the speech and undercuts Glickman's intended message, further complicating the relationship between biotech scientists and the public.

The scientific jargon sometimes used by government officials to support *political* positions also can create an *ethos* of scientific objectivity while obfuscating meaning, as in the following example: "Understanding the role natural site features play as part of an integrated system in protecting public health and safety is an important part of the comprehensive site assessment activities" (North Carolina Low-Level Radioactive Waste Management Authority 1996, p 1). What does this sentence really say? What is meant by "natural site feature"? How does it "play as part of an integrated system in protecting public health and safety"? What are "comprehensive site assessment activities"? These abstract words and noun compounds strung together as official terminology into a positive sounding sentence may seem scientific and impressive but actually are an exhibition of a false *ethos* of objectivity created by an inflated and vacuous style. We will discuss such abstraction in public communication further in Chapter 8.

The *ethos* of science also is used by advertisers to sell products ("9 out of 10 doctors recommend . . . "), a point that CAIRE et al. optimistically cites as one indication of the public's positive attitude toward science (CAIRE et al. 2002) but that Macrina points to as a problematic perception of science as infallible (2000). The use of the *ethos* of objectivity created by such devices as passive voice, abstraction, jargon, and "context-free" statistics helps foster a false public image of scientists as omniscient and infallible. The National Academy of Sciences warns scientists not to set science up as a form of knowledge superior to other forms of knowledge (1995). But the *ethos* of science created *by others* can raise some unforeseen social and political consequences for scientists as well.

As we will explore in Chapter 4, scientists understand (and indicate with the use of qualifiers) that scientific knowledge is always open-ended, uncertain, and subject to change. "Scientists recognize that this is how science normally works, but in general, people outside of science do not have this same understanding," says Macrina (2000, p 3). Because the public expects scientists to always be right and scientific knowledge to be absolute, public audiences often become frustrated and confused when scientists qualify their claims or when scientists disagree. In such cases, the public often reverts back to their own beliefs and previous convictions (Nelkin 1975; 1979). As the National Academy of Sciences points out,

> Many people harbor misconceptions about the nature and aims of science. They believe it to be a cold, impersonal search for truth devoid of human values. Scientists know these misconceptions are mistaken, but the misconceptions can be damaging. They can influence the way scientists are treated by others, discourage young people from pursuing interests in science, and, at worst, distort the science-based decisions that must be made in a technological society. Scientists must work to counter these feelings. (NAS 1989, p 20)

The traditional image of science as objective and absolute can be misleading and can engender a false faith in science. Although most scientists hold more temperate views concerning the certainty of the results of their work, they must realize how their work is perceived and interpreted by others in society, and must take responsibility for correcting misperceptions. As the National Academy of Sciences states, "concern and involvement with the broader uses of scientific knowledge are essential if scientists are to retain the public's trust" (1995, p 21). For instance, Stephen Zehr, exploring the accommodation of science in the popular press, discusses the issue of uncertainty in the public's perception of global climate change. For Zehr, the public's perception of the lack of certainty in meteorological research can be used to propel arguments

supporting or dismissing global climate change (Zehr 2000). The proliferation of scientific information in the public domain raises "issues of translation and recontextualization," as Bazerman et al. suggest (2003, p 474). So too, the image of scientists as lone geniuses devalues the collective sharing and extending of science, and potentially breeds cynicism about the scientific community and its social mechanisms (see Charney 2003).

Some discussions of popularizing science raise concerns about the mediating effects of "biographical and other social accounts of the research" (Faber 2006; also see Charney 2003); others, however, see professional and popular discourses as alternative or competing interpretations, not as issues of translation or distortions of professional discourse (e.g., Myers 2003; also see Fahnestock 1986). Many factors go into the public's perception of science including this identification with socio-economic classes (Wynne 1992) and intellectual and political contexts outside science (Ziman 2000).

Communication technology, particularly the Internet, also increases the interactivity between scientist and public. One question raised by the ubiquity of electronic communication is whether the increased presence of both scientists and public in the virtual world, noted in Chapter 2, will lead to a decrease in the public's "misperception" of scientists and science (level of certainty, lack of affect, importance of values) and scientists' misperceptions about the public (their different knowledge bases, the importance of emotions, and the power of values) (see Katz 2008). As already noted, one consequence of these new technological avenues of communication is that the scientist-authors need a broader set of communication skills to cope in different contexts (Ziman 2000).

But in becoming potentially less distanced and removed, the scientist-author relationship to the general reader-community is changing not only the definition and value of expertise, but also the role and responsibilities of the public as readers of science. General readers have many more sources and types of information available to them. While technology may seem to relieve readers of the responsibility of searching for information by making it easier than ever, they actually have more, not less, responsibility to assess the validity of information. Perhaps one of the implications of Miller and Shepherd's (2004) examination of blogs as a medium that merges private and public life is that emerging Internet genres may have built-in features that enhance their potential value as vehicles of social trust. These effects also may be created by security measures, connections to reputable associations, etc. However, the sheer volume and the variety of sources can be understood to make knowledge even less certain and creates a moral imperative for the public reader to assess the credibility of sources in order to decide how to judge the information, how to weigh competing claims, how to interpret the results, etc. In effect, by creating online communities and inviting the public to join the discussion, technology renders readers "authors" as well. The website of the American Cancer Society (2008), "the nationwide community-based voluntary health organization," perhaps best illustrates one of the new roles for the public in science, stating "[i]t's not about us, it's about you! Your stories. Your experiences. While we have experts researching causes and potential cures, you're the real expert on your own experience. And we want to learn from you—so upload your story today" (www.sharinghope.tv 2008).

In fact, the sharp distinction between popular and scholarly sources is becoming harder to make or maintain because of the merging of communication and social venues, and the similarity of media and thus strategies for communicating with colleagues and with the public. As scientists start communicating with each other via new media (e.g., YouTube), they increasingly use adaptation techniques similar to those used for public audiences. (We will discuss these techniques further in Chapter 8.) The general reader also instantly becomes a part of a community by virtue of visiting a site, and via instant messaging, blogs, and chatrooms, is inundated with reactions and responses from others in the audience. But will the broader access to scientific knowledge and conversation through new technologies make a difference in the perception of science, or the public's ability to comprehend? Do chatrooms and blogs and other technological

forms of communication afford adequate time and space for the public to interpret independently, or does it lead to groupthink? It remains to be seen what the effect of the new technologies will be.

EXERCISE 3.10

A. Nelkin (1979) discusses a case in which the California state legislature, deliberating about the safety of nuclear power, abandoned their attempt to seek the advice of experts after hearing 120 of them argue about the issue, deciding instead to rely on the opinion of the voters. How can scientists who disagree help avoid this response from the public and its official representatives? How should scientists disagree with each other? How should they explain their differences to the public? Make a list of the ways scientists could help avoid this kind of response from the public. Be sure to consider issues of communication and style.

B. In his book *Scientific Integrity,* Francis Macrina states: "Disagreements, errors, and new interpretations of results are sometimes reported to the public by the media. It is easy for such reporting to be misinterpreted. The debate about emerging or evolving scientific knowledge can be seen as confusion or interpreted as accusation. This may even cause some to question the integrity of science" (2000, p 3). Find a particular example of such misinterpretation in your field caused by a report in the media. How should scientists respond to the confusion created by the media? Can they do so in a way that won't create more conflict, misinterpretation, or confusion when it is reported? Should scientists respond to the press? Should they deal with the media differently in the future? Make a list of possible approaches and/or responses. In groups or as a class, discuss the pros and cons of each approach.

3.8 THE ETHICS OF STYLE AS SOCIALIZATION

There is another ethical dimension of style that you should be aware of, one that affects you personally as a new member of a scientific community. Because science is a social enterprise, governed by both explicit and tacit conventions, there is enormous pressure for new members of the field to abide by those conventions. In the following chapters, you will study the genres, principles, and conventions of communication used by scientists in your field. In learning these genres, principles, and conventions, you are engaged in a process of socialization.

We all conform to some set of values; and as the National Academy of Sciences implies, the values of science have produced an unprecedented period of scientific progress (1995). Conformity also facilitates communication; by adhering to conventions, writers and speakers in a community fulfill the expectations of readers and listeners in the community. In Chapter 4 you will see how conforming to standard disciplinary forms for scientific papers facilitates communication: by adhering to structural conventions, researchers place information where it is expected and thus make information more accessible and the structure of the overall argument more familiar and easier to follow. Demonstrating familiarity with conventions may also make researchers more credible in their scientific communities.

By the same token, however, conformity by its very nature constrains individuality, creativity, originality, and personal style. In adhering to these conventions, the engaged scientist does not necessarily say only what the community expects to hear, but does need to *acknowledge* what the community expects to hear when attempting to introduce new ideas (see Ziman 2000). Conventions exist for a reason, but we need to maintain an awareness of the rhetorical role of convention in science and the fact that conventions continually evolve. The use of active voice

and first-person pronouns in some fields—the recognition of the personal voice and *ethos* of the researcher(s) in a formal scientific text—is a profound shift in the social conventions of those fields. So too is the greater informality of email and the Internet in scientific communication and research.

We also should point out the possible consequences of violating the conventions of your field. As shown in the cases of Barry Marshall and of Pons and Fleischmann, failure to conform to the stylistic expectations of the field can result in difficulty being heard. In the long run, Marshall's case demonstrates that it is possible even for nonconformists to be heard and ultimately to influence the community's "language"—but only if the individual engages in free and open inquiry with the community, which Pons and Fleischmann apparently did not.

The ethical issue of style as socialization raises another question. Samson (2006) talks about the need for scientists to communicate with the public. However, in some quarters, in some fields, there exists professional pressure not to do so. Sometimes the efforts of scientists to communicate with the public damage their professional standing. Astronomer Carl Sagan was ridiculed and ostracized by some in his field after his television series and book, *Cosmos*. Some astronomers felt that his demeanor pandered to the public, debased the field of astronomy, and tarnished their image. Other scientists, such as Linus Pauling and B. F. Skinner, also have come in for criticism by their peers for statements made in public (Wilkes 1990). Johnson (2007) reports that Nobel Prize winning–scientists also can make what seem like some foolish statements—that life on earth may be part of an alien experiment (geneticist Francis Crick, co-discoverer of the double-helix), that Africans were not as intelligent as whites (geneticist James Watson, the other co-discover of the double helix), and that HIV was not the cause of AIDS (Kary Mullis, 1993 Nobel Prize in Chemistry) (p 5).

Wilkes (1990) suggests that as long as scientists talk about their own field instead of presenting themselves as general authorities, they'll be on safe ground. Johnson (2007) also suggests that scientists seem to get into trouble when they speak on topics outside their field of expertise.[8] But there are many examples of scientists from a variety of fields who have been able to write for a popular audience without damaging their professional *ethos*. The case of Carl Sagan, when contrasted with that of Jacob Bronowski, suggests that the answer may be more a matter of style than of subject matter. In his book and television program, Carl Sagan *was* talking about his own field! Jacob Bronowski, on the other hand, was a chemist who had a successful book and television series on Western civilization, *The Ascent of Man,* and remained well regarded by his professional colleagues. In this case, at least, the difference in the reception of their "popularizations" by their respective fields apparently was not related to whether they talked about their own field. Rather, Sagan was criticized more for his "gee whiz" style—for his Mr. Wizard *ethos*—than for the scientific content of his presentations. Jacob Bronowski, on the other hand, was praised for his dignified style of presentation, although he spoke on subjects outside the field of chemistry.

The barrier between expert and public realm appears to be further breaking down with the increasing use of new media by scientists, who appear in television interviews, newscasts, documentaries, and special programs; create podcasts, post websites and blogs; and appear on social networks like Facebook or in chatrooms. For example, Brian Greene, a noted physicist, works hard to build public interest in science. Greene is a regular contributor to *The New York Times* and the founder of the World Science Festival in New York City (e.g., Greene 2008; Overbye 2008). Medical practitioners, such as Dr. Sanjay Gupta, whose "skill in combining clinical explanations with enthusiasm for his subject matter immediately established his

[8] The pharmaceutical company Pfizer withdrew its highly successful direct-to-consumer advertisement featuring testimonial on Lipitor by Robert Jarvik, the inventor of the artificial heart, because of the controversy concerning a Congressional investigation into his lack of medical credentials to prescribe medication (see Bazell 2007; Pfizer 2008).

credibility as a clinical commentator" (Dinolfo 2008, p 192), also are successfully negotiating the digital terrain between professionalism and public spokesperson. NASA too is reaching out to the public in style with their Kids' Club, video archives, and live broadcasts from outer space on NASA TV (see http://www.nasa.gov/home/index.html).

While it's important to adapt your style to appeal to audience interests, moderation may be the key. But this is a complex issue. Both Albert Einstein and J. Robert Oppenheimer became outspoken advocates of world peace; but while Einstein was praised, Oppenheimer was destroyed by the politics of the Cold War. Thus, context—the time and place and politics in which scientists live—as well as style, undoubtedly play a role in the professional reception of public pronouncements by peers. And as the case of Heisenberg illustrates, it is not only or even the professional reputation that may suffer: as a citizen of a German nation occupying Denmark, Heisenberg lost the personal friendship of his father figure and mentor, Neils Bohr, who was Danish and half-Jewish.

Scientists must balance the need and desire to address the public with the need and desire to establish and maintain a successful career as a professional scientist. The taboo against communicating with the public has begun lessening, thanks in no small measure to the National Academy of Sciences (NAS 1989; 1995), as well as the American Association for the Advancement of Science (AAAS 2008c), which have pointed out the importance of the public to science itself. IRBs also stress the ethical obligations to communicate completely and openly with patients, and to respect confidentiality and the patient's right to privacy. Other organizations, such as the National Research Council (administered by NAS) and the National Academy of Engineering, help foster a climate of communication and cooperation across social and professional boundaries by gathering scientists and leaders from all parts of society to address scientific issues and give advice to the government and the public.

Science is a social institution. As such, new scientists will want to learn the conventions their research communities have established. Those conventions also constitute a system of ethics in your field, and behaving according to those ethics constitutes a process of socialization and increasing conformity. Socialization and conformity do not necessarily preclude individuality, as the Marshall case illustrates; but the process of joining a community has both moral obligations and moral implications. The scientist who recognizes the ethical dimension of these conventions will be in a better position to understand not only what is expected of her or him as a professional but also how to act in conflicting or difficult situations. Equally important, scientists who are aware of the conventions governing their fields and the assumptions underlying them are better able to work for change in their community's professional practices—to modify conventions that have become outmoded and no longer reflect or serve the interests and values of scientists, science, or society.

Activities and Assignments

1. For a class discussion or a short paper, go to the Department of Health and Human Services's Office of Research Integrity (2002) website at http://ori.dhhs.gov/misconduct/cases//; this URL should take you directly to "Handling Misconduct-Case Studies." Click on and read one or more of the case summaries of scientists who, after investigations by their institutions and the Office on Research Integrity, have been found guilty of scientific misconduct. Then answer the following questions.
   - **a.** According to the final findings, what acts of misconduct are the scientists guilty of? List the ethical criteria and conflicts involved. How did ORI classify these acts (i.e., falsification, fabrication, and/or plagiarism)? What are the communication dimensions of the misconduct? What were the immediate consequences of the misconduct for the research problem, the researcher's co-authors and colleagues, the publications and funding agencies, the public, the field? What were the administrative actions of ORI (i.e., the penalty for the misconduct)? What is the communication dimension of the penalty?

b. Do you think the final finding was fair? Do you think the penalty was too strict or too lenient? What scientific conventions are guiding ORI's decisions? (You can write a paragraph or two on each side of the issue or debate it in small groups or with your class.) What are the short-term effects on the career of the scientist(s) found guilty of scientific misconduct? Do you think there will be any long-term effects on the career of the scientist(s)? If so, what might they be? What do you learn from the case(s) about the ethics of communication in science?

2. Choose one of the ethical dilemmas described in this book or a case you know from your own field. Read about it, and plan a presentation for your class. What issues were involved? How were they handled? Were they solved by the institution, the discipline, or the government? What was the outcome? Was it satisfactory?

3. Watch an ad on television or online that seems to involve the testimony of scientists or health practitioners. Is an *ethos* of objectivity being created by advertisers for the purposes of selling products? If so, how? Do you feel it is appealing? Accurate? Ethical? On what do you base your answer? Can commercials be accurate and still appeal to their viewers' needs, interests, and values? How would you change this commercial to balance these conflicting needs?

PART 2

Exploring Conventions of Scientific Communication

CHAPTER

4

Reading and Writing Research Reports

4.1 RESEARCH JOURNALS AND THEIR READERS

An important first step for any new researcher is to become familiar with the primary journals in the field, for as we've discussed, these professional publications represent the principal medium through which individual scientists share their theories and results with others in the scientific community. The easiest way to identify the essential journals in your field is to notice those around you. Start by paying attention to what other researchers—your professors, teaching assistants, other students—are reading. When you are assigned research articles to read in your classes, take time to notice where and when the papers were published, what institutions the researchers represent, and what granting agencies provided funding for the research. Identifying the professional associations or institutions that sponsor the journals will help you understand who reads them. Most journals are quite explicit about their audiences and goals, posting editorial goals and guidelines on their websites and publishing them in their print issues as well (in every issue or in one issue annually). For example, dozens of journals are published in the field of physics, each intended for a specific segment of the physics community. The American Physical Society (APS) publishes seven *Physical Review* journals, reporting research in subfields such as atomic, molecular, and optical physics (*Physical Review A*) and nuclear physics (*Physical Review C*). The APS also publishes the prominent *Physical Review Letters*, "providing rapid publication of short reports of significant fundamental research in all fields of physics" (http://publish.aps.org/about). Beyond the needs of researchers, the *American Journal of Physics*, published by the American Association of Physics Teachers, addresses "the instructional and cultural aspects of physical science" (http://scitation.aip.org/ajp/masthead.jsp), and *Physics Today* (www.physicstoday.org) is a semi-popular magazine intended for a broader readership as well as for professional physicists. As in other areas of science, publications in physics have evolved to support the informational

needs of researchers, educators, hobbyists, and others interested in the subject matter of physics and in the advancement of this area of science.

To stay active in a research field or interdisciplinary area, then, scientists need to be aware of the purposes and intended audiences of the journals published in that area. This knowledge helps them decide which journals they will want to find time to read (of the thousands in publication); and, equally important, it helps them decide where they should submit their own work for publication. Choosing an appropriate journal is a critical step in the publication of a scientific paper, for the ultimate influence of a paper in the scientific community may be significantly determined by the journal in which it appears. In science as in other domains, the amount of attention an announcement receives is to some extent determined by the context in which it appears, that is, by where, when, how, and to whom the announcement is made (Miller 1992). A researcher's decision about where to submit his or her paper ultimately determines who will have access to the work.

As a case in point, Chapter 10 includes reports of a research project headed by Dr. JoAnn Burkholder, an aquatic botanist at North Carolina State University. In 1988, Burkholder's team discovered a new genus of algae, a "predatory" dinoflagellate that kills fish by releasing a lethal neurotoxin into the water. In a series of studies over the next few years, Burkholder and her colleagues determined that the alga was responsible for massive fish kills in estuaries along the southeastern coast of the United States and was very likely associated with fish kills in other regions as well. The striking nature of the finding (this was the first known instance of predatory behavior among such organisms), along with its potential international ramifications, warranted submission of the results to the British journal *Nature*, which has a broad, interdisciplinary, and international readership. Published in *Nature* in 1992, this first major paper from the project announced the discovery of the new organism, described its behavior, and briefly listed related fish kills that had been observed. In contrast, subsequent papers focused more narrowly on the results of individual studies of the organism in the lab and in particular estuarine locations. For these later reports, the researchers targeted more specialized audiences within the marine ecology community, publishing in such forums as the *Journal of Plankton Research* and the *Marine Ecology Progress Series*.

EXERCISE 4.1

Visit the websites, or obtain hard copy of three prominent journals or magazines in your research field.[1] Browse these sites or print texts to determine the purposes and intended audiences of each of these publications. Look for the publisher's description of each journal, typically found in the masthead section inside the front cover or under an "About" tab at the journal's homepage. Also peruse the editorial guidelines provided. How do these publications differ? What needs or interests in the research or broader community does each journal address? As you envision your own future as a scientist, which of these publications would you be most likely to read or to publish in? How would the articles you read in, or write for, these publications differ?

4.2 ARGUMENTATION IN SCIENCE

Given the critical role of the research report in the development and exchange of scientific knowledge, it is important to understand its distinctive features and the common strategies scientists use in writing and reading these documents. Research reports in scientific journals are variously referred to as *journal articles, papers*, or *reports*. In this text, we use these terms interchangeably to designate the class of texts reporting original results or theoretical developments in professional research journals. Our purpose in this chapter is to describe some

of the general conventions research reports follow and to help you analyze the specific conventions governing reports in your field.

The communication of research results is far from straightforward. It is traditional to think of scientific reports as purely factual or explanatory, but as we saw in Chapter 1, the report also serves an important interpretive and persuasive function. Scientists publish descriptions of their research not simply to tell others what they've done but also to persuade readers that the work is valid and useful. In terms of form, then, the research report is more than a narrative; it is a careful argument. The authors of a research report find themselves in the position of building a case for their research, not simply recounting actions and observations.

From this perspective, the research report represents an extended argument in which researchers seek to convince readers that their research questions are important, their methods were sensibly chosen and carefully carried out, their interpretations of their findings are sound, and their work represents a valid contribution to the developing knowledge of the field. These basic goals are clearly reflected in a common research report format, which consists of four standard parts or sections: introduction, methods, results, discussion. Each section of the report contains an argument, and each section plays a part in supporting the larger argument of the whole.[2] This structure, sometimes referred to as the *IMRAD* format, is the dominant pattern in modern science journals (Gross et al. 2002; Mackenzie Owen 2007). It is codified in editorial guidelines and science writing guides (Olsen and Huckin 1991; M. Katz 2006; Day and Gastel 2006) and is frequently introduced to students via various forms of the lab report in college courses (Carter, Ferzli, and Wiebe 2004; LabWrite 2004; Lerner 2007).[3] The basic elements of the IMRAD form are summarized by the Council of Science Editors (CSE 2006) in Figure 4.1.

Sections of a Research Report: Typical Headings and Functions

Headings for sections	Function of section; comments
Introduction	Describes the state of knowledge that gave rise to the question examined by, or the hypothesis posed for, the research. States the question (not necessarily as an explicit question) or hypothesis. A review of existing literature also may be found in the introduction.
Methods and Materials	Describes the research design, the methods and materials used in the research (subjects, their selection, equipment, laboratory or field procedures), and how the findings were analyzed. Various disciplines have highly specific needs for such descriptions, and journals should specify what they expect to find in a methods section.
Results	Findings in the described research. Tables and figures supporting the text.
Discussion	Brief summary of the decisive findings and tentative conclusions. Examination of other evidence supporting or contradicting the tentative conclusions. Final answer. Consideration of generalizability of the answer. Implications for further research.
References	Sources of documents relevant to elements of the argument and describing methods and materials used.

FIGURE 4.1 Sections of a research report as described by the Council of Science Editors (CSE 2006, p 464).

As the descriptions of these sections indicate, the IMRAD format consists of two sections in which the new study is actually described (methods and results), framed by two sections that place the new work in the context of previous knowledge (introduction and discussion). Both of

these "framing" sections describe the current state of the field's knowledge. The introduction describes the state at the start of the report—the state that created the need for the study—and the discussion describes the new state of the field's knowledge at the end of the report—now that the new results have been added to the knowledge base.

The distinction between framing sections and describing sections is often signaled by verb tense: framing sections usually use present tense to describe the field's current knowledge ("Factors that limit the distribution of the cougar *are* not known entirely but *include* climatic features, availability of prey, and habitat features"), whereas describing sections typically use past tense to describe actions already taken and data already recorded ("We *searched* for cougar tracks between December and April each year"; "Summer and winter home ranges for individual females *overlapped* extensively").[4] In an extensive analysis of verb tense patterns in research reports, Hawes and Thomas (1997) found that writers frequently use past tense to describe particular examples in support of generalized trends, whereas present tense is used when stating the generalizations themselves. One of the effects of past tense, then, is to localize and limit findings to particular researchers or labs, whereas present tense identifies a claim or conclusion as part of the field's current understanding.[5]

EXERCISE 4.2

Choose two or more full-length research reports from your field or from those included in this text. In each major section of the paper, circle the main verb in the first 10 or 12 sentences. Note whether and how verb tense shifts across sections and whether and how these verbs tend to localize findings or incorporate them into general knowledge claims.

4.3 THE LOGIC(S) OF SCIENTIFIC INQUIRY

We have included in this text three journal articles that follow the traditional IMRAD organizational pattern: Graham et al. (1992) and Chiba et al. (2002) in Chapter 9, both reporting clinical studies of treatments for the stomach bacterium *Helicobacter pylori*; and Burkholder et al. (2005) in Chapter 10, which examines methods for assessing toxicity of *Pfiesteria*, the "fish killer" dinoflagellate. The IMRAD format is a natural choice for reporting results from these studies, for in each case the research involved posing a question, choosing and carrying out experimental procedures, interpreting the resulting data, and drawing some conclusions about the significance of the outcome. Thus, the IMRAD format mirrors the basic logic of scientific method. Not surprisingly, this form is common in many scientific fields.

However, the emphasis on experimental methods and the presentation of new data in the IMRAD form are clearly unsuitable for papers reporting theoretical or historical research, in which the primary goal is to present new interpretations, theories, or models for understanding phenomena previously observed (Harmon 1992; Miller and Halloran 1993). Much of the research conducted in fields such as astrophysics, evolutionary biology, and geology, for example, is best described as theoretical or historical rather than experimental. Research in these areas may involve some data collection (e.g., core samples or satellite observations), but frequently the primary goal of such research is not to test hypotheses but to formulate hypotheses—to propose theories or models that account for the field's observations to date.

The structure of papers in the historical and theoretical sciences therefore tends to be more variable than that of experimental papers. As a case in point, skim the section headings of the *Geology* paper by J. Z. de Boer and colleagues (2001) on pages xxx-xxx and the *Clinical Toxicology* paper by Spiller et al. (2002) on pages xxx-xxx. Written by members of the same multidisciplinary research team and reporting on the same project, these papers nevertheless follow different organizational logics. Both begin by introducing the geographic location and history of the Delphic oracle. The researchers have compiled evidence that a gaseous vent was

present in the ancient temple at Delphi and was responsible for intoxicating, and thus "inspiring," the legendary priestesses who spoke prophecies there. After the introductory sections, the *Geology* article devotes separate sections to the tectonic setting, evidence of springs in the area, and analyses of gases present. Each of these sections incorporates both historical information and the results of the team's recent field survey and water sampling. In contrast to the IMRAD form, the survey and sampling methods are described briefly in each of the above sections; there is no separate section devoted to methodology, and few methodological details are included. This primary emphasis on observations or results over methods is common in geology reporting and consistent with the descriptive nature of this science.

The second report of the Delphi research—Spiller, Hale, and De Boer's *Clinical Toxicology* article—is organized somewhat differently. Though this article reports basically the same information as the *Geology* report, the historical background is treated as evidence in this report and the authors explicitly state their intention to defend the gaseous vent theory, an ancient theory that had long been dismissed as myth. After the introduction and an overview of the controversy, the paper devotes separate sections to each of three types of evidence the authors have compiled: historical, geological, and chemical. The paper does not follow a predetermined form but is organized to highlight the critical components of this particular argument.

Notice that all the report structures discussed above provide explicit opportunities for authors to describe the assumptions and implications of their theories, in a sense the "methods" and "results" of theoretical work. It is also important to notice that these papers provide clearly announced introductory and concluding sections or paragraphs that contextualize the argument just as the introductory and concluding sections do in the conventional IMRAD form. In stating the purpose of the study, the introduction lets readers know what kind of research is to be presented. The American Institute of Physics *Style Manual* explicitly reminds authors that the type and scope of the work, whether theoretical or experimental, should be clear from the introduction (AIP 1990).

In short, all research reports will include a framing introduction and discussion/conclusion (labeled or unlabeled), but the form of the body of the paper, the actual description of the work itself, will be determined by the type of work to be described. Because written texts communicate not only facts and observations but also the ideas and logic of their authors and their fields, texts will take different forms in different research communities. You will want to notice how reports in your field tend to be organized and how that organization compares with the organizational logic of the IMRAD form that we discuss here. As you read, pay close attention to the purpose and logic of each section. Notice how authors in your field convince readers of the need for the study and the significance of the outcome, as well as how they describe the methods, assumptions, and observations that serve as the evidence in their arguments.

In the next sections of this chapter, we describe the logic of each of the standard IMRAD elements in more detail.

EXERCISE 4.3

Read the research report by Etiope et al. (2006) in Chapter 11 and examine its organizational logic. What methods are described in this report, and where are they described? What results are reported, and where? Describe the function of each subsection and the overall logic of the report.

4.4 INTRODUCING THE RESEARCH PROBLEM

All research reports begin with an introduction of some sort, no matter what structure is followed in the rest of the paper. This is where you explain your research objectives, argue that the research is important, and place your study in the context of previous research. As Figure 4.1 demonstrates, editors and other readers expect the opening paragraphs of a journal article to describe the state of knowledge that motivated the research in the first place and to introduce the purpose of the study. We have referred to this opening section as a "framing" section above, to underscore its role in establishing a context or framework for interpreting the new research. To examine this framing more closely, take a minute to read the scrambled introduction in Figure 4.2. In what order do you think these sentences originally appeared? Rearrange the sentences to create a coherent paragraph that would clearly establish the purpose of the research it introduces. (Jot the sentence letters in an appropriate sequence in the margin before reading on.)

In unscrambling this intro, many of you probably chose to start the paragraph with sentence A, C, or D, presumably because you felt some background or announcement of the topic was warranted at the beginning, or perhaps because you were following the familiar "funnel" introduction pattern, which starts with a broad statement of the general topic and then narrows to the particular issue at hand. If you placed sentence E at the end of the paragraph, you chose to end by introducing the particular study to be reported in the paper, also in keeping with the funnel or inverted pyramid pattern. The actual introduction is reproduced in Chapter 9, on page xxx.

Notice in the original that the authors, David Graham and colleagues, begin as we've just described, using sentence D to announce the general topic or issue (peptic ulcer disease is chronic and recurs frequently), briefly elaborated with sentence C (which explains that antiulcer therapy can help but only temporarily, so does not affect the natural history of the disease). They then explain, in sentence A, that one approach *has* been shown to affect the natural history of the disease: eradicating the *H. pylori* infection. But this promising observation is qualified in sentences F and B, in which Graham et al. point out weaknesses in the research supporting this approach and also the absence of research investigating effects of this treatment on an important category of peptic ulcer (gastric). At this point, the discussion leads us to expect a response or solution to these problems, which is exactly what the authors then provide. In the final sentence, E, Graham et al. tell us they will report results of a study that has included control conditions (lacking in previous research) and that examines both types of peptic ulcer, gastric as well as duodenal. In this brief introductory paragraph, the authors have identified a research area, described the state of the field's knowledge in this area, and have shown how their study will advance that knowledge.

Effect of Treatment of *Helicobacter pylori* Infection on the Long-term Recurrrence of Gastric or Duodenal Ulcer

A. Recent studies have suggested that the eradication of *Helicobacter pylori* infection affects the natural history of duodenal ulcer disease such that the rate of recurrence decreases markedly (Coghlan et al. 1987, Lambert et al. 1987, Marshall et al. 1988, Rauws and Tytgat 1990, George et al. 1990).

B. In addition, studies of the effect of *H. pylori* eradication in patients with gastric ulcer have not been done.

C. The continuation of antiulcer therapy after ulcer healing results in a reduced rate of ulcer recurrence but does not affect the natural history of the disease, because the expected pattern of rapid recurrence resumes when maintenance therapy is discontinued (Sontag 1988).

D. Peptic ulcer disease is a chronic disease characterized by frequent recurrences.

E. We report the results of a randomized, controlled trial in which we evaluated the effect of therapy designed to eradicate *H. pylori* on the pattern of ulcer recurrence in patients with duodenal ulcer or gastric ulcer.

F. However, the interpretation of these results has been complicated by the fact that several of the larger studies did not use control groups or any form of blinding (Lambert et al. 1987, Rauws and Tytgat 1990, George et al. 1990).

FIGURE 4.2 Scrambled introduction to Graham et al. (1992), from *Annals of Internal Medicine*, p 705. (Citation form has been altered.)

In asking you to try the "scrambled intro" exercise, we have borrowed an instructional technique from John Swales, a linguist who has studied the logic and form of scientific papers (Swales 1984; 1990; 2004). In a study of introductions from 48 scientific papers published in three research fields, Swales (1984) discovered a remarkable degree of consistency across fields and journals. He found, as we did in the above analysis, that authors use introductions to demonstrate that their research responds to a need or a gap in the field's knowledge. Swales (1990) explains that the introduction to a research report is designed to create a space or a niche that the new research will fill. In describing this Create a Research Space (CARS) model, Swales identifies three interconnected moves commonly found in journal article introductions, which we have summarized in Figure 4.3.

Common Moves in Research Article Introductions

Move 1 Establish topic and significance ("establish a territory")
- By claiming that the topic is of central interest to the field *and/or*
- By making generalization(s) about the topic *and/or*
- By reviewing previous research

Move 2 Establish need for present research ("establish a niche")
- By indicating a gap in previous research *or*
- By raising a question about previous research *or*
- By proposing an extension of previous research

Move 3 Introduce the present research ("occupy the niche")
- By outlining the purpose and/or main features of the study (*obligatory*)
- By describing the findings or conclusions of the study (*optional*)
- By previewing the organization of the report (*optional*)

FIGURE 4.3 Based on Swales's (1990) Create a Research Space (CARS) model of research article introductions (p 141).

These three rhetorical moves can easily be seen even in Graham et al.'s brief introduction. (Take a minute to find them.) In Move 1, Graham et al. begin with generalizations about peptic ulcer disease and its treatment (sentences D, C, A), incorporating an overview of previous research. In Move 2 (sentences F and B), they raise questions about prior studies and point to a gap in the research: gastric ulcer has not been studied. And in Move 3 (sentence E) they describe the main features of their study (it uses a randomized, controlled design) and its purpose (to evaluate the effect of *H. pylori* treatment on ulcer recurrence). Notice that Moves 2 and 3 in particular are clearly signaled by the authors. Readers can't miss Move 2 in sentence F, which is signaled by the contrastive adverb *however*. Move 3 is also clearly signaled, in this case by the shift to first person active voice: "We report . . . "

As you continue to read research reports in your field and others, you will come across many variations on these moves and the strategies for accomplishing them. Though the sequence outlined in Figure 4.3 is quite common, sometimes the moves will be made in a different order or may overlap, and the listed strategies will occur in varying combinations. Such variations may reflect the nature of research in a particular disciplinary area. For example, Samraj (2002) found that research introductions in the applied field of conservation biology often point to gaps or problems in real-world conservation management practices, rather than gaps in prior research, to establish the need for a new study. In contrast, authors from the theoretical field of wildlife behavior more often justified their new work by emphasizing gaps in previous research. In another distinctive pattern, Swales (2004) notes that the Move 3 strategy of previewing the organization of the report is not very common in articles following the IMRAD form but is "close to obligatory" in fields that do not use the IMRAD convention, such as computer science, biostatistics, and economics (p 232). In the absence of the predictable IMRAD organization, such a preview serves a valuable function in helping readers anticipate the shape of the argument to come. (See the *Clinical Toxicology* article by Spiller et al. [2002] in Chapter 11 for an illustration of this strategy.) In sum, we find the CARS model

quite useful in identifying the basic gestures authors tend to make in introductions, but it is important to understand these gestures as flexible rhetorical moves that authors (and disciplinary communities) may combine in diverse ways to achieve their rhetorical goals. Despite variations in length, organization, headings, and other text features, effective introductions in all fields include broadly similar moves because they share the same broad goal: the authors want to convince readers that the topic is important and that their work on the topic will advance the field's knowledge. Thus the introduction serves several functions: it orients the reader to the research topic, reviews the current state of knowledge in the field, and establishes the need for the new work.[6]

The effectiveness of this argument for the significance of the new research rests largely on the authors' description of what the field knows now, which not only helps establish the authors' credibility in the field but in so doing creates common ground with readers and a shared context for understanding the new work. In an analysis of journal articles at early and later stages in the development of chaos theory, Paul and Charney (1995) found that when scientist authors were unable to use the conventional method of establishing shared context through research citation (i.e., when the research field was in its infancy and no prior research existed), they went to great lengths to create context through alternate means, for example, by introducing shared exemplars requiring extended elaboration. Once a research record developed, the same authors easily adopted the conventional research citation pattern that Swales had observed. Paul and Charney aptly describe research citation as a "disciplinary shorthand" (p 427) for establishing shared context with other members of a research community. Conventional ways to summarize the state of knowledge in the field and to acknowledge the work of others are discussed at more length in Chapter 5.

EXERCISE 4.4

Choose one of the sample research articles in this text and examine its introduction closely (for example, Chiba et al. [2002] in Chapter 9, Burkholder et al. [2005] in Chapter 10, or Reynolds et al. [2007b] in Chapter 12). Mark off the three basic moves outlined in Figure 4.3, circling any clear signals included in the text, and identify the strategies used to accomplish each of these moves. Write a paragraph in which you describe these moves and strategies, i.e., the authors' basic line of reasoning.

EXERCISE 4.5

Choose a published research report from a journal in your field. Type up a scrambled version of the introduction to this report, as in Figure 4.2. (If you choose a multiparagraph introduction, break it into "packets" or clusters of sentences rather than individual sentences.) In class, have two or three partners read and unscramble the introduction, with the goal of reassembling the original line of reasoning. Look for similarities and differences in these responses. Is there an easily recognizable pattern in this introduction? Look at some other research introductions in your field. How common is the pattern you've identified? Which moves and strategies are flexible and which seem to be obligatory?

4.5 DESCRIBING METHODS

The second major component of the research report is a description of the methods and materials used in the research. The "materials and methods" section traditionally follows the introduction, though some journals have begun to move these details out of the main body of the article to the end of the paper, sometimes set in a reduced font size, and/or to place some or all methodological details in online supplements. Berkenkotter and Huckin (1995) speculated

that the trend toward deemphasizing the methods section in some journals indicates that readers rely heavily on peer reviewers' assessment of methodological details, saving their own reading time for inspection of the study's results. Diminished attention to methods in the main argument may also reflect the maturation of a field or research area: as particular methods become more established and familiar, their description requires less and less detail (VandeKopple 1998). But as we observed in Chapter 2, this "shrinking" of the methods section in some journals coincides with a trend toward expanding research reports in other ways, as electronic publishing enables authors to embed links within the text and post supplementary materials online.

The location of the methods section and the amount of attention it receives will also vary according to its role in the research argument being presented. Burkholder et al.'s 2005 paper in *Proceedings of the National Academy of Sciences* (*PNAS*), reprinted in Chapter 10, reports on a comparison of two methods for detecting *Pfiesteria* toxicity and therefore features a prominent and extensive "Materials and Methods" section describing these techniques. In contrast, Reynolds et al.'s 2007 report of their analysis of the Kepler supernova remnant (Chapter 12) contains no distinct methods section. Methodological details (e.g., the timing and duration of Chandra observations and the subsequent analyses performed) are integrated into a section titled "Observations and Results," where this information provides critical context for the description of what was observed. Wherever methods are described in articles in your field, they constitute an important component of the overall argument of the research report, for they provide the framework within which the study's results and conclusions were generated.

The content and organization of the methods section will also vary according to the type of research to be described. This variation is illustrated in Figure 4.4 with a simple comparison of subheadings used by different authors to organize this section of their reports. Although the logic of the methods section is dictated by the logic of the research and therefore varies widely across fields, notice in Figure 4.4 that there are some basic organizational similarities. Methods descriptions begin by identifying the subjects of study, whether they are bacterial strains, forests, or human beings. It is conventional in many environmental science fields, for example, to include a separate "study area" section in which the ecosystem under study is identified and located and its distinctive features described (as in Example B). Papers reporting research involving human or animal subjects typically include a subsection labeled "subjects" or "patients" or "population characteristics" at the start of the methods section (Example A). Example C similarly begins by identifying the *Pfiesteria* strains that are the focus of study.

Once the subjects of study have been identified, the materials and procedures used to study them can be described. Subheadings are often used to subdivide the methods section to highlight the various types of analyses that were performed, as in Examples A and C. It is often helpful and sometimes essential to use graphics in describing methods, such as maps of study sites or diagrams of experimental apparatus. In Section 4.6 we will present some guidelines for incorporating graphics into your text.

Example A, from Chiba et al. (2002), *British Medical Journal* (reprinted in Chapter 9)

Methods
- Selection of patients
- Randomisation and interventions
- Adherence to drugs
- Outcome measures (6 subsections)
- Determination of sample size
- Statistical evaluation

Example B, from Lorimer et al. (1994), *Journal of Ecology*

Study areas

Methods
- Experimental design
- Plot measurements and analysis

Example C, from Burkholder et al. (2005), *PNAS* (reprinted in Chapter 10)

Materials and Methods
- Dinoflagellate Cultures and SFBs with Juvenile Fish
- Microbial Communities
- FMS with Larval Fish
- Tests for *Pfiesteria* Culture Purity
- Toxicity, Toxin Production, and Environmental Relevance

FIGURE 4.4 Subheadings from the methods sections of selected journal articles.

As noted earlier, the concrete information in the methods section is usually presented in simple past tense, either active voice ("We *collected* water samples every three days") or passive ("Water samples *were collected* . . . "). Although the "scientific passive" has a long and venerable tradition, it is often easier and more direct to write in active voice, which is the mode preferred by many journal editors in the interests of brevity and clarity. The editors of the *Journal of Heredity*, for example, directly inform contributors that "first-person active voice is preferable to the impersonal passive voice" (*Heredity* 2008).

On the other hand, it is observed in the American Institute of Physics *Style Manual* (AIP 1990) that "the passive is often the most natural way to give prominence to the essential facts" (p 14). The AIP editors offer as illustration the sentence "Air was admitted to the chamber," in which it is not important to know who turned the valve (p 14–15). In an analysis of research articles in the field of speech-language pathology, Riley (1991) found passive voice to be substantially more common in methods sections than in other parts of the reports, though all sections contained a mix of passive and active verbs. The AIP recommends shifting to active voice where necessary to avoid confusion or awkwardness. You'll notice that active voice often leads naturally to the use of first person ("We collected . . . "), which is increasingly common in scientific prose, a trend also endorsed by the AIP (p 14) and other editorial panels.

Although it is generally recognized that the methods section cannot describe every action of the experimenters, the description should be detailed and complete enough to enable knowledgeable colleagues to repeat the experiment, observation, or calculations successfully. Standard procedures that will be familiar to your in-field readers can be identified quickly without citations or further explanation. Procedures established in previous studies typically appear with citations acknowledging the precedent. And new procedures or substantial modifications will be explained and justified. Just as the introduction section argues that the study was needed, the methods section argues that the study was sensibly designed and carefully conducted. This is the occasion to defend the decisions you made in designing and

carrying out the research. Often these explanations are simply offered in passing, as in, "We increased the volume to 30 ml for the copepod *to minimize containment effects*." At other times, an explicit justification is offered to explain a methodological choice: "The dinoflagellate's TFVCs require an unidentified substance in fresh fish excreta; *hence, it was necessary to maintain cultures using live fish*."[7] Methods are sometimes described without such justification in student lab reports (because the primary audience, the instructor, has chosen the methods and does not need to be convinced of their validity), but in most other scientific contexts you will be describing methods *you* have chosen to readers who were not privy to your methodological decision making. How you explain and justify these choices is crucial to your *ethos* as a professional scientist.

The degree of justification needed for a procedure depends on the status of these procedures in the research community. We noted earlier that this status may well change over time as a research area matures. For example, in an analysis of *Physical Review* articles reporting research in spectroscopy over the course of the last century, VandeKopple (1998) found that authors publishing as the field first emerged in the 1890s included many more experimental details than authors reporting similar types of work in the 1980s. The early researchers also tended to adopt a more cautious tone in describing their instruments and materials, taking care to depict their methods "as applying to one particular time and place, rather than . . . as firmly established and widely generalizable" (p 190).

In sum, the methods section establishes the conditions under which the results of the study were generated, and therefore the context in which they must be interpreted. In this sense, the methods "frame" the results (and represent a frame within a frame). Notice that describing the methodological details of an experimental study is comparable to the articulation of assumptions required in theoretical papers. In describing their methods, researchers articulate the assumptions they made about the phenomenon under study: for example, that it will or will not vary over time or as a function of temperature or nutrient content or medical treatment or altitude or other factor; that the effects of these variables are observable with these instruments or observational techniques; that these techniques are reasonably free of bias; that these subjects are representative of the larger population to which the researchers wish to generalize; and so forth. The validity of the study design rests on the persuasiveness of the researchers' description of the methodological decisions they made.

EXERCISE 4.6

Look for instances of active and passive voice in one or more of the research reports in Chapters 9–13 or in sample articles from your field. Compare the types of information that tend to be presented in each mode. Do you perceive any patterns or strategies in the use of active and passive voice in different sections of these reports, or in articles from different research areas? (For example, how do your findings compare to the trend Riley [1991] observed in articles from the field of speech-language pathology [described above]?)

EXERCISE 4.7

In the article by Burkholder et al. (2005), reprinted in Chapter 10, look for examples of each of the three levels of procedural explanation described above: (1) standard or routine procedures, (2) procedures established in previous studies, and (3) new procedures or substantial modifications. How much explanation or justification is provided in each case? Why?

EXERCISE 4.8

Turn the methods section from one of your recent class lab reports into a methods section suitable for a journal audience in your field.[8] Where appropriate, state the rationale for your methodological choices. Target a specific journal, and use informative subheadings if editorial guidelines permit.

4.6 REPORTING RESULTS

The presentation of results plays a critical role in the developing argument of the research report, for it is here that new evidence is presented to address the gap or question outlined in the introduction. At first glance, the content of this section of the IMRAD form seems obvious: this is where the data are presented. But presenting data is not a simple matter. Even if a journal offers the option of posting supplemental material online, researchers cannot display all the information accumulated during the study, which may consist of pages and pages of lab data or field notes in print or digital form. Journals do not allow room to report each day's striped bass capture rate in a three-month study period, for example, or pH levels from all soil samples in a 200-sample design—nor would readers want to spend the time to read these raw data.

Instead, the data are summarized. The first step is to *reduce* the data to a manageable size for presentation; in experimental studies this is often accomplished by converting raw data to means (averages) and by using figures and tables to represent the data visually. Mean capture rates might be reported for each week or month, depending on how much variation was observed over those time periods; the results of soil tests might be grouped and averaged according to the location of the samples or the distance from a waste discharge point. Once the data have been reduced in these ways, comparisons can be made; for example, changes in capture rate can be examined over time, pH levels at different sampling sites can be compared. It is these observed changes or differences (or the lack of change or difference) that constitute the answers to a study's research questions.

Reducing the data thus enables authors to take a second step in presenting results, that of *generalizing* from the data. Researchers want to point out the trends they've noticed so their readers can see why they drew the conclusions they did. If they are to convince readers that their conclusions are valid, they must first ensure that the patterns they saw in the data are readily apparent. Olsen and Huckin (1991) point out that both levels of information must therefore be presented: "(1) the major generalization(s) you are making about your data and (2), in compact form, the data supporting the generalization(s)" (p 363).

Compare the following sentences, both of which refer to the data contained in a table:

Example A

Fifty percent of the eradication group and 36% of the placebo group responded successfully to treatment in the intention-to-treat analysis (table 2). In the all-evaluable-patients analyses, 54% of the eradication group and 40% of the placebo group responded favorably.

Example B

The proportion of patients who were considered a treatment success was significantly greater for the eradication arm than for the placebo arm, with comparable results in the intention to treat and all evaluable patients analyses (table 2).

Example B is from the report by Chiba et al. (2002), reprinted on pages xxx-xxx. Example A is invented. If you look at Table 2 in the Chiba report, you'll see that Example A simply repeats data that can easily be read in the table itself. Example B, on the other hand, generalizes from the data, emphasizing the difference between the eradication and placebo groups and the similarity between the trends observed in the two types of analyses. Such

generalizations are often stated in topic sentences at the beginning of paragraphs, as in Example B.

The relationship between data and generalizations is easily demonstrated by looking at how tables and figures are referred to in well-written reports. Tables, graphs, and other visual representations are essential tools for reporting scientific results, but it is important to keep in mind that graphics only present the data; the generalizations needed to interpret those data must be provided in the text. We recommend two essential steps in integrating visual and verbal information:

- Refer readers to the visual explicitly.
- Tell them what patterns to notice.

In Example B, the researchers refer readers to Table 2 by referencing it in parentheses at the end of the first statement describing data in that table. Other references to tables and figures are even more explicit, as in the following example, also from Chiba et al.:

Example C

Table 3 shows the impact of eradication treatment on disease specific measures of quality of life. The difference in the change in scores from pretreatment to study end showed significantly greater improvement in three of the five domains for the eradication arm.

The first sentence points readers to the table, identifying the kind of information to be found there (turn to Table 3 on page xxx). The authors then go on to highlight the trends to be noticed in this table, helping readers interpret the mean differences listed in the second column by calling attention to the significance levels (P values) reported in the fourth column. (Three of the five P values fall below the commonly accepted probability threshold of 0.05, indicating that these differences are unlikely to have occurred by chance and are therefore considered "real" or significant differences.) As in Example B, the authors of the excerpt in Example C do not simply repeat data from the table in the text itself; rather, they use the text to summarize and characterize the data, to help readers see what they see in this set of numbers.

In Chapter 2 we discussed the critical role that visuals play in modern scientific argument, a role that has dramatically increased over time (Swales 2004; Gross et al. 2002). In an historical comparison of articles from prominent research journals in a range of fields, Gross et al. (2002) found that 88 percent of articles in their 20th-century sample included figures or tables, compared to 48 percent of articles published in the 19th century. On average, 26 percent of the "surface area" in the sampled articles consisted of tables and figures (p 200), a clear indication of the importance of visual evidence in this genre. Digital technologies have enhanced the range of visual options, with each type of visual serving a specific purpose in the research argument.

Tables are particularly useful for summarizing data when the exact values of the data are important or when there are no clear patterns that would lend themselves to graphical presentation (Monroe et al. 1977). Tables are the least "visual" of visuals insofar as they don't actually transform data into a pictorial form; however, the spatial arrangement of columns and rows enables researchers to display and categorize information, facilitating comparisons between groups or study sites or along other dimensions. Tables may be used to organize verbal as well as numerical data. In the paper by Spiller et al. (2002), reprinted in Chapter 11 (see page xxx), Table 1 presents verbal data in two columns to facilitate comparison: a list of characteristic behaviors of the Delphic priestesses from the historical record is compared with a list of effects of ethylene inhalation documented in 20th-century science. In another paper from this study, De Boer et al. (2001) use tables to present and compare numerical data: hydrocarbon gas concentrations at different study locations (see Tables 1 and 2, reprinted on page xxx).

Other types of visuals are better able to highlight continuous trends and patterns. For example, line graphs illustrate chronological trends well, for lines as a visual form naturally illustrate movement and direction over time. Line graphs are included in the papers by Graham et al. (1992) in Chapter 9 (page xxx), and Burkholder et al. (1992) in Chapter 10 (page xxx). You'll notice in both that the line graph's *x*-axis represents time, measured in units such as weeks or days.

Compare these x-axes with the *x*-axis in the bar graph Burkholder and Rublee (1994) included in their proposal in Chapter 10 (Figure 5, page xxx). In this bar graph, eight sampling sites—four control sites and four discharge sites—are arrayed along the *x*-axis. Each bar represents one observation (the number of zoospores counted at the site), rather than a sequence of observations over time. The bar graph enables readers to see at a glance the relative magnitude of the counts at each site. The bar graph presents data in discrete categories, much like a table, but the visual depiction dramatizes the comparisons: similarities among control sites and among the discharge sites are easily apparent, as is the striking difference between the two conditions.

Graphs are labeled as *figures* in most scientific texts. Other types of figures include diagrams, cross-sections, maps, flowcharts, and various types of photographs, each of which serves a distinctive purpose and reflects the logic of the research design. For example, diagrams are useful for highlighting structural features and relationships (Olsen and Huckin 1991), as in Burkholder and Rublee's Figure 2 (page xxx), in which the authors illustrate the many life stages of the toxic dinoflagellate, the relationships among these stages in the life cycle, and interactions with other factors in the environment (finfish and phosphates). De Boer et al. (2001) use three different types of line-drawn maps to show Delphi's proximity to two geologic faults (Figures 1, 2, 3; pages xxx-xxx). In this article the maps function to locate the study site as well as to diagram the finding of the underlying faults, thus serving as support for both the methods and results of the study. As this example illustrates, though visuals tend to be concentrated in results sections, they may serve important functions in other parts of the research report as well.

Photographs and similar media are useful when observational detail of the object is important: Warren and Marshall use electron micrographs in their 1983 *Lancet* letters to show the shape and location of the *Campylobacter* bacteria they discovered (page xxx); Chambers et al. (2007) present Landsat satellite images that they used to demonstrate changes in biomass along the Louisiana–Mississippi state line after Hurricane Katrina (page xxx); and Reynolds et al. (2007b) merged three different types of X-ray images from the Chandra observatory to create a striking image of the Kepler remnant that enabled analysis of this supernova's origins. In these last two cases in particular, the visual images quickly came to represent the findings and were widely circulated. The Kepler image was featured as NASA's "Astronomy Picture of the Day," a research announcement of sorts that consists of little more than the visual itself (http://antwrp.gsfc.nasa.gov/apod/ap070116.html). Color is a significant feature of both the Kepler and the Katrina images that we are unfortunately unable to reproduce in the reprints in this text. If you access these articles (or the surrounding press coverage) online, you will see that color plays an important informational role in these images. In the Kepler visual, images from low-, medium-, and high-energy X-rays are represented in red, green, and blue respectively. Chambers et al.'s Landsat photos use a spectrum of colors to indicate the extent of biomass disturbance in locations that experienced different storm intensities. Both types of visuals are characteristic of their fields. (Chambers's use of before-and-after satellite imagery to study deforestation was a novel application of a method developed to study logging in the Amazon River basin [Kaufman 2007].)

As you examine research arguments in your own field, notice what types of nonverbal representations have become conventional. In addition to the types of visuals we've sampled here, consider other forms of modeling or numerical representation. For example, papers in

organic chemistry rely heavily on diagrams of molecular models, whereas modeling studies in physics often include mathematical equations and formulae. Advances in digital technologies have considerably eased the challenge of incorporating visual and mathematical evidence into a research argument, and you will want to familiarize yourself with the technologies that your field relies upon.

Guidelines for designing figures and tables can be found in style manuals such as the CSE manual for authors (2006), in writing guides and textbooks (M. Katz 2006; Pechenik 2007; Day and Gastel 2006), and in the instructions to authors published by individual journals, particularly in fields that rely heavily on specialized types of visuals. For example, the journal *Poultry Science* provides guidelines for authors preparing tables, line art, grayscale (black and white) figures, color figures, and photomicrographs (*Poultry Science* 2008). These varied sources all agree on the following general guidelines for preparing visuals:

- Each table or figure must be independent, that is, self-explanatory. Readers should be able to understand what kind of information is presented in the table without having to find the description in the text.
- For this reason, table titles (which appear *above* the table) should be as informative as possible: not "Table 1. Results" or "Table 1. Toxic Activity," but "Table 1. Toxic activity of purified PfTx extract from filtrate of *Pfiesteria* isolates in FMAs with larval *C. variegatus*, and cytoxicity to mammalian cells" (Burkholder et al. 2005; see page xxx). Titles should identify the variables being compared in the table. All labels in the table (column headings, row headings, notes, etc.) should be clear and brief.
- Similarly, figure captions (which appear *below* the figure) should be as informative as possible: not "Figure 2. Ejecta spectra" but "Figure 2. Spectra of three outer knots shown in Fig. 1. . . . " [followed by descriptions of the color and location of each knot's spectrum in the figure] (Reynolds et al. 2007b; see page xxx for the full caption). Symbols should be clearly identified in the caption or in a key; axes on graphs should be clearly labeled.
- Despite their independent status, figures and tables must also be *inter*dependent with the text. The visual and verbal presentations of results must work together. Visuals should be clearly referred to in the text, as discussed above, and they should appear in the text as close to the textual reference as possible.

Keep in mind that even though graphics are intended to be self-explanatory, readers will not know what *you* find interesting or noteworthy in the table or figure unless you tell them. Whether your data are presented graphically or discursively, that is, visually or verbally, be sure to highlight the trends you see and explain what they are based on.

It is conventional in many fields to subdivide the results section to highlight the different types of analyses reported, as in Burkholder et al.'s 2005 methodological comparison (Chapter 10) and Chiba et al's 2002 clinical study (Chapter 9). As these two papers illustrate, if subheadings are used in both the methods and results sections in an article, they typically include roughly parallel categories. Burkholder et al. organize both sections by detection technique (growth of microbial communities, SFBs (standardized fish bioassays), FMAs (fish microassays), toxicity); Chiba et al. subdivide both sections according to the various outcome measures they used (eradication of *H.pylori*, quality of life assessments, cost of health resources utilized). In sum, though researchers present their formal conclusions in later sections of the report, a great deal of interpretation goes on in results sections as well (Thompson 1993; Swales 2004). Summarizing, reducing, and generalizing from the data are all highly interpretive processes. It should be clear by now that researchers do not let the data speak for themselves; in summarizing their results, they also interpret them for the reader. They must present their data clearly, in the text and in any accompanying tables and figures, to demonstrate to readers that their interpretations are warranted.

EXERCISE 4.9

Read the introduction and methods sections (only) of the study by Graham et al. (1992) reprinted in Chapter 9 (pages xxx-xxx).

1. Before reading the results section, study Table 1 in this paper. What trends do you see in these data? Draft a few sentences describing the patterns in this table as though you were writing up these results.
2. Then study Figure 1 in the same paper, and again draft some sentences about the patterns in the data. How would you describe the results presented in this figure?
3. Compare your descriptions with the authors' descriptions of this table and figure.

EXERCISE 4.10

Look for explicit references to figures and tables in sample articles in this text and from journals in your field.

1. Notice that the parenthetical reference to Table 2 in Example B on page xxx is different from the direct reference to Table 3 in Example C. How common are these two "reporting formulae" in the articles you examined? Do these forms vary across fields? Across journals? Pay special attention to the ways in which authors in your field refer to figures and tables.
2. Find 5 to 10 sample parenthetical references to figures and rewrite them as direct references. You may find that you develop a formula of your own for transforming these structures.
3. Describe how the raw data have been transformed in the figures or tables you have found; that is, how have the raw data been reduced into a summary visual form?

EXERCISE 4.11

Go back to the sample articles you examined in Exercise 4.10. List the types of graphics used in these articles, the kinds of data contained in them, and the patterns revealed. What claim in the text does each visual support? Why were these visual forms selected, and not others? Pay special attention to the purpose of the visuals and the information contained in table titles and figure captions.

4.7 DISCUSSING TRENDS AND IMPLICATIONS

As noted earlier, the discussion section of the IMRAD form completes the frame opened in the introduction by returning to the significance argument. The purposes of introduction and discussion sections are inversely related. Whereas the introduction introduces the research question and reviews the state of knowledge in the field that motivated the question, the discussion explains how the question has been answered (at least in part) by the new research and shows how the field's knowledge is changed with the addition of this new knowledge. Thus, the discussion describes a new state of knowledge in the field, one that in turn motivates further research questions, which are typically highlighted in this final section.

Structurally, the introduction and discussion are mirror images as well. Berkenkotter and Huckin (1995) describe the introduction as proceeding "from outside in" in that it begins by talking about the general topic and reviewing the existing research in the field, and then it narrows to focus on the particular work at hand. Conversely, the discussion proceeds "from

inside out" by first summarizing major trends in the new results and then situating those results in the context of the field (p 41).

The new results are situated by comparing them with findings of previous studies and with the field's general understanding of the phenomenon under study. This is where the researchers offer their interpretation of their findings. They discuss how the new results extend, refine, or challenge previous findings or assumptions (Olsen and Huckin 1991). As the editors of the *British Medical Journal* (BMJ 2008) explain, a given study may have

> asked and answered a new question (one whose relevance has only recently become clear); contradicted a belief, dogma, or previous evidence; provided a new perspective on something that is already known in general; [or] provided evidence of higher methodological quality for a message which is already known. (http://resources.bmj.com/bmj/authors/types-of-article/research)

The discussion of implications must be clearly tied to the current results and must demonstrate an awareness of the limits of those results. In sum, the discussion section is the place to

- Briefly summarize the major findings, including the magnitude and direction of the effects observed (compared with what others found or compared with what was predicted or might be expected).
- Acknowledge the advantages and limitations of the methods used in the research (and comment on how these features may have influenced the observed effects).
- Explain the implications of the findings for current practice, policy, or theory.
- Outline the research questions that remain.

Notice that these discussion issues are interdependent. In commenting on the magnitude and implications of the new findings and the research questions that remain, it is important that the researchers recognize and acknowledge the limitations of their study. Scientists must anticipate the questions other researchers might have about their methods, findings, and conclusions, and must answer these questions in the text before they are asked. It must be clear to readers that the authors have considered "rival hypotheses," that is, possible alternative explanations for their findings. Philosopher Stephen Toulmin, an expert on scientific argumentation, calls these answers to potential questions, objections, and counterarguments "rebuttals" (Toulmin et al. 1984). According to Toulmin, rebuttals are the recognition of the circumstances or exceptions that might undermine the argument of the research.

Rebuttals often consist of further qualifications or acknowledgments of limitations, exceptions, and the need for further study and research. Rebuttals therefore are a way for a writer to verbally close loopholes, seal leaks, and tie up loose ends in the logic of the report. This sentence from the third paragraph of the discussion section in Graham et al. (1992) is a good example (see page xxx):

> Although some may argue that the lack of double-blinding introduced an important bias into our study, no objective data support such a contention, and we believe such a scenario extremely unlikely, especially considering the equipment now available for studying gastroduodenal mucosa.

All arguments, of course, are open to rebuttal; as we discussed in Chapter 1, scientific statements must be falsifiable to be accepted as valid. But in anticipating objections and answering them, scientists show they understand the limitations of their research, the nature of research problems in their field, and the expectations of their colleagues. Thus, the professional

use of rebuttals is another way scientists enhance the credibility of their research as well as their *ethos* as researchers.

As is the case in other sections of the report, the emphasis in discussion sections varies somewhat across fields. It is conventional in journals in applied fields, such as the *Journal of Wildlife Management*, to include a separate section on management implications after the main discussion. Similarly, discussion sections in agricultural journals may include advice for producers on feeding practices or litter composition. Contributors to medical journals may offer recommendations for clinicians and/or for public health policy (see the Chiba et al. paper in Chapter 9 for an example). In these and other applied areas, the discussion section is the place for researchers to show how their results pertain to actual practice or policy in the field.

In basic research areas the focus is not on practical applications but on the theoretical or methodological implications of the new results. In their report of the Kepler SNR discovery, for example, Reynolds et al. (2007b) explore the implications of their analyses for the field's understanding of supernovas and of the circumstellar medium (CSM), pointing out that this new information will also enable the field to test alternative models of the nature of the CSM (pages xxx-xxx). The "Discussion" section in Burkholder et al.'s methodological study (pages xxx-xxx) also explores the implications of their results for the field's theoretical understanding, in this case of toxic *Pfiesteria*, but their primary goal is to explore the methodological implications of their results. The study aimed to resolve conflicting reports in the field about *Pfiesteria's* toxicity by comparing methods used in studies with conflicting conclusions. The "Discussion" section highlights their conclusion that choice of method is critical in explaining this variation and thus an essential consideration for further research: "As shown by comparison of this study with refs. 21–23 and 25, recognition of variability in toxicity expression and other traits among strains (6), use of culture conditions conducive to toxicity expression (5, 10, 11), and appropriate assays for toxin will remain critical in forming sound insights about toxicity of harmful algal species and genera" (Burkholder et al. 2005; see page xxx).

Thus, discussion and conclusions sections, whether combined or labeled individually, represent the conclusion to the broader argument of the research report. Research authors do not leave it up to readers to draw conclusions about the data. They tell readers *their* conclusions, the ones the researchers believe the data support, and they provide enough information about the data and the conditions under which the data were generated to enable readers to determine whether their conclusions are justified. The American Institute of Physics (AIP 1990) describes conclusions as "convictions based on evidence" (p 4). The discussion section is the place to state your convictions and demonstrate how they follow from the evidence you present in other sections of the report.

We have focused thus far on the logic and structure of the arguments presented in research reports, but it is also important to notice distinctive features of the language in which these arguments are expressed. The persuasive and interpretive nature of scientific texts can be detected even in the language of individual sentences if we look carefully at how scientists phrase their claims and conclusions.

In a study of scientific claims, Penrose and Fennell (1993) asked experienced scientists from a variety of fields to complete sentences like the following[9]:

> These data _____ that the minimal response rate of interest should be .15.
>
> Results of this study _____ that significant genetic divergence has occurred among geographically separated groups of raccoons.

The verbs *suggest, indicate, show*, and *demonstrate* were the most common responses from these experts, regardless of field. The finding that responses from these individuals were

fairly uniform indicates that these terms are conventional across disciplines and are not unique to writing in, say, geology or botany. Notice that we've used one of these conventional verbs, *indicates*, in the preceding sentence to signal our interpretation of Penrose and Fennell's results. The sentence tells you that from the responses of these individual scientists we are generalizing about scientific discourse at large.

When we say that verbs like *suggest* and *indicate* are "conventional" in scientific discourse, we mean that they are commonly used constructions that carry particular, agreed-upon meanings in the community. These conventions enable scientists to make claims within the established parameters of knowledge-making in science. That is, these expressions enable a researcher to put forth a conclusion—to contribute to the advancement of knowledge in the field—while at the same time acknowledging that it is a conclusion—an interpretation of the facts and not a fact itself. Use of these tentative or hedging verbs signals to other scientist readers that this author is aware of the interpretive nature of scientific knowledge and that the claim is to be interpreted as "true" only within the boundaries of current knowledge and conditions (Hyland 1996; Gross et al. 2002). In examining research texts in psychology, Madigan et al. (1995) observed that hedged conclusions may be more convincing than more strongly worded claims because they convey "proper respect for the empirical process" (p 432). In addition to enhancing author credibility, there is some evidence to suggest that the inclusion of appropriate hedges helps readers comprehend the text (Crismore and VandeKopple 1988).

Scientists also use other kinds of hedges or qualifiers to convey the interpretive nature of their claims. Adverbs and adverbial phrases are often used to note limitations or special conditions; examples include *possibly, probably, very likely, necessarily, certainly, without doubt, presumably, in all probability, hypothetically, maybe, so far as the evidence suggests*, and *as far as we can determine* (Toulmin et al. 1984). Such qualifiers indicate the strength or extent of the claim being made, as in the following examples from the start of the "Discussion and Conclusions" section of the 2007 Reynolds et al. report (emphasis ours):

> We believe that X-ray and optical evidence points *compellingly* to the conclusion that Kepler resulted from a thermonuclear event.
>
> However, our deep Chandra observations also confirm that Kepler's blast wave is encountering material with at least solar metallicity, coincident with optically emitting N-enhanced material—*most likely* circumstellar material lost by a fairly massive star . . .

In addition to verbs and adverbs, a third type of qualifier is the modal auxiliary verb (Toulmin et al. 1984). Verbs like *may, might, would, could, should, must, can*, and *shall* are used to indicate qualifying conditions, as in the following examples:

> Given its broad temperature and salinity tolerance, and its stimulation by phosphate enrichment, this toxic phytoplankter *may* be a widespread but undetected source of fish mortality in nutrient-enriched estuaries. (Burkholder et al. 1992)
>
> The stomach *must* not be viewed as a sterile organ with no permanent flora. (Warren and Marshall 1983)

Hedging verbs, adverbs, and modal auxiliary verbs can and do occur anywhere in a scientific text where researchers need to qualify or limit their claims.[10] In a sense, then, qualifiers are related to rebuttals insofar as scientists use them to acknowledge the limitations of their work and to anticipate and head off questions and counterarguments that readers might pose. These linguistic devices thus reflect the interpretive and interactive nature of knowledge-

building in science. As you join the community of scientists, you are acquiring knowledge of both the logic of scientific arguments and the language in which that logic is expressed.

EXERCISE 4.12

The Graham et al. (1992) report contains several rebuttals in the last two paragraphs of the discussion, leading up to the final recommendation supporting Marshall's ulcer therapy (see page xxx). What rebuttals have the authors included? What counterarguments are these rebuttals to? Why do you think the authors felt they had to include these rebuttals in their report? It may be useful to know that Graham was a former opponent of Marshall's treatment.

EXERCISE 4.13

1. Analyze the discussion and conclusion sections of three or more full-length research reports from journals in your field (include any separate sections describing recommendations or management implications). List the types of discussion issues raised in these sections. Use the categories listed in this section as a guide (summary of results; advantages and limitations of methods; implications for practice, policy, or theory; remaining questions), but be prepared to expand the list or create subcategories as necessary to best describe the kinds of issues raised in your field.
2. In groups of three or four students from different fields, compare lists and prepare to discuss similarities and differences across these research areas. How do these similarities and differences reflect the nature of research in these fields?

EXERCISE 4.14

1. In the "fill-in-the-blank" study mentioned above, Penrose and Fennell (1993) found that first-year students and non-science majors were more likely to supply the word *prove* in these sentences than were science majors or expert scientists. Why is this usage less conventional among scientists? What is the difference between *suggest* and *prove* in these types of scientific claims?
2. Another unconventional choice some students made in this study was to use words like *conclude* or *hypothesize* in the sample sentences. What is unconventional about these choices? How does *conclude* differ from *suggest* or *indicate* in the context of these sentences? How might you revise these sentences to make *conclude* an acceptable option?

EXERCISE 4.15

Examine the discussion and conclusions section(s) of a research report from your field or one of the sample articles in this text, for example, Chiba et al. (2002) in Chapter 9, or Etiope et al. (2006) in Chapter 11. Look for instances of hedging in the text, particularly the three categories of qualifiers described above: verbs, adverbs, and modal auxiliary verbs. Look for other hedging devices as well. Would you propose any additional categories? What purposes do the hedges serve? How common are they in the sample articles you've chosen? Compare your findings with those of students examining other fields. Do you see any differences across fields in the use of hedges?

EXERCISE 4.16

The original title of the Burkholder team's letter to *Nature* (1992) was "New 'phantom' dinoflagellate is implicated as the causative agent of major estuarine fish kills." This title was

shortened during the publication process (see page xxx), much to Dr. Burkholder's dismay. What is the effect of the title change, and why do you think Burkholder was dismayed?

4.8 THE RESEARCH REPORT ABSTRACT

The abstract is a summary of a document's major points, typically appearing at the start of the journal article, and, as we saw in Chapter 2, accessible via online indexes and abstract databases. Along with the title of the report, the abstract helps readers decide whether the paper is pertinent to their research interests. The Council of Science Editors (CSE 2006) explains that "[b]ecause abstracts also appear in abstract journals and online databases, separated from the articles they describe, abstracts should be complete and understandable unto themselves, without reference to the full article" (p 460). The abstract therefore must represent the full argument contained in the report: the topic and purpose of the study, the methods used, the results obtained, and the conclusions drawn from those results. However, this argument must be outlined in extremely condensed form, usually only about 5 percent of the length of the full paper (AIP 1990).

Given its role in representing a larger document, the abstract can be described as a "contingent" genre: its content and form are contingent on the content and organizational logic of the document being abstracted. We will talk about research report abstracts in this chapter and will provide guidelines for the conference presentation abstract in Chapter 6 and the research proposal abstract in Chapter 7. Abstracts will vary considerably within these categories as well, however, reflecting variations in purpose and logic across research fields, journals, and articles. Some journals provide formal guidelines for the abstract that embody the standard research logic of their respective fields. *Annals of Internal Medicine*, for example, requires authors of research articles to follow a structured format for the abstract, as illustrated in the paper by Graham et al. (1992) in Chapter 9 (see page xxx). This type of structure—in this case with separate sections for the study's objective, design, setting, participants, intervention, measurements, results, and conclusions[11]—is used in other journals reporting clinical trials as well. (See Chiba et al. [2002], on page xxx, for an illustration of the *British Medical Journal*'s very similar form.)

Many journals, however, specify only a maximum length for the abstract (typically 150 to 250 words) and leave its structure up to the author. Because the abstract mimics the form and logic of the full report, the structure should be relatively straightforward. If the report follows the IMRAD form, the abstract is likely to include four basic moves representing the major parts of this pattern, and verb tense will shift accordingly (Olsen and Huckin 1991): the topic will be introduced in present tense, usually in a sentence or two; the background and/or need for the study will be outlined in another few sentences (but typically without references to prior studies [CSE 2006]); methods and results will be briefly described in past tense; and the major conclusions and implications of the study will be stated in present tense. Abstracts for IMRAD articles can be easily generated using this four-part structure. (See the Knutson et al. abstract in Chapter 13 for an example.)

If the report follows a logic other than the IMRAD pattern, however, the structure of the abstract will vary accordingly. For example, the abstract for Spiller et al.'s (2002) *Clinical Toxicology* paper defending the gaseous vent theory of the Delphic oracle (see page xxx) begins with one sentence summarizing the historical claim that intoxicating gases inspired the oracle, followed by three sentences summarizing the geological and chemical evidence that supports this claim. The fifth and final sentence states the authors' conclusion that the priestess's trance was caused by ethylene inhalation. Thus, the abstract encapsulates the line of reasoning followed in this particular article.

The IMRAD and non-IMRAD samples mentioned above are all examples of *informative* abstracts, that is, abstracts that summarize the information in the larger text. This type is

distinguished from the *descriptive* or *indicative* abstract often adopted for research reviews (Olsen and Huckin 1991; CSE 2006) and conference proposals. Indicative abstracts indicate what kinds of information will be contained in the paper, rather than providing a summary of that information. An example from the *Journal of Computational and Graphical Statistics* is presented in Figure 4.5. As this example illustrates, the descriptive approach is particularly appropriate when describing research involving mathematical procedures or models, which cannot be presented in condensed form. Rather than attempting to abbreviate these models, the authors in Figure 4.5 preview the basic steps or components of their model, telling readers what will be demonstrated in the paper. (Notice that this indicative approach previews the content of the paper in much the same way as the previewing strategy that Swales found to be common in introductions to non-IMRAD articles [Figure 4.3].)

Calculation of Posterior Bounds Given Convex Sets of Prior Probability Measures and Likelihood Functions

Abstract

This article presents alternatives and improvements to Lavine's algorithm, currently the most popular method for calculation of posterior expectation bounds induced by sets of probability measures. First, methods from probabilistic logic and Walley's and White-Snow's algorithms are reviewed and compared to Lavine's algorithm. Second, the calculation of posterior bounds is reduced to a fractional programming problem. From the unifying perspective of fractional programming, Lavine's algorithm is derived from Dinkelbach's algorithm, and the White-Snow algorithm is shown to be similar to the Charnes-Cooper transformation. From this analysis, a novel algorithm for expectation bounds is derived. This algorithm provides a complete solution for the calculation of expectation bounds from priors and likelihood functions specified as convex sets of measures. This novel algorithm is then extended to handle the situation where several independent identically distributed measurements are available. Examples are analyzed through a software package that performs robust inferences and that is publicly available.

FIGURE 4.5 Sample descriptive abstract from the *Journal of Computational and Graphical Statistics* (Cozman 1999).

The indicative abstract is less appropriate for reports of experimental research, for this approach provides little information about the study itself or its results and is therefore less useful to readers (Olsen and Huckin 1983). For example, compare the following hypothetical indicative abstract with the informative abstract that accompanies Graham et al.'s (1992) paper in the *Annals of Internal Medicine*, contained in Chapter 9 (page xxx):

> The purpose of this report is to determine the effect of treating *Helicobacter pylori* infection on the recurrence of gastric and duodenal ulcer disease. Results of a clinical study of recent ulcer patients under two treatments are reported.

Though this hypothetical abstract does provide a general outline of Graham's study, it withholds critical information that the clinical audience of this journal would be interested in, namely the types of treatment tested and the outcomes of the tests. Given the type of research being reported, the extended informative abstract that this journal requires is much better suited to its readers' needs.

EXERCISE 4.17

Read the abstracts for the papers by Burkholder et al. (2005) in Chapter 10 (pages xxx-xxx) and De Boer et al. (2001) in Chapter 11 (pages xxx-xxx). Identify each as an informative or an indicative abstract. Identify the major moves in the abstract and corresponding verb tense shifts.

EXERCISE 4.18

Write a 100- to 150-word informative abstract for the research report by Chambers et al. (2007), reprinted on page xxx.

4.9 BRIEF REPORT GENRES: RESEARCH LETTERS AND NOTES

In addition to the full-length research report, many journals publish brief reports in the form of *letters* or *notes*, an increasingly common set of genres designed to enable researchers to make quick announcements of important findings to the relevant scientific communities. The Burkholder team's original announcement of their *Pfiesteria* findings was presented as a research letter in *Nature*. According to *Nature*'s Guide to Authors (2008a), letters are "short reports of original research focused on an outstanding finding whose importance means that it will be of interest to scientists in other fields." Chambers et al.'s one-page report on Katrina's effect on Louisiana forests (Chapter 13) is an example of an even more abbreviated genre; it appeared in the "brevia" section of *Science*, another interdisciplinary journal that, like Nature, offers these briefer forms especially for findings of interest to scientists in a wide range of fields: "Interdisciplinary work, or experiments or analyses that produce a result of general interest, are especially appropriate for this section" (*Science* 2008). Other journals solicit similar types of articles. *Analytical Chemistry* (2007) publishes "Correspondence" ("brief disclosure[s] of new analytical concepts of unusual significance") and "Technical Notes" ("brief descriptions of novel apparatus or techniques"). The journal *Physical Review Letters* is devoted exclusively to "providing rapid publication of short reports of significant fundamental research in all fields of physics" (*PRL* 2008). Many of these genres have evolved from earlier, less formal forms: *Physical Review Letters* essentially began as a "Letters to the Editor" section in the journal *Physical Review* (Blakeslee 1994).

In most cases, research letters undergo an expedited review and publication process designed to enable researchers to communicate important findings as quickly as possible. The *Astrophysical Journal*, for example, publishes *Astrophysical Journal Letters* as Part 2 of the journal. The Letters is described as "a peer-reviewed express scientific journal" (*Astrophysical Journal Letters* 2008). *Letters* articles first appear on a Rapid Release website sponsored by the journal's publisher, University of Chicago Press. They then appear with a complete electronic issue of the journal and only later in a print version along with Part 1, which is published three times a month. Reynolds et al. announced their Kepler discovery in a 2007 letter in this journal (pages xxx-xxx). Though limited to four pages in length, the letters are not governed by any special organizational constraints and may be similar in form to Part 1 articles, which may run up to 20 pages. Letters are distinguished from full articles primarily by their urgency—their rhetorical exigence. In addition to satisfying the evaluative criteria established for Part 1 articles, *Ap.J.* letters must meet two further requirements, timeliness and brevity, which the editors describe as follows:

> **Timeliness**—A Letter should have a significant impact on the research of a number of other investigators or be of special current interest in astrophysics. Permanent, long-range value is less essential. A Letter can be more speculative and less rigorous than an article for Part 1 but should meet the same high standard of quality.
> **Brevity**—A Letter must be concise and to the point and require no more than 4 journal pages. . . . Within this space limitation, sufficient introductory background material should be included, and the content of the paper should be such that it can be generally understood by scientists who are not specialists in the particular field. (http://www.journals.uchicago.edu/page/apjl/ criteria.html)

Though the brief report category includes forms serving a variety of purposes, from presenting preliminary results, to introducing significant analytical concepts, to describing new techniques, research letters are typically used to present innovative research or to announce novel findings. Watson and Crick's 1953 letter to *Nature* on the double helix structure of DNA is a case in point, as is the Burkholder team's letter in the same prestigious journal. Marshall and Warren initially reported the presence of bacteria in the stomach in joint letters to the *Lancet* (Warren and Marshall 1983; see pages xxx-xxx). Notice that neither the dinoflagellate, *P. piscicida*, nor the "ulcer-causing" bacterium, *H. pylori*, had yet been named at the time the Burkholder and the Marshall and Warren letters were published, indicative of the early stage at which these reports appeared. Both might be considered cases of "revolutionary" or extraordinary science (Toulmin et al. 1984; Kuhn 1996). That is, both research teams were reporting findings that, if further supported, could significantly alter basic knowledge paradigms in their respective fields: the Burkholder team described a new family, genus, and species of algae that evidenced predatory behavior and was found to be responsible for numerous previously unexplained fish kills; Marshall and Warren described a bacterium that not only was found to live in the supposedly sterile environment of the stomach but also was potentially linked to illnesses the field firmly believed to be caused by psychological rather than physical factors. In both cases, these early announcements were (and continue to be) followed by a wealth of further research in which these preliminary findings are tested and extended.

In contrast to full-length reports, which can run 3000–6000 words, research letters and notes are quite restricted, at least in their print versions. *Science* brevia can be no more than 800 words (including author names and references) and may include one figure or table. *Nature* limits letters to 1500 words and 30 references (contrasted with the 50 references allowed in full-length reports). Electronic publication has enabled both journals to expand these limits online, however, as authors are permitted to link supporting material to the online version of their articles. For example, Chambers et al. (2007) posted eight pages of Supporting Online Material for their *Science* brevia piece, including a three-page Materials and Methods section, two figures, a table, and four additional references. Consistent with the trend reported earlier toward deemphasizing methods in research reports, both *Nature* and *Science* recommend moving some methods information into these supplements.

Notice that neither the Chambers nor the Burkholder letter uses subheadings, but both articles include all the standard components of the IMRAD format, albeit in much less elaborated form. As indicated in the *Astrophysical Journal*'s guidelines above, brief reports tend to follow the same logic and organization as full-length reports in a given research discipline. One interesting variation we've come across is in the abstract, an element that some journals have adjusted in keeping with the emphasis on brevity in the letter genre. *Nature* and its affiliated journals require a standard 150-word abstract for their full-length articles but have adopted a different convention for their shorter research letters. Letters are to include a 200-word summary paragraph at the start of the article in lieu of a conventional abstract. Though this paragraph is to include all the standard abstract components (background, rationale, main

results, implications), it is to be "fully referenced" and should function as part of the main text, not as a separate element (*Nature* 2008a). The Knutson et al. letter abstract from *Nature Geoscience* in Chapter 13 is an example, as is the first paragraph of the Burkholder et al. *Nature* letter. This introductory paragraph is then also reproduced as the letter's abstract online, so it must include a preview of results and conclusions, elements that are usually optional in research report introductions (review Move 3 in Figure 4.3). *Nature* provides an annotated illustration of their requirements for this summary paragraph in their guide to authors: www.nature.com/nature/authors/gta/Letter_bold_para.doc.

In a study of the journal *Physical Review Letters*, Blakeslee (1994) points out that the brevity of these reports may make it difficult for reviewers to evaluate the quality of the science being reported, and indeed the letters forum allows little room for the types of evidence we expect to find in full-length research arguments. Nor does it allow for detailed explanations of unexpected findings or extensive rebuttals (as illustrated by the responses elicited by Fleischmann and Pons's letter [1989] in the *Journal of Electroanalytical Chemistry*, announcing the creation of cold fusion). The letters genre is well suited, however, for presenting quick reports of new developments and recent observations, as the letters by Warren and Marshall and by the Burkholder, Chambers, and Reynolds teams illustrate. Letters often have something of a journalistic flavor when compared with the more formal full-length research report, consistent with the broader audience of this genre and with the function of presenting "cutting-edge" research (Blakeslee 1994).

EXERCISE 4.19

Look for the basic IMRAD elements in the Burkholder team's letter to *Nature* (Chapter 10). In what ways does this short report follow the IMRAD pattern? In what ways does it deviate from this pattern? Where are the basic research report moves made (introducing the problem, describing methods, reporting results, drawing conclusions)? Notice that table and figure captions are quite long in this report. What kind of information is contained in table and figure captions, and why is it there?

4.10 HOW SCIENTISTS WRITE REPORTS

The order in which report sections are written is rarely the same as the order in which they appear in the finished text. Your abstract is the first thing readers will see, but you won't be able to write it until you've at least sketched out the main body of your text. Perhaps you'll sketch out your methods section first, while specific details and decisions are still fresh; or you may begin by constructing the tables and figures you will use to present your results, filling them in as the data are generated and analyzed (Monroe et al. 1977). As noted earlier, your graphics represent the logic of your research design; the form of your tables and figures is likely to be determined long before you begin to write. LabWrite (2004), an online guide to writing lab reports, suggests writing methods and results first and then moving on to the intro and discussion sections (http://www.ncsu.edu/labwrite/po/ po-homepage.htm).

As is the case with many types of writing, the introduction to the research report is often revised throughout the drafting process; some authors even write it last. The focus and argument of the introduction depend in part on the outcome of the study. For example, a team of researchers may discover that their findings raise questions they did not expect to be important, and thus the study makes a somewhat different contribution to the field than they had anticipated. The introduction needs to prepare readers for this contribution so that it is recognized and appreciated as important. Even though the purpose and design of the study have not changed, the researchers will need to adjust their review of background issues and research to establish a context for later commenting on these new questions. In short, you may not be

able to finalize your introduction until you've thought about the implications you want to raise in the discussion section.

Writing a report is thus a recursive process in which authors continuously revisit and rethink their earlier arguments in light of their results and further thinking. In a study of the composing processes of nine eminent biochemists, Rymer (1988) found they employed a wide range of writing strategies and styles. Some subjects reported that they typically spend a great deal of time planning and outlining before drafting sections of the text, whereas others begin by writing a full "impressionistic" draft of the whole paper, refining it in later stages of the process. Most scientists use a combination of these approaches, adjusting their processes according to the type of research they're reporting, their familiarity with the prior research and the target journal audience, the amount of time they have available, and so forth.

The number of authors involved in a project also influences the structure of the writing process. As we've discussed, collaborative projects are increasingly the norm in most scientific fields. The average number of authors per article in the *New England Journal of Medicine (NEJM)*, for example, increased from one in 1925 to about six in 1995 (NAS 1995, p 13), by which time *NEJM* had instituted a cap of 12 authors per article (Kassirer and Angell 1991). In July 2002, *NEJM*'s editors lifted the cap, allowing the number of authors to continue to increase. The editors explain that as medical research has advanced, "investigators with a broader range of skills than were required in the past are often needed to take new ideas from the bench to the bedside and to conduct large clinical trials" (Drazen and Curfman 2002). This trend in multiple authorship has been a matter of some debate in science and in academia at large, for it raises issues of professional ethics and responsibility, as we discussed in Chapter 3.

Research teams manage the writing process in a variety of ways. In some teams, one author drafts the entire paper and sends it around to others for their comments and revisions. In fact, this is a common teaching model. Blakeslee (2001) observed a physics research team in which a graduate student learned to write papers by taking responsibility for the team's initial drafts, revising multiple drafts in response to his adviser's feedback. In other working groups, different members of the team may draft different sections according to their role in the research; for example, those who carried out the procedures and collected the data will draft the methods and results sections pertaining to their parts of the project, while the project leader who initially conceptualized the study will write the initial draft of the introduction and discussion (Rymer 1988). As discussed in Chapter 2, new digital technologies facilitate collaboration across time and distance, but this "distanced" collaboration may place higher demands on authors' project management skills and interpersonal relations.

If you completed the interview assignment in Chapter 1, you no doubt discovered that scientists spend a great deal of time writing, revising, and polishing papers before submitting them for journal review. The physics team studied by Blakeslee (2001) generated 21 drafts of their paper over a five-month period. One of Rymer's biochemists described a "predrafting" stage lasting approximately three years, during which the study was conceived and carried out and the postdoctoral fellows on the project drafted figures and tables as well as the methods and results sections. Once the lab work and analysis were completed, the project leader drafted and revised the introduction and discussion sections over a period of two weeks and then spent another two months pulling the manuscript together, which included revising the methods and results sections provided by the postdocs and soliciting feedback on the draft from colleagues (Rymer 1988).

Clearly, the form of the final written product tells us little about the process through which that text came to be. Unlike the conventions of the written report, writing processes seem to be governed not by field-specific convention but by the habits, skills, and preferences of the individuals who make up the research team.

4.11 HOW SCIENTISTS READ REPORTS

It should be clear from this chapter that the written reports themselves *are* governed by the conventions of their respective research fields and by the conventional practices of journals within fields. You'll recall that "conventional" practices are those that are customary in a community and thus familiar to all members. Readers in a community use their knowledge of these conventions to facilitate the reading and interpretation of the written texts those conventions govern. Thus, readers familiar with the IMRAD form will know where to find the results in a report quickly, where to look for the authors' interpretations of the results, and so forth. They will not need to read a paper from start to finish in order to discover what kind of research was conducted and what was found.

In fact, although editors and reviewers may take the time to read a paper from start to finish, scientists reading for their own purposes are far less likely to do so (Burrough-Boenisch 1999). Few scientists have the time or the inclination to read journal articles in their entirety in the order in which they appear in print (Bazerman 1985; Berkenkotter and Huckin 1995). Readers rely heavily on the titles and abstracts of published reports, not only to help them decide whether to read the paper but also to help them quickly learn the key features of the study. They then can turn immediately to pertinent sections of the report for the information they are most interested in. From consultations with researchers in physics and biology, Berkenkotter and Huckin (1995) determined that readers typically began by scanning the title and abstract of an article and then looking for the data, focusing on the tables and graphs in which the data are summarized. Only after examining the data themselves did these scientists read the results section provided by the authors. The rest of the reading process was quite variable; readers selectively read or skimmed the introduction, methods, and discussion sections, depending on how much they already knew about the topic, the methodological approach used, and the results of prior studies, and depending on their familiarity with other work of the authors. In an earlier study of physicists, Bazerman (1985) found similar variation in reading strategies. On some occasions readers would read an article's introduction and conclusion to get a sense of the focus of the study for future reference, skipping over details of methods and results; but in other contexts, as when reading a paper on a very familiar topic, the same readers might invert this pattern, ignoring the contextual information in the introduction and conclusion and concentrating instead on methodological details, calculations, and results. As we've discussed, readers of online journals may need to follow links to supplemental materials if they are interested in full details of materials and methods or additional results, an option that current technologies make readily available. In this sense, digital technologies have given readers even more control over, and responsibility for, their navigation of a given text.

Given these varied reading strategies, we can see why section headings, figure captions, and clearly labeled links are important in research reports, and why the content of titles and abstracts is critical. The final form of the report may reflect neither the order in which it was written nor the order in which it will be read, but it must match the expectations of readers in the research community, who will expect to find particular kinds of information and particular parts of the overall argument under conventional labels in predictable locations. The basic form and logic of research reports has remained relatively consistent over the last century, despite the many developments in technological publication and modes of access (Mackenzie Owen 2005; Gross et al. 2002). The paper must reflect the logic of presentation with which readers in the field have become familiar.

It's important to keep in mind that readers have expectations about the logic within sections as well. Paul and Charney's (1995) observations of scientists reading articles on chaos theory indicated that their readers were generally familiar with the basic introduction moves

described in Section 4.3 (though they may not be aware of this formula). When the authors had followed this pattern, these readers used this familiar structure to help them incorporate the new work into their current knowledge of the topic. In fact, the readers in this study—chaos researchers from the fields of physics, mathematics, ecology, engineering, and meteorology—all paid more attention to the context-setting information provided in the introduction than to the description of the new study itself. That is, the readers' first concern was "whether they could relate the reading to their prior knowledge and to their own work" (p 427). In short, readers expect to find these connections in the introduction, and authors must take care to provide them.

This discussion has implied that readers are active participants in the generation of knowledge through text. Scientists don't just gather facts when they read; they interpret those facts and carefully consider the interpretations proposed by the authors. They pay attention to how the authors designed and conducted the study, the conditions under which the work took place, and the operating assumptions underlying both the design of the project and the interpretation of its results. In other words, research readers are cautious consumers. Readers continually weigh the merits of the research and of the written argument as they read. The outcome of this evaluation process determines whether they accept the research as sound and important. And of course, current technologies provide forums for readers to take their active participation a step further, by posting their individual readings—their interpretations and evaluations—for others to see via blogs and other post-publication commenting features (Casper 2008).

4.12 HOW REVIEWERS EVALUATE REPORTS

In the manuscript review system, the process of weighing the merits of research becomes more formal and explicit. Editors and reviewers must evaluate the merits of the research not just for their own edification but for other members of the field as well. They are making the decision of whether to read or not to read on behalf of the larger community; the outcome of their deliberations determines whether the wider community gets to see the paper at all. As we discussed in Chapter 1, the peer-review process is the mechanism by which the scientific community monitors the integrity of its work—in effect, "filters" the work of individuals. Despite the concerns we explored in Chapter 3, the peer-review system remains a formidable structure, theoretically enabling the "volatile microcosm of individual scientists" to contribute to the "stable macrocosm of the scientific enterprise" (NAS 1989, p 10).

The logistics of the peer-review (or "peer-referee") system are relatively straightforward. Most journals publish their procedures and at least a tentative timetable in their instructions for authors. Authors submitting their work to *Nature*, for example, are told that the paper is first reviewed by a member of the editorial staff, who decides whether the research will be of significant interest to *Nature*'s interdisciplinary audience (*Nature* 2008c). If the paper does not pass this initial assessment, the authors are notified immediately, usually within a week. Papers that do pass then qualify for peer review and are reviewed by two or more referees, who are chosen on the basis of their expertise in the area, their lack of connection to the authors, and their availability to complete the review in a specified time period. Reviewers submit their reviews using an online manuscript tracking system. Once the reviews are received, the editor makes a decision on the basis of their advice, choosing one of four options: (1) accept (sometimes with editorial revisions); (2) invite authors to revise to address specific concerns before a decision is made; (3) reject, but invite authors to resubmit after completing further work; (4) reject outright (http://www.nature.com/authors/editorial_policies/peer_review.html; see this website for further information about *Nature*'s review process.)

The vast majority of scientific papers undergo significant revision in response to peer review. At the *Astrophysical Journal* "fewer than 3% of reviewers' reports recommend

acceptance . . . without significant revision" (http://www.journals.uchicago.edu/page/apj/guide-ed.html). Such a figure testifies to the extent of the scientific community's reliance on the peer-review system as a critical component of the scientific writing process. The elaborate editorial systems in place at *Nature, Astrophysical Journal*, and other prestigious journals suggest that it will likely remain so (e.g., see Harnad 1990).

There is a fair amount of consensus among journal editors and reviewers about what constitutes a publishable paper. Recall from the start of this chapter that journals clearly identify their target audience and the research areas they are interested in. It follows, then, that the minimum requirement for any paper is that it be of clear interest and importance to the readers of the journal to which it is submitted. Indeed, journal editors report that "suitability for the journal" is the primary concern when deciding whether to accept or reject a paper (Huler 1990). Lack of suitability is the most commonly cited reason for rejection of a manuscript (Davis 1985, cited in Olsen and Huckin 1991). Many journals, such as *Nature* and *Astrophysical Journal*, make the suitability assessment in the first stage of review.

You cannot begin to write a research report, then, until you've decided which journal audience you would like to reach. You can't develop a persuasive argument for the significance of your research without thorough knowledge of whom you're trying to persuade. In addition, the choice of journal dictates certain matters of presentation, from the purpose and organization of the article to, in some cases, details of style and formatting. Thus, prospective authors must understand not only the audience of the journal but also the nature of the communicative forum(s) the journal represents (Benson 1998) in order to write a paper that will be deemed appropriate for the journal and its audience. With the enormous number of papers competing for space in scientific journals (the *British Medical Journal* publishes only about 7 percent of the 7000–8000 manuscripts it receives per year [*BMJ* 2008]; *Nature*'s rate is 10 percent [*Nature* 2008b]), there is no room for papers that do not specifically address the interests of the journal's target audience and meet the expectations of its editors. (Lest new researchers despair, we point out that acceptance rates vary a great deal. The *Astrophysical Journal* (2008) reports an overall acceptance rate of 78 percent, though as noted above, all but 3 percent of articles undergo extensive revision.)

The following list of review criteria from the journal *Phytopathology* (2008; http://www.apsnet.org/phyto/submit.asp) provides a good summary of the features that reviewers are asked to evaluate and thus a good checklist for writers of research reports:

- Importance of the research
- Originality of the work
- Analysis of previous literature
- Appropriateness of the approach and experimental design
- Adequacy of experimental techniques
- Soundness of conclusions and interpretations
- Relevance of discussion
- Clarity of presentation and organization of the article
- Demonstration of reproducibility

Activities and Assignments

1. Select a research journal in your field, either print or electronic, for closer study. Examine several issues of the journal, and read the instructions for authors and other editorial information posted at the journal's website. Write a three- to four-page rhetorical analysis in which you discuss the following basic elements of communication:

   a. *Author*. Who publishes this journal? Whose research is reported there?

   b. *Audience*. Who are the intended readers? What types or levels of expertise do they have? Are they primarily researchers, policy makers, resource managers, educators, or other experts?

c. *Subject*. What topics or kinds of topics does the journal cover? How general or specialized are these topics?

d. *Text*. Describe the distinctive features of the text that helped you make inferences about author and audience. Do the articles have a formal or informal tone? Does the journal include more than one type of article (e.g., reports, letters, technical notes, reviews)? If so, how do these texts differ in style, tone, format, and purpose? (*Hint*: Don't overlook obvious features of the journal that might provide important information about its primary purpose and audience: the journal's title, institutions represented on the editorial board, announcements and advertisements, types of books reviewed, and so forth. If it is an online journal, who has access?)

2. Write a letter to a real or a hypothetical research collaborator in which you explain why you'd like to submit the results of your collaborative project to a particular research journal. Assume the two of you had narrowed your choices to two journals in the field. You've done some more investigating of the two journals, and you're ready to argue that one rather than the other will be the better place to report your findings. Your argument should be based on a clear comparison of the purpose, scope, and target audiences of the two journals.[12]

3. **a.** Using the IMRAD form as the organizational framework for your analysis, analyze the organizational structure of a research report in your field. Does this report illustrate the generic features described in Sections 4.3 through 4.7, or does it follow an alternative form? How does the form of the report reflect the goals, objects, or methods of research in this particular field? Your goal is to *analyze*, not just describe, the form of this particular research report. You'll need to think about why it takes the form it does. (An alternative assignment is to compare two articles from your field.)

   Note: In this sort of analysis, it is conventional to refer to the authors in the third person and to describe their strategies in present tense (e.g., "Sud and Sekhon divide their presentation of results into three sections . . . "; "Their findings indicate that . . . "). To orient your reader, include the following identifying information in your opening paragraph: the authors' names, the title of the article[s], the name of the journal[s], and the purpose or main conclusions of the research. Be sure to turn in a copy of the article[s] with your analysis.

   b. Either as part of your analysis above or as a separate activity, analyze the use of explanation, justification, and citations in a research report in your field. When, and how much, do the authors explain and/or justify statements in each section, and why are those explanations included? When, and how, are citations used (e.g., to cite relevant studies, to support an argument, to indicate awareness of a controversial or undecided issue)? What is the relationship of these strategies to the logic and purpose of each section of the IMRAD form? What does your analysis tell you about the knowledge and expectations of the authors' audience? How does the authors' awareness of the knowledge and expectations of the audience enhance the authors' *ethos*?

   c. In groups of four or five, read the analyses you wrote in part a, looking for similarities and differences among the fields your articles represent. Prepare an oral report for the class in which you identify the major structural variables in this set of papers. You'll want to describe *how* the papers differ and *why* they differ in these ways. What do these formal features reveal about the goals and methods of these different research areas?

4. Turn to Figure 1 in the Graham et al. (1992) study on page xxx. From the data in this line graph, try to create a table, a bar graph, and a diagram. What data did you select for each visual, and what data did you exclude? Why? What do your visuals show? Which visual forms were most useful in representing the findings of the Graham team and which weren't as useful? Why?

5. The *British Medical Journal* asks authors to provide "a thumbnail sketch of what [their] article adds to the literature, for readers who would like an overview without reading the whole paper" (http://resources.bmj.com/bmj/authors/types-of-article/research). Distinguished from the required abstract, this two-paragraph "What this paper adds" box appears at the end of the paper and essentially summarizes the motivation for the study and its major outcome. In other words, it condenses the arguments from the introduction and discussion sections. Authors are to write a two- to three-sentence paragraph summarizing "the state of scientific knowledge on this subject before you did your study and why this study needed to be done," followed by a second paragraph that succinctly answers the question, "What do we now know as a result of this study that we did not know before?"

See the Chiba et al. (2002) *BMJ* paper in Chapter 9 for an example, and see the URL above for further guidelines (scroll through to the section on the "What this paper adds" box).

Choose a research report from this text or from your field and write a "What this paper adds" box that meets the *BMJ* guidelines.

6. **a.** Choose a sample research question for which you can gather some actual data quickly from your classmates, friends, or fellow dorm residents. For example, you might be interested in who spends more time studying: women or men, seniors or first-year students, on-campus or off-campus residents. Or you might gather information about time spent writing papers for different classes, or the number of visits to the library in a semester. To enable comparisons, be sure to include more than one group in your sample (e.g., first-year students versus seniors) or more than one variable (e.g., time spent writing versus grade on paper).

   Present the data in a table or graph with an informative title or caption. Write a one-paragraph description of the purpose and research question (or hypothesis) of your mini-study. After you've reviewed the data yourself, exchange research questions and data sets with another student. Have that student describe the major trends he or she sees in the data and tell you the answer to your research question. If you've stated a formal hypothesis, have your reader tell you whether the hypothesis was supported.

   b. Plan a discussion section to contextualize the results of the informal study you conducted in part a. What kinds of previous research would you want to be familiar with if you were to conduct this study on a larger scale and prepare a formal report for a research audience? What implications can you draw from your results? What methodological limitations would you discuss? If your study were more formal, would you recommend changes in practice or policy on the basis of your results? What further research directions would you suggest? List, as specifically as you can, (1) the issues you would raise in such a discussion and (2) any further information you would need to complete this task.

7. If you are currently involved in a research project, write a research letter or full-length report of your study. Your instructor may ask you to work alone or with a partner or group. You will need to begin by reviewing prior research on the topic in order to identify what the field already knows, how the question has been approached in the past (what methods have been used), and what questions remain for you to address. See Chapter 5 for advice on locating previous research.

   Write this report as though you were preparing an article for submission to a research journal in your field. Choose an appropriate journal to target, and develop your paper with that journal's audience and editorial guidelines in mind. Select a sample report from your target journal to use as a model. Submit the guidelines and sample along with your report.

[1] For a large sampling of editorial guidelines, see http://mulford.meduohio.edu/instr/index.html. At this site, the library of the Medical University of Ohio has assembled links to the editorial websites of more than 3500 journals in the health and life sciences.

[2] Notice that we use the term argument in the sense of "case building" here, as opposed to the everyday sense of "confrontation" or "debate." Thus, the question "What is your argument?" means "What is your line of reasoning?"

[3] An excellent online resource for learning to write lab reports is the LabWrite program sponsored by NSF and developed at North Carolina State University:
http://www.ncsu.edu/labwrite/.

[4] Quoted sentences from Ross and Jalkotzy (1992, p 417, 418, 419). Italics added.

[5] You are already quite familiar with the effects of present and past tense verbs, for you use these distinctions in everyday conversation. Compare the statement "I mowed the lawn myself" with "I mow the lawn myself." The first sentence clearly refers to a specific occasion on which you mowed the lawn (a localized event), whereas the second refers to a general practice you've adopted (a recurring or general pattern).

[6] In fact, the structure of the introduction, in which the research gap or problem is made prominent, can be understood to create the psychological desire for a solution (see Olsen and Huckin 1991). As rhetorician Kenneth Burke puts it, "form is the creation of an appetite in the mind of the auditor, and the adequate satisfying of that appetite" (1968, p 31).

[7] Both examples are from Mallin et al. (1995), emphasis added.

[8] We are indebted to Olsen and Huckin (1991) for this exercise.
[9] Sentences from Sylvester (1988, p 833) and Hamilton and Kennedy (1987, p 270).
[10] See Hyland (1996) for a detailed analysis of these and other forms of hedging.
[11] The full Annals guidelines now also include an initial "background" section and a "limitations" section following results (http://www.annals.org/shared/author_info.html).
[12] We are indebted to Christina Haas for this assignment idea.

CHAPTER

5

Reviewing Prior Research

5.1 THE ROLE OF PRIOR RESEARCH IN SCIENTIFIC ARGUMENT

Scientific work is often conducted under solitary and isolated circumstances: late nights in the lab, long hours in the field collecting samples, visits to remote research sites. This work is neither planned nor interpreted in isolation, however. New studies are conducted because they promise to shed light on issues considered important by the research community; research questions are valid in that they reflect gaps or inconsistencies in the field's understanding; methodological decisions are made with an awareness of what has been done by others and how it has worked; and the outcomes of research are interpreted in light of the theories, questions, methods, and findings that have come before. Research becomes meaningful only when viewed in the context of the field's developing knowledge.

In his Nobel Prize lecture, Barry Marshall pointedly highlighted the situated nature of his and Robin Warren's research on *H. pylori*:

> The [lecture] title, "*Helicobacter* Connections" refers to the two components of our discovery. Firstly, we were able to associate a new bacterium with peptic ulcer disease. Secondly, we could see that the new bacteria could explain many phenomena observed by other gastric researchers over the previous 100 years. By connecting this literature with our own observations, we were able to confirm our hypothesis rather quickly. As a result, other researchers were often dismayed at our supreme confidence that these new bacteria were serious pathogens and that antibiotics would provide a cure for peptic ulcer. (Marshall 2005c)

Marshall's observation underscores the critical role of prior research in interpreting new discoveries. In the day-to-day work of scientific texts, such connections are concretely revealed through research citations. The practice of citing prior research is integral to arguments written for research audiences, including the arguments contained in grant proposals, research reports, and many types of brief research notes and letters. The National Academy of Sciences describes this practice as follows:

> Citations serve many purposes in a scientific paper. They acknowledge the work of other scientists, direct the reader toward additional sources of information, acknowledge conflicts with other results, and provide support for the views expressed in the paper. More broadly, citations place a paper within its scientific context, relating it to the present state of scientific knowledge. (NAS 1995, p 12)

Berkenkotter and Huckin (1995) argue that this process of contextualizing one's work is essential, for "it is only when scientists place their laboratory findings within a framework of accepted knowledge that a claim to have made a scientific discovery, and thereby to have contributed to the field's body of knowledge, can be made" (p 47). The importance of situating one's work is dramatically illustrated in their case study of a biologist, June Davis, whose initial submissions of a manuscript were twice rejected by journal reviewers who were not convinced that the study's findings were significant enough to warrant publication. The manuscript was accepted only after Davis bolstered her argument by responding to reviewers' calls for more explicit connections to previous research in the introduction and discussion sections of her report (Berkenkotter and Huckin 1995). See Dong (1996) for a similar account of a doctoral student's struggle to situate his work in the context of related literature in order to complete his dissertation in genetics.

As described in Chapters 4 and 7, reports and proposals always begin by reviewing the current state of the field's knowledge of the phenomenon under study. Many proposal formats require a separate background section devoted to reviewing prior research, sometimes referred to as a "review of the literature." Research reports tend to include a more abbreviated review of research in the introduction section, but as the Davis case illustrates, this brief review serves a critical role in establishing the context for the study. Citations of prior research also appear in the discussion sections of research reports, where authors make reference to previous studies in order to help readers interpret the scope, scale, and significance of the reported findings and to help them understand how the new research extends, refines, or challenges the state of knowledge in the field. Previous studies are frequently cited in methods and results sections as well, often as precedents for specific methodological decisions or data analysis procedures. As we discussed in Chapter 4, decisions about what statements need support or justification, and how much support or justification is appropriate, depend on the writer's awareness of what the audience knows and expects. Knowing when and to what degree to qualify, explain, justify, and cite is one of the ways scientists create a professional *ethos* (Herrington 1985).

In thus acknowledging the work of others, researchers demonstrate not only that their knowledge is up to date but also that they have taken advantage of the best of the field's expertise in designing, carrying out, and interpreting their own work. Researchers who fail to acknowledge the relevant prior research will appear either naïve (if readers are charitable) or arrogant (if they have no reason to be charitable). Pons and Fleischmann again represent a case in point. In their first paper in the *Journal of Electroanalytical Chemistry* (Fleischmann and Pons 1989), they claimed that the energy in their cold fusion experiment was produced by "an hitherto unknown nuclear process or processes" (p 301). In a critique of this paper, Huizenga (1992) criticized the researchers not only for neglecting to qualify their "risky assumption" but also for failing to "acknowledge the extensive literature on nuclear reactions acquired and the basic principles established over the last half century" (p 25). As described in Chapter 1, the general disapproval with which this research was met was due as much to the way in which Pons and Fleischmann presented and situated their work as it was to the quality of the research itself.

EXERCISE 5.1

Choose one or more full-length research reports or grant proposals, either from this text or from your own field. In each major section of the paper, find two or three sentences that include

citations of previous research. How are citations used in different sections of the paper? Look for citations that support qualifications, explanations, or justifications made in the text. What other functions do citations serve in the texts you've examined?

5.2 REVIEWING AS A GENRE: THE REVIEW ARTICLE

Before we discuss general strategies for reviewing research in scientific reports or proposals, we will briefly examine the *review article*, a distinct genre in which these strategies are paramount. Many journals publish full-length review articles, often solicited from experts in the field on topics of particular interest to the journal's readers (Noguchi 2006). Journals such as *Reviews of Modern Physics* and *Annual Review of Analytical Chemistry* are devoted entirely to this purpose. Review articles tend to be written for a journal's broadest readership, sometimes including researchers in related fields (Day and Gastel 2006; Noguchi 2006), and thus are pitched at a somewhat more general level than research reports. As described in *Nature*, review articles "survey recent developments in a topical area of scientific research or, on occasion, can be more wide-ranging" (Nature 2008d). Such surveys serve an important function in their respective fields in that they offer a comprehensive synthesis of the results of a wide and complex set of studies. In so doing, the review may have a substantial influence on how readers perceive the nature and implications of recent developments in a field and thus may influence the direction of subsequent research (Myers 1991). In their historical review of research genres, Gross et al. (2002) report that the review journal emerged in the late 19th and 20th centuries, presumably in response to the increasing volume of published literature, and coinciding with the emerging conception of research reports as developing arguments rather than simply displaying facts. Because review authors describe and evaluate the studies of others, highlighting important findings and also noting gaps or shortcomings in the literature, Gross et al. consider the review article a "second tier of peer review" (p 190). Indeed, Noguchi (2006) points out that inclusion in a review article indicates a certain level of acceptance or recognition of a finding, functioning in effect as "'a coming of age ceremony' to make official the recognition of a fact as a portion of 'truth' and as such, allow it to be used to construct other truths" (p 244). Thus, though research reviews do not report new results, they nevertheless play an important role in the development of disciplinary knowledge.

The review article we've included in Chapter 9 (page xxx) illustrates two primary traits implied above: comprehensiveness (it reviews 123 studies!) and recency or timeliness. Martin Blaser's review, published in *Gastroenterology* in 1987, was occasioned by the renewed interest in "gastric bacteria" sparked by Marshall and Warren's work in the mid-1980s. Like other important reviews, this piece helped the field take stock of a rapidly developing research area. As Blaser notes in his introduction, "The field has moved quickly, and a review of its current status is appropriate."

The goal of such status reports is to describe what the field has learned so far: what, if any, consensus is developing, and what questions remain to be answered? Review articles may be especially useful to those who distribute resources, both financial and human, including, for example, program officers at funding agencies and administrators in research agencies such as the EPA. Similarly, reviews are useful to practitioners, including medical professionals, agricultural producers, and resource managers, who must make daily decisions about courses of treatment, feed composition, management practices, and so forth, and who want to base those decisions on the most current information available. Comparable to the discussion and implications sections contained in reports of individual studies, review articles discuss the implications of the complex set of findings under review. Blaser, for example, helped researchers and clinicians make sense of the many reported observations of gastric bacteria by pointing out trends and patterns across studies. His concluding paragraph emphasized directions for future research and implications for clinical practice. As noted in Chapter 1, as early as 1993 over a thousand *Campylobacter pylori* studies had appeared in the new era

heralded by Blaser's review. The issues Blaser raised have not been fully resolved, but the field's understanding of the relationship between *C. pylori* and gastric illness has advanced to the point where much current research focuses on clinical techniques for detection and treatment.

In contrast to the trends toward multiple authorship in research reports and proposals, review articles are often single-authored. (In a sample of 25 review articles published in *PNAS (Proceedings of the National Academy of Sciences of the United States of America)*, Noguchi (2006) found 72 percent to be single-authored [p 102].) The review thus represents one expert reader's interpretation of the state of knowledge in the field. Given the important role that review articles play in shaping a field's understanding of the research base, journal editors are particularly careful to ensure the integrity of this interpretive process. To guard against potential bias, some journals have established stricter conflict-of-interest policies for authors of review articles. *The New England Journal of Medicine*, for example, will accept research reports from authors with significant financial ties to companies whose products are affected by their research, provided those relationships are disclosed. But such relationships are not allowed for authors of review articles and editorials (*NEJM* 2008).

Review authors must convince not only the journal's editors but also its readers that the selection and interpretation of prior studies are free of bias. In his review, Blaser based his advice to clinicians on his interpretation of the field's current understanding of the relationship between these bacteria and specific gastric conditions. For this interpretation to be accepted by readers in the field, it needed to be carefully and clearly supported, not only with citations of relevant studies but also with enough information about those studies to enable readers to see the trends the author had seen. We'll return to this issue later in this chapter.

Notice that research reviews typically present a synthesis of *findings* rather than a synthesis of *views*. Direct quotations are rarely found in research reviews because the primary focus is not on what previous authors have believed or said but on what their studies have demonstrated. Reviewers are interested in researchers' claims only insofar as they are supported by the empirical evidence they present. Even in reviews of theory, common in fields like geology, meteorology, and astrophysics, theories tend to be discussed in the context of the physical observations they seek to explain. In short, the goal of the research review is to help readers make sense of all the available evidence. The reviewer offers a description of what the field does and doesn't know on a given topic at a given point in time.

In keeping with this descriptive goal, scientists tend to adopt an objective and respectful tone when synthesizing the work of other researchers. In comparing and contrasting research findings, review authors often point out limitations in the scope or methods of individual studies, but by now it should be clear that *review* in this context means to synthesize or characterize a body of information, not simply to point out flaws (as is often the case, for example, in film reviews in the popular press). Though pointed and personal criticisms are somewhat more acceptable in the humanities literature, where authorial presence is generally more prominent (Madigan et al. 1995; Hyland 1999), such tactics are inconsistent with the *ethos* of the objective scientist and the high value placed on consensus in the scientific community. In the sciences (Gilbert and Mulkay 1984) and social sciences (Madigan et al. 1995), public discussion tends to stay focused on the strengths and limitations of the work itself. Though there is clearly an evaluative dimension to the review, the overall goal is descriptive.

EXERCISE 5.2

It will be useful to have some potential topics in mind as you continue to read this chapter about reviewing prior research. Researchers frequently discover topics for research while reading the work of others. Review articles are excellent sources of research topics. As you saw in Chapter 4, research reports also tend to outline directions for further research in discussion

or conclusion sections. Review the discussion sections of two or more research reports, either those contained in this textbook or, ideally, papers from your field. What kinds of further studies are suggested? List the potential research questions proposed or implied by these authors.

5.3 LOCATING THE LITERATURE

Whether writing stand-alone review articles or reviews embedded in other kinds of scientific texts, experienced researchers rarely begin their reviews of research from scratch. By the time they are ready to write the introduction to a research report or the background section of a grant proposal, they have become very familiar with previous work in the area, some of which may be their own. Thus, the scientist-author already knows which previous studies are pertinent to the argument at hand. But new scientists, or researchers working in new areas, may need to do a more extensive search of the available literature in order to develop this sort of familiarity with the research base. Therefore, some search strategies are in order.

Research reviews focus on primary sources—original reports of individual studies published in professional research journals—as opposed to secondary sources such as textbooks or magazine articles written for nonexpert audiences. But secondary sources are excellent places to start in your search for the primary literature. Biddle and Bean (1987) recommend beginning a search with the sources you find at home, for example, your textbooks and lab manuals, both of which may include lists of works cited or suggestions for further reading. To this we would add as easily accessible starting points other course readings, class discussions, and conferences with your professors. If you have chosen a topic that was raised in class, your professor or lab instructor should be able to refer you to a recent paper on the subject. If your topic was suggested in the discussion section of another researcher's report, then you've already identified the first study to include in your review.

The easiest way to search for prior research on a topic you are investigating is to begin with such a reference in hand. This advice is more helpful than it sounds. First, the paper will contain at least a brief review of relevant research and a discussion of implications, providing you with a quick introduction to the topic. Second, if you have even one study in hand, you'll be able to locate the network of previous work by searching "backwards" through its reference list or "forwards" via author or citation searches (more on this below). This process will take some trial and error; you will undoubtedly come across studies that are not directly relevant to your specific topic. Streamline your search by using the descriptions of the cited studies in your article-in-hand to help you decide which are likely to be most pertinent to your particular research interest.

For example, turn to the first paragraph of the Burkholder et al. (2005) article on *Pfiesteria* toxicity (page xxx). This text is dense with citations, each selected to illustrate or provide support for the statement in which it appears. If you want to learn more about linkages between fish kills and human health, the first sentence tells you that references 1–3 will be useful sources. If you want to find out just how toxic different strains of *Pfiesteria* are, the second sentence will lead you to examine sources 5–7. Even the brief reviews embedded in article introductions such as this can point you to promising sources for your own research. Electronic indexes and abstract services are powerful tools in the digital information age and can be especially useful if you are starting from scratch—that is, if you don't have a source in hand. But be prepared to spend some time exploring multiple databases and experimenting with different keywords and combinations. A wide variety of digital search tools are available in the sciences, ranging from general multidisciplinary services such as *Web of Science* and *Academic Search Premier* to domain-specific sources such as *Agricola* (agriculture and related fields), *Medline* (biomedical sciences), and *GeoRef* (earth sciences), to sources focusing on specific research areas within domains, for example, *Fish and Fisheries Worldwide, Textile Technology Index*, and *Bacteriology Abstracts*. The reference staff in your campus library are familiar with

the databases accessible to students on your campus. (Just as libraries subscribe to journals for use by library patrons, they also subscribe to databases for access by library patrons.) This staff can help you choose appropriate databases for topic searches in your field and will also be able to help you get started on keyword searches once you've identified the index tool you want to use.

In addition to the library staff, consult with your professors to identify the most useful indexes and abstract databases for your research topic, and/or check the websites or masthead pages of the primary journals in your field. Journal websites typically include a list of databases in which the journal is indexed, often under a heading such as "Abstracting/Indexing" on an "About this Journal" or "Information for Authors" page. In print journals, indexing information is generally included on the masthead page, which provides information about the publisher, copyright notices, subscription procedures, and so forth, and usually appears inside the front cover or somewhere near the table of contents. Two sample index lists are reprinted in Figure 5.1.

If you do have an article in hand, it can help you both test and navigate the indexes you've identified as potentially useful. First, see if you can find your initial article in the database, e.g., by searching on the first author's name and the date of the publication. If your original source is not contained in the database you've chosen, it may not be an appropriate search tool for your topic. Try some others. Once you've found a database that contains your initial article, notice how the article is indexed—that is, see what keywords or identifiers are associated with the paper. Then use those keywords to help you design a search for related articles.

Behavioral Ecology

(Copyright 2008 Oxford University Press)
Behavioral Ecology is covered by the following major indexing/abstracting services: Animal Behavior Abstracts; Current Contents/Agriculture; Biology & Environmental Sciences; BIOSIS; Ecology Abstracts; Elsevier BIOBASE/Current Awareness in Biological Sciences; E-Psyche; Geo Abstracts; GEOBASE; Research Alert; SCISEARCH; Wildlife Review; Zoological Record; PsychINFO.

Nature

(Copyright 2008 Nature Publishing Group)
The Nature and Nature Publishing Group journals are indexed by the following abstracting and indexing services: British Library, CABS (Current Awareness in Biological Sciences), Chemical Abstracts Service, Crossref, EBSCO Publishing, EMBASE, Google Scholar, Infotrieve, IngentaConnect, ISI Web of Knowledge, OCLC (Online Computer Library Center), Ovid, PubMed, PubMed Central, Scopus, Ulrich's periodicals directory.

FIGURE 5.1 Indexing information from selected journals.

Many indexing services also enable you to search "forward" from an article, by identifying other sources in which it was later cited. Subscription-based *Science Citation Index* and the open access *Google Scholar* (http://scholar.google.com/) both provide this type of citation tracking, as well as other search tools. Citation tracking is also a useful way for researchers to see how their work is being used and to assess its impact on the field.

Lastly, we noted in Chapter 2 that some individual journals and professional associations (and general services such as *Google Scholar*) offer their members various types of alert services to let them know about new research on a given topic as soon as it appears in digital (that is, searchable) form. Public Library of Science (PLoS) users can register to receive weekly or monthly alerts of newly published research, or newsfeeds providing summaries and

headlines from PLoS blogs or journals on specific topics (http://www.plos.org/connect.html). This up-to-the-minute notification constitutes a more proactive or anticipatory search mechanism, adding in effect a "real time" option to the backward and forward searching described above.

EXERCISE 5.3

Either online or in print, find the indexing information for three to five major journals in your field. List the indexing and abstract services used by these journals. Put a star by those currently available through your university library.

EXERCISE 5.4

Working alone or with a partner, choose a topic in your field that you would like to know more about. It may be a topic you identified in Exercise 5.2; it may be an area you are currently exploring in another course or at work; or it may come from your own reading or browsing through journals in the library. Conduct a keyword or subject search on this topic in at least two different indexes appropriate for your field (print or electronic). Compare the outcomes of your searches. How useful was each search tool? Did the two systems produce similar sets of sources? What journals were cited in each search? Which database contained more relevant references on your topic? How easy was it to narrow the search in each system? Which provided greater flexibility in defining and combining keywords? Which search was more efficient? In what other ways did these indexes differ? List the advantages and disadvantages of each system you examined. Your instructor may ask you to compare these findings with those of your classmates.

5.4 READING PREVIOUS RESEARCH

In most cases, you will be reviewing research as part of a research report or grant proposal. Thus, the goal of your literature search is to determine the context for your research: What does the field already know about this topic? What kinds of studies have been done? What methods have been used, and how useful have they turned out to be? What has been found? What kind of information is still needed? Your answers to such questions will help you design a project that represents a reasonable next step for your field. When you write the review itself, you will aim to help your readers see the trends that you have seen in this literature.

In conducting your search, use paper titles and abstracts to help you sort through the sources you've located. As you begin to identify the studies that seem most relevant, read the introduction and discussion sections carefully. Your goal in reading each paper is to understand why the authors conducted this research, what questions they hoped to shed light on, and what conclusions they came to. What were they trying to find out, and how does this relate to what you're trying to find out?

As you begin to compare and contrast the studies to be included in your review, skim the methods and results sections as well to see what kinds of materials were used (or sites or subjects observed), what kinds of measurements were taken or observations made, and what kinds of analyses were performed. Locate the major findings of the study. Recall from our discussion in Chapter 4 that in well-structured results sections major findings are highlighted in the text. Look for the authors' generalizations about their results, often contained in topic sentences.

5.5 IDENTIFYING TRENDS AND PATTERNS

Whether your review is a stand-alone document or part of a report or proposal, readers will expect you to have read widely in the research literature and to have selected the most significant and most relevant studies to include in your review. Your goal is to present an overview of what this research has demonstrated. That is, you will want to sift and synthesize, pointing out similarities and differences in the findings these researchers report and, if pertinent, in the methods they used and the focus of their experiments or observations. This synthesizing goal will lead you to talk about the studies in groups or clusters, rather than describing each in isolation. (Notice in the sample texts in Chapters 9 to 13 that studies are frequently cited in clusters of two or three.) The review should not be a list of individual article summaries but a discussion of the trends that you noticed across studies.

A useful way to identify trends is to construct a grid to help you record distinctive features of the studies as you read them. List the studies down the left-hand side of the page, and mark off several columns across the top. Early in your reading, the grid might include column headings such as "research question," "methods," and "principal results." As you become more familiar with the literature and the issues raised by these studies, you will want to develop more specific column headings.

For example, when he began reading the clinical research on *Campylobacter pylori*, Blaser (1987) might have used a column headed "conditions associated with *C. pylori*" to organize his notes. After a while, he would notice by reading down this column that some researchers documented the presence of *C. pylori* in patients with gastritis, others found associations with peptic ulcer, others with still other conditions. The grid would thus help him notice clusters or subgroups of studies that could usefully be discussed together in his review and may suggest subheadings he could use to organize the body of the paper. (Skim the subheadings in Blaser's review in Chapter 9 to see where the gastritis and peptic ulcer "clusters" were included.) Blaser could then use a similar grid to help him notice differences and similarities within each cluster. For example, he could compare the different types of methods used to study gastritis to see if results were consistent under different conditions. In fact, the table Blaser created to summarize the results of the gastritis studies looks very much like the sort of grid we have been describing (see Table 2 on page xxx). Rublee et al. (2005) provide a similar table in their review of methods used for detecting *Pfiesteria* (Table 1 on page xxx). Both the Blaser and Rublee tables may well have functioned as planning devices for the authors as they sorted through their respective research bases.

Whether you use a formal grid or some other note-taking system, your primary goal is to identify trends in this body of research. Are findings consistent across the set of studies? If the phenomenon was studied in different regions, at different times of year, with different methods, or under different conditions, were the findings similar or different? Is there theoretical consensus in the field, or have different interpretations been put forward? To help readers understand the current state of the field's knowledge on the topic, your review should highlight consistent patterns and points of agreement as well as inconsistencies and issues that are unresolved.

Consider two examples. First, read how Blaser synthesizes the findings from the gastritis studies he had listed in Table 2 of his review (see page xxx, under the heading "Association of Gastric Campylobacter-like Organisms with Gastritis"). Since the presence of *C. pylori* and the condition of gastritis were strongly associated in all but one of these studies, Blaser highlights this consistent trend in the topic sentence that opens the paragraph. Contrast this emphasis on consensus with the example in Figure 5.2. In this mini-review excerpted from a research report, astrophysicists Fulbright and Reynolds (1990) describe an unresolved issue in shock acceleration theory, the question of whether quasi-parallel or quasi-perpendicular shocks are more efficient in accelerating electrons. Their review emphasizes the lack of consensus in the field, a gap in the field's knowledge that their study will go on to address.

Notice in both examples that the authors offer conclusions or *generalizations* about the set of studies under review, and they cite the *specific studies* on which their conclusions are

based. Notice also that, as discussed in Chapter 4, generalizations tend to be stated in present tense (because they describe the current state of knowledge), whereas past tense is used to describe the results of specific studies (which were conducted in the past).

The most obvious mechanism to produce a bipolar structure is the compression by a factor of 4 of magnetic field where it is perpendicular to the shock normal, compared to no amplification where it is parallel (van der Laan 1962; Whiteoak and Gardner 1968). However, this mechanism can produce only a limited amount of azimuthal modulation of intensity. Roger et al. (1988) and Leckband, Spangler, and Cairns (1989) point out that another possible mechanism for producing bipolar structure in shell remnants is a systematic dependence of the efficiency of shock acceleration on the obliquity angle θ^{Bn} between the shock normal and the external magnetic field, if the field is assumed to be fairly well ordered on the scale of the remnant diameter. Shock acceleration theorists are divided on whether quasi-parallel ($\theta_{Bn} \sim 0°$) or quasi-perpendicular ($\theta_{Bn} \sim 90°$) shocks are more efficient in accelerating electrons. The quasi-parallel geometry seems more adapted to classical diffusive shock acceleration (see reviews such as Drury 1983 or Blandford and Eichler 1987), while quasi-perpendicular geometry allows the so-called shock drift mechanism (Pesses, Decker, and Armstrong 1982; Decker and Vlahos 1985, among others) in which electric fields along the shock front accelerate particles, a process which can be considerably more rapid (Jokipii 1987). Leckband, Spangler, and Cairns (1989) attempted to study this issue by examining the limb-to-center ratios of SNRs, inferring the direction of the external magnetic field for each remnant using a model of the galactic magnetic field, and comparing with model calculations for profiles of SNRs. They could not come to a definite conclusion.

FIGURE 5.2 Sample review paragraph from Fulbright and Reynolds (1990, p 592): Bipolar supernova remnants and the obliquity dependence of shock acceleration. *The Astrophysical Journal*.

EXERCISE 5.5

Choose a sample paper or proposal in your field. Modify one paragraph of a research review section by stripping out research citations. Type up the "research-free" review paragraph, and exchange with another member of the class. Read the paragraph you've been given, and note in the text where you think the authors would need to cite prior research and why. Compare your analysis with the original review.

5.6 ORGANIZING THE REVIEW

There is no standard organizational format for the research review, for the scope and purpose vary widely. Though review articles originally tended to survey historical trends (Day and Gastel 2006), today they are more likely to concentrate on recent history, as indicated by *Nature's* (2008d) emphasis on "recent developments in a topical area." In Noguchi's (2006) sample, reviews tended to be organized around one of four goals: "presenting [an] historical view of a facet of the field; describing the current situation in a field; proposing a theory or model to resolve some issue in the field; [or] calling attention to some issue in the field" (p 120). Swales (2004) views these goals as parameters that reviews may exhibit to greater or lesser degrees and in various combinations. Blaser (1987), for example, includes a section titled "Historical Developments" at the start of his review article on *C. pylori*, although the goal of that review is clearly to assess the current state of the field's knowledge. This section is particularly appropriate in Blaser's review because a notable feature of Marshall and Warren's discovery was the fact that gastric bacteria had been observed for decades but largely ignored. Now as the relationship between these bacteria and gastrointestinal conditions is becoming clearer, this "old" evidence is suddenly interesting. In this situation, a brief discussion of past history helps to contextualize the more recent advances discussed in the main body of the

review. The main body of the review is then organized not by chronology, but around those advances.

Whether you are writing a review article or the literature review section of a proposal or report, use basic principles of good writing as your guide:

- Introduce your discussion by establishing the significance of the topic. It is helpful to give a quick preview of the major trends or topics to be covered in the review.
- Organize the body of the review to reflect the clusters or subtopics you have identified, using headings if the review is lengthy.
- Use topic sentences at the start of paragraphs and sections to highlight similarities and differences and points of agreement and disagreement.
- Conclude with an overview of what is known and what is left to explore.

Notice that the headings in Blaser's review identify the major subtopics he covers (e.g., "Microbiologic Characteristics of *Campylobacter pylori* and Related Organisms"; "Pathological Associations With Gastric *Campylobacter*-like Organism Infection"). These *topical* or *content* (Swales 2004) headings are quite different from the *functional* headings of the IMRAD form followed in research reports. The IMRAD headings—introduction, methods, results, and discussion—let readers know what function each section of the report serves: the introduction introduces, the methods section describes methods, and so forth. Functional headings are useful because they enable readers who are familiar with a standard format to quickly locate the kinds of information they expect the document to include. But unlike the research report, the review article is rarely subdivided by function and therefore follows no standard functional format. Some reviews will include an explicit description of the methods by which studies were selected for inclusion (which may or may not be labeled as a separate functional section), but in general, the sections within the body of a review all have the same goal or function: to review research. Each section does, however, describe a distinctive trend, feature, or area of that research, and headings should be used to highlight those subtopics (CSE 2006). Thus, in a research review, headings signal shifts in the focus or content of the discussion.

A striking example can be found in the background section of the research proposal by Burkholder and Rublee (1994) in Chapter 10 (see pages xxx-xxx). Burkholder and Rublee's first two headings summarize not just the major areas of research they will describe but the major claims they are basing on that research: that a linkage between fish kills and *Pfiesteria* has been established, and that highly specific molecular probes are needed to detect the pathogen. In this text, topical headings are used to outline the "plot" or argument of the review (Myers 1991).

EXERCISE 5.6

Carefully examine the headings that Rublee et al. have used to organize their 2005 research review in the *Journal of Eukaryotic Microbiology* (reprinted in Chapter 10). Use the title and abstract of this review to help you understand its focus and primary goals. Given this agenda, how would you characterize the major subdivisions in this article (Application of Methods, Sequence Analyses, Conclusions)? Are these functional headings, topical headings, or a mix?

5.7 CITING SOURCES IN THE TEXT

The Council of Science Editors identifies three primary citation systems used in scientific journals: name-year, citation-sequence, and citation-name (CSE 2006). A glance at the reference lists of journal articles in your field will reveal which system or systems are conventional in your research community. This information will also appear in the instructions to authors, typically posted along with editorial goals and guidelines at the journal's website

and/or published annually in a hard-copy issue of the journal. Full descriptions of these documentation systems can be found in comprehensive style guides such as the CSE's *Scientific Style and Format*, now in its seventh edition (2006) or the National Library of Medicine's *Citing Medicine: The NLM Style Guide for Authors, Editors, and Publishers* (Patrias 2007). Some journals will simply refer you to a pertinent style manual for guidelines on handling citations. Others will include samples of their required citation and reference formats in their instructions to authors. For example, the journal *Gastroenterology*, in which Blaser's review was published, uses a citation-sequence system and provides sample reference entries at its website (http://www.gastrojournal.org/ authorinfo#prep). *The Astrophysical Journal*, where the Reynolds team's Kepler report appeared, uses a name-year system and provides extensive guidelines for citing sources (http:// www.journals.uchicago.edu/page/apj/instruct.html). Our descriptions here are based on the guidelines compiled by the CSE (2006).

Figure 5.3 illustrates how references are cited in the text in these systems (these are called "in-text citations" or "in-text references"). Under the **name-year system**, which we are using in this textbook, any sources referred to in the text are identified by the author's last name and the date of publication. These sources are then listed alphabetically in the list of references or works cited at the end of the text. This system is followed in such journals as the *Journal of Eukaryotic Microbiology, The Astrophysical Journal*, and *Geology* (see sample articles in Chapters 10–12).

The **citation-sequence and citation-name systems** differ only in the order in which sources are listed in the reference list at the end of the paper. Under the **citation-sequence** system, cited sources are listed and numbered in the order in which they are mentioned in the text, whereas under the **citation-name** system, all cited sources are listed alphabetically at the end of the text and then numbered in that order. In either case, the resulting numbers are used as identifiers for citations in the text itself. Numbers may be inserted in superscript (above the line) or in parentheses, depending on journal style and software capabilities. Of the journals represented in this textbook, the citation-sequence system is used in *Nature, PNAS, Clinical Toxicology, Science*, and in the four medical journals: *Annals of Internal Medicine*, the *Lancet, Gastroenterology*, and the *British Medical Journal* (see sample articles in Chapters 9–13). Journals using the somewhat less common citation-name system include the *Journal of Bacteriology* and the *Journal of Scientific Computing*. (You'll be able to recognize this system quickly by checking the list of works cited to see if the numbered sources are listed alphabetically.)

Sample In-Text Citations

Name-Year System

Example A

Oldach et al. (2000) also utilized a heteroduplex mobility assay (HMA) for detection of *Pfiesteria* species.

Example B

We used the nonequilibrium-ionization (NEI) version 2.0 thermal models, based on the APEC/APED spectral codes (Smith et al. 2001) and augmented by addition of inner-shell processes (Badenes et al. 2006).

Citation-Sequence or Citation-Name System

Example C

Gastric bacteria now are being observed with regularity (2–4), and recently, Marshall and Warren (5,6) were able to isolate a spiral bacterium that had never been cultivated before.

Example D

Recent studies have suggested that the eradication of *Helicobacter pylori* infection affects the

natural history of duodenal ulcer disease such that the rate of recurrence decreases markedly (2–6).

Example E

A worldwide increase in toxic phytoplankton blooms over the past 20 years[1,2] has coincided with increasing reports of fish diseases and deaths of unknown cause.[3]

FIGURE 5.3 Sample in-text citations from the following sources included in Chapters 9 through 12: A. Rublee et al. (2005); *B*. Reynolds et al. (2007b); *C*. Blaser (1987); *D*. Graham et al. (1992); *E*. Burkholder et al. (1992). Sample reference list entries for A–D are presented in Figure 5.5.

In addition to the basic form of the citation, the examples in Figure 5.3 illustrate a number of other variations in citation practices, as described below.

DIRECT VERSUS INDIRECT CITATIONS. Authors may be identified directly in the text, as in Examples A and C of Figure 5.3, or they may be cited indirectly, using parenthetical or numerical identifiers as in Examples B, D, and E. That is, the citations may be integral or nonintegral to the structure of the sentence in which they are mentioned (Swales 1990). Swales (1984) notes that direct or integral citation focuses discussion on the researcher(s) who did the work; in contrast, indirect or nonintegral citation features the research claim or finding as the subject of the sentence and thus focuses attention on the research itself. Writers use these different "reporting formulae" not only for variety but also to emphasize the contributions of individual researchers or to highlight trends in the research.

In fact, the use of reporting formulae can become a strategic dimension of a scientific argument. In a section titled "Modern Controversies" in their *Clinical Toxicology* piece, Spiller, Hale, and De Boer (2002) discuss one researcher, Amandry, by name, but they use indirect citation to refer to similar conclusions by several other archaeologists (see page xxx). Spiller et al. hold Amandry responsible for discouraging scientific interest in the Gaseous Vent Theory in the 1950s, a theory that their new evidence now supports. Using direct citation in this instance enables the authors to focus attention (and, in this case, blame) on this particular scientist's conclusions, underscoring their argument that ancient accounts of the oracle had been wrongly discounted. Highlighting the role of this individual researcher and downplaying the line of research he represents makes it easier to discredit this work, for it comes across as the mistaken assumption of one man.

The practice of direct citation is more often used to allocate credit than to place blame, however, as can be seen in the introduction to the letter by Marshall (Warren and Marshall 1983) contained in Chapter 9 (pages xxx-xxx). Note how Marshall uses direct citation when highlighting the fact that earlier researchers had observed bacilli in the stomach lining of ulcer victims, a finding that supports Marshall and Warren's own claim. But Marshall uses indirect citation when reporting the fact that other researchers failed to confirm those observations or recognize their importance. The effect of indirect citation here is to downplay the negative findings of these other researchers. These two examples illustrate the potential impact of stylistic choices such as reporting formulae.[1]

As the Amandry example illustrates, it is conventional to refer to authors by last name only when using direct citation; first names and titles are not included. Once you have included the authors' names in the sentence, it is unnecessary (in fact redundant) to include them in the parenthetical citation. If you are using the name-year system, insert only the date of the source in parentheses immediately after any author mentions in your text, as in Example A of Figure

[1] In reviewing and citing, scientists indicate what work they consider valuable as well as what work remains to be done. In so doing, they are engaging in what might be considered "epideictic" argument, or the rhetoric of praise and blame (see Sullivan 1991), one of three types of classical argument that we will talk more about in Chapter 7. For further discussion of how scientists use citations strategically, see Latour (1987) and Paul (2000).

5.3. In the citation-sequence and citation-name systems, the numerical identifier remains the same in direct and indirect citations.

PLACEMENT OF INDIRECT CITATIONS. Indirect citations appear most frequently at the end of a sentence, as in Examples B, D, and E, but they are also commonly found at the ends of clauses or phrases (Examples B and E). A parenthetical or numerical citation should be inserted immediately after the statement, word, or phrase to which it is directly relevant (CSE 2006), so that it is clear to readers which part of your claim or observation is based on that particular source.

CITING WORK BY MULTIPLE AUTHORS. Whether you are citing directly or indirectly, always acknowledge all the authors of a work. If the cited work has two authors, include both names, as in Example C. For works with more than two authors, use *et al*., as in Examples A and B. An alternative form suggested by the Council of Science Editors (2006) is to replace the Latin abbreviation with the English equivalent: "Koyama and others (1995)."

EXERCISE 5.7

Compare a research report or proposal using the name-year citation system with one using the citation-sequence or citation-name system. What do you notice about the effects of these different systems on your reading? List the advantages and disadvantages of each of these approaches.

EXERCISE 5.8

Obtain copies of the instructions to authors for three major journals in your field. What citation systems do these journals follow? What style guidelines do they offer? Which style manuals are recommended? Where can these manuals be found on your campus? Are they available online?

5.8 PREPARING THE LIST OF WORKS CITED

Any sources cited in your text should be included in a reference list, alternatively called a works cited list, at the end of the paper. The general format for journal references is basically the same in the three systems, except for the placement of the year of publication. In the name-year system, the year of publication must appear directly after the authors' names, so that references can be easily recognized from their name-year citations in the text. In the citation-sequence and citation-name systems, the year appears later in the reference. The basic formats for print and Internet references, as prescribed by the Council of Science Editors, are presented in Figure 5.4.

Focusing first on references to standard print journal articles, we've reprinted some sample reference entries in Figure 5.5. You'll notice that though the general ordering of reference components is relatively consistent, some formatting details vary from journal to journal. For example, though CSE's format includes the issue as well as the volume number, issue numbers tend to be omitted if pagination is continuous throughout a volume. You'll find that some journals require first and last page numbers; others allow only the starting page number. Some put dates in parentheses; others do not. Some journals will limit the number of author names; others will not. (The *NLM Style Guide* now requires that all authors be listed [Patrias 2007]. *Astrophysical Journal* allows only up to eight authors in a reference entry; articles with more than eight authors are listed by first author only, followed by "et al." [http://www.journals.uchicago.edu/page/apj/instruct.html].) Some reference formats omit article titles altogether, as in Example B in Figure 5.5. Most journals do not use quotation

marks around article titles in references (but some do!). Punctuation around authors' initials and journal title abbreviations varies across journals, as does capitalization and the use of italics and boldface. The bracketed content designator in Fig. 5.4 allows you to indicate if the article is something other than a research report, e.g., an editorial or a research review; such information may or may not be required by your journal. The format of in-text references varies as well: some journals require a comma between name and year in parenthetical name-year citations, others do not.

Though these differences may seem arbitrary, in most cases the modifications were adopted in an effort to save space, enhance consistency, or make typesetting processes more efficient. Unfortunately, journal staffs have tended to experiment with these modifications independently, making a common set of rules difficult to maintain. For this reason, even if you're following the general formatting guidelines in Figure 5.4, it is important to read the journal's instructions to authors and to use a sample reference list from the target journal as a model.

Components of End References

Print Journal Articles	
Name-Year System	Citation-Sequence/ Citation-Name System
Author(s) Date Article title Journal title [Content designator] Volume/Issue Location (Pagination)	Author(s) Article title Journal title [Content designator] Date Volume/Issue Location (Pagination)
Internet Sources	
Name-Year System	Citation-Sequence/ Citation-Name System
Author(s) Year of publication Article title Journal title [Medium designator] [Date updated; date cited] Volume/Issue Location (Available from: Internet address)	Author(s) Article title Journal title [Medium designator] Year of publication [Date updated; date cited] Volume/Issue Location (Available from: Internet address)

FIGURE 5.4 Components of end references for journal articles and Internet sources. Based on CSE (2006), guidelines 29.3.6 and 29.3.7.13, pp 504, 557–558.

Sample References

Name-Year System

Example A

Oldach, D. W., Delwiche, C. F., Jakobsen, K. S., Tengs, T., Brown, E. G., Kempton, J. W., Schaefer, E. F., Bowers, H., Steidinger, K., Glasgow, H. B. Jr., Burkholder, J. M. & Rublee, P. A. 2000. Heteroduplex Mobility Assay guided sequence discovery: elucidation of the small subunit (18S) rDNA sequence of Pfiesteria piscidida from complex algal culture and environmental sample DNA pools. *Proc. Natl. Acad. Sci. USA*, 97:4303–4308.

Example B

Smith, R. K., et al. 2001, ApJ, 556, L91

Citation-Sequence or Citation-Name System

Example C

2. Steer HW. Ultrastructure of cell migration through the gastric epithelium and its relationship to bacteria. J Clin Pathol 1975:28:639–46.

Example D

2. Coghlan JG, Gilligan D, Humphries H, McKenna D, Dooley C, Sweeney E, et al. Camplyobacter pylori and recurrence of duodenal ulcers—a 12-month follow-up study. Lancet. 1987;2:1109–11.

FIGURE 5.5 Sample references from the following sources included in Part 3: A. Rublee et al. (2005); B. Reynolds et al. (2007b); C. Blaser (1987); D. Graham et al. (1992). In-text citations are presented in Figure 5.3.

As outlined in the lower half of Figure 5.4, Internet citations differ from the formats specified above primarily in identifying the Internet as the medium and including the URL and copyright date, if available, as well as the date the material was accessed and cited. Because web materials can be continually updated (and even discontinued), the date cited serves to identify which version of the source you read—in effect rendering a potentially transitory source permanent by fixing it in time. Sample Internet references from CSE are reprinted in Figure 5.6.

We have focused on citing journal articles in this chapter, but of course scientists make use of many other types of source material as well. For guidelines on formatting references to other types of sources, such as conference proceedings, technical reports, monographs, chapters in books, and homepages and other online sources, consult the appropriate style manual in your field or find an example in the reference list you're using as a model. Style manuals will also provide guidelines for citing multiple articles by the same author, citing authors with the same last name, citing organizations as authors, citing unpublished work, and many other documentation variables.

Citing Journal Articles from the Internet

Name-Year System

Savage E, Ramsay M, White J, Beard S, Lawson H, Hunjan R, Brown D. 2005. Mumps outbreaks across England and Wales in 2004: observational study. BMJ [Internet]. [cited 2005 May 31]; 330(7500):1119–1120. Available from: http://bmj. bmjjournals.com/cgi/reprint/330/7500/1119 doi:10.1136/bmj.330.7500.1119

Citation-Sequence or Citation-Name System

1. Savage E, Ramsay M, White J, Beard S, Lawson H, Hunjan R, Brown D. Mumps outbreaks across England and Wales in 2004: observational study. BMJ [Internet]. 2005 [cited 2005 May 31]; 330(7500):1119–1120. Available from: http://bmj. bmjjournals.com/cgi/reprint/330/7500/1119 doi:10.1136/bmj.330.7500.1119

FIGURE 5.6 Sample CSE reference entries for journal articles from the Internet (CSE 2006, pp 557–558).

5.9 THE RESEARCH REVIEW ABSTRACT

Finally, if you are writing a review article—as opposed to a review section embedded in a research report or grant proposal—you will also need to prepare an abstract summarizing the focus and scope of the project. As we noted in Chapter 4, the abstract is a contingent genre; that is, its form is contingent upon the form of the paper it is intended to represent. Your review abstract may be either informative (summarizing the trends you observed in the literature and the conclusions of the review) or indicative (identifying the topics you will cover but not what you found). Check the journals in your field to see which is preferred. In either case, the abstract should preview the major topics under which you have organized the review itself.

EXERCISE 5.9

Read the abstracts for Blaser's (1987) review article (see page xxx) and/or the abstract for the review by Rublee et al. (2005; see page xxx). What major topics does the abstract highlight? How does this set of topics map onto the content and structure of the review itself? Is this an informative or indicative abstract? Write an alternative abstract in the other mode.

Activities and Assignments

1. Choose a research report on a topic in your field. Read the introduction carefully. Find three to five of the works cited in this section. Write a one-paragraph summary of each cited paper and a one-sentence explanation of why it is cited in the review.
2. Conduct an electronic search on a topic in your field or a topic assigned by your instructor. You may want to limit your search to the 10 to 15 most recent publications. Find and read as many of the sources as you can. Summarize the critical features of these studies in a grid that you could use to plan a literature review on the topic.
3. Use the grid you developed in Activity 2 to help you write a two- or three-page review of recent research on a topic in your field. Follow a citation format appropriate for a primary journal in your field.

CHAPTER

6

Preparing Conference Presentations

6.1 THE ROLE OF RESEARCH CONFERENCES IN THE SCIENCES

Although this book is primarily concerned with writing, much if not most day-to-day communication in science occurs orally in informal discussions, lab meetings, and seminars, as well as more formal participation in professional conventions—all of which may take place face to face or, increasingly, via virtual media such as Webinars, teleconferences, and Second Life. In fact, these newer communication technologies are extensions of traditional modes of socializing and communicating (Weaver and Morrison 2008), and thus rely on many of the techniques and strategies for oral and visual presentation discussed in this chapter. While online social networking has become a popular and even conventional form of social gathering (Weaver and Morrison 2008), it is through oral, more personal modes of interacting that much of the work of science gets done.

No matter what the medium, the ability to interact and orally communicate with other scientists is essential for scientific progress. At a time that would later be recognized as the beginning of a technological revolution in scientific communication, Reif-Lehrer noted that for an individual to participate in the knowledge-sharing and consensus-building business of science, publication is not enough (Reif-Lehrer 1990). Conferences therefore represent another formal mechanism that, like the journal article discussed in Chapter 4, has developed to facilitate the exchange of scientific knowledge. Like research journals, conferences vary in size, scope, and audience. Most are sponsored by professional organizations whose membership and areas of interest vary widely. For example, an ecosystem science student Bethany Ryan reports that researchers in her field belong to several associations in environmental and related sciences, such as the Society for Environmental Toxicology and Chemistry, the International Society of Environmental Forensics, as well as the International Phytotechnology Society, the American Chemical Society, and the American Society for Microbiology. Most groups meet annually, allowing researchers to present recent results directly to others in their field even before studies appear in print. Conferences thus provide

opportunities for immediate feedback from other researchers, often on work in progress. Local or regional conferences, as opposed to national or international ones, play different roles in different fields. For example, a local or regional conference may be especially designed to address scientific issues specific to that region. Learning about these roles is an important part of the socialization of a new researcher.

Regardless of the medium, location, or venue, a scientist's personality and interpersonal skills come into play in oral modes of communication, perhaps more directly than in writing. We saw in the case of Barry Marshall in Chapter 1 that a scientist's personality and style are an important dimension of conference presentations and of scientific communication generally (see Chazin 1993; Monmaney 1993; SerVaas 1994). As Peter Raven, former Home Secretary of the National Academy of Sciences, states: "In contrast to published manuscripts, oral presentations establish personal contact with an audience. The favorable or unfavorable impression created through this contact often permanently shapes a scientist's reputation—a reputation that can either help or haunt the scientist for the rest of his or her career" (Anholt 1994, p ix). Of all the oral modes of communication, the conference presentation is the most formal and structured, and therefore it is more explicitly governed by generic conventions that can be studied.

Professional conferences, virtual or physical, are an important part of your career. Most scientists present their research at several conferences in their field per year. They attend conferences to share information, get feedback on new ideas or ongoing research, catch up with the latest developments in the field, and create professional relationships—to "network." Conferences provide a more immediate means for scientists to share new research or research in progress, typically before it is even published. Probably the best way to learn about conference presentations is to attend a few professional conferences yourself. If you have not already done so, make plans to accompany your professors and/or peers to a meeting in your field. Observe the format and conventions of talks, technological demonstrations, or poster sessions. Do presenters speak from notes, from visual aids, or from prepared texts? What kinds of visuals are common (tables, graphs, photographs), and what kinds of equipment are used (for example, are PowerPoint slides the norm?) What is the time limit for presentations, and is it strictly enforced? How are the presentations organized? How are they different from written research reports?

In this chapter, we'll focus on two presentation modes common in the sciences: the oral presentation, often referred to as the conference "talk" or "paper"; and the research poster. We offer here some basic principles that will help you investigate the conventions for presenting research in either mode at conferences in your field.

EXERCISE 6.1

An easy way to find out about important conferences in your research field is to take notice of conference announcements posted in your department and to pay attention to the details when your professors, lab directors, or teaching assistants go out of town to present papers. Ask where they went, whom they spoke to, what kind of work they presented. Borrow their conference programs or find the program at the sponsoring association's website. Read these materials to get a sense of the kinds of topics the meeting covers and the kinds of sessions scheduled. What are the major differences of audience, purpose, content, and format of the different conferences you are examining? In class, or in a short paper, discuss why you would attend one over another.

6.2 WRITING CONFERENCE PROPOSAL ABSTRACTS

We discussed the writing of abstracts for research papers in Chapter 4. You'll recall that the generic abstract summarizes the major points of the research report in four moves: purpose,

method, results, implications. The same is generally true for conference proposal abstracts. For example, in their "Abstract Submission Guidelines" for their 109th General Meeting, the American Society for Microbiology requests that the one-paragraph abstract proposals contain background, methods, results, and conclusions ("Content" 2008); note that ASM's descriptions of the contents of these sections thus exactly mirror the IMRAD form. Also contained in this call for abstracts is a lot of attention and detailed instructions under the heading "Key Submission Elements": formatting, style, graphs and tables, number of characters, contact information, subject category, keywords, student travel grants, as well as "Content." In addition to instructions and options for electronically coding the abstracts, further attention is paid to the deadlines for submission and to the submission procedures themselves, which in 1999 became completely web-based. All these requirements are essential in the electronic submission of an abstract to ASM; failure to adhere to these guidelines may result in your abstract being rejected (automatically, by the website!).

In Figure 6.1, "Criteria for Abstract Acceptance," ASM lists its scientific and presentation criteria for accepting abstracts, as well as reviewers' reasons for rejecting them. In their submission guidelines not shown in Figure 6.1, ASM also states that there will no time for rejected abstracts to be appealed or resubmitted. Likewise, ASM, like most conference organizers, does not edit or proofread proposal abstracts, which are reproduced in conference programs exactly as they are submitted. Thus, the abstract you submit to a conference must be ready for publication. While not all calls for abstracts provide as much detail as the ASM, any guidelines that are provided should be adhered to with great care. Conference proposals are typically reviewed under a tight schedule. As ASM points out in Figure 6.1, abstracts that do not meet the criteria are excluded from the review pool altogether. As indicated in their "Abstract Submission Guidelines" (2008), so too are abstracts that exceed a stipulated length.

1. The main factors considered by the Scientific Program Organizers in qualifying abstracts for acceptance are:
   - The quality of the research;
   - The importance/significance of the topic to the conference;
   - The content of the abstract;
   - Adherence to submission criteria.
2. Abstracts may be rejected by the reviewers for the following reasons:
   - No Hypothesis—The abstract does not clearly indicate the reason for conducting the research and the question being tested by the experiments performed;
   - Inadequate Experimental Methods—The investigators failed to describe procedures used or neglected to include important or essential controls;
   - Insufficient Data Presented—The investigators failed to show the outcome(s) of their research. Insufficient data are presented to support the authors' conclusion(s);
   - No Summary Form of Essential Results—The investigators failed to concisely summarize the result(s) of their research;
   - No Conclusion—The investigators failed to describe the conclusions of their research with regard to the hypothesis being tested;
   - Duplicate Abstract—The abstract contents substantively overlap with contents of another submitted abstract by the same author or co-author. Only the last version of the abstract will be considered (based on the completion of time recorded in the Oasis system);
   - Not Appropriate for the Conference—The content of the abstract is not relevant to the topic(s) of the Conference;
   - Promotional in Nature—The abstract was written to promote a specific product or procedure on behalf of a specific company or organization;
   - Poorly written—Improper use of the English language renders the abstract incomprehensible.

FIGURE 6.1 "Criteria for Abstract Acceptance." American Society for Microbiology (2008).

We have included this section on conference abstracts at the beginning rather than the end of this chapter because, while abstracts for research reports are almost always written last,

abstracts for conference papers are often written "*before* the paper is written, indeed sometimes even before the work itself is done" (Olsen and Huckin 1991, p 369). Olsen and Huckin describe this type of abstract as "promissory." In promissory abstracts, the research purpose and methodology are described, but results and implications may be projected or occasionally omitted entirely. In some cases, an overview of prior or preliminary results is provided.

In Figure 6.2 we have reprinted two sample promissory abstracts on cold fusion from the 2006 Annual Meeting of the American Physical Society (APS 2008a). Notice that these abstracts contain sufficient detail for reviewers and readers to know what will be discussed, even though the research may be incomplete and ongoing. Instead of detailing the new findings (which at this point in the research may be at least partially unknown), these promissory abstracts announce what types of information will be included in the presentation.

Though promissory moves are common in conference proposals, it is important to note that some organizations discourage this practice. In fact, ASM's guidelines explicitly prohibit the use of such predictive statements. ASM stipulates that "data should be summarized and enough presented to allow reviewers to judge the content," and states that "Generalizations such as 'will be discussed' or 'will be presented' are not acceptable" ("Abstract Submission Guidelines" APS 2008a). In doing so, the ASM explicitly requires informative abstracts much like the report abstracts described in Chapter 4 and explicitly bans promissory moves as less useful to reviewers.

Abstract: W421.00001: Cold Fusion—A 17 Year Retrospective

Michael C.H. McKubre, Francis L. Tanzella (SRI International, Menlo Park, CA)

Seventeen years after the APS voted to refute the reality of Cold Fusion in Baltimore, it is appropriate to consider what has changed. Who was right? We will review the current state of knowledge from the perspective of what we know now compared to what we knew then. Discussion will be made of various avenues of research that have followed from the original Fleischmann-Pons proposal: some failed, some unresolved and some successful.

Abstract: W41.00011: Comments on Summary of Condensed Matter Nuclear Science

Xing Z. Li, Bin Liu, Qing M. Wei (Department of Physics, Tsinghua University, Beijing, 100084, China.)

Shu X. Zheng, Dong X Cao (Department of Engineering Physics, Tsinghua University, Beijing, 100084, China)

Research involving investigations of the production of tritium in electrolytic cells was a topic that was recommended by the Energy Research Advisory Board (ERAB) report of the U.S. Department of Energy (DOE) in November 1989. Fifteen years later, the evolution of related research has proven that this was an important recommendation. In the talk, a selective resonant tunneling model is used to attempt to explain the initial discoveries of tritium production. Deuterium flux might play a key role for solving the problem of reproducibility. A further investigation is suggested based on this model.

FIGURE 6.2 Two promissory abstracts from Session W41—Cold Fusion, American Physical Society Meeting (March 2006).

Unlike ASM, the American Physical Society (APS) does not prescribe the content of the abstracts, nor does it specify whether proposals may include promissory statements (see http://www.aps.org/meeting/abstract/policy/cfm.html). APS contributors select a meeting they wish to attend and submit their abstract via the Internet; they need not use LaTex unless they need special symbols (APS 2008b). The AAS/AAPT, to which Reynolds et al. (2007a) submitted the abstract contained in Chapter 12, also requires submitters to upload their abstract via the Online Abstract Submission and Invitation System (OASIS). Note, however, that the sample abstracts in Figure 6.2, as well as the Reynolds et al. abstract in Chapter 12, seem to follow the general structure of the IMRAD form; this form can help you write abstracts when

the content for proposals is not delineated. Also note that while the Reynolds et al. AAS/AAPT proposal abstract does not contain references or include explicit acknowledgments of lab or funding sources, the APS abstracts do. Such acknowledgments are not necessary in a research report abstract (because this information appears elsewhere in a printed article). But remember that the conference abstract is often the only written version of your paper that conference attendees will see; thus, it is conventional in many organizations to include these critical acknowledgments. As the contrasts between ASM, APS, and AAS/AAPT expectations illustrate, however, conference organizers, like journal editors, establish their own guidelines. As a consequence, the critical features of conference proposals vary across and within fields. Always check the organization's call for proposals before submitting.

In proposal abstracts, as in all the work you do as a scientist, hypotheses, methods, results, and implications must be logical and reasonable to professionals in your field, as well as appropriate to the conference. Since the abstract is the document conference organizers use to select the presentations to be given, it goes without saying that these abstracts must be exceedingly well written. The guidelines from the ASM make this absolutely clear.

Conference proposal abstracts are often reproduced in print or electronic form prior to the meeting at which the presentation will be made. After the meeting, many organizations also publish selected "proceedings," which consist of extended summaries or even the complete texts of some or all of the presentations themselves. Check the conference guidelines to understand how papers will be selected and what the final form of the proceedings will be. Will you need to write up your presentation in the form of a conference paper after it is delivered? In effect, some conference proceedings are a hybrid document, for the paper intended to be delivered orally may wind up as a print or electronic text document. Often revision, as well as a full documentation of sources, is necessary for the publication or posting of a previously delivered paper in conference proceedings.

EXERCISE 6.2

In Chapter 11 we have reprinted the abstract of a talk given by Hale and his colleagues at the 103rd Annual Meeting of the Archeological Institute of America (page xxx). Analyze the structure of this abstract. Does it include the standard IMRAD components? If so, where? How much attention does each component receive? How does the structure and logic of this abstract compare to the structure and logic of the journal articles you've read from this team (pages xxx–xxx and xxx–xxx)? Are there any "promissory" moves in this abstract?

EXERCISE 6.3

Make a list of conferences in your field, and select one you'd be interested in attending. Obtain the conference guidelines and copies of sample abstracts, perhaps from the previous year's posted program. Read over the conference instructions, and look at the logic and structure of the sample abstracts. Do these abstracts tend to include "promissory" statements? Are the abstracts overall more informative or descriptive? Describe the distinctive features of these abstracts, such as length, format, use of references, and acknowledgments of funding sources.

6.3 ORGANIZING THE RESEARCH TALK

It is important to recognize that the conference presentation, like its written counterpart, the journal article, is primarily an act of persuasion, not simply of fact dissemination. As we noted in Chapter 4, when presenting results to other scientists, researchers seek to convince their audiences that their research questions are important, their methods sensibly chosen and carefully carried out, and their interpretations of results sound—in short, that their work represents a valid contribution to the developing knowledge of the field. Like the author of a

journal article, a scientist presenting his or her research at a conference must build a convincing case for the project. The primary difference is that it must be done quickly—often within 10 minutes—and without the benefit of a formal written document in the reader's hand.

Because of the strict time constraints, scientists carefully plan oral presentations to ensure that the essential parts of the research argument are included. As in the written report, you will need to report your research questions, methods, results, and conclusions; but the amount of attention devoted to each component is somewhat different in the oral presentation. You will not have time for an extensive review of literature or a detailed description of your experimental methods—that is, unless purpose of your presentation is to introduce a new method. Instead, you will want to devote as much of your brief time as possible to reporting your new results and discussing their implications.

Thus, the first two components of the IMRAD form are rather abbreviated in the conference presentation. State the purpose and rationale for your study quickly but clearly at the start. The standard three-part intro described in Chapter 4 provides a useful framework for conference paper introductions as well: announce the topic and briefly overview trends in previous research, explain the gap or question raised by that research, and state the purpose of your study. Though the first two moves will be abridged in the interest of time, the purpose statement is often expanded in an oral presentation to more fully outline for the listening audience the research to be presented or the major ideas to be discussed. Some written reports also provide this sort of preview for readers (see Figure 4.3 on p xx), but it is particularly important in the conference setting because listeners cannot "turn back" later to the first page to see what your main point is. Thus, in addition to announcing the purpose of the study, introductions to oral presentations have the added burden of orienting the audience to the organization and scope of the presentation itself.

Carl Blackman (1997), a biophysicist at the EPA's National Health and Environmental Effects Research Laboratory, told us an interesting story that highlights the importance of the orientation function of the introduction. Early in his career, while preparing a conference talk Blackman discovered that his data would take less time to describe than he had expected, leaving his presentation rather short. To fill the time, he finished his introduction by elaborating on the structure of the presentation itself, telling his listeners in some detail what he was going to talk about. After talking about the data, he also summarized what he had said. To his surprise, the president of the society hosting the conference and others attending his session told him that this presentation was one of the clearest presentations they had heard, and one of his best. Taking time to orient the audience can be well worth the effort.

After your introductory remarks, briefly outline your research design, identifying who or what was studied under what conditions (or where); but unless your research focuses on methodological issues, save the details for later. A slide or overhead transparency outlining the essential features of your design can be very effective in communicating this basic information quickly. A conference audience is not going to replicate an experiment on the basis of a talk alone, so listeners do not need the comprehensive description of materials and methods required in the written report. Interested listeners will ask for further information during the question-and-answer period after the session.

Spend most of your allotted time describing the results of your study, illustrating your presentation with carefully prepared visuals that clearly highlight the major trends in your results. If you are presenting a series of findings, it may be helpful to spend some time discussing the implications of each finding while the visual is still on the screen, rather than saving all your discussion comments for later. In any case, you will want to prepare your concluding comments with great care, as this is the part of your talk that is most likely to be remembered. Attention typically wanders during the course of a presentation (distractions, fatigue, and cogitation can all affect the attention span of your audience), but it returns when listeners sense the speaker is wrapping up (Olsen and Huckin 1991). Since the introduction and concluding sections of your talk are when you have your audience's greatest attention, take

extra care in preparing these sections, and deliver them slowly and clearly. Stressing the importance of these sections, Gurak (2000) recommends actually memorizing an outline of your introduction and conclusion; you may also wish to write out these sections. We will discuss presentation options next.

6.4 METHODS OF ORAL PRESENTATION

Scientists employ a variety of oral presentation techniques, depending not only on the customary practices of their fields but also on such variables as the type of topic and its reliance on visual as opposed to verbal explication, the length of time allowed for the presentation, and the speaker's own experience, comfort level, and familiarity with the material. Physicist Stephen Reynolds, some of whose work is contained in Chapter 12, reported to us that he never writes out a talk. Instead, he practices his talks several times beforehand, giving careful thought to how the presentation will begin and end; he then works from his slides when presenting.

Researchers use prepared text and notes to varying degrees when presenting. Early in his career, EPA biophysicist Carl Blackman (1997) used to prepare scripts for his talks. Blackman wrote out his introduction, indicated which slides he would present in which order, and scripted some of his commentary on the slides. He believes that such scripts might be especially useful for young scientists, particularly those who do not teach and thus do not regularly practice speaking to groups.

Scripting sections of your talk beforehand can help you stay within the time limit and ensure the accuracy of your remarks. Blackman (1997) suggests that if your text is written out beforehand and rehearsed, your presentation may be better organized and more accurate, subtle, and polished in wording and argument, even if you don't read from the written script when you present. He cautions against simply reading a paper to an audience, however. When notes and texts are used, they serve as an aid or a prompt for the presenter, not as a substitute for careful practice and preparation. Blackman now prepares his talks by drafting detailed outlines, which he then condenses and incorporates into slides that serve as notes for a more extemporaneous presentation.

Both Blackman and Reynolds, then, work out their presentations ahead of time. Blackman develops a written outline; Reynolds rehearses from his slides. And both present from slides. The degree to which a presenter uses these strategies depends on his or her personality and confidence, according to Blackman, as well as on the audience, purpose, and conventions of the discipline. However, Blackman (1997) adds, "Students should not feel something is lacking if they can't do a presentation from overheads or slides; it is a skill that needs to be developed." Relying on prepared scripts can be an effective interim measure.

In actual practice, conference presenters usually combine three presentation methods: memorizing, reading, and speaking extemporaneously (German et al. 2007).

Memorizing can be useful for *short* presentations for which time limits are severe (Reif-Lehrer 1990): if a speaker sticks to the script and does not ad lib, memorizing will allow him or her to gauge the length of the talk fairly accurately; memorizing also may allow for continuous eye contact with the audience when presenting. Memorizing takes time, however, and a memorized delivery is often stilted and stiff; there also is the danger that if a speaker forgets one part, the rest of the presentation may unravel as well. Presenters rarely work entirely from memory, using it instead to help deliver short pieces of their talk or to make transitions from one part of a presentation to another.

Reading from a full text is rare at scientific conferences, as noted earlier, but speakers may prepare and read particularly critical or intricate parts of their presentation to facilitate clarity, coherence, and timing. The danger with the reading strategy is that it may hinder the speaker's ability to look at the audience. There is also the danger when reading a prepared text that the speaker's delivery will be flat and that the presentation will lack energy and variety. Scientists reading parts of their presentation must be very aware of these tendencies and make a

special effort to maintain eye contact with the audience. Experienced speakers look up between sentences or paragraphs, as well as at important or strategic points that they want to emphasize in the text. Good speakers, even when reading, also vary their rate of speed, pitch, and intonation pattern to enliven their speech and hold listeners' attention.

Speaking extemporaneously from notes or slides is the most frequently used method of presenting at scientific conferences. Speaking extemporaneously is not the same as speaking impromptu or "off the cuff," which is often required after a formal presentation during the question-and-answer period. To "extemporize" means to elaborate, usually on written notes or graphics. As the examples of both Blackman and Reynolds demonstrate, professional scientists spend time thinking about and preparing visuals and notes to elaborate on during their presentations. (In fact, Blackman goes so far as to prepare extra slides to handle questions that may arise after his talk. Blackman (1997) anticipates his audience's reaction, considers his answers and arguments, and creates "rebuttal graphics" that will provide backup illustrations and evidence; he does not present this material unless he is asked, at which time he can extemporize rather than speak impromptu because he is better prepared.)

As we have seen, extemporaneous presenters may choose to prepare a formal introduction and conclusion, but they will usually speak only from slides or overhead transparencies or from an outline of the main points and supporting subpoints. Notecards, outlines, text, or graphics can be used as "cue cards" to organize a talk and keep the speaker from rambling or straying too far from the subject. Thus, the extemporaneous presentation is a combination of reading, speaking impromptu, and perhaps to some extent memorizing, and it shares some of their advantages and disadvantages. In an extemporaneous presentation important parts may be read so that they can be worded carefully; the discussion of the visuals may be part impromptu and part memorized, while the general structure and movement of the presentation may be both in outline form and in memory. The result is a presentation that appears spontaneous but is actually based on a careful structure worked out beforehand. Extemporaneous talks thus have all the energy of a spontaneous talk but are clearer, are better organized, and fit within the time allotted. To speak extemporaneously, Blackman (1997) adds, "you have to reach a comfort zone; to get there, you might need notes, crib sheets, etc."

No matter what method of presentation is used, both Blackman and Reynolds advise that speakers time themselves. Practice your entire presentation several times at the speed you will deliver it.

EXERCISE 6.4

Turn to Chapter 9 in this textbook, and click on the link to Barry Marshall's Nobel Prize lecture. On the Nobel Prize website, you will find links not only to a podcast of the oral lecture he delivered with PowerPoint slides, but also to the PowerPoint slides themselves and to a typescript of his lecture. Compare Marshall's typescript and PowerPoint slides. How has material in the typescript been represented or reworked in the slides (that is, what has been deleted, changed, reworded, added)? Why? How difficult would it be to deliver the presentation without the slides? What is the value of preparing an outline or typescript to begin with?

6.5 DELIVERING CONFERENCE PRESENTATIONS

Although much about presenting orally is innate and physical and is influenced by factors such as the speaker's personality, voice, and physical appearance, presentation skills can be developed and improved through practice. In a well-known book on oral presentations, zoologist Robert Anholt asserts that a scientific presentation "stands or falls with delivery. . . . Delivery is important in establishing the impact a scientific presentation makes on an audience, and speaking skills can be determining factors in scientific careers" (1994, p 152). In addition to the content of the presentation, delivery speed, body language, eye contact, voice, gestures,

and the clothes you wear all influence how effectively you communicate and how professional an *ethos* you create (see Gurak 2000).

Because papers are presented orally to listeners who do not have a text and are more distant than they would be in conversation, speakers need to deliver their presentation more slowly than they would normally speak if it is to be comprehensible. This is especially true if parts of the presentation are read. German et al. (2007) state that the normal rate of speech in conversation is typically between 200 and 250 words per minute; O'Haire et al. (2007) put that rate at 120–150 words per minute, but also point out that "there is no standard, ideal, or most effective rate" (2007, p 132) for normal conversation. German et al. indicate that the difference in normal speaking rates may be related to geographical region. However, many public speaking experts recommend that presentations to large audiences average 120 to 150 words per minute, so 130 words per minute is probably a safe speed. Thus, for example, a 250-word typed page should take about two minutes to read. (To establish a good presentation speed, you can practice this yourself.) Almost all conference presentations have strict time limits for each speaker on a panel. (The APS [2008] stipulates that invited speakers have thirty minutes, with six minutes of questions; the speaking time for oral presentations based on approved abstracts is 10 minutes, with two minutes for questions [http://www.aps.org/meeting/abstract/policy/cfm.html].) Thus, it is important to try to observe time limits: it is unfair and infuriating to other speakers to have someone use up a part of their time. (Imagine trying to adjust your carefully planned 20-minute presentation to fit the 12 minutes left to you by the previous speaker[s].)

Remember, presenting orally is a different experience from reading to yourself. Whether using notes, visuals, or text, it is much easier for you to lose your place when addressing a live audience. In addition to any nervousness you may experience, you may lose your place as you extemporize or look up from reading. To make your notes, visuals, or text easier to "perform," double- or even triple-space them (as newscasters do). Pick a readable typeface. A sans-serif typeface such as New Courier is easier to read than more ornamented fonts such as Times Roman. Underline words in your notes or text that you want to emphasize, and "underline" them vocally with a change of volume or intonation when you deliver your presentation.

Unlike written presentations, oral presentations are very physical—very much rooted in the body. It is the person (not a piece of paper) who presents, the person who is the focus of attention. Thus, in delivering a conference paper, the speaker becomes a part of the presentation; and except for situations involving broadcast, the audience is live and present too. A good speaker is aware of the reactions and needs of his or her audience throughout the presentation.

One of the most important ways of doing this is to maintain eye contact with the audience. Blackman notes that, in his experience, eye contact does not occur naturally but rather comes with verbal flexibility, must be cultivated, and requires practice. There are at least four reasons to maintain eye contact with the audience during a presentation (especially when reading from notes, visuals, or text). The first is to monitor the audience: Can they hear you? Can they see the graphics? Are they following you? Do they agree with you? Do they need a point explained? The second reason is more subtle: when speakers periodically make direct eye contact with individuals, audience members are less likely to let their attention wander; psychologically, they know the speaker is watching and so will want to pay closer attention. Third, by looking at people directly, speakers establish a good rapport with them—a personal relationship of sorts, which is very important in scientific oral presentations (Anholt 1994). Finally, eye contact helps establish the speaker's sincerity and belief in what he or she is saying (can the speaker "look them in the eye" and say it?). In other words, eye contact helps establish the speaker's credibility, an important component of the scientist's *ethos* or professional character.

Of course, in oral presentations the voice is the medium of communication. Even if you use visual aids, the bulk of the presentation will be carried by your voice. Just as the typeface

has to be dark enough and the manuscript free of errors to render the text as readable as possible, so your voice has to be loud and clear enough to render your words audible. There are several variables of voice that can be improved with practice: the volume, rate, and pitch of delivery (German et al. 2007).

Volume is crucial to delivery, even with electronic amplification, for a microphone can pick up only what's coming out of the speaker's mouth. The worst presentation is a mumbled one, essentially because there is no presentation; no one can hear what is being said, even if it's brilliant. You must speak loudly enough so that those at the very back of the room can hear you. You can do a sound check before you begin your presentation by asking people in the back of the room if they can hear you.

Voice is physical, and so it is difficult to change, but it can be improved. If you are someone who naturally speaks softly, try opening up your entire vocal passage and work on pushing air up from your diaphragm as you speak; think of your whole body as a hollow instrument, and let your voice resonate in it. Sometimes people speak softly or choke up because they are nervous; we all have noticed how people get louder as a presentation goes on and nerves subside and the speaker gathers more confidence. Breathing helps. So does a glass of water. Try to channel and use nervous energy to increase your volume and your presence as you speak, rather than letting it stiffen or choke you up. If you are nervous, look into the eyes of audience members in different parts of the room. No one wants you to fail, for they are more or less a captive audience and will have to suffer with you.

In addition to the timing of a speech, already discussed, the **rate** or speed is also an important element in the effective delivery of oral presentations. Because a speaker's voice is the text, the speed at which a talk is delivered should not be so fast that listeners will not be able to follow or keep up with it. Nor should it be so slow that listeners will fall asleep. An intelligible but lively pace, with some variation in speed, is best. Some speakers tend to speed up when they're nervous. Taking a deep breath before every sentence will slow you down and calm you down—and will lend a clarity and dignity to your presentation that will do much for your confidence as you continue speaking.

Pitch, the "musical" tone of your voice, also is important in the delivery of an oral presentation, even in science (Anholt 1994). Sometimes people start speaking at a higher pitch than they normally talk because they are nervous, and then find they are uncomfortable with that pitch but are too embarrassed to change it; find a starting pitch that is natural or comfortable for you. Also pay particular attention to your intonation pattern, the musical scale, of your voice. Variety of pitch (as opposed to a droning monotone) keeps your presentation pleasant, lively, interesting, and intelligible. Intonation also can be used to highlight your key points. In fact, just as volume can be used to underline key words, phrases, or concepts, so too pitch can be used for emphasis.

Just as the voice is a verbal text, the body is a visual element. Body stance and movement, facial expressions, and hand gestures, whether intentional or not, all become part of the message being communicated and in fact often reveal a speaker's feelings toward his or her subject and audience (German et al. 2007). How do you feel about someone when they can't look you in the eye? If they hang their head and hunch their shoulders as they speak? If they keep jingling change in their pockets? If they keep twiddling their thumbs? If they have a pained expression on their face as they talk? In addition to being distracting, this kind of body language reveals much about a speaker's attitude and so becomes a part of his or her message—part of the speaker's *ethos*.

But body language, like voice, can also be used to subtly communicate parts of the talk (German et al. 2007). Purposeful body movements can visually communicate a change in the focus or direction of a discussion, as when a speaker shifts weight or changes position as he or she moves to a new topic. Hand gestures too can help a speaker emphasize key points in a presentation. While hand gestures are generally toned down in scientific presentations, they can be useful, in moderation, to reinforce important points.

Your body is a natural visual, and it is always with you. Your body is part of your professional character. There's no getting around it: an oral presentation is a self-presentation.

EXERCISE 6.5

For this exercise choose something that you have written, or a sample text from this book. For example, the Huyghe (1993) article in Chapter 10 (p xxx–xxx) would work well.

1. Read the first few paragraphs to yourself, listening to the volume, rate of delivery, and intonation pattern in your mind. Now read the paragraph out loud. Do the volume, speed of delivery, and intonation pattern best capture and express the nuances of meaning in this paragraph? Try delivering the paragraph again, varying the volume, the rate of delivery, and intonation pattern as needed, until your delivery conveys most accurately the nuances of meaning. How does the voice help communicate meaning? Deliver this paragraph out loud a few times to practice volume, rate, and pitch.
2. Now listen to someone else read the same passage, and compare your presentations. Where did he or she alter pitch, volume, or intonation? What different decisions did you make in presenting the same passage?

6.6 THE USE OF GRAPHICS IN ORAL PRESENTATIONS

It has long been generally assumed that "two channels" working together can be more effective than one channel in getting a message across and retained (e.g., Hsia 1977). Therefore, most speakers try to complement the spoken word with graphics. According to Anholt (1994), graphics are the heart of a scientific presentation. In Chapter 4 we discussed some of the more conventional graphics used in research papers; in Chapter 8 we will talk about those used by scientists to communicate with general audiences. In this section we will focus on conventions for using graphics in conference presentations, particularly PowerPoint slides.

The kinds of graphics used to represent trends or summarize results in written reports are also used in conference presentations. The difference between the two lies mainly in the amount of detail that can be accommodated in each medium. While many scientists simply reproduce the visuals from their text for use on a graphic or slide at a conference, visuals that are too "busy" are distracting and at worst confusing (Day and Gastel 2006). Tufte (1997, 2003) makes similar points about PowerPoint. If you believe this might be the case with one of your graphics or slides, consider simplifying or redesigning them explicitly for the purpose and audience of your oral presentation. Eliminate any unnecessary detail so that listeners do not have to work at literally seeing what you're talking about. With today's software programs, cleaning up graphics, most of which are or can be converted to electronic file forms, is easily accomplished.

This is certainly the case with PowerPoint slides—as long as the designer maintains control over the technology. In Chapters 2 and 3, we touched on some of the technological and ethical issues concerning PowerPoint; here we will focus primarily on some principles for creating effective slides, and integrating them into the presentation. For despite critics such as Edward Tufte, PowerPoint slides are one of the most frequently used media for creating and delivering oral presentations (O'Haire et al. 2007). A built-in tutorial or one of many books can provide you with the background you need to create a PowerPoint presentation (also see O'Haire et al., 2007 [p 151–157] for a thorough walk through the basics of PowerPoint). In the sciences, PowerPoint slides are used in lectures and classrooms, at professional seminars and conferences, and online in teleconferences and webinars. In addition to podcasts, PowerPoint presentations can be posted on websites as silent stand-alone demonstrations or as part of audio-visual presentations (visit the Nobel Prize site listed in the Additional Resources in Chapter 9 to experience the effect of each).

Perhaps one reason PowerPoint presentations have become so popular is that not only is the software relatively easy to use, but it also is a powerful visual delivery system, combining slide creation and projection, notes for the speaker, art, animation, and sound into computer software programs; speakers often use their own computer at professional meetings and conferences, which also allows them to work on their presentation right up to the time they speak. And perhaps the ease of use and power of PowerPoint technology leads to the abuse of it that Tufte notes. At the personal level of what Arnold Pacey (1983) called "the technological imperative," people go overboard with all the technological possibilities of PowerPoint because they can. Often they bury their content in ornamental or clip art, and all the bells and whistles (German et al. 2007). As Tufte (2003) notes, they also often succumb to the bullet style of slides, relying too heavily on it as a "cognitive style" when other ways of thinking are called for by the content or purpose of the material presented.

In short, Power Point can easily take over a presentation. Based on Tufte's work Figure 6.3 contains some potential pitfalls to avoid when creating PowerPoint slides that can generally be applied to the design of digital graphics in other media as well. Below are a few tips on designing effective PowerPoint slides that will supplement rather than supplant the content of your presentation. As you read these tips, you might want to refer to Marshall's slide show, accessible via the links listed in the Additional Resources in Chapter 9.

- Create an effective title page, with a short but informative title for the talk. As you may observe in Marshall's slide show, Marshall's title page is simple but informative. One also might note the occasion for the presentation (which Marshall may not have wanted to do here!), one's lab or university, and/or the date of the presentation, but these are personal stylistic choices that will be effective if they also are based on the other principles below.
- Develop material out from the center of the slide, rather than along or running off the edges. As we can see in Marshall's slides, centering helps balance the slide; we can also see that Marshall used some variation in his "Results" slide, perhaps because of the length of the line or the size of the slide, but the change is visually effective in calling attention to his argument as well.

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FIGURE 6.3 Summary Interpretation of Tufte Heuristics (D'Elia et al. 2009).

- Use highly contrastive colors for background and content, preferably from different ends of the light spectrum. A sharper contrast between background and content is essential for visibility. A yellow font against a white background is not only hard to read but painful to look at as well. For his slides, Marshall has chosen a simple and appealing blue background for his slides, with the first order of bulleted items in yellow, and second order of items (set off by dashes) in white (see hierarchy discussion below).
- Make sure slides can be seen from the back of the room (12-point font, which is the larger size of many text documents, is too small for a PowerPoint slide, even with the magnification of projection; 18+ is more the norm). The bigger the room, the larger the print has to be; many venues that have LCD projectors installed have already anticipated this need, but it is still important to make the typeface larger than usual. Obviously, in doing so, there is a point of diminishing returns, where the font is too big to fit anything meaningful onto the slide. Capitalization, as well as boldface, which many people like to use to make the text show up better, also takes up more room on the slide, and so influences the design of slides. All of these design issues need to be taken into account and balanced.
- Keep slides relatively simple and uncluttered. Don't write out your text on the slide; just bullet your major points/ideas that you will discuss orally. How many ideas/points should you put on the slide? German et al. (2007) report that experts say six lines is the maximum. In the end, the amount of content on the slide will be dictated by the topic, how much room you have on a slide, and common sense.
- Maintain a parallel syntax on each slide, and across slides insofar as that is possible. Notice that in his presentation, Marshall begins the second slide, reporting his activities with verbs (present tense, active voice, which is unusual but effective in communicating real activities); also notice that the third slide switches the pattern when it is called for by the content but maintains the syntactic and formatting pattern across similar slides.
- Create a hierarchy of bulleted items through font type, font size, color, spatial arrangement, and placement on the slide to show the relative relationship of ideas, and try to maintain that hierarchical pattern across all similar slides. The parallel formatting across all slides not only creates a uniform appearance and consistency throughout the presentation, but also makes comprehension easier as well, since readers already will be able to anticipate where they will find certain kinds of information on new slides. In Marshall's long Nobel Prize lecture we can see the pattern he has created. (Warren's Nobel lecture and PowerPoint slides also may be viewed at the URL provided in the Additional Resources in Chapter 9.) We can see that Marshall as well as Warren have learned to communicate very well indeed!
- Change the pattern when the scientific content calls for it. Note that in the fifth slide, Marshall presents a table. As Tufte (2003) rightly insists, if the data you are presenting calls for a different way of perceiving or thinking, it ought to be presented in the way that reveals the new pattern. As he states, "if displays of data are to be truthful and revealing, then the logic of the display design must reflect the logic of the analysis" (1997, p 53).

An important dimension of graphics or PowerPoint slides in an oral presentation—one often overlooked in the dazzle and discussion of the technology and software—is the actual delivery of them. In Chapter 4, we discussed how graphics must be both independent (clearly labeled) and interdependent (referenced in the text). The same applies to any graphic and PowerPoint slides in an oral presentation. A graphic without a label or slide without a title will

be less comprehensible, especially if someone in the audience misses your verbal reference to it. At the same time, your visuals and your talk are interdependent. Even a labeled graphic or titled slide should not be displayed without explanation. German et al. (2007) advise students to coordinate their slides with their talk, perhaps even presenting individual slides "one line or topic at a time" (p 202). Whether or not you have mastered the animation tools necessary to do this, the point is not to let the slide show itself get ahead of or fall behind your presentation (German et al. [2007] even discuss establishing a rhythm in changing slides so that individual slides [and your presentation as a whole] don't go too fast or too slow.) The time and attention the audience spends trying to figure out how the visual relates to what you're saying is time and attention taken away from your presentation. Take advantage of the opportunity to interact with your visuals, an opportunity unique to the oral presentation mode. Present your visual at the appropriate time in your discussion; refer to it directly ("Here are the results from the two trials"); and as you proceed, point to significant features ("As you can see in the final column, temperatures in the second trial were substantially higher than in the first"). If you are not able to highlight the image electronically, stand clear of the screen and use a pointer or a lightpen, always trying to face the audience.

Ultimately a PowerPoint presentation is still an oral presentation: "Many speakers become so enamored of generating slides that they forget that their primary mission is to communicate through the spoken word and their physical being" (O'Haire et al., 2007, p 150). The effective use of graphics and slides is an adventure with many hidden pitfalls. Remembering the relationship among you, your slides, and your actual presentation will help you keep the PowerPoint technology in its place and use it to your advantage. Like conference presentations themselves, the creation and use of graphics and slides can be improved by an awareness of the pitfalls and with practice. If they are designed well and are appropriate, graphics and slides can make complex information visually comprehensible at a glance.

EXERCISE 6.6

Take one of your assignments for this or another class and turn it into a short PowerPoint presentation. (Alternatively, you may take the list of pointers in the section above and create a PowerPoint presentation of them.) Be sure to apply the principles discussed above. Try creating a slide containing another graphic (a table, a chart, a movie), implementing the principles in Figure 6.3. What decisions did you make? What problems did you encounter, and how did you solve them?

6.7 PREPARING RESEARCH POSTERS

The increasingly popular research poster genre offers several advantages over the traditional oral presentation, for conference organizers as well as presenters. Large organizations typically receive proposals for far more conference papers than can be accommodated in the time available, despite the practice of scheduling concurrent sessions. Because many posters can be displayed simultaneously (limited only by the size of the room or hall available), conference organizers are able to accept a much larger proportion of proposals than would be possible if each presenter needed a 10- or 15-minute presentation period. The American Society for Microbiology reviewed 3600 abstracts for its 2008 general meeting, 3400 of which were placed on the program as poster presentations (ASM 2008b). Because posters "allow far more time and flexibility," they have become "the default presentation type" at annual meetings of the American Astronomical Society as well (AAS 2008b).

In addition to the logistical advantages for conference organizers, poster sessions offer presenters a chance to meet and talk one-on-one with scientists who are specifically interested in their research topic. In a poster session, presenters can field questions and provide clarification for their audience directly and immediately in a less formal setting than in the oral

presentation format. The size of the audience and the effectiveness of poster sessions depend to a large extent on how the sessions are designed by conference organizers. If posters are displayed in an out-of-the-way room or hallway, attendance can be sparse, but if they are prominently displayed and easily accessible between speaking sessions, poster sessions can offer broad exposure. The American Astronomical Society schedules blocks of time each day for poster viewing, when no other presentations are scheduled. AAS describes the poster area as the "meeting's social center, including coffee breaks and cocktail hours" (AAS 2008b). Steve Reynolds reports that at this and other physics and astronomy conferences, presenters thus are able to reach a much larger proportion of the attendees at a given meeting than are likely to be reached through a 10-minute talk in a small, remote meeting room.

Poster titles are listed in conference programs, and authors typically stand by their posters to be available for questions and discussion with conference attendees who have come to find out about their work. AAS advises presenters to post the hours when they will be available at their poster to answer questions. ASM and other conferences stipulate hours for which poster presenters must be present. At some meetings it is conventional to provide a written abstract or summary for attendees to take away with them, often including important figures and tables and always including contact information to facilitate further dialogue with the research team.

The size and format of posters vary across conferences and are constrained by the space and facilities available at the conference site. Always check for guidelines before you begin designing your poster. Most organizations provide bulletin-board space and specify dimensions for the poster itself. The ASM allows posters up to 40 × 88 inches; the American Astronomical Society provides space up to 44 × 44 inches. The poster that Reynolds et al. presented at the January 2007 AAS meeting is reproduced in Figure 6.4. We also include, in Figure 6.5, a poster presented by Burkholder and colleagues at the 2000 CDC National Conference on *Pfiesteria.*

In addition to guidelines provided by conference organizers, you'll want to adhere to general principles of effective page design when preparing your poster. As with any type of presentation, an aesthetically pleasing poster is more likely to communicate effectively (and to attract an audience in the first place) than one that is put together without regard to readers' needs. The sample posters in Figures 6.4 and 6.5 illustrate several important design principles:

- Arrange the presentation in columns within the poster or allotted bulletin-board space. A columnar arrangement is congruent with natural reading and viewing patterns, which proceed from top to bottom and from left to right (Dondis 1973). Be sure to clearly indicate the path readers are intended to take (Day and Gastel 2006), using ample vertical and horizontal margins and prominent headings. It is conventional to place an abstract or introduction in the top-left position and a conclusion in the bottom-right portion of the poster, taking further advantage of natural reading preferences.
- Use a large, readable typeface for titles and headings. Font sizes from 16-to 20-point type are recommended for body text, larger for titles and headings. Both AAS and ASM recommend that posters be readable from three to four feet away; Day and Gastel (2006) suggest the title should be readable from a distance of 10 feet. Highly visible titles ensure that conference goers can easily discern whether the project is relevant to their own research interests and thus worth a closer look. Notice in Figure 6.5 that the titles in Burkholder et al.'s densely packed poster are made clearly visible by centering them and using all capital letters.
- Clearly label figures, tables, and other graphics. Figures should, of course, be uncluttered and easy to read, but they will not need to be simplified for the poster as much as is needed in the oral presentation, because poster audiences can take as much time as they need to examine figures closely.
- Avoid large blocks of uninterrupted text. Use bulleted lists where appropriate, for example, in listing major conclusions. In Figure 6.4 you'll notice that Reynolds et al. utilize a list or numbered format in each major section of their poster.

- If previous research is cited on the poster, include a list of works cited. Notice that Burkholder et al. place their references at the bottom of the middle column, which allows them to balance the spatial layout of their visuals. Reynolds et al. place their references in a more traditional position at bottom right.
- Finally, color and variety are appropriate and desirable in posters (Day and Gastel 2006), but don't get carried away. The poster should be readable and informative, not purely decorative. Substance and clarity impress professional readers more than glitz. Many associations recommend the use of related background colors or shades as organizing elements to underscore connections between closely related portions of the presentation and to distinguish among major sections. And of course one of the main advantages of posters is that figures can be reproduced in color (in contrast to this textbook, which obscures the effective use of color in Reynolds's and Burkholder's figures).

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FIGURE 6.4 Poster presented by Reynolds et al. (2007 Jan) on their Kepler discovery at the January 2007 meeting of the American Astronomical Society.

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FIGURE 6.5 Poster presented by Burkholder et al. (2000) at the CDC National Conference on *Pfiesteria:* From Biology to Public Health, 2000.

As with all forms of presentation, you will want to notice the distinctive features of research posters in your field. Look around your department for sample posters that faculty and graduate students may have on display in offices or hallways. What types of visuals are typical? What kinds of information are included in captions? How much color is used? How much variation is there in poster size and shape? What is the ratio of visual to verbal information? You'll also want to investigate the technologies available for creating and printing posters on your campus. A number of excellent resources on preparing posters have emerged online, many of which offer practical advice on creating posters using PowerPoint or other software. See the list in Exercise 6.7 for a sampling of these sites.

To conclude, the poster presentation is in effect a hybrid form of communication, combining features of both oral and written modes. The poster session offers the immediacy of one-to-one interaction between the researcher and his or her audience—as listeners—but also provides a carefully structured formal presentation that the same audience—as readers—can peruse at their own pace.

EXERCISE 6.7

See Figure 6.6 for a rating form developed by conservation scientist George Hess that summarizes some essential features of poster design and presentation. Use this form to critique posters created for your class, and/or posters found at these or other web resources devoted to poster design:

- Creating Effective Poster Presentations, hosted by George Hess at NC State University—http://www.ncsu.edu/project/posters
- Advice on designing scientific posters, by CB Purrington at Swarthmore College—http://www.swarthmore.edu/NatSci/cpurrin1/posteradvice.htm

- Poster Presentations, by Fred Stoss at SUNY-Buffalo—http://ublib. buffalo.edu/libraries/asl/guides/bio/posters.html
- PhD Posters, developed by doctoral students at Duke University: http://phdposters.com/
- ePosters.net, The Online Journal of Scientific Posters: http://www. eposters.net/

As you examine individual posters, describe the features that you consider most effective in these presentations. What advice would you offer to the authors of these posters?

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FIGURE 6.6 Poster evaluation rubric adapted from forestry researcher George Hess's 60-Second Poster Evaluation and extended Poster Evaluation Criteria. See Hess, Tosney, and Liegel (2006), Creating Effective Poster Presentations at http://www.ncsu.edu/project/posters.

Activities and Assignments

1. Imagine you have been working as a research assistant on Jeffery Chambers's research team, investigating the effect of Hurricane Katrina on forests and the carbon dioxide sink. You have been asked to write a conference proposal abstract of the research contained in "Hurricane Katrina's Carbon Footprint on U.S. Gulf Coast Forests" (published in *Science,* and contained in Chapter 13). The abstract is to be submitted to the Estuarine Research Federation's 20th Biennial International Conference (see http://www.erf.org/erf2007/), one of several conferences sponsored by the Coastal and Estuarine Research Federation (http://www.erf.org/). Using the *Science* article to help you understand the goals, methods, and outcomes of that research, write a promissory abstract for the project.
2. A. Prepare and deliver to the class an oral presentation of a set of research findings in your field. You may choose to present the results of a study you have conducted in another class or at work. Or your instructor may suggest you practice by developing a presentation based on published research conducted by another research team. (In this case, identify the original researchers, and present yourself as a "representative" of that team.) Choose an appropriate professional conference for your presentation, and identify the target audience at the start of your presentation. Use either the extemporaneous or the reading method of presentation, whichever you are more comfortable with. Supplement and illustrate your presentation with carefully prepared visuals, using media available to you.

   B. As part of this assignment, you may be asked to serve as a respondent for one of the scheduled talks in your area of expertise. Your assigned speaker will give you a copy of his or her conference paper ahead of time so you can read it and prepare two or three follow-up questions to ask during a question-and-answer period after the presentation.
3. Use the criteria in Figure 6.7 to evaluate the effectiveness of in-class presentations. Even if you do not follow all the technical detail in presentations outside your research area, you should be able to tell from the discussion in this chapter which presentations were effective and why.

4. Prepare a poster presentation of a set of research findings in your field, following the topic guidelines outlined in Activity 2. As in that activity, identify an appropriate conference and audience for the poster session. Use Figure 6.6 to evaluate the poster presentations.
5. Use the criteria in Figure 6.6 and/or 6.7 to evaluate presentations given at a professional conference that you attend. Which speakers gave the best presentations? Which posters were most readable? Which generated the most interest? Why were these presentations more effective than others you observed?

Rank your response to each question from 1 (low) to 5 (high). Beside each, write a brief statement explaining the reason for your ranking and/or the effect of that element on the presentation.

1. Was the type of presentation appropriate and effective?
2. Was the length of the presentation appropriate? Were time limits adhered to?
3. Was the rate (speed) of delivery effective?
4. Did the introduction establish an adequate context?
5. Was the presentation well organized?
6. Was the conclusion effective in emphasizing the major point of the presentation?
7. Was there sufficient (and direct) eye contact?
8. Did the speaker:
   - Speak loudly enough?
   - Vary pitch (intonation)?
   - Use voice to emphasize important points?
9. Was body language purposeful and appropriate?
10. Were hand gestures meaningful and appropriate?
11. Were visuals:
    - Appropriate (to the content, purpose, and method of presentation)?
    - Independent (adequately labeled)?
    - Interdependent (referenced and used in the presentation)?
    - Well designed and professional in appearance?
    - Informative?
12. Was the medium for the visuals (PowerPoint slides, etc.) used effectively?

FIGURE 6.7 Criteria for evaluating conference presentations.

CHAPTER

7

Writing Research Proposals

7.1 THE ROLE OF THE PROPOSAL IN SCIENCE

As is no doubt clear by now, the quest for research funding is a central activity in science. Just as journal editors and conference organizers exert control over what information is made available to the community, so funding agencies influence what kinds of research are undertaken in the first place. Berkenkotter and Huckin (1995) illustrate the interrelationships of these gatekeeping processes in a diagram we've reproduced in Figure 7.1. As the diagram indicates, peer review plays a critical role in funding decisions, just as it does in decisions about the publication of journal articles. We saw in Chapter 1 that in denying funding to cold fusion researchers, the U.S. Department of Energy dealt a blow to ongoing investigation in the United States as well as the credibility of the research. Because these all-important decisions are based on reviewers' assessments of the quality and persuasiveness of the proposal document, many scientists consider proposal writing the most important writing they do.

Like the professional associations that sponsor journals, funding agencies have specific interests; most will accept proposals only on specified topics and may limit their funding to projects with certain types of applications (e.g., industrial, educational, or environmental). Consider, for example, two proposals written by the Burkholder team for their research on toxic algae, both of which were awarded funding. One proposal, for basic research on the algae's place in the estuarine food web, was submitted to the National Science Foundation's Biological Oceanography division. Another proposal described a more applied project, the development of gene probes to help detect the organism in water samples. This project (included in Chapter 10) was submitted to the National Sea Grant College Program in response to a specific call for proposals in the area of marine biotechnology. Before sitting down to write a proposal, researchers select a target agency carefully and become thoroughly familiar with its funding history and preferences. In this chapter we'll take a close look at how scientists create proposals to address their target agencies' interests as well as their own research agendas.

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FIGURE 7.1 Life cycle of lab knowledge in scientific publication system, from Berkenkotter and Huckin (1995, p 62).

Throughout this book we have taken the position that scientific texts are not just informative but also persuasive documents. This persuasive dimension of scientific discourse is nowhere more obvious than in the research proposal. When writing reports and journal articles, researchers present and defend a particular interpretation of the prior research, of their new findings, and of the relationship between the two; the research report aims to convince readers that the work is valid and important. When submitting a grant proposal to a potential funding agency, however, the researchers must go a step further. Now they must convince readers not only that the work will be valid and important but also that the readers should pay for it!

In a classical rhetorical framework, the proposal may be classified primarily as a *deliberative argument*. Aristotle distinguished three types of argument: forensic, epideictic, and deliberative, which can be described as arguments of fact, of value, and of policy, respectively. Most types of writing contain elements of more than one argument type. In research reports the overriding goal is forensic: the authors try to convince readers to accept a set of "facts"—the results of their study. However, because the introduction and discussion sections assess the current state of knowledge, and argue at least implicitly about the value and limitations of that knowledge, the report has an epideictic dimension as well. And the discussion section's recommendations for future research or policy are deliberative. Similarly, the research review serves a forensic function in that it presents a summary of previous research, but its implicit goal of identifying those studies that are most pertinent or valuable to the field's understanding entails an epideictic dimension. The proposal is distinguished from both these genres in that, although it too contains forensic and epideictic elements, its purpose is primarily deliberative: the proposal argues for a specific research plan as well as a general research direction.

The stakes become clear when we think about the number of scientific questions that could potentially be explored; the amount of time, effort, and money that would be needed to support all these explorations; and the resources actually available for scientific research. The National Science Foundation funds roughly one-quarter of the 40,000 proposals it receives each year (NSF 2008a). The success rate is slightly lower at the National Institutes of Health, which

funded 10,100 or 21.3 percent of the 47,455 proposals received in 2007 (USDHHS 2008). The proposal document plays a critical role in how these scientific resources are allocated.

Research proposals are written for a variety of audiences and purposes in science: they are submitted to funding agencies to solicit financial support for new research, to academic departments to request approval of dissertation projects, to research facilities to gain access to equipment and resources, and to other parties whose approval must be secured for research to proceed. For example, in Chapter 11 we have included the brief proposal that Jelle de Boer and John Hale sent to the Greek government to request permission to remove rock samples from the ancient site at Delphi. Though the present chapter will focus primarily on proposals for research funding, the goal in addressing any of these proposal audiences is to convince the relevant gatekeepers that a particular problem is significant enough to justify the costs and consequences of exploring it, whether those costs be in terms of money, time, or risks to participants or resources. To succeed, a research proposal must present a well-reasoned and carefully documented argument that persuades its decision-making audience that the potential benefits of the research outweigh the costs.

The U.S. Department of Energy's grant application guidelines summarize the content of the proposal as follows:

> The application should present the objectives and scientific significance of the proposed work; the rationale for selecting the proposed approach to achieve the objectives; qualifications of the principal investigator and the applicant organization; and amount of funding required. Since the application will compete with others on related topics . . . it should present the scientific merit of the proposed project clearly and convincingly and should be prepared with the care and thoroughness of a paper submitted for publication. (DOE 2008)

This definition highlights the two primary persuasive goals of the research proposal:

- To convince your scientific audience that the problem you propose to investigate is important and worth exploring
- To convince them you will explore the problem in a sensible way

Thus, your proposal must convince readers not only that the research problem is significant but that your research approach is likely to succeed. Proposal reviewers will need to ascertain whether the methods you propose to use represent the most efficient and most worthwhile use of their agency's resources. They also will need to determine whether you are well qualified for the job. Funding agencies will request a description of your track record as part of the grant application, usually in the form of a *curriculum vitae,* an "academic résumé" that lists your research training and experience. But this ancillary material comes later in the application package; it is not the primary focus of readers' attention as they read and evaluate your project description. The text of the proposal itself also must demonstrate that you know what you're doing.

Recall that a text creates a professional *ethos;* it projects a character. Readers will form an impression of you based on the competence revealed in your proposal: Does your review of research demonstrate a thorough knowledge of the field? Have you exercised good judgment in the design of the study and the choice of materials and procedures (and are you therefore likely to exercise good judgment in other phases of the study, such as in recording and interpreting data)? Does your description of methods demonstrate the technical competence needed to carry out the project effectively? Thus, while your proposal contains an explicit argument for the importance and validity of the study and its design, it also contains an implicit argument for your own research competence (Myers 1985). It is important to note that even superficial features of your presentation may enhance or detract from the professional *ethos* created in the

proposal. The NIH cautions that "Your presentation can make or break your application. Though reviewers assess science, they are also influenced by the writing and appearance of your application. If there are lots of typos and internal inconsistencies, your score can suffer" (NIAID 2008a; http://www.niaid.nih.gov/ ncn/grants/cycle/part04.htm).

EXERCISE 7.1

Read De Boer and Hale's proposal to the Greek government to remove samples of stones from Delphi, (p xxx-xxx). In granting permission for this project, Greece's Ministry of Culture specified three conditions: (a) the size of the rock samples is 15 centimeters, and samples will be taken from areas already excavated; (b) the samples "will come under the supervision . . . of the Ephoreia for Prehistoric and Classical Antiquities in a timely manner"; (c) the results "will be made known to the Ephoreia and to the Conservation Authority for their archives" (Hellenic Ministry of Culture 1997). From the government's standpoint, what are the costs of allowing this research to proceed? What are the potential benefits? Where and how do De Boer and Hale address these costs and benefits in their short proposal?

EXERCISE 7.2

In Chapter 12 we have included a proposal that Stephen Reynolds and colleagues submitted to NASA's Chandra Observatory Research Program (p xxx-xxx). Read this proposal, paying special attention to the *ethos* it projects. What clues are there to the authors' experience and expertise? What have you learned about the researchers themselves from reading their proposal?

7.2 MULTIPLE AUDIENCES OF THE PROPOSAL

Most granting agencies use peer-review mechanisms that are similar in principle to, though typically more elaborate than, the peer-review systems used by journal editors. Because most agencies fund research in many different areas and must allocate the agency's resources among these areas, the typical proposal document is reviewed by in-house "generalists" as well as outside specialists and thus must be comprehensible and persuasive to a broader range of readers than is typical for journal articles. In-house reviewers are program officers and other agency staff who read proposals from a number of related topic areas; though educated scientists, readers at this level are not likely to be specialists in the particular topic area of a given proposal. The in-house readers will solicit reviews from specialists in pertinent scientific communities, as many as 3–10 in the case of the National Science Foundation (NSF 2008d).

The logistics of the proposal review process vary from agency to agency. NIH, for example, incorporates outside reviewers through a system of review groups and study sections (CSR/NIH 2008). Grant applications received by NIH's Center for Scientific Review are first read by a CSR Referral Officer, who assigns the proposal to an Integrated Review Group (IRG) in an appropriate research area. The IRG assigns it to one of its study sections, consisting of 20 or more outside experts. Each proposal is reviewed by three study section members, who lead discussion of that project when the study section holds its two-day review meeting. (See http://cms.csr.nih.gov/ResourcesforApplicants/PolicyProcedureReview+Guidelines/OverviewofPeerReviewProcess/ for a full description of this process.) In this first stage of review, panels are charged with evaluating proposals for scientific and technical merit. In a second review stage, the study section's recommendations are summarized and sent to the appropriate NIH institute or center where they are evaluated in light of the institute's program goals and priorities. NIH's standing review groups include representation from a fairly wide range of fields, which underscores the importance of pitching a proposal at a more general level than is

necessary for journal articles and other technical reports. As a case in point, a study section on AIDS-associated infections and cancer includes members representing departments of genetics, pathology, veterinary molecular biology, infectious diseases, biochemistry, pediatrics, and other areas (CSR/NIH 2006). Given the size of these groups and the breadth of expertise represented, NIH's Institute of Allergy and Infectious Diseases (NIAID) urges researchers to keep in mind that the application "has two audiences: a small number who are likely to be familiar with your techniques or field and the majority who are not" (NIAID 2008a).

In sum, research proposals will be read and evaluated by readers with varying types and degrees of experience and expertise, some of whom will know more about your research topic than will others. This multiplicity of audiences clearly complicates the writing process, for the proposal must address all these readers at once. Given the variety of audiences to be addressed and the multiple agendas to be accomplished, writing the research proposal is one of the most challenging—and most important—tasks scientists engage in.

EXERCISE 7.3

Choose a research topic in your field and identify a funding agency likely to support research in this area. (Review Exercise 5.2, page xxx on identifying topics.) Obtain a copy of the agency's proposal guidelines. In most cases, guidelines and calls for proposals will be posted online. For example, visit NSF at http://www.nsf.gov/funding/, the NASA funding site at http://nspires.nasaprs. com/external/, or the Department of Energy at http:// www.science.doe. gov/grants/. Or, visit Grants.gov, a federal clearinghouse established in 2002 that provides access to information about more than 1000 grant programs across federal agencies (http://www.grants.gov). Once you've located the guidelines, find the section(s) that describe the review or evaluation process. Based on this information, write a paragraph describing the mixed audience for a proposal on your topic and your readers' likely areas of expertise. Follow this with a paragraph describing ways in which you might adapt your proposal for those readers.

7.3 LOGIC AND ORGANIZATION IN THE RESEARCH PROPOSAL

Whether you are responding to a specific request for proposals or submitting an unsolicited proposal to a general program, your proposal must meet the specific guidelines established by your target funding agency. In addition to examining the main argument or project description, funding agencies will request an abstract or summary, a table of contents, a complete budget, biographical information about the investigator(s), and other supporting material pertinent to the type of research being proposed, for example, information about the treatment of laboratory animals, the protection of human subjects' rights and confidentiality, the handling of hazardous materials and other worker and environmental safety issues, or provisions for sharing research data. The scope, form, and ordering of these ancillary materials will vary across research fields and funding agencies.

The components of the main argument in a proposal are, however, fairly consistent. All proposals are designed to do the following:

- Introduce the purpose, significance, and specific objectives of the proposed research.
- Explain the background and rationale for the project by surveying previous research, summarizing the current state of the field's knowledge on the topic, and showing how the proposed project will further that knowledge.
- Describe the methodology to be used in the proposed study, and explain the rationale behind these methodological choices.

Where these goals are accomplished in the proposal document will differ from one proposal to another. For example, in their Sea Grant proposal to develop gene probes to detect *Pfiesteria* (Chapter 10; see Table of Contents, p xxx), Burkholder and Rublee combine their introduction and background under one major heading and describe their research objectives in a separately labeled section for that purpose. Reynolds and colleagues, in a proposal to the *Chandra* guest observer program (Chapter 12), embed their background discussion in subsections under the "Introduction" heading, with objectives discussed more explicitly with an overview of methods in Section 2., "Summary of Proposed Work." Their proposal also includes a separate "Technical Feasibility" section in response to the specific information needs of the *Chandra* program. Burkholder and Rublee have divided their extensive methodology section into seven subsections describing the different elements of their research design. The arrangement and labeling of sections and subsections in a proposal will depend in part on your funder's guidelines but also on your own writing style and the nature and logic of your research topic.

7.4 INTRODUCING THE RESEARCH PROBLEM AND OBJECTIVES

In some respects, the proposal introduction is similar in structure and content to the introductions found in most research reports. The three moves Swales (1990) observed in report introductions provide a useful heuristic for proposal introductions as well (see Figure 4.3, p xx). In both the report and the proposal, your goals are to introduce the research topic; identify the research gap, question, or problem that motivates the study; and announce the purpose of the study.

But within this general framework, emphasis and development may differ considerably in the two genres, due to the different audiences these texts address and the purposes for which they are written. In the research report, the introduction serves to quickly establish the context for the study and announce its purpose. Unless you are writing for a multidisciplinary journal such as *Nature* or *Science,* the journal audience consists of specialists in your field, and the stance is one of expert to expert; you are reminding fellow marine biologists or physicists or pathologists of the state of the field's knowledge on your topic, showing them which specific issues or previous findings you consider most pertinent to your study, and highlighting the gap your study responds to. In other words, you are guiding them through a review of information that is at least generally familiar to them, refocusing the discussion to situate the new results you are reporting. Because most of your report audience shares your specialized knowledge to some extent, this review can be accomplished rather quickly, sometimes in a single paragraph.

The proposal, however, carries a greater burden of proof and must therefore provide a more fully elaborated introduction to the project at hand. We noted in Section 7.2 that proposal readers are a diverse group, including specialists in your field and "generalists" with other areas of expertise. The significance of your line of research will not be obvious to all the members of this group; therefore you will need to make a stronger case than would be necessary in a journal article. Some of your proposal readers will also need to be educated about the general topic before they can make an informed judgment about the merits of your project. Lastly, keep in mind that you are asking more of your proposal readers than of a journal audience—you're asking them not just to entertain your ideas but to invest in them.

Thus, one of the primary goals of the proposal is to convince this audience of the significance of the proposed work. It will not be enough to assert that a problem exists, or that a question has not been answered. The researcher must convince proposal reviewers that the problem is important enough to spend money on, that answering the question will be worthwhile. What readers consider "worthwhile" will be largely a function of the goals and priorities of the agencies they represent. Just as research journals differ with respect to the topics and types of research they are interested in publishing, funding agencies also have

distinctive research agendas and preferences. The first step in writing a successful proposal is to choose an appropriate agency to submit it to.

A funding agency's general priorities are well known to experienced researchers in the field, but they are also explicitly stated in the agency's proposal guidelines or requests for proposals (RFPs). Most funders accept proposals in their areas of interest on an ongoing basis but also issue RFPs to solicit proposals on particular topics for which they have set aside special funds. (The NIH uses the term *RFA*: request for applications; NASA uses *NRA*: NASA Research Announcement.) RFPs typically announce a new initiative in a carefully delimited research area. Researchers responding to RFPs must demonstrate that their proposed research fits within these parameters and will significantly further the announced goals. For example, Burkholder and Rublee's proposal in Chapter 10 was submitted in response to an RFP from the National Sea Grant College Program soliciting proposals for research on marine biotechnology. We have reproduced sections of the RFP on pages xxx-xxx. The need for this type of research and thus the rationale for this RFP are clearly laid out in the document's "Background" section:

> A national commitment to research and development in marine biotechnology will help respond to societal needs by (1) increasing the food supply through aquaculture, (2) developing new types and sources of industrial materials and processes, (3) opening new avenues to monitor health and treat disease, (4) providing innovative techniques to restore and protect aquatic ecosystems, (5) enhancing seafood safety and quality, and (6) expanding knowledge of processes in the world ocean. (See p xxx.)

Throughout their proposal, Burkholder and Rublee carefully explain how their research will address goals in this list, culminating in their final "Application" section, which states these connections directly: "This work, addressing several key targets identified by a national Sea Grant initiative for research in Marine Biotechnology, will yield applications of both immediate and long-term value" (see p xxx). The section then proceeds to summarize the project's projected implications for improving the safety of aquaculture facilities and processes, for safeguarding human health, and for assessing environmental quality in natural estuarine ecosystems—all critical concerns expressed in the RFP.

As this example illustrates, successful proposal authors leave nothing to chance. In discussing the significance of their research, they carefully highlight the specific ways in which the proposed work will further the goals and interests of their target funding agency. In so doing, the researchers are appealing to the agency's *values*. The appeal to values is one type of classical rhetorical argument. Aristotle described three types of rhetorical appeals: those based on the logic of the subject matter (*logos*), those based on the character of the speaker (*ethos*), and those based on the emotions and values of the audience (*pathos*). Most arguments contain all three types of appeal, and each can clearly be seen in the proposal genre: successful proposals present a logical, well-supported line of reasoning; project a professional *ethos* of competence and knowledgeableness; and clearly address the values and concerns of the funding agency.

These values are both articulated and implied in the RFP or proposal guide. Each agency has a fairly well-defined research domain that gives it a distinctive character or identity. For instance, the NSF was initially established in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense . . . " (NSF 2008e). The agency describes itself as "the premier Federal agency supporting basic research at the frontiers of discovery, across all fields, and science and engineering education at all levels" (NSF 2006). This concern with the nation's science infrastructure and education is revealed in a number of critical places in the NSF Grant Proposal Guide, most notably in the discussion of review criteria. NSF's two primary review criteria place as much emphasis on the development

of infrastructure and dissemination of results as on the intellectual merit of the proposed research (see Figure 7.2).

A funding agency's values may also be revealed in the diction or word choice of other sections of their proposal guide. For example, an examination of NSF's description of who is eligible to submit proposals also clearly underscores the agency's stated mission. Go to the NSF's Grant Proposal Guide at http://www.nsf.gov/pubs/policydocs/pappguide/nsf08_1/gpg_1.jsp#top and scroll down to Section E: Who May Submit. Note the values communicated in the diction ("national," "Federal," "nation," "U.S."), as well as the recurrence of agents such as "scientists, engineers . . . educators" throughout the section. Even the categories of who may submit, and the order in which they appear, underscore the NSF's overarching concern with the infrastructure of American science and education: (1) universities and colleges, (2) non-profit, non-academic organizations, (3) for-profit organizations, (4) state and local governments, (5) unaffiliated individuals, (6) foreign organizations, (7) other federal agencies (NSF 2008b). According to this list, proposals that do not appear to further these goals (e.g., research at foreign institutions or proposals from professional societies *not* "directly associated with educational or research activities") are rarely funded. Funding agencies spend time, money, and effort carefully wording their proposal guides in order to clearly indicate the kinds of research they will and will not consider. These guidelines can be an invaluable resource in selecting an appropriate agency for your proposal and in developing the significance argument for that audience.

NSF Merit Review Criteria

What is the intellectual merit of the proposed activity?

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? . . . To what extent does the proposed activity suggest and explore creative, original, or potentially transformative concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

What are the broader impacts of the proposed activity?

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

FIGURE 7.2 Merit review criteria, NSF Grant Proposal Guide (NSF 2008d; NSF 08-1, section III.A.).

The introduction does not have to build the case for significance all on its own, of course; this is the purpose of the full proposal. In most cases the introduction serves as a preview of issues to be discussed further in other sections of the document. The introduction identifies the problem, but specific research objectives are often elaborated elsewhere, for example, in the background or methods sections or in a separate section altogether, as in the Burkholder and Rublee proposal. Similarly, the introduction overviews previous research and the questions that motivated the study, but a more extensive discussion of prior research and explanation of the research problem are generally presented in a background section. The introduction also identifies the methodological approach to be used in the study, but a detailed description of methods is saved for the methods section. In some cases, the significance argument may be elaborated in a separate section as well, as in the Burkholder and Rublee proposal (see "Expected Results" and "Application"). These sections, appearing at the end of the document,

provide a neat conclusion to the proposal argument as a whole, leaving readers with a strong sense of the importance and potential value of the proposed work.

In short, the introduction orients readers to the topic, purpose, and significance of the research, providing a framework or scaffold for other sections of the proposal to build on.

EXERCISE 7.4

As noted above, the Burkholder and Rublee proposal (Chapter 10) combines the introduction and background sections. As you read this section, look for the three standard introductory moves (establish topic, establish the need for the new research, introduce the new research). Are these moves recognizable in this elaborate introduction, and, if so, where is each move made? In one or two paragraphs, describe the structure and logic of this section.

EXERCISE 7.5

Read the RFPs we have included from the National Sea Grant College Program (Chapter 10, p xxx-xxx), from NASA's *Chandra* program (Chapter 12, p xxx-xxx), and from the U.S. Department of Energy's National Institute for Climatic Change Research (Chapter 13, p xxx-xxx). Describe the values and goals of each agency as revealed in these documents. Compare and contrast the values and goals of these programs. Now look at the proposals that were submitted to these programs: where and how do the authors demonstrate that their research addresses the values and goals of their respective funding agencies? What do you learn about the identity and priorities of these agencies by reading their proposal guidelines and the arguments created in response to them?

7.5 PROVIDING BACKGROUND

Most proposals contain a separate background section or sections where the authors can present a more extensive explanation of the research problem, grounded in a thorough review of previous research. This section serves different purposes for the two segments of your audience. Your discussion should bring program officers and other generalists up to speed on the nature of the problem and the reasoning behind your specialized project. At the same time, it provides an opportunity for in-field readers to judge how familiar you are with the current state of knowledge in the field and how well you understand the issues and constraints involved in conducting research of this sort. With regard to this second purpose, one NIH institute explains that "[r]eferences show your breadth of knowledge of your field. If you leave out an important work, reviewers will assume you're not aware of it" (NIAID 2008b).

As this statement indicates, the way in which you review the literature significantly influences the professional *ethos* projected by your text. Readers will want to know not only that you understand what other researchers have done but also that you appreciate the contributions their studies have made to the developing knowledge in your research area. Situating your work in this context is essentially a cooperative gesture as opposed to a competitive one. While oversights and methodological limitations must be taken into account in interpreting the results of individual studies, the primary goal in a review is to highlight what has been learned by the field so far (see Chapter 5). In the proposal, the review of research shows how far the previous research has gone and where it still needs to go. Once this groundwork is established, you will be in a position to explain how your proposed study will take the field forward.

Chapter 5 provides some general guidelines for structuring research reviews and citing sources. You'll see in the sample proposals in Chapters 10 and 12 that subheadings are a useful device for organizing the background section and are usually needed because of the length and

complexity of these discussions. Notice that, as in the research report, the major headings in the proposal are *functional* headings (introduction, background, methods). But subheadings within sections are *topical;* that is, they identify the topic to be discussed in the section rather than simply announcing the function the section serves. We noted that Reynolds et al. combine the intro and background sections in their 2005 proposal. Notice that the major headings are functional (1. Introduction, 2. Summary of Proposed Work), but that subsections within the introduction are topical (1.1 SN Ia Progenitors, 1.2 Nucleosynthetic Products). Topical subheadings provide important cues to help readers navigate your background argument. (Announcing this sequence of topics at the start of the section can be an effective opening strategy.)

As you develop the background section, keep in mind the overall purpose of your proposal. You are reviewing research in order to introduce your study and show how it will further the field's knowledge and the agency's goals. You'll want to be sure to tie the background research clearly to the proposed research, especially as you bring this section to a close. Notice, for example, that Burkholder and Rublee finish their "Introduction and Background" section by describing "Progress to Date on Gene Probe Development" in subsection C, followed by a restatement of their research goals and hypotheses in subsection D, in which they explain how they will extend that progress (p xxx-xxx). Another way to connect the background argument to the proposed study is to follow this section with a list of specific research objectives (Pechenik 2007), a strategy also illustrated by the Burkholder and Rublee proposal. Once readers have read the background section, they are well prepared to understand and appreciate the specific goals of your study. Another advantage of placing the specific objectives here is that they can serve as a preview of the methods section, enhancing the coherence of the overall proposal argument.

EXERCISE 7.6

Choose a sample research topic in your field, perhaps one suggested in the discussion section of a research report you've read recently. List the research areas that would need to be reviewed in the background section of a proposal for this project. Design sample subheadings for this section.

7.6 DESCRIBING PROPOSED METHODS

The methods section of a research proposal is distinguished from that of a journal article in two respects: the proposal generally contains fewer details but more explanation of rationale. Fewer details are to be expected, given that the research being proposed has not yet been conducted; but the need for rationale is more a function of the deliberative purpose of the proposal. This section must do more than describe how the study will be carried out; it must explain why this approach, as opposed to others, was chosen. The researcher must articulate and defend the methodological decisions he or she has made in such a way that the diverse readers in the proposal audience will be able to understand and appreciate those decisions. Remember that your target agency is being asked to pay for these activities. Its program boards must be convinced that this approach represents the best possible use of their limited funds.

As a consequence, the description of methods in the proposal tends to be heavily documented. In effect, it is an extension of the background discussion and serves a similar dual purpose. This extended explanation of materials and procedures helps your generalist readers understand what's needed to accomplish this research and allows your in-field readers to determine whether *you* understand what's needed for this research. The NIH has cautioned:

> While you may safely assume the reviewers are experts in the field and familiar with current methodology, they will not make the same assumption about you . . . . Since the reviewers are experienced research scientists, they will undoubtedly be aware of possible problem areas, even if you don't include them in your research plan. But they have no way of knowing that you too have considered these problem areas unless you fully discuss any potential pitfalls and alternative approaches. (NIH 1993, p 6)

Of course, you will describe your proposed methods in future rather than past tense, but otherwise the basic guidelines presented in Chapter 4 (Section 4.5) can be followed in developing this section. See Section 4.6 for advice on incorporating figures and tables. As in the background section, subheadings are common in this section of the proposal. As illustrated in the Burkholder and Rublee proposal, headings and subheadings help readers keep track of the basic components of your methodology. In some proposals, the research objectives introduced earlier may become subheadings for organizing the methods section. In sum, the proposal must convince readers that the project is significant and that it will be conducted expertly. Each section of the proposal document plays a role in building this case.

EXERCISE 7.7

In either the Burkholder and Rublee (1994) proposal (Chapter 10) or the Reynolds team's (2005) proposal (Chapter 12), look for places where the authors include a brief or extended rationale for a methodological choice. What kinds of decisions have they chosen to explain? Why do these issues warrant further explanation? What role do citations play in these explanations? Look for examples of each of the three levels of procedural explanation described in Chapter 4: routine procedures, procedures established in previous studies, and new procedures or substantial modifications (see Section 4.5, p xxx).

EXERCISE 7.8

Examine De Boer and Hale's proposal to the Greek government for permission to remove rock samples from the Delphi site (Chapter 11, p xxx-xxx). The researchers' proposed methods are mentioned in several places in this brief proposal, particularly under the "Request" and "Laboratory" headings. In contrast to proposals to funding agencies, in which methods must be described to withstand scrutiny by expert scientists, De Boer and Hale's plans were also evaluated by officials of the Greek government concerned with cultural preservation. What methodological details have the authors included to reassure this audience that their resources will not be abused and that the tests have a high probability of success?

7.7 THE RESEARCH PROPOSAL ABSTRACT

The proposal abstract or summary is likely to serve a number of purposes and reach a number of audiences: it may be used at the start of the review process to help program officers sort proposals and select appropriate reviewers; it will be used by reviewers during the process as a preview of the larger document; and it may be used in reporting or publicizing an agency's funding decisions after those decisions are made. Thus, the NSF's proposal guidelines specify that the proposal summary should be "suitable for publication" and "informative to other persons working in the same or related fields and, insofar as possible, understandable to a scientifically or technically literate lay reader" (NSF 2008c).

The general shape of the proposal abstract reflects the shape of the proposal itself and thus includes a synopsis of the research problem, goals, and methods. Specifications for

abstracts vary. A limit of one page or 200 to 300 words is common, but some agencies will accept more elaborate summaries, as illustrated in the Burkholder and Rublee proposal (Ch. 10). The National Institute for Climatic Change Research (NICCR), which funded Chambers and Hurtt's research on hurricane impacts, requires an abstract of 400 words or less containing five specified paragraphs: (1) project objectives, (2) specific hypotheses or questions, (3) location of research activities, (4) outline of methods, and (5) "a statement of what the research is intended to accomplish, including expected deliverables" (NICCR 2008; http://www.tulane.edu/%7ENICCR/rfps.html). The Chambers and Hurtt abstract is included in Chapter 13 (see p xxx).

Whether brief or elaborated, the overview of methods in the abstract or summary must, of course, be "promissory" in that it describes what you *will* do. But the discussion of the research problem and goals is expected to be informative rather than descriptive (review these terms in Chapter 4, p xxx); it must provide a clear, concise summary of what the project is about. Most, if not all, of your readers will read the abstract; some will read only the abstract (Olsen and Huckin 1991). The NIAID guidelines explain that although all proposals receive a careful reading from the assigned primary reviewers who will represent the project in the review committee discussion, most members of the committee will "read just your Abstract, Background and Significance, and Specific Aims" (NIAID 2008c; http:// www.niaid.nih.gov/ncn/grants/ cycle/part08.htm#f6). Given the vast number of proposals to be reviewed and the real-life constraints under which reviewers work, the abstract may well be the most important section of the proposal document.

EXERCISE 7.9

Read the abstract written by Chambers and Hurtt (2006) for their study, "Hurricane Impacts on Structure and Functioning of Southeastern Forests" (reprinted in Ch. 13). Also review NICCR's specifications for abstracts, earlier in this section. Unlike NSF, NICCR's guidelines do not specify that the abstract be "understandable to a scientifically or technically literate lay reader," but abstracts of funded projects are later posted at the NICCR website and thus available to the public (http://www. tulane.edu/%7ENICCR/projects.html). Which parts of this abstract are most understandable to non-specialists? How would you revise this abstract to address a public audience?

EXERCISE 7.10

Write a 200-word abstract for the Burkholder and Rublee proposal, using their one-page project summary as a starting point (Ch. 10). What parts of the summary did you use, and what parts didn't you use? Why?

7.8 HOW SCIENTISTS WRITE RESEARCH PROPOSALS

As discussed in Chapter 4, research scientists, like all writers, follow a wide range of writing processes and preferences. This variation applies equally to the processes of writing and revising research proposals. Individual scientists may prefer one drafting method over another; research teams may develop preferred patterns of collaboration that enable them to produce and revise documents efficiently. Authors may vary their methods of composing and collaborating from one occasion to the next. The one constant in all this variation is an overriding concern with audience in developing the proposal. A critical dimension of the proposal writing process is the assessment of the potential funding agency's interests, values, and goals.

The goals of most funding agencies are widely known and are articulated in RFPs, but many researchers also actively seek out new information about their target agency and establish

a dialogue with program staff well before they submit proposals. Many funding agencies encourage this sort of early contact and information exchange. Program staff are readily available by phone and email for such consultations. It is in the agency's interests to provide this guidance in advance to ensure that the proposals it receives fall within its program guidelines and include all the information needed in the review process. In a study of the funding process, Mehlenbacher (1994) found this give-and-take among researchers and program staff to be quite common. The prominent researchers Mehlenbacher interviewed consistently described the proposal process as a long-term, interactive process.

If a proposal is not accepted on its first submission, the dialogue generally continues. Most agencies will send copies of reviewers' comments to the proposer and will continue to consult with the researcher as he or she revises the text for resubmission. In an extensive case study of this revision process, Myers (1985) found that proposal arguments changed significantly as researchers evaluated and responded to reviewers' concerns. Changes were effected on several levels, from the shape of the argument, to the amount of explanation, to the tone and *ethos* established in the text. But significantly, basic content remained relatively unchanged. Steve Reynolds reports that their proposal for *Chandra* observer time was accepted on the third try; the team had submitted proposals twice before, modifying and improving the document each time (personal correspondence).

In sum, the proposal writing process is a complex, long-term endeavor that involves the participation of many. Given the high degree of interaction among researchers, program staff, and reviewers—and the continuing interaction among members of a research team (some of whom may be geographically separated)—it is no wonder that researchers in Mehlenbacher's (1994) study cited management and organizational skills as essential components of the research process.

EXERCISE 7.11

Some funding agencies provide extensive advice for grant writers. For example, see NIH's Grants Process Overview (http://grants.nih.gov/grants/grants_process.htm) and NSF's Grant Proposal Guide (http://www.nsf.gov/pubs/policydocs/ pappguide/nsf08_1/gpg_index.jsp). Take some time to familiarize yourself with these resources, and/or those of other agencies likely to fund research in your field. Given the advice you find in these guides and in this book, and considering your own writing habits and preferences, think about how you would write a grant proposal of your own. Draft a set of writing steps and a tentative timeline for preparing a grant proposal for submission.

7.9 HOW REVIEWERS EVALUATE RESEARCH PROPOSALS

The proposal review process exerts a powerful influence on the direction of research in scientific fields. In issuing RFPs on specific topics, funding agencies encourage research in some areas and not others; proposal guidelines ensure that researchers who work in these areas address the agency's goals and priorities; and in responding to reviewers' comments in the revision process, researchers may further tailor their research to fit within the parameters established by the targeted research program.

This degree of control makes some scientists nervous. As with the journal article review system, there are always worries about potential abuses such as favoritism, censorship, breaches of confidentiality, or misappropriation of ideas—concerns that may be enhanced by the political context in which these organizations operate; federal funding agencies such as NIH and NSF depend on congressional approval of their budgets and thus may be subject to the economic tug of political priorities. An additional concern in the granting process is the role that non-specialists play in the review process, as, for example, in NIH advisory councils

(Cohen 1996). In response to such concerns, the NSF and other agencies have initiated changes in the review process designed to give proposers more "say" in the choice of reviewers and to provide authors of unsuccessful proposals more complete information about the reasons for the rejection. Like the peer-review process used by journal editors, the proposal review process may perhaps best be described as an imperfect system that nevertheless provides careful scrutiny of thousands of proposals every year.

Proposal guidelines and RFPs routinely include a list of the criteria reviewers will use in evaluating new applications. The review criteria for the Sea Grant program to which Burkholder and Rublee submitted their 1994 proposal are presented in Figure 7.3. NASA's review criteria for the *Chandra* observer program, in effect for the Reynolds team's 2005 proposal, are presented in Figure 7.4. Notice that these criteria clearly reflect the different goals of the two programs as represented in their respective RFPs (Ch. 10 and Ch. 12).

A comparison of Figures 7.3 and 7.4 also will reveal some common concerns that reflect the generic goals of the research proposal. Both evaluation guides highlight the relevance of the study to the agency's goals or mission, the scientific merit of the proposed work, and the capabilities of the investigators. This chapter has argued that while there are specific places in the proposal document to establish the relevance of the study and the scientific merit of the design, the professional competence of the researcher is indirectly demonstrated throughout. As these review criteria indicate, the researcher's professional *ethos* plays a critical role in the evaluation of his or her work.

Criteria for Evaluation of Proposals

The following criteria will be used to evaluate the proposals.

1. *Rationale*—the degree to which the proposed activity addresses an important issue, problem, or opportunity in marine biotechnology, and how the results will contribute to the solution of the problem.
2. *Scientific Merit*—the degree to which that activity will advance the state of the science or discipline through use and extension of state-of-the-art methods.
3. *User Relationship*—the degree to which users or potential users of the results of the proposed activity have been brought into the execution of the activity, will be brought into the execution of the activity, or will be kept apprised of progress and results.
4. *Innovativeness*—the degree to which new approaches (including biotechnological ones) to solving problems and exploiting opportunities will be employed or, alternatively, the degree to which the activity will focus on new types of important or potentially important issues.
5. *Programmatic Justification*—the degree to which the proposed activity will contribute an essential or complementary unit to other projects, or the degree to which it addresses the needs of important state, regional, or national issues.
6. *Relationship to Priorities*—the degree to which the proposed activity relates to guidance priorities in this document.
7. *Qualifications and Past Record of Investigators*—the degree to which investigators are qualified by education, training, and/or experience to execute the proposed activity and past record of achievement with previous funding.

FIGURE 7.3 Review criteria, National Sea Grant College Program (1994). "Statement of Opportunity for Funding: Marine Biotechnology." No page number. Reviewers of the Burkholder and Rublee proposal in Chapter 10 were guided by these criteria.

Evaluation of Research Objectives

The criteria used in the Stage 1 evaluation are listed below in order of importance.

1. The overall scientific merit of the investigation and its relevance to the *Chandra* science program and capabilities. This includes addressing the scientific objectives of the *Chandra* mission and achieving the goals of the most recent NASA strategic plans. For observing proposals, the degree to which the objectives have been satisfied by one or more previous observations will be evaluated . . . .
2. For observing proposals, the suitability of using the *Chandra* X-ray Observatory and data products for the proposed investigation and the need for new X-ray data beyond that already obtained; the feasibility of accomplishing the objectives of the investigation within the time, telemetry, and scheduling constraints; and the feasibility of the analysis techniques. For programs incurring a large expenditure of observatory time relative to exposure time (multiple short exposure or grid scans), the total observatory time required will be considered . . . .
3. The competence and relevant experience of the Principal Investigator and any collaborators as an indication of their ability to carry the investigation to a successful conclusion. Past performance in scientific research, as evidenced by the timely publication of refereed scientific papers including those on previous *Chandra* programs, will be considered.

FIGURE 7.4 Review criteria, *Chandra* X-ray Observatory (CXO) Research Program (2007, p. 41). Other excerpts from this RFP are reproduced in Chapter 12. The reviewers of the Reynolds et al. *Chandra* proposal were guided by these criteria.

EXERCISE 7.12

The National Institute of Allergy and Infectious Diseases (NIAID), one of the Institutes of Health, has compiled a list of the most common reasons given by reviewers for rejecting a proposal. We have reprinted these in Figure 7.5. Consider this list carefully.

A. Which of these reasons are related to the researcher's projected competence or professional *ethos?*

B. How and where in the proposal argument should each of these potential concerns be anticipated and addressed?

Common Problems Cited by NIAID Peer Reviewers

- Problem not important enough.
- Study not likely to produce useful information.
- Studies based on a shaky hypothesis or data.
- Alternative hypotheses not considered.
- Methods unsuited to the objective.
- Problem more complex than investigator appears to realize.
- Not significant to health-related research.
- Too little detail in the Research Plan to convince reviewers the investigator knows what he or she is doing, i.e., no recognition of potential problems and pitfalls.
- Topic scientifically premature.
- Over-ambitious Research Plan with an unrealistically large amount of work.
- Direction or sense of priority not clearly defined, i.e., the experiments do not follow from one another and lack a clear starting or finishing point.
- Lack of original or new ideas.
- Investigator too inexperienced with the proposed techniques.
- Proposed project a fishing expedition lacking solid scientific basis, i.e., no basic scientific question being addressed.
- Proposal driven by technology, i.e., a method in search of a problem.
- Rationale for experiments not provided, i.e., why they are important, or how they are relevant to the hypothesis.
- Experiments too dependent on success of an initial proposed experiment. Lack of alternative methods in case the primary approach does not work out.
- Proposed model system not appropriate to address the proposed questions.
- Relevant controls not included.
- Proposal lacking enough preliminary data, or preliminary data do not support project's feasibility.
- Insufficient consideration of statistical needs.
- Not clear which data were obtained by the investigator and which reported by others.

FIGURE 7.5 Most common reasons cited by NIAID reviewers for rejection of proposals (NIAID 2008a; http://www.niaid.nih.gov/ncn/grants/cycle/part04.htm#e3).

7.10 ACCOUNTABILITY IN THE RESEARCH PROCESS

Public trust in science rests on the assumption that all parties involved in research—from the researchers themselves to the reviewers and program officers who pass judgment on their work—are competent and trustworthy. This basic assumption shapes the nature of the relationship between researchers and granting institutions, as exemplified in the NASA policy statement reproduced in Figure 7.6.

In this statement, prominently displayed in the introduction to their *Guidebook for Proposers,* NASA (2008c) clearly identifies itself as an agent of the American citizenry, charged with facilitating work that is in the public's interest and thus worthy of public funds. The professional conduct of that research is thus NASA's responsibility, yet as the policy statement indicates, the agency exercises minimal oversight, placing their trust, as all funding agencies do, in the integrity of the research participants. We've explored the ethics of research reporting at greater length in Chapter 3, but it is important at this point to acknowledge the mechanisms through which such trust is maintained in the granting process.

In addition to the checks and balances inherent in the peer-review systems used to evaluate research proposals, funding agencies also rely on internal controls at the researcher's home institution. Most agencies require that proposals be accompanied by verification of approval by an institutional review board (IRB) at the home institution. Such boards are typically composed of researchers from a variety of departments on campus who review the

proposed study design to ensure compliance with good research practice, as well as with federal regulations on such issues as the ethical treatment of human subjects and laboratory animals and the use of materials that may be hazardous to researchers, research subjects, or the surrounding community and environment. As noted in Section 7.3, funding agencies also may require special declarations on such issues as part of the proposal package, in addition to documentation of IRB approval.

NASA's Partnership with the Research and Education Communities

Funding for NASA-related research and development projects is a privilege accorded to qualified science, engineering, and educational personnel by NASA acting on behalf of the citizens of the United States through Congressional and Executive action. NASA's proposal and selection procedures work only because the various research communities and NASA Program Offices together maintain the highest level of integrity at all stages of the processes. As a general rule, recipients of NASA research awards largely manage their own research projects with minimal oversight by the Agency. Throughout the entire process—starting with the identification of program objectives, the preparation and peer review of submitted proposals, the conduct of the research itself, and, finally, the exposition of new knowledge through publications, public outreach, and education—NASA sees itself as a partner with the scientific, engineering, and educational communities in making its programs relevant and productive.

FIGURE 7.6 NASA general policy statement (NASA 2008c, p P-2).

Once a grant is awarded, researchers are expected to keep the agency informed of their activities, usually through annual reports summarizing their progress to date. For example, in the case of multi-year projects, NASA "requires that a brief progress report be submitted to the Program Officer 60 days before the anniversary date of the award, in order to allow for the timely recommendation for a continuation of funding" (NASA 2008c, p F-3). At the end of the grant period, a final report is required, including "substantive results from the work, as well as references to all published materials from the work" (NASA 2008c, p F-3). The focus in such reports is on showing how the research team is accomplishing the goals that the researchers and funder agreed upon through the proposal approval process.

In Figure 7.7 we've reproduced the reporting requirements set by the National Institute of Allergy and Infectious Diseases for the projects they fund. Notice that in addition to certifying that they're behaving ethically and that they're making sufficient progress, researchers are also responsible for managing their finances and keeping careful records of their spending. This reporting requirement brings us back once again to the additional challenge that grant proposals pose: your readers must be convinced that their funds will be wisely invested in a project that is important, well conceived, and likely to succeed.

Your Reporting Requirements

Once your project is underway, you and your institution have ongoing requirements, described below:

- Quarterly reports
- Financial status reports
- Invention reports
- Progress report
- Audit requirements

In some cases, you may have additional requirements.

- For example, if you are working with human subjects, you need to get your certification of institutional review board approval re-approved every year of your award.
- If you're working with research animals, you need to get your certification of institutional animal care and use committee approval re-approved every three years.

As PI [Principal Investigator], you play a large role in preparing the reports, though you don't actually submit them. You give information to your business office so it can send us the reports. Along with the reports described above, your institutional business official will need to submit an *Annual Report on Possible Research Misconduct* to the Office of Research Integrity. ORI will impose a bar on your award if it does not receive this report.

FIGURE 7.7 Reporting requirements for projects funded by the National Institute of Allergy and Infectious Diseases (NIAID 2008d; http://www.niaid.nih.gov/ncn/grants/cycle/part11a.htm#e).

Activities and Assignments

1. Berkenkotter and Huckin (1995) outlined the "life cycle" of research in general terms in the diagram reproduced in Figure 7.1. Create a life cycle diagram for a specific project in your field, in which you identify the journals and funding agencies that served as "gatekeepers" for this line of research.
2. Obtain a copy of an RFP from a funding agency in your field. Imagine that you and a colleague at another institution plan to submit a proposal to this agency for a collaborative project you have in mind. Based on the information contained in the RFP, write a letter to your colleague describing what you think are the most important goals and constraints the proposal will have to meet. Identify the intended audiences and their interests, needs, and knowledge. Summarize the program goals, the evaluation criteria that will be used, and any special considerations you will have to keep in mind in preparing the proposal.
3. Obtain a copy of a successful research proposal on a topic in your field, along with the appropriate RFP and/or proposal guidelines. Write a descriptive analysis in which you begin by examining the organization of the proposal as revealed in the headings and subheadings of sections. Comment on any distinctive features of this organizational plan that reflect distinctive characteristics of research in this area. Then examine the program goals and criteria listed in the RFP. Describe how and where each of these issues is addressed in the proposal.
4. Write a two- or three-page analysis of the rhetorical appeals in a research proposal from this text or one from your field. In your analysis, examine how logical, ethical, and emotional appeals (*logos, ethos, pathos*) are made or implied in the text. That is, you should describe the shape of the logical argument being presented (the major claims made in each section and the kind of evidence offered in support of those claims); describe the character or *ethos* projected by the author(s) and the ways in which that *ethos* is created in the text; and describe any appeals to readers' interests, needs, and broader social concerns. In which section(s) of the report is each type of appeal found?
5. We noted in Section 7.1 that most texts contain elements of all three types of classical argument: arguments of fact (forensic), of value (epideictic), and of policy (deliberative). Choose a proposal

from this text or from your field and look for instances of each type of argument. In which sections of the proposal does each type appear? In which sections does one or the other type predominate? Write a two- or three-page analysis outlining the role each type of argument plays in the proposal.

6. Write a proposal for a new research project on a topic in your field. The project should build on, and represent, a logical "next step" in a current line of research reported in the literature. (Review Chapter 5 on identifying topics and sources.) Target a specific funding agency that is likely to support work in this area, and obtain the agency's proposal guidelines and/or an RFP. Structure your text in accordance with the generic form described in this chapter (introduction, background, proposed methods), unless your guidelines include more specific instructions for organizing the project description. Use an appropriate documentation format in citing sources and in preparing your reference list. You may be asked to include a table of contents, a budget, biographies of investigators, and other ancillary information pertinent to your specific research focus.
7. Find a description of your university's requirements for internal review of research, that is, the guidelines for submitting proposals to an institutional review board for their approval. Following the IRB's form and/or guidelines, prepare a description of the study you designed in Activity 6.
8. In this activity you and your classmates will be organized into groups. Your group will role-play a peer-review committee for a research proposal written by a team in your class. The team will provide copies of the RFP, proposal guidelines, or other agency material that they used to write their proposal, as well as the proposal itself. First, evaluate the proposal on your own: is it well thought out, well argued, and well written? Then, use the criteria discussed in this chapter to help you evaluate the merits and limitations of the proposal: Does the proposal adhere to the agency's guidelines for organizing and formatting proposals (or follow the generic form discussed in this chapter if the agency does not specify one)? Have the authors avoided the problems listed in Figure 7.6? Does the introduction demonstrate the merits of the project based on the goals, priorities, and values of the funding agency? Does the review of literature seem to demonstrate a knowledge of the subject and the field? Do the design of the study and choice of methods seem to reflect good judgment? Does the description of methods seem to demonstrate the technical competence needed to carry out the project? Is the proposal free of surface-level errors that would detract from the professional *ethos* of the writer? In short, are you persuaded that this project is worth funding?

   After you have made your own assessment, discuss the merits and limitations of the proposal with your fellow reviewers, and arrive at a consensus concerning which of the following actions should be taken on this proposal.

   A. Recommend this proposal for funding

   B. Reconsider with revision (provide suggestions for revision)

   C. Reject

   Write a statement to the research team explaining the reasons for your decision. Your instructor may ask review teams to review their findings with the proposers.

CHAPTER

8

Communicating with Public Audiences

8.1 WHY DO SCIENTISTS COMMUNICATE WITH PUBLIC AUDIENCES?

In Chapter 1 we noted that scientific disciplines are not only communities in themselves but also parts of the larger society in which these communities are situated and in which scientists work and live. This relationship between scientists and society is of great interest to the National Academy of Sciences and other national research associations, who together convened the Committee on Assessing Integrity in Research Environments (CAIRE). In a report issued in 2002, CAIRE et al. state:

> The pursuit and dissemination of knowledge enjoy a place of distinction in American culture, and the public expects to reap considerable benefit from the creative and innovative contributions of scientists. As science becomes increasingly intertwined with major social, philosophical, economic, and political issues, scientists become more accountable to the larger society of which they are a part. (p 33)

In previous chapters we have explored genres and conventions that professional scientists use to communicate with each other. In this chapter we will explore conventions used to communicate knowledge of science and scientific research to public audiences in the larger society.

The term *public audience* is a rather loose one and is meant here to imply a wide range of listeners and readers with a variety of interests, needs, and educational backgrounds. It may be a group or a professional person (even with a PhD in another field) in need of information about a particular scientific topic, or a general reader or listener simply curious about science. Public audiences for science thus can include, but are not limited to, those who regularly use

the results of scientific research in the course of their daily work (such as agricultural producers, fish and game managers, medical professionals); administrators, local government agencies, and other public officials who need scientific information to make decisions about issues such as waste management, industrial and environmental regulations, and road construction; clubs, classes, and other educational or special-interest groups that want to learn about science; private citizens who use natural resources for hiking, hunting, fishing, and other recreational purposes; and members of the public at large, who have a vested interest in science insofar as they support it financially through government funding and must live with its consequences.

Thus, public audiences are not monolithic, but rather quite diverse, and so no single, "rationalistic" formula will suffice to define them or their interests (see Locke 2001). In addition to addressing more general audiences *within* the scientific community (e.g., readers of journals such as *Science* and *Nature*, or the mixed audience of the research proposal), scientists may wish to write articles for the much broader audiences that read science-oriented journals such as *Scientific American* and *Discover*, general-interest publications such as *Time* and *Newsweek*, or the feature section of a newspaper. They also may be called on to make presentations to public audiences, participate in question-and-answer sessions, take part in public policy debates affected by developments in their research areas, and give press releases and radio, television, or online presentations and interviews on important discoveries or issues in their field.

There are three major reasons scientists communicate with the general public: moral, economic, and political. The National Academy of Sciences asserts that scientists have an ethical responsibility to understand and explain the effect of the work that they do on the society in which they live:

> The occurrence and consequences of discoveries in basic research are virtually impossible to foresee. Nevertheless, the scientific community must recognize the potential for such discoveries and be prepared to address the questions that they raise. If scientists do find that their discoveries have implications for some important aspect of public affairs, they have a responsibility to call attention to the public issues involved. (NAS 1995, p 20)

Genetic research—including genetically modified foods (GMFs), pharmacogenomics, stem cell research, cloning—are obvious cases in which scientific discoveries are morally controversial or have complicated, long-term implications for society. Other controversial areas of research include global climate change, nuclear power, environmental protection and wildlife preservation, the use of laboratory animals in medical research, the prescribing of psychiatric drugs, the unnecessary overuse of medical technology diagnosis and treatment (see Berenson 2008) and in artificially prolonging life, and biological studies of race and gender.

A second reason scientists communicate with the general public is economic and hinges on the practical question: Who funds science? In addition to private labs, corporations, and universities, it is the government, and therefore the public, that funds science through tax dollars and so indirectly chooses which projects to support. Public financial support of science takes two forms: the funding of governmental agencies that conduct scientific research and the funding of government grant programs that support research by scientists at other institutions. The federal government's proposed budget for 2008 included $6.065 billion for NSF (Mould and Cabbage 2008g), $17.6 billion for NASA (2008e), $95 billion for the USDA (2008), and approximately $28 billion for NIH (2008), with a request of $29.5 billion for year 2009. Increases in some areas of scientific research and education were undoubtedly spurred by the terrorist attack on the United States on September 11, 2001, notably research on biochemical and biological agents. But other government-run programs have either been scaled back

because of budget cuts (e.g., NASA's Mars expeditions) or eliminated altogether (the Superconducting Super Collider). "Big science" projects in which the federal government plays a major role (such as the Hubble Telescope, the International Space Station, and the Human Genome Project) require costly equipment and the coordination of efforts of scientists around the world and can be prohibitively expensive. In times of renewed budget deficits and economic belt tightening, scientists must be able to convince not only their peers but also the public and its official representatives in government of the worthiness of scientific projects. Responsibility for garnering public understanding of, enthusiasm for, and goodwill toward science ultimately rests with scientists.

The third reason scientists should learn to communicate with the general public is related to the politics of a democracy. A democratic society requires that its citizens (both electorate and elected) be informed about the issues that confront it. Since science is a major cultural force in our democracy, many of the policy decisions we make are about or based on science. As the National Academy of Sciences states:

> [S]cience and technology have become such integral parts of society that scientists can no longer isolate themselves from societal concerns. Nearly half of the bills that come before Congress have a significant scientific or technological component. Scientists are increasingly called upon to contribute to public policy and to the public understanding of science. They play an important role in educating nonscientists about the content and processes of science. (NAS 1995, p 21)

Thus, a democracy such as ours needs a scientifically informed citizenry to arrive at good decisions about what research to support and how to interpret and apply its results (see O'Keefe 2001). In a 1996 survey of the American public, the National Science Foundation found only 25 percent performed well on a basic test in science and economics (Associated Press 1996). That same survey, however, found that 72 percent of the participants considered scientific research valuable. A later study by NSF found that "[M]ost Americans have a positive attitude about science and technology" (CAIRE et al. 2002, p 16), but also argues that scientists themselves have an important role to play in maintaining that positive relationship with the public. Citing a 2005 article by Michael Specter in the *New Yorker*, Donald Samson writes that the United States lags behind other countries in students' and the public's understanding of science. According to Specter, the high school seniors in the United States "'performed below the average of twenty-one countries on a test of general knowledge of mathematics and science—and in advanced courses, the U.S. was close the bottom (p 68)'" (Samson 2006, p 5). Significantly, Samson's article is not (only) an argument for increased education in science and math, but also an analysis of the role of ineffective and even damaging communication of science to students and to the public, and the need for improved reading and writing skills in scientific education. It is also an argument for the need to make science not only accessible and comprehensible to students and public, but more interesting and appealing to them as well. (Farmelo [2000] had made a similar argument but added that scientists also need to battle bungled science that gives scientists bad press.)

Scientists can help citizens understand and continue to appreciate science by becoming aware of the various media and genres through which the public gets its information and by learning to use the technologies of those media and the conventions of those genres to effectively communicate with the public. In 1990, John Wilkes, director of the Science Communication Program at the University of California–Santa Cruz, noted that "U.S. citizens get up to 90% of their information about science from newspapers, magazines, and, to a lesser extent, television. As producers of scientific knowledge, scientists are in the best position to use the media to teach the public what it wants—and needs—to know about developments in

medicine, science, and technology" (1990 p 15). In 2006, Samson, a science communication expert, argued that despite the increasing prominence and importance of science via television and the Internet, most Americans still get the bulk of their news from print sources. Samson suggests that while television broadcasts by their very (technological?) nature tend to be superficial, and the credibility of Internet posts is always an issue, general public science journals like *Popular Science* and specialty public science journals like *Scientific American* can cater to specific sets of interests, explore issues in much more depth, and are more reliable. In addition, Samson (2006) states that: "We tend to associate science coverage with the specialty magazines, but far more readers get information about science from daily newspapers and more general weekly and monthly magazines," publications with enormous circulations (p 7).

While most scientists are not professionally trained in speaking or writing to general audiences, many scientists have recognized that the general public is an important audience to reach. As Bazerman demonstrates in *The Languages of Edison's Light* (1999), Thomas Edison was a master of public relations; it would not be far-fetched to say that the adoption of electric power and light was the result of his ability to employ various media (including the light bulb itself in spectacular displays of electric power) to persuasively communicate with a diversity of audiences: investors, businessmen, the U.S. Patent Office, international governments, the press, and the public.[1] Books and articles by such famous scientists as physicist Stephen Hawking, paleontologist Stephen Jay Gould, marine biologist Rachel Carson, research physician Lewis Thomas, and anthropologist Richard Leakey—just to name a few—as well as the current popularity of television programs about science (*National Geographic Explorer, Nature*, and *NOVA*), represent more traditional but effective means for scientists to reach outside their profession to wider audiences.

But earlier studies of the impact of technologies on audiences also suggest that technologies do change "the range of experiences and skills that audiences bring to media" (Nightingale 1986, p 31). Given Edison's achievement, it is perhaps also fitting that the explosion of communication technologies should make communicating with the public easy and more urgent. Popular websites like PubMed Central (www.pubmedcentral.nih.gov), "aims to fill the role of a world class library in the digital age" (PubMed Central 2008). The non-profit Public Library of Science (PLoS) (http://www.publiclibraryofscience.org/), or *SEED Magazine* (http://seedmagazine.com/) allow readers to view, listen to, read, research, and respond to science by blog. YouTube broadcasts and/or iTune podcasts of webcam, video, or 3D animation feature how-to astronomy demonstrations or physical explorations of space specifically designed by amateurs, companies, or agency-scientists themselves. These new forms of communication make use of newer low-cost as well as high-end technologies to appeal to younger viewers and shape the public's understanding and perception of science (see Shida and Gater 2007).

But the availability of powerful communication technology does not in itself guarantee successful communication. In Chapters 3 we explored how new communication technologies, as a potentially democratizing force, have both provided the means but also increased the need for scientists to communicate with the public. We also explored how it is a commonplace that because of the open, rapid, and anonymous sources of the public communication of science online, and the frequent lack of quality control mechanisms, not all the information found on the web is reliable. Given this technology, both the general reader *and the scientist* have the added responsibility to communicate directly and effectively with the public in a variety of media (see Shida and Gater 2007).

[1] Lievrouw (1990) studied the Pons and Fleischmann debate as a modern-day example of the way "scientists strategically use popular media to make knowledge accessible to the public at large and to make themselves known" (p 1).

One solution to the inconsistency of online communication, then, may be the direct interaction of scientists with the public online. The interactive capabilities of the World Wide Web make the Internet a potential meeting place where scientists can interact not only with each other but also with other publics. In fact, the online journal *Issues in Science and Technology Online* (2007), "a forum for discussion of public policy related to science, engineering, and medicine" envisions itself as a public meeting place, focusing on social policy as well as policies designed to enhance specific research fields—and not only the communication of social policy, but also the interactive discussion of it. The journal's editors state their mission on their homepage:

> Although *Issues* is published by the scientific and technical communities, it is not just a platform for these communities to present their views to Congress and the public. Rather, it is a place where researchers, government officials, business leaders, and others with a stake in public policy can share ideas and offer specific suggestions.
> Unlike a popular magazine, in which journalists report on the work of experts, or a professional journal, in which experts communicate with colleagues, *Issues* offers authorities an opportunity to share their insights directly with a broad audience.
> And the expertise of the boardroom, the statehouse, and the federal agency is as important as that of the laboratory and the university.
> (http://www.issues.org/about.html)

All of these developments suggest that rather than heading to ivory-tower labs and leaving the communication of science to journalists, scientists are taking to public pages and airwaves and fiber-optic cables to explain their work. An understanding of the principles and techniques of audience adaptation, and of general audiences themselves, is essential for successfully communicating with the public in any medium.

EXERCISE 8.1

Choose a topic in your field (perhaps derived from a research report you have read), and identify some specific public audiences you might address on this topic. Who outside your field might read or listen to what you as an expert have to say about this topic? Why would they be reading or listening? What media would they likely use? How do the needs and interests of these groups differ from those of experts in your field? What do they want or need from your presentation, and how much would they already know? (Are there any public audiences with whom experts in your field might communicate but currently don't?)

EXERCISE 8.2

On the World Wide Web, search for information on a subject that you are interested in but don't know anything about. After reading the material, speculate on whether the information is reliable—whether you can trust this website. How do you know? List your specific observations about the author(s), the organization(s), the website design and graphics, the content, the terminology and style, and anything else that you are using to assess the validity and truthfulness of the information the site contains. What are some of the ways the public evaluates online information? What questions about the validity and truthfulness of the information remain unanswered for you? What else do you need to know before you can trust this site? How can online communication with the public be improved?

8.2 UNDERSTANDING "GENERAL" AUDIENCES

Some research indicates that human reasoning, even in sciences, is "proverbial"—based on human experience and common sense (e.g., Shapin 2001). But of course, human experience varies. Public audiences can be as diverse as the general population in their knowledge, interests, and needs. Listeners and readers in these audiences will possess varying types and degrees of scientific knowledge. What these general audiences have in common is a presumed lack of knowledge about *your* topic. Just as scientists must understand the conventions governing communication with their peers to be successful professionals, so too must they understand the conventions of communicating with public audiences in order to do so successfully. In this chapter we discuss some general strategies for adapting scientific information to meet the needs and interests of non-scientists in a wide range of situations. These strategies can then be applied to specific audiences, genres, and mediums as the occasion demands.

The basic principle of audience adaptation is that we build a discussion or argument on the knowledge, goals, values, and experience of the audience. This principle is the basis of *all* successful communication and teaching, including that between professional scientists. It is also essential for the scientist communicating with public audiences in any medium. In adapting scientific information for nonspecialists, the writer or speaker introduces new knowledge by trying to relate it to what the audience knows or values; this new knowledge, grounded in what the audience already knows, then becomes the foundation for more new knowledge and so forth.

When you write for other scientists in your area of specialization, such as in the research report, you can assume your readers have some degree of familiarity with the topic to begin with, as well as some degree of interest. When you write for public audiences, however, you need to be more cautious. Instead of assuming knowledge on the part of your readers, you must help them develop that knowledge; instead of assuming interest in the topic, you must generate interest. The way to begin is by assessing your audience's knowledge, needs, and goals.

In *The Rhetorical Act*, Karlyn Kohrs Campbell (1982) gives the following advice on assessing audience (p 149–150). Consider your subject *from the point of view of your readers or listeners*.

- What expectations does your audience have about the subject? About you?
- How is your audience likely to see and/or understand the topic or issue?
- Are there conflicting beliefs or concepts that will have to be dealt with, and how will you deal with them?
- Are familiar explanations trite or boring?
- Does the audience have firsthand experiences that you can draw on to illustrate points in your discussion?

To answer these questions, you will need to find out as much as possible about the background, areas of expertise, probable beliefs, values, and general interests of members of your audience. One way to learn about your audience is to ask the organization sponsoring your talk about who will be in attendance and why. Or read the magazine you are writing for and look at specific text features as described in Exercise 8.3; these features can often provide hints about how to interpret and adapt to a particular audience.

Consider the rhetorical situation in the following scenario.

> Jane, a premed student working with lasers, wanted to show her friend, Mike, a zoology major, how a new laser in her lab worked: "Come on over to my lab and I'll give you a demonstration." Mike had never studied or worked with lasers, but from what he had heard, they seemed fascinating; so one day he took Jane up on her offer. When Mike got to the lab, Jane escorted him through a maze of machines

> to the lab table where her laser was set up, and she proceeded to take the laser apart and explain each major component. Mike quickly lost interest and wandered away to look at the other machines, while Jane continued to discuss at length the technical details she had learned about lasers, oblivious to the fact that Mike was no longer listening. What do you think happened? Using the information given about Mike and your own common sense and empathy (both necessary in audience adaptation), what do you think Mike expected when he walked into Jane's lab? What would Mike like to see and learn about lasers? If Mike were an administrator of the lab—say in charge of personnel and finance—why would he be interested in the laser? What would he want to see and learn? If Mike were a parent whose child's school was about to purchase a laser for use in science classes, what would he want to know about it?

To extend a distinction drawn by Flower (1993), Jane was "speaker-based" rather than "listener-based": She was more concerned with what she as the speaker was interested in and had to say about lasers than in what Mike as the listener was interested in and may have wanted to hear about lasers. The story of Jane and Mike is a microcosm of large- and small-scale breakdowns in communication that occur every day in our society. In fact, communication breakdown has been cited as a major contributing factor in a number of serious technological accidents. In the case of the Three Mile Island nuclear reactor meltdown in 1979, for example, faulty assumptions about how to communicate with the public hampered the efforts of officials to find the best way to inform the public and to control the emergency, which led to widespread panic and social disarray (Farrell and Goodnight 1981). The inability of engineers and managers to understand each others' values has been directly implicated as a major cause of the *Challenger* shuttle explosion (Herndl et al. 1991; Tufte 1996, 2006), and is more than likely an important factor in the *Columbia* accident as well (see *Columbia* Accident Investigation Board 2003, esp. Chapter 7). And the inability of experts and government officials to consider the values and emotions of public audiences has been a factor in unsuccessful attempts to site low-level radioactive waste facilities all around the country (Katz and Miller 1996) and to convince the global public of the safety of biotechnology (Katz 2008).

In all these situations, communicators in one area of expertise seriously misunderstood the audience outside their fields, with dire consequences. Unlike the expert colleague, who has both knowledge of the subject and an intrinsic interest in it, public audiences have different perspectives on and interests in the subject, and thus different expectations and needs that must be appealed to. While experts are interested in theory and technical details, in methods and results, public audiences are generally interested in what things "do" and their effect on public safety, health, and welfare.

In addition to the three general modes of appeal (*logos, pathos, ethos*) discussed in Chapter 7, two special appeals often come into play in the accommodation of scientific knowledge to public audiences (Fahnestock 1986). The first is the *wonder appeal*, which emphasizes the sense of surprise and joy and awe that people (both generalists and specialists!) often feel when confronted with an exciting scientific discovery. The second is the *application appeal*, which emphasizes the practical benefits of a scientific concept or discovery for a particular audience, a society at large, or humankind. This appeal is especially effective with administrators and public officials. The administrator is interested in what things do from the point of view of cost, production, public health, environmental safety, and resource management: How can this new piece of equipment be used in the lab? How much does it cost to purchase and maintain? What products (or discoveries) are likely to arise from it, and will they be profitable for the lab or company? Is the piece of equipment or product cost-effective? Safe? Efficient?

Most of us are fascinated by the accomplishments and spectacle of science, and interested in what things do from the point of view of common experience or daily life. Practical application is also important to the general public. Figure 8.1 contains a blurb by John O'Neil in *The New York Times*, reporting the results of an *H. pylori* breath test in a study published in the *British Medical Journal*. Comparing the blurb to Chiba et al. (2002), contained in Chapter 10 (p xxx–xxx), note the amount of Chiba et al. detail that has been left out of the blurb. Also note the appeals to "wonder" in the title and the graphic that is not included in the Chiba et al. article in *BMJ*, and the two direct appeals to "application," quoted from the BMJ article, in the last paragraph of the blurb: the breath test (which is as good as endoscopy) is less invasive than endoscopy and is cheaper than endoscopy.

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FIGURE 8.1 Blurb on *H. pylori* breath test (O'Neil 2002, p D6).

Both the wonder appeal and the application appeal work well with general audiences. In the scenario described earlier, Mike may have secretly wanted to ask: "Can we see the laser burn a hole in something?" (wonder). "How can lasers be used to shoot down missiles in outer space and also perform delicate eye surgery?" (wonder and application). "How could I use lasers in my zoology major?" (application). He never got a chance.

In the remainder of this chapter, we will explore several principles and specific strategies writers can use to adapt scientific and technical discussions for general audiences.

EXERCISE 8.3

In Figure 8.2 we have reproduced the introductions to five different articles on the same topic. You'll see that they are clearly intended for different audiences. As you read, think about what kind of publication these pieces would have appeared in. (This exercise has been adapted from Bradford and Whitburn [1982].)

A. Read the five introductions and categorize them according to the level of specialized knowledge assumed on the part of the audience. Use a scale of 1 (general audience) to 5 (most specialized audience). Speculate about where each piece might have been published.

B. After you've categorized the texts, reflect on what criteria you used to do so. In what ways do these introductions vary? What made you decide that one article is intended for a more general audience than another? Be sure to consider all dimensions of the text, including such features as content and organization, terminology and phrasing, formatting and visual presentation, tone and point of view. List the many ways in which these texts vary. Illustrate each of these features with a pair of contrasting examples from the passages.
C. Your instructor may ask you to work in small groups to develop a consensus ordering of the five texts, a consensus list of the features on which they vary, and a set of contrasting examples to illustrate each feature.

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FIGURE 8.2 Five introductions. Bradford and Whitburn. "Analysis of the same subject in diverse periodicals." *Technical Writing Teacher* 9 (Winter 1982).[2]

[2] Original formatting and typeface are reproduced as closely as possible. Sources for these introductions are listed in the Works Cited list and identified in the Instructor's Manual.

EXERCISE 8.4

Assume you're a member of Stephen Reynolds's research team. You've been invited to speak to a local amateur astronomy club about the origin of the Kepler supernova remnant. Using Campbell's audience analysis questions on page xxx as your starting point, write a paragraph describing your audience. Write a second paragraph describing what kinds of appeals you would use to discuss the topic with this audience. What would you talk about with them?

8.3 ADAPTING THROUGH NARRATION

Narration is a powerful means of audience adaptation. Research has shown that stories are basic to the formation of human identity and knowledge—even scientific knowledge (Fisher 1987; Polkinghorne 1988). By creating a human story through which an audience can identify with a scientific subject, narration can make science accessible and acceptable to general audiences (Katz 1992a). Jorgensen-Earp and Jorgensen (2002) have examined the way Alexander Fleming, unlike his less remembered rival, Howard Florey, used narratives from the British wartime press to make his penicillin research salient to a victorious World War II public. Unlike the research report—with its hypothesis, methods, results, and conclusion sections—science, when presented to the general public, often takes the form of a dramatic story, with characters, plot, conflict, and resolution.[3] When the *New Yorker* reported the discovery of *H. pylori*, for example, its story was titled "Marshall's Hunch" (Monmaney 1993) and focused on Marshall himself, tracking his rise to prominence from relative obscurity and emphasizing his iconoclastic style. Marshall the rebel, not *H. pylori*, was the hero of this story for a general audience. (Haller [1998] analyzes a similar characterization of researchers studying chronic fatigue syndrome.)

Parts of the "story of science" often take the form of a *history*, a brief chronology of events. It may be a recounting of steps leading to a discovery or the development of a phenomenon, concept, project, or field. Historical narrative can be especially effective if the story can be accommodated to the audience's interest and/or general (cultural) experience. Such narratives are usually given dramatic flair, as in the following "scene" in Huyghe's description of the discovery of the killer algae (contained in Chapter 10): "The story properly begins one night early in 1988, with a massacre in Edward Noga's laboratory at North Carolina State University in Raleigh" (1993, p 72).

These principles of narration apply equally to communicating with the public in electronic media, whether television or online. In Chapter 6 we discussed the use of body and voice in conference presentations. In narratives broadcast via electronic media, both principles of narration and oral presentations are brought together. Dr. Sanjay Gupta, a well-known physician who regularly appears on major network television as a host of primetime specials or as a medical consultant on the evening news, combines scripted narratives with a more informal delivery that, combined with some of the audience adaptation techniques to be

[3] As you will see in this chapter, the application of what appears to be "literary technique"—not only narrative, but also metaphor, analogy, and even imagery—can be very effective in making abstract or complex science tangible and accessible to the public (see Arroliga [2002]). Because of this ability to make abstractions palpable, literary technique is increasingly being used to develop and teach empathy in medical education: Martin Blaser, who in 2000 became Chairman of the Department of Medicine and Professor of Microbiology at New York University and whose work is represented in Chapter 9, believes so much in the value of the study of writing and literature for scientific and medical education (www.blreview.org/staff.htm) that he co-founded the *Bellevue Literary Review*, a prestigious literary journal published by Bellevue Hospital that features poetry and fiction "that touch upon relationships to the human body, illness, health and healing" (http://www.blreview.org/index.htm).

described below, including graphics, creates an informative but persuasive ethos that will appeal to a general audience (see Dinolfo 2008); in a sense, in these television appearances the narrator becomes a character in her or his own presentation. As NASA hurricane specialist Jeffrey Halverson (NASA 2008a) demonstrates, online, sophisticated animation and satellite imagery can be combined with narration to create a compelling as well as informative educational series of podcast seminars (see Additional Resources #2, contained in Chapter 13).

EXERCISE 8.5

Read the Huyghe (1993) article (Chapter 10, p xxx–xxx) from *Discover* magazine about the Burkholder team's research on toxic dinoflagellates. Look for instances of narrative storytelling and character development. What parts of this project are dramatized in this article written for a general audience? Who are the main "characters"? What is the "plot"? What is the "conflict"? How is it "resolved"?

EXERCISE 8.6

Watch an episode of a science program such as *Nature* or *NOVA* on television. As in Exercise 8.5, is the scientific information adapted to a general viewing audience through the use of narrative storytelling? What parts of the science are being dramatized? Who are the main "characters"? What is the "plot"? What is the "conflict"? How is it "resolved," and how does the resolution support scientific research?

8.4 ADAPTING THROUGH EXAMPLES

Examples play a prominent role in audience adaptation and are essential for comprehension. As shown in Figure 8.3, specific examples provide increasingly more particular instances of a general class or concept to which the examples belong. As we move down "the ladder of abstraction," the more specific example of the class or concept under discussion tends to make the class or concept easier to grasp. The trick in every instance is to pick the right level of specificity and language for your topic and purpose. For instance, a pet care booklet for cat owners might feature a particular housecat (Golden Boy) with Feline Immunodeficiency Virus (FIV) to help illustrate the symptoms of this disease; but while an article about effects of global climate change on animal health might include the category of diseased mammals again, it also could include different categories (e.g., starving mammals), and both of these might be illustrated with other specific examples from those categories (sickened cattle, endangered polar bears, etc.).

Examples also can provide an effective way to relate unfamiliar concepts to what readers or listeners already know, value, and are interested in—if they are drawn from the reader's or listener's experience. Red tide, which many coastal visitors have seen firsthand, might be a more effective example of the class of biological phenomena called *algal blooms* than *Pfiesteria* if you were addressing coastal visitors. As you discovered in the Mike and Jane story above, different audiences will be interested in different issues—in this case, different aspects of lasers. In speaking to or writing, you would want to draw examples from that particular audience's area of interest.

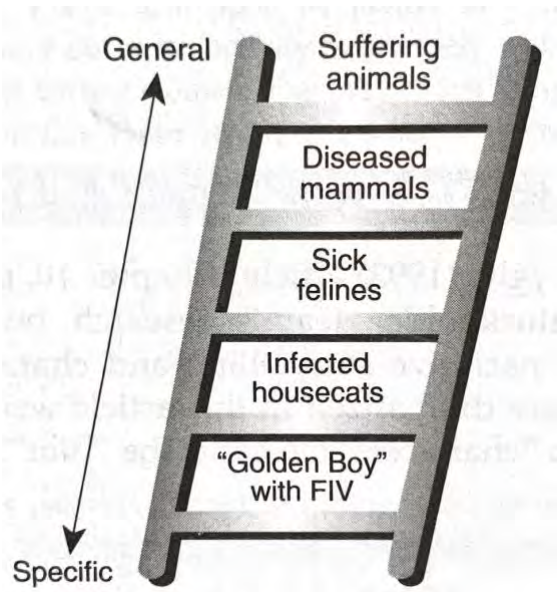

FIGURE 8.3 The use of examples: Movement from general classes to particular instances.

In this book we have used examples to illustrate our discussion of various genres and conventions. Imagine this book without them!

8.5 ADAPTING THROUGH DEFINITION

Several definitional strategies can be used to "unpack," or "translate," scientific terms for a general audience. Before you consider any of these strategies, you will want to ask yourself whether the particular term is needed by the audience at all. Think about the knowledge, needs, and interests of your audience. Is the term absolutely essential for the audience to learn?

If you decide it will bog down the reader, omit the term. For example, when you read our descriptions of the appeals to wonder and application in Section 8.2, did you need to know that the technical term for the appeal to application is the *teleological appeal* and that the appeal to wonder is the *deontological appeal* (Fahnestock 1986)? What good does it do you to know this information now? What would have been the effect if we had used these terms instead of the general terms in the earlier discussion? Are there circumstances in which this technical terminology might be appropriate?

If you decide a term is important enough to take the time to explain it to your audience, then you can use one of the following definitional strategies to define it. These strategies are not just different ways of explaining terms but also different ways of thinking about concepts. Each definitional strategy gives you (and thus the audience) a different "angle" on a term, a different perspective on a concept. Thus, your choice of definitional strategy will depend on (1) the term or concept; (2) the audience's knowledge, values, interests, and needs; and (3) what you want to say to this audience (your purpose).

When you define using the *classical* (*Aristotelian*) *definition*, you place a term or concept in a general class of things to which it is similar and then delineate how the term or concept is different from other members of this class. This genus-differentia definition is the one we find most often in dictionaries. It depends on classification as the primary intellectual strategy to

explain a concept. For example, in *Sky & Telescope's* coverage of the Reynolds team's Kepler analysis, "type 1A supernova" is the term to be defined, "thermonuclear explosion" is the genus, and "of a white dwarf" is the differential (Naeye 2007; reproduced in Chapter 12).

The definitional strategy *etymology* explains a term by examining the history of the word(s). Notice how in the following etymological definition Huyghe (1993) employs the narration strategy to enhance audience appeal as well:

> They have proposed calling [the dinoflagellate] *Pfiesteria piscimorte* (the genus name was picked to honor the late dino specialist Lois Pfiester of the University of Oklahoma and also because Burkholder liked the name's echo of both *feast* and *cafeteria*; the species name means 'fish killer'). (p 75)

8.6 ADAPTING THROUGH ANALYSIS

Analysis breaks a whole into constituent elements. Thus, in analysis, division, not classification, is the primary strategy used to unpack a concept. Analysis can be used to discuss the structure of a molecule or the stages of a supernova. Huyghe (1993) uses analysis to divide the life cycle of dinoflagellates into stages to emphasize the scientific oddity of these creatures and their devastating effect:

> [The new dinoflagellate's] life cycle consists of more than 15 stages . . . . The dino lives most of its life as an amoeba; in one toxic "giant" amoeboid stage it grows to be nearly 20 times the size of the flagellated toxic cells. The stage when the dino leaves its cyst to attack fish is actually quite ephemeral, appearing only when fish are present. The researchers also found that this stage is the only time the creature sexually reproduces. (p 75)

8.7 ADAPTING THROUGH COMPARISON

Comparison is a particularly useful method for explaining concepts to non-specialists. Using this strategy, the scientist indicates how a phenomenon is similar to or different from other phenomena the audience is more familiar with: "Dinoflagellates are twilight-zone creatures: half-plant, half-animal. They produce chlorophyll, but they also move about, using their two flagella, or whiplike tails, to swim rapidly through the water" (Huyghe 1993, p 72).

The use of synonyms is one type of comparison strategy. *Synonym*, substituting one or more words for another, can be used to define a term in a context the audience is more familiar with, as in the example above: "flagella, or whiplike tails." This sort of definition in context is also known as *parenthetical explanation* (if in parentheses), and *apposition*, if inserted between commas without parentheses.

It is because no two words have exactly the same meaning or connotation that synonym falls under the category of comparison: for the writer or speaker, the use of synonyms really involves a comparison of terms and concepts rather than exact substitution—a search for a similar word that the audience will be more likely to understand and be able to relate to. Given that technical terms are part of a precise vocabulary of a field, the scientist using synonym usually has to trade off some accuracy for the sake of gaining the audience's comprehension.

You've all learned that *simile* is a comparison that uses *like* or *as*. Simile can be used to drive home a point figuratively, as in the following example: "Efforts to describe [the dinoflagellate] have evoked the strangest comparisons: like grass feeding on sheep, said one scientist. And that's not stretching things much" (Huyghe 1993, p 72). Unlike simile, *metaphor* does not use *like* or *as*. It is thus a less obvious, but a much more pervasive, method of

comparison than we might think. By omitting *like* or *as*, metaphors not only conceal the comparison but also imply an identification of the things compared, as in the following example: "The creature is in fact a tiny plant with a Jekyll and Hyde personality, one that preys on animal life a million times its size" (Huyghe 1993, p 72). Notice that the attribution of a specific behavior to the alga through the personality metaphor of "Jekyll and Hyde" is grounded in the audience's cultural knowledge.

Some researchers believe that metaphors actually structure, and to some extent determine, the way we conceptualize the world (e.g., Lakoff and Johnson 1980). It has been argued that metaphors are implicit in scientific models and thought (Turbayne 1970; Kuhn 1979; Leary 1990; Boyd 1993; Spraggins 1999; Shea 2008); Neils Bohr's early model of the atom as a solar system immediately comes to mind, but there are many others. In any case, common sense tells us that the metaphors we choose both color and reflect the way we think about phenomena. Metaphors are used not only in communicating with general audiences (e.g., "biological clock" [Brown 1959]; "killer algae" [Huyghe 1993]), but also by scientists themselves in exploring new phenomena (e.g., "genetic code" [Watson and Crick 1953]; "phantom dinoflagellate" [Burkholder et al. 1992]) the "ears" of the Kepler supernova remnant [Reynolds et al. 2005. p 1]).[4]

In creating metaphors for nonexpert audiences, it is important to remember two things: (1) Find the metaphors in the language, knowledge, and experience of your audience; do not merely switch to other technical metaphors embedded in your field that the audience will not understand. (2) Use metaphors consistently; mixing metaphors confuses readers and may introduce inconsistencies into your discussion.

EXERCISE 8.7

An excerpt from Monmaney's (1993) profile of Barry Marshall in the *New Yorker* is presented in Figure 8.4. Identify and circle the metaphors Monmaney uses to discuss the *H. pylori* bacteria. What are the bacteria being compared to? Why? Are the metaphors related to each other (i.e., consistent)? What do the metaphors communicate? Compare the description of this bacterium in *The New Yorker* with its description in the Marshall and Warren letters (1983) in Chapter 9. Are there any metaphors in the technical letters? What conclusions can you draw about the use of metaphors for scientific and non-scientific audiences? What is the scientific basis for the metaphors in *The New Yorker* excerpt? What is the popular basis of the metaphor?

See next page (175A).

FIGURE 8.4 Metaphor identification: From "Marshall's Hunch," by Terence Monmaney, originally published in *The New Yorker*. Copyright © 1993 by Terence Monmaney. Excerpted by permission of the author.

[4] Quotation marks are often used around "popular" terminology by scientists writing to general and specialist audiences to distance themselves from it, reflecting an abiding concern for their professional credibility.

It takes a kind of cunning for *Helicobacter pylori* to fill its niche, for the adult human stomach is one of nature's most hostile habitats. Each day, the stomach normally produces about half a gallon of gastric juice, whose strong hydrochloric acid and digestive enzymes readily tear meat and microbes apart. Gastric juice is like a binary chemical weapon—so destructive that it's constituted only on the way to the target. As cells in the stomach lining secrete the raw ingredients of gastric juice into the mucus that coats the stomach lining, the ingredients mix into an even more caustic brew, which then oozes into the cavity. There the gastric juice breaks pabulum down chemically while muscles in the stomach wall act to crush it. The viscoelastic mucus, as thick as axle grease, keeps the stomach from digesting itself.

Once *Helicobacter* reaches the stomach, it probably does not linger out in the open cavity—a tossing sea of toxic chemicals. It heads for cover. The bacterium's helical shape seems to have been designed for speedy travel in a dense medium. *Helicobacter* is living torque; a microscopic Roto-Rooter, it corkscrews through the mucus. Then, instead of penetrating the cells of the stomach lining, it settles in the mucus just beyond the lining. More often than not, it settles in the pylorus. No one knows why. Under the microscope, a *Helicobacter* infection looks like a satellite image of an armada gathered off a ragged shore. At one end of the bacterium is a cluster of long, wispy, curving flagella, which may serve as anchors. It's a graceful menace.

Helicobacter possesses a vital defense against stomach acid, and this adaptation, too, is a marvel of evolutionary design. Its coat is studded with enzymes that convert urea—a waste product, virtually unlimited supplies of which can be found in the stomach—directly into carbon dioxide and also into ammonia, a strong alkali. Thus *Helicobacter* ensconces itself in an acid-neutralizing mist. In like fashion, it generates another antacid—bicarbonate, as in Alka-Seltzer.

A *Helicobacter* infection that establishes itself succeeds largely because the immune system can't reach it. In response to a *Helicobacter* invasion, immune-system cells in the bone marrow produce white blood cells, killer cells, and other microbe destroyers, and those float through the bloodstream to the very edge of the stomach lining—and go no farther, because the lining holds them back. The *Helicobacter,* hovering in the mucus, are out of range. And yet the immune system sends reinforcements. Killer cells pile up, gorging the stomach lining; permanently alerted, seldom engaged, the killers become trigger-happy. Some die, fall apart, and spill their microbe-fighting compounds into the host tissue. Friendly fire begets friendly fire. Metabolic hell breaks loose. The lining is now inflamed: acute gastritis. Micronutrients are pumped from the bloodstream to the front lines, to feed the killers, but loads of them seep out of the stomach lining and into the mucus. Offshore, the *Helicobacter* feast; having drawn the immune system into battle, the bacteria now loot the provisions. "I propose that inflammation is good for *Helicobacter,*" Blaser says. "That's what it wants."

Chronic gastritis, a standoff between the bacteria and the host's immune system, may persist for years—decades, according to some estimates. As it happens, whatever serious damage is done to stomach or intestinal tissue is apparently done not by the bacteria themselves but by the inflammatory response they provoke. That the host plays such a large role in his own pathology may help explain why *Helicobacter* infection affects different people differently. (Also, scientists recently discovered that there are at least two strains of *Helicobacter pylori,* and that one of them is far more likely to cause a peptic ulcer than any other.) Inevitably, though, for *Helicobacter* to be really successful it has to meet a parasite's final challenge: to start another colony before the host dies.

FIGURE 8.4 Metaphor identification: From "Marshall's Hunch," by Terence Monmaney, originally published in *The New Yorker*. Copyright © 1993 by Terence Monmaney. Excerpted by permission of the author.

Analogy is an extended comparison that may include similes and metaphors. In fact, an analogy might comprise a series of related metaphors running throughout a text. Like other methods of comparison, the advantage of an analogy is that the writer can begin with what the audience knows and then move back and forth between the known and the unknown as the concept is explained or new terms are further defined. For example, in the Huyghe piece, the metaphor "killer algae," announced in the title of the article, "surfaces" throughout the text. In a series of multimedia segments for students and teachers, Halverson (NASA 2008a) uses the extended analogy of the car engine to explain how hurricanes form (see segments 20–22 of this resource: http://www.nasa.gov/mission_pages/hurricanes/ multimedia/AtlanticHurricanesWithJeff.html). Halverson uses this analogy both verbally and visually to describe the "fuel" (water vapor), "flywheel" (rotating winds), "combustion" (condensation), "exhaust" (rain and clouds), and other components of the "natural heat engine" of the hurricane. Halverson wisely observes that this analogy will become less effective over time: as the hybrid car's electric motor replaces the gas-powered engine, students are less likely to be familiar with the workings of the internal combustion engine that forms the base of this analogy.

You should note that *analogy* **is not** *example*. While examples are drawn from the general class of concepts they are a part of, the "examples" in analogies are drawn from similar or parallel classes of concepts; that is, they are based on comparison. As Ziman (2000) might indicate, scientists can draw on intellectual and political contexts outside science in comparing unfamiliar concepts with concepts more familiar to their general audiences.

EXERCISE 8.8

In the Huyghe (1993) piece, look at definitions, similes, metaphors, and other places where the metaphor "killer algae" is extended in the discussion through analogy. Are there places where the analogy breaks down or is violated? Why? What is the effect? Do you see any similiarity between the analogy in the Huyghe piece on dinoflagellates and the analogy in the excerpt from Monmaney's piece on *H. pylori?* What do these analogies tell you about common attitudes toward microorganisms?

8.8 ADAPTING THROUGH GRAPHICS

Graphics are visual representations of phenomena. Like metaphor, they also have the power to persuasively portray abstract *concepts* as physical phenomena and relations (see Gilbert and Mulkay 1984; Tufte 2006). As discussed in previous chapters, visual aids such as tables, line graphs, diagrams, and site maps are conventionally used to present information to scientific audiences in research reports and conference presentations. But graphics can also be used to explain concepts to general audiences, whether in material that is printed, broadcast, or accessed digitally. Note the use of Figure 8.3 to illustrate audience adaptation strategies in this chapter, or Halverson's extensive use of graphics in the NASA educational segments mentioned above. Like verbal examples, visual examples should be based on your audience's knowledge, interests, and values.

For general audiences, photographs, slides, maps, drawings, bar graphs, pie charts, and simple diagrams serve to make the verbally abstract visually concrete. One advantage of these types of pictorial representation is that they can be made colorful, attractive, and thus very appealing. They also can be discussed at any level of generality that is appropriate. A striking photograph can even be used to introduce a topic. For example, the opening page spread of the "Killer Algae" article (Huyghe 1993) catches readers' attention by juxtaposing a "supersized" image of the toxic dinoflagellate with smaller pictures of the fish that become its victims,

effectively dramatizing the magnitude of the threat posed by the microscopic algae. The Kepler image in *Sky & Telescope's* description of Reynolds et al.'s finding serves as a dramatic introduction to this research (see p xxx in Chapter 12). More prominent than the text itself, this visual plays a significant role in conveying the nature of this discovery.

The medium, size, shape, and color of a visual representation also can be used to communicate symbolically. Line graphs use colors (e.g., black and red) as well as the direction of the line (up and down) to symbolically (and dramatically) show increase and decrease *visually*. Thus, a pie chart showing percentages of food consumed by Americans during the day versus the night, for instance, might color the day part of the graph yellow and the night part blue, communicating basic information at a glance through color as well as labels. A graph showing annual deforestation by fire might have bars colored red or orange (known as "hot colors," as opposed to blue or green, known as "cool colors") or even shaped like flames! The use of size, shape, and color in graphics is especially important for nonexpert audiences when knowledge of the appearance of phenomena cannot be assumed but can be communicated quickly through the visual medium, or when dramatic effect is desired to make a point.

When using graphics to communicate to a general audience, consider all the possibilities the visual medium has to offer you. Recall from Chapter 6, though, that one of the dangers of pictorial representation is that the visual aid (whether print or pixel) may contain too much detail, especially if it is not designed specifically for the purposes of your presentation (see Figure 6.3). Visual aids, like text, should be focused and uncluttered when communicating with non-specialists.

EXERCISE 8.9

The public announcements of the Reynolds team's discovery of the Kepler supernova remnant (Roy and Watzke 2007; Cowden 2007; contained in Chapter 12, p xxx, and xxx) use many of the audience adaptation techniques discussed above. Turn to those pieces and see if you can identify the various techniques. In what ways do these techniques make the science more accessible and relevant to a general audience? Are any techniques used together in the same sentence to unpack concepts? In what ways do these techniques "change" the scientific information? What do you learn about using audience adaptation techniques by looking at how they are used in these two articles?

EXERCISE 8.10

Imagine that you are an editor working for *Discover* or *Scientific American*. You have assigned one of your staff writers to write an article describing the Reynolds team's research on the Kepler supernova remnant. While your writer reviews the research and flies to North Carolina State University to conduct an interview, you call in your design staff to start planning the visual presentation. You notice that all the popular coverage features the image from Chandra as the only visual. After reviewing this research (see Chapter 12), think about what other visual effects you'd like to create. Describe (or better yet, sketch) the first page spread for the article. Think of an effective title for the piece, and incorporate it into your design.

EXERCISE 8.11

Burkholder and Rublee diagram the life cycle of the toxic dinoflagellate in Figure 2 of their 1994 Sea Grant Proposal (see p 290). Patrick Huyghe presents a brief verbal description of the life cycle on the last page of his *Discover* piece (1993, p 277). Assume that you are working with Huyghe on a revision of this piece. Your task is to adapt Burkholder and Rublee's technical diagram for the general readership of *Discover*. Redesign this diagram, using both the

original diagram and Huyghe's verbal description as your guide. You may add to or revise Huyghe's verbal description to accommodate your graphic if you wish.

8.9 LOGIC AND ORGANIZATION IN WRITING FOR PUBLIC AUDIENCES

Unlike the research report and proposal, there is no standard structure for articles written for general audiences. Thus, you will want to consult the publication you are writing for to get a sense of stylistic and formatting options. Major topics or points are often indicated by headings, as in Blaser's (2005) *Scientific American* article on *H. pylori*, contained in Chapter 9. When headings are used, they are topical rather than functional; that is, they provide clues to the content rather than the structure of the text. Functional headings (such as "Introduction," "Methods," "Results," "Discussion") are useful in genres governed by a standard structure, for they enable readers familiar with that structure to quickly locate the types of information they're most interested in. But such headings are of no use when no particular pattern of organization is expected by readers.

Topical headings help readers see at a glance what major topics or issues will be raised in each section of an article. Thus, this type of heading serves to introduce the unique pattern of organization used in a given essay. To do so, they must be clearly comprehensible to the general reader. Topical headings also provide an opportunity to catch readers' attention and pique their interest. Thus, authors writing for general audiences aim to create titles and headings that are not only informative but also intriguing.

Articles in general-reader publications may end with a list of suggested readings but usually do not include a formal reference list. These articles rarely report the results of individual experiments, focusing instead on the general outcomes of a body of research. They therefore do not typically include citations of individual research reports. Such reports are occasionally included in a list of further readings (see Blaser [2005], Chapter 9), but it is not common practice to include sources written for research journal audiences when writing for newspapers or general-interest magazines. For those readers, it is more helpful to list resources that are specifically designed for general readers and are readily available in local bookstores or public libraries.

Instead of drawing on prior research reports to support their claims, authors often use interview data when writing for general audiences. Direct quotations are rarely used in other genres of scientific discourse (see Chapter 5), but they are legitimate and popular forms of evidence in general-reader publications such as newspapers and magazines. In fact, *quoting* can be understood to constitute another major strategy for adapting science to a general audience. Quotations from "characters" in a scientific story can enliven it, and thus are frequently used when the narrative strategy is employed. The Huyghe (1993) article in *Discover* and the popular coverage of Chambers and Hurtt's research on the effects of Hurricane Katrina include numerous examples of this strategy (see the pieces by Cook-Anderson and Kaufman in Chapter 13). Another common use for quotations is to provide support for or elaboration of a claim made in an essay, as when the author quotes a prominent authority's opinion of a new finding or its implications. In classical argumentation terms, quotations thus represent either *appeals to experience* (testimonials) or *appeals to authority*. For general readers or listeners, both types of testimony enhance the credibility and authenticity of the scientific story being told.

EXERCISE 8.12

Compare the headings in Blaser's (2005) *Scientific American* piece (p xxx–xxx) with those of a standard research report, such as those by Marshall and Warren (1984) or Graham et al. (1992). Then compare the title and headings of the *Scientific American* piece with the review article that Blaser (1987) wrote for *Gastroenterology* (p xxx–xxx). (These readings are all contained

in Chapter 9.) Write a brief (two-page) analysis in which you use these sample articles to illustrate the differences between topical and functional headings and the differences between specialized and general audiences.

EXERCISE 8.13

Blaser (2005) does not include direct quotations in his *Scientific American* piece (Chapter 9), most likely because he himself is one of the researchers involved in this research and thus provides the authenticity that quotations would contribute. However, if you were to write on his topic for a general readership, what kinds of quotations would you want to obtain to supplement your article? In a paragraph or two, choose a target publication and audience for your piece, and explain whom you would like to interview, what kind of information you'd hope to obtain from those interviewed, and how you would use this material in your article.

EXERCISE 8.14

Chapter 10 (p xxx–xxx) includes a piece on *Pfiesteria* from *Environmental Science and Technology Online*, published by the American Chemical Society (Engelhaupt 2008). This document utilizes a range of strategies for communicating complex scientific knowledge to non-specialists. Analyze this text, describing the adaptation strategies it employs and speculating on the effectiveness of each. Don't limit your analysis to the strategies discussed in this chapter. Overall, does this seem an effective article? What is the assumed audience like? What public needs, interests, or concerns does it seem intended to address?

Activities and Assignments

1. Watch a local weather forecast on television or online. In a two- or three-page paper, identify and describe the audience adaptation strategies being used, and assess their effect on you as a member of the audience.
2. A. Choose a paragraph from an expert text in your field (e.g., from a textbook or journal). Select and analyze a general audience for which this topic might be appropriate and a preferred medium of communication. Adapt the paragraph for that audience using the audience adaptation strategies you have studied in this chapter. Be sure to specify the intended audience (by publication/medium, age, education, background, interests, goals, etc.). Compare your adaptation with the original, and explain the similarities and differences.

   B. Now select and analyze an appropriate administrative audience and medium, and adapt the same piece for this audience (e.g., suppose you are working in a lab and need to explain a piece of equipment or an experiment to the lab administrators so that they will continue funding your project). Note what changes you had to make in content and strategy from the piece written for a general audience. Compare this piece written for an administrative audience with the original text written for an expert audience; explain any similarities and differences between these texts.
3. Jeffrey Chambers' research on Gulf Coast forest damage after Hurricane Katrina was described for public audiences in a number of venues. Read the feature story that NASA posted on November 15, 2007 and the *Washington Post*'s report the following day (see p xxx–xxx in Chapter 13), both of which are based on the brevia article published by Chambers et al. in Science (also in Chapter 13). Analyze and compare the adaptation strategies used in these two articles. For example, who is the "hero" in each of these stories? Also, who has been interviewed for each story, and why were they chosen? What is the overall message conveyed by each article? What purpose does each serve?
4. Write a scientific essay for a popular magazine or newspaper in print or online that traditionally covers science (*Time, National Geographic, Scientific American, Discover, The New York Times*, etc.). Choose an essay from that publication or website as a model. Analyze the audience for the magazine using the questions in Exercise 8.3B as a guide, and examine your model for the audience adaptation strategies we have discussed. Use these strategies where necessary and appropriate in your

essay. Create visuals designed for this journal and audience to include with your text. Be sure to include your model with your assignment.

5. Choose a particular public audience and occasion for an oral presentation on a topic in your field. For example, you might address a club, a junior high classroom, a congressional committee, the press. (If you have the equipment and the technical expertise, you also might decide to prepare this presentation as if for television broadcast or streaming online.) Give an oral presentation appropriate to this audience. The talk may be based on a previous topic you wrote about in this or other classes for an expert audience, or for Activity 4, but be sure to adapt it fully for an oral presentation to your new audience, using the principles and strategies in this chapter. Remember to eliminate any terms, concepts, and details that don't fit your general audience's needs and interests; make sure other terms are appropriately explained. Design visuals for this audience. Before you present this talk in class, inform your listeners of the intended purpose, audience, and occasion for the presentation—who and where they are supposed to be as they role-play the target audience. Because they most likely represent a diverse public audience for your topic, they will be able to give you direct feedback about what they understood.
6. Write an online "fact sheet" for the public on an issue in your field. EPA's *Pfiesteria* fact sheet, which provides a useful model, can be viewed online at http://www.medhelp.org/NIHlib/GF-394.html. Consider where your fact sheet should be posted: Where would interested publics look for it or be likely to come across it? What government agency or private organization should provide such a fact sheet? Design a fact sheet that is clearly adapted to the needs of the general public and that uses the Internet medium to full advantage. What text features does the Internet enable you to include that would not be available in a hard copy text?
7. Reporter Andrew Revkin described a range of positions in the climate change debate in a 2007 *New York Times* article titled "New Middle Stance Emerges in Debate over Climate." Read this article, the final item in Chapter 13, paying special attention to the stances taken by the scientists interviewed, as well as their comments about scientists' roles or potential roles in this public debate. Consider the roles that scientists play in public discussion of this and other science-related issues. Write an essay in which you reflect on scientists' responsibilities in such discussions, and conversely, on the public's responsibility in interpreting science. How do, or should, non-specialists make decisions when the experts disagree?

PART 3

Sample Research Cases

CHAPTER

9

Research on the "Ulcer Bug": From Theory to Clinical Application

NOTE for 3e OPEN ACCESS: Many of the documents described below have been removed from the open access version due to copyright restrictions. We encourage you to access these articles from their original publishers via your university library and/or to locate more recent publications to expand this research case.

At an international conference on *Campylobacter* infections in 1983, a young Australian internist, Dr. Barry Marshall, reported that he and Dr. Robin Warren had identified a bacterium responsible for stomach ulcers—a revolutionary claim, given the prevailing assumption in the medical community that ulcers were caused by stress and other psychological factors. Warren and Marshall announced their discovery in print that same year, in a pair of letters in the *Lancet*, the first items reprinted in this chapter. Their theory that ulcers and other gastric illnesses were related to bacterial infection in the stomach lining was greeted with both intense interest and skepticism by experts in the field. By the time Martin Blaser wrote a review of research on the topic for *Gastroenterology* in 1987, the next document included here, over one hundred studies had been published. The theory was much debated in a number of scientific forums and, despite the controversial nature of the claim, research such as a 1992 research report by David Graham and colleagues at the Houston Veterans Affairs Medical Center (our next selection in this chapter) began to support Marshall and Warren's hypothesis.

The evidence mounted quickly. In 1994 the National Institutes of Health acknowledged a relationship between *H. pylori* and ulcer disease and recommended that antibiotics be used in the treatment of stomach ulcers, and in 1996 the FDA approved the first drug specifically designed for treating ulcers based on Marshall's findings. Soon commercial testing kits became available, offering techniques for easily detecting the presence of *H. pylori* from breath samples, a concept

initially proposed in the late 1980s by research teams headed by Barry Marshall and by David Graham (Fallone et al. 2000). In 2002, a Canadian research team headed by Naoki Chiba used one of these commercially available breath tests to detect the presence and eradication of *H. pylori* in an investigation of its role in common dyspepsia. This piece, published in the *British Medical Journal* and included here, is representative of the field's focus on clinical detection and treatment of *H. pylori*, twenty years after Marshall and Warren's startling announcement of its presence in the stomach. Reports of the revolution in ulcer treatment began appearing in the popular press in the 1990s; we've included an article written by Martin Blaser in 2005, addressing the general readership of *Scientific American*.

With the widespread acceptance of their research and its application in clinical practice, Marshall and Warren received the Nobel Prize in Medicine in 2005. We have provided links to their Nobel Lectures below.

Additional Resources

1. Marshall's Nobel Prize Speech and Lecture from (Marshall 2005)
   http://nobelprize.org/nobel_prizes/medicine/laureates/2005/marshall-lecture.html
2. Helicobacter Foundation Website (Helicobacter Foundation 2006)
   http://www.helico.com/
3. Warren's Nobel Prize Lecture (Warren 2005)
   http://nobelprize.org/nobel_prizes/medicine/laureates/2005/warren-lecture.html
4. Bacteria as History: Connections Between *H. pylori* and Early Humans from *Scientific American* (Swaminanthan 2007)
   http://www.sciam.com/article.cfm?id=out-of-africa-stomach-ulc
5. *WebMD.com* on *H. pylori* Tests (WebMD.com 2008)
   http://www.webmd.com/digestive-disorders/helicobacter-pylori-tests

Chapter 9 Document 1

Warren JR, Marshall B. 1983. Unidentified curved bacilli on gastric epithelium in active chronic gastritis. Lancet 1:1273–5.

Document removed due to copyright restrictions.

Chapter 9 Document 2

Blaser MJ. 1987. Gastric Campylobacter-like organisms, gastritis, and peptic ulcer disease. Gastroenterology 93:371–83.

Document removed due to copyright restrictions.

Chapter 9 Document 3

Graham DY, Lew GM, Klein PD, Evans DG, Evans DJ Jr, Saeed ZA, Malaty HM. 1992. Effect of treatment of Helicobacter pylori infection on the long-term recurrence of gastric or duodenal ulcer. Annals of Internal Medicine 116:705–8.

Document removed due to copyright restrictions.

Chapter 9 Document 4

Chiba N, Veldhuzen van Zanten SJO, Sinclair P, Fergusson RA, Escobedo S, Grace E. 2002. Treating Helicobacter pylori infection in primary care patients with uninvestigated dys-pepsia: the Canadian adult dyspepsia empiric treatment—Helicobacter pylori positive (CADET-Hp) randomised controlled trial. British Medical Journal 324:1012–6.

Document removed due to copyright restrictions.

Chapter 9 Document 5

Blaser MJ. 2005 Feb. An endangered species in the stomach. Scientific American 292(2):38–45.

Document removed due to copyright restrictions.

CHAPTER

10

Research on Predatory Algae: From Environmental Event to Environmental Policy

NOTE for 3e OPEN ACCESS: Many of the documents described below have been removed from the open access version due to copyright restrictions. We encourage you to access these articles from their original publishers via your university library and/or to locate more recent publications to expand this research case.

The United States was stunned in the mid 1980s by reports of massive unexplained fish kills in estuaries along its southeastern coast. In 1988, a team headed by Dr. JoAnn Burkholder, an aquatic botanist at North Carolina State University, discovered a new genus of "predatory" algae present at the site of several of these disasters: a dinoflagellate that kills fish by releasing a lethal neurotoxin into the water. This startling discovery was first reported to the scientific community in a letter to *Nature* (1992) and quickly gained the attention of the press. The letter and an early article from *Discover* magazine by journalist Patrick Huyghe (1993) are included as the first two documents in this chapter. The third entry is an RFP from the National Sea Grant College Program, followed by a 1994 proposal to this program in which Burkholder and co-investigator Parke Rublee proposed a plan for developing gene probes to help detect the dinoflagellate in estuarine waters. (You'll notice that the dinoflagellate was referred to as *Pfiesteria piscimorte* in early reports but was later formally named *Pfiesteria piscicida*.)

The next set of articles examines how detection methods had progressed a decade later. The first, an article by Burkholder et al. (2005) published in *Proceedings of the National Academy of Sciences*, compares methods for detecting and measuring toxicity of Pfiesteria. In the second article, a literature review from the *Journal of Eukaryotic Microbiology* (2005), Rublee et al. survey existing detection methods used to identify and study the distribution of dinoflagellates and their tolerance in different environments. An online publication for public audiences, from *Environmental Science and Technology* (2007), reports on the discoveries and debates of researchers in their efforts to identify the toxin and its effects on human activity and the environment.

As this research proceeded, government agencies in coastal states began developing safety policies and informational resources for citizens living and working near waterways vulnerable to the *Pfiesteria* threat. These documents are continually revised as research and knowledge on the topic evolve. In North Carolina, the Departments of Environment & Natural Resources and Health & Human Services began posting *Pfiesteria*-related safety guidelines

to their websites in the late 1990s; below we've included links to safety recommendations for workers on the waterways (Additional Resource #1) and also to information for the general public (#2-3). The state of Maryland also issued guidelines early on and continues to provide information for the public; and at the federal level, the Environmental Protection Agency (EPA) developed a *Pfiesteria* fact sheet for a general readership. These materials have since been posted online (#4-5), where they, too, are continually updated. This research case thus allows us to see basic scientific research transformed into public information, procedures, and policy.

Additional Resources

1. Instructions for Lab Technicians Handling Fish Pathology Samples
   (North Carolina Department of Environment and Natural Resources 2008)
   http://www.esb.enr.state.nc.us/Fishkill/fishsamp.html
2. Health Precautions Around Fish Kills from North Carolina Public Health
   (North Carolina Department of Health and Human Services 2006a)
   http://www.epi.state.nc.us/epi/oee/protect.html
3. Information on *Pfiesteria* from North Carolina Public Health (North Carolina Department of Health and Human Services 2006b)
   http://www.epi.state.nc.us/epi/oee/pfie.html
4. Harmful Algae Blooms in Maryland: Resource for the Public (Maryland Department of Natural Resources 2008)
   http://www.dnr.state.md.us/bay/hab/pfiesteria.html
5. Fact Sheet on *Pfiesteria piscicida* from the EPA (National Center for Environmental Publications and Information 1998)
   http://www.medhelp.org/NIHlib/GF-394.html

NOTE for OPEN ACCESS version: Some of the URLs above have expired or changed since the 3e was published. The resources below offer useful alternatives.

Harmful Algae Blooms in Maryland, Maryland Department of Natural Resources
https://dnr.maryland.gov/waters/bay/Pages/algal_blooms/Pfiesteria.aspx

Fact Sheet on Pfiesteria piscicida from the EPA
https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=200050HU.txt

HAB-Associated Illness: CDC
https://www.cdc.gov/habs/index.html

Chapter 10 Document 1

Burkholder JM, Noga EJ, Hobbs CH, Glasgow HB Jr, Smith SA. 1992. New “phantom” dinoflagellate is the causative agent of major estuarine fish kills. Nature 358:407–10; Nature 360:768.

Document removed due to copyright restrictions.

Chapter 10 Document 2

Huyghe P. 1993 Apr. Killer algae. Discover 14(4):71–5.

Document removed due to copyright restrictions.

Chapter 10 Document 3

National Sea Grant College Program. 1994. Statement of opportunity for funding: marine bio-technology. [Excerpts] Raleigh: North Carolina State University, UNC Sea Grant College Program.

NATIONAL SEA GRANT COLLEGE PROGRAM

STATEMENT OF OPPORTUNITY FOR FUNDING: MARINE BIOTECHNOLOGY

DEADLINE: FEBRUARY 15, 1994

FIVE COPIES OF PROPOSAL AND SUMMARY REQUIRED

UNC SEA GRANT COLLEGE PROGRAM
BOX 8605, N.C. STATE UNIVERSITY
RALEIGH, NC 27696
(919) 515-2454

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NATIONAL SEA GRANT COLLEGE PROGRAM

STATEMENT OF OPPORTUNITY FOR FUNDING: MARINE BIOTECHNOLOGY

[Excerpts]

INTRODUCTION

The National Sea Grant College Program is accepting proposals in marine biotechnology for projects of one, two, or three years duration (with annual funding) to begin on or about August 1, 1994.

The primary emphasis will be on research opportunities although advisory and educational proposals also are eligible to compete for funds from an appropriation of $3.2 million. The maximum annual project budget that will be considered for single and multiple investigators is $75,000 and $500,000, respectively, in federal funds. As required by law, at least one third of the total cost of all projects must come from nonfederal matching funds. Industrial matching funds and other close interactions with industry are highly desirable. The National Sea Grant College Program has identified the following preferred areas for proposals:

Aquaculture
Biomaterials/Biosensors
Bioprocessing/Environmental Remediation
Policy/Economics
Education/Technology Transfer

Because of limited funding and widespread interest in marine biotechnology, proposals will be evaluated rigorously. Clear and complete proposals that meet the objectives of the National Sea Grant College Program as outlined in the enclosed materials will have the best chance of success.

BACKGROUND

The United States is the leader in research expertise in marine biotechnology. However, it faces strong competition in other countries that are moving ahead with national investment and planning in this field. Focused research in marine biotechnology in concert with commercial development offers the opportunity to provide scientific, economic, and social advancements. It will lead to new industries and new jobs and will help higher education to meet U.S. needs for scientists and technicians in an increasingly technical and competitive world. It will assist in reversing our trade deficit, which is $2.7 billion a year in seafood alone. It will lead to economic development and increased exports.

A national commitment to research and development in marine biotechnology will help respond to societal needs by (1) increasing the food supply through aquaculture, (2) developing new types and sources of industrial materials and processes, (3) opening new avenues to monitor health and treat disease, (4) providing innovative techniques to restore and protect aquatic ecosystems, (5) enhancing seafood safety and quality, and (6) expanding knowledge of processes in the world ocean.

A Sea Grant report, "Marine Biotechnology: Competing in the 21st Century," outlines a framework for research in support of marine biotechnology. Its three broad themes—Molecular Frontiers in the Ocean Sciences, Applications of Marine Biotechnology, and Marine Biotechnology and Society—encompass a range of research, education, and outreach needed to develop this field. (The report is available from the National Sea Grant Office and the thirty state and regional Sea Grant programs.)

The U.S. House of Representatives recently passed the "Marine Biotechnology Investment Act" which is designed to enhance the National Sea Grant College Program efforts in biotechnology to (1) expand the range and increase the utility of products from the oceans, (2) improve condition of marine ecosystems by developing substitute products that decrease the harvest pressure on living resources, (3) improve production of aquaculture, (4) provide new tools for understanding ecological and evolutionary processes, and (5) improve techniques for remediation of environmental damage.

The U.S. Senate is considering a companion bill to (1) expand the range and increase the utility of products from the oceans, (2) understand and treat human illness, (3) enhance the quality and quantity of seafood, (4) improve the stewardship of marine resources by developing and applying methods to restore and protect marine ecosystems, manage fisheries, and monitor biological and geochemical processes, and (5) to contribute to business and manufacturing innovations, create new jobs, and stimulate private sector investment.

In increasing the National Sea Grant College Program's budget by $3.2 million for fiscal year 1994, the U.S. Congress specified that the increase was to be used to expand research, education, and outreach in marine biotechnology. Focused research, education, and outreach in concert with commercial development offers promise of economic and social benefits. They will lead to new industries and new jobs and advance higher education to meet U.S. needs in an increasingly technical and competitive world.

Biotechnology may be defined as the application of scientific and engineering principles to provide goods and services through mediation of biological agents. The Federal Coordinating Council for Science, Engineering, and Technology, which identified marine biotechnology as an important field, defined biotechnology as "any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific use. The development of materials that mimic molecular structures or functions of living organisms is also included . . . [and] research involving recombinant DNA, DNA transfer techniques, macromolecular structure, cell fusion, bioprocessing, etc., and the infrastructure that supports that research." These broad definitions encompass more than DNA technology. Exclusive of agriculture, application of biotechnology in sewage treatment and water purification now comprises the largest sector in volume. Production of beer and spirits, cheese and other dairy products, baker's yeast, organic acids, and antibiotics follow in order of decreasing value. These traditional applications of biotechnology, which are based primarily on use of terrestrial organisms, are enormously important to the economy as well as human health and nutrition. For example, worldwide production of antibiotics by fermentation generates $10s of billions in sales annually.

While biotechnology is not new, developments in modern molecular biology indicate that it is still in its emerging phase. Many authorities expect biotechnology to be a primary basis of America's economic development and strength in the twenty-first century. Oceanic organisms harbor a major portion of the Earth's genetic resources (biodiversity), yet the large majority of marine organisms are not known well enough for their gene pool and biological processes to be accessible to those who develop and practice biotechnology in industry and academe. However, exploratory research shows the rich potential for exploiting the biochemical capabilities of marine organisms to provide models for new classes of pharmaceuticals, polymers, other chemical products, and new industrial processes as well as vaccines, diagnostic and analytical reagents, and

genetically altered organisms for commercial use. Sea Grant has interests in the development of modern tools and technologies for aquaculture, resource management, seafood processing, bioprocessing, bioremediation, production of biomaterials and analogues, and controlling biofouling and biocorrosion.

The opportunities for advancing science and providing results directly supporting the development of marine biotechnology are broad. Because many of these developments will be realized only in the long-term it is essential to recognize that results will be enhanced through dissemination of information, through personnel mobility, and through cooperation and collaboration between universities and the private sector.

Chapter 10 Document 4

Burkholder JM, Rublee PA. 1994. Improved detection of an ichthyotoxic dinoflagellate in estuaries and aquaculture facilities. Proposal submitted to the (U.S.) National Sea Grant College Program. North Carolina State University, Department of Botany.

IMPROVED DETECTION OF AN ICHTHYOTOXIC DINOFLAGELLATE IN ESTUARIES AND AQUACULTURE FACILITIES

A Research Proposal Submitted to
The National Sea Grant College Program
Marine Biotechnology Initiative

by
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MARINE BIOTECHNOLOGY PROPOSAL: PROJECT SUMMARY

Title: Improved Detection of an Ichthyotoxic Dinoflagellate in Estuaries and Aquaculture Facilities

Principal Investigators:

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Telephone:
Time Devoted to Project: 15%

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Telephone:
Time Devoted to Project: 25%

Project Period: 080194--073196 **Budget Period:** 080194--073195

Amount: $96,243 federal / $48,135 matching (NC Agricultural Research Service)

Objectives:

1) To refine rDNA probes, using cultures of the toxic dinoflagellate *Pfiesteria piscimorte,* to ensure high specificity in detecting flagellated, amoeboid, and encysted forms of this fish pathogen.
2) To test the probes to detect *P. piscimorte* in estuarine waters / sediments and aquaculture facilities.
3) To develop a "family" of probes that enable rapid, routine detection / quantification of intraspecific genetic strains of this toxic dinoflagellate at fish kill / ulcerative disease sites.
4) To apply fluorescent gene probes in screening for targeted chemosensory areas (portals of entry, attachment sites) for the dinoflagellate pathogen on /in fish prey.

Methodology:

State-of-the-art PCR amplification techniques for targeted sequence(s) of the dinoflagellate's rRNA genes from algal cultures will enable refinement of gene probes for use in routine detection of *P. piscimorte* in water / sediment samples from estuaries and aquaculture facilities. A fluorescent anti-sense oligoprobe will be developed and tested for rapid visual identification and localization of the alga in water, sediments, and fish tissues. Culture isolates from North Carolina estuaries and other fish kill sites in the mid-Atlantic and Southeast will be tested for intraspecific sequence variation, needed to develop a "family" of probes that vary in specificity depending on the targeted strain of *P. piscimorte*. These probes, in combination with fish bioassay experimental data, will also enable us to detect the presence of other toxic species that may closely resemble this dinoflagellate.

Rationale:

Unexplained "sudden-death" fish kills and ulcerative diseases have increased in North Carolina's estuaries over the past decade. The dinoflagellate *P. piscimorte* recently has been implicated as the causative agent of at least 30% of the major fish kills in these estuaries, and also has been tracked to fish kill sites on the mid-Atlantic Coast and Southeast. Despite its importance, the ephemeral toxicity, multiple cryptic flagellated and

amoeboid stages, substantial size range (5–250 μm), and close resemblance of this pathogen to other non-toxic algae make reliable detection difficult in light microscopy analysis. Development of sensitive, highly specific gene probes for *P. piscimorte* will answer a critical need for its routine, early detection by regulatory staff and finfish / shellfish aquaculturists.

Some Suggested Reviewers:

Dr. Edward DeLong, Biol. Dept., Univ. Calif., Santa Barbara, CA 93106
Dr. Lucie Maranda, Dept. of Pharmacognosy & Env., URI, Kingston, RI 02881
Dr. Norman Pace, Inst. Molec. & Cell. Biol., Indiana Univ., Bloomington, IN 47405
Dr. John Paul, Dept. Mar. Sci., Univ. S. Florida, St. Petersburg, FL 33701
Dr. Karen Steidinger, FL DEP, FL Mar. Res. Inst., St. Petersburg, FL 33701
Dr. Susan Weiler, Dept. of Biol., Whitman College, Walla Walla, WA 99362

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TITLE: Improved Detection of an Ichthyotoxic Dinoflagellate in Estuaries and Aquaculture Facilities

PRINCIPAL INVESTIGATORS: JoAnn M. Burkholder and Parke A. Rublee

INTRODUCTION AND BACKGROUND

A. The Established Linkage between Sudden-Death Fish Kills, Unexplained Fish Disease, and a Toxic Ambush-Predator Dinoflagellate

A recent cosmopolitan rise in the frequency and spatial extent of toxic phytoplankton blooms suggests that these noxious species can significantly reduce our estuarine and marine fishery resources (White 1988, Shumway 1990, Robineau *et al.* 1991). Among the most notorious of toxic phytoplankton are the dinoflagellates that cause "red tides," resulting in the death or "poisoning" of many finfish and shellfish as well as humans (Steidinger & Baden 1984). The United States and other industrialized nations spend billions of dollars annually in research aimed toward prediction, mitigation, and control of toxic outbreaks (Shumway 1990, Culotta 1992). Despite these efforts, accumulating evidence suggests that toxic dinoflagellates may be increasing their activity and geographic range (Steidinger & Baden 1984, Smayda 1989, Hallegraeff 1993). Moreover, the past decade has yielded discoveries of previously unknown toxic species that have suddenly appeared in bloom concentrations, causing millions of dollars of damage to coastal fisheries and aquaculture industries in many U.S. coastal waters (Steidinger & Baden 1984, Smayda 1989, Shumway 1990).

Among the many estuaries in the United States with increasing incidence of unexplained ulcerative fish disease and "sudden-death" fish kills are the Pamlico, Neuse and New Estuaries in North Carolina (Miller *et al.* 1990, North Carolina Division of Marine Fisheries 1992). In the past three years a phytoplankter contaminant from these estuaries was implicated as the causative agent of approximately 30% of North Carolina's major estuarine fish kills (involving 10^3–10^9 fish; Burkholder *et al.* 1992a, 1993; Fig. 1). The dinoflagellate, *Pfiesteria piscimorte* (gen. et sp. nov.) Steidinger & Burkholder (Steidinger *et al.* 1994), represents a new family, genus and species. Unlike red tide dinoflagellates, its lethal forms are ephemeral in the water column and require live fish for toxic activity. When a school of finfish comes within detectable range, the dinoflagellate exhibits remarkable "phantom-like" behavior. The population swims up into the water from dormant cysts or amoebae on bottom sediments; the cells excrete a lethal toxin, complete sexual reproduction while killing the fish, and then rapidly descend back to the sediments (Burkholder *et al.* 1993). The toxin strips skin tissue from the fish and creates open bleeding sores; it also attacks the renal system, induces hemmorrhaging, suppresses the immune system, throws the nervous system into dysfunction, and apparently causes death by suffocation from muscle paralysis (Burkholder *et al.* 1993, E. Noga unpubl. data).

Toxic outbreaks of this "ambush-predator" dinoflagellate have been documented at salinities ranging from freshwater ($0^0/_{00}$ salinity) to full-strength seawater ($35^0/_{00}$), and across temperatures of 4–33°C (Burkholder 1993; Burkholder *et al.* 1992a, 1993). Further, the alga has proven lethal to all 28 species of native and exotic finfish and shellfish tested thus far (Burkholder *et al.* 1993; Table 1).

B. The Need for Highly Specific Molecular Probes to Detect This Fish Pathogen

Detection of *Pfiesteria piscimorte* (gen. et sp. nov.) demands well-timed sampling because the algal population displays rapid encystment without live fish, typically "disappearing" or settling out of the water

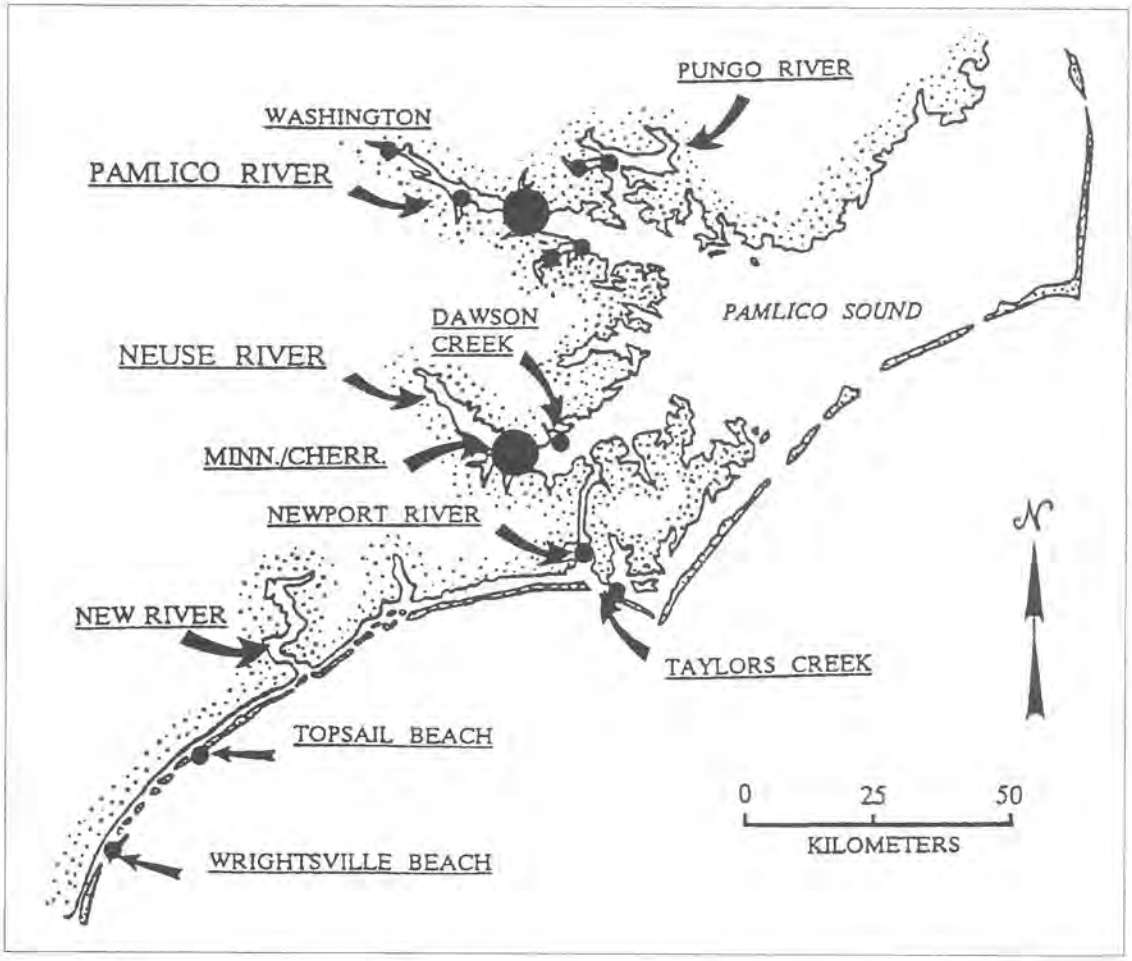

FIGURE 1. Locations where lethal stages of *Pfiesteria piscimorte* (gen. et sp. nov.) has been verified in North Carolina. Kill sites (documented in association with this toxic dinoflagellate in all labeled locations except the New River Estuary) are designated by blackened circles, with large circles representing sites where fish kills are most frequent with substantial area affected. The large circle on the Neuse River Estuary at Minnesott Beach / Cherry Point (MINN./CHERR.) designates the site with highest known fish loss; more than 1 billion Atlantic menhaden were killed, requiring bulldozers to clear the beaches over a 6-week period when the menhaden schools were moving out to sea.

column within only a few hours after fish death (Burkholder *et al.* 1992a). Efforts to establish the presence of *P. piscimorte* (gen. et sp. nov.) in fish kills also have been hampered because this small dinoflagellate resembles several other common nontoxic species so closely that it is difficult to reliably identify it in routine light-microscope analyses. The confusion is further compounded because the alga has a complex life cycle that includes rapid transformations (sometimes within minutes) among at least 15 different flagellated and amoeboid forms, many of which are amorphous and colorless and, hence, easily missed or mistaken for

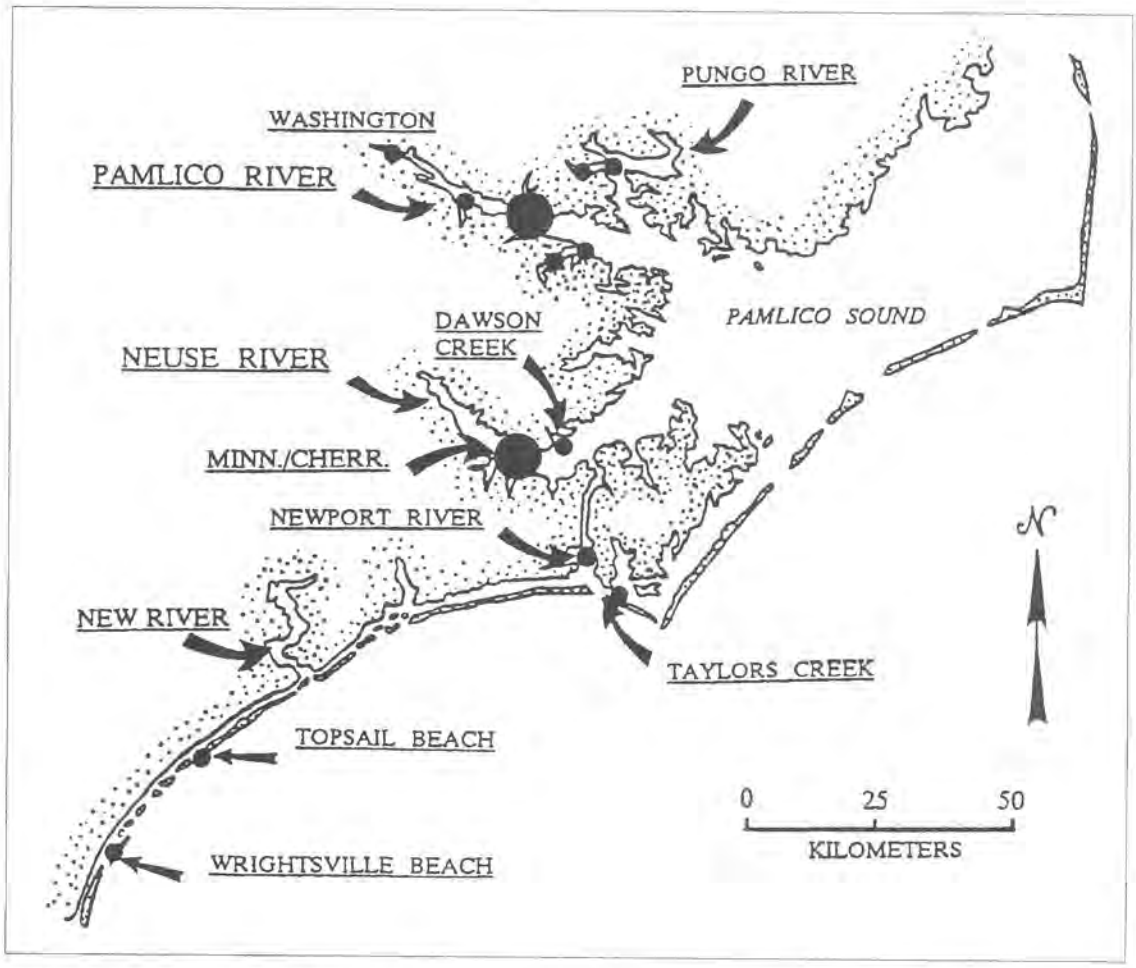

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TABLE 1. Species of finfish and shellfish that are known to be killed by *Pfiesteria piscimorte* (nov. gen et sp.)*

NATIVE ESTUARINE / MARINE SPECIES

American eel *(Anguilla rostrata)*
Atlantic croaker *(Micropogonias undulatus)*
Atlantic menhaden *(Brevoortia tyrannus)*
Bay scallop *(Aequipecten irradians)*
Black grouper *(Mycteroperca bonaci)*
Blue crab *(Callinectes sapidus)*
Channel catfish *(Icatalurus punctatus)*
Hogchoker *(Trinectes masculatus)*
Killifish (mummichog) *(Fundulus heteroclitus)*
Largemouth bass *(Micropterus salmoides)*
Littleneck clam *(Mercenaria mercenaria)*
Pinfish *(Lagodon rhomboides)*
Red drum *(Scianops ocellatus)*
Redear sunfish *(Lepomis microlophys)*
Southern flounder *(Paralichthys lethostigma)*
Spot *(Leiostomus xanthuris)*
Spotted sea trout *(Cynoscion nebulosus)*
Striped bass *(Morone saxatilis)*
Striped mullet *(Mugil cephalus)*
White perch *(Morone americana)*

EXOTIC (INTRODUCED) SPECIES

Clownfish *(Amphiprion percula)*
Goldfish *(Carrasius auratus)*
Guppie *(Poecilia reticulata)*
Hybrid Striped Bass *(Morone saxatilis × Morone chrysops)*
Mosquitofish *(Gambusia affinis)*
Tilapia *(Oreochromis aureus, Oreochromis mossambicus, Tilapia nilotica)*

* All 28 species of finfish and shellfish species tested thus far have proven susceptible to lethal effects of this ambush predator dinoflagellate (Burkholder *et al.* accepted b).

debris (Burkholder *et al.* 1993; research supported by a UNC Sea Grant mini-grant to PI JMB; Fig. 2, Plate 1). These considerations have led many U.S. coastal regulatory agencies to express the need for development of a species-specific "marker" that would enable rapid detection of this dinoflagellate, in its many stages, at sites of fish disease outbreaks or kills in their coastal waters and aquaculture facilities.

In the short time since its discovery in the Pamlico Estuary in 1992, *Pfiesteria piscimorte* (gen. et sp. nov.) has come to be regarded as a potentially widespread but typically undetected source of major fish mortality in nutrient-enriched estuaries (Burkholder *et al.* 1992a, 1993). Within the past two years, JMB and colleagues have tracked this organism to fish kill sites in eutrophic estuaries from the Delaware Bay south to Florida on the western Atlantic Coast, and as far west as Mobile Bay, Alabama on the Gulf Coast (Burkholder *et al.* 1993, Burkholder *et al.* submitted, Lewitus *et al.* submitted; Fig. 3). Scientists and regulatory staff on

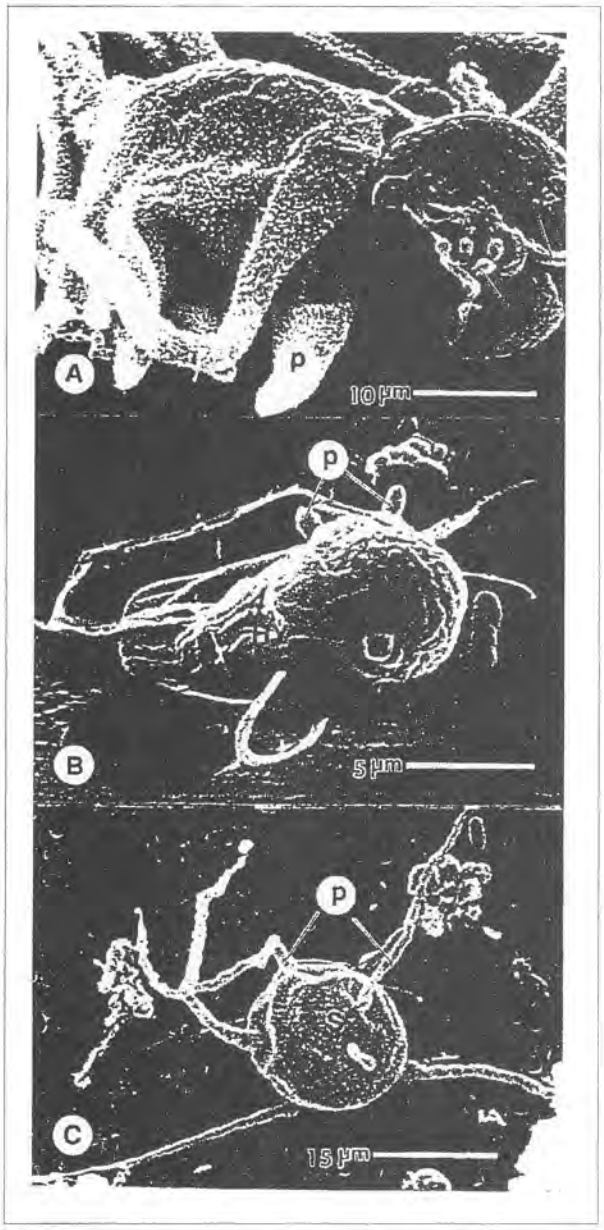

PLATE 1. Scanning electron micrographs of the ambush predator *Pfiesteria piscimorte* (gen. et sp. nov.), including (A) a large lobose amoeba [AM] with pseudopodia [p] and a TFVC [DI] beginning to form pseudopodia [p], but with the transverse flagellum [tf] still intact (× 3520); (B) More advanced state of TFVC conversion to an amoeba [ep = epitheca, hy = hypotheca] (× 2570); and (C) "Star" or filipodial amoeba stage [S] (formerly a TFVC) with long pseudopodia (× 1520).

the Atlantic, Gulf and Pacific Coasts have begun to hunt for the dinoflagellate at sites of ulcerative fish disease and sudden-death kill areas (Anonymous 1992; Kay 1992; Rensberger 1992a,b; Greer 1993; Huyghe 1993). **Methodology for rapid, reliable detection of this pathogen in advance of fish disease outbreaks**

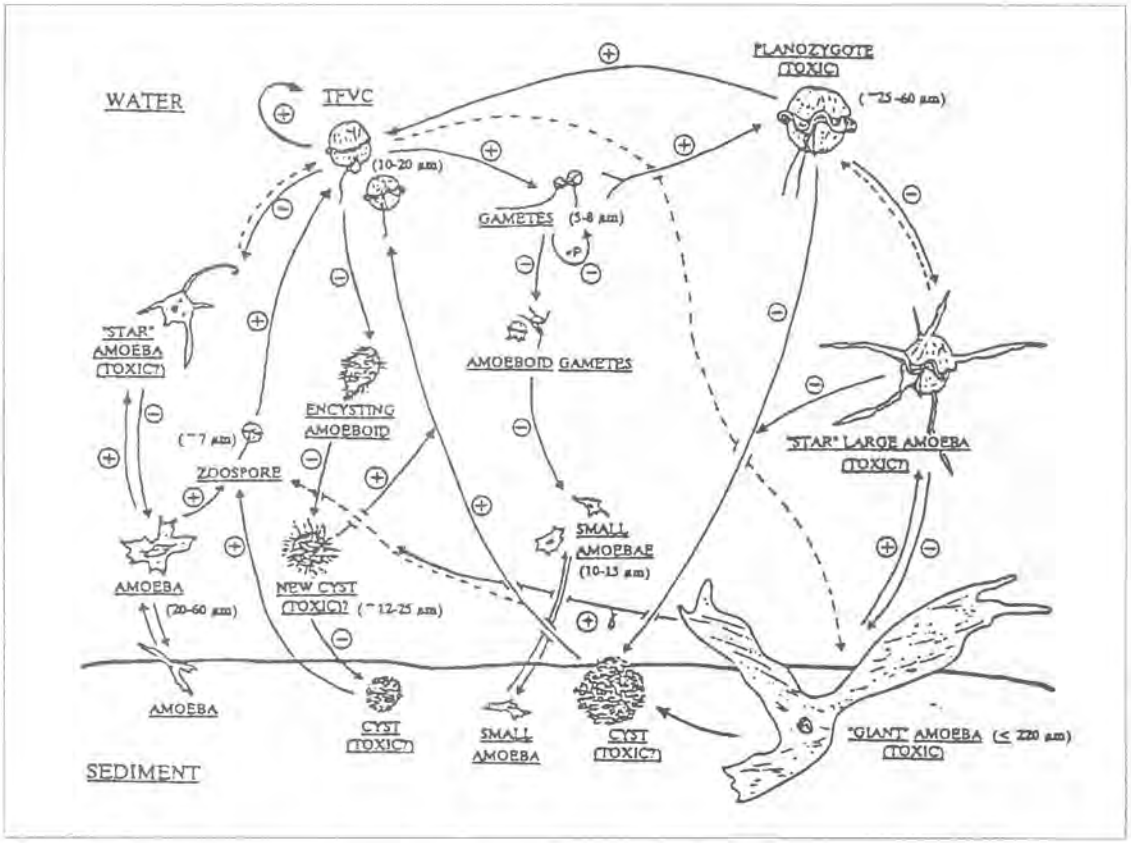

FIGURE 2. The life cycle of *Pfiesteria piscimorte* (gen. et sp. nov.), a representative toxic fish ambush-predator dinoflagellate (TFVC = toxic flagellated vegetative cell, the most toxic stage). Symbols indicate how the dinoflagellate appears in the presence (+) versus absence (–) of live finfish. Solid lines represent verified pathways in the complex life cycle; dashed lines indicate hypothesized additional pathways. "P" designates stimulation of amoeboid gamete production by phosphate enrichment. Stages known or suspected (?) to be toxic are also shown (from Burkholder *et al.* 1993).

and kills is critically needed in order to develop effective management strategies to predict its toxic activity and mitigate its acute and chronic effects on our estuarine fisheries.

C. Progress to Date on Gene Probe Development for *Pfiesteria piscimorte*

Within the past three years, both national and international workshops on toxic marine phytoplankton have identified an "imperative" for improved techniques to enable accurate, rapid detection and identification of harmful algae by regulatory staff on a routine basis (UNESCO 1991, Anderson *et al.* 1993). From a practical standpoint, the need for a sensitive highly species-specific technique to detect harmful species such as *Pfiesteria piscimorte* (gen. et sp. nov.) with multiple cryptic stages would be especially critical. Under a cur-

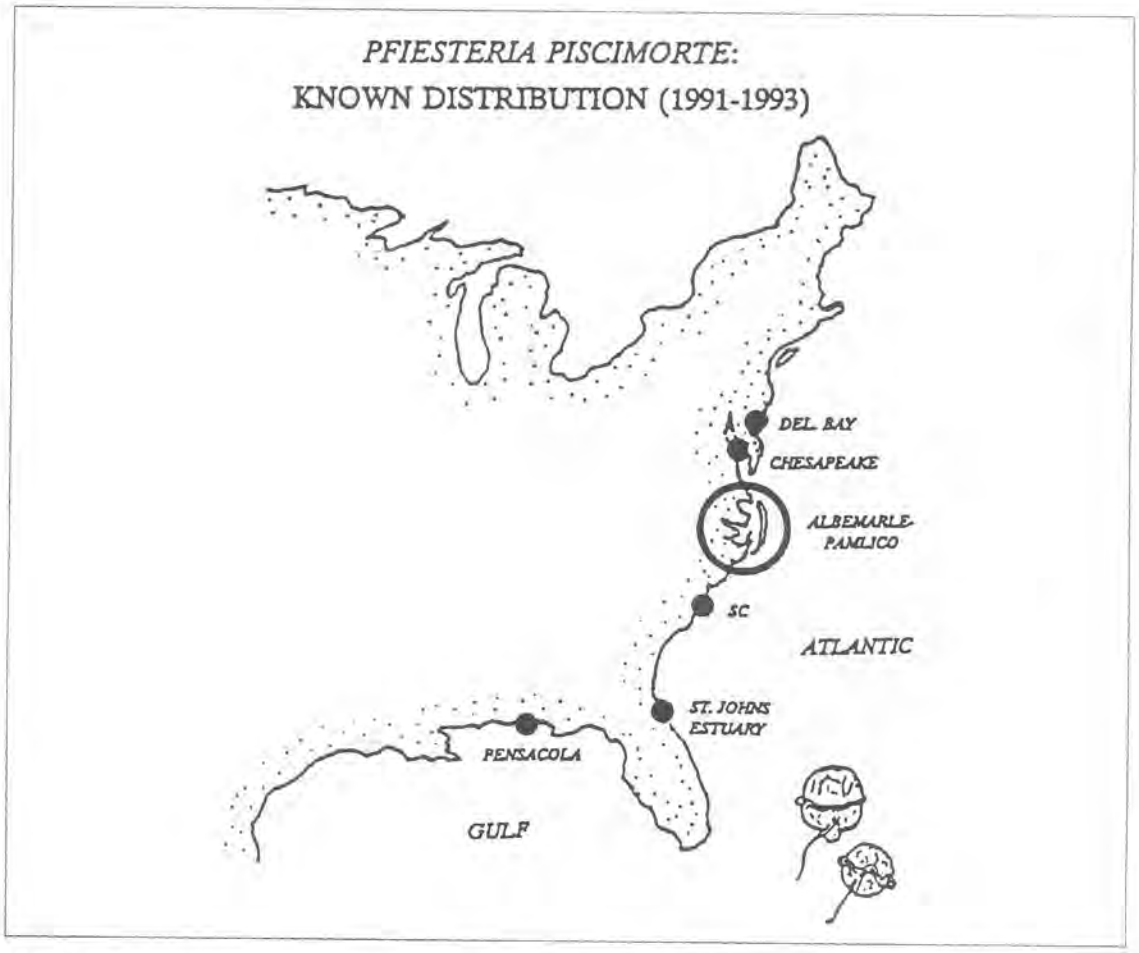

FIGURE 3. Locations where water samples have been confirmed to contain toxic stages of *Pfiesteria piscimorte* (gen. et sp. nov.) (data from PI JMB with H. Glasgow, B. Anderson, R. Lewis, K. Steidinger, and J. Landsberg); Mobile Bay, AL recently has been confirmed as an additional distribution site.

rent mini-grant from the UNC Sea Grant and the UNC Water Resources Research Institute (9/93–7/94), we are developing a gene probe to cultures of *P. piscimorte* (gen. et sp. nov.) that was isolated from the most concentrated known region of toxic activity by this organism—the Albemarle–Pamlico Estuarine System of North Carolina. At present we have successfully extracted DNA from *P. piscimorte* (gen. et sp. nov.), and have amplified a 1.0–1.1 kb fragment (Fig. 4) using "universal" primers to the small subunit ribosomal-DNA gene (16S-rDNA; Pace *et al.* 1986, Lynn & Sogin 1988, Britschgi & Giovannoni 1991, Manhart & McCourt 1992, Weisburg *et al.* 1991). The fragment has been ligated into the *BamH*I-*Xho*I restriction sites of the pBluescript II SK plasmid, which was then used to transform competent *Escherichia coli* DH5α cells with standard techniques (Sambrook *et al.* 1989, Ausubel *et al.* 1992). We now have available a total of 40 bacte-

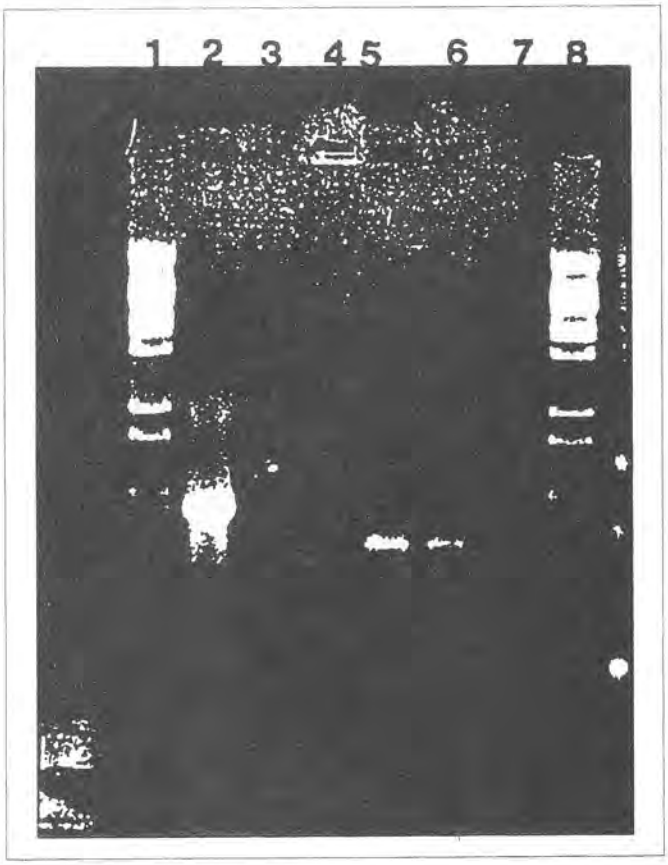

FIGURE 4. Gell electrophoresis of PCR reaction of *Pfiesteria piscimorte* (gen. et sp. nov.) from the large lobose amoeba stage. Lanes 1 & 8, Lambda, *BstE*II DNA marker. Lane 2, positive control. Lanes 5 & 6, PCR products from the dinoflagellate (length ca 1.1 kb).

rial clones from 2 isolates of the dinoflagellate. We are set to begin sequencing these clones by the dideoxy chain termination method (Sanger 1977), while continuing to establish additional clones from other isolates. After the sequence has been determined, we will look for 17–34 base pair consensus regions within the 16S rDNA that are unique to this toxic alga, for use as species-specific gene probes.

The consensus sequence will be tested as a probe against samples of *P. piscimorte* (gen. et sp. nov.) and other algae. A radioactively end-labeled oligonucleotide probe corresponding to the sequence will be tested at high-stringency with Southern blots and later with dot/slot blots using preparations of the dinoflagellate's DNA in varying amounts. Salt and temperature concentrations will be adjusted so that the probe hybridizes specifically with samples containing the alga's DNA (high-stringency). Its specificity will be further tested by mixing samples of the dinoflagellate's DNA and nontarget DNA in known proportions, to determine whether the probe evokes a signal proportional to the amount of DNA from *P. piscimorte* (gen. et sp. nov.) in the mixed samples. We actually plan to test several probes under these conditions to identify optimal sequences for sensitivity and specificity among culture isolates representing different strains of this dinoflagellate. We are confident that we will have a radiolabeled probe that can be used on extracted DNA samples of cultured *P. piscimorte* (gen. et sp. nov.) by July 1994.

D. Goals and Hypotheses of the Proposed Research

The major goal of the proposed research is to refine state-of-the-art techniques for application of gene probes to enable routine detection of *Pfiesteria piscimorte* (gen. et sp. nov.) in natural estuarine habitat and aquaculture facilities. In this study we will extend application of gene probes to this toxic dinoflagellate for use on water and sediment field samples. We plan to determine the distribution of *P. piscimorte* (gen. et sp. nov.) in coastal systems and assess (a) genetic variability among populations; (b) whether this species is unique or representative of additional, as-yet-unknown toxic dinoflagellates, and (c) the distribution of "cyst banks" as it relates to nutrient conditions, especially to sites of anthropogenic nutrient input. We will also examine physical relationships (portals of entry / attachment) of this fish pathogen to its fish and invertebrate hosts, as indicative of sites of chemosensory attraction. Our research will focus on the following hypotheses:

1. Diverse races or strains within the species *Pfiesteria piscimorte* (gen. et sp. nov.) are abundant and widespread in eutrophic estuaries of North Carolina. Intraspecific genetic variability increases among populations in similar habitat of major estuaries from the mid-Atlantic to the Gulf Coast in the southeastern United States.
2. The unique primers that allow for PCR (polymerase chain reaction) amplification of targeted sequence(s) of rRNA genes in this toxic dinoflagellate can be used as a template from which other gene probes can be developed to enable detection of various strains within *P. piscimorte* (gen. et sp. nov.).
3. Sensitive, highly specific radiolabeled or fluorescent gene probes for *P. piscimorte* (gen. et sp. nov.), developed from cultured material, can be applied successfully for rapid detection of flagellated, amoeboid, and encysted stages of this fish pathogen—even in low abundance—in estuarine water column / sediment samples, and in aquaculture facilities.

OBJECTIVES

The overall objective of this research is to develop, test and refine application of gene probes for rapid, routine detection / quantification of the toxic dinoflagellate *Pfiesteria piscimorte* (gen. et sp. nov.), in all its stages, from natural estuarine waters and sediments and from aquaculture facilities. Specific objectives to accomplish this goal are as follows:

1. **Extend application of the gene probe(s) for this toxic dinoflagellate so that we can (a) detect it quickly during fish kills or disease outbreaks; (b) assay estuarine sediments for detection of ambient active (amoeboid) and dormant (encysted) populations; and (c) apply the probes as a basic tool** for further research on the ecology, toxicology, and developmental biology of this fish pathogen. [Years I–II]. Specifically, this work will require development in two directions:
   - **(i) Gene probe** development for use as an extremely sensitive "field" detection tool to determine genetic variability in *P. piscimorte* (gen. et sp. nov.) populations from both the water column and the sediments, and for use as a basis for additional gene probes to related species. This gene probe will consist of the unique primers that allow for PCR amplification of the target sequence of rRNA genes, even if the rRNA genes are present in low copy number. The high quantity of DNA per dinoflagellate cell (ca 3–200 pg $cell^{-1}$; Triplett *et al.* 1993), relative to DNA content in other algae (average of 0.54 pg DNA $cell^{-1}$; Rizzo 1987) assures that substantial material can be obtained from relatively few cells of this organism.

(ii) **Fluorescent probe** development as an *"in situ"* probe for rapid visual identification and localization of the target species. This second probe will actually be an anti-sense **mRNA oligoprobe** with a fluorescent tag that binds to target mRNA, found in high copy number in the dinoflagellate's cells, to facilitate microscopic visualization (DeLong *et al.* 1989).

2. **Apply the probes for detection / quantification of this dinoflagellate from the water column and sediments of known sudden-death fish kill sites, and at major fish kill events** [Year I (pilot); Years II–III]. This will involve examining the intraspecific genetic variability in *P. piscimorte* (gen. et sp. nov.), a process that will also lead to detection of closely related species with similar behavior and appearance.
3. **Screen and identify targeted areas (portals of entry, sites of attachment) of the pathogen on/in fish prey,** of use in related research to identify the substance(s) from fish tissues that trigger toxin production, and to aid in understanding the pathology of this organism. The fluorescent probe will facilitate light-microscopy inspection of specific tissues. This application will also be of value in providing evidence for the presence of the organism in "individual" fish kill events.
4. **Determine utility of gene probes for this pathogen to the aquaculture industry** [Years II, III]. Our probes will enable identification of problematic periods for use of estuarine waters, and rapid determination of the degree of water source contamination by the toxic dinoflagellate. The probes will also be of use in discerning contaminated tanks or fish.

METHODOLOGY AND RATIONALE

A. Culturing This Unique Toxic Dinoflagellate (Burkholder; Objective 1; Years I–III)

Accomplishment of the central goal of this research—refinement of gene probes for *Pfiesteria piscimorte* (gen. et sp. nov.)—depends on successful maintenance of culture isolates for quality assurance in efficiency of extraction of the dinoflagellate's DNA from water and sediment samples. This organism is unique among toxic dinoflagellates in two major characteristics: (i) Unlike nearly all other known toxic dinoflagellates, it is animal-like rather than photosynthetic. As mentioned, it is capable of assuming a photosynthetic habit only by consuming other algae and digesting all but their chloroplasts, which it retains as cleptochloroplasts for extended periods (Steidinger *et al.* 1994); and (ii) *P. piscimorte* (gen. et sp. nov.) requires an as-yet-uncharacterized substance(s) from live fish at least daily to maintain toxic activity and complete its life cycle. These features mandate aeration of cultures, with best dinoflagellate growth when aeration is accomplished using box filters (Burkholder *et al.* 1993).

The challenge of safely culturing this alga demands considerable expense and effort. Because of the potential for impairment to human health from neurotoxic aerosols, all cultures are maintained in an isolated, quarantined modular facility with restricted access (Burkholder *et al.* 1993). Each aquarium must be separately housed within a completely contained, custom-designed isolation chamber that is vented (through HEPA filters) to the air outside the facility. As we collect isolates from sudden-death fish kill sites in North Carolina and other areas for testing with our gene probes, these isolation chambers will protect cultures from cross-contamination while affording safe working conditions. We have successfully maintained high concentrations ($\geq$ 1,000 to ca 90,000 cells mL^{-1}) of toxic flagellated stages and cysts using tilapia prey (*Oreochromis mossambica;* 3 fish, each 5–7 cm in length, added 1x or 2x daily per 9-L aquarium). The culture medium consists of 15‰-salinity water obtained by adding Instant Ocean salts to well water (NCSU School of Veteri-

nary Medicine). To obtain unialgal cultures, fish are physically separated from dinoflagellate cells that have been isolated by hand (with micromanipulator at 400x) and inoculated into 0.45–0.80 µm-porosity dialysis tubing that allows passage of the toxin and finfish secreta / excreta.

Our modular culture facility includes a separate "cold" (uncontaminated) room for final cleaning of all aquaria and glassware with dilute bleach, a procedure which destroys even the encysted dinoflagellates without leaving toxic residues from the alga or the fixative. A larger adjacent room serves as the culture area, with facilities at one end for soaking contaminated labware and aquaria in strong bleach as initial steps in our cleaning procedures. We routinely use respirators (with HEPA + organic acid filters), disposable gloves, disposable boots, and clothing that is removed and treated with dilute bleach (0.05%) after use, as standard operating procedure. To de-contaminate aquaria, all reusable labware is soaked in dilute bleach for 12 hr to destroy the cells and cysts, and then is rinsed thoroughly with deionized water. All work in the culture facility further mandates a "buddy system" for additional safety assurance, with at least two people present at all times.

B. Rationale for Use of Genetic Probes

Recent advances in molecular biology have shown great promise in unraveling many basic and applied ecological questions. Brand (1988) reviewed the topic of genetic variation in phytoplankton and concluded that such variation, while not well understood, likely is important in determining the ecological "success" of algal species. Manhart & McCourt (1992) noted the potential value of molecular tools in clarifying phytoplankton speciation and species identifications. Within the past five years, an extensive literature on molecular biology of phytoplankton has become available, including studies of structural characteristics of algal nuclear, chloroplast, and mitochondrial genomes (e.g., Coleman & Goff 1991, Li & Cattolico 1992, Anderson *et al.* 1992, Reynolds *et al.* 1993), as well as information on ribosomal RNA genes (e.g., Rowan & Powers 1992, Scholen *et al.* 1993) and specific functional genes such as large subunit ribulose-1,5-bisphosphate carboxylase (*rbcL;* e.g., Pichard *et al.* 1993).

The potential value of such knowledge has been recognized by recent workshops to identify essential research needs for understanding and mitigating harmful algal blooms (UNESCO 1991, Anderson *et al.* 1993), where strong recommendations have called for development of immunologic and molecular probes to economically important toxic algal species. Such probes could provide rapid sample analysis while avoiding subjective visual identifications, made with light microscopy, that can be challenging even to scientists who are experienced in working with this dinoflagellate (Burkholder *et al.* 1993). Further, many of the difficulties associated with probe development (e.g., limited knowledge base, intensive laboratory effort, expense) have been resolved or reduced in recent years (e.g., significant advances in PCR technology and applications).

Our choice of gene probes over immunologic probes is based on several considerations. First, gene probes offer a high degree of specificity, and technology has improved to the point that development of such probes is realistic within the projected time frame. Second, gene probes have all the advantages of immunologic probes (e.g., specificity, sensitivity, capacity for linkage with radiochemical, fluorescent, or enzymatic markers), with the additional advantage of providing direct insights about genetic variability among isolates via the nucleotide sequence. Selection of rDNA probes over alternative gene probes to specific functional genes (e.g., enzymes) derives from their common use (e.g., DeRijk *et al.* 1992) as well as the state of our knowledge about the genetic structure of *Pfiesteria piscimorte* (gen. et sp. nov.). The rDNA probes have been developed and used extensively over the past decade as both intra- and interspecific markers, since ribosomal RNA is abundant in cells of all living organisms. Further, the DNA that codes for the RNA contains regions

which are conserved across all kingdoms as well as variable regions that are unique at species / subspecies levels (Pace *et al.* 1986, Britschgi & Giovannoni 1991, Scholin *et al.* 1993). As a result, a large information base is available that includes both applications and rDNA sequences (e.g., GenBank, EMBL), and which spans a wide array of prokaryotic and eukaryotic organisms including dinoflagellates (e.g., Lenaers *et al.* 1989, Geraud *et al.* 1991, Fritz *et al.* 1991, Rowan & Powers 1992, DeRijk *et al.* 1992).

The use of probes to specific functional genes can offer insights about organism abundance and activity, as Pichard & Paul (1993) and Pichard *et al.* (1993) have shown with *rcbL* genes in photosynthetic algae. Our limited knowledge of *Pfiesteria piscimorte* (gen. et sp. nov.), however, makes it difficult to identify functional genes of optimal use as targets for such probes. For example, the organism "borrows" or retains chloroplasts from algal prey; aside from these "cleptochloroplasts," this dinoflagellate has none of its own (Steidinger et al. 1994). Hence, use of *rcbL* probes would be misleading. Further, the ability of this fish pathogen to transform rapidly among stages that are distinct in morphology and function suggests that targeting highly specific functional genes would be premature. Thus, at present we have focused our efforts toward developing "conservative" probes which we believe will have the most utility. In particular, with respect to aquaculture application of pretesting facilities for the presence of *P. piscimorte* (gen. et sp. nov.), this approach is less likely to lead to false negatives and subsequent economic loss. Ultimately, we hope to develop not only markers to specific strains of this dinoflagellate, but also to find markers that are unique to different stages in the life cycle and/or different functions of the organism—that is, unique signatures of mRNA expression to each stage (e.g., markers specific to flagellated, encysted, or amoeboid structures).

C. Research Plan for Extending Probe Applications

1. Fluorescent Probe Development (Burkholder/Rublee; required for Objectives 1-ii, 2–5; Years I–III; Table 2)—Immediately upon confirming suitability of the gene probe currently under development from cultured isolates, we will generate an anti-sense oligonucleotide probe tagged with a fluorescent marker (procedure of DeLong *et al.* 1989), using aminoethyl phosphate linkers and fluorescein dyes. This probe will first be tested for specificity and sensitivity against cultured dinoflagellate cells, followed by tests against water samples from fish kills or fish kill areas in which *Pfiesteria piscimorte* (gen. et sp. nov.) has been implicated as the causative agent.

2. Selection of Sediment Extraction Techniques (Rublee/Burkholder; required for Objective 3; Year I)—In sandy sediments, fluorescent probes should facilitate detection of the dinoflagellate's cysts as well as filipodial and lobopodial amoeboid stages, which tend to wrap their pseudopodia around particulate matter and tightly adhere when disturbed so that they are exceedingly difficult to detect by light microscopy. We anticipate that the amoebae will behave in this manner when they are sampled during or following distribution into aquarium cultures for bioassay of toxic activity in the presence of fish. The probes will be applied to water-column samples from the aquarium bioassays, of use as an aid in "ground truthing" our direct microscope counts.

We expect that detection of *Pfiesteria piscimorte* (gen. et. sp. nov.) in sediments with low cell abundance or high organic content will require use of more sensitive assays. We will probe these types of samples by extracting sediment DNA and using PCR amplification with our species-specific primers (e.g., Tsai & Olsen 1991, 1992; Moran *et al.* 1993). Since estuarine sediments vary in mineral and organic content (Rublee 1982; which may affect DNA extraction efficiency), we will first test defined sediments that have been seeded

TABLE 2. Timetable for completing the proposed research

PROJECT ACTIVITY	YEAR I	YEAR II	YEAR III
1. Culturing the dinoflagellate	———	———	———
2. Extending probe applications:			
A. Fluorescent probe development	——		
B. Development of sediment extraction methods	———		
C. Development of probes with varying sensitivity	———	- - - - - - - - - - - - - - - - - - - -	
3. Field sampling effort:			
A. Analysis of natural "bloom" samples	- - -	——	——
B. Collection trips—North Carolina	- - —	——	——
C. Sampling from other locations (including network)	———	———	———
4. Probe application to detect the dinoflagellate on fish prey	- - ———	——— - - - -	
5. Testing aquaculture sites		———	———
6. Completion of reports and publications	——	——	——

with the dinoflagellate's cells, followed by tests of natural sediments using added cells as an "internal standard" for DNA extractions. The lysozyme-SDS-freeze-thaw extractions procedure of Tsai & Olsen (1992) will be followed by purification by electrophoresis (cf. Erb & Wagner-Döbler 1993, Herrick *et al.* 1993), to the lysozyme-hot phenol extraction method of Moran *et al.* (1993, omitting the DNAse digestion step). An alternative procedure, to be considered if the rDNA probes prove unsuitable, will be to assay directly for rRNA with anti-sense oligonucleotide primers using reverse transcriptase PCR (Moran *et al.* 1993).

3. Development of Probes that Differ in Sensitivity (Rublee/Burkholder; required for Objective 2; Year I [pilot]; Years II–III)—Within the past year, the discovery of a second Pfiesteria-like species (Landsberg *et al.* 1994) suggests that *Pfiesteria piscimorte* (gen. et sp. nov.) likely is one of a number of similar ambush-predator dinoflagellates (Burkholder 1993) that may play important roles in coastal ecosystems due to their varied life forms. An approach to screen for other such species which, like *P. piscimorte* (gen. et sp. nov.), may be cryptic with ephemeral stages, is to extend the utility of our probes by altering their specificity and developing a "family" of probes (*sensu* Anderson 1993). This will be accomplished either by (1) varying the conditions under which hybridization is allowed to occur (altering stringency), or (2) altering the nucleotide sequence in the probes themselves. We plan to test isolates as well as natural samples from kill sites under varying stringency conditions.

Improved selection of probe sequence will be achieved over time as we strengthen our understanding of the intraspecific genetic variability in *P. piscimorte* (gen. et sp. nov.) and related taxa. In particular, for all

estuarine / aquaculture sampling efforts (see D, below), where we find dinoflagellates that appear visually similar to *P. piscimorte* (gen. et sp. nov.) but do not hybridize with probes under high-stringency conditions, we will reprobe using lower-stringency conditions as a test for other strains or closely related species (cf. Barkay *et al.* 1990). In either case, if we are able to isolate dinoflagellate cells from such samples, we will then use "universal" PCR primers to repeat the amplification, cloning, and sequencing process that was initially used to develop the *P. piscimorte* (gen. et sp. nov.) gene probes (see "Introduction and Background Information"). These steps will enable us to confirm new strains or species, and to develop additional probes of appropriate specificity.

D. Analysis to Verify Ability to Track the Pathogen in Natural Habitat (Rublee/Burkholder; required for Objective 2; Year I [pilot], Years II–III)—

As a component of a related research effort (with separate funding support), over the next four years PI JMB will be intensively sampling the Minnesott Beach / Cherry Point region of the Neuse Estuary, which represents a major repeat-kill site for this dinoflagellate (Burkholder *et al.* 1993). In the proposed research, we plan to take advantage of that sampling effort in order to assess the utility of our probes in tracking toxic *Pfiesteria piscimorte* (gen. et sp. nov.) blooms. The water column will be sampled at biweekly to monthly intervals from April–October, which is the period associated with maximal growth and toxic outbreaks of this organism. We will check for increasing abundance of toxic stages using the Utermöhl technique (Lund *et al.* 1958) as in Burkholder & Wetzel (1989), and will verify our identifications using SEM. The data will be compared with / without application of our fluorescent probe to ground truth our direct counts by light microscopy. Fish kill events will be sampled more intensively (2-hr intervals on short-term kills; daily intervals during kills of longer duration [≥ 1 week]), extending for 1 week after the kill to track the dinoflagellate's decline. Analysis of the results will provide insights about the level of spatial / temporal resolution required to adequately sample such events. Live water samples from fish kills (parts D,E) will be screened for the presence of toxic stages using aquarium bioassays with our standard tilapia test species (Burkholder *et al.* 1992a). Tilapia is not endemic to North Carolina estuaries; it offers the advantages of constant availability, wide salinity tolerance, and certainty of no prior contamination by the alga.

E. Analysis of Natural Samples for Geographic Distribution (Burkholder/Rublee; required for Objective 2; Year I [pilot-NC]; more intensive during Years II–III, including surveys of selected estuaries in DE, MD, GA, FL)—

An understanding of regional as well as local genetic variability among strains of *Pfiesteria piscimorte* (gen. et sp. nov.) is critical to development of highly specific gene probes that can be used by regulatory staff to detect this dinoflagellate in water samples on a routine basis. Our knowledge of intraspecific variability will be strengthened by the field component of the proposed research. Throughout this study we plan to collect natural water and sediment samples from sudden-death fish kills, known fish kill sites (from surveys of the Pamlico, Neuse and New River Estuaries in North Carolina; the Indian River in Delaware; the Choptank River in Maryland; the Savannah River in Georgia; and the St. Johns (Atlantic) and Pensacola (Gulf) areas in Florida that are suspected to harbor *Pfiesteria piscimorte* (gen. et sp. nov.). Samples will be obtained as follows:

1. **Bloom events during kills—We plan to continue to coordinate a network of state personnel and volunteer citizens** (established in 1991, with help from NC Division of Environmental Management and the NC Division of Marine Fisheries, and from concerned citizens groups such as the Neuse River Foundation and the Tar-Pamlico River Foundation) to help sample estuarine fish kills while in progress. We will also sample waters and sediments during fish kills ourselves whenever possible (i.e., whenever we are able to mobilize and complete the 3-hr drive to the North Carolina coast to sample the sudden-death fish kills while in progress). Water samples will be taken with an integrated water-column sampler (Neuse mean depth in the study area = 3.5 m); the upper 2 cm of sediment will be quantitatively sampled in two randomly positioned 0.1 m^2 quadrats per site with gentle siphoning guided by SCUBA divers (technique tested well at 26 sites in the Cherry Point area, October 1993).

   Our network has been highly successful in helping to establish the presence of the toxic dinoflagellate at kills during previous years. Based on data from May–Oct. 1991–1993, we expect that 8–12 major fish kills yr^{-1} (involving $\geq 10^3$ fish) will be linked to this organism (Burkholder *et al.* 1993). Following a kill in which *P. piscimorte* (gen. et sp. nov.) is found swarming in the water, with toxicity verified using aquarium bioassays, we will sample biweekly for 3 months to follow the dinoflagellate's population dynamics over time in both the water and sediments. Environmental variables to be sampled (as part of the separate funding support) will include temperature, salinity, pH, dissolved oxygen, total phosphorous, phosphate, total Kjeldahl nitrogen, nitrate, and ammonium, using techniques described in Burkholder *et al.* (1992b).
2. **Local surveys—We will collect replicate water and sediment samples from ca 50 representative estuarine sites in North Carolina** that previously have experienced fish kills (Neuse and Pamlico Rivers) or high incidence of unexplained ulcerative disease (Neuse, Pamlico, and New Rivers; Burkholder *et al.* 1993). Control sites will also be tested, using areas without incidence of fish kill / disease that are regarded as prime habitat for commercially important fisheries. These sites will span salinity gradients from rivers to sounds, and will include areas with/without wastewater discharge. Sampling of surveys sites in NC will begin during Year I, with major field effort planned for July–October (maximal kill / disease incidence) of Years II–III. These samples will be quickly assayed by our gene probe(s) for comparison with direct microscope counts, to confirm utility of the probe and strengthen our database about the distribution of *P. piscimorte* (gen. et sp. nov.) and abundance of flagellated / amoeboid stages in North Carolina estuaries.

   As part of this effort, we plan to examine correlations between the abundance of this pathogen and nutrient enrichment (P,N), to determine whether the dinoflagellate may be a useful biosensor of cultural eutrophication (as indicated by nutrient bioassays on some stages in culture [Burkholder *et al.* 1992], and by surveys of the New River Estuary that yielded significantly higher abundance of the toxic precursor stage in sewage outfall sites than in control areas without wastewater discharge [Burkholder & Glasgow unpubl. data; Fig. 5]). Accompanying environmental data will include the variables listed for analysis in the Minnesott Beach / Cherry Point area (1, above).
3. **Geographic distribution (Southeast region)—We will complete a sampling survey of sites in the selected estuaries of Delaware, Maryland, Georgia and Florida,** known or suspected to support populations of this dinoflagellate and close relatives. Culture isolates will be established from each location for tests against our gene probes. [Note that any research with the Pfiesteria-like species discovered by Landsberg *et al.* will be pursued in collaborative efforts led by our Florida Marine Research Institute colleagues, Drs. K. Steidinger and J. Landsberg.]

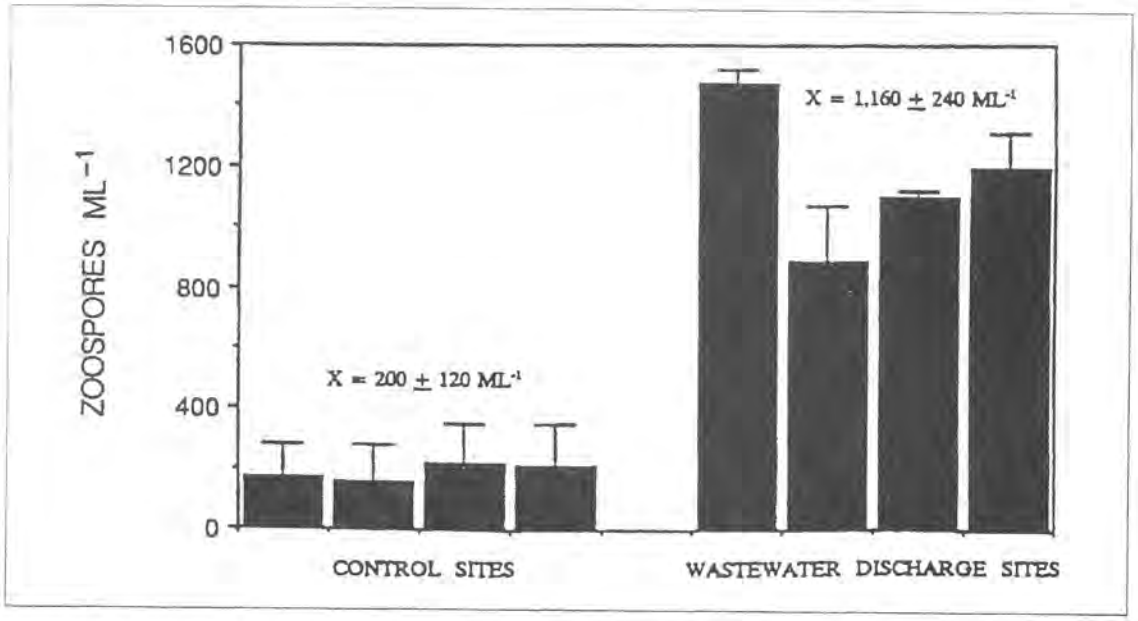

FIGURE 5. Abundance of the zoospore precursor stage to lethal TFVCs (see Fig. 2) from 4 control sites (upper Stones Bay, Swan Point, Ellis Cove, and Sneads Ferry Marina, in order of presentation) and 4 wastewater discharge sites (sampled within ca 100 m from the discharge point: Morgan Bay, mouth of French's Creek, lower Northeast Creek, and lower Stones Bay) at the end of the growing season in the New River Estuary, NC (duplicate samples per site; means ± 1 standard deviation). The data suggest that *Pfiesteria piscimorte* (gen. et sp. nov.) may be of use as a biosensor of cultural eutrophication.

F. Localization of Sites with Maximal Chemosensory Attraction on Finfish (Burkholder; required for Objective 3; Year II)—

In a related project, we have begun to screen fish tissues (e.g., gill, cloacal area, blood, mouth) for "swarming" activity or high incidence of attachment of dinoflagellate cells indicating obvious chemosensory attraction. This task has been approached using both light microscopy and scanning electron microscopy (SEM), but with only limited success. Light microscopy does not afford the high resolution needed to readily discern colorless amoeboid stages and small flagellates among fish debris. SEM greatly improves resolution, but analysis is restricted to extremely small tissue areas. We anticipate that fluorescently labeled probe(s) will greatly facilitate screening of larger quantities of tissue by light microscopy.

Juveniles or young adults of three fish species (hybrid striped bass, tilapia, and mosquitofish *[Gambusia affinis]*), known to span a range of sensitivity to the toxins of this dinoflagellate (Burkholder & Glasgow unpubl. data), will be examined with the fluorescent probe(s) to discern sites / tissues that attract high concentrations of toxic cells. In separate bioassays, each fish species will be exposed to an actively growing culture of *Pfiesteria piscimorte* (gen. et sp. nov.). At intervals between introduction and death of prey, individual animals (each considered a "repeat trial" for the given species) will be sacrificed and gills, cloacal area, blood, mouth, and epidermis in localized regions of interest (e.g., for hybrid striped bass, the lymphatic canal region

below the dorsal fin which typically fills with blood in response to the dinoflagellate's toxin) will be exposed to our fluorescent probe in the manner of DeLong *et al.* (1989). Time course analysis (1 hr, 2 hr, and 4 hr) of incubation with the fluorescent probe will be completed to determine the optimum exposure period for labeling dinoflagellate cells. Samples can then be screened for detection of the pathogen's flagellated / amoeboid stages among fish debris.

G. Aquaculture Site Testing
(Rublee and Burkholder; required for Objective 4; Year III)

This project component will be addressed using two approaches. First, we plan to obtain water samples and bottom scrapings in culture tanks used in finfish aquaculture at NMFS–Beaufort. For the past three years, PI JMB has counseled colleagues at this facility (Dr. A. Powell and Mr. W. Hettler, who are culturing southern flounder, Atlantic menhaden, spot *[Leiostomus xanthuris]*, bay scallops and other species) at this facility. The seawater supply is Taylors Creek, which is a known "hot spot" and kill site for *Pfiesteria piscimorte* (gen. et sp. nov.; Burkholder *et al.* 1993). In collaborative efforts we have learned that menhaden eggs do not hatch when lethal stages of the alga are abundant in the culture tank water (Burkholder *et al.* 1993). Moreover, southern flounder delay reproduction and develop large open, bleeding ventral sores when populations of toxic amoebae begin to grow on the tank floor. We will provide gene probe versus light microscope analyses of the samples as our probes come on line especially during years II–III of this effort. Secondly, through UNC–Sea Grant aquaculture extension specialists, we will obtain and similarly test samples from large-scale commercial operations for hybrid striped bass *(Morone saxatilis × Morone chyrsops)*, a species which is known to be extremely susceptible to the dinoflagellate (Burkholder *et al.* 1993). Such sampling will enable additional ground truthing or quality assurance of our probes for an extended period of time, and also will provide a means to introduce this early detection technology into the aquaculture industry.

EXPECTED RESULTS

With bacterial clones containing rDNA fragments now established from two *Pfiesteria piscimorte* (gen. et sp. nov.) isolates, we have made significant progress toward developing a sensitive and reliable detection method for this toxic dinoflagellate. We expect to complete development of this probe for routine monitoring and detection by the fishing industry, as well as for use in basic ecological studies. Insights into the ecology, life history, and genetic character of this organism is a necessary prelude to the development of applications in medical research, and to developing management strategies to mitigate impacts of *P. piscimorte* (gen. et sp. nov.) on estuarine waters which serve as nursery areas and habitat for many commercially and recreationally important finfish and shellfish species.

Within the past year, one Ph.D. candidate has undertaken thesis research to examine nutritional controls on the population dynamics and transformations of *Pfiesteria piscimorte* (gen. et sp. nov.), and will be trained in development of gene probes. This graduate assistant will be continuing his dissertation experiments as a member of the project team for the proposed research. A Master of Science graduate research assistant will be conducting field population studies of this dinoflagellate as thesis research in this project, and she will also be trained in probe development. A second M.S. student and an undergraduate will be involved in gene probe development for the organism at UNC–Greensboro. At least four publications are planned per year from this research in internationally refereed journals. In other education-related activities, PI JMB has presented an average of more than 80 lectures and seminars per year in 1991–1993 about this toxic dinoflagel-

late and its effects on estuaries and aquaculture, including presentations to undergraduate students, graduate students, concerned citizens groups, regulatory staff, legislators, and scientists.

Research on this organism by PI JMB and her staff (1991–1993) has been translated into 37 languages and disseminated by the British Broadcasting Corporation, the Canadian Broadcasting Corporation, CNN, "Good Morning America," *Discover* Magazine, the *New York Times*, the *Washington Post*, and *Time* Magazine. There is strong public support in North Carolina, the United States, and other nations for rapid progress to be made in understanding and mitigating the effects of this organism on our fishery resources. To acquire this knowledge, techniques are critically needed to enable rapid, reliable, early detection of *P. piscimorte* (gen. et sp. nov.) prior to major ulcerative disease outbreaks or kill events. The central goal of the proposed research will be to meet this essential need by developing sensitive, highly specific gene probes for fish pathogen.

Education, graduate student training, and lecture / seminar presentations are important components of information transfer. To further aid in disseminating information about the availability of our gene probes for *Pfiesteria piscimorte* (gen. et sp. nov.), we plan to conduct demonstration / training workshops among regulatory agencies in the North Carolina Department of Environment, Health & Natural Resources (notably the Division of Environmental Management, Shellfish Sanitation, and Division of Marine Fisheries); the National Marine Fisheries Service–Beaufort, NC; and aquaculture specialists in UNC–Sea Grant extension program to inform them of the availability and power of this new technology as it is refined and tested. Staff members from these agencies have already expressed interest in participating in such workshops.

APPLICATION

This work, addressing several key targets identified by a national Sea Grant initiative for research in Marine Biotechnology, will yield applications of both immediate and long-term value. Development of a sensitive, highly specific diagnostic technique for this ichthyotoxic dinoflagellate pathogen will enable routine *in situ* monitoring of water quality in aquaculture. First, the probes can immediately be used to test for the presence of *Pfiesteria piscimorte* (gen. et sp. nov.) as a contaminant of aquaculture facilities, thereby preventing introduction of valuable fish stocks into ponds with high probability of later fish kills. The probes will enable early detection of the organism's presence so that steps can be taken (e.g., removal of fish so that ponds can be drained and treated with chlorox pellets, known to destroy all stages of the dinoflagellate including resistant resting cysts) so that toxic outbreaks in the ponds or tanks can be mitigated or avoided. In addition, the gene probes will facilitate detection of contaminated fish, leading to improved quarantine measures and improved quality assurance when fish and fish products are transported to/from other states—also an important consideration for human health, since this alga is known to be toxic to humans as well as fish (Burkholder *et al.* 1993; Burkholder & Glasgow unpubl. data and medical records; D. Baden, NIEHS Center Director & Rosenstiel Institute of U. Miami, unpubl. data on the neurotoxins of *P. piscimorte* [gen. et sp. nov.]).

In more long-term benefits, our research will enable more accurate assessment of environmental quality, as related to the presence of this dinoflagellate, in natural estuarine ecosystems. As we improve our knowledge of the distribution of the organism and its relation to nutrient enrichment, we will gain insights about controlling *Pfiesteria piscimorte* (gen. et sp. nov.) and mitigating its acute and chronic effects on commercially important fisheries. Additonal long-term value of this research relates to medical and biological research applications. Medical concerns include the potential for toxin accumulation in humans and, conversely, use of the toxin(s) in medical applications (cf. Carmichael 1994). In related efforts we are working with a colleague, Dr. Daniel Baden (also president of Chiral Corporation, Miami, FL, a firm that specializes

in developing test kits for routine analysis of dinoflagellate toxins), to characterize the toxins produced by this alga. Once this is accomplished, we plan to join forces to develop rapid detection / quantification procedures for both the organism and its toxins in natural estuarine samples and aquaculture ponds. *P. piscimorte* (gen. et sp. nov.) also offers interesting features from a developmental biology standpoint; in response to environmental cues, its ability to transform rapidly among stages that differ dramatically in both form and function (Burkholder *et al.* 1993) suggest well-regulated developmental controls.

From an ecosystem standpoint, greater understanding of this abundant, widespread organism—with multiple amoeboid stages that previously were not even recognized as dinoflagellates—has already begun to change existing paradigms about the role of dinoflagellates in estuarine food webs (Mallin *et al.* submitted). Moreover, the data on dinoflagellate-related fish kills gained from our coordinated monitoring effort will contribute to a long-term data base that will be of value in correlating toxic outbreaks with environmental conditions, and evaluating the impacts of this toxic alga on our fisheries resources. Development of sensitive, highly specific gene probes for *P. piscimorte* (gen. et sp. nov.) will answer a critical need for routine, early detection of this toxic dinoflagellate by regulatory staff and finfish / shellfish aquacultrists.

REFERENCES

Anderson, D.A. & L. Hall. 1992. *State of Maryland Water Quality Monitoring Report for Fish Kills in 1990–1991.* Wye River Center, State of Maryland Department of Environmental Management.

Anderson, D.M. 1993. Identification of harmful algal species using molecular probes. In: *Proceedings, Sixth International Conference on Toxic Marine Phytoplankton.* Nantes, France, p. 22.

Anderson, D.M., S. Galloway & J.D. Joseph. 1993. *Marine Biotoxins and Harmful Algae: A National Plan.* Woods Hole Technical Report WHOI 93-02. NOAA, National Marine Fisheries Service.

Anderson, D.M., A.W. White and D.G. Baden. 1985. *Toxic Dinoflagellates.* New York, Elsevier Science Publishing Company.

Anderson, D.M., A. Grabher & M. Herzog. 1992. Separation of coding sequences from structural DNA in the dinoflagellate *Crypthecodinium cohnii. Molec. Mar. Biol.* 1:89–96.

Anonymous. 1992. "Phantom" algae are linked to mass fish deaths. *The New York Times,* 30 July, p.1.

Ausubel, F.M., R. Brent, R.E. Kingston, D.D. Moore, J.G. Siedman, J.A. Smith & K.H. Struhl. 1992. *Short Protocols in Molecular Biology.* 2nd ed. New York, John Wiley & Sons.

Barkay, T., M. Gillman & C. Liebert. 1990. Genes encoding mercuric reductases from selected gram-negative aquatic bacteria have a low degree of homology with *merA* of transposon Tn*501. Appl. Environ. Microbiol.* 56:1695–1701.

Brand, L.E. 1988. Review of genetic variation in marine phytoplankton species and the ecological implications. *Biol. Oceanogr.* 6:397–409.

Britschgi, T.B. & S.J. Giovannoni. 1991. Phylogenetic analysis of a natural marine bacterio-plankton population by rRNA gene cloning and sequencing. *Appl. Environ. Microbiol.* 57:1707–1713.

Burkholder, J.M. 1992. Phytoplankton and episodic suspended sediment loading: Phosphate partitioning and mechanisms for survival. *Limnol. Oceanogr.* 37:974–988.

Burkholder, J.M. 1993. Tracking a "phantom:" The many disguises of the new ichthyotoxic dinoflagellate. In: *Proceedings, Fifth International Conference on Modern and Fossil Dinoflagellates.* Zeist (The Netherlands), p. 22.

Burkholder, J.M. & R.G. Wetzel. 1989. Epiphytic microalgae on natural substrata in a hardwater lake: seasonal dynamics of community structure, biomass and ATP content. *Arch. Hydrobiol./Suppl.* 83:1–56.

Burkholder, J.M., R.G. Wetzel & K.L. Klomparens. 1994. Track SEM-autoradiography of adnate microalgae. In: *Periphyton Methods Manual,* by R.G. Wetzel (Ed.). Boston, Dr. W. Junk Publishers (in press).

Burkholder, J.M., H.B. Glasgow Jr. & C.W. Hobbs. Response of a ichtyotoxic estuarine dinoflagellate to gradients of salinity, light and nutrients. *Mar. Ecol. Prog. Ser.* (submitted).

Burkholder, J.M., H.B. Glasgow, E.J. Noga & C.W. Hobbs. 1993. *The Role of a New Toxic Dinoflagellate in Finfish and Shellfish Kills in the Neuse and Pamlico Estuaries.* Report No. 93-08, Albemarle–Pamlico Estuarine Study. Raleigh, North Carolina Department of Environment, Health & Natural Resources and U.S. Environmental Protection Agency–National Estuary Program, 58 pp. (3rd printing).

Burkholder, J.M., E.J. Noga, C.W. Hobbs, H.B. Glasgow, Jr. & S.A. Smith. 1992a. New "phantom" dinoflagellate is the causative agent of major estuarine fish kills. *Nature* 358:407–410; *Nature* 360:768.

Burkholder, J.M., K.M. Mason & H.B. Glasgow Jr. 1992b. Water-column nitrate enrichment promotes decline of eelgrass *Zostera marina* L.: Evidence from seasonal mesocosm experiments. *Mar. Ecol. Prog. Ser.* 81:163–178.

Carmichael, W.W. 1994. The toxins of cyanobacteria. *Sci. Amer.* 270:78–86.

Coleman, A.W. & J.L. Goff. 1991. DNA analysis of eukaryotic algal species. *J. Phycol.* 27:463–473.

Culotta, E. 1992. Red menace in the world's oceans. *Science* 257:1476–1477.

DeLong, E.F., G.S. Wickham & N.R. Pace. 1989. Phylogenetic strains: Ribosomal RNA-based probes for the identification of single cells. *Science* 243:1360–1363.

DeRijk, P., J-M. Neefs, Y. Vn de Peer & R. De Wachter. 1992. Compilation of small ribosomal subunit RNA sequences. *Nucleic Acids REs.* 20(Supp.):2075–2089.

Droop, M.R. 1974. Heterotrophy of carbon, pp. 530–559. In: *Algal Physiology and Biochemistry,* by W.D.P. Stewart (Ed.). Botanical Monograph Vol. 10. Berkeley, University of California Press, 989 pp.

Erb, R.W. & I. Wagner-Döbler. 1993. Detection of polychlorinated biphenyl degradation genes in polluted sediments by direct DNA extraction and polymerase chain reaction. *Appl. Environ. Microbiol.* 59:4065–4073.

Fritz, L., P. Milos, D. Morse & J.W. Hastings. 1991. *In situ* hybridization of luciferin-binding protein anti-sense RNA to thin sections of the bioluminescent dinoflagellate *Gonyaulax polyedra. J. Phycol.* 27:436–441.

Gaines, G. & M. Elbrächter. 1987. Heterotrophic nutrition, pp. 224–268. In: *The Biology of Dinoflagellates,* by F.J.R. Taylor (Ed.). Boston, Blackwell Scientific Publications, 785 pp.

Geraud, M.-L., M. Sala-Roviera, M. Herzog & M.-L. Soyer-Gobillard. 1991. Immunochemical localization of the DNA-binding protein HCs during cell cycle of the histone-less dinoflagellate protocista *Crypthecodinium cohnii* B. *Biol. Cell* 71:123–134.

Greer, J. 1993. Alien in our midst? Phantom algae suspected in Bay. *Marine Notes.* University of Maryland Sea Grant, March.

Hallegraeff, G.M. 1992. A review of harmful algal blooms and their apparent global increase. *Phycologia* 32:79–99.

Hallegraeff, G.M., D.A. Steffenson and R. Wetherbee. 1988. Three estuarine Australian dinoflagellates that can produce paralytic shellfish toxins. *J. Plankt. Res.* 10:533–541.

Hauser, D.C.R., M. Levandowsky, S.H. Hutner, L. Chunosoff & J.S. Hollwitz. 1975. Chemosensory responses by the heterotrophic marine dinoflagellate *Crypthecodinium cohnii. Microb. Ecol.* 1:246–254.

Herrick, J.B., E.L. Madsen, C.A. Batt & W.C. Ghiorse. 1993. Polymerase chain reaction amplification of naphthalene-catabolic and 16S rRNA gene sequences from indigenous sediment bacteria. *Appl. Environ. Microbiol.* 59:687–694.

Huyghe, P. 1993. A horrific predatory little plant is beating up on fish around the world. *Discover* Magazine, April.

Kay, J. 1992. Eerie killer algae may be stalking Bay fish. *San Francisco Examiner,* 17 Aug., p.1.

Landsberg, J.H., K.A. Steidinger & B. Blakesley. 1994. Fish-Killing dinoflagellates in a tropical aquarium. In: *Proceedings, Sixth International Conference on Toxic Marine Phytoplankton.* Amsterdam, Elsevier (in press).

Lenaers, G., C. Scholin, Y. Bhaud, D. Saint-Hilaire & M. Herzog. 1991. A molecular phylogeny of dinoflagellate protists (Pyrrhophyta) inferred from the sequence of 24S rRNA divergent domains D1 and D8. *J. Mol. Evol.* 32:53–63.

Levine, J.F., J.H. Hawkins, M.J. Dykstra, E.J. Noga, D.W. Moye & R.S. Cone. 1990. Species distribution of ulcerative lesions on finfish in the Tar-Pamlico Estuary, North Carolina. *Dis. Aquat. Org.* 8:1–5.

Lewitus, A.J., R.V. Jesien, T.M. Kana, J.M. Burkholder & E. May. Discovery of the "phantom" dinoflagellate in Chesapeake Bay. *Estuaries* (submitted).

Li, N. & R.A. Cattolico. 1992. *Ochromonas danica* (Chrysophyceae) chloroplast genome organization. *Mol. Mar. Biol. Biotech.* 1:165–174.

Lund, J.W.G., C. Kipling and E.D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimates by counting. *Hydrobiologia* 11:143–170.

Lynn, D.H. & M.L. Sogin. 1988. Assessment of phylogenetic relationships among ciliated protists using ribosomal RNA sequences derived from reverse transcripts. *BioSystems* 21:249–254.

Mallin, M.A., J.M. Burkholder, L.M. Larsen & H.B. Glasgow Jr. Response of two zooplankton grazers to an ichthyotoxic estuarine dinoflagellate. *Mar. Ecol. Prog. Ser.* (submitted). [published 1995 in *J. Plankton Research*. 17:351–363]

Manhart, J.R. & R.M. McCourt. 1992. Molecular data and species concepts in the algae. *J. Phycol.* 28:730–737.

Miller, K.H., J. Camp, R.W. Bland, J.H. Hawkins, III, C.R. Tyndall and B.L. Adams. 1990. *Pamlico Environmental Response Team Report* (June–December 1988). North Carolina Dept. of Environment, Health, and Natural Resources. Wilmington, North Carolina, 50 pp.

Moran, M.A., V.L. Torsvik, T. Torsvik & R.E. Hodson. 1993. Direct extraction and purification of rRNA for ecological studies. *Appl. Environ. Microbiol.* 59:915–918.

North Carolina Division of Marine Fisheries. 1992. *Description of North Carolina's Coastal Fishery Resources.* Draft Report. Morehead City, North Carolina Department of Environment, Health and Natural Resources–Division of Marine Fisheries, 215 pp.

Pace, N.R., D.A. Stahl, D.J. Lane & G.J. Olsen. 1986. The analysis of natural microbial populations by ribosomal RNA sequences. *Adv. Microb. Ecol.* 9:1–55.

Pederson, B.H. & K.P. Anderson. 1992. Induction of trypsinogen secretion in herring larvae *(Clupea harengus). Mar. Biol.* 112:559–565.

Pichard, S.L. & J.H. Paul. 1993. Gene expresion per gene dose: a specific measure of gene expression in aquatic microorganisms. *Appl. Environ. Microbiol.* 59:451–457.

Pichard, S.L., M.E. Fisher & J.H. Paul. 1993. Ribulose bisphosphate carboxylase gene expression in subtropical marine phytoplankton populations. *Mar. Ecol. Prog. Ser.* 101:55–65.

Rensberger, B. 1992a. Huge fish kills linked to slumbering algae. *The Washington Post*, 30 July, p.1.

Rensberger, B. 1992b. Look! In the water! It's a plant, it's an animal, it's a toxic creature. *The Washington Post*. 17 August, Science Feature.

Reynolds, A.E., B.L. McConaughy & R.A. Cattolico. 1993. Chloroplast genes of the marine alga *Heterosigma carterae* are transcriptionally regulated during a light/dark cycle. *Molec. Mar. Biol. Biotech.* 2:121–128.

Rizzo, P.J. 1987. Biochemistry of the dinoflagellate nucleus, pp. 143–171. In: *The Biochemistry of Dinoflagellates*, by F.J.R. Taylor (Ed.). Oxford, Blackwell Scientific.

Robineau, B., J.A. Gagne, L. Fortier and A.D. Cembella. 1991. Potential impact of a toxic dinoflagellate *(Alexandrium excavatum)* bloom on survival of fish and crustacean larvae. *Mar. Biol.* 108:293–301.

Rowan, R. & D.A. Powers. 1992. Ribosomal RNA sequences and the diversity of symbiotic dinoflagellates (zooxanthellae). *Proc. Natl. Acad. Sci.* 89:3639–3643.

Rublee, P.A. 1982. Seasonal distribution of bacteria in salt marsh sediments of North Carolina. *Est. coastal Shelf Sci.* 15:67–74.

Rublee, P.A. 1992. Community structure and bottom-up regulation of heterotrophic microplankton in arctic LTER lakes. *Hydrobiologia* 240:133–141.

Sambrook, J., E.F. Fritsch & T. Maniatis. 1989. *Molecular Cloning: A Laboratory Manual.* 2nd ed. New York, Cold Spring Harbor.

Sanger, F., S. Nicklen & A.R. Coulson. 1977. DNA sequencing with chain-terminating inhibitors. *Proc. Nat. Acad. Sci.* 74:5463–5467.

Scholen, C.A., D.M. Anderson & M.L. Sogin. 1993. Two distinct small-subunit ribosomal RNA genes in the North American toxic dinoflagellate *Alexandrium fundyense* (Dinophyceae). *J. Phycol.* 29:209–216.

Shimizu, Y. 1991. Dinoflagellates as sources of bioactive molecules, p.71. In: *Program and Abstracts of the Second International Marine Biotechnology Conference.* Baltimore, Society for Industrial Microbiology, October (Abstract).

Shumway, S.E. 1990. A review of the effects of algal blooms on shellfish and aquaculture. *Journal of the World Aquaculture Society* 21:65–104.

Smayda, T.J. 1989. Primary production and the global epidemic of phytoplankton blooms in the sea: A linkage?, pp. 449–484. In: *Novel Phytoplankton Blooms*, by E.M. Cosper, V.M. Bricelj and E.J. Carpenter (Eds.). Coastal and Estuarine Studies No. 35. New York, Springer-Verlag, 799 pp.

Steidinger, K.A. & D.G. Baden. 1984. Toxic marine dinoflagellates, pp. 201–262. In: *Dinoflagellates*, by D.L. Spector (Ed.). New York, Academic Press, 545 pp.

Steidinger, K.A., E.W. Truby, J.K. Garrett & J.M. Burkholder. 1994. The morphology and cytology of a newly discovered toxic dinoflagellate, 6 pp. In: *Proceedings, 6th International Conference on Toxic Marine Phytoplankton*. Amsterdam, Elsevier (in press).

Tsai, Y.-L. & B.H. Olsen. 1991. Rapid method for direct extraction of DNA from soil and sediments. *Appl. Environ. Microbiol.* 57:1070–1074.

Tsai, Y.-L. & B.H. Olsen. 1992. Rapid method for separation of bacterial DNA from humic substances in sediments for polymerase chain reaction. *Appl. Environ. Microbiol.* 58:2292–2295.

Triplett, E.L., N.S. Govind, S.J. Roman, R.V.M. Jovine & B.B. Prezelin. 1993. Characterization of the sequence organization of DNA from the dinoflagellate *Heterocapsa pygmaea* (*Glenodinium* sp.). *Molec. Mar. Biol. Biotech.* 2:239–245.

UNESCO. 1991. *Programme on Harmful Algal Blooms*. Workshop Report No. 80. Newport (RI), Intergovernmental Oceanographic Commission.

Weisberg, W.G., S.M. Barns, D.A. Pelletier & D.J. Lane. 1991. 16S ribosomal DNA amplification for phylogenetic study. *J. Bact.* 173:697–703.

White, A.W. 1988. Blooms of toxic algae worldwide: Their effects on fish farming and shellfish resources. In: *Proceedings of the International Conference on Impact of Toxic Algae on Mariculture*. Aqua-Nor '87 International Fish Farming Exhibition, August 1987, Trondeim, Norway, pp. 9–14.

Chapter 10 Document 5

Burkholder JM, Gordon AS, Moeller PD, Law JM,Coyne KJ, Lewitus AJ, Ramsdell JS, Marshall HG, Deamer NJ, Cary SC, Kempton JW, Morton SL, Rublee, PA. 2005. Demonstration of toxicity to fish and to mammalian cells by Pfiesteria species: comparison of assay methods and strains. Proceedings of the National Academy of Sciences of the United States of America. 102(9): 3471–3476.

Document removed due to copyright restrictions.

Chapter 10 Document 6

Rublee PA, Remington DL, Schaefer EF, Marshall MM. 2005. Detection of Dinozoans Pfiesteria piscicida and P. shumwayae: a review of detection methods and Geographic Distribution. Journal of Eukaryotic Microbiology. 52(5): 83–89.

Document removed due to copyright restrictions.

Chapter 10 Document 7

Engelhaupt E. 2007. New Pfiesteria toxin identified. Environmental Science & Technology Online News. [Internet]. [cited 2008 Mar 7].

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CHAPTER

11

Research on the Oracle at Delphi: From Ancient Myth to Modern Interdisciplinary Science

NOTE for 3e OPEN ACCESS: Many of the documents described below have been removed from the open access version due to copyright restrictions. We encourage you to access these articles from their original publishers via your university library and/or to locate more recent publications to expand this research case.

This case features the interdisciplinary collaboration of a geologist, an archeologist, a geochemist, and a clinical toxicologist, all centered on understanding the origin of prophecies given by the ancient priestesses of the Temple of Apollo in Delphi, Greece. The theory that the legendary trances and visions of the prophesying priestesses at the Delphic oracle were caused by their inhaling vapors was first postulated by writers in antiquity, most notably Plutarch. But this theory was cast into doubt in the late 19th century and again in the mid-20th century by French archeologists and geologists, who found no major fault in the region from which the fumes could rise. In 1981, however, Jelle Zeilinga de Boer, a geologist hired by the Greek government to determine the geological conditions for constructing nuclear reactors in the area, discovered a hidden fault that ran under the fissured floor of the Temple of Apollo. After discussing his discovery at a chance meeting with archeologist John Hale 14 years later, the two explored the area and found a second fault that ran from a spring, and petrochemicals that can produce intoxicating gases in the bedrock. They applied to the Greek government for permission to take samples from the area for chemical analysis. Their proposal (1996) is included as the first document in this chapter.

The analyses were performed back in the United States by geochemist Jeffrey Chanton, who then ventured to Greece where he found an unstable but even more intoxicating gas in the stream. In 2001, De Boer, Hale, and Chanton published a report on their findings in *Geology*, the next document in this chapter, in which they presented their evidence that the fault and the spring exist, that they were petro-gaseous, and that these gases were the likely cause of the priestesses' trances. Further pharmacological investigation by toxicologist Henry Spiller, director of the Kentucky Regional Poison Center, compared the effects of the gases found in the deposits with the known effects from 20th-century uses of these gases in anesthesia; Spiller, Hale, and De Boer published a "A Multidisciplinary Defense of the Gaseous Vent Theory" the following year in Clinical Toxicology, the next piece in this chapter. In a 2002 article from *The New York Times*, William Broad reported the story for a wider audience, providing fuller context and details of

this interdisciplinary collaboration: an account of chance and circumstance that led these four scientists to work together to solve an ancient riddle. This collaborative circle is continued in this case with the abstract of a 2002 conference presentation by all four scientists at the Annual Meeting of the Archeological Institute of America.

In the final document, the debate over the theory of subterranean gases as the cause of prophetic trances continues as DeBoer et al.'s findings are reexamined by another collaborative team, composed of earth scientists from Italy and Greece (*Geology*, 2006).

Additional Resources

1. Plutarch's Discussion of the Delphic Oracle: *Moralia* (Section 50) (Plutarch 2008)
   http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Plutarch/Moralia/De_defectu_oraculorum*.html

2. Description of the Temple at Delphi from Sacred Sites.com (Sacredsite.com 2006)
   http://www.sacredsites.com/europe/greece/tholos_temple_delphi.html

3. Review of the Research on the Delphic Oracle from *National Geographic* (Roach 2008)
   http://news.nationalgeographic.com/news/2001/08/0814_delphioracle.html

   Related video clip from *National Geographic*: https://video.nationalgeographic.com/search?q=delphi

4. Websites Representing the Cultural Conflict Concerning the Parthenon Marbles

   The Official Greek Position (Hellenic Ministry of Culture 2007)
   http://odysseus.culture.gr/a/1/12/ea121.html

   BBC Ancient History: Greece (Beard M 2004)
   http://www.bbc.co.uk/history/ancient/greeks/parthenon_debate_01.shtml

5. Environmental and Scientific Background: Ethylene Scorecard (Scorecard.com 2005)
   http://www.scorecard.org/chemical-profiles/summary.tcl?edf_substance_id=74-85-1
   UPDATE for 3e OPEN ACCESS:
   From NIH's PubChem database: Ethylene
   https://pubchem.ncbi.nlm.nih.gov/compound/ETHYLENE

Chapter 11 Document 1

De Boer JZ, Hale JR. 1996. Proposal to the Greek Ministry of Culture: A study of the evidence for geological faults and gaseous emissions at the sanctuary of Delphi. 21 September 1996.

PROPOSAL

DATE:

21 September 1996

RESEARCH PROJECT:

A study of the evidence for geological faults and gaseous emissions at the sanctuary of Delphi, in order to test the validity of ancient testimonia concerning the origins of the oracle of Apollo.

INVESTIGATORS:

Dr. Jelle Zeilinga de Boer, Professor of Earth and Environmental Sciences, Wesleyan University.
Dr. John R. Hale, Lecturer in Archaeology and Director of Liberal Studies, University of Louisville.

ADDRESS:

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REQUEST:

Permission to take ten small samples of travertine rock from the vicinity of the Apollo temple at Delphi. Samples need to be no larger than 15 centimeters in diameter, and could consist of pieces formerly removed during excavation.

If permission is granted, the samples will be submitted to testing and isotopic analyses. Using a mass spectrometer the isotopic ratio C13 to C12 can be determined which will provide information on the source of the carbon (non-organic vs. organic) and the ratio 018 vs. 016 which will reveal the origin of the waters (rain or deep groundwater) that rose along the young fault that underlies the site. The latter ratio can also provide data on the original temperature of the spring. Using a gas chromatograph the dissolved travertine can be checked for gasses and/or minerals left behind during incorporation of gases in the travertine.

Analyses will be carried out by the Geochemical and Environmental Research Group at Texas A & M University which group has done extensive work on gas emissions along faults in the Gulf of Mexico that are similar to the fault exposed East and West of the Oracle site.

RATIONALE:

The travertine rock (often referred to as tufa) is very porous and spongy, indicating that the emerging waters of the springs in the sanctuary were rich in air and gases.

De Boer and Hale proposal to Government of Greece, 1996

New tufa rock was being formed on the slope around the Apollo temple throughout the historic period, as is shown by the heavy encrustation of stalactite-like material on the retaining wall just north of the temple. An elaborate system of conduits and drains suggests a massive discharge of water from the Kassotis spring during the period of the oracle.

Some of the pores in the spongy travertine may still contain trapped pockets of the gas that bubbled up from the spring in antiquity. Laboratory analysis could potentially determine both the temperature at which the water emerged from the ground, and the chemical composition of the gases.

BACKGROUND:

Ancient sources referred to oracles coming "from the rock" at Delphi, and specified a chasm and vapor as important elements in the power of the oracle. This evidence accords with that for another oracular shrine, Didyma in Anatolia, where a prophetess customarily inhaled vapors rising from a spring in the temple of Apollo. As at Delphi, blocks of local tufa were used in the building of the temple at Didyma. A link between oracles and gas emissions is also attested in Italy and Persia.

In spite of this historic evidence, a number of modern archaeologists and geologists have denied the existence, or even the possibility of the existence, of a chasm and vapors at Delphi. Modern doubts are based on the failure of archaeological excavators to identify a chasm in the adyton of the Apollo temple, and on geological reports which concluded that the substrata of rock under the sanctuary solely consisted of limestones incapable of producing gaseous emissions.

Surveys in and near Delphi have on the contrary demonstrated that 1) beneath the travertine and shales at Delphi lies a stratum of bituminous limestone which could produce gases when sheared and superheated during seismic events; 2) fractures in the floor blocks of the temple, along with other evidence, suggest a history of seismic activity which could have stimulated emissions of gases; 3) the visible "bedrock" reached by the archaeologists appears to have once been covered by deposits of travertine, laid down by waters percolating through the site; and 4) the fault zone at Delphi is of a nature which is known to have produced gaseous emissions at similar tectonic settings elsewhere.

LABORATORY:

In recent years, geochemists at Texas A&M University have tested gaseous emissions from submarine faults in the Gulf of Mexico. The region provides a close parallel with Delphi in terms of the system of faults and the underlying rock strata. Sediments formed along the lines of the faults were analyzed at the College of Geosciences and Maritime Studies.

The gases proved to be light hydrocarbons, predominantly methane with small proportions of ethane and propane. All these gases are colorless and odorless, and produce narcotic effects when inhaled in sufficient concentration.

We propose that the laboratory at Texas A&M University be permitted to analyze the travertine samples from Delphi so that a direct comparison can be made with the results already obtained from faults in the Gulf of Mexico.

Chapter 11 Document 2

De Boer JZ, Hale JR, Chanton J. 2001. New evidence for the geological origins of the ancient Delphic oracle (Greece). Geology 29:707–10.

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Chapter 11 Document 3

Spiller HA, Hale JR, De Boer JZ. 2002. The Delphic Oracle: a multidisciplinary defense of the gaseous vent theory. Journal of Toxicology—Clinical Toxicology 40:189–96.

Document removed due to copyright restrictions.

Chapter 11 Document 4

Broad WJ. 2002 Mar 19. For Delphic oracle, fumes and visions. New York Times (National Ed.) Science D1, D4.

Document removed due to copyright restrictions.

Chapter 11 Document 5

Hale JR, De Boer JZ, Chanton J, Spiller H. [Conference abstract] 2002. New evidence for the geological origin of the Delphic oracle: active faults, gaseous emissions, and architectural anomalies in the temple of Apollo. 103rd Annual Meeting of the Archeological Institute of America. American Journal of Archeology 106:231–306.

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Chapter 11 Document 6

Etiope G, Papatheodorou G, Christodoulou D, Geraga M, Favali P. 2006. The geological links of the ancient Delphic Oracle (Greece): a reappraisal of natural gas occurrence and origin. Geology 34 (10): 821–24.

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CHAPTER

12

Research on Kepler's Supernova: From Satellite Image to Public Knowledge Space

NOTE for 3e OPEN ACCESS: Many of the documents described below have been removed from the open access version due to copyright restrictions. We encourage you to access these articles from their original publishers via your university library and/or to locate more recent publications to expand this research case.

The research in this case is based on data from the *Chandra* X-ray Observatory, a spacecraft in high-earth orbit with "the world's most powerful X-ray telescope" as its pay-load (O'Dell 1997). Since *Chandra*'s launch from Space Shuttle Columbia in 1999, researchers around the world have used its X-ray images to analyze numerous celestial objects in the Milky Way galaxy and beyond. *Chandra*'s ability to "see" through the gas and dust of space enables astronomers to detect objects invisible to optical telescopes. Data on these long-obscured objects is providing critical information about how stars form and die, how galaxies form, and how the universe as a whole has evolved.

The study of the universe and its contents is a highly theoretical science and thus difficult for non-specialists to make sense of. Yet many non-scientists are exceedingly interested in the secrets of the universe—fascinated by these spacecraft telescopes and the pictures and stories they reveal. Research in astrophysics thus offers an ideal opportunity to examine how scientists communicate with those who do not share their expert knowledge. In this research case we explore how the complex science that interprets these images from space is made available, comprehensible, and meaningful to the public.

The first document contains excerpts from the *Chandra* program's annual Call for Proposals, which invites scientists to request segments of the telescope's observing time to enable them to gather data on particular objects of interest. The CfP is followed by a proposal submitted to the program in 2005 by NC State astrophysicist Stephen Reynolds and six colleagues. The Reynolds team requested 750 ksec (about nine days) of *Chandra*'s time to view Kepler's supernova remnant (SNR), so named because it originated in a supernova explosion documented by the German astronomer Johannes Kepler in 1604 (Hill et al. 2004). The proposal was successful, and by late 2006 *Chandra*'s data had enabled Reynolds et al. to resolve a critical and longstanding question about the Kepler SNR's nature and origin: Kepler resulted from a Type Ia supernova, an exploding white dwarf.

The remaining documents in this case are reports of this discovery. The Reynolds team reported their finding at the January 2007 meeting of the American Astronomical Society, in a poster presentation and a NASA-sponsored press conference. Their poster is reproduced in Chapter 6. The abstract is included here, followed by a news release issued by NASA's Marshall Space Flight Center on the same day. *Science News Online* ran a story on the announcement later that month, and *Sky & Telescope* magazine covered it in its April 2007 issue. By the time Reynolds et al.'s formal research report appeared in *The Astrophysical Journal* in October, word of their discovery had already reached a number of audiences within and beyond the astrophysical community.

Additional Resources

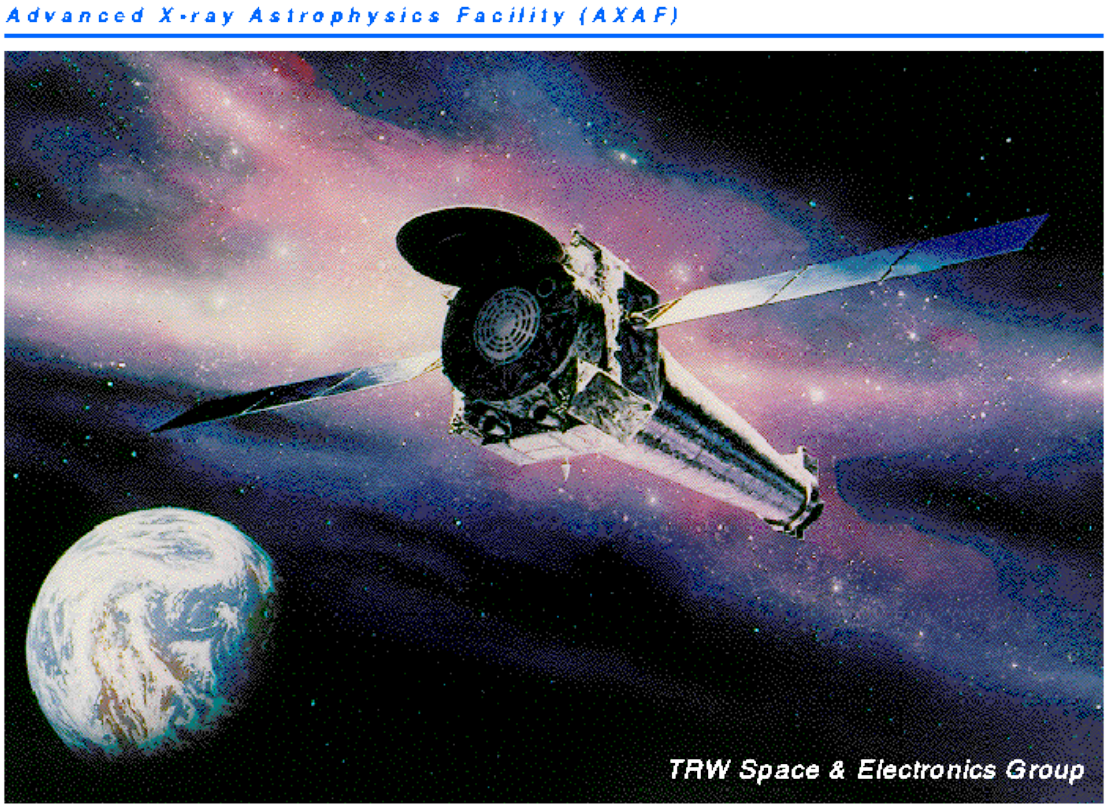
1. Image of Kepler's Supernova from NASA's Astronomy Picture of the Day (Nemiroff and Bonnel 2007)
   http://antwrp.gsfc.nasa.gov/apod/ap070116.html

2. Information on the *Chandra* X-ray Observatory from NASA (NASA 2008b)
   http://www.nasa.gov/mission_pages/chandra/main/index.html

3. Headline Stories from Science@NASA
   http://science.nasa.gov/

4. Public Information and Education Resources from the *Chandra* X-ray Center (Harvard Smithsonian Center for Astrophysics 2008)
   http://chandra.harvard.edu/index.html

5. Homepage of the International Year of Astronomy 2009 (International Year of Astronomy 2008)
   http://astronomy2009.org



NASA Marshall Space Flight Center (O'Dell 1997).
https://wwwastro.msfc.nasa.gov/xraycal/papers/AIAA/Page03.html

Chapter 12 Document 1

Chandra X-ray Center. 2007. The *Chandra* X-ray Observatory (CXO) Research Program Call for Proposals: Cycle 10. Cambridge (MA): NASA/Chandra X-Ray Center. [Excerpts]

The *Chandra* X-ray Observatory (CXO) Research Program

Call for Proposals

Cycle 10

Due Date: 20 March 2008, 6 p.m. EDT

Prepared by:
Chandra X-ray Center
60 Garden Street,
Cambridge, MA 02138

14 December 2007

The *Chandra* X-ray Center is operated for NASA by the Smithsonian Astrophysical Observatory.

NASA/*Chandra* X-ray Center, 2007 [excerpts]

Chapter 1 - General Information

1.1 The *Chandra* Program: Call for Proposals

We invite scientists to participate in Cycle 10 of the *Chandra* X-ray Observatory's (CXO) science program. The *Chandra* program is sponsored by NASA's Science Mission Directorate (SMD) and managed by the NASA Marshall Space Flight Center (MSFC). The *Chandra* X-ray Center (CXC), which is funded by NASA via a contract to the Smithsonian Astrophysical Observatory (SAO) in Cambridge, MA, has the responsibility for managing the *Chandra* science program, carrying out the *Chandra* Education and Public Outreach (EPO) program, conducting the peer review that recommends the allocation of observing time and funds to the user community, selecting the proposals, and operating the *Chandra* spacecraft. The *Chandra* X-ray Observatory is described in Chapter 2.

The funding of all awards associated with this Call for Proposals (*CfP*) flows from NASA through SAO and the CXC to the Awardees. The CXC is the organizational unit within SAO that carries out SAO's contractual obligation to operate the *Chandra* X-ray Observatory and solicit proposals and when used in this document will encompass the NASA/SAO/CXC interrelationship.

1.2 Proposal Review Process: Deadlines and Schedule

Science proposal submission and review will be conducted in two stages to minimize the burden of proposal preparation. For details, please refer to Chapter 5:

- **Stage 1:** Involves the scientific and technical merits of the proposed investigation. Evaluation criteria include overall scientific merit, relevance to the *Chandra* program and the competence of the proposers (Section 7.1).
- **Stage 2:** The PIs of those proposals selected in Stage 1 will be invited to submit a cost proposal for the Stage 2 review (Chapter 8) and will also be given an opportunity to submit an Education/Public Outreach (EPO) proposal (Chapter 9).

Table 1.1 Schedule and Deadlines for the *CfP* Cycle

EVENT	DATE
CfP Release	14 December 2007
Science Proposal Deadline (Stage 1)	**6 p.m. EDT, 20 March 2008**
Peer Review	16-20 June 2008
Selected Proposals Announced	Early July 2008
Budget Deadline (Stage 2)	**6 p.m. EDT, 18 September 2008**
Cost Review	October 2008
Stage 2 Final Selection	November 2008
EPO Electronic Deadline	**5 p.m. EDT, 24 October2008**
EPO Hardcopy Deadline	**4 p.m. EDT, 29 October 2008**
EPO Review	December 2008
Cycle 10 Starts	About December 2008

Late Proposals will not be considered. We recommend submission well before the deadline.

1.3 Summary of the *CfP*

This *CfP* solicits basic research proposals for participation in the program for the conduct of space science observations and subsequent analysis of the resultant scientific data from the *Chandra* X-ray Observatory (CXO). The *CfP* also solicits proposals for research that makes use of publicly available archived *Chandra* data and for theoretical and modeling studies related to the *Chandra* mission. A separate supplementary *CfP* will be issued following the Stage 1 review to solicit EPO proposals from eligible PIs whose *Chandra* proposals have been selected in Stage 1. The primary goal of the *Chandra* mission is the investigation of the nature and physics of astronomical objects as revealed through their X-ray emission.

This *CfP* offers the opportunity for the submission of seven different types of proposals (Chapter 4) and two types of EPO proposals.

Types of Science Research Proposals:

1. **General Observing Projects (GO)** involving new *Chandra* observations, generally (but not limited to) requiring less than 300 ksec of observing time (regardless of the number of objects observed);
2. **Large Observing Projects (LP)** involving new *Chandra* observations that require 300 ksec or more (regardless of the number of objects observed) and designated as LPs by the PI;
3. **Very Large Observing Projects (VLP)** involving new *Chandra* observations that require 1 Msec or more (regardless of the number of objects observed) and designated as VLPs by the PI;
4. **Target of Opportunity (TOO) Projects** that are triggered by the occurrence of an unanticipated astrophysical phenomenon (e.g., a supernova);
5. **Joint Observing Projects** that require multi-wavelength sets of data taken by *Chandra* and one or more of the facilities described in Section 4.5;
6. **Archival Research Projects** that use data from the *Chandra* archives or the *Chandra* Source Catalog; and
7. **Theory/Modeling Projects** that seek to better understand and interpret the data that have been taken with *Chandra*, or that seek to determine what new observations might be taken to test a hypothesis.

The observations selected as a result of this *CfP* will be implemented during a one-year period beginning about December 2008. Based on guidelines set by the *Chandra* Observing Policy (Chapter 3), 3.5% (700 ksec) of the on-target observing time available during this cycle is allocated to calibration observations, and 700 ksec is allocated to Director's Discretionary Time (DDT). Following this allocation, 85% of the remaining time is available for General Observations (GO), and 15% is allocated to Guaranteed Time Observations (GTO). The time available for General Observers (including Large and Very Large Projects) under this *CfP* is estimated at about 17 Msec. It is anticipated that further opportunities for participation in the *Chandra* Research Program will be announced annually, including the analysis of the increasing body of archival data.

Chapter 5 - Proposal Preparation and Submission Instructions

5.1 Overview and Schedule of Process

Science proposal submission and review will be conducted in two stages to minimize the burden of proposal preparation.

- **Stage 1:** During the first stage, the scientific and technical merits of the proposed investigation (Archival Research and Theory/Modeling as well as new observations) will be reviewed, including the appropriateness of using *Chandra* to address the scientific objectives and the relevance of the investigation to furthering our understanding of high-energy astrophysical processes. Based upon the recommendation of the Stage 1 peer review (scientific and technical), the Selection Official (the CXC Director) will select a set of proposals for award of observing time (proposals for new observations) or award of support for analysis and/or interpretation of existing data (Archival Research and Theory/Modeling proposals).
- **Stage 2:** The PIs of those proposals selected in Stage 1 will then be invited to submit a cost proposal for the Stage 2 review (Chapter 8) and will also be given an opportunity to submit an Education and Public Outreach (EPO) proposal (Chapter 9). A subset of the Stage 1 science peer review panel will evaluate the cost proposals and provide a list of those recommended for selection to the Selection Official. A separate peer review panel will be convened to review the EPO proposals.

Once the targets are identified, the *Chandra* X-ray Center (CXC) is responsible for generating the schedule of observations or science timeline. The timeline is determined for the most part by observing constraints, as specified in the proposal and as recommended by the peer review. These constraints are described in detail in the *Chandra* Proposers' Observatory Guide (POG) (http://cxc.harvard.edu/proposer/POG/index.html). Proposers may also specify additional constraints such as a particular time or time interval during which an observation must take place. Proposers should note that time-constrained observations are difficult to accomplish efficiently and will be limited 15 % of the total number of observations selected. Details of constraint classification and quotas are described in section 5.2.8

5.2 Stage 1 Research Proposal Details

5.2.1 Proposal Content

The Stage 1 proposal must include:

- Cover Page Form;
- General Form;
- Target Summary Form, if the proposal requires new observations;
- Scientific Justification and Technical Feasibility (as described below);
- Previous *Chandra* Programs listing (one page, described below); and
- CV/Bibliography for the PI (one-page, optional).

The page limits are listed in Table 5.2. The proposal must be submitted electronically (see Section 5.3 for proposal submission instructions). The information will be entered into a database that will be used in cataloging and evaluating proposals, as well as for scheduling those observations that are selected for implementation. The forms must be completed in the requested format. Cost sections and EPO proposals should not be submitted for the Stage 1 scientific review. However, proposals for the Archival Research or Theory/Modeling projects must include a preliminary cost estimate and a brief narrative describing the proposed use of these funds within the science justification section of the Stage 1 proposals. Formal cost and EPO proposals will be considered as part of the Stage 2 process.

5.2.2 Cover Pages

Although a signature block is included on the General Form, institutional endorsements are optional for the Stage 1 proposal but may be provided by separate hardcopy (to the address in Section 1.7) in those cases where the proposing institution requires them. In all cases, institutional endorsements are required for the hardcopy submission of a Stage 2 cost proposal.

The abstract on the Cover Page Form is limited to 800 characters, including spaces between words. If the abstract exceeds this length, it will automatically be truncated at 800 characters when entered into the database. The list of selected targets and corresponding abstracts will be made public once the results have been announced.

5.2.3 Target Forms

The RPS target forms must include full specification of the observing parameters for every target and for every observation of that target. In complex cases that cannot be entered on the forms, please enter a detailed description in the Remarks section of the target form and/or contact the CXC HelpDesk for advice. If any additional constraints or preferences are included in the Remarks, you must set the corresponding flag (above the Remarks) to ensure that they are implemented. **The information in the RPS forms will take precedence over any contradictory/different information described in the proposal science justification.** Information included in the science justification and not in the RPS forms will not be accepted. Additional constraints or changes to observing parameters requested after the proposal deadline will only be considered in very unusual circumstances and will require approval by the CXC Director.

PIs should ensure that information on target forms is correct. Incorrect information will jeopardize the acceptance of a proposal.

For proposals involving observations, the proposer is urged to be as accurate as possible when entering the position of the target, since even small errors can seriously reduce the quality of the data. Positions must be given in equinox/epoch J2000. Upon proposal submission, the RPS will run a crosscheck of coordinates and object names entered with the SIMBAD catalog and will notify PIs should any errors be found in this crosscheck. If there is time before the deadline, the PI should re-check the target(s) in question and, if necessary, re-submit his or her proposal (both target form and science justification) with corrected target name and coordinates. If the deadline has passed, the PI should contact the CXC, via the HelpDesk, (http://cxc.harvard.edu/helpdesk/) as soon as possible, to confirm the coordinates or make any necessary corrections. Proposers requesting more than one target, or multiple pointings at a single target, should assign a Target Number that indicates the order of priority. Prioritization will aid the Selecting Official in the event that a reduction in observing time is recommended. In such cases, every attempt will be

made to honor the highest priority targets. If a large number of targets are requested (more than 5), the email version of the RPS is the recommended method of preparing the forms.

5.2.4 Science Objectives

State clearly the scientific objectives, with relevant background and reference to previous work. Show how the proposed investigation may be used to advance our knowledge and understanding of the field. Justify the use of *Chandra* or its archival data to accomplish the objectives, in contrast to using other available observatories. If X-ray data from *Chandra*, XMM-Newton, or any other facility exists, justify the need for additional *Chandra* data to achieve the scientific objectives. To search for other data, see e.g., HEASARC Browse web page (http://heasarc.gsfc.nasa.gov/db-perl/W3Browse/w3browse.pl). Any constraint on the observations must be clearly stated and justified. Discuss the data analysis program required to attain the science goals including the scope of the effort.

5.2.5 Technical Feasibility

For all observing proposals, the proposer needs to justify the use of the *Chandra* X-ray Observatory. The proposal should show how the particular details (observing time, instrument, instrument mode, etc.) of the proposed observations allow one to achieve the stated scientific objectives. State how targets or pointing directions were selected. List of assumptions about source intensity, surface brightness, and spectrum. Estimates of both counting rates and total counts needed to accomplish the investigation must be provided. It is in the proposer's best interest to allow a reviewer to understand the assumptions and to be able to easily reproduce the estimates of the counting rate(s). The proposer should also demonstrate that the estimated counts are sufficient to extract the desired science results from the observation. The impacts of pileup on the observed energy spectrum should be addressed for observations with ACIS, HETG/ACIS, or LETG/ACIS of even moderately bright sources. Proposals for observations that might encounter pileup must explicitly discuss the plans for dealing with such data in order to demonstrate a thorough understanding of the implications for their proposed research. To maximize the scientific utility of the Chandra archive, proposers are encouraged to select for imaging the maximum number of ACIS CCDs that their core science allows. Please see the Proposers' Observatory Guide (POG, Section 6.20.2) concerning optional ACIS chips.

5.2.6 Archival Research and Theory/Modeling

Proposals that request funding for Archival Research must include a discussion of any publications that already have resulted from the observations and an indication as to how and why the proposed research will significantly extend these results. Proposals for Theory/Modeling must discuss how the proposed research will further the understanding of *Chandra* data.

Proposers interested in Archival Research should also discuss how and why the specific archival data are sufficient to meet their objective(s). Furthermore, such proposals must address the analysis tools to be used, their suitability for accomplishing the investigation, and the proposer's ability to apply such tools to the project. Archival Research and Theory/Modeling proposals should include a brief budget narrative within the science justification section.

Chapter 12 Document 2

Reynolds SP, Borkowski K, Blondin J, Badenes C, Hughes J, Hwang U, Laming M. 2005. Kepler's supernova remnant: the youngest galactic remnant of a thermonuclear explosion. Proposal submitted to Cycle 07 of the *Chandra* X-ray Observatory (CXO) Research Program. North Carolina State University, Department of Physics.

KEPLER'S SUPERNOVA REMNANT: THE YOUNGEST GALACTIC REMNANT OF A THERMONUCLEAR EXPLOSION

Proposal submitted to Cycle 07 of the *Chandra* X-ray Observatory (CXO) Research Program

DATE: 2005-03-13

Principal Investigator: Stephen P. Reynolds, North Carolina State University
Co-Investigators:
Kazimierz Borkowski, North Carolina State University
John Blondin, North Carolina State University
Carles Badenes, Rutgers University
John Hughes, Rutgers University
Una Hwang, NASA/GSFC
Martin Laming, Naval Research Laboratory

ABSTRACT

Recent work implies that Kepler's supernova remnant resulted from a Type Ia event, but circumstellar medium (CSM) interaction is also evident. Neither the progenitors nor the detailed explosion mechanisms of SNe Ia are understood, so Kepler offers us a unique opportunity to constrain the progenitor by studying CSM interactions, and the explosion mechanism by studying ejecta. We propose a 750 ks observation, to map the Fe K alpha line on spatial 5" scales, and obtain high-quality spectra in brighter regions on 8" scales. Fe K will map ejecta and discriminate thermal and nonthermal emission at rims. K lines of other alpha elements will show stratification; all should show Doppler broadening to characterize dynamics. A deep observation of Kepler should be a legacy of Chandra.

KEPLER'S SUPERNOVA REMNANT: THE YOUNGEST GALACTIC REMNANT OF A THERMONUCLEAR EXPLOSION

1 Introduction

Supernovae and supernova remnants exhibit nucleosythesis and energy deposition into the interstellar medium (ISM) in the form of photons, kinetic energy, and cosmic rays. Recently, SN Ia have achieved prominence as cosmological standard candles, even though the progenitor systems and explosion mechanism are poorly understood. As these supernovae and their remnants are crucial to the synthesis and dispersal of iron in galaxies, our ignorance is both an embarrassment and a significant impediment to understanding chemical enrichment of galaxies and to our confidence in the use of SN Ia as distance indicators. Evidence has mounted recently that Kepler's supernova remnant (1604 AD) is a Type Ia remnant, but one showing substantial interaction with circumstellar material. This property means that a complete understanding of Kepler may unlock the whole problem of the origins of Type Ia supernovae. We propose a Large Project to address this fundamental problem.

The nature of Kepler's progenitor also impacts our interpretation of apparent nonthermal X-ray emission produced by $\sim$ 100 TeV electrons (Cassam-Chenäi et al. 2004) in the outer rims. Only young remnants have the requisite high blast-wave velocities for shock acceleration to reach these energies, but this poorly understood process also depends on magnetic-field orientation, ambient density, and other properties. Unraveling these dependencies can only be done in parallel with interpreting Kepler's circumstellar interaction, but if that interpretation can be achieved, Kepler can provide powerful new information on the physics of particle acceleration in shocks. This information can be obtained from arcsecond-scale spectroscopy, uniquely possible with a sufficiently long *Chandra* observation.

1.1 SN Ia Progenitors

Kepler's high galactic latitude and high apparent iron abundance are characteristics of Type Ia events. Another, Hα emission from nonradiative shocks (Blair et al. 1991), is seen around much of the northern periphery, implying that the upstream medium there is at least partially neutral. Balmer-dominated knots also appear in the interior. But the high upstream density implied by low optical proper motions, and optical emission in radiative shocks, including slow-moving knots with enhanced N (Leibowitz & Danziger 1983), imply interaction with a dense circumstellar medium (CSM), which could arise from a core-collapse event, perhaps a runaway Type Ib progenitor (Bandiera 1987).

However, a Type Ib origin is highly problematic. It would not produce the nonradiative optical emission, while the overall X-ray spectrum resembles Type Ia objects like Tycho much more closely than core-collapse objects like Cas A. Iron lines are very prominent, both Kα and L-shell emission (Cassam-Chenäi et al. 2004). Most recently, infrared spectra (Roellig & Onaka 2004) fail to show a silicate feature around 10μm that has been seen from SN 1987A (Polomski et al. 2004) and in red-supergiant outflows. All these considerations have led us to favor a Type Ia origin. On this assumption, the clear circumstellar interaction is with mass lost either from the mass-donor companion or from a common-envelope stage of both stars, and is likely to be in the form of a disk or torus, perhaps to be associated with the band of central emission and the "ears" (Fig. 1). We attribute the strong N-S asymmetry to the same cause as did Bandiera (1987): motion through an ambient medium.

Decades of theoretical effort have still not clarified fundamental details of the SN Ia explosion mechanism, such as the mode of propagation of the burning front. Accreting white dwarfs could explode in a number of different ways: Chandrasekhar-mass C-O white dwarfs accreting from a companion could explode by detonation, deflagration, initial deflagration with a transition to detonation ("delayed detonation"), or detonation after one or several pulses; sub-

Chandrasekhar mass white dwarfs could explode following detonation of the accreted He layer or by other means; or two white dwarfs could merge ("double-degenerate" scenario) (see Hillebrandt & Niemeyer 2000 for a review). These different mechanisms should leave distinctive imprints in the structure and composition of the SN ejecta. Unfortunately, attempts to identify these imprints in the optical spectra of Type Ia SNe have been forestalled by the enormous complexity of the required radiative transport calculations. The X-ray emission from the shocked ejecta in young Type Ia SNRs like Kepler provides an entirely independent way of constraining the explosion physics.

The evolution of the pre-explosion progenitor system is also poorly understood. In the preferred scenario, the white dwarf grows in mass by accreting material from its stellar companion. In order to grow quietly, the white dwarf has to avoid nova explosions and accretion-induced collapse. Most theoretical calculations rely on the accretion wind mechanism (Hachisu et al., 1996) to stabilize the accretion rate: an optically thick wind from the white dwarf blows away the excess material into the surrounding ISM. In principle, this mass loss should modify the CSM around the progenitor and the subsequent evolution of the SNR (Badenes & Bravo 2001), but no observational evidence of this has been found yet.

In Kepler, we have the unique opportunity of examining the X-ray emitting Type Ia SN ejecta *and* the CSM interaction in the same object. The ejecta give information on the explosion mechanism, while the CSM interaction illuminates the nature of the progenitor. A detailed analysis of this SNR could provide answers to many important questions that have puzzled the community for decades.

If Kepler did result from a core-collapse supernova, it would have to have been highly anomalous, and not only for the lack of large amounts of oxygen. The large iron content already known to exist would require a very high-mass progenitor, implying among other things the synthesis of significant amounts of ^{44}Ti, which should produce detectable gamma-ray decay emission. Demonstrating that Kepler was a core-collapse remnant would be a startling result, at least as important as our proposed analysis assuming a Type Ia event interacting with circumstellar material.

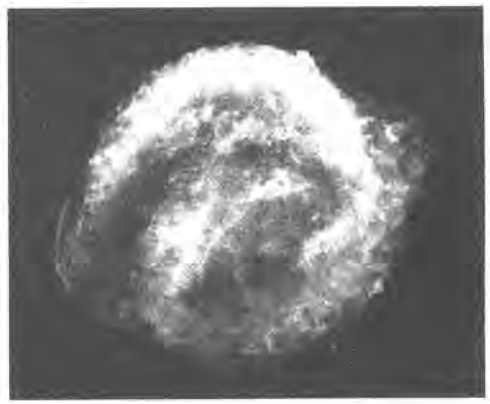


Figure 1: Kepler's SNR, *Chandra* 42 ks exposure, 0.3-10 keV. Diameter is about 200″.

1.2 Nucleosynthetic Products

The ejecta of SNe Ia are dominated by iron, with substantial amounts of α-elements Si, S, Ar, and Ca. Locating and characterizing iron emission throughout the remnant would be a major step to constraining explosion models and confirming the Ia hypothesis. Unfortunately, the data currently available (a 42 ks GTO observation plus another 50 ks Cycle 5 observation) are inadequate for this purpose. At this time the main problem is the difficulty of analyzing and interpreting emission from strongly inhomogeneous Fe-rich ejecta with data of limited spatial and/or spectral resolution. In addition, there are still serious problems with Fe L-shell atomic data. The bulk of Fe ejecta is seen through Kα emission in the remnant's interior. This more diffuse Fe has been heated to high temperatures by a fast reverse shock. Cassam-Chenaï et al. (2004) were able to image Kepler in Fe Kα at the spatial resolution of *XMM-Newton*, showing clumpy emission down to the spatial resolution limit of 15″.

Thus progress requires examination of ejecta Fe Kα emission in Kepler's interior. Analysis of good-quality CCD spectra near Fe Kα is rel-

atively straightforward because this line complex is well separated from other emission lines. One can measure the line strength and energy without reliance on uncertain modeling. Furthermore, *Chandra* can resolve the spatial structure of Fe K emission. The Fe Kα line energy provides us with crucial information about the Fe ionization state, while its strength depends on the emission measure of the X-ray emitting gas. When interpreted through both simple NEI models and more complex hydrodynamic simulations, this information alone is sufficient to determine the shocked Fe mass. Additional constraints are available if the underlying continuum also arises in the hot Fe. L-shell emission should also be produced by the hot Fe at the typical (few $\times 10^{10}$ cm^{-3} s) ionization ages found in Kepler's interior. Spatially-resolved spectroscopy involving both Fe L-shell and Kα emission will allow for discrimination between emission from the cold outer Fe clumps and the inner hot Fe.

Analysis of well-defined, non-overlapping K-shell emission from other nucleosynthetic products, particularly Si, S, Ar,and Ca, can confirm and extend what can be learned from Fe. For instance, expansion velocities are expected to be $\sim 5,000$ km s^{-1}. However, line broadening can also be due to a range of ionization conditions. Since Doppler broadening should produce the same profile in all lines, use of several K lines should allow the distinction. Sufficient spatial and spectral resolution at small scales can allow the characterization of local variations in ejecta properties. By comparing the emission from Si and Fe, for instance, it is possible to know which element was shocked first, and thus to evaluate the amount of stratification that was present in the SN ejecta, a key discriminant among explosion models (Badenes et al. 2003).

1.3 Circumstellar material

The dense circumstellar medium (CSM) required around Kepler has X-ray signatures as well. In particular, oxygen emission should distinguish CSM from ejecta, especially toward the center, where a dense torus would be most likely to lie. The dynamics of CSM interaction should provide important evidence for the nature of mass loss from the progenitor system. The conjecture that the N-S asymmetry is due to motion through ambient material predicts a variation in shock strength around the rim, which is in principle testable if CSM and ejecta emission can be separated. The nature of the progenitor system may affect the latitude dependence of the CSM density, while the donor-star mass may influence the abundances in the CSM.

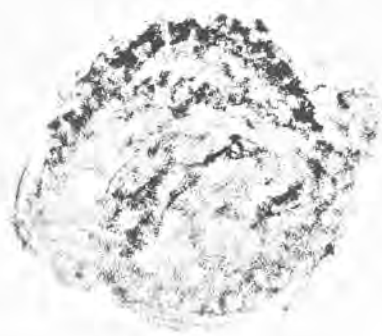


Figure 2: High-pass-filtered version of Fig.1, showing structure on scales smaller than *XMM-Newton* resolution.

1.4 Particle acceleration

Like Tycho and SN 1006, Kepler shows sharply bounded, thin rims of X-ray emission over some of its periphery. The SE quadrant of the shell has been shown in *XMM-Newton* observations to have a harder than average spectrum, possibly synchrotron in origin (Cassam-Chenaï et al. 2004). In principle, spectral analysis could distinguish thermal and synchrotron emission in the rims. Their relative importance may encode important information about the density-dependence of the mysterious mechanism of electron "injection" into the Fermi acceleration process. Furthermore, possible contributions of the reverse shock wave to electron acceleration may exist, but their discovery in the form of interior synchrotron X-rays would require very deep observations. The interpretation of any syn-

chrotron emission in terms of basic parameters such as local shock velocity and upstream density means that an understanding of shock acceleration in Kepler is tightly coupled to an understanding of the distribution of circumstellar material, that is, to the question of Kepler's progenitor.

In Kepler, most explanations for the strong brightness contrast around the shell invoke a strong density gradient (e.g., Borkowski et al. 1992). If this is the case, by studying the outermost emission at different locations around the shell, we perform an experiment with upstream density being almost the only variable. Kepler can act as a laboratory for the careful examination of electron injection and acceleration in shocks. The rim/edge emission is faint, however. As we discuss below, current observations cannot discriminate between thermal and nonthermal models for rim emission, let alone constrain parameters of shock acceleration.

2 Summary of proposed work

We propose to investigate the iron distribution, detailed dynamics, and electron acceleration processes in Kepler's SNR, using as our primary tool spatially resolved spectroscopy of very small-scale regions. Fig. 2 shows a high-pass-filtered version of Fig. 1, showing spatial structure unresolvable by *XMM-Newton*. Large amounts of clumping are present; in the N rim, this is probably due to mixing of shocked CSM and shocked ejecta, meaning that spatially-averaged spectra may be difficult to interpret and give misleading results. In addition, Fig. 2 shows plentiful coherent structures: not only the thin rims along much of the eastern and southern peripheries, but linear features flanking the SE-NW band in the interior, and cell-like structures on angular scales of $8'' - 10''$. We wish to obtain an exposure deep enough to provide significant flux in the Fe Kα line in these structures.

Our primary goal is to **map Fe K emission** on scales of order $4'' - 8''$. The analysis of this emission should allow us to conduct an **iron census** of Kepler. The small-scale analysis will also provide information on the properties of other elements that will help constrain the type of explosion: relative abundances, amount of stratification, and ionization stage all reflect the explosion mechanism.

The absence of Fe Kα emission at locations of the strongest shocks will identify synchrotron X-ray emission. We propose to analyze **thin rims** ($< 5''$ thick), where we expect to see the interaction of Kepler's outer blast wave with surrounding material. In the rims we will search for nonthermal synchrotron radiation as well as the progress of ionization as heavier elements are ionized. We hope to be able to study the density-dependence of the relative importance of these two processes, from the lowest upstream densities in the S to the highest in the N.

These data require a range of models for intelligible interpretation. One source of confusion lies in the high expansion velocities expected for Kepler. *XMM-Newton* RGS observations indicate Doppler expansion velocities at least as high as 3000 km s^{-1} (Ballet 2002). The Doppler broadening from high ($\sim 5,000$ km s^{-1}) velocities is detectable even with CCD resolution, and has perhaps been seen, in our analysis of both Cycle 1 *Chandra* data and archival *XMM-Newton* data. This amount of broadening is required to reproduce the observed width of Fe Kα line, and a similar broadening is seen in Si and S Kα lines. We used a locally created uniformly expanding shell model for these fits. High sensitivity is required to discriminate between Doppler broadening and a range of ionization states. Most spectral models currently available make various global assumptions, so we will also use more basic analysis, such as fitting directly in terms of ionic fractions with models already implemented in our local XSPEC installation. Our local spectral models are based on NEI APEC/APED data, but we have added essential inner-shell processes.

It is not enough just to compile maps of ionization timescale and abundances of elements, useful though that may be. Integrating this information into a coherent picture will require the use of hydrodynamic simulations. An example of a 3-D simulation of a blast wave encountering first a torus and then a shell with a substantial

Figure 3: Hydrodynamic simulation of blast wave encountering torus and asymmetric shell.

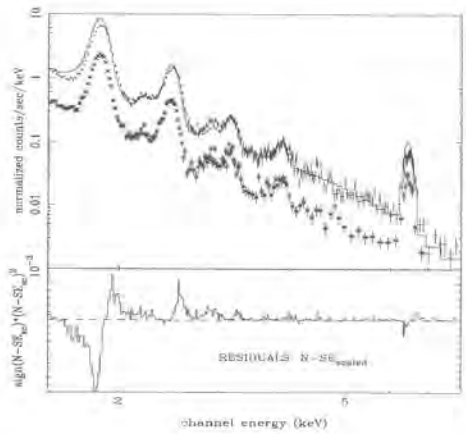


Figure 4: Spectra from SE (lower) and N (upper) regions. Solid line: model fit to SE shifted upward to emphasize obvious spectral differences. Note characteristic patterns in the residuals.

density gradient is shown in Fig. 3. Such simulations generate predicted distributions of temperature and ionization timescale which can be compared with our results. More detailed NEI spectral predictions can also be generated, along the lines of those performed in 1-D for different SN Ia progenitors by Badenes et al. (2003).

3 Technical feasibility

At this time a high-spatial-resolution study of Fe Kα emission in Kepler is not possible. *XMM-Newton's* spatial resolution is inadequate, while the existing 42 ks *Chandra* observation is compromised by poor photon statistics. There are just 5 counts on average per $8'' \times 8''$ bin in that image, implying an extremely poor S/N at this spatial resolution. Only 15% of bins have 10 or more counts. Even with the addition of the second 50 ksec *Chandra* observation (PI L. Rudnick), a high spatial resolution mapping of hot Fe is not possible. **In order to map hot Fe, we need a much longer exposure.**

The required exposure depends on the minimum acceptable spatial resolution. Complete resolution of all spatial structures is not possible, but we need at least to resolve the hot shocked Fe ejecta layer, so we turn for guidance to theoretical models. The thickness of shocked ejecta in models of young SNRs is about 10% of the remnant's radius on average in the hydrodynamical simulations of Chevalier, Blondin, & Emmering (1992). It is highly desirable to have at least two resolution elements per shocked ejecta thickness for imaging, and at least 1 resolution element for spectroscopy of the Fe Kα line. The N-S diameter of Kepler is about $200''$, resulting in an expected shocked ejecta thickness of $\sim 10''$.

A 750 ksec exposure with the ACIS S3 chip will provide us with 90 counts on average per $8'' \times 8''$ bin, which is sufficient for the spectral analysis of the Fe Kα line. About 20 counts per $4'' \times 4''$ resolution element will be available, which will allow imaging at this spatial resolution. We show in Figure 4 spectra from two regions with pronounced differences in their ejecta emission. All Kα complexes in a large interior Fe-rich region in SE are shifted to lower energies compared with emission from the N. There are also systematic differences in widths of Si and S lines. Doppler shifts and broadening due to gas motions and ionization effects may be responsible for these differences; this is still under investigation. Let us assume ionization effects as the origin of these differences for the following dis-

cussion, although a large observed Fe L/K ratio in the interior may favor bulk Doppler motions. We fit a simple combination of vnei and vpshock models to both spectra with pure Si, S, Ar, Ca, and Fe ejecta (plus additional bremsstrahlung models to account for excess continuum emission). We find that Doppler broadening is necessary for Fe Kα in both spectra, and for Si and S Kα lines in the N. We then used our fit to the SE spectrum to simulate emission from an interior $8'' \times 8''$ bin, using Cycle 7 ACIS S3 response files. The SE simulation has $kT = 5$ keV, an ionization timescale of 3.3×10^9 cm^{-3} s, and an expansion velocity of 4712 km s^{-1} for Fe Kα; and $kT = 2$ keV and an ionization timescale of 1.8×10^{10} cm^{-3} s for Si, S, Ca, and Ar. We show below we can recover these numbers and distinguish them from fits to the N region.

We expect about 112 counts in the Fe Kα line in a bin of this size. Fitting the simulated spectrum recovers an Fe ionization age of 5.3×10^9 ($0 - 9.5 \times 10^9$ 90%) cm^{-3} s, consistent with a lower than average Fe Kα centroid of 6.42 keV in the SE spectrum. (The Fe Kα centroid in the N is equal to 6.45 keV, corresponding to an ionization timescale of 1.7×10^{10} cm^{-3} s, that is, distinguishably different.) We find a shell expansion velocity of 4815 km s^{-1}. Errors on the expansion velocity are of course large (2600–5900 km s^{-1}) with just 110 counts. But we will distinguish between the N and SE Fe Kα spectra of Figure 4 with this number of counts. For Si, S, Ca, and Ar, we obtain ionization timescales of 2.0×10^{10} ($1.8 - 2.2 \times 10^{10}$) cm^{-3} s. A fit to the N spectrum gives an ionization timescale of Si- and S-rich gas of 3.5×10^{10} cm^{-3} s, so again we will distinguish between spectra of Figure 4 on $8''$ scales with the proposed observations. We will be able to measure relatively weak lines of Ca and Ar with these spectra; when expressed in terms of model abundances (relative to solar), we obtain 2.0 (1.5–2.5) and 4.2 (2.6–5.8) (vs. model 2.4 and 5.0), respectively. When this heavy-element-rich model is plotted over the entire photon energy range, strong Fe L-shell emission is evident at low energies. While we have not attempted broadband fitting because of problems with Fe L-shell atomic data, the presence of both Fe L-shell and Kα emission provides important constraints on the electron temperature and ionization timescale of the hot Fe (a lower limit to the electron temperature can be derived from the observed Fe L/K ratio, while the L-shell centroid is sensitive to ionization age). We can then model heavy-element plasma in Kepler's interior using both relatively simple models with heavy elements and sophisticated X-ray emission calculations based on hydrodynamical simulations of realistic SNR models.

A 750 ks exposure also results in the ability to discriminate thermal from nonthermal emission in thin rims. Simulations based on a thermal (plane shock) fit in which absence of lines near 1 keV results from low ionization timescale ($\tau \sim 10^8$ cm^{-3} s) predict of order 100 counts in Fe Kα, easily distinguishable from a synchrotron fit in 750 ks, but not in the Cycle 1 data.

Our team includes the range of expertise required for an intensive analysis: Type Ia theory (Badenes), hydrodynamic simulations (Blondin), atomic physics (Laming, Borkowski), X-ray observations (Hwang, Hughes), and nonthermal emission (Reynolds), with all parties having some experience with X-ray data analysis. However, all of our efforts could not extract all the value of deep observation of Kepler in one year, so we propose to waive the proprietary period. Such an observation would be of great interest to the entire SNR community and beyond, and should be an essential legacy of *Chandra*.

4 References

Badenes, C., & Bravo, E. 2001, ApJ, 556, L41

Badenes, C., et al. 2003, ApJ, 593, 358

Ballet, J. 2002, in High Resolution X-ray Spectroscopy with *XMM-Newton* and *Chandra* (London)

Bandiera, R. 1987, ApJ, 319, 885

Blair, W.P., et al. 1991, ApJ, 366, 484

Borkowski, K.J., et al. 1992, ApJ, 400, 222

Cassam-Chenaï et al. 2004, AA, 414, 545

Chevalier, R.A., et al. 1992, ApJ, 392, 118

Hachisu, I., et al. 1996, ApJ, 470, L97

Leibowitz, E.M., & Danziger, I.J. 1983, MNRAS, 204, 273

Polomski, E., et al. 2004, BAAS, 36, 1466

Roellig, T.L., & Onaka, T. 2004, BAAS, 36, 1520

Previous *Chandra* Observations
Stephen P. Reynolds

Cycle 1:

1. SN 1006 and the Physics of Shocks. I. NE nonthermal limb. (K.S. Long, PI)

Cycle 2:

1. SN 1006 and the Physics of Shocks. II. NW thermal limb. (K.S. Long, PI)
   - Long, K.S., Reynolds, S.P., Raymond, J.C., Winkler, P.F., Dyer, K.K., & Petre, R. "Chandra CCD Imagery of the Northeast and Northwest Limbs of SN 1006." 2003, ApJ, 586, 1162–1178.
2. Thermal and Nonthermal X-ray Emission in the Supernova Remnant RCW 86 (S.P. Reynolds, PI)
   - Rho, J., Dyer, K.K., Borkowski, K., & Reynolds, S.P. "X-Ray Synchrotron-emitting Fe-rich Ejecta in Supernova Remnant RCW 86." 2002, ApJ, 581, 1116–1131.
3. High-Resolution X-ray Imaging of SNR 3C 396 (S.P. Reynolds, PI)
   - Olbert, C.M., Keohane, J.W., Arnaud, K.A., Dyer, K.K., Reynolds, S.P., & Safi-Harb, S. "Chandra Detection of a Pulsar Wind Nebula Associated with the Supernova Remnant 3C 396." 2003, ApJ, 592, L45–L48.
4. Mature Supernova Remnants in the Large Magellanic Clouds (K.J. Borkowski, PI)
   - Hendrick, S.P., Borkowski, K.J., & Reynolds, S.P. "Ejecta Detection in Middle-Aged Large Magellanic Cloud Supernova Remnants 0548-70.4 and 0534-69.9." 2003, ApJ, 593, 370–376.
   - Gaensler, B.M., Hendrick, S.P., Reynolds, S.P., & Borkowski, K.J. "Discovery of a New Pulsar Wind Nebula in the Large Magellanic Cloud." 2003, ApJ, 594, L111–L114.

Cycle 4:

1. Moderately-Sized, Middle-Aged Supernova Remnants in the Magellanic Clouds: An Unexplored Population (K.J. Borkowski, PI)

Cycle 6:

1. G15.9+0.2: A Missing Young Galactic Supernova Remnant? (not yet observed)
2. The Oxygen-Rich SNR N132D: Ejecta Detection and Chemical Abundances (K.J. Borkowski, PI) (not yet observed)
3. Type Ia SNRs in the Large Magellanic Cloud: an Analysis of Archival Data (archival proposal) (K.J. Borkowski, PI)
4. Spatial Structure of Supernova Ejecta in Cassiopeia A NASA (archival proposal) (K.J. Borkowski, PI)

Chapter 12 Document 3

Reynolds SP, Borkowski KJ, Badenes C, Hughes JP, Hwang U, Laming JM, Blondin, JM [conference abstract]. 2007a. A deep Chandra observation of Kepler's supernova remnant: a type IA supernova with circumstellar interaction. Conference abstract. 2007 Joint Meeting of the American Astronomical Society and the American Association of Physics Teachers.

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Chapter 12 Document 4

Roy S, Watzke M. 2007 Jan 9. Press release: A star's death comes to light. NASA [Internet]. Available from: http://www.nasa.gov/centers/marshall/news/news/releases/2007/07-004_prt.htm.

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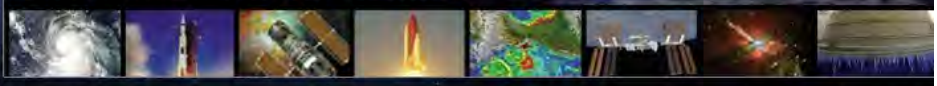
Marshall Space Flight Center



News Releases

Text Size

A Star's Death Comes to Light

01.09.07

Steve Roy
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Chandra X-ray Center, Cambridge, Mass.
(Phone: 617.496.7998)

News release: 07-004

Using NASA's Chandra X-ray Observatory, scientists have created a stunning new image of one of the youngest supernova remnants in the galaxy. This new view of the debris of an exploded star helps astronomers solve a long-standing mystery, with implications for understanding how a star's life can end catastrophically and for gauging the expansion of the universe.

Over 400 years ago, sky watchers -- including the famous astronomer Johannes Kepler -- noticed a bright new object in the night sky. Since the telescope had not yet been invented, only the unaided eye could be used to watch as a new star that was initially brighter than Jupiter dimmed over the following weeks.

Chandra's latest image marks a new phase in understanding the object now known as Kepler's supernova remnant. By combining nearly nine days of Chandra observations, astronomers have generated an X-ray image with unprecedented detail of one of the brightest recorded supernovas in the Milky Way galaxy.

The explosion of the star that created the Kepler remnant blasted the stellar remains into space, heating the gases to millions of degrees and generating highly energized particles. Copious X-ray light, like that shining from many supernova remnants, was produced.

Astronomers have studied Kepler intensively over the past three decades with radio, optical and X-ray telescopes, but its origin has remained a puzzle. On the one hand, the presence of large amounts of iron and the absence of a detectable neutron star points toward a so-called Type Ia supernova. These events occur when a white dwarf star pulls material from an orbiting companion until the white dwarf becomes unstable and is destroyed by a thermonuclear explosion

Continued on next page

Chapter 12 Document 4 continued

On the other hand, when viewed in optical light, the supernova remnant appears to be expanding into dense material that is rich in nitrogen. This would suggest Kepler belongs to a different type of supernova (known as "Type II") that is created from the collapse of a single massive star that sheds material before exploding. Type Ia supernovas do not normally have such surroundings.

A team of astronomers, led by Stephen Reynolds of North Carolina State University in Raleigh, N.C., was able to use the Chandra dataset to address this mystery. By comparing the relative amounts of oxygen and iron atoms in the supernova, the scientists were able to determine that Kepler resulted from a Type Ia supernova.

In solving the mystery of Kepler's identity, Reynolds and his team have also given an explanation for the dense material in the remnant. Kepler could be the nearest example of a relatively rare "prompt" Type Ia explosion, which occur in more massive progenitors only about 100 million years after the star formed rather than several billion years.

If that is the case, Kepler could teach astronomers more about all Type Ia supernovas and the ways in which prompt explosions from massive stars differ from their more common cousins associated with lower mass stars.

This information is essential to improve the reliability of the use of Type Ia stars as "standard candles" for cosmological studies of dark energy as well as to understand their role as the source of most of the iron in the universe.

In the new Chandra Kepler image, red represents low-energy X-rays and shows material around the star -- dominated by oxygen -- that has been heated up by a blast wave from the star's explosion. The yellow color shows slightly higher energy X-rays, mostly iron formed in the supernova, while green (medium-energy X-rays) shows other elements from the exploded star. The blue color represents the highest energy X-rays and shows a shock front generated by the explosion.

NASA's Marshall Space Flight Center, Huntsville, Ala., manages the Chandra program for the agency's Science Mission Directorate. The Smithsonian Astrophysical Observatory controls science and flight operations from the Chandra X-ray Center, Cambridge, Mass.

Additional information and images are available at:

http://chandra.harvard.edu

and

http://chandra.nasa.gov

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Roy S, Watzke M. 2007 Jan 9. Press release: A star's death comes to light. NASA [Internet]. Available from: http://www.nasa.gov/centers/marshall/news/news/releases/2007/07-004_prt.htm.

Chapter 12 Document 5

Cowen R. 2007 Jan 27. Solving a 400-year-old supernova riddle. Science News Online [Internet]. [cited 2008 Jun 14]. Available from: http://www.sciencenews.org/view/generic/id/8166.

Document removed due to copyright restrictions.

Chapter 12 Document 6

Naeye R. 2007 Apr. Kepler saw a white dwarf explode. Sky & Telescope 113(4): 15.

Document removed due to copyright restrictions.

Chapter 12 Document 7

Reynolds SP, Borkowski KJ, Badenes C, Hughes JP, Hwang U, Laming JM, Blondin, JM. 2007b. A deep Chandra observation of Kepler's supernova remnant: a type IA supernova with circumstellar interaction. The Astrophysical Journal: 668: L135–L138.

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CHAPTER

13

Research on Katrina's Carbon Footprint: From Science to Public Debate

NOTE for 3e OPEN ACCESS: Many of the documents described below have been removed from the open access version due to copyright restrictions. We encourage you to access these articles from their original publishers via your university library and/or to locate more recent publications to expand this research case.

Research on global climate change offers an ideal opportunity to examine the influence of public knowledge and political context on the interpretation of science. Popular understanding of and attitudes toward global climate change are intimately intertwined with current political discourse on this issue. Public discussion of global warming has long been characterized by disagreement: within and between governmental agencies, between presidential administrations and environmental advocacy groups, among political and social commentators, even at times within segments of the scientific community itself. How we understand the science determines what actions we think are necessary on the part of government, industry, and individuals, and the costs of such actions are clearly quite high. Scientists have found themselves playing various roles in this controversy, including educator, advocate, spokesperson, whistle-blower—in addition, of course, to their roles as researchers.

In this case we look at a scientific study, at some of the ways in which the findings were reported in the public domain, and at a sampling of the surrounding public conversation. We begin with a 2008 call for proposals from DOE's National Institute for Climatic Change Research (NICCR, pronounced "nicer"). The NICCR Coastal Center, hosted by Tulane University, "funds basic research that aims at reducing scientific uncertainty about the response of coastal ecosystems to changes in climate and sea level during the next 50–100 years" (NICCR 2007). Tulane ecologist Jeffrey Chambers and co-investigator George Hurtt of the University of New Hampshire received funding in 2006 to study the impact of hurricanes on forest ecosystems and the regional carbon sink. Their project summary is included here. Their later finding—that extensive forest loss in the wake of Hurricanes Katrina and Rita may exacerbate carbon build-up in the atmosphere—created a bit of a stir when it appeared in *Science* in November 2007. This one-page "brevia" article is included here, along with a feature story from NASA's website about the role of NASA's Landsat 5 satellite in providing data for the study.

Next we've included an example of the popular press coverage of this finding, a 2007 story in the *Washington Post*. Chambers' research also was featured on National Public Radio's *All Things Considered* as part of their Climate Connections series; this story can be accessed via Resource #1 below. The final documents in this chapter provide some broader context. We've included the Advanced Online Publication (AOP) abstract of the *Nature Geoscience* study that challenges the popular idea that global warming is responsible for heightened hurricane activity—a piece that also received some attention in the press—and lastly, a *New York Times* report exploring a range of positions in the climate change debate.

Additional Resources

1. National Public Radio's Climate Connections Series Website (NPR 2008)
   http://www.npr.org/templates/story/story.php?storyId=9657621&ft=1&f=9657621

   For coverage of Chambers' research (Shogren 2008), see
   http://www.npr.org/templates/story/story.php?storyId=17814049

2. Educational Video on Katrina's Wake from NASA (Frostic M 2008)
   http://learners.gsfc.nasa.gov/mediaviewer/KATRINA/
   Note for Open Access version: This video now available at https://youtu.be/HZjqvqaLltI.

3. Multimedia Resources for Educators on Atlantic Hurricanes from NASA (NASA 2008a)
   http://www.nasa.gov/mission_pages/hurricanes/multimedia/AtlanticHurricanesWithJeff.html

4. Online Resource for Communicating Science with the Public American Association for the Advancement of Science (AAAS 2008c)
   http://communicatingscience.aaas.org/Pages/newmain.aspx

5. Interview with Dr. John P. Holdren on the topic of climate change. *The Late Show with David Letterman* (Holdren 2008)
   http://www.cbs.com/latenight/lateshow/video_player/index/php/953125.phtml
   Note for Open Access version: For AAAS coverage of this interview, see
   https://www.sciencemag.org/news/2009/09/holdren-gets-warm-embrace-letterman-climate-policies.

Chapter 13 Document 1

[NICCR] US Department of Energy National Institute for Climatic Change Research [Internet]. [posted 2008 Feb 28]. Request for proposals notice RFP-04. [cited 2008 Aug 17]. Available from: http://www.tulane.edu/%7ENICCR/rfps.html.

DOE National Institute for Climatic Change Research (NICCR)

Notice RFP-04

Summary

The U.S. Department of Energy (DOE) National Institute for Climatic Change Research (NICCR) hereby announces its request for research proposals. Proposed research is requested that would answer important questions about potential effects of contemporary climatic change on the structure and functioning of important U.S. terrestrial ecosystems, or that would answer important questions about possible feedbacks from terrestrial ecosystems to changes in climate or atmospheric composition.

This request for proposals is to either (1) renew ongoing NICCR research projects for one or two years or (2) carry out new research projects for one or two years. The question(s) proposed by investigators should be answerable within the one- or two-year proposed project period.

NICCR divides terrestrial ecosystems into two groups: inland (not adjacent to an ocean) and coastal (adjacent to an ocean, including barrier islands).

For inland terrestrial ecosystems, the main climatic changes of interest are changes in temperature and precipitation. Research should: (1) answer important questions about potential effects of climatic change on the structure and functioning of terrestrial ecosystems within the 50 states or District of Columbia; (2) evaluate or improve the understanding and prediction of potential effects of climatic change on the future geographic distribution of U.S. terrestrial ecosystems at the regional scale; (3) use measurements of contemporary exchanges of mass and energy between the atmosphere and terrestrial ecosystems to answer important questions about possible effects of an altered terrestrial carbon cycle and/or surface energy exchange on global and/or regional climate; or (4) use synthesis of existing experimental or observational data, or modeling, to answer important questions about potential effects of climatic change on U.S. ecological systems and/or feedbacks from U.S. terrestrial ecosystems to climate at the regional scale. Proposals for research on inland ecosystems should be submitted to one of the four NICCR Regional Centers.

For coastal ecosystems, the climatic changes of interest are sea-level rise and the possibility of increased frequency and/or intensity of storms (including hurricanes) directly affecting U.S. coastal ecosystems. Ecosystems to be studied will be the terrestrial ecosystems (including wetland and freshwater ecosystems, but not marine or estuarine ecosystems) in the coastal states that could be directly and significantly altered by sea-level rise or increased frequency or intensity of coastal storms. The ecological endpoints of interest are ecosystem or species migrations, changes in biodiversity, changes in primary production, or alterations in goods and services uniquely supplied by coastal terrestrial ecosystems. Proposals for research on coastal ecosystems should be submitted to the NICCR Coastal Center.

....

DOE National Institute for Climatic Change Research, February 28, 2008 [Excerpts]

Background

The purpose of NICCR is to mobilize university scientists, from all regions of the country, in support of the research goals of DOE's Climate Change Research Division (in the DOE Office of Science's Office of Biological and Environmental Research). Information about the Division's research goals is at http://www.sc.doe.gov/ober/CCRD_top.html.

The NICCR national web site is at http://nicc.nau.edu. Web sites maintained by the NICCR Centers are linked to the national web site. Current NICCR research projects are described at these sites.

Request for Proposals

This notice solicits proposals to conduct research related to effects of climatic changes on terrestrial ecosystems and potential feedbacks from terrestrial ecosystems to climatic change. Proposals should state clearly how the proposed research will fill important knowledge gaps that hinder regional-scale or national-scale forecasts of effects of climatic change on important ecosystems or feedbacks from ecosystems to climatic change. Proposals should state why the ecosystems to be studied are important. Criteria that could be considered are areal extent, primary production relative to total production in the region, habitat for threatened and endangered species, or ecosystem characteristics that would allow extrapolation of results to large areas or many ecosystem types.

It is expected that most projects supported by NICCR will be for individual investigators or small research teams (single institutions), but coordinated, multi-institutional (collaborative) projects will be considered for funding (see Collaborative Projects section). The purpose of considering collaborative projects is to allow science questions to be addressed that cannot be readily addressed with traditional single-investigator research projects, and to encourage synthesis activities that are integrated into observational or experimental studies at the regional scale; *collaborative proposals should clearly state how their collaborative nature will satisfy these objectives.* Proposals for Collaborative Projects must present either evidence of past collaborative success, or a clear plan that will facilitate successful project integration.

. . . .

All Research Foci (Foci 1-5): All proposals should briefly and clearly describe tangible outcomes (products or deliverables) of the proposed activities, including a timetable of those outcomes. It is expected that all data and analyses (including model codes) obtained and developed with NICCR support will be made available to the public in a timely manner. Each proposal must *briefly* state how and when the data and analyses (including model codes) will be made publicly available and must include sufficient resources to provide this access. For example, data collected, databases synthesized, and/or codes developed might be posted to a public web site within 12 months of collection (for data) or development (for syntheses conducted and codes developed). Public access will not circumvent the rights of investigators to publish their work and/or receive proper acknowledgement for use of their research products. Established data and metadata formats should be used when they exist.

Chapter 13 Document 2

Chambers JQ, Hurtt G. 2006. Hurricane impacts on structure and functioning of southeastern forests. NICCR Project Summary.

ABSTRACT

Hurricane Impacts on Structure and Functioning of Southeastern Forests

Principal Investigator: *Jeffrey Q. Chambers*, Tulane University, Ecology and Evolutionary Biology, New Orleans LA, chambers@tulane.edu, 504-862-8291

Co-Investigator: *George Hurtt*, University of New Hampshire, Institute for the Study of Earth Oceans and Space, Durham NH, george.hurtt@unh.edu

The primary goals of this project are to: (***i***) Develop empirical relationships between wind-field parameters and species-specific tree mortality rates for Major (Saffir-Simpson Category 3-5) hurricanes striking the Southeastern Region, (***ii***) Modify an ecosystem simulation model (Ecosystem Demography – ED) to allow simulation of catastrophic hurricane-driven tree mortality dynamics; (***iii***) Develop a set of hurricane scenarios based on historical records and possible future trends driven by natural cycles and anthropogenic climate change, and employ ED to predict forest carbon balance impacts from these scenarios; and (***iv***) Utilize hurricane events that are likely to strike the Southeastern Region during the course of this study to further expand and test empirical relationships and model predictions.

Research activities will be conducted in the NICCR Southeastern Region, and initially focus on hurricane Katrina. Tulane University's location in New Orleans is uniquely suited to facilitate local hurricane impacts studies. During the hurricane season of 2006 and 2007, priority will be given to carry out field investigations on new Major hurricanes that strike in Louisiana, Mississippi, Alabama, East Texas and the pan-handle of Florida. Second priority will be given to Georgia, South Carolina, and North Carolina.

The overall working hypothesis is that disturbance related to hurricane activity in the Southeastern Region has significant negative impacts on forest carbon balance and the regional carbon sink, and that expected future changes in the hurricane disturbance regime will further degrade the Southeastern Region carbon sink.

This project will employ a synthetic approach combining field-based tree mortality and damage investigations, remote sensing image analyses, and an ecosystem simulation model. Forest inventory analysis methods will be employed to estimate biomass loss from damage and tree mortality. Spatial variability in mortality rates will be correlated to hurricane wind-field parameters using regression methods. Remote sensing investigations using spectral mixture analysis on non-photosynthetic vegetation endmembers will provide maps of disturbance variability within wind-field classes, and allow further development of tree mortality probability distribution functions. A modified ED model will allow integration of results, and be used to explore historical and future hurricane scenarios on Southeastern Region forest carbon balance.

Expected deliverables include: (***i***) A network of forest inventory plots for Major hurricanes striking the Southeastern Region. (***ii***) Atmospherically corrected remote sensing images (e.g. ALI, Hyperion, Landsat) and relative abundance maps of disturbed areas within footprints of Major hurricanes. (***iii***) A modified ED model allowing simulation of past hurricane events and future scenarios.

Chapter 13 Document 3

Chambers JQ, Fisher JI, Zeng H, Chapman EL, Baker DB, Hurtt GC. 2007. Hurricane Katrina's carbon footprint on U.S. Gulf Coast forests. Science 318:1107.

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Chapter 13 Document 4

Cook-Anderson G. 2007 Nov 15. Forests damaged by hurricane Katrina become major carbon source. NASA [Internet]. Available from: http://www.nasa.gov/mission_pages/hurricanes/archives/2007/katrina_carbon.html.

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Hurricanes/Tropical Cyclones

Latest Storm Images and Data From NASA

Feature

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Forests Damaged by Hurricane Katrina Become Major Carbon Source

11.15.07

With the help of NASA satellite data, a research team has estimated that Hurricane Katrina killed or severely damaged 320 million large trees in Gulf Coast forests, which weakened the role the forests play in storing carbon from the atmosphere. The damage has led to these forests releasing large quantities of carbon dioxide into the atmosphere.

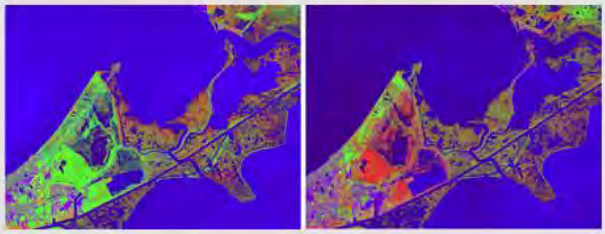

Image above: The devastation of southern Gulf Coast forests by Hurricane Katrina was documented in before-and-after images from the Landsat 5 satellite. The Interstate 10 "twin-span" bridges that cross Lake Pontchartrain east of New Orleans is seen here pre- and post-Katrina. Bayou Sauvage National Wildlife Refuge is the large patch of forest (green) the lower left portion of the LEFT image, which suffered heavy tree mortality (seen in red in the RIGHT image after the storm)". + Larger before image + Larger after image Credit: USGS

+ Click for Web Short entitled, "In Katrina's Wake"

The August 2005 hurricane affected five million acres of forest across Mississippi, Louisiana and Alabama, with damage ranging from downed trees, snapped trunks and broken limbs to stripped leaves.

Young growing forests play a vital role in removing carbon dioxide, a greenhouse gas, from the atmosphere by photosynthesis, and are thus important in slowing a warming climate. An event that kills a great number of trees can temporarily reduce photosynthesis, the process by which carbon is stored in plants. More importantly, all the dead wood will be consumed by decomposers, resulting in a large carbon dioxide release to the atmosphere as the ecosystem exhales it as forest waste product. The team's findings were published Nov. 15 in the journal Science.

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Cook-Anderson G. 2007 Nov 15. Forests damaged by hurricane Katrina become major carbon source. NASA [Internet]. Available from: http://www.nasa.gov/mission_pages/hurricanes/archives/2007/katrina_carbon.html.

Image left: Hurricane Katrina was closing in on the Mississippi-Louisiana coastline and the adjacent Gulf Coast forests on Aug. 28, 2005, as glimpsed by a state-of-the-art instrument aboard NASA's Terra satellite. + Higher resolution image Credit: NASA

"The loss of so many trees will cause these forests to be a net source of carbon dioxide to the atmosphere for years to come," said the study's lead author Jeffrey Chambers, a biologist at Tulane University in New Orleans, La. "If, as many believe, a warming climate causes a rise in the intensity of extreme events like Hurricane Katrina, we're likely to see an increase in tree mortality, resulting in an elevated release of carbon by impacted forest ecosystems."

Young forests are valued as carbon sinks, which remove carbon dioxide from the atmosphere and store it in growing vegetation and soils. In the aftermath of a storm as intense as Katrina, vegetation killed by the storm decomposes over time, reversing the carbon storage process, making the forest a carbon source.

"The carbon cycle is intimately linked to just about everything we do, from energy use to food and timber production and consumption," said Chambers. "As more and more carbon is released to the atmosphere by human activities, the climate warms, triggering an intensification of the global water cycle that produces more powerful storms, leading to destruction of more trees, which then act to amplify climate warming."

Image right: Damaged forests in the Pearl River Basin along the Louisiana-Mississippi border were photographed from the air in late 2005. Resistant cypress and tupelo trees surround downed and dead hardwood forest trees such as oak, sweetgum and maple. + Larger imageCredit: Louisiana State University Hurricane Katrina & Rita Cooperative Clearinghouse

Chambers and colleagues from the University of New Hampshire in Durham, N.H., studied Landsat 5 satellite data captured before and after Hurricane Katrina to pull together a reliable field sampling of tree deaths across the entire range of forests affected by Katrina. They found that some forests were heavily damaged while others like the cypress-tupelo swamp forests fared remarkably well.

The NASA-built Landsat 5, part of the Landsat series of Earth-observing satellites, takes detailed images of the Earth's surface. Chambers combined results from the Landsat image sampling with data from the Moderate Resolution Imaging Spectroradiometer instrument on NASA's Terra satellite to estimate the size of the entire forested area affected by Katrina. The instrument can detect minute changes in the color spectrum on the land below, enabling it to measure differences in the percentage of live and dead vegetation. This helps researchers improve their estimates of changes in carbon storage and improves their ability to track the location of carbon sinks and sources.

Continued next page

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Cook-Anderson G. 2007 Nov 15. Forests damaged by hurricane Katrina become major carbon source. NASA [Internet]. Available from: http://www.nasa.gov/mission_pages/hurricanes/archives/2007/katrina_carbon.html.

The field samples and satellite images, along with results from computer models that simulate the kind of vegetation and other traits that make up the forests, were used to measure the total tree loss the hurricane inflicted. The scientists then calculated total carbon losses to be equivalent to 60-100 percent of the net annual carbon sink in U.S. forest trees. "It is surprising to learn that one extreme event can release nearly as much carbon to the atmosphere as all U.S. forests can store in an average year," said Diane Wickland, manager of the Terrestrial Ecology Program at NASA Headquarters in Washington. "Satellite data enabled Chambers' research team to pin down the extent of tree damage so that we now know how these kinds of severe storms affect the carbon cycle and our atmosphere. Satellite technology has really proven its worth in helping researchers like Chambers assess important changes in our planet's carbon cycle."

Related Link:

+ Carbon cycle info

Gretchen Cook-Anderson
Goddard Space Flight Center

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Cook-Anderson G. 2007 Nov 15. Forests damaged by hurricane Katrina become major carbon source. NASA [Internet]. Available from: http://www.nasa.gov/mission_pages/hurricanes/archives/2007/katrina_carbon.html.

Chapter 13 Document 5

Kaufman M. 2007 Nov 16. Katrina, Rita caused forestry disaster. Washington Post [Internet]. [cited 2008 Jul 19]. Available from: http://www.washingtonpost.com/wp-dyn/content/article/2007/11/15/AR2007111501359_pf.html.

Document removed due to copyright restrictions.

Chapter 13 Document 6

Knutson TR, Sirutis JJ, Garner ST, Vecchi GA, Held IM. 2008 May 18. Simulated reduction in Atlantic hurricane frequency under twenty-first century warming conditions. [Internet; letter abstract]. Nature Geoscience. [cited 2008 Jun 11]. Available from: http://www.nature.com/ ngeo/journal/v1/n6/abs/ngeo202.html.

Document removed due to copyright restrictions.

Chapter 13 Document 7

Revkin AC. 2007 January 1. A new middle stance emerges in debate over climate. New York Times [Internet].

Document removed due to copyright restrictions.

References

[AAAS] American Association for the Advancement of Science [Internet]. Summer 2000. Professional ethics report XIII. [cited 2000 Dec 11]. Available from: http://www.aaas.org/spp/dspp/sfrl/per/per22.htm.

[AAAS] American Association for the Advancement of Science [Internet]. 2008a. About us. [cited 2008 Jun 24]. Available from: http://www.eurekalert.org/aboutus.php.

[AAAS] American Association for the Advancement of Science [Internet]. 2008b. Science: General information for authors/Database deposition policy. [cited 2008 Jun 28]. Available from: http://www.sciencemag.org/about/authors/prep/gen_info.dtl#conditions.

[AAAS] American Association for the Advancement of Science [Internet]. 2008c. Communicating Science: Tools for Scientists and Engineers. [cited 2008 May 19]. Available from: http://communicatingscience.aaas.org/Pages/newmain.aspx.

[AAAS] American Association for the Advancement of Science 2008d. AAAS CEO Alan I. Leshner calls for global science enterprise, science diplomacy. News Archives [Internet]. [cited 2008 Sep 03]. Available from: http://www.aaas.org/news/ releases/2008/0729leshner_testimony_intro.shtml.

[AAS] American Astronomical Society [Internet]. 2008a. Homepage; Public Policy; Council Resolutions. [cited 2008 Jun 18]. Available from: http://www.aas.org.

[AAS] American Astronomical Society [Internet]. 2008b. AAS Abstracts: Presentation of Papers/Poster Presentations. [cited 2008 Sep 7]. Available from: http://www.aas.org/meetings/aas209/.

Abbott A. 1996. Scientists lose cold fusion libel case. Nature 380:369.

[ACS] American Chemical Society [Internet]. 2006. ACS journal editor's policy on preprints. Chemical and Engineering News. [cited 2008 Jun 21]. Available from: http://pubs.acs.org/cen/preprint.html.

[ACS] American Cancer Society [Internet]. 2008. Sharing hope.tv. [cited 2008 Dec 15] Available from: www.sharinghope.tv.

Adams JL. 1976. Conceptual blockbusting: a pleasurable guide to better problem solving. New York: W. W. Norton.

[AIP] American Institute of Physics [Internet]. 1990. AIP style manual. 4th ed. New York: American Institute of Physics. [cited 2008 Jul 07]. Available from: http://www.aip.org/pubservs/style/4thed/toc.html.

Alimenterics. Pylori-Chek Breath Test Kit. FDA 1999 Feb 4. Morris Plains (NJ): Alimenterics Inc.

Amato I. 1993. Pons and Fleischmann redux? Science 260: 895.

American Institute for Biological Science [Internet]. 2008. Online social networking. [cited 2008 Jun 16]. Available from: http://www.aibs.org/online-social-networking/.

American Public Health Association [Internet]. 2008. Accessibility. [cited 2008 Sep 03]. Available from: http://www.apha.org/meetings/access.

Analytical Chemistry [Internet]. 2007. Author's Guide to Analytical Chemistry. [updated 2007 Nov 13; cited 2008 Jul 13]. Available from: http://pubs.acs.org/.paragonplus/submission/ ancham/index.html.

Anderson M 2007. Cold-fusion graybeards keep the research coming. Wired Magazine [Internet]. [cited 2008 May 25]. Available from: http://www.wired.com/science/ discoveries/news/2007/08/cold_fusion.

Angell M, Kassirer JF. 1991. The Ingelfinger rule revisited. New England Journal of Medicine 325:1371–3.

Angier N. 1992 May 10. Women still scarce on membership rolls of science academy. News and Observer (Raleigh, NC); Sect A:18.

Anholt RRH. 1994. Dazzle 'em with style: the art of oral scientific presentation. New York: Freeman and Company.

[Annals] Annals of Internal Medicine. [cited 2002 Oct 27]. Information for authors. Annals of Internal Medicine 136(1) [Internet]. Available from: http://www.annals.org.

[APS] American Physical Society [Internet]. 2008a. Abstract submission. [cited 2008 Sep 06]. Available from: http://www.aps.org/meetings/abstract/index.cfm.

[APS] American Physical Society [Internet]. 2008b. Help with LaTeX. [cited 2008 Sep 06]. Available from: http://www.aps.org/meetings/abstract/latex.cfm.

Aristotle. 1954. The rhetoric and the poetics of Aristotle. Rhys RW, Bywater I, translators. New York: Random House.

Arroliga AC. 2002. Metaphorical medicine: using metaphors to enhance communication with patients who have pulmonary disease. Annals of Internal Medicine [Internet] 137(5) (Part 1). [cited 2003 Oct 5]. Available from: http://www.annals.org.

arXiv.org [Internet]. [cited 2003 Feb 3]. Available from: http://arXiv.org.

[ASCE] American Society of Civil Engineers [Internet]. 2008. Ethical standards for publications of ASCE journals. [cited 2008 Sep 03]. Available from: http://pubs.asce.org/editors/journal/generalresource/ethicalstandards.htm.

[ASM] American Society for Microbiology [Internet]. 2008a. Homepage; ASM media information; online journal e-alerts. [cited 2008 Jun 18]. Available from: http://www.asm.org.

[ASM] American Society for Microbiology [Internet]. 2008b. Call for abstracts, 109th General Meeting. [updated 2008 Aug 5; cited 2008 Sep 7]. Available from: http://gm.asm.org/images/stories/gm2009call_for_abstractsweb.pdf.

Associated Press. 1992 Sep 5. Funding withheld for conference on genetics-crime link. News and Observer (Raleigh, NC); Sect A:7.

Associated Press. 1996 May 24. Quiz of adults discovers unscientific Americans. News and Observer (Raleigh, NC); Sect A:9.

Astrophysical Journal [Internet]. 2008. Guide: Editorial review. [cited 2008 Jul 14]. Available from: http://www.journals.uchicago.edu/page/apj/guide-ed.html.

Astrophysical Journal Letters [Internet]. 2008. Editorial criteria. [cited 2008 Jul 13]. Available from: http://www.journals.uchicago.edu/page/apjl/brief.html.

[ATTW] Association of Teachers of Technical Writing [Internet]. 2008. [cited 2008 May 21]. Available from: http://cms.english.ttu.edu/attw.

Bacon F. 1605, 1859. The advancement of learning. The works of Francis Bacon. Volume 3. Spedding J, Ellis RL, Health DD, editors. New York: Longman.

Bakhtin M. 1984. Rabelais and his world. Iswolsky H, translator. Bloomington (IN): Indiana University Press.

Ball P. 2008 Aug 08. Crime and punishment in the lab. Nature News [Internet]. [cited 2008 Sep 08]. Available from: http://www.nature.com/news/2008/080808/full/ news.2008.1015.html.

Barald K, Gutmann M, Noll D [Internet]. 2008. University of Michigan comprehensive ethics training program in basic and social sciences and engineering. National Science Foundation: Awards. [cited 2008 Sep 3]. Available from: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0832862.

Barker R. 1997. And the waters turned to blood. New York: Simon and Schuster.
Bazell R. 2007 Mar 1. Is this celebrity doctor's TV ad right for you? MSNBC.com [Internet]. [cited 2008 Sep 03]. Available from: http://www.msnbc.msn.com/id/16039753/.
Bazerman C. 1983. Scientific writing as a social act: a review of the literature of the sociology of science. In: Anderson P, Brochmann R, Miller C, editors. New essays in technical and scientific communication: research, theory, and practice. Farmingdale (NY): Baywood. p 156–84.
Bazerman C. 1985. Physicists reading physics: schema-laden purposes and purpose-laden schema. Written Communication 2(1):3–23.
Bazerman C. 1988. Shaping written knowledge: the genre and activity of the experimental article in science. Madison: University of Wisconsin Press.
Bazerman C. 1999. The languages of Edison's light. Cambridge (MA) : MIT.
Bazerman C, Little J, Chavkin T. 2003. The production of information for genred activity spaces: informational motives and consequences of the Environmental Impact Statement. Written Communication 20:455–77.
Beadle G, Beadle M. 1966. The language of life: An introduction to the science of genetics. Garden City (NY): Doubleday.
Beard M. 2004 Jul 30. Lord Elgin—Saviour or Vandal? BBC Ancient History: Greeks [Internet]. [cited 2008 May 24]. Available from: http://www.bbc.co.uk/history/ancient/greeks/parthenon_debate_01.shtml.
Beardsley S. 2006 Feb 20. Down in flames: can stem cell research recover from Woo Suk Hwang? Scientific American [Internet]. [cited 2008 Sep 09]. Available from: http://www.sciam.com/article.cfm?id=down-in-flames.
Bell GD. 1991. Anti-*Helicobacter pylori* therapy: clearance, elimination, or eradication? Lancet 337:310–11.
Bellevue Literary Review [Internet]. [cited 2003 Feb 24]. Available from: http://www.blreview.org/index.htm.
Benditt J. 1995. Conduct in science. Science 268:1705.
Benson PJ. 1998. Changing moorings in scientific writing: suggestions to authors, allusions for teachers. Essays in the study of scientific discourse: methods, practice, and pedagogy. Battalio JT, editor. Stamford (CT): Ablex. p 209–25.
Benthien C. 2002. Skin: on the cultural border between the self and the world. New York: Columbia University Press.
Berenson A, Abelson R. 2008 Jun 29. Weighing the costs of a CT scan's look inside the heart. New York Times [Internet]. [cited 2008 Sep 11]. Available from: http://www.nytimes.com/2008/06/29/business/29scan.html?_r=1&scp=7&sq=berenson%202008%20technology%20medicine&st=cse&oref=login.
Berkenkotter C, Huckin TN. 1995. Genre knowledge in disciplinary communication: cognition/culture/ power. Hillsdale (NJ): Lawrence Erlbaum.
Biddle AW, Bean DJ. 1987. Writer's guide: life sciences. Lexington (MA) : D. C. Heath and Company.
BioMed Central [Internet]. 2008. What is BioMed Central? [cited 2008 Jun 20]. Available from: http://www.biomedcentral.com/info/.
BIOVISIONS at Harvard University [Internet]. 2008 Jun 16. The inner life of a cell. YouTube. [cited 2008 Jul 01]. Available from: http://www.youtube.com/watch?v=THKXy_YOK_w.
Blackman C. 1997 June 13. Personal interview. Raleigh, NC
Blakeslee AM. 1994. The rhetorical construction of novelty: presenting claims in a letters forum. Science, Technology, and Human Values 19:88–100.
Blakeslee, AM. 2001. Interacting with audiences: social influences on the production of scientific writing. Mahwah (NJ): Lawrence Erlbaum.

Blaser MJ. 1987. Gastric *Campylobacter*-like organisms, gastritis, and peptic ulcer disease. Gastroenterology 93:371–83.

Blaser MJ. 2005 Feb. An endangered species in the stomach. Scientific American 292(2):38–45.

[BMJ] British Medical Journal [Internet]. 2002. Advice to contributors. [cited 2002 Dec 31]. Available from: http://bmj.com/advice/sections.shtml.

[BMJ] British Medical Journal [Internet]. 2008. Resources for Authors/Research Articles. [cited 2008 Jul 12]. Available from: http://resources.bmj.com/bmj/authors.

Bolter JD, Gromala D. 2003. Windows and mirrors: interaction design, digital art, and the myth of transparency. Cambridge (MA): Massachusetts Institute of Technology Press.

Bowler M, Amato-Henderson S, Holles J, Ren J, Lockhart T [Internet]. 2008. Responsible conduct of research in science and engineering education: moral motivation and ethical sensitivity in multi-national graduate students. National Science Foundation: Awards. [cited 2008 Sep 03]. Available from: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0832922.

Boyd R. 1993. Metaphor and theory change: what is a metaphor a metaphor for? Metaphor and Thought. Ortony A, editor. London: Cambridge University Press. p 481–532.

Bradford A, Whitburn M. 1982. Analysis of the same subject in diverse periodicals: one method for teaching audience adaptation. Technical Writing Teacher 9:58–62.

Broad WJ. 2002 Mar 19. For Delphic oracle, fumes and visions. New York Times (National Ed.) Science D1, D4.

Brody H. 1996 Sep. Wired science. Technology Review [Internet]. Available from: http://web.mit.edu/afs/athena/org/t/techreview/www/tr.html.

Bronowski J. 1965. Science and human values. Rev. ed. New York: Harper and Row.

Brown FA. 1954 Apr. Biological clocks and the fiddler crab. Scientific American 190:34–7.

Brown FA. 1959. Living clocks. Science 130:1535–44.

Brown FA. 1960. Life's mysterious clocks. Saturday Evening Post 233:18–19, 43–44.

Brown FA. 1962. Responses of the planarian, Dugesia, and the protozoan, Paramecium, to very weak horizontal magnetic fields. Biological Bulletin 123:264–81.

Brummett B. 1976. Some implications of "process" or "intersubjectivity": postmodern rhetoric. Philosophy and Rhetoric 9:21–51.

Burke K. 1966. Language as symbolic action; essays on life, literature, and method. Berkeley: University of California Press.

Burke K. 1968. Counter-statement. Berkeley: University of California Press.

Burkholder JM, Glasgow HB, Springer J, Parrow MW. 2000. The life cycles of toxic *Pfiesteria* species and other estuarine dinoflagellates: toward verification of Pfiester's hypothesis. [poster]. The CDC National Conference on Pfiesteria: From Biology to Public Health. Atlanta, GA. October 2000.

Burkholder JM, Gordon AS, Moeller PD, Law JM,Coyne KJ, Lewitus AJ, Ramsdell JS, Marshall HG, Deamer NJ, Cary SC, Kempton JW, Morton SL, Rublee, PA. 2005. Demonstration of toxicity to fish and to mammalian cells by *Pfiesteria* species: comparison of assay methods and strains. Proceedings of the National Academy of Sciences of the United States of America. 102(9): 3471–3476.

Burkholder JM, Noga EJ, Hobbs CH, Glasgow HB Jr, Smith SA. 1992. New "phantom" dinoflagellate is the causative agent of major estuarine fish kills. Nature 358:407–10; Nature 360:768.

Burkholder JM, Rublee PA. 1994. Improved detection of an ichthyotoxic dinoflagellate in estuaries and aquaculture facilities. Proposal submitted to the (U.S.) National Sea Grant College Program. North Carolina State University, Department of Botany.

Burrough-Boenisch J. 1999. International reading strategies for IMRD articles. Written Communication 16:296–316.

Butler D, Wadman M. 1999. Mixed response to NIH's web journal plan. Nature 399:8–9.

[CAIRE] Committee on Assessing Integrity in Research Environments, Board of Health Sciences Policy, Division of Earth and Life Studies (The National Academies). 2002. Integrity in scientific research: creating an environment that promotes responsible conduct. Washington (DC): The National Academies Press [Internet]. [cited 2008 Dec 31]. Available from: http://books.nap.edu/openbook.php.?record_id=10430.

Campbell JA. 1975. The polemical Mr. Darwin. Quarterly Journal of Speech 61:365–90.

Campbell KK. 1982. The rhetorical act. Belmont (CA): Wadsworth Publishing.

Carey J. 1992 Aug 10. What Barry Marshall knew in his gut. Business Week 68–9.

Carnap R. 1950. Logical foundations of probability. Chicago: University of Chicago Press.

Carpenter JH & Krest M. 2001. It's about the science: student writing and thinking about data in a scientific writing course. Language and Learning Across the Disciplines 5.2: 20 pages.

Carter M, Ferzli M, Wiebe E. 2004. Teaching genre to English first-language adults: a study of the laboratory report. Research in the Teaching of English 38:395–419.

Cartwright L. 1995. Screening the body: tracing medicine's visual culture. Minneapolis (MN): University of Minnesota Press.

Caruso D. 2007 Dec 2. Lots of little screens: TV is changing shape. New York Times (national edition). Sunday Business BU YT 4.

Casper C. 2008 May 23. New genre ecologies in science: post-publication review in online journals. 13th Biennial Conference Rhetoric Society of America, Seattle, WA.

[CBE] Council of Biology Editors. 1995. Report from the annual meeting—1994. [CBE] Views 18(1):14–16.

[CBE] Council of Biology Editors Task Force on Authorship. 2000 Feb. Who's the author? Problems with biomedical authorship, and some possible solutions. Report to the Council of Biology Editors (now Council of Science Editors) from the Task Force on Authorship. Science Editor 23(4):111–9.

Chambers JQ, Fisher JI, Zeng H, Chapman EL, Baker DB, Hurtt GC. 2007. Hurricane Katrina's carbon footprint on U.S. Gulf Coast forests. Science 318:1107.

Chambers JQ, Hurtt G. 2006. Hurricane impacts on structure and functioning of southeastern forests. NICCR Project Summary.

Chandra X-ray Center [Internet]. 2006. News release guidelines and contacts. [updated 2006 Aug 29; cited 2008 Jun 24]. Available from: http://chandra.harvard.edu/press/ release_guidelines.html.

Chandra X-ray Center. 2007. The *Chandra* X-ray Observatory (CXO) Research Program Call for Proposals: Cycle 10. Cambridge (MA): NASA/Chandra X-Ray Center.

Charney D. 1994. The impact of hypertext on processes of reading and writing. Literacy and computers: The complications of teaching and learning with technology. CL Selfe and S. Hilligoss editors. New York: Modern Language Association. p 238–63.

Charney D. 2003. Lone geniuses in popular science: the devaluation of scientific consensus. Written Communication 20:215–41.

Chazin S. 1993 Oct. The doctor who wouldn't accept no. Reader's Digest: 119–24.

Chiba N, Veldhuzen van Zanten SJO, Sinclair P, Fergusson RA, Escobedo S, Grace E. 2002. Treating *Helicobacter pylori* infection in primary care patients with uninvestigated dyspepsia: the Canadian adult dyspepsia empiric treatment—*Helicobacter pylori* positive (CADET-*Hp*) randomised controlled trial. British Medical Journal 324:1012–6. [cited 2000 July 21]. Available from: http://www.bmj.com/.

Chubb S. 2006. Chair of Session W41: Cold Fusion. APS March Meeting, March 13–17; Baltimore, MD.

[CITI] Collaborative Institutional Training Initiative [Internet]. [cited 2008 Aug 15]. Available from: https://www.citiprogram.org/dev/default.asp?language=english.

Clarke M. 2007. Harnessing the Web—Nature's way: new tools and resources to help researchers communicate and innovate. Logos 18:173–9.

Clayton CL, Mobley H. 1997. *Helicobacter pylori* protocols. Oxford; Cambridge (MA): Blackwell Healthcare Communications.

Clayton DD. 21 2007. Hoyle's equation. Science 318:1876–7.

Close F. 1992. Too hot to handle: the story of the race for cold fusion. London: Penguin Books.

Cohen J. 1995. The culture of credit. Science 268:1706–11.

Cohen J. 1996 Jan 5. AIDS trials take on peer review. Science 271:20–1.

Cohen N. 2008 Mar 16. Start writing eulogies for print encyclopedias. New York Times (National (Ed.) National 3.

Columbia Accident Investigation Board. 2003 Aug. Report volume 1. 1st limited edition, Columbia Accident Investigation Board [Internet]. Subsequent printing by NASA and the U.S. Government Printing Office, Washington DC. [cited 2003 Sep 23]. Available from: http://i.a.cnn.net/cnn/SPECIALS/2003/shuttle/CAIB.report.pdf.

Constantinides H. 2001. The duality of scientific ethos: deep and surface structures. Quarterly Journal of Speech 87:61–72.

Cook-Anderson G. 2007 Nov 15. Forests damaged by hurricane Katrina become major carbon source. NASA [Internet]. [cited 20 June 2008]. Available from: http://www.nasa.gov/mission_pages/hurricanes/archives/2007/katrina_carbon.html.

Copher JI, Kanfer AG, Walker MB. 2002. Everyday communication patterns of heavy and light email users. The Internet in Everyday Life. Wellman B, Haythornthwaite C, editors. Malden (MA): Blackwell Publishing.

Cornell News [Internet]. 2002 Sep 24. Cornell professor Paul Ginsparg, science communication rebel, named a MacArthur Foundation fellow. [cited 2003 Feb 3]. Available from: http://www.news.cornell.edu/release/Sept02/Ginsparg-MacArthur.ws.html.

Couture B. 1993. Provocative architecture: a structural analysis of Gould and Lewontin's "The Spandrels of San Marco." Understanding scientific prose. Selzer J, editor. Madison: University of Wisconsin Press. p 276–309.

Couzin J. 2006. Truth and consequences. Science 313 (5791): 1222–6.

Covich AP [Internet]. 2006 Oct 16. Welcome to the Ecological Society of America's blog. ESA News & Views. [cited 2008 Jun 18]. Available from: http://www.esa.org/ esablog/.

Cowen R. 2007 Jan 27. Solving a 400-year-old supernova riddle. Science News Online [Internet]. [cited 2008 Jun 14]. Available from: http://www.sciencenews.org/view/ generic/id/8166.

Cozman FG. 1999. Calculation of posterior bounds given convex sets of prior probability measures and likelihood functions. Journal of Computational and Graphical Statistics 8(4):824–38.

Crease RP, Samios NP. 1989 Oct 1. The science of things that aren't so. News and Observer (Raleigh, NC); Sect. D:1, 3.

Crismore A, VandeKopple WJ. 1988. Readers' learning from prose: the effects of hedges. Written Communication 5:184–202.

[CSE] Council of Science Editors, Style Manual Committee. 2006. Scientific style and format: The CSE manual for authors, editors, and publishers. 7th ed. Reston (VA): The Council.

[CSR/NIH] Center for Scientific Review, National Institutes of Health [Internet]. 2006. AIDS-associated opportunistic infections and cancer study section. [updated 2006 Feb 28; cited 2008 Aug 15]. Available from: http://cms.csr.nih.gov/PeerReviewMeetings/ CSRIRGDescription/AARRIRG/AOIC.htm.

[CSR/NIH] Center for Scientific Review, National Institutes of Health [Internet]. 2008. What happens to your grant application: a primer for new applicants. [Updated 2008 Mar 28: cited 2008 Aug 15]. Available from:

http://cms.csr.nih.gov/ResourcesforApplicants/PolicyProcedureReview+Guidelines/OverviewofPeerReview Process/.

Dagani R. 1993 Jun 14. Latest cold fusion results fail to win over skeptics. Chemical & Engineering News 71:38–41.

Dagani R. 1995 May 15. New journal forgoes traditional peer review. Chemical & Engineering News 73:26–7.

Darwin, C. 1998. The expression of the emotion in man and animals. Ekman P, editor. Oxford: Oxford University Press. p xiii–xvii.

Day M. 1999. The scholarly journal in transition and the PubMed Central. Ariadne [Internet] 21. [cited 2002 Dec 30]. Available from: http://www.ariadne.ac.uk/issue21/.

Day RA, Gastel B. 2006. How to write and publish a scientific paper. 6th ed. Westport, CT: Greenwood Press.

De Boer JZ, Hale JR. 1996. Proposal: a study of the evidence for geological faults and gaseous emissions at the sanctuary of Delphi, in order to test the validity of ancient testimonia concerning the origins of the oracle of Apollo.

De Boer JZ, Hale JR, Chanton J. 2001. New evidence for the geological origins of the ancient Delphic oracle (Greece). Geology 29:707–10.

DeAro J. 2008. ADVANCE: Increasing the participation and advancement of women in academic science and engineering careers (ADVANCE). National Science Foundation: Funding [Internet]. [cited 2008 Sep 03]. Available from: http://www.nsf.gov/ funding/pgm_summ.jsp?pims_id=5383.

D'Elia C, Richards D, Hovan M. Summary interpretation of Tufte heuristic. Unpublished graphic.

Delmothe T, Smith R. 1999. Moving beyond journals: the future arrives with a crash. British Medical Journal 318:1637–9.

[DHHS] Department of Health and Human Services. 2005 May 17. 42 CFR Parts 50 and 93: Public Health Service Policies on Research Misconduct; final rule. [cited 2009 Jan 19]. Available from: http://74.6.239.67/search/cache?ei=UTF-8&p=DOE+%22Report+of+the +Review+of+Low+Energy+Nuclear+Reactions%22&fr= moz2&u=www.lenrcanr.org/ acrobat/DOEreportofth.pdf&w=doe+%22report+of+the+rev iew+of+low+energy+nuclear +reactions%22&d=XQxz1g-YSFHR&icp=1&.intl=us. Federal Register 70 (94): Rules and Regulations.

[DHHS] Department of Health and Human Services [Internet]. 2008 Jun 25. Peer review policies & practices. National Institutes of Health: Office of Extramural Research. [cited 2008 Sep 03]. Available from: http://grants.nih.gov/grants/peer/peer.htm.

DiMaggio P, Hargittai E, Neuman WR, Robinson JP. 2004. Social implications of the Internet. Academy and the Internet. Nissenbaum H, Price ME, editors. New York: Peter Lang Publishing. p 35–70.

Dinolfo J. 2008. Seeing and re-viewing the human body: reflections on the rhetoric of medical videography. Rhetoric of Healthcare: Essays Toward a New Disciplinary Inquiry. Heifferon B, Brown S, editors. Cresskill (NJ): Hampton Press. p 181–203.

Dinolfo J, Heifferon B, Temesvari LA. 2007. Seeing cells: teaching the visual/verbal rhetoric of biology. Journal of Technical Writing and Communication 37(4): 395–417.

DNATube [Internet]. Re: the inner life of the Cell-Atp sythase. YouTube. [cited 2008 July 7]. Available from: http://www.youtube.com/watch?v=aIMGS0cSoFI.

[DOE] Department of Energy [Internet]. 2004 Dec. Report of the review of low energy nuclear reactions.

[DOE] Department of Energy [Internet]. 2008. Grant application guide: the application: instructions for application preparation. DOE Office of Science Financial Assistance Program. [cited 2008 Aug 14]. Available from: http://www.science.doe.gov/grants/ App.html.

Dondis DA. 1973. A primer of visual literacy. Cambridge (MA): MIT Press.

Dong YR 1996. Learning how to use citations for knowledge transformation: non-native doctoral students' dissertation writing in science. Research in the Teaching of English 30:428–57.

Drazen JM, Curfman GD [Internet]. 2002. On authors and contributors. New England Journal of Medicine 347:55. [cited 2008 Nov 02]. Available from: http://content.nejm.org/cgi/content/full/347/1/55.

DuMez E. 2000. The role and activities of scientific societies in promoting research integrity. Professional ethics report XIII, American Association for the Advancement of Science [Internet]. [cited 2000 Dec 11]. Available from: http://www.aaas.org.spp/sfrl/per/per22.htm.

Einsenberg A. 2008 July 6. Electronic papyrus: The digital book, unfurled. New York Times [National Ed.] Business 3.

Eisend M. 2002. The Internet as a new medium for the sciences? The effects of Internet use on traditional scientific communication media among social scientists in Germany. Online Information Review. 26(5): 307–17.

Ekman P, editor. 1998. Preface to the third edition. Darwin C. The expression of the emotion in man and animals. Oxford: Oxford University Press. p xiii–xvii.

Elkin-Koran N. 2004. The Internet and copyright policy discourse. Academy and the Internet. Nissenbaum H, Price ME, editors. New York: Peter Lang Publishing. p 252–74.

Engelhaupt E. 2007. New *Pfiesteria* toxin identified. Environmental Science & Technology Online News. [Internet]. [cited 2008 Mar 7]. Available from: http://pubs.acs.org/subscribe/journals/esthag-w2007/jan/science/ee_pfiesteria.html.

[EPA] U.S. Environmental Protection Agency. 1998. What you should know about *Pfiesteria piscicida*. EPA Document #842-F-98-011. Washington: U.S. Government Printing Office [Internet]. Also posted online as *Pfiesteria piscicida* Fact Sheet [updated 2002 Nov 27; cited 2003 Mar 7]. Available from: http://www.epa.gov/owow/estuaries/pfiesteria/fact.html.

[ESA] Ecological Society of America [Internet]. 2008a. Homepage. [cited 2008 Jun 18]. Available from: http://www.esa.org.

[ESA] Ecological Society of America [Internet]. 2008b. About ESA. [cited 2008 Jun 23]. Available from: http://www.esa.org/aboutesa.

[ESA] Ecological Society of America [Internet]. 2008c. Science Community Resources. [cited 2008 Jun 28]. Available from: http://esa.org/science_resources/scienceresources.php.

Etiope G, Papatheodorou G, Christodoulou D, Geraga M, Favali P. 2006. The geological links of the ancient Delphic Oracle (Greece): a reappraisal of natural gas occurrence and origin. Geology 34 (10): 821–24.

Faber B. 2006. Popularizing nanoscience: the public rhetoric of nanotechnology, 1986–1999. Technical Communication Quarterly 15(2): 141–69.

Fahnestock J. 1986. Accommodating science: the rhetorical life of scientific facts. Written Communication 3:275–296.

Fahnestock J. 1999. Rhetorical figures in science. New York: Oxford University Press.

Fallone CA, Veldhuyzen van Zanten SJO, Chiba N. 2000. The urea breath test for *Helicobacter pylori* infection: taking the wind out of the sails of endoscopy. Canadian Medical Association Journal 162:271–2.

[FAO] United Nations Food and Agriculture Organization [Internet]. 2008. AGORA (Access to global online research in agriculture)/About AGORA. [cited 2008 Jun 29]. Available from: http://www.aginternetwork.org/en/about_agora/.

Farmelo G. 2000 Jan 7. Why should scientists bother talking to the public. Science Careers. Available from: http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2000_01_ 07/noDOI.1907316693707911051.

Farrell TB, Goodnight GT. 1981. Accidental rhetoric: the root metaphors of Three Mile Island. Communication Monographs 48:271–300.

Feder T. 2005. Cold fusion gets chilly encore. Physics Today [Internet]. [cited 2008 May 25]. Available from: http://scitation.aip.org/journals/doc/PHTOAD-ft/vol_58/iss_1/31_1.shtml.

Feyerabend P. 1978. Against method. London: Verso.

Fisher WR. 1987. Human communication as narration: toward a philosophy of reason, value, and action. Columbia: University of South Carolina Press.

Fleischmann M, Pons S. 1989. Electrochemically induced nuclear fusion of deuterium. Journal of Electroanalytical Chemistry 261:301–8.

Flower L. 1993. Problem-solving strategies for writing. 4th ed. New York: Harcourt Brace Jovanovich.

Foster J, Lehoux D. 2007. The Delphic Oracle and the ethylene-intoxication hypothesis. Clinical Toxicology 45: 85–89.

Foucault, Michel. 1977. Discipline and punish: the birth of the prison. New York: Vintage.

Frankel MS. 2002. Seizing the moment: scientists' authorship right in the digital age. Report of a study by the American Association for the Advancement of Science [Internet]. [cited 2008 Sept 03]. Available from: http://www.aaas.org/spp/sfrl/projects/epub/finalrept.html. Frayn M. 2000. Copenhagen. New York: Anchor Books.

Friedlander A, Bessette RS. 2002. Scholars debate the implications of information technology for scientific journal publishing. InfoBrief: NSF 03-304 [Internet]. [cited 2008 Sep 03]. Available from: http://www.nsf.gov/statistics/infbrief/nsf03304.

Frostic M. 2008. In Katrina's wake. National Aeronautics and Space Administration [Internet]. [cited 2008 Jun 6]. Available from: http://learners.gsfc.nasa.gov/mediaviewer/KATRINA/.

Fry J. 2003. The disciplinary shaping of scholarly communication: patterns of computer-mediated communication across three diverse specialisms. Seminar, Center for Information Society Studies (CISS). February 12. North Carolina State University.

Fulbright MA, Reynolds SP. 1990. Bipolar supernova remnants and the obliquity dependence of shock acceleration. Astrophysical Journal 357:591–601.

Fuller S. 2000. Governing science before it governs us. Interdisciplinary Science Reviews 25:95–100.

Garfield E. 1995. Giving credit only where it is due: the problem of defining authorship. The Scientist 9:13.

Gastroenterology [Internet]. 2008. Instructions to authors. Gastroenterology 124(2). [updated 2008; cited 2008 Aug 31] Available from: http://www.gastrojournal.org/authorinfo.

German KM, Gronbeck BE, Ehninger D, Monroe AH. 2007. Principles of public speaking 16th ed. Boston: Pearson Education, Inc.

Gilbert GN, Mulkay M. 1984. Opening Pandora's box: a sociological analysis of scientists' discourse. Cambridge: Cambridge University Press.

Gillispie CC. 1960. The edge of objectivity: an essay in the history of scientific ideas. Princeton: Princeton University Press, 1960.

Ginsparg P. 1994. First steps towards electronic research communication. Computers in Physics 8:390–6.

Glickman D. 1999. New crops, new century, new challenges: how will scientists, farmers, and consumers learn to love biotechnology and what happens if they don't? Remarks prepared for delivery before the National Press Club, Washington, DC, July 13, 1999. Release No. 0285.99.

Good GA. 2000. The assembly of geophysics: scientific disciplines in frameworks of consensus. studies in history and philosophy of modern physics 31B:259–92.

Google Sky [Internet]. 2008. About Google Sky. [cited 2008 Jul 1]. Available from: http://www.google.co.uk/sky/about.html.

Gragson G, Selzer J. 1993. The reader in the text of "The Spandrels of San Marco." Understanding scientific prose. Selzer J., editor. Madison: University of Wisconsin Press. p 180–202.

Graham DY, Lew GM, Klein PD, Evans DG, Evans DJ Jr, Saeed ZA, Malaty HM. 1992. Effect of treatment of *Helicobacter pylori* infection on the long-term recurrence of gastric or duodenal ulcer. Annals of Internal Medicine 116:705–8.

Greene B. 2008 Jun 1. Put a little science in your life. New York Times (National Ed.) Week in Review; WK14.

Greenland PT. 1994. Essay review: the story of cold fusion. Contemporary Physics 35:209–11.

Griffith D. 1999. Exaggerating environmental health risk: the case of the toxic dinoflagellate *Pfiesteria*. Human Organization 58:119–27.

Gross AG. 1990. The rhetoric of science. Cambridge (MA): Harvard University Press.

Gross AG, Harmon JE, Reidy M. 2002. Communicating science: the scientific article from the 17th century to the Present. New York: Oxford UP.

Gurak Laura J. 2000. Oral presentations for technical communication. Boston: Allyn and Bacon.

Haas C. 1996. Writing technology: studies on the materiality of literacy. Mahwah (NJ): Lawrence Erlbaum.

Haas C and Hayes JR. 1986. What did I just say? Reading problems in writing with the machine. Research in the Teaching of English 20:22–35.

Habermas J. 1970. Technology and science as "ideology." Trans. Jeremy Shapiro. Toward a Rational Society: Student Protest, Science, and Politics. Boston: Beacon. p 81–127.

Hagmann M. 2000. Cancer researcher sacked for alleged fraud. Science 287:1901–2.

Hale JR, De Boer JZ, Chanton J, Spiller H. [Conference abstract] 2002. New evidence for the geological origin of the Delphic oracle: active faults, gaseous emissions, and architectural anomalies in the temple of Apollo. 103rd Annual Meeting of the Archeological Institute of America. American Journal of Archeology 106:231–306.

Hall J. 1971. Decisions, decisions, decisions. Psychology Today 5(6): 51–54, 86, 88.

Haller CR. 1998. Foucault's archeological method and the discourse of science: plotting enunciative fields. Essays in the study of scientific discourse: methods, practice, and pedagogy. Battalio JT, editor. Stamford (CT): Ablex. p 53–79.

Halloran SM. 1984. The birth of molecular biology: an essay in the rhetorical criticism of scientific discourse. Rhetoric Review 3:70–83.

Hamilton MJ, Kennedy ML. 1987. Genic variability in the racoon procyon lotor. The American Midland Naturalist 118:266–74.

Harmon JE. 1992. Current contents of theoretical scientific papers. Journal of Technical Writing and Communication 22:357–75.

Harnad S. 1990. Scholarly skywriting and the republication continuum of scientific inquiry. Psychological Science 1: 342–3.

Harnad S. 1997. The paper house of cards (and why it's taking so long to collapse). Ariadne 8 [Internet]. [cited 2002 Dec 30]. Available from: http://www.ariadne.ac.uk/issue8/harnad/.

Harnad S, Hey J. 1995. Esoteric knowledge: the scholar and scholarly publishing on the net. Networking and the future of libraries. Dempsey L, Law D, Mowat I, editors. London: Library Association. p 110–6.

Harris AW, Misiewicz JJ. 1996. *Helicobacter pylori*. Oxford; Cambridge (MA): Blackwell Healthcare Communications.

Harris RA, editor. 2005. Rhetoric and incommensurability. West Lafayette (IN): Parlor Press.

Harvard Medical School. 2007. Peptic ulcers and bacterial infections. Harvard Men's Health Watch 11(11): 1–4.

Harvard-Smithsonian Center for Astrophysics [Internet]. 2008. Chandra X-ray Observatory. [cited 2008 Jun 6]. Available from: http://chandra.harvard.edu/index.html.

Havelock EA. 1986. Orality, literacy, and Star Wars. Written Communication 3:411–20.

Hawes T, Thomas S. 1997. Tense choices in citations. Research in the Teaching of English 31:393–414.

Hayles K. 1999. How we became posthuman: virtual bodies in cybernetics, literature and informatics Chicago: University of Chicago Press.

Heatley RV. 1999. The *Helicobacter pylori* handbook. Oxford; Cambridge (MA): Blackwell Healthcare Communications.

Heidegger M. 1977. The question concerning technology and other essays. Trans. William Lovitt. New York: Harper and Row.

Heisenberg W. 1958. Physics and philosophy: The revolution in modern science. New York: Harper.

Heisenberg W. 1971. Physics and beyond: encounters and conversations. New York: Harper and Row.

Helicobacter Foundation [Internet]. 2006. [cited 2008 Jun 18]. Available from: http://www.helico.com/.

Hellenic Ministry of Culture. 1997 May 21. Permit issued to John Hale for removal of porous stone from Delphi. Tick E, translator (2003).

Hellenic Ministry of Culture. 2007. The restitution of the Parthenon marbles: The official Greek position [Internet]. [cited 2008 May 31]. Available from: http://odysseus.culture.gr/a/1/12/ea121.html.

Helsloot I. 2005. Bordering on reality: findings on the Bonfire Crisis Management Simulation. Journal of Contingencies and Crisis Management 13(4): 159–69.

[Heredity]. Journal of Heredity [Internet]. 2008 [copyright 2008 American Genetic Association]. Information for authors. [cited 2008 Jul 10]. Available from: http://www.oxfordjournals.org/our_journals/jhered/for_authors/msprep_submission.html.

Herndl CG, Fennell BA, Miller CR. 1991. The accidents at Three Mile Island and the shuttle *Challenger*. Textual dynamics of the professions. Bazerman C, Paradis J, editors. Madison: University of Wisconsin Press. p 279–305.

Herrington AJ. 1985. Writing in academic settings: A study of the contexts for writing in two college chemical engineering courses. Research in the Teaching of English 19(4):331–61.

HeSCA [Internet]. 2008. Featured speakers. 49th International Conference on Health & Science Communications. [cited 2008 May 17]. Available from: http://www.hesca.org/meeting/ featured.php#moss.

Hess, GR, K. Tosney K, Liegel L [Internet]. 2006. Creating effective poster presentations. [cited 2008 Sep 07]. Available from: http://www.ncsu.edu/project/posters.

Heylin M. 2000 Oct 9. Journalism 101. Chemical Engineering News 46.

Hill GY, Savage D, Watzke M, Weaver D. [Internet; release]. 2004 Oct 6. NASA's great observatories may unravel 400-year-old supernova mystery. [cited 2009 Jan 19]. Available from: http://chandra.harvard.edu/press/04_releases/press_100604.html.

Hogan M. PubMed 1999. Central and beyond. HMSBeagle: The BioMedNet Magazine [Internet] 61:3. [cited 2002 Dec 28]. Available from: http://www.bmn.com.

Hojat M, Gonnella JS, Caelleigh AS. 2003. Impartial judgment by the "gatekeepers" of science: fallibility and accountability in the peer review process. Advances in Health Sciences Education 8: 75–96.

Holden C. 2006 February 17. Schatten: Pitt panel finds "misbehavior" but not misconduct. Science 311: 928.

Holdren JP [Internet]. 2008. The Late Show with David Letterman: DaveTV. [cited 2008 Jul 16]. Available from: http://www.cbs.com/latenight/lateshow/video_player/index/ php/953125.phtml.

Holton G. 1973. Thematic origins of scientific thought: Kepler to Einstein. Cambridge (MA): Harvard University Press.

Horn D. 1998. The shoulders of giants. Science 280:1354–5.

Hoshiko T. 1991 Oct 28. Facing ethical dilemmas: scientists must lead the charge. The Scientist 11, 13.

Howard TW. 2004. Who "owns" electronic texts? Central works in technical communication. Johnson-Eilola J, and Selber SA, editors. New York: Oxford University Press. p 398–408.

Hsia HJ. 1977. Redundancy: is it the lost key to better communication? Audiovisual Communication Review 25:63–85.

Huizenga JR. 1992. Cold fusion: the scientific fiasco of the century. Rochester (NY): University of Rochester Press.

Huler S. 1990 Nov 12. How to get your research published: editors' thoughts. The Scientist 23.

Huyghe P. 1993 Apr. Killer algae. Discover 14(4):71–5.

Hyland K. 1996. Talking to the academy: forms of hedging in science research articles. Written Communication 13:251–81.

Hyland K. 1999. Disciplinary discourse: writer stance in research articles. Writing: texts, processes and practices. Candlin CN, Hyland K, editors. New York: Longman. p 99–121.

[ICMJE] International Committee of Medical Journal Editors [Internet]. 2007. Uniform requirements for manuscripts submitted to biomedical journals. [cited 2008 September 03]. Available from: http://www.icmje.org.

Ingelfinger FJ. 1977. The general medical journal: for readers or repositories? New England Journal of Medicine 296:1258–64.

International Year of Astronomy [Internet] 2009. Homepage. [cited 2008 Jun 22]. Available from: http://astronomy2009.us/.

Internet2 [Internet]. 2008. Internet2 past showcases. [cited 2008 May 7]. Available from: http://www.internet2.edu/pastshowcases.cfm#494.

Issues in Science and Technology Online [Internet]. 2007 National Academy of Science, National Academy of Engineering, Institue of Medicine, University of Texas at Dallas. Available from: http://www.issues.org/about.html.

IText Working Group. 2001. IText: future directions for research on the relationship between information technology and writing. J. Business and Technical Communication 15: 269–308.

Jacobs M, Storck W. 2000 May 8. Women in industry still hit glass ceiling. Chemical & Engineering News 78(9): 36–7.

Jacob M. 2003. Rethinking science and commodifying knowledge. Policy Futures in Education 1(1): 1.

Jaffe S. 2003. No Pardon for poor English in science. The Scientist 17(5): 44.

Jayaraman KS. 2008 Jan 17. Cold fusion hot again. Nature India [Internet]. [cited 2008 May 25]. Available from: http://www.nature.com/nindia/2008/080117/full/nindia.2008.77.html.

Johnson G. 2007 Oct 28. Bright scientists, dim notions. New York Times (national edition). Week in Review: WK 5.

Jones SE, Palmer EP, Czirr JB, Decker DL, Jensen GL, Thorne JM, Taylor SF, Rafelski J. 1989. Observation of cold nuclear fusion in condensed matter. Nature 338:737.

Jorgensen-Earp CR, Jorgensen DD. 2002. "Miracle from mouldy cheese": chronological versus thematic self-narratives in the discovery of penicillin. Quarterly Journal of Speech 88:69–90.

Journal of Applied Ecology [Internet]. 2008. [cited 2008 Dec 14]. Blackwell Publishing. Available from: Htt://www/blackwellpublishing.com/journal.asp?ref=0021.8901$site=1.

Kassirer JP, Angell M. 1991. On authorship and acknowledgements. New England Journal of Medicine [Internet] 325:1510–12. [cited 2003 Jan 4]. Available from: http://www.nejm.org/hfa/authorandacknowledge.asp.

Katz MJ. 2006. From research to manuscript: a guide to scientific writing. Dordrecht, The Netherlands: Springer.

Katz SB. 1992a. Narration, technical communication, and culture: *The Soul of a New Machine* as narrative romance. Constructing rhetorical education. Secor M, Charney C, editors. Carbondale (IL): Southern Illinois Press. p 382–402.

Katz SB. 1992b. The ethic of expediency: classical rhetoric, technology, and the Holocaust. College English 54:255–75.

Katz SB. 1993. Aristotle's rhetoric, Hitler's program, and the ideological problem of praxis, power, and professional discourse. Journal of Business and Technical Communication 7:37–62.

Katz SB. 1996. The epistemic music of rhetoric: towards the temporal dimension of affect in reader response and writing. Carbondale (IL): Southern Illinois University Press.

Katz SB. 2001. Language and persuasion in biotechnology communication with the public: How to not say what you're not going to not say and not say it. AgBioForum [Internet] 4:2. [cited 2003 Feb 3]. Available from: http://www.agbioforum.org.

Katz SB. 2008. Biotechnology and global miscommunication with the public: rhetorical assumptions, stylistic acts, ethical implications. Connecting People with Technology: Issues in Professional Communication. Grady H, Hayhoe G, editors. Amityville (NY): Baywood Publishing Company, Inc. p 167-175.

Katz SB, Miller CR. 1996. The low-level radioactive waste siting controversy in North Carolina: toward a rhetorical model of risk communication. Green culture: environmental rhetoric in contemporary America. Herndl CG, Brown SC, editors. Madison: University of Wisconsin Press. p 111–40.

Kaufman M. 2007 Nov 16. Katrina, Rita caused forestry disaster. Washington Post [Internet]. [cited 2008 Jul 19]. Available from: http://www.washingtonpost.com/wp-dyn/content/article/2007/11/15/AR2007111501359_pf.html.

Knutson TR, Sirutis JJ, Garner ST, Vecchi GA, Held IM. 2008 May 18. Simulated reduction in Atlantic hurricane frequency under twenty-first century warming conditions. [Internet; letter abstract]. Nature Geoscience. [cited 2008 Jun 11]. Available from: http://www.nature.com/ ngeo/journal/v1/n6/abs/ngeo202.html.

Koshland D Jr. 1989 Aug 25. Minimizing fraud without stifling science. News and Observer (Raleigh, NC); Sect. A:16.

Kostelnick C. 1995. Cultural adaptation and information design: two contrasting views. IEEE Transactions on Professional Communication 38(4): 182–96.

Kostelnick C, Hassett M. 2003. Shaping information: the rhetoric of visual conventions. Carbondale (IL): Southern Illinois University Press.

Kress G, Van Leeuwen T. 1996. Reading images: grammar of visual design. London: Routledge.

Kuhn TS. 1979. Metaphor in science. Metaphor and thought. Ortony A, editor. London: Cambridge University Press. p 409–19.

Kuhn TS. 1996; org. 1970. The structure of scientific revolutions. 3rd ed. Chicago: University of Chicago Press.

LabWrite [Internet; online instructional resource]. 2004. LabWrite: improving lab reports. [cited 2008 Jul 09]. Available from: http://www.ncsu.edu/labwrite/.

Lakoff G, Johnson M. 1980. Metaphors we live by. Chicago: University of Chicago Press.

Lam SK. 1989. Duodenal ulcer relapse after eradication of *Campylobacter pylori*. Lancet 1:384.
Lancet. 1984. Spirals and ulcers. Lancet 1:1336.
Lancet. 1990. Information for authors. Lancet 336:1117.
Lane N. 2001. The new security environment. APS News Online [Internet]. January 2001. [cited 2002 Jun 18]. Available from: http://www.aps.org/apsnews/0101/010115.html.
LaTeX [Internet]. 2008 February 18. LaTeX: a document preparation system. [cited 2008 May 5]. Available from: http://www.latex-project.org/.
Latour B. 1987. Science in action: how to follow scientists and engineers through society. Cambridge (MA): Harvard University Press.
Latour B, Woolgar S. 1979. Laboratory life: the social construction of scientific facts. Beverly Hills (CA): Sage.
Lawler A. 2000a. Silent no longer: model minority mobilizes. Science 290:1072–7.
Lawler A. 2000b. Relief, rebuke follow agreement on Lee. Science 289:1851, 1853.
Leary DE. 1990. Psyche's muse: the role of metaphor in the history of psychology. Metaphors in the history of psychology. Leary DE, editor. New York: Cambridge University Press. p 1–78.
Lerner N. 2007. Laboratory lessons for writing and science. Written Communication 24: 191–222.
Lewontin RC. 1993. Biology as ideology: the doctrine of DNA. New York: HarperPerrenial.
Liedes J. 1997. Copyright: evolution not revolution. Science 276: 223–5.
Lievrouw LA. 1990. Communication and the social representation of scientific knowledge. Critical Studies in Mass Communication 7:1–10.
Lindeman N. 2007. Creating knowledge for advocacy: the discourse of research at a conservation organization. Technical Communication Quarterly 16:431–51.
Locke S. 2001. Sociology and the public understanding of science: from rationalization to rhetoric. British Journal of Sociology 52:1–18.
Loffeld RJLF, Stobberingh E, Arends JW. 1989. Response to David Y Graham et al. Lancet 1:569–70.
Lohr S. 2008 Mar 23. Why old technologies are still kicking. New York Times (national edition). Sunday Business BU Y4.
Lorimer CG, Chapman JW, Lambert WD. 1994. Tall understorey vegetation as a factor in the poor development of oak seedlings beneath mature stands. Journal of Ecology 82:227–37.
Lury C. 1998. Prosthetic culture: photography, memory and identity. London: Routledge.
Lyne J. 1998. Knowledge and performance in argument: disciplinarity and proto-theory. Argumentation and Advocacy 35:3–9.
MacArthur Fellows Programs [Internet]. 2002. MacArthur award announcement. [cited 2003 Feb 3]. Available from: http://www.macfound.org/program/fel/2002fellows/ginsparg_paul.htm.
Mackenzie Owen J. 2007. The scientific article in the age of digitization. Dordrecht, The Netherlands: Springer.
Macrina FL. 2000. Scientific integrity. 2nd edition. Washington: ASM Press.
Maddox J. 1989. End of cold fusion in sight. Nature 340:15.
Madigan R, Johnson S, Linton P. 1995. The language of psychology: APA style as epistemology. American Psychologist 50:428–36.
Mallin MA, Burkholder JM, Larsen LM, Glasgow HB Jr. 1995. Response of two zooplankton grazers to an ichthyotoxic estuarine dinoflagellate. Journal of Plankton Research 17:351–63.
Markoff J. 2008a May 25. Global dreams for a wireless web. New York Times (national edition). Sunday Business BU1.

Markoff J. 2008b June 8. Nature gave him a blueprint. Then came the tough part. New York Times (National Ed.) Sunday Business BU3.

Marshall B. 2002. Helicobacter pioneers firsthand: accounts from the scientists who discovered Helicobacter 1892–1982. London: Blackwell.

Marshall BJ [Internet]. 2005a. Acceptance speech Nobel Prize, delivered 10 Dec 2005. [cited 2008 May 04]. Available from: http://nobelprize.org/nobel_prizes/medicine/ laureates/2005/marshall-lecture.html.

Marshall BJ [Internet]. 2005b. Slides from Nobel Lecture, "Helicobacter Connections," delivered 08 Dec 2005. [cited 2008 May 04]. Available from: http://nobelprize.org/ nobel_prizes/medicine/laureates/2005/marshall-lecture.html.

Marshall BJ [Internet]. 2005c. Transcript of Nobel Lecture, "Helicobacter Connections," delivered 08 Dec 2005. p 250–1. [cited 2008 May 04]. Available from: http://nobelprize.org/nobel_prizes/medicine/laureates/2005/marshall-lecture.html.

Marshall BJ [Internet]. 2005d. Video of Nobel Prize Lecture, "Helicobacter Connections," delivered 08 Dec 2005. [cited 2008 May 04]. Available from: http://nobelprize.org/nobel_prizes/medicine/laureates/2005/marshall-lecture.html.

Marshall B, Armstrong J, McGechie D, Glancy R. 1985. Attempt to fulfil Kochs postulates for pyloric campylobacter. Medical Journal of Australia 142:436–9.

Marshall BJ, Warren JR. 1984. Unidentified curved bacilli in the stomach of patients with gastritis and peptic ulceration. Lancet 1:1311–5.

Marshall BJ, Warren JR, Goodwin CS. 1989. Duodenal ulcer relapse after eradication of *Campylobacter pylori*. Lancet 1:836–7.

Marshall E. 1995. Dispute slows paper on "remarkable" vaccine. Science 268:1712–5.

Marshall E. 1996a. Trial set to focus on peer review. Science 273:1162–4.

Marshall E. 1996b. Peer review: battle ends in $21 million settlement. Science 274:911.

Marshall E. 2000a. Storm erupts over terms for publishing Celera's sequence. Science 290:2042–3.

Marshall E. 2000b. Rival genome sequencers celebrate a milestone together. Science 288:2294–5.

Martinson BC, Anderson MS and de Vries R. 2005. Scientists behaving badly. Nature 435: 737–8.

Maryland Department of Natural Resources [Internet]. Pfiesteria piscicida/Pfiesteria shumwayae. [cited 2008 Dec 17]. Available from: http://www.dnr.state.md.us/bay/hab/ pfiesteria.html.

Matzat U. 1998. Informal academic communication and scientific usage of internet discussion of groups. IRISS '98 [Internet; conference papers]. [cited 2002 Jun 18]. Available from: http://www.sosig.ac.uk/iriss/ papers/paper19.htm.

Maugh TH [Internet]. 2008 Jul 19. Physicist is found guilty of misconduct. Los Angeles Times. [cited 2008 Sep 05]. Available from: http://articles.latimes.com/2008/jul/19/science/sci-misconduct19.

McDonald KA. 1995 April 28. Too many co-authors? The Chronicle of Higher Education 42:A35.

Medawar PB. 1964 Aug 1. Is the scientific paper fraudulent? Saturday Review 47:42–3.

Mehlenbacher B. 1994. The rhetorical nature of academic research funding. IEEE Transactions on Professional Communication 37:157–62.

Memory JD. 2003 Feb 11. Science is working together. News and Observer (Raleigh, NC); Sect. A:10.

[MEPS] Marine Ecology Progress Series. 2002 Mar 6. [Editorial statement.] Marine Ecology Progress Series 228: no page number.

Merton RK. 1973a. The normative structure of science. The Sociology of Science: Theoretical and Empirical Investigations. Chicago: University of Chicago Press. p 267–8.

Merton RK. 1973b. Priorities in scientific discovery. The sociology of science: Theoretical and empirical investigations. Chicago: University of Chicago Press. p 286–324.

Mervis J. 2000. Diversity easier said than done. Science 289 (5478): 378–9.

Miller CR. 1978. Technology as a form of consciousness: a study of contemporary ethos. Central States Speech Journal 29 (1978): 228–36.

Miller CR. 1984. Genre as social action. Quarterly Journal of Speech 70:151–67.

Miller CR. 1992. *Kairos* in the rhetoric of science. A rhetoric of doing. Witte SP, Nakadate N, Cherry RD, editors. Carbondale: Southern Illinois University Press. p 310–27.

Miller CR, Halloran SM. 1993. Reading Darwin, reading nature; or, on the ethos of historical science. Understanding scientific prose. Selzer J, editor. Madison: University of Wisconsin Press. p 106–26.

Miller CR, Shephard D. Blogging as social action: a genre analysis of the weblog. Into the Blogosphere.[Internet]. [cited 2008 Jun 15]. Available from: http://blog.lib.umn.edu/ blogosphere/blogging_as_social_action_a_genre_analysis_of_the _weblog.html.

Mobley HL, Hazel SL, Mendz G. 2001. *Helicobacter pylori*: physiology and genetics. Oxford; Cambridge (MA): Blackwell Healthcare Communications.

Monmaney T. 1993 Sept 20. Marshall's hunch. New Yorker 64–72.

Monroe J, Meredith C, Fisher K. 1977. The science of scientific writing. Dubuque (IA): Kendall/Hunt.

Montgomery SL. 1996. The scientific voice. New York: Guilford Press.

Moore B. 2000. Could cold fusion be for real? An interview with Dr. Eugene Mallove—Part 1. EV World [Internet]. [cited 2002 Jun 11]. Available from: http://www.evworld.com/ archives/interviews2/ mallove1.html.

Morris AJ, Nicholson GI, Perez-Perez GI, Blaser MJ. 1991. Long-term follow-up of voluntary ingestion of *Helicobacter pylori*. Annals of Internal Medicine 114:662–3.

Morton CC. 2000. Company, researchers battle over data access. Science 290:1063.

Moses MG, Katz SB. 2006. The phantom machine: the invisible ideology of email (a cultural critique). Critical Power Tools: Technical Communication and Cultural Studies. Scott JB, Longo B, and Wills KV, editors. Albany (NY): State University of New York Press.

Mould D, Cabbage M. 2008 February 04. Release 08–034: NASA Unveils $17.6 billion budget [Internet]. [cited 2008 Sep 10]. Available from: http://www.nasa.gov/home/ hqnews/2008/feb/HQ_08034_FY2009_budget.html.

Myers G. 1985. The social construction of two biologists' proposals. Written Communication 2:219–45.

Myers G. 1991. Stories and styles in two molecular biology review articles. Textual dynamics of the professions. Bazerman C, Paradis J, editors. Madison: University of Wisconsin Press. p 45–75.

Myers G. 2003. Discourse studies of scientific popularization: questioning the boundaries. Discourse Studies 5: 265–79.

Naeye R. 2007 Apr. Kepler saw a white dwarf explode. Sky & Telescope 113(4): 15.

Narin F, Hamilton KS, Olivastro D. 1997. The increasing linkage between U.S. technology and public science. Research Policy 26: 317–1730.

[NAS] National Academy of Sciences. 1989. On being a scientist. Washington: National Academy Press.

[NAS] National Academy of Sciences. 1995. On being a scientist: responsible conduct in research. 2nd edition. Washington: National Academy Press.

[NASA] National Aeronautics and Space Administration [Internet]. 2008a. Atlantic hurricanes with Dr. Jeff Halverson: understanding the 21st century's new threat. Hurricanes: Latest Storm Images and Data from NASA. [cited 2008 Jun 18]. Available from:

http://www.nasa.gov/mission_pages/hurricanes/multimedia/AtlanticHurricanesWithJeff.html.

[NASA] National Aeronautics and Space Administration [Internet]. 2008b. Chandra: exploring the invisible universe. [cited 2008 Jun 6]. Available from: http://www.nasa.gov/mission_pages/chandra/main/index.html.

[NASA] National Aeronautics and Space Administration [Internet]. 2008c. Guidebook for proposers responding to a NASA Research Announcement (NRA). [cited 2008 Dec 14]. Available from: http://www.hq.nasa.gov/office/procurement/nraguidebook/ proposer2003.pdf.

[NASA] National Aeronautics and Space Administration [Internet]. 2008d. NASA—Home. [cited 2008 Sep 03]. Available from: http://www.nasa.gov/home/.

NASA [Internet] 2008e. NASA unveils $17.6 budget. Mould D, Cabbage M. [cited 2008 15 Dec]. Available from: 12/15/08http:/www.nasa.gov/home/hqnews/2008/feb/ HQ_08034_FY2009_budget_prt.ht m.

[NASA] National Aeronautics and Space Administration [Internet]. 2008f Science@NASA: Headline News. [cited 2008 Jun 6]. Available from: http://science.nasa.gov/default.htm.

National Center for Environmental Publications and Information [Internet]. 1998 Oct 13. What you should know about Pfiesteria piscicida. [cited 2008 May 7]. Available from: http://www.medhelp.org/NIHlib/GF-394.html.

National Digital Science Library [Internet]. 2008. [cited 2008 Jul 1]. Available from: http://nsdl.org/search/?q=Basic&include_collection%5B%5D=367822&verb=Search&s=60&n=10&item_num=4&identifier=http%3A%2F%2Fxxx.lanl.gov%2F.

National Geographic [Internet]. 2008. Delphic Oracle. National Geographic Video. [cited 2008 Jun 18]. Available from: http://video.nationalgeographic.com/video/player/places/ culture-places/historical/greece_delphioracle.html.

National Library of Medicine [Internet]. Turning the Pages Online. [cited 2008 Jun 29]. Available from: http://archive.nlm.nih.gov/proj/ttp/books.htm.

National Sea Grant. [Internet]. Sea Grant is competitive. [cited 2003 Mar 12]. Available from: http://www.nsgo.seagrant.org/Competitive_FactSheet.html.

National Sea Grant College Program. 1994. Statement of opportunity for funding: marine biotechnology. Raleigh: North Carolina State University, UNC Sea Grant College Program.

Nature [Internet] 2008a. Nature guide to authors: Manuscript formatting. [cited 2008 Jul 13]. Available from: http://www.nature.com/nature/authors/sitemap.html.

Nature [Internet]. 2008b. Getting published in Nature: the editorial process. [cited 2008 Jul 14]. Available from: http://www.nature.com/nature/authors/get_published/index.html.

Nature [Internet] 2008c. Nature guide to authors: Editorial Policies. [cited 2008 Jul 14]. Available from: http://www.nature.com/authors/editorial_policies/peer_review.html.

Nature [Internet] 2008d. Nature guide to authors: Other submitted material. [cited 2008 Jul 16]. Available from: http://www.nature.com/nature/authors/gta/others.html#insights.

[NEJM] New England Journal of Medicine [Internet]. 2008. Information for authors: Article types. [cited 2008 Jul 16]. Available from: http://authors.nejm.org/help/acHelp.asp.

Nelkin D. 1975. The political impact of technical expertise. Social Studies of Science 5:35–54.

Nelkin D. 1979. Controversy: politics of technical decisions. 2nd edition. Beverly Hills (CA): Sage Publications.

Nemiroff R, Bonnell J [Internet]. 2007 January 16. Kepler's supernova remnant in X-Rays. Astronomy Picture of the Day. [cited 2008 Jul 7]. Available from: http://antwrp.gsfc.nasa.gov/apod/ap070116.html.

Newsweek/AP [Internet] 2008. Purdue panel finds misconduct by fusion scientist. Newsweek.com [cited 2008 Aug 04]. Available from: http://www.newsweek.com/id/146938/page/2.

[NIAID] National Institute of Allergy and Infectious Diseases, National Institutes of Health [Internet]. 2008a. NIH Grant Cycle: Part 4. Target your audience. [updated 2008 Jun 31; cited 2008 Aug 15]. Available from: http://www.niaid.nih.gov/ncn/grants/cycle/part04.htm.

[NIAID] National Institute of Allergy and Infectious Diseases, National Institutes of Health [Internet]. 2008b. NIH Grant Cycle: Part 5. Research Plan. [updated 2008 Jun 29 cited 2008 Aug 17]. Available from: http://www.niaid.nih.gov/ncn/grants/cycle/part05.htm.

[NIAID] National Institute of Allergy and Infectious Diseases, National Institutes of Health [Internet]. 2008c. NIH Grant Cycle: Part 8. Assignment and Review. [updated 2008 Jun 29; cited 2008 Aug 17]. Available from: http://www.niaid.nih.gov/ncn/grants/cycle/part08.htm#f6.

[NIAID] National Institute of Allergy and Infectious Diseases, National Institutes of Health [Internet]. 2008d. NIH Grant Cycle: Part 11a. Managing your grant. [updated 2008 Jun 29; cited 2008 Aug 17]. Available from: http://www.niaid.nih.gov/ncn/grants/cycle/part11a.htm#e.

[NICCR] US Department of Energy National Institute for Climatic Change Research [Internet]. 2007. About the Coastal Center. [cited 2008 Nov 02]. Available from: http://www.tulane.edu/~NICCR/about.html.

[NICCR] US Department of Energy National Institute for Climatic Change Research [Internet]. [posted 2008 Feb 28]. Request for proposals notice RFP-04. [cited 2008 Aug 17]. Available from: http://www.tulane.edu/%7ENICCR/rfps.html.

Niehoff D. 2005. The language of life: How cells communicate in health and disease. Washington, DC: Joseph Henry Press.

Nightingale V. 1986. Community as audience—audience as community. Australian Journal of Communication 9 & 10:31–41.

[NIH] National Institutes of Health. 1993. Helpful hints: preparing an NIH research grant application. Bethesda (MD): National Institutes of Health, Division of Research Grants.

[NIH] National Institutes of Health, Consensus Development Panel on *Helicobacter pylori* in Peptic Ulcer Disease. 1994. *Helicobacter pylori* in peptic ulcer disease. Journal of the American Medical Association 272:65–9.

[NIH] National Institutes of Health [Internet]. 2008. NIH budget. [cited 2008 Sep 10]. Available from: http://www.nih.gov/about/budget.htm.

[NIH/OER] National Institutes of Health/ Office of Extramural Research [Internet]. 2008 Jan 11 [release date]. Revised policy on enhancing public access to archived publications resulting from NIH-funded research. [cited 2008 Jun 28]. Available from: http://grants.nih.gov/grants/guide/notice-files/NOT-OD-08-033.html.

Noguchi J. 2006. The science review article: an opportune genre in the construction of science. Series: Linguistics Insights: Studies in Language and Communication, vol. 17. Bern: Peter Lang.

North Carolina Department of Environment and Natural Resources. [cited 2008 May 7]. Collection and handling of fish pathology samples [Internet]. Available from: http://www.esb.enr.state.nc.us/Fishkill/fishsamp.html.

North Carolina Department of Health and Human Services. 2008a Apr 21. Safety and personal protection during fish kills [Internet]. [cited 2008 May 7]. Available from: http://www.esb.enr.state.nc.us/Fishkill/persprotect.html.

North Carolina Public Health. 2006a December 12. Health precautions around fish kills [Internet]. [cited 2008 May 8]. Available from: http://www.epi.state.nc.us/epi/oee/protect.html.

North Carolina Public Health. 2006b December 12 [Internet]. Pfiesteria. [cited 2008 May 8]. Available from: http://www.epi.state.nc.us/epi/oee/pfie.html.

North Carolina Low-Level Radioactive Waste Management Authority [Newsletter]. 1996. Spectrum 8(2):104.

North Carolina Low-Level Radioactive Waste Management Authority [Newsletter]. 1996. Authority begins comprehensive site assessment. Spectrum 8:1, 4.

[NSF] National Science Foundation [Internet]. 2006. NSF strategic plan FY 2006–2011. Chapter 1 Introduction: Strategic Planning in a Changing Landscape. [cited 2008 Aug 17]. Available from: http://www.nsf.gov/pubs/2006/nsf0648/nsf0648.jsp.

[NSF] National Science Foundation [Internet]. 2007a. Web policies and important links. [upated 2007 May 16; cited 2008 Jun 23]. Available from: http://www.nsf.gov/policies/.

[NSF] National Science Foundation [Internet]. 2007b. RSS feeds and podcasts. [updated 2007 Dec 06; cited 2008 Jun 23]. Available from: http://www.nsf.gov/rss/.

[NSF] National Science Foundation [Internet]. 2008a. About Funding. [updated 2008 Jan 09; cited 2008a. Aug 14]. Available from: http://www.nsf.gov/funding/aboutfunding.jsp.

[NSF] National Science Foundation [Internet]. 2008b January. NSF 08-1grant proposal guide: chapter I: pre-submission information. [updated 2008 Jan 19; cited 2008 Aug 17]. Available from: http://www.nsf.gov/pubs/policydocs/pappguide/nsf08_1/gpg_1.jsp#top.

[NSF] National Science Foundation [Internet]. 2008c [2008 January]. NSF 08-1grant proposal guide: chapter II: proposal preparation instructions. [cited 2008 Aug 17]. Available from: http://www.nsf.gov/pubs/policydocs/pappguide/nsf08_1/gpg_2.jsp#IIC2b.

[NSF] National Science Foundation [Internet]. 2008d [2008 January]. NSF 08-1grant proposal guide: chapter III: NSF proposal processing and review. [cited 2008 Aug 15]. Available from: http://www.nsf.gov/pubs/policydocs/pappguide/nsf08_1/gpg_3.jsp.

[NSF] National Science Foundation [Internet]. 2008e. About the National Science Foundation. [updated 2008 June 19; cited 2008 Aug 17]. Available from: http://www.nsf.gov/about/.

NSF [Internet] 2008f. About awards. [last update: July 10, 2008]. Available from: http://www.nsf.gov/awards/about.jsp.

[NSF] National Science Foundation. 2008g. NSF Congressional Highlight: President Signs Omnibus Appropriation Bill [Internet]. [cited 2008 Sep 10]. Available from: http://www.nsf.gov/about/congress/110/highlights/u08_0108.jsp.

[OASIS] Online Abstract Submission and Invitation System [Internet]. 2008. [cited 2008 Sep 28]. Available from: http://www.abstractsonline.com/.

Odlyzko AM. 1995. Tragic loss or good riddance? The impending demise of traditional scholarly journals. International Journal of Human-Computer Studies (formerly International Journal of Man-Machine Studies) 42:71–122.

O'Dell S. 1997. AXAF Observatory and scientific objectives. Presentation to the American Institute of Astronautics [Internet]. [cited 2008 May 20]. Available from: http://xanth.msfc.nasa.gov/xraycal/papers/AIAA/.

O'Haire D, Rubenstein H, Stewart R. 2007. A pocket guide to public speaking. Boston: Bedford/St. Martin's.

O'Keefe WF. 2001. The bridge from cold facts and hot rhetoric to rational climate policy. Fuel Processing Technology 71:131–7.

Okerson AS, O'Donnell JO. 1995. Scholarly journals at the crossroads: a subversive proposal for electronic publishing. Washington: Office of Scientific and Academic Publishing, Association of Research Libraries.

Olsen LA, Huckin TN. 1983. Principles of communication for science and technology. New York: McGraw-Hill.

Olsen LA, Huckin TN. 1991. Technical writing and professional communication. 2nd ed. New York: McGraw-Hill.

O'Neil J. 2002 Apr 30. Easy way to find ulcers: breathe. Vital Signs. New York Times; Sect. D6.

Open Science Grid [Internet]. 2008. [cited 2008 May 7]. Available from: http://www.opensciencegrid.org/.

[ORI] Office of Research Integrity. 2000. A research conference on research integrity. Science 290:1662–3.

[ORI] Office of Research Integrity [Internet]. 2002. Handling misconduct: investigations. [Updated 2002 Jan 24; cited 2003 Jan 25]. Available from: http://ori.dhhs.gov/html/misconduct/investigation.asp.

[ORI] Office of Research Integrity [Internet]. 2005a Aug 9. Policies—Regulations. [cited 2008 Sep 03]. Available from: http://ori.hhs.gov/policies/Requirements-Reg-6-05.shtml.

[ORI] Office of Research Integrity [Internet]. 2005b Nov 29. Responsible conduct of research (RCR) education. Policies. [cited 2008 Aug 17]. Available from: http://ori.dhhs.gov/policies/RCR_Policy.shtml.

ORI [Internet] 2006a. Policy on plagiarism. [Updated 2006 Jan 6; cited 2008 Dec 15]. Available from: http://oti.dhhs.gov/policies/plagiarism.shtml.

[ORI] Office of Research Integrity [Internet]. 2006b Aug 15. Responsible Conduct of Research. [cited 2008 Aug 18]. Available from: http://ori.dhhs.gov/education/.

[ORI] Office of Research Integrity [Internet]. 2008c May 9. International-Activities. [cited 2008 Sep 03]. Available from: http://ori.dhhs.gov/international/activity/index.shtml.

[OSTP] Office of Science and Technology Policy. 2000 Dec 06. Federal Research Misconduct Policy. Washington, D.C.: The White House.

Overbye D. 2002 Nov 19. After two scandals, physics group expands ethics guidelines. New York Times [Internet]. [cited 2008 Aug 17]. Available from: http://query.nytimes.com/gst/fullpage.html?res=9C02EFDB1130F93AA25752C1A9649C8B63&scp=2&sq=overbye%20scandal&st=cse.

Pacey A. 1983. The Culture of Technology. Cambridge (MA): The MIT Press.

Patrias K. 2007. Citing medicine: the NLM style guide for authors, editors, and publishers. 2nd edition [Internet]. Wendling, Daniel L., technical editor. Bethesda (MD): National Library of Medicine (US). [cited 2008 Jul 17]. Available from: http://www.nlm.nih.gov/citingmedicine.

Paul D. 2000. In citing chaos: a study of the rhetorical use of citations. Journal of Business and Technical Communication 14:185–222.

Paul D, Charney D. 1995. Introducing chaos (theory) into science and engineering: effects of rhetorical strategies on scientific readers. Written Communication 12:396–438.

Pechenik JA. 2007. A short guide to writing about biology. 6th edition. New York: Pearson Education.

Perkins J. 1999.Communicating in a global, multicultural corporation: other metaphors and strategies. Exploring the Rhetoric of International Professional Communication: an agenda for teachers and researchers. Lovitt CR, Goswami D, editors. Amityville (NY): Baywood Publishing Company, Inc. p 17–37.

Penrose AM, Fennell BA. 1993 Apr 1–3. Discourse conventions and the making of knowledge: linguistic socialization in academic disciplines. Conference on College Composition and Communication, San Diego, CA.

Peterson WL. 1989. Antimicrobial therapy of duodenal ulcer? Hold off for now! Gastroenterology 97:508–10.

Petrasso RD, Chen X, Wenzel KW, Parker RR, Li CK, Fiore C. 1989a. Problems with the g-ray spectrum in the Fleischmann et al. experiments. Nature 339:183–5.

Petrasso RD, Chen X, Wenzel KW, Parker RR, Li CK, Fiore C. 1989b. Response to Fleischmann et al. Nature 339:667–9.

Pfizer 2008. February 25. Pfizer voluntarily withdraws Lipitor advertising featuring Dr. Robert Jarvik. Pfizer Press Releases [Internet]. [cited 2008 Sep 03]. Available from: http://pfizer.com/news/press_releases/pfizer_press_releases.jsp?rssUrl=http://mediaroom.pfizer.com/portal/site/pfizer/index.jsp?ndmViewId=news_view&ndmConfigId=1010794&newsId=20080225006247&newLang=en#&source=google&HBX_PK=s_dr+robert+jarvik&HBX_OU=50&o=23127370/166376222/0.

Phytopathology [Internet]. 2008. Instructions to authors. [cited 2008 Jul 14]. Available from: http://www.apsnet.org/phyto/submit.asp.

PLoS (Public Library of Science) [Internet]. Homepage. [cited 2008 Nov 02]. Available from: http://www.plos.org.

Plutarch 2008 Aug 27. Moralia [Internet]. [cited 2008 Sep 1]. Available from: http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Plutarch/Moralia/De_defectu_oraculorum*.html.

Polkinghorne DE. 1988. Narrative knowing and the human sciences. Albany: State University of New York Press.

Pons S, Fleischmann M. 1993. Calorimetry of the Pd-D_2O system: from simplicity via complications to simplicity. Physics Letters A 176:118–29.

Popper K. 1959. The logic of scientific discovery. London: Hutchinson.

Poultry Science [Internet] 2008. Instructions to authors [updated Jun 2008; cited 2008 Jul 11]. Available from: http://ps.fass.org/misc/PS_instructions_2008.pdf.

[PRL] Physical Review Letters [Internet]. 2008. About Physical Review Letters. [cited 2008 Jul 13]. Available from: http://prl.aps.org/about.

Prelli LJ. 1989. A rhetoric of science: inventing scientific discourse. Columbia: University of South Carolina Press.

Prodger P. 1998. Appendix III: Photography and *the expression of emotions*. The expression of the emotion in man and animals. Darwin C. Ekman, P, editor. Oxford: Oxford University Press. p 399–410.

PubMedCentral [Internet]. 2008. PMC overview. [cited 2008 Jun 20]. Available from: http://www.pubmedcentral.nih.gov/about/intro.html.

Rae-Dupree J. 2008 Sept 7. When academia puts profit ahead of wonder. New York Times. Bus 4.

Reif-Lehrer L. 1990 May 14. For today's scientist, skill in public speaking is essential. The Scientist 4 (10):25.

Relman AS. 1999. The NIH e-biomed proposal—a potential threat to the evaluation and orderly dissemination of new clinical studies. New England Journal of Medicine 340:1828–9.

Revkin AC. 2007 January 1. A new middle stance emerges in debate over climate. New York Times [Internet]. [cited 2008 Jun 11]. Available from:http://www.newyorktimes.com/2007/01/01/science/01climate.html?_r=1&oref=slogin&emc=eta1&pagewanted=print.

Reynolds SP. 2008 May 18. Personal e-mail.

Reynolds SP, Borkowski K, Blondin J, Badenes C, Hughes J, Hwang U, Laming M. 2005. Kepler's supernova remnant: the youngest galactic remnant of a thermonuclear explosion. Proposal submitted to Cycle 07 of the *Chandra* X-ray Observatory (CXO) Research Program. North Carolina State University, Department of Physics.

Reynolds SP, Borkowski KJ, Badenes C, Hughes JP, Hwang U, Laming JM, Blondin, JM [conference abstract]. 2007a. A deep Chandra observation of Kepler's supernova remnant: a type IA supernova with circumstellar interaction. Conference abstract. 2007 Joint Meeting of the American Astronomical Society and the American Association of Physics Teachers.

Reynolds SP, Borkowski KJ, Badenes C, Hughes JP, Hwang U, Laming JM, Blondin, JM. 2007b. A deep Chandra observation of Kepler's supernova remnant: a type IA supernova with circumstellar interaction. The Astrophysical Journal: 668: L135–L138.

Reynolds SP, Borkowski KJ, Hwang U, Hughes JP, Badenes C, Laming JM, Blondin JM [Poster]. 2007c. A deep Chandra Observation of Kepler's Supernova Remnant: a Type Ia Supernova with circumstellar interaction. 209th Meeting of the American Astronomical Society (2007 AAS/AAPT Joint Meeting). Seattle, WA. January 2007.

Riley K. 1991. Passive voice and rhetorical role in scientific writing. J. Technical Writing and Communication 21:239–257.

Roach J. Delphic oracle's lips may have been loosened by gas vapors. National Geographic News [Internet]. [cited 2008 Jun 18]. Available from: http://news.nationalgeographic.com/news/2001/08/0814_delphioracle.html.

Roberts A. 2005 Jun 06. LaTeX isn't for everyone but it could be for you [Internet]. [cited 2008 Jun 24]. Available from: http://www.osnews.com/story/10766/LaTeX_isnt_for_everyone_but_it_could_be_for_yo u.

Rose M. 2004. The mind at work: valuing the intelligence of the American worker. New York: Viking Penguin.

Rosenthal E. 2007 Nov 17. Climate panel says immediate changes are necessary. New York Times (national edition). International 3.

Ross PI, Jalkotzy MG. 1992. Characteristics of a hunted population of cougars in southwestern Alberta. Journal of Wildlife Management 56:417–26.

Rowe A. 2008 May 31. Why are senior pemale scientists so heavily outnumbered by men? Wired [Internet]. [cited 2008 Sep 03]. Available from: http://blog.wired.com/wiredscience/2008/05/why-are-senior.html.

Rowland F. 1997. Print journals: Fit for the future? Ariadne 7 [Internet]. [cited 2002 Dec 30]. Available from: http://www/ariadne.ac.uk/issue7/fytton.

Roy R [Opinion]. 1993. Science publishing is urgently in need of major reform. The Scientist 7:11.

Roy S, Watzke M. 2007 Jan 9. A star's death comes to light. NASA [Internet]. [cited 13 Aug 2008]. Available from: http://www.nasa.gov/centers/marshall/news/news/releases/2007/07-004_prt.htm.

Rublee PA, Remington DL, Schaefer EF, Marshall MM. 2005. Detection of Dinozoans *Pfiesteria piscicida* and *P. shumwayae*: a review of detection methods and Geographic Distribution. Journal of Eukaryotic Microbiology. 52(5): 83–89.

Rymer J. 1988. Scientific composing processes: how eminent scientists write journal articles. Advances in writing research Jolliffe DA, editor. Norwood, NJ: Ablex. Vol 2, Writing in academic disciplines. p 211–50.

Sacredsites.com [Internet]. 2006. The Temple of Delphi, Greece. [cited 2008 Jun 21]. Available from: http://www.sacredsites.com/europe/greece/tholos_temple_delphi.html

Samarajiva R. 1990. Implications of technological change for scientific communication in the third world: a case study. Asian Journal of Communication 1:81–97.

Samraj B. 2002. Introductions in research articles: variations across disciplines. English for Specific Purposes 21: 1-17.

Samson DC Jr. 2006. Writing about science in newspapers and magazines. Currents: 1–10.

Scheetz MD. 2000. Promoting integrity through "instructions to authors": a preliminary analysis. Investigating Research Integrity: Proceedings of the First ORI Research Conference on Research Integrity [Internet]. Washington: Office of Research Integrity. [cited 2003 Mar 25]. Available from: http://ori.dhhs.gov/html/publications/rcri.html.

Schultz W. 2000 Dec 18. *Science* strikes a deal with Celera over paper. Chemical & Engineering News 5–6.

Schwitters RF. 1996 Feb 16. The substance and style of "big science." The Chronicle of Higher Education 43:B2.

Science. 1995. Conduct in science [series]. Science 268:1705–19.

Science [Internet]. 2008. General information for authors. [cited 2008 Jul 13]. Available from: http://www.sciencemag.org/about/authors/prep/gen_info.dtl#categories.

Science.gov Alliance [Internet]. About Science.gov. [Updated 2008 Jan 23; cited 2008 Jun 24]. Available from: http://www.science.gov/.

Science Blogs [Internet]. 2008. [cited 2008 May 18]. Available from: http://www.scienceblogs.com/.

SciVee. 2008. SciVee: make your research known [Internet]. [cited 2008 May 07]. Available from: http://www.scivee.tv/.

Scorecard.com [Internet]. 2005. Ethylene. Scorecard: The pollution information site. [cited 2008 May 21]. Available from: http://www.scorecard.org/chemical-profiles/summary.tcl?edf_substance_id=74-85-1.

Scott JB, Longo B, Wills KV, editors. 2006. Critical power tools: technical communication and cultural studies. New York: SUNY Press.

Seiken J. 1992 Mar 2. A reviewer's-eye view of evaluation processes at NIH, NSF. The Scientist 19.

Selfe CL. 1999. Technology and literacy: a story about the perils of not paying attention. College Composition and Communication. 50:411–36.

SerVaas C. 1994 May/June. The ulcer cure from down under. Saturday Evening Post 62–5.

Shabecoff P. 1989 May 8. Scientist's words on global warming changed by OMB to soften conclusions. News and Observer (Raleigh, NC); Sect A:1, 4.

Shah R. 2007. Dyspepsia and helicobacter pylori. British Medical Journal 334: 41–43.

Shapin S. 2001. Proverbial economies: how an understanding of some linguistic and social features of common sense can throw light on more prestigious bodies of knowledge, science for example. Social Studies in Science 31:731–69.

Shea EP. 2008. How the gene got its groove: figurative language, science, and the rhetoric of the real. Albany (NY): State University of New York Press.

Shida Y, Gater W. 2007 Oct 1. I tune, you tube, we rule. CAP 1:30–31.

Shogren E. 2008 Jan 21. Trees lost to Katrina may present climate challenge. NPR: All things considered [Internet]. [cited 2008 Jun 2]. Available from: http//www.npr.org/templates/story/story.php?storyId=17814049.

Sierra Club. 2003. EPA's environmental report leaves out global warming [Internet]. [cited 2003 Sep 25]. Available from: http://www.sierraclub.org/globalwarming/epareport2003.asp.

Skolimowski H. 1966. The structure of thinking in technology. Technology and Culture 7(3): 371.

Smith R. 1997. Peer review: reform or revolution? Time to open up the black box of peer review. British Medical Journal 315:759–60.

Spiller HA, Hale JR, De Boer JZ. 2002. The Delphic Oracle: a multidisciplinary defense of the gaseous vent theory. Journal of Toxicology—Clinical Toxicology 40:189–96.

Spragins E. 1999. A metaphorical analysis of the debate on physician-assisted suicide. New York: Edwin Mellen Press.

Srinivasan M. 2008. Energy concepts for the 21st century. Current Science 94 (7): 842–83 [Internet]. [cited 2008 May 07]. Also available from: http://www.newenergytimes.com/Library2/2008/2008SrinivasanEnergyConcepts.

Stelter B. 2008 Jun 15. The buffet of Internet access is going a la carte. New York Times (National Ed.) National Y1, Y21.

Stiegler B. 1998. Technics and time. Beardsworth R, Collins G, translator. Palo Alto (CA): Stanford University Press.

Strickland E. 2008 July 21. Nuclear fusion researcher found guilty of scientific misconduct. Discover Blogs/80 Beats [Internet]. [cited 2008 Sep 04]. Available from: http://blogs.discovermagazine.com/80beats/2008/07/21/nuclear-fusion-researcher-found-guilty-of-scientific-misconduct/.

Sullivan D. 1991. The epideictic rhetoric of science. Journal of Business and Technical Communication 5:229–45.

Swales J. 1984. Research into the structure of introductions to journal articles and its application to the teaching of academic writing. Common ground: shared interests in ESP and communication studies. Williams R, Swales J, Kirkman J, editors. New York: Pergamon. p 77–86.

Swales J. 1990. Genre analysis: english in academic and research settings. Cambridge: Cambridge University Press.

Swales JM. 2004. Research genres: explorations and applications. Cambridge UK: Cambridge UP.

Swaminathan N. 2007 Feb 7. Out of Africa: Stomach ulcer bug migrated with humans 60,000 years ago. Scientific American [Internet]. [cited 2008 Jun 21]. Available from: http://www.sciam.com/article.cfm?id=out-of-africa-stomach-ulc.

Swarts J. 2004. Cooperative writing: achieving coordination together and apart. ACM Special Interest Group for Design of Communication (SIGDOC). Proceedings of the 22nd annual international conference on design of communication: 83–89.

Swarts J. 2006. Coherent fragments: the problem of mobility and genred information. Written Communication 23 (2): 173–201.

Swarts J. 2008a. Together with technology: writing review enculturation, and technological mediation. Amityville (NY): Baywood Pub.

Swarts J. 2008b Jun 24. Personal email.

Swarts J, VanNorman M. 2008. Effective information design for PDAs in veterinary medical education. Journal of Veterinary Medical Education 35(1): 118–128.

Sweeting LM [Internet]. 2000. Professional ethics for scientists: annotated bibliography for a course in ethics in science at Towson University. [updated 2000 Jan; cited 2002 Jun 11]. Available from: http://www.towson.edu/~sweeting/ethics/ethicbib.htm.

Sylvester, RJ. 1988. A bayesian approach to the design of phase II clinical trials. Biometrics 44:823–36.

Szpak S, Mosier-Boss PA, editors. 2002. Thermal and nuclear aspects of the Pd/D2O system—Volume 1: a decade of research at Navy laboratories. Technical Report 1862, San Diego: Office of Naval Research/Space and Naval Warfare Systems Center [Internet]. [cited 2008 May 21]. Available from: http://www.spawar.navy.mil/sti/publications/pubs/tr/1862/tr1862-vol1.pdf.

Taubes G. 1995. McGill: analyzing the data. Science 268:1714.

TeraGrid [Internet]. About. [cited 2008 May 21]. Available from: http://www.teragrid.org/about/.

Terracini ED, Brown FA. 1962. Periodisms in mouse “spontaneous” activity synchronized with major geophysical cycles. Physiological Zoology 35:27–37.

Tierney J [Internet]. 2008 July 15. A new frontier for Title IX: science. New York Times. [cited 2008 September 03]. Available from: http://www.nytimes.com/2008/07/15/science/15tier.html?_r=1&oref=slogin.

Thompson DK. 1993. Arguing for experimental “facts” in science: a study of research article results sections in biochemistry. Written Communication 8:106–28.

Toulmin S, Goodfield J. 1962. The architecture of matter. New York: Harper and Row, 1962.

Toulmin S, Rieke R, Janik A. 1984. Chap 14, Argumentation in science. An Introduction to Reasoning. 2nd ed. New York: Macmillan. p 229–64.

Tufte ER. 1997.Visual explanations: images and quantities, evidence and narrative. Cheshire (CT): Graphics Press.

Tufte ER. 2003 Sept. The cognitive style of PowerPoint. Cheshire (CT): Graphics Press.

Tufte ER. 2006. Beautiful evidence. Cheshire (CT): Graphics Press.

Turbayne CM. 1970. The myth of metaphor. Columbia: University of South Carolina Press.

Uglow J. 2002. The lunar men: five friends whose curiosity changed the world. New York: Farrar, Straus and Giroux.

[USDA] United States Department of Agriculture [Internet]. 2008. About USDA: budget for 2009. [cited 2008 Sep 10]. Available from: http://www.usda.gov/wps/portal/usdahome?navid=BUDGET.

[USDHHS] U.S. Department of Health and Human Services [Internet]. 2008. NIH research portfolio online reporting tool: research project success rates by type and activity for 2007. [updated 2008 Jul 10; cited 2008 Aug 14]. Available from: http://report.nih.gov/award/success/Success_ByActivity.cfm.

Van Noorden R. 2007 April. Cold fusion back on the menu. Chemistry World [Internet]. [cited 2008 May 25]. Available from: http://www.rsc.org/chemistryworld/News/2007/March/22030701.asp.

VandeKopple WJ. 1998. Relative clauses in spectroscopic articles in the *Physical Review*, beginnings and 1980: some changes in patterns of modification and a connection to a possible shift in style. Written Communication 15:170–202.

Veldhuyzen van Zanten SJO, Goldie J, Riddell RH, Hunt RH. 1988. *Campylobacter pylori* infection. Annals of Internal Medicine 109:925.

Warren JR [Internet]. 2005a. Transcript of Nobel Prize Lecture, delivered 08 Dec 2005. p 250–51. [cited 2008 May 4]. Available from: http://nobelprize.org/nobel_prizes/medicine/laureates/2005/ warren-lecture.html.

Warren JR [Internet]. 2005b. Video of Nobel Prize Lecture, delivered 08 Dec 2005. [cited 2008 May 4]. Available from: http://nobelprize.org/nobel_prizes/medicine/laureates/2005/warren-lecture.html.

Warren JR, Marshall B. 1983. Unidentified curved bacilli on gastric epithelium in active chronic gastritis. Lancet 1:1273–5.

Watson JD. 1968. The double helix. New York: New American Library.

Watson JD, Crick FHC. 1953. A structure for deoxyribose nucleic acid. Nature 171:737–8.

Weaver AC, Morris BB. 2008 February. Social networking. Computer 97–100.

WebMD.com [Internet]. 2008 January 11. Helicobacter pylori tests. Digestive Disorders Health Center. [cited 2008 Jun 18]. Available from: http://www.webmd.com/digestive-disorders/helicobacter-pylori-tests.

Wells JA. 2008. Final report: Observing and reporting suspected misconduct in biomedical research. The Gallup Organization for The Office of Research Integrity. Washington, D.C.: The Gallup Organization.

White WJ. 2001. A communication model of conceptual innovation in science. Communication Theory 11:290–314.

[WHO] World Health Organization [Internet]. 2000. “Life-saving” scientific information boost via internet to health researchers in Africa, Central Asia and Eastern Europe. [Internet; press release]. [cited 2002 Jun 18]. Available from: http://www.who.int/inf-pr-2000/en/pr2000-76.html.

Wilkes J. 1990 Jan 8. Scientists should spend more time communicating with the public. The Scientist 15.

Winsor DA. 1993. Constructing scientific knowledge in Gould and Lewontin’s “The Spandrels of San Marco.” Understanding scientific prose. Selzer J, editor. Madison: University of Wisconsin Press. p 127–44.

Winsor DA. 2001. Learning to do knowledge work in systems of distributed cognition. Journal of Business and Technical Communication 15:5–28.

Wynne B. 1992. Misunderstood misunderstanding: social identities and public uptake of science. Public Understanding of Science 1:281–304.

Wysocki AF. 2004. The multiple media of texts: how onscreen and paper texts incorporate words, images, and other media. What writing does and how it does it: an introduction to analyzing texts and textual practices. Bazerman C, Prior P, editors. Mahwah (NJ): Lawrence Erlbaum Associates, Publishers.

Yu PK. 2007. Reconceptualizing intellectual property interests in a human rights framework. Michigan State University College of Law. Legal Studies Research Paper Series 40: Research Paper No. 04-01: 1039–39.

Zehr SC. 2000. Public representations of scientific uncertainty about global climate change. Public Understanding of Science 9:85–103.

Ziman JM. 1968. Public knowledge: the social dimension of science. Cambridge: Cambridge University Press.

Ziman J. 2000. Are scientific questions debatable? Social Epistemology. 14:187–99.

Credits

Chapter 1

Figure 1.3: Hall J. Adapted from "Decisions, decisions, decisions." *Psychology Today*. Copyright © 1971 Sussex Publishers, LLC.

Chapter 3

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Chapter 4

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Chapter 8

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Chapter 9

Warren JR and Marshall B, "Unidentified curved bacilli on gastric epithelium in active chronic gastritis." *The Lancet*, Vol. 321, page 1273–1275, Copyright © 1983 Elsevier.
Martin J. Blaser, "Gastric *Campylobacter*-like organisms, gastritis, and peptic ulcer disease," *Gastroenterology*, Vol. 93, pages 371–383. Copyright © 1987 Elsevier.
Graham et al., "Effect of treatment of *Heliobacter pylori* infection on the long-term recurrence of gastric or duodenal ulcer," *Annals of Internal Medicine*, 1992, Vol. 116: 705–708. American College of Physicians.
Chiba, Veldhuyzen van Zanten, Sinclair, Ferguson, Escobedo, and Grade, "*Treating Helicobacter pylori* infection in primary care patients with univestigated dyspepsia: the Canadian adult dyspepsia empiric treatment—*Heliobacter pylori* positive (CADET-*Hp*) randomized controlled trial." *British Medical Journal*.
M. J. Blaser, "An endangered species in the stomach," from *Scientific American*, February 2005. Copyright © 2005 Scientific American, Inc.

Chapter 10

Burkholder JM et al. "New 'phantom' dinoflagellate is the causative agent of major estuarine fish kills," *Nature* 1992 Vol. 358:407–410. Macmillan Publishers Ltd.
Corrections. *Nature* Vol. 360: 768. Huyghe, Patrick. "Killer Algae," *Discover Magazine*, 1993 April.
Burkholder, J. M. and P. A. Rublee. Proposal submitted to the (US) National Sea Grant College Program. North Carolina State University, Department of Botany, 1994. Reprinted by permission of the authors.
Burkholder, JM et al. "Demonstration of toxicity to fish and to mammalian cells by *Pfiesteria* species: Comparison of assay methods and strains" from *Proceedings of the National Academy of Sciences*, Copyright © 2005 National Academy of Sciences.
Rublee et al. (2005). "Detection of the Dinozoans *Pfiesteria piscicida* and *P. shumwayae*: A Review of Detection Methods and Geographic Distribution." Copyright © *The Journal of Eukaryotic Microbiology*. Blackwell Publishing Ltd.
Englehaupt (2007). "New *Pfiesteria* toxin identified." *Environ. Sci. Technol*., Feb 15, 2008 41(4), 160. Copyright © 2008 American Chemical Society.

Chapter 11

De Boer J. Z., Hale J. R. "A study of the evidence for geological faults and gaseous emissions at the sanctuary of Delphi, in order to test the validity of ancient testimonial concerning the origins of the oracle of Apollo," 1996. Reprinted by permission of the author.
De Boer JZ, Hale JR, Chanton J. "New evidence for the geological origins of the ancient Delphic oracle (Greece)" from *Geology* 29:707–10. 2001. Copyright © 2001 *Geology*. Geological Society of America.
Spiller HA, et al. "The Delphic oracle: a multidisciplinary defense of the gaseous vent theory." *Journal of Toxicology—Clinical Toxicology*. Copyright 2002 by Informa Healthcare-Journals.
William J. Broad, "For Delphic oracle, fumes and visions," *New York Times*, pages 1 and 4.
John R. Hale, Jelle de Boer, Jeffrey Chanton, and Henry Spiller, "New evidence for geological origin of the Delphic oracle: active faults, gaseous emissions, and architectural anomalies in the Temple of Apollo," *American Journal of Archaeology*, 2002, Vol. 106 (2): 261–262.
Etiope G, et al. "The geological links of the ancient Delphic Oracle (Greece): A reappraisal of natural gas occurrence and origin" from *Geology* April 2006. Geological Society of America.

Chapter 12

From "The Chandra X-ray Observatory (CXO) Research Program Cycle 10 Call for Proposals" Copyright © 2008.
Reynolds et al. (2005). Kepler's Supernova Remnant: the Youngest Galactic Remnant of a Thermonuclear Explosion. Proposal submitted to Cycle 07 of the Chandra Guest Observer Program. Reprinted by permission of the authors.
Reynolds et al. (2007a). Abstract for poster presentation at the January 2007 meeting of the American Astronomical Society: A Deep *Chandra* Observation of Kepler's Supernova Remnant: A Type 1a Event with Circumstellar Interaction.
Ron Cowen. "Solving a 400-year-old supernova riddle." *Science News Online*. Copyright © 2007 by Society for Science and the Public.
Naeye R. "Kepler Saw a White Dwarf Explode" from *Sky & Telescope*, April 2007. Copyright © 2007 *Sky & Telescope*.
Reynolds, et al. "A Deep Chandra Observation of Kepler's Supernova Remnant: A Type 1a Event with Circumstellar Interaction." *The Astrophysical Journal*, Oct 2007. American Astronomical Society.

Chapter 13

"The Summary, Background and Request for Proposal from DOE's National Institute for Climatic Change Research." Feb. 28, 2008. Copyright © 2008 NICCR.
Chambers & Hurtt (2006). Hurricane Impacts on Structure and Functioning of U.S. Coastal Forests. One-page project summary; proposal submitted to NICCR. Reprinted by permission of the authors.
Chambers J, et al. "Hurricane Katrina's Carbon Footprint on U.S. Gulf Coast Forests," from *Science* 318: 1107 (2007). AAAS.
Kaufman, M. "Katrina, Rita Caused Forestry Disaster—Die-Off Will Add to Buildup of Greenhouse Gases," from *The Washington Post*, 11/16/07 © 2007. *The Washington Post* All Rights Reserved.
Knutson et al., "Simulated reduction in Atlantic hurricane frequency under twenty-first century warming conditions." Copyright © 2008. Macmillan Publishers Ltd: *Nature Geoscience*.
Revkin, AC. "A New Middle Stance Emerges in Debate over Climate," from *The New York Times*, 1/1/07 © 2007 *The New York Times* All Rights Reserved.

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