SCIENTIFIC ENGLISH

"When *I* use a word," Humpty Dumpty said, in a rather scornful tone, "it means just what I choose it to mean—neither more nor less."

"The question is," said Alice, "whether you *can* make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master—that's all."

—Lewis Carroll, *Through the Looking Glass and What Alice Found There*

LANGUAGE AS A TOOL OF SCIENCE

Scientific English is a number of things. It is a communication tool, a culture of writing, and a plain and readable manner of writing with specific compositional strategies and uses of language—all of which permit the community of scientific researchers to conduct its professional affairs. In desiring essentially to be masters of their own language, scientists rely on narrowly restricted uses of words. The linguist Leonard Bloomfield has explained the benefits of this scientific way of communicating: "The use of language in science is specialized and peculiar. In a brief speech the scientist manages to say things which in ordinary language would require a vast amount of talk. His hearers respond with great accuracy and uniformity. The range and exactitude

of scientific prediction exceed any cleverness of everyday life: the scientist's use of language is strangely effective and powerful. Along with systematic observation, it is this peculiar use of language which distinguishes science from non-scientific behavior."[1]

The primary purpose of this chapter is to delineate and illustrate the unique linguistic values that the scientific community places on the way it uses words for conducting its activities and achieving its goals. How do scientists use language? How does using English (or for that matter any other language) scientifically differ from other uses to which language may be put? The explanations in the first sections of this chapter on the professional, historical, and philosophical contexts that define scientific uses of language will be followed in the remaining sections by actual examples of scientific English in practice. Defining scientific English risks making hard and fast distinctions about the way language works or among the things that humans do with it. Therefore, making general pronouncements in an attempt to draw lines between kinds of uses of language is bound to be met, on one intellectual front or another, by resistance. Language study today is a complex field that utilizes multiple perspectives, including those of composition and rhetorical theory, communication, cognitive psychology, sociology, anthropology, and neurobiology.

All that said, there are nonetheless practical distinctions to be drawn. In practice, it is safe to say that a basic criterion for defining scientific uses of language is that of the user's intent. Scientists use language strictly and narrowly as a communication tool. This distinguishing intention of communication shapes the professional culture and compositional style of scientists as writers. The communication model of using language suggests that words are merely physical objects or mechanical tools. Applied to scientific language, this rather simplistic view limits the role of words to something like conveyor belts in automated factories, delivering to their readers units of objective information derived from and in the service of the equally objective methods of scientific inquiry. In contrast, non-scientific uses of language like those in the literary world give prominence to personal and subjective expression. In actuality, the use of scientific language has inherent biases and subjectivities that, however desirable it may be to eliminate them, are an inescapable dimension of the human presence in written texts. Here we have, then, the key distinguishing criterion: the priority that scientists as writers, as users of the English language, give to the objective information that words impart. This central priority of communicating information demands that scientists use the tool of language responsibly and effectively to serve a scientific purpose, with the aim of convincing

their intended readers of that purpose's value. There is a wide range of documents that scientists can use for achieving this effect with their discourse.

The fundamental point to keep in mind is this: any attempt to understand scientists as writers must begin with the observation that their work and their documents depend vitally upon language. From note taking to publishing and teaching, language is the tool that gives sense to scientific activity. Whatever scientists do and observe, everything they come to know or to hypothesize, is mediated through language: "There is no real world that scientists know independently of the linguistic, graphic, and mathematical formulations by which they conceive it," one author on scientific writing has underscored.[2] Without the resources of language, the scientific enterprise would not progress for long. The mathematician Jacob Bronowski asserted that "the method of science, the objectification of entities, abstract concepts, or artificial concepts like atoms, is in fact a direct continuation of the human process of language, and that it is right to think of science as being simply a highly formalized language."[3] What does "a highly formalized language" mean? What are the specific and practical rules of scientific English? To understand what it means to use scientific English effectively—at the level of words, sentences, and paragraphs—it is helpful to understand what scientific English is in its broader contexts: What are its scope, aims, and linguistic qualities? What are the professional relationships among scientist-writers, their documents, and their intended readers? What is the historical origin of the scientific attitude toward language? It is only through the lens of the historical evolution of modern science's view of language that the effectiveness of today's scientist-writers can be gauged. Therefore, the specific practical examples given later in the chapter will make more sense in light of this modern linguistic evolution. The basic nature of scientific English can be illuminated within two basic contexts: first, as constituting a practical communication framework, a culture of writing, founded on certain professional aims and purposes, and second, as a utilitarian attitude that cultivates an ethic of plainness in the use of language for scientific ends.

THE COMMUNICATION RANGE OF SCIENTIFIC ENGLISH

The sense of scientific English as a tool for organized communication is not disconnected from the classical Greek and Roman philosophies of discourse that two millennia later have come to shape the way college English, especially report writing, is taught today. Expository writing in any discipline has roots in Aristotle's methods for supporting a thesis or in Cicero's way of di-

viding an oration that easily translates into the various parts of a research report. Therefore, much of traditional college English is also part of what defines scientific English. Also apparent, however, is that a relative newcomer to the academic world—Francis Bacon's experimental science—brought along new and scientifically plain ways of using language for new purposes in new documents for new readers. Scientific English, then, has its own professional culture of writing. Its historical evolution since Bacon actually has extended rather than rejected Aristotle's and Cicero's contributions to the effective use of language. The Baconian outlook became an irrepressible impetus toward the emergence of the ethic of mathematically plain scientific communication.

Given the prime motive of communication in the culture of scientific writing, several questions naturally follow: To communicate what? Why? To whom? In what forms and styles? The geneticist Bentley Glass observed that there are "at least five distinct obligations" shared by scientists in their professional communication:

- publishing their methods and findings truthfully, clearly, and fully so that they can be verified and extended by fellow researchers;
- disseminating their findings more widely through abstracting and indexing media;
- writing critical reviews that synthesize current knowledge in their field;
- sharing their knowledge and its practical implications with the public;
- teaching what they know to future generations of scientists.[4]

To Glass's list, one may add the writing of laboratory notes on research methods and outcomes, proposals of research to acquire grant funding, and daily on-the-job communication. Given all these goals, we can identify six basic kinds of purposes that researchers have when they write particular documents for particular readers in order to achieve those purposes effectively: recording and archiving, professional exposition or dissemination of research results, teaching, job duties, seeking financial resources, and informing citizens (Table 1.1). In scientific activity itself, the most immediately important uses of language occur in making a reliable and permanent record or archive of research methods, outcomes, and conclusions (see Chapter 2). The next professional purpose for researchers is to share their work with peers through publication. Beyond these prime archival responsibilities—which allow the profession to advance in the collaborative spirit it requires—scientists also must share their knowledge in various forms with a range of reader-

Table 1.1 Purposes, types, audiences, and styles of scientific writing

Purpose	Document Types	Intended Readers	Linguistic Style
Recording and archiving	Laboratory notes, with other preservable forms of documentation, such as equipment, printouts, photos, and special artifacts for verifiability	Self; research collaborators; workplace supervisors	Informal to highly formal notations in arcane shorthand; lab jargon
Professional exposition and synthesis	Scholarly articles and books; abstracts; notes and visual media for conference papers and seminars; letters; e-mail	Researchers in same or related field	Highly formal, with heavy use of jargon
Teaching	Textbooks, syllabi, electronic slides, Web-based information, and other pedagogical materials	Students at all levels	Moderately to highly formal, with parallel range in jargon
Performing job duties	On-the-job communications, including e-mail, letters, memoranda, meeting minutes, and activity or progress reports; internal and external	Research associates, colleagues, and administrators	Informal to highly formal; low to high level of jargon
Seeking research resources	Grant proposals to government agencies, corporations, and philanthropic foundations	Granting agency officials; peer reviewers	Highly formal; moderate to heavy use of jargon

(*continued*)

Table 1.1 (*continued*)

Purpose	Document Types	Intended Readers	Linguistic Style
Informing citizens	Articles, essays, and books; special letters; Web-based material; creative forms; expert testimony and other consulting documents	General public; special-interest groups	Formality and jargon low to moderate

constituents. These interested readers range from students and fellow researchers to public officials and citizens. Each of the important purposes in scientific writing calls for a particular nuance in the basic manner of using scientific English, in how formal or detailed the communication may need to be. A culture of writing also means a culture of readers. The particular choices that scientists make as writers must be guided by assumptions about their readers.

It is not enough, then, for effective and responsible scientist-writers to know their subject. They also must know a document's readers; for example, how much do *they* know about the subject? Is the document for a research supervisor, a journal, a public official? How should a document's technical formality and style be adjusted for its reader(s)? Do the writer's intentions match the reader's expectations? Consider any given document mentioned in Table 1.1 in light of this question: What would the reader expect? Scientists do write for their all-important and diverse readers with their range of expectations. The professional standards for *doing* science are reflected in the strict standards and practices for *writing* science. The modern scientific community's culture of writing also demands a unique sense of plain language. This sense of scientifically plain English is both a cause and an effect of the rise of the experimental sciences inspired by Francis Bacon's revolutionary new senses of human "knowledge," of "reality," and of "truth." One prefatory caveat: Although the historical evolution of the notion of modern scientific language as thoroughly objectified is well documented, today scientific language is more accurately seen as also having subjective elements—psychosocial and political—that may affect its ultimate truth value. Before considering that humanized dimension of scientific language, however, a broader sense of its history is necessary to explain its Baconian roots.

THE LEGACY OF SCIENTIFICALLY PLAIN ENGLISH

The truly monumental achievement of the so-called father of modern science, Francis Bacon, is twofold: First, he set human learning on a new course that resulted in what today we call modern science, which seeks to advance human understanding through observing and manipulating our natural and physical world. Sometimes we refer to this modern method of study as the "experimental" or "hard" or "exact" sciences—like biology, chemistry, and physics—with the primary sense of the word "research" as inquiry that goes on in a laboratory setting. Second, and just as important, Bacon set the new communication standard or ethic of linguistic plainness that empowered his new scientific program to achieve the grand success it has enjoyed to this day. In short, Bacon at once provided both the method and the language of modern science. What, then, is the linguistic revolution that brought us scientifically plain English? What does it mean to be scientifically plain? What are the specific qualities of plain writing that are expected in scientists' writing?

OLD AND NEW USES OF LANGUAGE: WORDS VERSUS THINGS

In Bacon's view, traditional or past uses of language—stilted, convoluted, clouded with subjective and flowery language—were no longer adequate for advancing human understanding. At the dawn of the seventeenth century, as he laid out a new and bold scientific enterprise, Bacon also chastised those who "hunt more after words . . . than after the weight of matter, worth of subject, soundness of argument, life of invention, or depth of judgment." With the rise of modern science, the dominance of the old attitude of taking pleasure in linguistic artistry and subjective thoughts for their own sake—as in literary writing—was displaced by the Baconian ethic of linguistic utility: how effectively the words serve their readers in delivering "real" knowledge with clarity and exactness. Whereas the traditional linguistic style reveled in subjective ambiguity, the new one was to be utterly and objectively plain in the service of true learning. When Bacon's dream of a modern research institution became a reality in the Royal Society of London, the society's members officially resolved "to reject all the amplifications, digressions, and swellings of style: to return back to the primitive purity, and shortness, when men deliver'd so many *things,* almost in an equal number of *words.* They have exacted from all their members, a close, naked, natural way of speaking; positive expressions; clear senses; a native easiness: bringing all things as near the Mathematical plainness, as they can." Rather than a return to

some golden era of "natural" writing, however, Bacon's was a new and future-oriented standard that reflected modern science's forward-looking way of thinking and learning. The essence of the pivotal linguistic revolution that accompanied the modern scientific revolution is the emergence of this new ethic of "mathematical plainness" that values things over words. This Baconian attitude toward language can be translated, or paraphrased, into the following current mantra of scientific plainness: "There should be little figurative language . . . an economy of words . . . intelligible, clear, and unequivocal meanings . . . common words which are closer to material realities . . . no emphasis upon or interest in the mode of expression for its own sake . . . Rhetorical ornaments and sheer delight in language represent a pernicious misplacing of emphasis, and in the end destroy the solid and fruitful elements of knowledge."[5] For scientists, writing that is worth reading has real *things* to offer in mathematically plain language. The utility of scientifically plain English lies in those two fundamental and interconnected features: first, that it has practical material to offer, and second, that it communicates that material plainly so it can be used by the reader.

The key shift in the rise of the new sciences with their new senses of knowledge and truth was in what was meant by "things." Baconian things were not the same as, say, the relatively subjective Aristotelian or Ciceronian things. According to Robert Adolph: "Bacon means by 'things' objective physical reality and its causes, existing before and after the writer's perception of them and independent of him. The Baconian writer, like his ideal researcher, submits his mind to these things, rather than constructing a mental edifice of his own according to some ideal pattern or looking within himself to relate the physical world to his own private concerns."[6] Scientists as writers must offer objective knowledge to their readers in plain language. Scientifically plain writing is objective, simple, precise, concrete, direct, and unadorned, with straightforward constructions and the minimum number of words needed to deliver the document's material things to its readers. Of these pivotal changes in human history, it is rightly put that "no clearer proclamation could be desired of the victory of the new world-picture, the fact world, over the older worlds of traditional feeling. 'Truth' was the exclusive possession of the Real Philosophy."[7] The new language of science focused not on psychological but rather on material reality. The Baconian attitude toward language largely defines the present culture of writing in the community of scientific researchers, wherein words are used in very specific, constrained, highly formalized, and generally impersonal ways that accord with scientific objectivity. The old emphasis on the writer and on artistic language has given way in the past four

centuries to the modern scientific emphasis on words merely as neutral conveyors of information for the practical benefit of the reader.

THE PLAIN ENGLISH MOVEMENT AND READABLE SCIENTIFIC WRITING

Since the 1970s and 1980s, and not just coincidentally with the emergence of the computer age and then the information age, the ethic of mathematical plainness in scientific discourse has been at the center of the so-called Plain English Movement. Computers have made it easier both to create and to retrieve vast seas of technical information, which users expect to be reader-friendly. One document designer's definition is not much different from that of the Baconians: "Plain English means writing that is straightforward, that reads as if it were spoken. It means writing that is unadorned with archaic, multisyllabic words and majestic turns of phrase that even educated readers cannot understand. Plain English is clear, direct, and simple." The historical circumstances in the last quarter of the twentieth century sparked a reinvigorated demand for readable technical language. Technical businesses like International Business Machines and General Motors developed plain-writing guidelines for their employees and have supported them with in-house desktop publishing resources. In government, President Jimmy Carter led the way with his signing of Executive Order 12044 on March 24, 1978, part of which required that federal regulations be "written in plain English and [be] understandable to those who must comply with [them]." In the world of public affairs, plain and reader-friendly English is not just more effective for getting the job done; it is also more economically efficient. This reinvigorated call for plainness by the public was accompanied by a widespread interest in theories of document readability.[8]

Defining Scientific Readability

In academic writing, the *Publication Manual of the American Psychological Association* (APA) tells us how to be scientifically clear and "agreeable" for the reader; as to how scientific prose should read, there are plenty of current variations on the Baconian theme of plain and measured English. One experienced editor of scientific books and journals writes: "The beauty of science is in the science, not in the language used to describe it. The beauty of English is its ability, when properly used, to express the most complicated concepts in relatively clear words and to point up the beauty of the science. Successful communication in science involves that magic word, *clarity,* a kissing cousin of *simplicity.*" Again, the call in science is for reader-centered writing. In our age of information technology, reader-friendly communication

will only continue to grow in demand. The basic principle remains simple: No matter how much information a document may contain, if comprehension of it is blocked by inaccessible or imprecise language then the writing is not much more useful than the pre-Baconian varieties of linguistic ambiguity and opaqueness. Fundamentally, the concept of readability simply places readers at the center of communication, facilitating their decoding of information without making them expend undue time and effort re-reading. Writing readable scientific prose means putting into practice, using various compositional strategies, the principles of objective wording valued by research scientists. The more generalized call of the Plain English Movement for reader-centered writing, with its readability theories, also produced mathematical formulas for measuring how readable a document is.[9]

Measuring Scientific Readability

Readability formulas are designed to measure qualities of writing that comport with a scientific style, with simple, direct, and concise wording. The word-processing software you use probably has a feature to calculate the readability of your writing. Stand-alone style and grammar checkers also have been marketed under such names as RightWriter, CorrectGrammar, Editor, and Grammatik. These programs use readability formulas, such as Flesch-Kincaid, Dale-Chall, Spache, and Gunning, to measure the number of technical words, number of syllables, and length of sentences and paragraphs in a written work. To get a sense of how readability formulas work, try computing the so-called Gunning Fog Index by taking a short technical report and following three simple steps:

1. *Average sentence length (ASL):* Count the sentences in several 100-word samples and divide the total word count by the sentence count.
2. *Percentage of hard words (PHW):* Count the words in your samples that have at least three syllables, excluding proper names, simple compound words (e.g., afternoon, humankind), and verbs with three syllables due to *-ed, -es,* or *-ing* endings (e.g., enriches, extruded).
3. *Gunning Fog Index (GFI):* Add your ASL and PHW from the first two steps and multiply that sum by 0.4. For example, an ASL of 15 and a PHW of 21 adds up to 36, which, when multiplied by 0.4, yields a GFI of 14.4.[10]

The GFI value represents the document's level of difficulty as a grade level, which in this case means that readers should have a grade 14, or college sophomore, reading ability. The various formulas work their magic in different