SCIENTIFIC ENGLISH
A Guide for Scientists and Other Professionals

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by Robert A. Day

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The rare Arabian Oryx is believed to have inspired the myth of the unicorn. This desert antelope became virtually extinct in the early 1960s. At that time several groups of international conservationists arranged to have 9 animals sent to the Phoenix Zoo to be the nucleus of a captive breeding herd. Today the Oryx population is over 800, and nearly 400 have been returned to reserves in the Middle East.

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Preface

It should be our pride to teach ourselves as well as we can always to speak as simply and clearly and unpretentiously as possible, and to avoid like the plague the appearance of possessing knowledge which is too deep to be clearly and simply expressed.

—Karl Popper

This book is brilliantly (if illegitimately) conceived from this germ of thought: When used simply, English is a simple language.

In the corners of our craniums (or crania if you prefer), we have probably all registered the fact—and it is a fact—that the most profound thoughts ever expressed have usually been expressed in simple language. Plato recognized this fact two millennia ago when he said "Beauty of style and harmony and grace and good rhythm depend on simplicity."

Yes, we know this. But too often we forget. When we forget, we use *long* words in *long* sentences. We start with a simple thought, but then we dress it up in fancy words. As a result, we sometimes lose clarity. At worst, the thought has been overwhelmed by the verbiage; at best, the thought takes second place to the fancy ornamentation surrounding it.

I have spent many years at the interface between science and English as an editor and publisher of scientific books and journals. I have learned two facts that now serve as the thesis for this book: 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*.

To be simple, writing usually needs to be short; that is good for me because it matches my attention span.

But, you say, English has a massive vocabulary, and English professors have concocted a zillion rules; therefore, it is virtually impossible to write in English with clarity and with confidence.

To you, I say, this book and its simple guidelines just might improve your knowledge of English and your ability to communicate in English. If you want to learn about such esoteric things as the subjunctive mood and the pluperfect tense, do *not* read this book; if you want to write with simple, straightforward accuracy, this book just might help. Although it is aimed directly at those who write articles for publication in primary scientific journals, many of this book's principles may also be useful in other types of writing.

English *is* simple. Consider this: English has a truly massive vocabulary of some 500,000 words, but how many different *kinds* of words does it have? The answer is nine, the nine "parts of speech." You could construct nine pigeonholes, and every one of those 500,000 English words would fit into one (or more) of those pigeonholes. Thus, to get a real feel for the use of English, you do not need to master a half-million words (you *will* need a few thousand, however); instead, you need to look at the nine kinds of words and learn a few simple rules about using them.

Then, you can group words into phrases and clauses. How many phrases and clauses are there? There are essentially four main types of phrases and two types of clauses. Of course, you need a few definitions and a few rules. Simple rules.

Next, you can combine phrases and clauses into sentences. How many different types? A mere six. Every sentence ever constructed in English is of one of these six types. Relatively simple rules for constructing and punctuating these six types of sentences can be stated.

Finally, knowing how to construct sentences, the basic building blocks of communication, you can go on to paragraphs and then to papers and books and all the rest.

Am I oversimplifying? Perhaps. But I have tried in this book to simplify English. In the past, too many grammarians have established far too many arcane "rules" about the use of our language. Some of these people believed (or pretended?) that English can be used precisely only by the literati. Common folk (scientists, for example) couldn't be expected to master the profusion of arbitrary rules that were supposed to relate to English. When grammarians dangled their rules, many of us got splitting headaches from worry about dangling participles and split infinitives.

I have good news. You *may* split infinitives. In fact, you may, on occasion, violate every one of the "rules" dreamed up by generations of

grammatical fussbudgets. (When I was young, I was told to always obey my superiors. I said that I would, if I ever found any.) The obvious purpose of grammatical rules is to facilitate clear communication. When rules of grammar do not serve this purpose, they should be disregarded.

Remember only one main rule. A sentence is a unit of *thought.* If you write it down, it becomes a unit of expression. The simple truth is this: If you can think logically, you can write logically. A logical sentence is a good sentence. Now let's turn that around: A good sentence is a logical sentence. So, just possibly, you might learn to *think* more clearly if you learn to *write* more clearly. Perhaps this book will help.

> Clear communication, which is the prime objective of scientific reporting, may be achieved by presenting ideas in an orderly manner and by expressing oneself smoothly and precisely. By developing ideas clearly and logically, you invite readers to read, encourage them to continue, and make their task agreeable by leading them smoothly from thought to thought.
>
> —*Publication Manual* of the American Psychological Association

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Contents

Chapter 1
Principles of Scientific Writing

It is impossible to dissociate language from science or science from language, because every natural science always involves three things: the sequence of phenomena on which the science is based; the abstract concepts which call these phenomena to mind; and the words in which the concepts are expressed. To call forth a concept a word is needed; to portray a phenomenon, a concept is needed. All three mirror one and the same reality.

—Antoine Laurent Lavoisier

KINDS OF WRITING

Writing can be used in many different ways to express ideas. Thus, there are many kinds of writing. One style of writing might be appropriate for one purpose but totally inappropriate for another. Many of the "writing" courses in our colleges and universities are appropriate for teaching creative writing. In some ways, however, they are inappropriate for teaching the principles of scientific and technical writing.

I would not for a moment denigrate creative writing. Life would be bleak indeed without the grand heritage provided by our poets, novelists, dramatists, and essayists. However, there is a world of difference between creative writing and scientific writing. The one deals primarily with feeling, emotion, opinion, and persuasion. The other emphasizes the dispassionate, factual recording of the results of scientific investigations. The one uses language of extraordinary beauty and complexity, with fascinating metaphors and other figures of speech; scientific writing uses (or should use)

prosaic words of certain meaning, organized simply into precise phrases, clauses, sentences, and paragraphs.

Does this mean that scientific writing never expresses "feeling, emotion, opinion, and persuasion"? Of course not. The practice of science is engaged in by people (scientists) who have the same complement of good and bad points (did someone say "egos"?) as the rest of us. Thus, I admit that the above paragraph is too idealistic, because scientific writing is often, sometimes heavily, infested with persuasion, opinion, etc. But isn't the ideal of "dispassionate, factual recording of the results of scientific investigations" worth striving for? It is the thesis of this book that it is.

Does this mean that scientific writing must be dull? Not necessarily. Dullness can result when writers give up the pretty ornaments of creative writing; however, if clarity is increased, the reader may enjoy the comprehension and not notice the loss of ornaments. In writing, as in the making of jewelry, true elegance often results from the simple rather than the ornate.

A fundamental difference between creative writing and scientific writing was well stated by the novelist John Fowles: "For what good science tries to eliminate, good art seeks to provoke—mystery, which is lethal to the one, and vital to the other."

Scientific writing, the subject of this book, is not the same as "science writing." Both are related, of course, because the subject matter of both is science. However, an important distinction to keep in mind is that "scientific writing" is written by scientists for an audience of scientists, whereas science writing is written (sometimes by scientists, sometimes by journalists) for an audience of nonscientists (or scientists reading outside their own narrow discipline). Thus, the vocabulary, tone, and complexity of these two types of writing differ.

Further, scientists must write in different ways for different purposes, using one language in their research papers, a slightly different language in their review papers, and a very different language in communications directed to lay audiences. The emphasis in this book is on the language of research papers, but the guidelines presented and the examples used may be of use in many types of writing.

GUIDING PRINCIPLES

The principles of scientific writing derive from the purposes of scientific writing. The basic purposes of scientific publications are (1) to *record* (the archival function of our research journals); (2) to *inform* peers; and (3) to *educate* the next generation of scientists.

The archival use of journals is very significant, because a journal in a library can be consulted by a great variety of readers for any number of reasons over a long time period. It is primarily this potential audience that scientists should write for. Jargon and unexplained abbreviations, although understandable to peers, should therefore be avoided. Students also will benefit from such consideration.

I would guess that a great many of the really bad (incomprehensible) papers that appear in our journals are bad because the authors ignored the archival and student audiences for their papers and wrote in the arcane shorthand of laboratory jargon. Moreover, scientists sometimes go out of their way to flaunt this jargon, and they (only the worst of them, fortunately) often combine their jargon with an incredibly verbose style of writing that leads to real confusion.

Too many scientists, and perhaps members of all professions, want to "sound" scholarly. Therefore, they sometimes dress up a simple thought in an outrageous costume. Sometimes, the thread of the idea gets lost along the way, and all we see is the frayed costume.

As for me, I don't want the costume. If I have learned anything from my years of experience in scientific writing, editing, and publishing, it is this: Simplicity of expression is a natural result of profound thought.

> The theory that scientific discovery is impersonal or, as it is called, objective, has had several evil consequences. One is that the style of describing and publishing the results of scientific research which is fashionable today has been developed to sustain it. One should write, one is told, in the third person, in the passive voice, without betraying conviction or emphasis, without allusion to any concrete or everyday object but with the feeblest indifference and the greatest abstraction. This practice has proved to be so readily acquired that it has now, for a whole generation, been debauching the literary languages of the world. The result has been that science, instead of being a source of strength and honesty is in fact robbing the common speech of these very qualities. For the style itself is neither strong nor honest.
>
> —C. D. Darlington

Chapter 2
Style of Scientific Writing

By all means, you should write in your own personal style, but keep in mind that scientific writing is not literary writing. Scientific writing serves a completely different purpose from literary writing, and it must therefore be much more precise.

—*The ACS* (American Chemical Society) *Style Guide*

DEFINITION OF STYLE

The word "style," when applied to writing, pertains not only to writing style, but also to the basic organization of a scientific paper or other publication, the editorial style of the journal or publisher, and the typographical style of the publisher or printer. In short, style defines the *personality* of a publication. Each publication has its own style, its own personality. Well-edited journals have very distinctive styles. Careful writers make it their business to learn the general stylistic conventions used in their field and also the specific style requirements of the particular journal for which they are preparing a manuscript.

GENERAL STYLE IN SCIENTIFIC WRITING

In a general way, the style of scientific writing is (or should be) distinctive in two principal ways. First and foremost, as already stated, scientific writing should be simple and clear. Its purpose is not to entertain or to paint pretty pictures, but to inform.

But, you say, why should scientific writing be simple, plain, and ordinary? Why can't it be *interesting?* I would argue, and argue strongly,

that *good* scientific writing is often beautiful in its elegant simplicity. However, if you are faced with a choice between expressing a thought with a beautiful but complex metaphor or with simple, concrete words, choose the concrete words. There is really only one essential goal in scientific writing: clarity. And short words are not necessarily dull. Lincoln's famous Gettysburg Address contained only 267 words, of which 196 (73%) were one-syllable words.

The second general aspect of style in scientific writing is organization. Of course, all types of writing are "organized"; however, scientific writing is rigidly organized, and each scientific paper is organized *in the same way.* (This is true for the vast majority of research papers, less true for other types of papers produced by scientists.) This type of organization has come to be known by the acronym IMRAD (Introduction, Methods, Results, and Discussion). Inasmuch as a book describing the IMRAD system of organization already exists (Day, R.A., *How to Write and Publish a Scientific Paper,* 3rd ed., Oryx Press, Phoenix, 1988), I shall not expand upon the subject here.

SPECIFIC STYLE IN SCIENTIFIC WRITING

Style has so many aspects that entire books have been written on the subject. These books (style manuals) are filled with useful information pertaining to specific fields. I strongly recommend that every scientist own at least one style manual. Biologists should own the *CBE Style Manual: Guide for Authors, Editors, and Publishers in the Biological Sciences,* 5th ed., Council of Biology Editors, Inc., Bethesda, MD, 1983. Microbiologists should own, in addition, a copy of the *ASM Style Manual for Journals and Books,* American Society for Microbiology, Washington, DC, 1991. Chemists should own J.S. Dodd's *The ACS Style Guide: A Manual for Authors and Editors,* American Chemical Society, Washington, DC, 1986. Medical and biomedical researchers should own either (or both) the *American Medical Association Manual of Style,* 8th ed., Williams & Wilkins, Baltimore, 1989, or E.J. Huth's *Medical Style & Format: An International Manual for Authors, Editors, and Publishers,* Williams & Wilkins, Baltimore, 1987. Psychologists should own the APA's *Publication Manual,* 3rd ed., American Psychological Association, Washington, DC, 1983. Professionals in *any* field can find a wealth of information in *The Chicago Manual of Style,* 13th ed., University of Chicago Press, Chicago, 1982.

I also recommend that every scientist read the Instructions to Authors of a journal before starting to write a paper, consult the Instructions while writing the paper, and check the paper against the Instructions before submitting it. These Instructions are usually short, but they often contain the

highly specific information that defines the editorial and typographical personality of that particular journal as well as the basics of how and where to submit manuscripts. Authors who ignore these specific journal requirements are likely to receive many rejection letters.

SPELLING AND GRAMMAR

Naturally, proper grammar should be used, and words should be spelled correctly. But correctness may sometimes depend on style. Is it "color" or "colour"? The answer depends on whether the journal uses American English or British English. Is "labeled" or "labelled" correct? Unfortunately, the dictionaries seem to be about evenly split, so both are "correct." However, journals and publishers are likely to choose one or the other, and their copy editors will attempt to invoke this adopted style consistently. Is it "ameba" or "amoeba"? Is it "orthopedics" or "orthopaedics"? The simpler (and newer) spelling seems to be replacing the older usage, but many journals retain the older style.

Does this matter? In individual instances, such choices seem to have little meaning. But, collectively, such considerations may have great importance. For one thing, consistent spelling simplifies things for the reader, especially for the reader whose native language is not English. If the same word is spelled two different ways in one article or in one issue of a journal, a reader is likely to assume that the different spellings somehow mean different things. Confusion, or at least delayed comprehension, can result.

More importantly, slight alterations in spelling sometimes do indeed mean different things. Two words commonly confused by some scientists are "phosphorus" and "phosphorous"? Both are correct, but the meanings are different. The word "phosphorus" is a noun, and it refers to the element phosphorus. The word "phosphorous" is an adjective, not a noun; it refers to compounds containing phosphorus, in particular those with a valence lower than the valence in phosphor*ic* compounds.

Are such "slight alterations in spelling" really significant? Yes, for two main reasons. First, even a slight misspelling can cause confusion of meaning. Second, misspellings can foil even the best computer search programs; as scientists increasingly rely on computers to access journal articles, variations in spelling become ever more dangerous.

Stylistic conventions relate not only to spelling but to such things as word choice and capitalization. Which is correct: formalin, Formalin, or formaldehyde? The term formaldehyde is a generic name, and it is normally acceptable. The term Formalin is a registered trademark, and this proprietary status is recognized by the capital F. The use of "formalin" without a capital is incorrect. Finally, "Formalin" should not be cavalierly changed to

"formaldehyde" (on the grounds that most journals prefer generic names to proprietary names), because formaldehyde exists as a gas and Formalin is a solution containing a small amount of methanol.

BY THE NUMBERS

Because numbers are used so often in science, it will be helpful to memorize the stylistic rule that a great many scientific publications follow: Spell out one-digit numbers (one to nine) and use numerals for all larger numbers (10 and up).

> One for the money, two for the show.
>
> All 13 of us went to the lecture.

Now that you have memorized that simple rule, I must unfortunately ask you to memorize the main exceptions.

Spell out any number that starts a sentence.

> Thirteen of us went to the lecture.

Use numerals whenever numbers are followed by units of measure.

> I added 3 ml of distilled water.

In a series, use numerals if any number in the series is 10 or more.

> I did 4 experiments on Monday, 5 on Tuesday, and 11 on Wednesday.

PRINTING STYLE

The careful author consults the Instructions to Authors *and* a recent issue of a journal before submitting a manuscript to that journal. The author needs answers to such questions as these: What types of headings and subheadings are used? Are footnotes allowed? Which style of literature citation is used? What is the format for tables and figures and their legends? How are chemical and mathematical formulas presented? Get all the answers, and then write with style.

> It is usually found that only stuffy little men object to what is called "popularization," by which they mean writing with a clarity understandable to one not familiar with the tricks and codes of the cult. We have not known a single great scientist who could not discourse freely and interestingly with a child. Can it be that the haters of clarity have nothing to say, have observed nothing, have no clear picture of even their own fields?
>
> —John Steinbeck and Ed Ricketts

Chapter 3
The English Language

Language is the only instrument of science, and words are but the signs of ideas.

—Samuel Johnson

THE BEAUTY OF ENGLISH

Modern science contends with some extremely complicated problems. Hence, the language scientists communicate in must be capable of precise descriptions of complex problems and concepts.

Fortunately, scientists have such a language in English. The skilled user of English has a rich supply of words to describe and differentiate the finest gradations of meaning. We can even play games. For example, the word "stand" has many different meanings: two common usages are "to rise to an erect position" and "to tolerate." Thus, we can describe a person who doesn't like desk work as one who might say "I can't stand sitting." A strange concept, perhaps, but probably no stranger than the classic "I think I will sit out this dance." The remarkable thing, of course, is that the English language has this tremendous array of words that can be constructed into phrases, clauses, and sentences in a seemingly inexhaustible variety of ways if we play by the rules of logic.

ENGLISH—THE INTERNATIONAL LANGUAGE

It has often been said that science is international. Now it can be said that English is international. For scientists, especially, English is virtually the *only* language.

Look at what has happened in the field of microbiology, for example. For many years, the principal language of this science was German, and the leading journal was the renowned *Zentralblatt für Bakteriologie.* This distinguished journal is still published, and the title remains the same. But the articles are in English.

The *Journal of Antibiotics,* published in Tokyo, is perhaps the most important journal in the world dealing with this subject. Every word is in English.

For French, perhaps the denouement (one of many useful words that came into English from French) to its use as a language of science occurred in 1989, when the January issue of the famous *Annales de l'Institut Pasteur* was published under a new name, *Research in Immunology.* Every article was in English, as were the Instructions to Authors, the book reviews, and even the small-print subscription information. An accompanying editorial had this to say:

> Times have changed . . . biological sciences, and immunology in particular, have evolved, with an enormous increase in the volume of research work performed and very distinct requirements in terms of scientific communication . . . . All journals must now find their roots in the international community at large and interact with a wide network of scientists and institutions. Such will be the case for "Research in Immunology", which will now replace the one hundred and one year old "Annales".

UNIVERSALITY OF ENGLISH

English is not just the international language of science. Increasingly, English is becoming the international language of business and of the computer.

In late 1986, Public Television presented a six-part series (since published in book form) titled "The Story of English." In the first scene of the first episode, viewers saw and heard the conversation between an airplane pilot and a control tower operator while the plane was being brought in for a landing. Every word was in English. Eventually, the narrator broke in to inform the audience that they were witnessing a pilot-tower conversation during a flight originating and ending in Italy. The tower, of course, must handle both domestic and international flights, and use of a single language is a necessity.

The world is getting smaller indeed, and English is becoming the international language. Any final resistance to this trend will be wiped out by the economics of the computer. Computer software and documentation