

The Basic Elements of Writing a Scientific Paper: The Art of Scientific Style

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Winston Churchill is reported to have said of literary critics who insisted that sentences never end in a preposition (1), "This is the type of arrant pedantry up with which I shall not put." This historic example of what is and what is not considered proper in good writing applies to technical scientific writing as well as other, more literary forms of communication. For those who do not write regularly, the experience can be intimidating. Knowing what is important and reviewing some common pitfalls of science writing at the outset is always helpful.

Scientific writing is a form of writing called expository. Its primary goal is to explain. Implicit in any expository writing is another goal: to persuade. The two go hand in hand, for it is hard to explain a scientific fact without taking a position on it. The goal, then, is both to have your readers *understand* you and to *convince* them that your interpretation of your data is the only correct one.

Correct and Concise Usage: Less is More

Good writing begins with a profound respect for words, their precise denotations, and their connotations. Do not use three or four words when one will suffice. Every word of every sentence should work for maximum efficiency to achieve clarity and brevity. What looks like a natural gift to write is really great persistence, compulsiveness, and discipline.

Along with brevity and clarity, accuracy is the third element of good scientific writing. The words "scientific" and "data" themselves suggest knowledgeable, documented, and organized information. Any manuscript should be written with the goal of its becoming a permanent and accurate record in the scientific literature.

Organization and Continuity

Good scientific writing, then, is direct and definite. It demonstrates confidence and inspires confidence in your readers. Weak writing, on the other hand, reveals uncertainty. One serious fault that weakens the reporting of careful scientific work is the lack of organization. Results reported in a disorganized manner take more time to interpret than readers are willing to spend. Without a well-organized presentation of the data, years of work and money may be wasted.

For good organization, effort is required. For any subject, interrelationships should be addressed and then recapitulated as they relate to other elements. Transitional sentences, which bridge thoughts, are often missing in poorly written pieces.

Inherent in good organization is continuity. Every sentence should connect the one preceding it to the one following it. Often neglected are explicit connectors that signal to the reader that the direction of the argument is changing, being paralleled, or being contrasted to an earlier one. The signposts to use in these cases are conjunctive adverbs or brief transitional phrases that signal the thought coming next. The following list offers a variety of choices for creating continuity and greater precision. Use them often.

above all
accordingly
and so
again
also
besides
but
consequently
finally
first
for example
for instance
furthermore
hence
however
in addition
in conclusion
indeed
in fact

in particular
instead
in summary
likewise
moreover
more specifically
nevertheless
nonetheless
on the other hand
rather
second
similarly
so
still
then
therefore
though
thus
to sum up
yet

Specific Parts of Scientific Papers

Science writing is a unique process because scientific papers consist of specific elements that include the title, introduction, methods, results, discussion, conclusions, summary, and bibliography. Do not underestimate the importance of the title. It is a clear statement of the paper's content and contains key words that will be indexed for information retrieval systems.

The introduction gives the necessary historical perspective and then states *why* the work was done. It should seize the attention of the readers and emphasize the area of interest. Often the introduction is more effective if it is written last.

Unfortunately, the structured methods and results are often written as rote copies of previous, similar works. This can result in incongruities between these two complementary sections. The important point is to give the reader enough accurate information to allow a good understanding of *how* the work was done and *what* the results were.

In the discussion and conclusion, it is necessary to return to the argument you planted earlier in the introduction. Your readers cannot be left seeing the trees but no forest. A comparison of your work with others' and explanations of similarities or discrepancies form the discussion, which moves to a logical justification and conclusion of your paper.

The writing of a summary follows easily. The summary is composed of highlights of each preceding section, and though it often appears first as the paper's abstract, it is best written last.

It is hoped that your readers will respond intellectually to your information. Disagreement with your conclusions is far better than disinterest in ideas that are not clearly enough stated to be understood. The goal of all writing is to get a message across. A well-written paper is a pleasure to read and a great satisfaction to the seeker of scientific information.

Common Pitfalls

The hardest step for most writers is getting past the first draft. One must be able to say, "This wonderful creation of mine still needs work." Compulsiveness is a trait of good writers. When you think that you have a finished product, go back over it several times to check the specific points outlined

This is publication no. 388 from the Eleanor Roosevelt Institute for Cancer Research.

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below which identify some of the most common errors and weaknesses.

Read your manuscript through once, looking exclusively at your subjects and verbs. Are subjects and verbs matched for singular and plural forms? Check that verb tense and form denote conviction instead of doubt. Do not use constructions like "appeared to be" and "can be seen to" if verbs like "occurs" and "shows" would state the same ideas. The latter not only result in more decisive statements but also use fewer words.

Next read through your manuscript checking to see that each procedure described in the methods section was actually performed and reported on in the results section. At the same time, compare every figure and table to the statements attributed to them in the text. Make certain that the text fully describes these illustrations. In addition, captions for figures and tables should stand by themselves as brief explanations of such visual representatives of the data.

Recall that brevity and clarity are essential. Do not use three or four words where one will suffice. Why say "in the event that" instead of "if"; "on the order of" instead of "about"; "for the reason that" instead of "since"; or "one and the same" instead of "the same"?

Finally, check the cited references to insure that they actually contain the material attributed to them. Do not rely on references from similar papers. Typing errors are very common among the numbers used in bibliographical information.

Odds and Ends

What follows is a catch-all of various stylistic and procedural items that particularly plague science writing.

Punctuation

Semicolons. A semicolon replaces a connecting word like "and" and can be replaced by a period; it is not a substitute for a comma. It is often used to combine two or more related independent clauses. Another common use of the semicolon is to separate items in a series. This is not a violation of the rule that each part must be a complete sentence; the form may be viewed as elliptical, the missing words being understood. The writings of Mark Twain and G. B. Shaw abound with semicolons. An illustration of the use of semicolons in good scientific writing occurs in the paragraph below (2) in which the words "These hybrids have been used for" are understood as a common prelude to each phrase separated by semicolons:

In this paper I review newer experimental developments in our laboratory, which are based on development of auxotrophic and other mutants of mammalian cells and the construction of a series of hybrid Chinese hamster ovary (CHO) cells containing single, or small numbers of, human chromosomes. These hybrids have been used for genetic, biochemical, and differentiation analysis of cell surface macromolecules; regional mapping of particular genetic markers; an approach to biochemical understanding of the human aneuploid diseases; a new method for detection of environmental mutagens and carcinogens; and an amalgamation of somatic cell genetic techniques with those of recombinant DNA in order to devise a new method for mapping the human genes, which promises wide application and high resolving power (2).

Commas. Insert a comma where there is a light natural pause. Reading aloud your words is the best way to determine this. Conjunctive adverbs and signpost expressions like "moreover," "therefore," and "on the other hand," must be set off by commas both before and after if they occur in the middle of a sentence. Never connect two independent clauses by a comma; use only a semicolon.

Colons. The colon, like the semicolon, joins related thoughts; however, it is used only when the first thought introduces the second. Any colon used properly can be replaced by "that is" or "namely."

Abbreviations

Abbreviations that have not become standardized must be

defined the first time they are used in your text. Some well-known abbreviations that are generally acceptable, but commonly misused, are given with their full meaning:

- e.g., *exempli gratias*, for example—Use commas before and after and periods after each letter of the abbreviation.
- et al., *et alii*, and others—Since "et" is a complete Latin word, do not use a period after it. The second word is abbreviated, and a period must follow it.
- i.e., *id est*, that is—As with "e.g.," i.e. must be set off with commas before and after and periods after each letter.
- viz., *videlicet*, namely—Also set this off with commas before and after.

Some Commonly Misused Words

Affect-effect. "Affect" is commonly used as a verb that means to influence and less commonly as a noun that means an artificiality. "Effect" is used commonly as a noun to mean the result or outcome and less commonly as a verb that means to cause or to bring about.

Consensus. It is redundant to use the phrase a "consensus of opinion" because consensus means a collective opinion.

Criterion-Criteria. Criterion is singular; criteria is plural. Other related words are medium-media, datum-data, and stratum-strata.

Different from-Different than. The preferred preposition after *different* is *from*; however, *different than* is acceptable if it avoids a wordy clause.

Factor. This word resonates with scientific overuse; its synonyms—element, ingredient, and component—are underused.

First-Firstly. "First" is a genuine adverb itself and should be used without the suffix "-ly." "Second," "third," etc., fall into this same category.

Imply-Infer. If an author implies something in his paper, something is hinted at; the reader infers or understands the hint.

Like-As. In formal usage "like" should be used only as a preposition. "As" is acceptable as both a preposition and a conjunction.

Only. Make sure "only" is placed immediately before the word it is intended to modify.

Principal-Principle. A rule or truth is a principle and it is used only as a noun. Its homonym, "principal," is a noun or adjective and means chief or leading.

Revert back. Simply use "revert"; "revert back" is redundant.

Reason is because. "Because" means "for that reason"; this is a common redundancy.

Thus-Thusly. "Thus" is an adverb by itself and needs no suffix.

Unique. There is only one of a kind of a unique thing. "Most unique," "very unique," or "rather unique" events do not exist. Use "unusual" or "rare" in place of these incorrect terms.

Everyone can develop skill in the use of language that conveys scientific information in a meaningful, persuasive, and understandable manner. It is an accomplishment that is learned and that grows by paying attention to good writing to see how these skills are used to their fullest. None of these learned skills are intended to conflict with an individual's writing style, which is a unique portrayal of the author's personality. A natural writing style is the best and most pleasurable to read; such a style comes only with practice and a desire to improve your writing. Two quotes, one from a scientist and the other from a well-known literary figure, sum up these ideas appropriately.

When we encounter a natural style, we are astonished and delighted; for we expected to see an author, and we find a man.

Pascal (3)

Interviewer: How much rewriting do you do?

Hemingway: It depends. I rewrote the last page of *Farewell to Arms* thirty-nine times before I was satisfied.

Interviewer: Was there some technical problem there? What was it that stumped you?

Hemingway: Getting the words right.

Ernest Hemingway
interviewed by George Plimpton (4)

Literature Cited

- (1) Flesch, R., "The Art of Readable Writing," Collier Books, New York, 1962, p. 149.
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- (3) Pascal, "Pensees," Section I, no. 29.
- (4) Hemingway, E., "The Paris Review Interviews," Second series. Plimpton, G. (Ed.) Viking, New York, 1965, p. 222.