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

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 rough copies of previous, similar works. This can re-
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.

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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 ensure 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 below which the 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
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 autotrophic and
other mutants of mammalian cells and the construction of a se-
ries of hybrid Chinese hamster ovary (CHO) cells containing sin-
gle, or small numbers of, human chromosomes. These hybrids
have been used for genetic, biochemical, and differentiation anal-
ysis of cell surface macromolecules; regional mapping of partic-
ular genetic markers; an approach to biochemical understanding of
the human aneuploid diseases; a new method for detection of en-
vironmental 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 in-
troduces the second. Any colon used properly can be replaced
by “that is” or “namely.”

Abbreviations

Abbreviations that have not become standardized must be
defined only in a margin in italics or roman type if the
adjective and means chief or leading.

Revert back. Simply use “revert”; “revert back” is redun-
dant.

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 per-
sonality. A natural writing style is the best and most plea-
surable to read; such a style comes only with practice and a
desire to improve your writing. Two quotes, one from a sci-
entist and the other from a well-known literary figure, sum
up these ideas appropriately.

When we encounter a natural style, we are astonished and de-
lighted; 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.

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**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)

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**Scenarios in Science**

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Many students who are nonscience majors are enrolling in science courses today at both the high school and college levels. These students are interested in learning more than science history and fact. They want to know how science and technology are affecting them now and how it will affect them in the future. A technique that we have employed while teaching nonscience majors at our school involves the use of scenarios as introductions to the topics under discussion. These scenarios are sometimes biased and may take either a positive or negative view of the subject matter. Most important, the scenario gets the student involved in the topic and sets the stage for an in-depth discussion once a particular chapter in the course has been covered.

Here is our suggested method of operation. A scenario is presented to the student in hand-out form at the time that a new topic is introduced. The majority of students have not yet begun to read the assigned chapter. A short discussion of the subject matter follows and students are allowed to ask questions pertaining to the topic. On many occasions it becomes apparent that the students are not familiar with the subject matter and are not able to discuss the issues raised by the scenario. The students clearly see the need to read the text assignment, as well as any supplementary material available, and attend the lectures so that they will be able to participate in an in-depth discussion of the scenario upon conclusion of the topic.

What follows are examples of three scenarios that we use in our nonscience majors chemistry course. The first scenario of war and destruction and decided instead to pool their knowledge and wealth to improve the human condition. Many of the problems that plagued human society in the late 1900's were brought under control by 2025. Programs to stabilize population growth and produce adequate food for those living on the planet were becoming effective. Medical science, as well as the natural sciences such as biology, chemistry, and physics reached new frontiers.

However, it was the discovery in this year of 2050 that was to bring startling news to the scientific community. Scientists and engineers had transplanted the brain of an individual into an artificial body. The new body had the appearance of a human being and functioned in a completely humanlike manner. The transplant had been a success. The ramifications of this event were awesome. This new body would not age and would last 200 years!

**Scenario: The Day We Lost New Jersey**

It is a bright, sunny day in New Jersey on April 5, 1990. New Jersey has grown through the years to become a major industrial state in the northeast; a state that consumes a tremendous amount of industrial power. Almost 80% of this power is supplied by ten nuclear power plants located either in the state or surrounding it. Two of these power plants are off the coast of Atlantic City, built on manmade islands in the Atlantic Ocean. New Jersey is not a state that is prone to many natural hazards. Tornadoes, hurricanes, and earthquakes are infrequent. That is why it came as such a complete surpris...
in our non-science majors chemistry course. The first scenario is entitled “New Bodies for Old.” It is used as an introduction to the course when discussing the impact of chemical science and chemical technology in today’s world. The second scenario is called “The Day We Lost New Jersey.” It presents a somewhat biased view of nuclear energy and serves as an introduction to the topic of nuclear energy and nuclear power. We must point out, lest we offend the proponents of nuclear power, that although this particular scenario appears somewhat one-sided, it is quite successful in getting the students involved in the subject matter. A well-balanced view of nuclear energy is presented in class. When students have read the assigned material and attended lectures, they have sufficient information to allow them to make their own decisions regarding nuclear power.

The third scenario entitled “Starting Off Right” is used to introduce the subject of food chemistry. The scenario deals with the topic of infant formula versus breast milk. As you read these short scenarios, keep in mind their main purpose which is to whet the student’s interest and foster involvement in the subject matter.

Scenario: New Bodies for Old

The year is 2050. During the first fifty years of the 21st century science and technology were used by the governments of the earth to improve the quality of life on this planet for all people. It was the year 2000 when the major powers on this planet agreed to stop spending billions of dollars in weapons

inherent. That is why it came as such a complete surprise when on this day a major earthquake hit the state, sending shock waves from Boston to Virginia Beach. The quake was as strong as the one that devastated the city of San Francisco in the early 1900’s. However, in New Jersey the results were more devastating. The earthquake demolished numerous buildings and tore up many roads. The quake was centered on the central Jersey coast, not a highly populated region. Large numbers of people were not killed by the initial devastation. The problems arose with the four nuclear power plants located just off the coast and with those located on the coast of the Jersey shore.

Although these plants were supposed to be earthquake-proof, they were not strong enough to withstand the power of this quake. Sections of these power plants broke away. Cooling systems were lost and the atomic cores melted down. Radioactive clouds of steam were dispersed into the atmosphere. Offshore breezes blew the clouds across the state. Tens-of-thousands of New Jersey residents died of the effects of this radiation and tens-of-thousands more were to die of radiation-linked diseases.

Scenario: Starting Off Right

It is the year 2010; a step into the 21st century. A baby has just been born and has been given to her mother to be fed. The baby is being breast-fed and a natural process is taking place once again. The mother is relaxed and comfortable and the baby is being well nourished.