EMBO reports

viewpoint

Writing readable prose

When planning a scientific manuscript, following a few simple rules has a large impact

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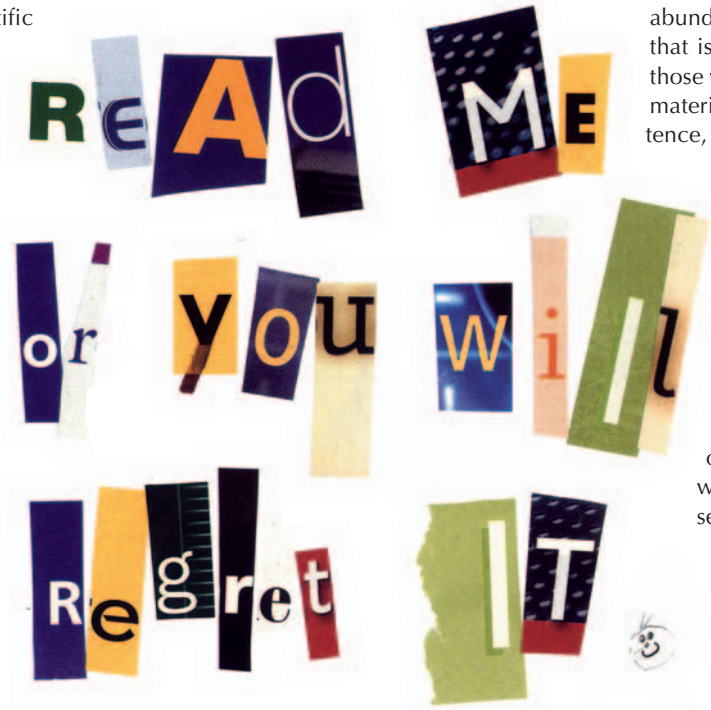
The purpose of a scientific paper is to communicate results and analysis to the wider scientific community. The better a paper is written, the more readers it will attract and the more citations it is likely to receive. This alone should be sufficient to convince any scientist to put significant effort into his or her writing; unfortunately, this is rarely the case. More than a decade ago, Martin Gregory observed in *Nature* that "There are two kinds of scientific writing: that which is intended to be read, and that which is intended merely to be cited. The latter tends to be infected by an overblown and pompous style. The disease is ubiquitous, but often undiagnosed, with the result that infection spreads to writing of the first type" (Gregory, 1992). It seems that little has changed. The bulk of scientific literature is still almost unreadable, and is usually only read by scientists with a vested interest in the subject. Those who want to read about science for pleasure are advised to pick up the science pages of a newspaper or a popular-science magazine instead.



Scientists cannot complain that they lack guidance: there is an abundance of literature on how to write clearly and understandably to attract the interest of the readers. Many journalists and professional authors will have read two standard books on writing good prose: *On Writing Well* (Zinsser, 1976) and *The Elements of Style* (Strunk & White, 1959). But these—and other books like them—are unknown to, or ignored by, most scientists. Although such books might not cater explicitly for scientific writing, they are nevertheless valuable as they explain how to organize material in a coherent way, and how to write a manuscript that is both informative and readable.

More importantly, such books convey an important message: authors should write not for themselves but for their readers. Many scientists would do well to heed this advice, as a clear and understandable manuscript is more likely not only to draw citations but also to be accepted for publication in the first place. Unfortunately, the scientific and medical literature is still abundant with lengthy, unclear prose that is likely to confuse readers, even those who are familiar with the subject material. Take, for example, this sentence, chosen at random: "There was a strong correlation between the sexual orientation of those sharing a strain, with 71% of the 197 strains shared by two or more individuals recovered exclusively from either men who have sex with men or heterosexuals (86% of these were from groups of individuals who were at least 80% of a single sexual orientation), with the remaining 29% of strains seen in both men who have sex with men and heterosexuals" (Choudhury *et al*, 2006).

Of course, there are limitations on the style and format of a scientific manuscript. In addition to taking into account the specific requirements of scientific journals, a paper must generally have an introduction, separate sections on methods and results, and a discussion of the results in relation to the original hypothesis. The very nature of a scientific paper—presenting and discussing results in an unbiased way—also poses restrictions on the writing style: the passive voice is ubiquitous in order to appear impersonal, and the need to cite relevant references can interrupt the concise and clear flow of text. However, these rules are flexible enough to allow a paper to be written in both an informative and interesting way. In this viewpoint, we lay out a few basic rules on how to present results in a way that is more likely to attract interested readers.

Old wisdom in architecture holds that 'form follows function'. The same applies to writing. Many scientists think that there is nothing more important than their results. But, in fact, neither the results nor the paper itself is of utmost importance to the scientific world. The primary function of a scientific paper is to transmit a message—to convince the reader and the community that this is important research. It is therefore a good strategy to first think about the message before sitting down to write.

Even before the title or first sentence is written, it is helpful to scrutinize the results carefully, as modern science deals less with demonstrating facts and more with interpreting and discussing results (Horton, 1995). Although a writer's confidence in the results might be fully justified, the ease of his or her convictions sometimes is not. A writer might hold the results as self-evident truths that require no further explanation, but the reader might think otherwise; in fact, many queries raised by peer reviewers are rooted in the writer's assumption that what has become obvious to them through long contemplation and discussions with colleagues will automatically be obvious to the reader. This also means that experimental results should be excluded if they do not contribute significantly to the main message of the manuscript, regardless of how interesting they are. If discarded results are sufficiently substantial, they might form the basis of another paper.

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A paper should address one main question, and the failure to do this is one of the most common reasons for reviewers to reject a manuscript (Lambert *et al*, 2003). A good research question should be specific, novel and of interest to the scientific community, and will dictate the choice of journal and its readership (Perneger & Hudelson, 2004). Readers of highly specialized journals will be easily turned off by lengthy explanations of what is common knowledge in the field; conversely, readers of general journals might need more background information to be able to follow the arguments. When writing a paper, scientists should put themselves in the readers' position and assess the depth of detail from their point of view.

The division of a paper into introduction, methods, results and discussion reflects Aristotle's requirements for introduction, narration, proof and epilogue in oratory—the art of communication using rhetorical skills (Aristotle, 1991). Although a scientific paper should not be an oratory in the original sense of the word, it can accommodate some rhetoric without compromising its integrity; indeed, rhetoric is an ingredient of good scientific writing. "In addition to a simple presentation of the facts, I would point out that the best writing—medical, scientific, or otherwise—tries to convince the reader of something," wrote David Reese (1999). "In making an argument, the polished author relies on rhetoric, or the facility of using spoken words or literary composition effectively." Objectivity is the basis of research, but effective communication of science requires some subjectivity on the part of the writer.

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However, there is a big difference between subjective—and sometimes even emotional—assessment and scientific rhetoric. The statement that a particular result is interesting has no scientific merit. Unless the reason for this particular interest is explained, it remains an empty appeal or, worse, an admission that the author does not fully understand the implications of that result. Similarly, subjectivity does not require the pervasive use of adverbs to state that a result is "very interesting", "highly significant" or "particularly relevant".

Good writing does not need an abundance of adverbs and adjectives. If the presentation of results and the ensuing discussion are logical and conclusive, the reader will be able to follow them more easily than if he or she must traverse a thicket of unnecessary words. The main message of *The Elements of Style* is to omit unnecessary words: "Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell" (Strunk & White, 1959).

The same applies to writing in general. Long-winded sentences with multiple clauses, disclaimers and parentheses are hard to read and are guaranteed to discourage even the most interested readers. In the following example, these problems are compounded by the use of brackets to denote both references and items in a list: "We adopt this broad-scale approach to determine that relationships occur both at the level of the population (and hence not confounded by [1] potential environmental variation and/or [2] statistical nonindependence of individuals) and also across individuals (because [1] relatively recent colonization of the UK by rabbits [15], and [2] previous work [18] demonstrating extremely fine-scale genetic structuring in UK rabbits over short spatial scales both make it difficult to define what constitutes a 'population' for analysis)" (Gage *et al*, 2006). Good writing involves self-editing to clean up the language until the prose is clear and understandable. "If those who have studied the art of writing are in accord on any one point, it is on this: the surest way to arouse and hold the attention of the reader is by being specific, definite, and concrete" (Strunk & White, 1959).

Readers expect to find certain types of information in particular locations in a scientific paper. Although the divisions between the sections are not set in stone, disregarding them results in a shapeless paper. Excessive experimental details in the results section or unwarranted reiteration of results in the discussion will leave the reader wondering what the main message is. A result must be presented before it can be discussed, and any results that do not add to the point being discussed should be excluded. It is possible to cross the internal divisions of a paper to enhance the message and to preserve the flow of arguments, but this should be done judiciously. In the following, we discuss each part of a scientific article and how to increase its readability.

The title is the single most important phrase in the entire paper. Its impact must not be underestimated: a reader who cannot extract the significance of a paper from its title is unlikely to read further. For instance, 'Polarization, key to good localisation' (van

Beest *et al*, 2006) or 'Hormones and progeny of breast tumor cells' (Schneider & Bocker, 2006) do not convey much useful information. Longer titles can be more informative, but they are less likely to catch the attention of readers who scan quickly through journal contents or article listings. Short titles can be more attractive but they carry the risk of being too cryptic. Titles using puns or clever word-play, although not necessarily informative, can attract readers' interest, but this should not be done at the expense of information that portrays the article's content. The title should first be informative, and any word-play should only be used as embellishment. Again, when formulating the title, it is helpful to put oneself in the readers' position and consider whether it sounds sufficiently informative.

Equally important is a good abstract. It is frequently on the merits of the abstract alone that a reader decides whether to peruse a paper. The whole article might be a treasure trove of information, but if this does not come across in the abstract, the article might be ignored. There are two main ways to write an abstract: free-form and structured (Fuat *et al*, 2003; Gallagher *et al*, 2003). Free-form abstracts are more common in molecular and cell biology journals, whereas clinical and social science journals tend to favour structured abstracts. A free-form abstract is usually written as a single paragraph, whereas structured abstracts are organized into sections, the most basic of which are objectives, methods, results and conclusions.

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The merits and shortcomings of structured abstracts have been reviewed (Hartley & Sydes, 1997). Regardless of one's personal view on the best method, writing the first draft of an abstract in a structured form might help to get a better idea of how much of it should be devoted to different aspects of the paper to achieve a well-balanced text. There are also divided views on whether to write the abstract at the outset (Baillie, 2004) or as the last step (Fisher, 2005). In any case, it might be a good exercise to try both methods and see which works better.

There is a clear difference between an introduction and a literature review, as the latter is an article type in itself. Consequently, a good introduction should not cover as much of the literature as possible within the space constraints. Its main goal is to draw a map of the research area, situate the manuscript within this map, and put its aims, results and interpretation into context. In general, an introduction moves from a general overview to address specific questions. A short historical overview could lead to a brief description of the state of current knowledge and highlight any gaps. This provides the roadmap for stating the problem that the paper addresses, its aims and the results. Of course, this is not a rigid framework, rather a flexible guide that can be changed to suit the aims and purpose of each paper.

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The methods section should be specific and sufficiently detailed to allow other scientists to reproduce the experiments, but no more. They should be able to use it as a set of clear instructions on how to perform the work. One common mistake in describing methods is failing to provide essential information. Again, putting oneself in the reader's position helps to assess whether the description of a particular experiment is sufficient to repeat it. Procedures adopted from the literature should of course be referenced, but they could also be outlined in brief for the benefit of the reader.

Results should be presented in a coherent and organized way that tells a logical, rather than a chronological, story. Of course, research is rarely a linear process from observation to hypothesis to experimental proof: any scientist knows how often his or her research backtracked or branched off in unexpected directions. But this is not relevant for the reader; in fact, there is nothing more disconcerting than trying to assemble a story from a jigsaw puzzle of results. It is therefore paramount to study the results and organize them in a logical fashion before writing the paper; otherwise this disorganization will manifest itself in the paper and be noted by readers and reviewers alike. Furthermore, including extraneous results that provide little support for the main theme will dilute the message and confuse the reader.

The purpose of writing a research paper is not only to present results, but also to explain, interpret, predict, suggest, hypothesize and even speculate. The main purpose of the discussion is to provide a forum in which the author seeks to convince the reader of the logical experimental setup, the soundness of the results and the validity of the speculations. At every step, it should be clear to the reader whether the discussion merely interprets results and predicts further outcomes, or launches into more far-fetched speculations. References are essential for this process, but readers are easily annoyed if they are dragged through every publication that has a bearing on the main theme. For the most part, readers expect a coherent interpretation of the results and a demonstration of their relevance. If the discussion must perform intellectual or literary acrobatics to interpret and convince, the results are obviously not sufficiently convincing on their own. If reviewers and editors feel this way, they might require additional experiments before accepting the paper.

The exponential increase of both primary papers and reviews means that scientists are under increasing pressure to keep up with the literature in their field of interest, let alone anything else. Furthermore, as the performance of text retrieval and analysis algorithms to draw meaningful information from the literature improves, scientists will increasingly rely on these to harvest relevant papers from the deluge of available information. However, scientists will still read papers if they think that the title is interesting or that the message or question being answered is important. And the better the paper is written and the more logical its arguments, the higher the chances that the reader will proceed beyond the abstract and find it convincing enough to cite. Consequently, it is of utmost importance to keep two things in mind throughout the writing process: the main message and the reader. After all, the author's goal is to convince the reader that this is important research. If a paper ignores readers' interests, they in turn might ignore the paper.

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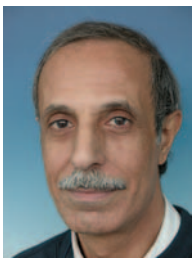
This article represents the authors' opinions and does not necessarily reflect *EMBO reports*' guide to authors for scientific manuscripts.

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