



Writing the results and discussion of a research paper

by Amin Bredan

Despite the availability of a wide variety of resources on good science writing and the introduction of science writing courses in many academic institutions, journal editors continue to air their gripes about having to slog through poorly written manuscripts [1]. The journal *Nature* has this to say on its website: “Many papers submitted for publication in a *Nature* journal contain unnecessary technical terminology, unmanageable descriptions of the work that has been done, and convoluted figure legends” [2]. Not all can be blamed on inadequate fluency in English; even manuscripts that are grammatically sound can be unnecessarily difficult to read. The roots of the problem seem to lie deep in ingrained habits transmitted from mentors to protégées. In an article recently published in *Science* [3], the author states that academic language “uses sophisticated words and complex grammatical constructions that can disrupt reading comprehension and block learning” and mentions the “impenetrability of prose constructions.” However, nowhere in the article does the author address the need for improving and simplifying academic writing, and instead suggests that students should be taught better how to deal with the status quo.

Many science papers also have problems in the organisation and presentation of the information in the different sections. In this article I first discuss some important elements in the organisation and presentation of results and the requirements for a scholarly discussion, and I then deal with issues of writing style.

Provide the information where the readers expect it

The research paper has a well-established structure, commonly referred to as IMRAD, though some exceptions exist, such as articles in *Nature* and *Science*. In the IMRAD format, the introduction is succeeded by the methods section, after which come the results, followed by the discussion, though it is quite common to combine results and discussion in one section. If these sections are separate, the results section should recount the results and refrain from interpretations, discussions and reference to previous work. The discussion should provide a brief summary of the important results and discuss them in the context of the aims, but it should not restate the results in detail or repeat the background material provided in the introduction. Also, it should not discuss methods unless it is a methodology paper or there is a specific issue affecting the results.

Keep the readers in mind

Sometimes scientists spend such a long time with their experiments and manuscripts that everything becomes obvious through familiarity. Whether a particular point is

obscure because the authors did not explain it clearly or because they thought it did not need explanation, the result is the same. Authors should be continuously aware of this and keep their readers in mind while writing. They should also try to read their manuscript through the readers’ eyes. It is even better to ask someone who is familiar with the topic but not involved in the work to review the manuscript.

Writing results

Good results speak for themselves, but their eloquence can be stifled by bad writing. One can view the process of writing the results as a continuum through which the laboratory notes are morphed into the final version of the results section of a manuscript. For experienced writers, this process comes naturally. But for younger scientists, it can be a difficult process and the result is not always pleasing. Though writing is not an exact science and there is no magic formula to follow, adhering to some simple rules can reduce the stress and avoid many pitfalls.

Don’t just report results chronologically: Tell a coherent story

There is general agreement among editors and professional science writers that the results section should tell a story and not be a chronological account of the results. Studies can run into difficulties that necessitate backtracking, introduction of new experiments and the tying up of loose ends. Presenting the results in their chronological order in such cases can be disorienting for the reader, who has to invest much effort to follow what was done and why. Readers are not interested in what was done when, but in grasping the overall picture as well as the details as easily as possible.

One way to prepare for writing the results is to collect the various pieces of evidence, be they tables, graphs, gels, micrographs or brief summaries of data, and to place them on a table. Sheets of paper can be easily rearranged to find the best way for presenting the results. That arrangement can then serve as a road map for the actual writing. Alternatively, one can write an outline of the results or draw it diagrammatically. The outline can fit on one page and it can be easily modified. Regardless of which method one adopts, it is always important to prepare a plan ahead of the actual writing, to follow it, and to modify it if necessary.

Hand the results to the readers: Do not drop them in their laps.

The results section should report the results of the experiments without interpreting them or describing the rationale or methodology. Some journals might enforce this policy, but others might have different requirements. For >

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> example, the instructions to authors on the website of *Infection and Immunity* state that the results section should “include the rationale or design of the experiments as well as the results.” Introductory notes on rationale and methodology orient the readers. This is particularly relevant when the experimental setup is complex or there are many similar experiments. A good example of providing context to results without being intrusive is the following:

“To prove that M2e-tGCN4 is indeed a tetramer, chemical cross-linking experiments were performed with the homobifunctional cross-linkers BS3 and DSP” [4].

However, one should not include references to previous work or interpretation and analysis.

Discussion: Going beyond the results

In the discussion, authors try to explain how they answered the research question and convince the readers of the validity and significance of the results. To this end, authors use several means. They interpret the results by explaining what they mean and by comparing them with published results. If the results contradict published data, the author should try to explain why. Citing only papers that agree with the current work not only shows bias but undermines the authors’ intention to convince. The author should discuss how the results fit with previous hypotheses, and whether existing hypotheses should be modified or new ones proposed. By accurately describing the limitations of the study and how they might affect the results, the author engages in self-criticism and provides evidence for objectivity. Finally, by proposing future lines of work, the author indicates how the current work serves as a stepping stone for greater understanding or development.

Avoid rehashing the results

The basic requirement for a good discussion is not to simply rehash the results with a sprinkling of references to the literature. One should have a strong grasp not only of the results, but also of the relevant literature. As the author is writing a particular result, he or she should be aware of how it relates to the literature. If the author has to repeatedly shuffle through published papers in search of something relevant to insert after a particular result, the discussion is likely to be disjointed.

Should the discussion aim to discuss the research question or the results?

When I asked a few colleagues this question, most of them seemed surprised: To them it was obvious that it should discuss the results. In my opinion, by concentrating on the research question, one discusses the results more effectively because the discussion will circle around how the results answer the research question. Concentrating on discussing the results, on the other hand, can generate a mental check list that the author addresses one by one. This could fragment the discussion and leave it up to the reader to assemble the pieces, which is contrary to the principle of conveying a clear message.

Organising the discussion

Inexperienced authors can be faced with the dilemma of where to start the discussion and how to proceed. Perneger

and Hudelson propose a framework for writing the discussion [5]. They suggest starting out by stating the main findings and discussing them in the context of published data, discussing the implications of the results, and ending with their strengths and limitations and finally possibilities for future work. However, one should not restate all the results or refer to figures or tables, unless it is a figure proposing or modifying a hypothesis. Following such a ‘template’ should yield a discussion that is, at least in principle, well structured. Some authors preface this ‘template’ with a brief statement on the current state of knowledge, such as

“Development of polarity in epithelial cells requires specialized localization of proteins to distinct PM domains. Increasing evidence has been gathered concerning the important role of adhesion system and cytoskeletal components in the various processes leading to this organization (41)” [6].

This is acceptable, providing that it is kept brief, as in this example.

Combining results with discussion

Many journals allow presentation and discussion of results in one section. If this is an option, the author should carefully consider both possibilities, because the data might be more easily dealt in one of the two formats. When results and discussion are combined, the results are organised into a coherent story, and the discussion accompanies the narrative as it unfolds.

Write in a simple, clear style

Many scientists seem to have an aversion to writing in a simple style that is clear and easy to read. They do not seem to heed the request of science journals that authors should “present their findings and conclusions in simply constructed sentences” [2]. It might be argued that the complexity of scientific prose arises from the complexity of the science. I propose that it is the complexity of scientific prose that frequently makes science difficult to read. For example, there is no scientific value in adherence to the passive voice, long parenthetical clauses and a pompous writing style.

Paragraphs: one topic each

Text is divided into paragraphs for a good reason: Each paragraph should address one central topic. We are always aware that a new paragraph signifies a change in topic. If a paragraph contains more than one topic, the reader misses that signal. Though a long paragraph is not in itself a problem, authors should be particularly wary of any long paragraph because it could mean that it deals with two or more topics. Though one cannot judge a paragraph as too long when it surpasses a certain number of words, any paragraph that goes beyond about one page should be scrutinised for multiplicity of topics.

Sentences: one idea each

While a paragraph should be devoted to only one topic, a sentence should be limited to stating only one fact, observation, instruction, idea, concept or argument. Sentences in English are generally structured to provide introductory or linking material at the beginning and new information

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at the end, which is known as the ‘stress position.’ Readers tend to pay greater attention to material in the ‘stress position’ [7]. If a sentence addresses more than one idea, this pattern is lost.

Avoid long sentences

Long sentences that are well written are not difficult to read, but it is difficult to write long sentences that maintain fluidity and clarity. Moreover, long sentences are at a greater risk of having grammatical faults. Long sentences can be shortened by deleting unnecessary words or phrases, and if this is insufficient, by splitting them. In the following example, the sentence is about a regulatory loop, but it mentions five successive steps:

“A feedback regulatory loop in which MYC directly binds and activates the transcription of the cluster *miR-17-92* that consequently negatively regulates E2F1 by direct interaction, while *c-Myc* is directly inducing expression of the E2F1 that in turn induces *c-Myc*, was recently described (37)” [8].

In such instances, splitting the sentence will facilitate assimilation of the information.

Avoid abuse of the passive voice

The passive voice used to be considered an essential part of the scientific writing style because it gives an air of objectivity. But journals have been encouraging the use of the active voice, and it seems that authors have been responding. The passive voice is a more awkward construction than the active voice. This is particularly true for long sentences because the main verb comes at the end. For example, the sentence in the previous section For example, the sentence in the previous section (reference 8) can be improved by converting to the active voice: “O’Donnell et al. (37) recently described a feedback regulatory loop in which...”

Avoid long parenthetical clauses

Parentheses are useful, but they work well only if the parenthetical material is brief. Multiple insertions of lengthy parenthetical material can make the sentence unreadable. One of the best examples of this is the following:

“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)” [9].

Long and repeated interruptions of a sentence can oblige the reader to restart reading the sentence, and that is annoying. Long parenthetical material is better split off as a separate sentence, or perhaps even deleted if it is not important.

Avoid writing in a style that seeks to impress

Trying to sound scholarly by adopting an inflated language style is not a good idea for two reasons. First, an officious style can put off readers. Second, such a style is usually

convoluted and requires more words. Let us look at the following sentence:

“The answer to this question is still unclear, probably due to the limits of the techniques used to resolve temporally events that are almost coincident” [10].

What the author means is

“This question has not been answered probably because the techniques cannot resolve events that almost coincide.”

Vocabulary: Keep it simple

Finally, the choice of vocabulary is important. Scientists have many pet words and phrases. They are perfectly good parts of the language, but they usually have shorter or simpler alternatives. The CBE Style Manual advises authors to “Review the text of the manuscript to eliminate phrases and words that are not needed” [11]. Moreover, good writing requires variety, and insistence on the use of a particular set of vocabulary can cause the prose to be dull. For example, ‘due to the fact that’ can be phrased more simply as ‘because,’ ‘the number of cells was determined’ should be changed to ‘the cells were counted,’ and there is no justification for the omnipresent preference for ‘prior to’ over ‘before.’

Final words

The main purpose of writing a paper is to convey a message. To help achieve that effectively, it is useful to adopt the following guidelines.

1. Organise the results into a meaningful coherent story.
2. Reserve the results section only for presentation of the results.
3. When writing the discussion, follow the guidelines of Perneger and Hudelson [5].
4. Write in a direct, simple and clear style.

Amin Bredan

Ghent, Belgium
amin.bredan@dmb.vib-ugent.be

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