How to write a research journal article in engineering and science[1]

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Abstract: Writing a research article can be a daunting task, and often, writers are not certain what should be included and how the information should be conveyed. Fortunately, scientific and engineering journal articles follow an accepted format. They contain an introduction which includes a statement of the problem, a literature review, and a general outline of the paper, a methods section detailing the methods used, separate or combined results, discussion and application sections, and a final summary and conclusions section. Here, each of these elements is described in detail using examples from the published literature as illustration. Guidance is also provided with respect to style, getting started, and the revision/review process.

Keywords: scientific writing, technical writing, journal article, how to, outline

1 Introduction

Writing a journal article can be an overwhelming process, but breaking it down into manageable tasks can make the overwhelming the routine. These manageable tasks can be identified by determining what the essential elements of a successful article are and how they function together to produce the desired result: a published journal article. Often, different languages and cultures write in different styles and with different organization than English-language authors. This can compound the problem for non-native English writers. In this article, I outline the essential elements of an English-language journal article in engineering or the sciences, providing a functional template and guidelines for authors.

Many of the ideas in this article were gleaned from my own reading of various journal articles, both in the review process and after publication, and of both good and bad articles. However, there are also a great number of good books available that also address the issue of scientific writing. One book whose philosophy of writing contributed to many ideas presented here is "Writing a Thesis: Substance and Style," by van Wagenen (1990). I also benefited greatly from a set of outline notes provided to me by Prof. Gerhard H. Jirka at

the University of Karlsruhe. Many of his insights find their way throughout this text. Also to note is a series of editorial comments published in the *Journal of Hydraulic Engineering* pertaining to abstracts, introductions, conclusions, and reducing a paper's length (McNown 1996*a*, McNown 1996*b*).

Other helpful resources are the various style manuals and grammar tutorials. The LaTeX system is a convenient way to get a professional-quality layout to your article (this paper was written using LaTeX). Likewise, a very helpful guide to writing is the (in)famous "Strunk and White," a short paperback book titled "The elements of style" (William Strunk & White 1979). Strunk and White do a great job of eliminating the excess so that the clearest writing results. Their motto is "Vigorous writing is concise," an axiom that should guide any writing that wishes to be clearly understood. They are also especially strong in the use of punctuation and in the proper use of words. These resources will help any writer, new or old, native English speaking or not.

The remainder of this article condenses these resources and others down to a brief "how-to" for writing a journal article submission. The first section gives some constructive ideas for how to get started with the writing process (do not just start by writing on page one, paragraph one). The structure section provides a detailed outline for an article and gives the required content of each section. Some of the more difficult parts are illustrated with examples from published journal articles. The section on how to write gives a few pointers on good writing style. The last section covers the revision and review process and gives tips on how to use feedback to improve the article. The summary and conclusions section reiterates the key points and provides a skeletal outline for the journal submission. Together, these sections should reduce the writing task to manageable projects and result in a successfully published article, providing the scientific merit does not let you down.

2 Before starting to write

Before you start to write, you should spend some time thinking about the article content. At this stage, you should write down ideas in a free form, creating a general outline for the paper. Jirka suggests you consider such questions as:

- What is the message of the paper?
- What is the new result or contribution that you want to describe?
- What do you want to convince people of?

If you have not already done so, you should conduct a thorough literature search to identify those important contributions that are related to your work. As you are ready to submit your article, it is always helpful to do one more search; including articles that were published just as you submit your paper will show that you are aware of the current work going on in your field (Russel & Morrison 2003).

As you get ready to write, try to summarize these initial ideas into concrete bullets that will eventually become paragraphs. Start to organize these bullets into a logical structure

and develop them in the form of key sentences. If the outline is convincing, then the article will be successful. Likewise, a weak outline cannot be saved by any good writing skills.

3 Structure and function of the article: What to write

In formulating the outline it is important to know that most engineering or science journal articles have a well-accepted general format. Each of the following sections are included, usually also in this order, though specific articles may disguise them under different section titles that relate closer to the actual contents of each section. These sections are

1. Abstract
2. Introduction
3. Methods
4. Results
5. Discussion
6. Summary and Conclusions
7. Acknowledgments
8. References

Each part serves a different purpose and has a narrowly defined content and purpose. Understanding how each section functions together with the whole will help the author minimize overlap and repetition.

3.1 The Abstract

The abstract is a single paragraph that precedes the article and summarizes the content. The abstract reduces the whole paper to a single paragraph. Many times, the abstract will be published by itself in an index to the article and often only the words in the abstract can be searched using library databases; hence, the abstract is a critical element of the research paper. It contains a general introduction to the topic, outlines the major results, and summarizes the conclusions. It is shorter than the summary and conclusions section of the main paper and is less of an outline than the closing paragraph of the introduction. Often, the abstract does not require citations; some journals discourage use of mathematical symbols. The guideline for a good abstract is:

> ***The abstract should inform the reader in a succinct manner as to what the article is about and what the major contributions are that are discussed***

The abstract is more general than the conclusions section and can have a *staccato* literary style.

The following are two examples of well-written abstracts:

- "Fishes swim by flapping their tail and other fins. Other sea creatures, such as squid and salps, eject fluid intermittently as a jet. We discuss the fluid mechanics behind these propulsion mechanisms and show that these animals produce optimal vortex rings, which give the maximum thrust for a given energy input. We show that fishes optimize both their steady swimming efficiency and their ability to accelerate and turn by producing an individual optimal ring with each flap of the tail or fin. Salps produce vortex rings directly by ejecting a volume of fluid through a rear orifice, and these are also optimal. An important implication of this paper is that the repetition of vortex production is not necessary for an individual vortex to have the 'optimal characteristics." (Linden & Turner 2004).

- "Aquatic plants convert mean kinetic energy into turbulent kinetic energy at the scale of the plant stems and branches. This energy transfer, linked to wake generation, affects vegetative drag and turbulence intensity. Drawing on this physical link, a model is developed to describe the drag, turbulence and diffusion for flow through emergent vegetation which for the first time captures the relevant underlying physics, and covers the natural range of vegetation density and stem Reynolds numbers. The model is supported by laboratory and field observations. In addition, this work extends the cylinder-based model for vegetative resistance by including the dependence of the drag coefficient, C_D, on the stem population density, and introduces the importance of mechanical diffusion in vegetated flows." (Nepf 1999).

Both abstracts tell the reader what to expect, summarize what the important contribution is, and entice the reader to look further. Neither abstract gives detailed quantitative results. This level of detail lets the reader know what to expect without overwhelming him with details, derivations, or sophisticated results—the reader is equipped to safely set the article aside or delve deeper to uncover the details.

3.2 The Introduction

The introduction is perhaps the most important sections in a research article. Nearly every reader will at least skim through the introduction. The introduction is also written with the strictest requirements in terms of organization.

3.2.1 Paragraph 1

The first paragraph should follow the inverted triangle principle: start with a broad statement and become more detailed until finally identifying the specific problem that the paper addresses. The purpose of the first paragraph is to interest the reader in the paper, to clearly identify for the reader what the paper will address, and to quickly bring the reader

to the edge of knowledge in the field the paper addresses (Russel & Morrison 2003). The paragraph should end with the general problem addressed by the paper.

To have the greatest impact, the first sentence should be broad in scope and should attract the reader's attention. Here are five opening sentences from the current issue of the *Journal of Fluid Mechanics*:

- "Turbulence is not a universal state of nature, but there are similar forms of eddy motion, and mixing processes with similar statistical properties for a variety of turbulent flows within a particular 'type." (Hanazaki & Hunt 2004).
- "There is a long-standing interest in flow over isolated topography, such as seamounts, with regard to both theoretical and practical issues." (Nycander & Lacasce 2004).
- "Breaking waves at the sea surface promote vigorous mixing of momentum, energy, and scalars, and thus are a key process in upper-ocean dynamics and air-sea interaction." (Sullivan et al. 2004).
- "We investigate a family of exact solutions of the Navier-Stokes equations that describe the steady flow of a rivulet down an incline." (Perazzo & Gratton 2004).
- "Granular flow exhibits a variety of dynamical phenomena, which have been attracting research interest for many years (for reviews, see e.g. Savage 1984 and Jaeger, Nagel & Behringer 1996)." (Mitarai & Nakanishi 2004).

Clearly, there is a wide variety of levels of detail, but each statement, except for the fourth example, follows the rule of thumb outlined above

> ***Start with an attention-getting broad statement that establishes a general topic for the article***

Here are four more examples from papers by some of the best authors:

- "Observations of swimming fishes and other organisms such as salps reveal a series of vortex rings forming behind the animals, which play an important part in their mechanisms of propulsion." (Linden & Turner 2004).
- "Freshwater and saltwater wetlands provide important transition zones between terrestrial and aquatic systems, mediating exchanges of sediment [*Phillips*, 1989], nutrients [*Nixon*, 1980; *Barko et al.*, 1991], metals [*Orson et al.*, 1992; *Lee et al.*, 1991], and other contaminants [*Dixon and Florian*, 1993]." (Nepf 1999).
- "Shallow flows are ubiquitous in nature" (Jirka 2001).
- "The entrainment hypothesis was first introduced by Sir Goeffrey Taylor in a wartime report on the dynamics of hot gases rising in air." (Turner 1986).
- "The convection currents which rise from heated bodies have been discussed previously, but in most cases attention has been directed towards finding the distribution of fluid velocity and temperature near such bodies." (Morton et al. 1956).

These also exhibit a wide variety, but each follows our general principle.

The next sentences of the introduction narrow the topic. These sentences often contain citations to other work and build up to a specific lack of knowledge that culminates in the problem statement. This section can vary in length from one to many sentences, but the general goal is to educate the reader about an important gap in knowledge that the paper will address (Russel & Morrison 2003). Here are three good examples of a complete introductory paragraph: the first is short, the second contains no citations, and the third is longer. The problem statement in each paragraph has also been italicized.

- "There is a long-standing interest in flow over isolated topography, such as seamounts, with regard to both theoretical and practical issues. Trapped flows are often observed over seamounts, and these flows evidently affect the distribution and concentration of subsurface fauna, filter feeders and the like (e.g. Genin, Noble & Lonsdale 1989 and references therein). *These flows are often so intense that they alter the ambient vorticity and, as such, can modify the allowable frequencies of internal waves.* This in turn may affect wave breaking (Kunze & Toole 1997 and references therein)." (Nycander & Lacasce 2004), emphasis added.

- "Observations of swimming fishes and other organisms such as salps reveal a series of vortex rings forming behind the animals, which play an important part in their mechanisms of propulsion. Fishes produce these vortices by an undulatory motion of the body and tail, controlling the periodic shedding of vorticity into the wake, and salps form them more directly, by ejecting fluid backwards through an orifice. In both cases the vortices roll up into three-dimensional (3D) ring-like structures. For fishes, the important question is what frequency and amplitude of the undulatory motion provide the most efficient propulsion? A similar question faces the oarsman of a gondola. For efficient motion, should the oar be moved slowly at large amplitude or quickly with a smaller amplitude? *Here, we discuss this question, not in terms of a periodic motion, but by considering each flap of the tail or fin as a single event.* This may be repeated periodically during steady swimming, but may be aperiodic during a turn or other manoeuvre. For other organisms using a jet for propulsion, the question is how long a jet provides the optimal efficiency." (Linden & Turner 2004), emphasis added.

- "Granular flow exhibits a variety of dynamical phenomena, which have been attracting research interest for many years (for reviews, see e.g. Savage 1984 and Jaeger, Nagel & Behringer 1996). Its complex behavior can be seen even in a simple situation like the gravitational flow on a slope. When the inclination angle is large and the slope is rough, a rapid and relatively low-density flow is realized, and the interaction between grains is dominated by inelastic collisions. On the other hand, when the inclination angle is small, the flow becomes dense and slow, and the frictional interaction plays an important role (Savage 1984; Mitarai & Nakanishi 2003). The comprehensive rheology of the granular flow has not been fully understood yet, except for the rapid collisional

flow regime, where hydrodynamic models have been developed with constitutive relations based on the kinetic theory of inelastic hard spheres (Jenkins & Savage 1983; Campbell 1990; Lun et al. 1984; Goldhirsh 2003); it has been demonstrated that some quantitative agreement can be achieved for the steady flow by introducing the spinning motion of each grain (Mitarai, Hayakawa & Nakanishi 2002). *The steady granular flow, however, turns out to be unstable in various ways, and shows rich phenomena.*" (Mitarai & Nakanishi 2004), emphasis added.

In each case there is reference to broader knowledge beyond the scope of the actual article. This knowledge is narrowed to a specific problem, or gap, in the understanding of the subject. As a result, each example illustrates our next rule-of-thumb (adapted from Russel & Morrison (2003)):

> ***Narrow the topic in successive sentences that outline the state of the art and introduce a gap in knowledge***

Each paragraph also contains a statement of the main problem addressed by the article. The second example has a specific problem statement, though it is expanded in the final sentence. The other two paragraphs have somewhat more open-ended problem statements. This statement is not always the final sentence; however, any statements that follow the problem statement serve to make it more specific or further justify its importance. Our final rule for the introductory paragraph follows:

> ***End the introductory paragraph with a general statement of the problem and optional supporting/specifying statements***

By following this procedure, the introductory paragraph will serve its purpose of attracting the reader, identifying the context of the problem, and specifying the general direction of the article. After reading this paragraph, the reader should be able to safely set aside the article if he concludes that the topic is not applicable to his area of research. Hence, the statement of the problem should be specific enough for the reader to anticipate the kinds of results that will be reported. Writing in this way, your article will be read by more people and not overlooked by your colleagues in the field.

3.2.2 Middle paragraphs

Following the introductory paragraph is a series of paragraphs that traditionally function as a literature review (McNown 1996*b*). The extent of this section varies somewhat by journal and by topic, but generally follows a specific format. The beginning of the literature review should cite the most important historical contributions that build the foundation to the topic the paper will extend (Russel & Morrison 2003). The goal is not to cite everything, as in a review article, but to cite the seminal contributions that directly lead to the problem the article addresses. The remaining paragraphs should focus on the state-of-the-art knowledge base and the significant differences between what has already been published and the new contribution that your article is presenting. Together, these paragraphs give another guiding principle:

The literature review identifies the seminal historical contributions, outlines the state of knowledge, and justifies the novelty of the article's contribution

The literature review should be based on refereed journal articles to the extent possible. Conference proceedings can be referenced where they never resulted in journal publications; web sites can be referenced where they present unique, multi-media oriented content. Keep in mind that non-refereed material does not bolster an argument. Hence, the literature review gives credit to our predecessors and justifies the need and novelty of the article's contribution.

3.2.3 Final paragraph

The introduction ends with the "road-map" paragraph. This paragraph outlines the remaining sections of the paper. It can either give a general outline of the contribution, or a specific, section-by-section breakdown of the remaining article. Here are two examples illustrating these two possibilities:

- "In addition to the theory, we present results from numerical simulations. These are done in order to examine whether the predicted stable flows can arise naturally as a result of the time-dependent evolution. As the initial condition, we use various non-stationary vortices near or on top of a seamount. We also revisit two-dimensional turbulence over a bump. The simulations are broadly supportive of the theoretical predictions, although time-dependence can produce exotic and interesting final states." (Nycander & Lacasce 2004).

- "Section 2 introduces models for drag, turbulence, and diffusivity for flow through emergent vegetation. Laboratory and field experiments described in section 3 provide observations which support these models. The comparison of model prediction and experimental observation is given in section 4. Finally, the models are used to compare the mean flow, turbulence intensity, and diffusivity in vegetated and unvegetated regions (section 5)." (Nepf 1999).

This paragraph serves two important functions. First, it puts the complete contribution of the article in the context of the previous contributions, thereby, emphasizing novelty and the extent of the new contribution. Second, it guides the expert reader, who may want to skip sections of your article, to the sections that interest him. Thus, we have our final principle for the Introduction:

End the introduction by outlining for the reader the specific contribution of the article and tell the reader the overall organization

This paragraph will also help you organize your logic: if this paragraph is unclear, the rest of the paper will be built on a weak foundation.

3.3 The Methods

The methods sections often come disguised with other article-specific section titles, but serve a unified purpose: to detail the methods used in an objective manner without introduction of interpretation or opinion (van Wagenen 1990). The methods sections should tell the reader clearly how the results were obtained. They should be specific. They should also make adequate reference to accepted methods and identify differences. The governing principle is as follows:

> ***Describe all of the techniques used to obtain the results in a separate, objective Methods section***

In the case of a paper that develops both an analytical model and laboratory results, it is common to write separate methods sections for each. At the conclusion of the methods sections, the reader should be able to form an educated opinion about the quality of the results to be presented in the remaining sections (van Wagenen 1990).

Here are five examples of the titles of the methods sections in some of the papers referenced above:

- "2. Model Development; 2.1 Draft Model for Emergent Vegetation, 2.2 Turbulence Intensity within Emergent Vegetation, 2.3 Diffusion within Emergent Vegetation. 3. Methods; 3.1 Laboratory Experiments, 3.2 Field Experiments." (Nepf 1999).
- "Gravitational Convection; The main assumptions." (Morton et al. 1956).
- "2. Classification of 2-D coherent structures in shallow flows. 3. Methods of investigation." (Jirka 2001).
- "2. Theory of Vortex Ring Formation" (Linden & Turner 2004).
- "2. Theory; 2.1. Conservation laws and variational principle, 2.2. Flat topography or circular seamount, 2.3. Irregular seamount, 2.4. Comparison with the theory of Carnevale & Frederiksen." (Nycander & Lacasce 2004).

One thing to notice is that subsections should only be used when there will be more than one subsection; a subsection implies that the material should be classified into *more than one* group.

3.4 The Results

The results section and the following discussion section allow the most flexibility in terms of organization and content. In general, the pure, unbiased results should be presented first without interpretation (van Wagenen 1990). These results should present the raw data or the results after applying the techniques outlined in the methods section. The results are simply results; they do not draw conclusions. Often the results are combined with the discussion section, which does make interpretations and suggest implications. When these are presented in one section, there should be a clear distinction between a result and

discussion. This could be done by paragraphing, by section headings, or by careful writing within a single paragraph. The main purpose of the results section, however, is to provide the data from your study so that other researchers can draw their own conclusions and understand fully the basis for your conclusions.

A common format for the results section is to present a series of figures and to describe the figures in detail through the text. A good results section presents clear figures with efficient text. The figures should support the assertions in the paper or illustrate the new insights. Where applicable, results should be illustrated in terms of non-dimensional variables. These characteristics lead to our principle for results sections:

> ***Results should be clear, convincing, and general and should be free from interpretations or opinions***

Whether together with the discussion or in their own section, results need to be communicated objectively.

3.5 The Discussion

The discussion section is where the article interprets the results to reach its major conclusions. This is also where the author's opinion enters the picture (van Wagenen 1990)—the discussion is where the argument is made. Often writers will combine the discussion and results sections so that they can avoid repetition and so that they can give their conclusions parallel with the results. This is acceptable if there maintains a clear distinction between facts and opinion. Most scientific papers, however, require the results and discussion to be in separate sections.

A common feature of the discussion section is comparison between measured and modeled data or comparison among various modeling methods. Jirka suggests considering the following questions:

- How do the results compare with earlier work?
- What is new and significant?

Another common element in a discussion section applies the results obtained to solve a specific engineering or scientific problem. Some journals, notably the *Journal of Hydraulic Engineering*, even require a separate applications section for this purpose. The main feature of the discussion section can be summarized as follows:

> ***Discussion sections interpret the results to reach the main conclusions of the article***

The discussion section is the main impact section where the researcher has the most freedom to tout the implications of his research. A word of warning, though: never make an assertion of which you are not 100% sure—do not open the door for a negative review or the eventual rejection of your article. As a rule, it is better to be conservative. Most of the experts reading your article will draw their own conclusions anyhow. This section allows you to highlight the conclusions you think are important.

3.6 The Summary and Conclusions

The final section of the paper does not introduce any new information or insights: it merely summarizes and concludes. This section is longer than the abstract and generally includes more specific conclusions. It is often more quantitative than the abstract, however, listing equations or citations should not be necessary (McNown 1996*a*). The summary and conclusions section also has a more fluid literary style than the abstract.

A good format for this section is to write it in two paragraphs. The first paragraph summarizes various sections of the article. The second paragraph draws the important conclusions. The summary paragraph is different than that at the end of the introduction section. Here, the summary paragraph draws on the fact that the reader knows all of the new results presented in the article. It then summarizes what the important results where. The conclusion paragraph identifies the significant conclusions. McNown (1996*a*) suggests two possible formats for this second paragraph:

1. Organize based on logical flow for points that are interconnected

2. Organize based on merit, where the most important items appear first

It is important to remember that this paragraph should not present new information. It may combine parts of the article to underscore an important conclusion, but it cannot present information that could not be gleaned from the other sections. A third, optional, paragraph may identify future research directions that flow naturally from the article.

The guiding principle for the summary and conclusions section may be formulated as follows:

> ***The summary and conclusions section tells the reader what has already been read and draws the important conclusions—keep it short and make it as specific as possible***

If the reader wants to know specifically what aspects of a problem your paper will address, he will often read the introduction and then the summary and conclusions section. Hence, it is important that all of the significant findings are summarized and united in the significant conclusions. Follow these guidelines and your papers will have maximum impact and receive the most positive reviews that your work warrants.

3.7 The Acknowledgments

The acknowledgments are given at the end of the research paper and should at a minimum name the sources of funding that contributed to the article. You may also recognize other people who contributed to the article or data contained in the article, but at a level of effort that does not justify their inclusion as authors.

There is a growing trend to also acknowledge the contributions of the reviewers. This is a controversial issue. Since acknowledgment sections cannot be referenced or listed on a curriculum vitae, this seems only a means of getting the reviewers to agree with a revision and accept the paper. I would suggest that if the reviewer's comments are great enough that

they substantially changed the paper, the reviewer might be invited as an author; a flowery acknowledgment seems unjustified, given that every article is presumed to have benefited from reviewer comments.

3.8 The References

All reference works cited in the paper must appear in a list of references that follow the formatting requirements of the journal in which the article is to be published. You may not include references that were not cited. Refereed journal articles, research monographs, and books are preferred over less stable or reliable sources, such as personal communications, unrefereed conference proceedings, or web-site addresses.

4 Literary style: How to write

Scientific writing does not leave a lot of room for creativity, but good writing style is inherently more understandable and enjoyable to read. Readers respond well when sentences have a varied length and when paragraphs have a consistent length (Gray 2003). There should be a good mix of short and long sentences. There should also be a mix of sentence structure (Gray 2003). Punctuation, the use of subordinate clauses and compound sentences, and varied tempo are examples of ways to alternate sentence length. On the other hand, readers prefer paragraphs to be of about equal length. Long paragraphs are daunting; short paragraphs make it difficult to fully develop an idea.

Each paragraph itself should also have a well-organized flow. They should have a key sentence, supporting sentences, and a concluding or summary sentence (Gray 2003). The key sentence does not have to be the first sentence in the paragraph, though often it is, but it should clearly contain the purpose for the paragraph. The supporting sentences should relate to the key idea and should develop the idea as needed. The final sentence should draw a conclusion or summarize the key concept in light of the supporting sentence. Conjunctive adverbs, such as therefore, hence, thus, consequently, and however, among others, are excellent tools to force a conclusion to develop. By following this format, your paragraphs will be clear, convincing, and easy to organize.

A good way to structure your paper is by organizing the key sentences (Gray 2003). If the logical flow from one key sentence to the next does not work, then no addition of supporting sentences will save the article. Create your outline first, then work on the key sentences for each paragraph until a convincing, clear, well-organized plan is in place. Only at that point should you start writing your full paragraphs.

When writing the article, the active voice (he said, we derive, they found) is preferred to the passive voice (was communicated by, is derived as follows, was found by). In scientific writing, the passive voice is often more convenient and sometimes is unavoidable. Wherever the active voice is used, however, the sentences appear stronger, more convincing, and more clear.

In searching for your personal style, feel free to be creative (William Strunk & White 1979). Be sure to include the elements described above, but explore different paragraph

styles, sentence structures, and reporting methods. In this regard, the more you read, the more prepared you will be with examples that will provide a palette from which to experiment. Reading and writing daily are necessary to be productive. And above all: write something. Even when you feel the words are terrible, put something into print. The revision process is much easier than the creation process, so just start writing. Research has shown that those writers who write 30 minutes every day are 5 to 10 times more productive than those who wait for extended periods of time in which to write (Gray 2003). Therefore, write often and write freely, and you will be a productive writer.

5 The review process: What to expect

After spending hours writing your journal submission, you are ready to begin the review process. This process likely contains three stages: editorial review by your advisor (or yourself if you are the only author), external review by peer reviewers, and publication, modification, or rejection. If you follow the structure outlined above, hopefully most of the review process will focus on the scientific merit of your work. However, sometimes the best science is difficult to communicate, so it is good to get as much input as possible.

5.1 Editorial review

You or your co-authors should critically evaluate the article before sending it to a journal for external reviews. In this process I suggest one over-arching principle:

> ***Revise and edit your article as if you are not the one who has to do all the work***

This is what I learned during my Ph.D. dissertation. My advisor would always suggest large changes to what I had written: complete organizational changes, additions and removal of sections, new work to be included. These always appeared daunting and overwhelming and were suggestions I never would have considered on my own. However, once the changes were complete, the article was always greatly improved, and the level of effort was invariably far less than I originally anticipated. So, read your own work and decide what changes need to be made objectively, without regard to how time consuming they may be. You can always revert back to your original version if a revision is poor or not feasible. Also, expect to revise what you write. It is not a mark of a poor writer to receive a draft back that is more red than it is black. A good writer makes use of this feedback to create a stronger article. The goal of this stage of the process should be to submit the strongest article possible, both in terms of communication quality and scientific merit.

5.2 Review process

These days most articles will be reviewed by 2 to 4 external reviewers. These are experts in your field who read the article and give their opinions. They comment on scientific merit, suitability to the journal for which you are applying, and readability. They are not likely to

correct grammar or poor organization; however, negatives in these areas will probably lead to a negative assessment of the scientific merit. By writing the best literary article you can, you maximize the chances that the reviews will be favorable. The bulk of the decision will then land where it should: on the scientific merit of your contribution. The best-written article that presents poor science is still not publishable.

The duration of the review process varies widely by journal. It is a good idea to investigate the review timeline before submitting your article.

5.3 Results of the reviews

If all goes well, your paper will be accepted without changes or accepted without re-review. The later case is the most common, and basically means that you are given the opportunity to modify your article in response to the reviewer comments, but that no further review is necessary before the article is published.

If there is a preponderance of negative reviews, the result may be to re-submit subject to re-review or reject. In the earlier case, the article is still alive, through there is an uphill battle to be won; whereas, in the later case, the article has hit a dead end with that journal.

In the case of a resubmission subject to re-review, the author should prepare a detailed response to the reviewers. Reviewers do not have the time or patience to track down every recommendation they made to see how you have addressed it in your article; therefore, you should prepare a point-by-point response. For each major comment by a reviewer, you should summarize the comment in your response letter and then state how the comment has been addressed. This could be an excerpt from the paper where the comment has been incorporated, a gentle reminder as to where the comment was addressed in the original draft, or a rebuttal explaining why the comment is not addressed in the paper. When you feel that the original draft addressed the comment, you should consider whether the original draft was clear enough. If the reviewer missed it, chances are that it was not communicated as well as you thought. The better your response, the easier it will be on the reviewers and the faster you are likely to get back the second round of decisions.

6 Publication

Once the article is accepted and your final version is submitted, you have achieved your goal of being published. Hopefully, you have also achieved the goal of the article: to communicate the results of your research to a broad audience. The Science Citation Index keeps track of article citations and will provide you with a means to track who is citing your work.

A couple things to keep in mind once your article has been accepted are these. Once it's published, there's no changing your mind. Carefully re-review your own equations. It is not common that the reviewers will check the accuracy of every equation—only you can do that. Also, re-read your discussion and conclusions. Has your recent research changed your interpretation of the results in any significant way? Be sure the article you submit is the article you want to go into print.

In the same way that you critically evaluate your work before submission, you should also be critical of the published literature. Not every equation is right: in fact, many published equations contain typographic errors. The published model results generally correspond to the correct equations, but article text often contains errors. So, read the literature with a keen eye for errors and a critical ear so that you will be prepared to make the greatest impact with your own publications.

7 Summary and Conclusions

In this article I have briefly described the necessary elements of a good scientific or engineering journal publication, some of the steps along the publication process, and have provided specific guidelines for developing the journal article. Some sections, like the introduction, have very specific requirements, whereas, other sections, like the results and discussion, have a freer form. In the end, the decision to publish should lie most heavily on the scientific merit of your article, but by following these guidelines, you should maximize your opportunity for success.

The general outline of a journal article with the governing principles outlined above is presented here as follows:

1. Abstract
    - The abstract should inform the reader in a succinct manner as to what the article is about and what the major contributions are that are discussed
2. Introduction
    (a) Introductory paragraph
        - Start with an attention-getting broad statement that establishes a general topic for the article
        - Narrow the topic in successive sentences that outline the state of the art and introduce a gap in knowledge
        - End the introduction with a general statement of the problem and optional supporting/specifying statements

    (b) Middle paragraphs
        - The literature review identifies the seminal historical contributions, outlines the state of knowledge, and justifies the novelty of the article's contribution

    (c) Final paragraph
        - End the introduction by outlining for the reader the specific contribution of the article and tell the reader the overall organization of the paper
3. Methods

- Describe all of the techniques used to obtain the results in a separate, objective Methods section

4. Results

   - Results should be clear, convincing, and general and should be free from interpretations or opinions

5. Discussion

   - Discussion sections interpret the results to reach the main conclusions of the article

6. Summary and Conclusions

   - The summary and conclusions section tells the reader what he already read and draws the important conclusions—keep it short and make it as specific as possible

7. Acknowledgments

8. References

9. Appendices

And throughout the writing process, keep in mind the best principle for an effective revision:

> ***Revise and edit your article as if you are not the one who has to do all the work***

Also remember that each journal has its own personality and may have some specific requirements in addition to these or that supersede these. It is always a good idea to read the information for authors before submitting your article. Best of luck and happy writing.

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