Writing It Up: A Step-by-Step Guide to Publication for Beginning Investigators

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The secret of getting ahead is getting started.
Attributed to Mark Twain (source unknown)

OBJECTIVE. Writing scientific manuscripts can be unnecessarily daunting, if not paralyzing. This paralysis is usually the result of one of two reasons: either researchers do not know how to start, or they do not know what to put where. However, most radiology manuscripts follow a definable blueprint. In this article, I attempt to lay out the paragraph-by-paragraph development of a typical radiology paper.

CONCLUSION. If authors can accomplish the writing of the 18 paragraphs of text described in this article, they will produce a manuscript that is properly organized, correct in its essentials, and ready for the finishing hand of a seasoned writer and mentor.

Young investigators often finish the data collection and analysis phases of their projects flush with the enthusiasm of finally arriving at an answer, only to find that enthusiasm dwindle as they make their first attempts to write the manuscript. Indeed, the number of abstracts presented at national meetings far exceeds the number of manuscripts that ultimately are published in the medical literature [1]. Such failure to bring good work to publication stems in part from the confusion and perplexity that besets inexperienced writers as they attempt to begin the process of manuscript preparation.

Writing a research paper, however, is largely formulaic. Guidelines for structure and organization can be followed to make the process much more straightforward. Although there have been several fine discussions of the construction of a scientific manuscript [2–4], I believe these resources tend not to be as prescriptive and directive as needed for a true novice. The intents of this article, then, are to provide a concrete framework, a template of sorts, that can be followed to achieve a nearly complete paper, and to provide the young writer with techniques that will facilitate a quick entry into the process of manuscript preparation.

Arranging the Pencils: Preliminary Steps

Decide to Write the Paper

Make a conscious commitment to start and complete the paper. Nothing succeeds like persistence and resolve. If you are junior faculty, writing papers is fundamental to your profession and crucial to your promotion.

Confer with a Mentor

Before you begin writing, make sure you are launching in an appropriate direction [2]. You and your mentor should come to agreement on the hypothesis, the data analysis, and the basic interpretations of your study. Your mentor should also be able to make a reasonable appraisal of the study and recommend a suitable target journal. Identifying a target journal early in the process allows you to format the paper in accordance with the particular guidelines of that journal as you write.

Create a Timetable

It is commonplace that large jobs should be divided into smaller steps with provisional completion dates. Some psychologists recommend conditioned response strategies (defined workplace, timers) to help bring concerted effort to the defined subtask and to keep you from the temptation (and disillusionment) of viewing the project as

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one monumental and arduous whole. Here is one timetable:

- Session 1: Make notes on the literature, outline template papers, set provisional date for completion.
- Session 2: Devise an outline and title for your paper.
- Session 3: Create a rough first draft.
- Sessions 4 and 5: Write revisions one and two.
- Session 6: Write third revision, prepare tables and graphs, then give to coauthors.
- Session 7: Incorporate suggestions from coauthors into the text.
- Session 8: Prepare all figures and abstract.
- Session 9: Proof all changes, check all numbers and units, and review the final product with mentor.
- Session 10: Read one last time and send out.

Begin with a Thorough Literature Search

Strongly consider a formal search by the reference librarians because they tend to do a better job of it. Request all articles with direct relevance to your topic, but be pragmatic: you can waste a lot of time reading articles that are off the mark. Literature searches should be at least 2 months current at the time of the paper submission.

Sort Gathered Articles by Relevance

Photocopy the articles and number in order of greatest relevance. This will be your preliminary reference list and can be used for callouts (reference numbers at end of sentences) as you work through the drafts. Do not worry that your final reference list will use different numbering: reordering can be easily done by shuffling and renumbering the papers for the final reference list. The photocopied papers will be your file cards.

To be sure, many younger authors will doubtless prefer software reference programs (such as EndNote) to the paper methods just described. These programs, I understand, have particular advantages for large projects with numerous references (review articles, chapters) and for writers who type their own drafts.

Read the Articles with Varying Degrees of Thoroughness

Identify two or three of the most relevant articles and read these completely for content and topic development. Use these articles as ***templates*** or guides to the development of your own paper. Think about it: these authors are published where you want to be published. Pay attention to what parameters and variables were included in the study. You should have a similar set of parameters in your own study. Outline these papers in the margins, identifying the topic of each paragraph. Make notes on the first page (face sheet) under these headings: the main point, the population studied, paragraphs or statements of particular interest (highlight these), and the section of your paper where this paper might be used. As you paraphrase, be careful about plagiarism. If you make use of a particularly felicitous phrase or statement, make sure it is appropriately attributed and set off with quotation marks.

Read all other articles quickly. ***Keep the pages turning***. Read for concepts. Highlight sparingly. Direct your attention to the first and last paragraphs of the introduction, first sentences of methods and results, first and last paragraphs of the discussion. Make notes on the face sheets (as above).

Circumventing the Critical Mind

Sketch an Outline

Sort the papers on the basis of the section(s) of your paper in which you think they might be most useful. Use the papers as you would file cards, shuffling and reshuffling them as they become relevant to the writing of different sections. Devise a preliminary title and then a sketchy outline containing only main headings, guided by the outline you discerned in the template papers and the rules for section development given in the text that follows. In the outline, do not be too detailed. Do not write sentences, but rather jot notes and phrases for the paragraphs of each section.

Wing the First Draft

The first draft is the largest hurdle because writers often start with standards that are too exacting and strive for eloquence too early in the writing process. The goal is to get something on paper as quickly as possible. I prefer to dictate a first draft because I can talk faster than I can type, because I have an excellent secretary, and because it more effectively creates for me the illusion that I am producing persuasive, well-formed sentences. Such self-deception is important and necessary because it circumvents the overly critical, easily discouraged editorial mind [5].

If you do not have a secretary who will transcribe your dictation, then I suggest you write the first draft as freely and extemporaneously as you can. Whether dictated or written, the end result, more likely than not, will be a draft that is rough, disorganized, and disappointing…and an entirely satisfactory start.

Put your sketchy outline in the middle of your desk. Find the references you marked for each particular section and stack them in four piles corresponding to the four sections of the manuscript. Pick up the introduction pile and spread these papers out before you. Then grab your pencil, keyboard, or Dictaphone, and start. If possible, the first draft should be conceived in one sitting, relentlessly moving from section to section.

Blueprint for a Radiology Research Paper

A research article has five sections: the abstract, introduction, methods, results, and discussion (Appendix 1). Although so ordered in the manuscript, the writing of these sections is often in an alternative sequence, such as materials and methods, results, introduction, discussion, and abstract. The reason for this is that the process of writing is in fact the process of thinking through the paper. Often, the central message of the paper is discovered only after the results are analyzed and written out.

As an ***organizing principle***, you should consider the gap of white space in a manuscript between the methods section and results section as the space in which the experiment was performed. Everything before this gap could be written before a single subject was enrolled. Everything after this space can only be written after the analysis of the data has been completed. It is often helpful to write the introduction and the methods sections before beginning any work on the study. This will tend to focus the investigation on a single purpose.

The following is a structured approach to writing the manuscript.

Preliminary Title

The title should include the imaging technique, the disease process, and an allusion to the patient population. The title should be short. Often, the linking of two important phrases with a colon satisfies the need for brevity and provides a sense of urgency. The title will almost surely change in the second draft, but writing this title first allows you to write the first sentence of your introduction.

Introduction

The purpose of the introduction is to provide a rationale for the study. You must provide the motivation and context for the current investigation. The first sentence of the ***first paragraph*** should pick up some or most of the words from the title. You need to articulate the issue your paper addresses within the first three sentences to satisfy the expectations of your readers and maintain their attention. For the opening sentence of the introduction, be sure to avoid sweeping generalizations (e.g.,

Sonography is a proven means of assessing renal transplants.). Such statements are usually vacuous and impede rather than advance your purposes, and worse, waste the opportunity to make your point in one of the most important stress positions of the entire manuscript. Once the issue is established, the intellectual claim of the manuscript—its point—should be made explicit in the concluding sentence.

The ***second paragraph*** of the introduction should provide a context and motivation for the current investigation. Typically, ***there are two reasons to write a paper:*** the study or experiment is the logical next step in a line of investigation, or prior studies have been somehow deficient in some way that the current study addresses. You should decide which rationale best justifies your study. If it is the first reason, then the literature review should focus on the most important two to four articles (you can reference many more if you like), and show how this line of investigation has led to your study. If the reason is the inadequacy of previous studies, then the two to four most important studies should be cited and their deficiencies explicitly stated. You will try to justify your contentions by means of examples, proofs, or reasons, or by providing a narrative unfolding of the details or intricacies of the issue. As a rule, avoid referring to papers using author names (e.g., Anderson, Lee, and Wilson report in their 1967 study that…). Such strings of proper names tend to slow the pace of the writing and become altogether too cumbersome. Rather, state the point you want to make about the study and reference it with a number at the end of the sentence.

The ***third paragraph*** of the introduction should open with the explicit statement of the overarching reason your study is needed, drawing from the preceding paragraph. The last sentence of this paragraph should begin, "The purpose of this study was to…" Readers have a very strong and fixed expectation that the purpose of the study will be found in last sentence of the last paragraph of the introduction. Do not worry about being unoriginal: this is not creative writing (at least in the common sense), but rather formulaic, patterned writing. A busy reviewer does not want to search for certain elements of the paper: these should be where he or she expects to find them, like tools in their rightful place.

Remember that the lack of a clearly stated research question is the most common reason for rejection of manuscripts by journal editors. There must be an identifiable hypothesis. There must be a question being asked.

This first attempt should be regarded as a preliminary introduction, and it may need to be modified as your interpretation of your data matures. You may find that the argument you make for your study can be recast for greater import and immediacy as you discover the more compelling aspects of your results and interpretations.

In summary, the basic structure of the introduction is

statement of the issue →
why your paper is needed →
explicit purpose or hypothesis.

Materials and Methods

If lengthy, the materials and methods section should be organized under subheadings. The first subheading should refer to subjects; the second subheading to procedures; the third subheading to definitions and criteria; the fourth to data collection; and the final subheading should refer to statistical tests. These subheadings should be considered a kind of scaffolding that can be modified and collapsed as needed to suit the investigation being reported and the requirements of the target journal.

Under the ***subjects*** subheading, you should indicate in the first sentence the overall design of the study. The choices are case report, case series, case-control study, cohort study, and clinical trial. You should also indicate whether the collection of data was retrospective or prospective.

Next, indicate how the study group was assembled. The criteria for inclusion or exclusion should be explicitly stated. If there is a control group, the assembly of the control group must be discussed. Were the case and control groups chosen randomly; if not, were they representative of a certain population? Often, the composition of the study group is characterized by a listing of the clinical indications that brought the patients to imaging. Be sure to indicate how many patients were enrolled for each indication. Statements about informed consent and institutional review board approval belong here.

The ***demographics*** of the patient population should be written in the methods section if this is a retrospective study. If this is a prospective study, then the inclusion and exclusion criteria represent the rules by which the study groups are chosen. Your rules create the bins into which subjects will be collected, and the ultimate result of that collection will be reported in the results section. That is, the demographics go in the results section for prospective studies.

The second subheading should be ***procedures***. In this segment, you should detail exactly what you did in the order in which you did it. The experiment should be described in steps, so that readers can reproduce exactly what you did if they so choose. Report the technical parameters you found in your template papers. For the equipment used, provide manufacturer's name and location (although some journals will edit this out as advertising).

The next subheading is ***terms and measures***. In this segment, operational definitions and criteria should be explicitly stated. If you have devised a ranking system, then the criteria for each category should be stated explicitly. Do not assume everyone knows what you mean by a certain diagnosis or level of severity. You may think everyone agrees on what defines an abdominal aortic aneurysm, but they don't. Think criteria, criteria, criteria.

In the next paragraph, the ***collection and validation of the data*** should be described with particular attention as to how the data quality is ensured, usually with blinding or intra- and interobserver variability measures. Here too you should establish what constitutes truth in your study (i.e., your gold standard). If proof against a diagnosis is presumed by a lack of symptoms or manifestations, then it must be clear how long the subjects were observed.

In the next paragraph, the ***statistical tests*** should be discussed in the order in which they were applied to the data. If there were several questions asked of the data, the statistical tests should be described in the same order as the experiment was developed. Typically, you will start with descriptive statistics to describe the study subject population, and then proceed to specific statistical tests of association to describe the effects of the experiment or a comparison between populations. In these comparisons, use multiple comparison techniques. This means use a global test of significance and then make pairwise comparisons. This approach first shows that there is some difference between populations in the global test and then teases out the specific differences between populations in the pairwise comparisons.

Make sure that the independent variables (factors or predictor variables) are clearly identified, and that the dependent variables (outcomes) are also identified. A statement about sample size and power calculations may be needed, especially if the study reports negative results. The last sentence of this paragraph should include a statement of what *p* value represents an acceptable level of statistical signif-

icance. Traditionally, this value is 0.05, but if a different level is chosen (usually a more conservative one), then that should be stated and the reason given.

The methods section can often be written at the outset of the study, even as the study is being planned. Presumably, all these factors have been decided on before the experiment occurs, and it is helpful to write this section, and indeed the introduction section as well, before the experiment occurs.

In summary, the basic structure of the methods section is

subjects → procedures and techniques →
definitions and criteria →
data collection and validation →
statistical tests.

Results

The development of the results section should parallel that of the methods section. If subheadings are used in the methods section, then the same subheadings should be provided in the same order in the results section. Again, you may choose to eliminate these subheadings, but the organization of the methods and results sections must coincide.

The ***first paragraph*** of the results section should describe the study population if this is a prospective study. Here, general comparisons of the baseline characteristics of the study populations are needed, and the descriptive statistics (means, medians, SDs, range) should be reported in tables or graphs. The population should be described in terms of number, sex, age, symptoms, or presentations. The baseline comparison should allow the readers to decide whether the case and control groups are similar or not, and more important, whether these groups resemble the patient populations in their own practice.

The ***second paragraph*** should describe the results of the experiments or the sorting of patients into the created categories (what percentage of subjects or experiments leads to which results; often best illustrated with tables and graphs). The results of the various procedures should be reported in the same order as described in the methods section. Keep editorializing out of results as much as possible. This section is simply for the reporting of facts and numbers, not for the interpretation of these findings.

In your reporting, make sure you check your units (e.g., cm vs mm). Make sure the numbers add up (all patients, lesions, and outcomes must be accounted for). When numbers do not add up or make sense, the paper will almost surely be harshly reviewed.

Depending on the study design, at least one paragraph should be devoted to how well the predictor or independent variables led to the outcome or dependent variable. If the experiment is such that the effects of several factors are being measured against an outcome, then the effect sizes of all the variables should be explicitly stated so that the reader will know whether these are clinically significant (in addition to being statistically significant). Statistical significance is a statement of the strength of the evidence, not necessarily of clinical importance.

The primary purpose of ***tables, graphs, and figures*** is to present data in a way that is easily and quickly grasped. To this end, data should be summarized, condensed, and displayed as transparently and memorably as possible. The most common and significant problem with tables is that authors will attempt to present too much information [6] and create an overly complex and undistilled smattering of numbers that will almost surely be ignored by all but the most diligent and critical of readers. Tables are an especially effective way to summarize demographic information and descriptive statistics. If two nominal variables (names or categories) are being compared, use a contingency table.

Regarding graphs, if you want to display the amounts or the percentages of a variable in different categories, use either a bar chart or a histogram. If two numeric measures of the same subjects are being compared, then choose scatterplots. If measurements consist of one or more nominal variables (categories) and one numeric variable, consider using box plots to illustrate the distribution of the numeric observations for each category [6]. Line charts can be used to display changes of a quantitative variable over time. Pie charts and pictographs are best used to display resource information, such as the relative portion or percentage of a population that falls into various categories.

Figures and images should illustrate the major imaging findings. The liberal use of arrows on figures is encouraged. If the details of the data are reported in tables, graphs, or images, then the text should summarize the major points of the figure but not exhaustively recapitulate the detail.

In summary, the basic structure of the results section is

descriptive statistics and baseline
population comparisons →
procedural results and sorted outcomes →
measures of data validity →
results of statistical analyses.

Discussion and Conclusion

The ***first paragraph*** of this section should summarize the results that address your study objectives. Do not start with a literature review or a protracted discussion of the pathologic entity under discussion. Such information should never be included unless the particulars have direct bearing on your conclusions, and even then, should never be introduced before the third paragraph of this section (see following text). Talk specifically about your ***principal findings***, which will be the findings that address the questions posed in the introduction. References to data from the results section should be limited to the most important numbers. Do not reiterate all the data from the results section, and never introduce new data here.

The ***second paragraph*** advances the thesis from findings to ***interpretations***. The principal findings of the first paragraph become the substrate on which the principal conclusions of the second paragraph are drawn. Do not extrapolate beyond the evidence. Draw reasonable conclusions from this current investigation only. Stay on topic: do not stray into discursive asides. If you have several major points to make, you may need to write more than one paper. Too many conclusions dilute the impact of any one: it is always better to produce two, or even three, papers that are focused and tight rather than create one comprehensive but diffuse magnum opus.

The ***third paragraph*** should state whether your interpretations are in concert with those of other researchers. Your interpretations will represent either consistency with current thinking or a departure from current thinking. Decide which it is and suggest reasons for this consistency or inconsistency (such as different patient populations, different procedures, or different level of data quality). This paragraph should place your conclusions in the context of conclusions from prior studies. References to the literature in this paragraph should not rehash the second paragraph of the introduction (which provided a rationale for the study), but rather should develop lines or axes of comparison between your study and earlier studies. Do not exhaustively describe all the aspects of all studies, but focus on the conclusions of those studies that relate to your own conclusions. Again, avoid strings of author names when referring to other studies.

In the ***fourth paragraph***, clearly articulate the ***clinical implications*** of your findings. What are the important clinical lessons to be drawn from your work? Are there diagnostic pitfalls to avoid? Are there key imaging findings that can aid diagnosis? New factors to consider? Try to make your new insights clinically relevant. If your work is more basic science in orientation, explain how your findings illuminate larger issues of pathophysiology. Can your findings be fit into what is known about the physiology, pathology, chemistry, or mechanics of the disease process under study? Offer a theory as to why matters just might be as you contend.

The ***fifth paragraph*** should indicate the ***limitations*** of your study. Be forthright, but do not flagellate yourself or your investigation. You want to be thoughtful and self-critical without undermining the validity of your study. Such commentary will tend to preempt criticism and thereby diffuse it, but more important, it provides your readers with an understanding of the practical limits of your data and interpretations.

The ***last paragraph*** should be a ***summary*** paragraph. First, restate your principal findings and conclusions. Second, emphasize the clinical or basic science implications of your findings. The last sentence should describe the logical next step, if one is needed. If there is no logical next step, do not recommend that people do further studies if you think this line of investigation is going nowhere.

In summary, the basic structure of the discussion section is

your chief results →
your interpretation of your results →
your interpretation in the context
of the literature →
clinical or pathophysiologic implications →
limitations → summary.

The Abstract

The abstract is usually written after all the basic components of the paper have been written. The abstract is a distillation of the four major segments: introduction, methods, results, and discussion. The abstract is organized along these subheadings. Economy is paramount. The purpose of the study should be encapsulated in one or two sentences. The methods paragraph should include only an outline of the procedures and variables. The results should report only the principal findings of the study. The conclusion should be limited to one or two sentences and should directly reflect the words of the purpose. There should be direct correspondence between the purpose of the study and the conclusions from the study.

The Good-Enough Paper

Revising the work is a task of systematic culling. If the first draft is the sowing of seeds, then revision is the work of weeding and pruning. In editing, you must be willing to delete your most cherished flights of rhetorical flourish in the service of a coherent thesis. This is detail work, best done piece by piece. For the revision, take a segment of text and work it over, then move to the next and the next systematically. Try not to linger: This is not your last chance at the text. Take that rough first draft and write all over the paper copy. Reorder things, restructure things, draw arrows, cross out. Make the changes, then sleep on it and look at it again the next day.

By the third or fourth draft, you should have a paper that is about 50–75% good. Stop here. Pass off the paper to your coauthors and let them earn their place on the paper. You may also want to enlist a dispassionate third party (not a coauthor), who will have greater critical distance. Tell them you want their comments in 1 week. Oftentimes, your coauthors will offer interpretations that you did not think of, or make suggestions that lead to a complete restructuring of your argument. Once you get the paper back from your coauthors, critically decide which comments you choose to incorporate into the next draft of your paper and which you choose to ignore.

This leads to the thorny issue of coauthorship and order of authors. At one level, the issue is relatively simple: authorship establishes accountability, responsibility, and credit [7, 8]. Unfortunately, the issue of authorship can become awkwardly politicized. A substantial proportion of manuscripts contain honorary and ghost authors [7, 9, 10]. The most egregious abuses come from senior staff and division chiefs who insist that their name be included, if only because the project was conducted within their division. No editor would endorse such honorary authorship, but it is a strong junior faculty member indeed who can stand up to that kind of pressure. The best advice perhaps is to clearly define exactly who is a member of the research group at the outset of a project and have everyone in that group agree to their roles and responsibilities in a collective meeting. Coauthorship then becomes a condition of the individual's fulfillment of this public contract. As a secondary resort, junior authors may also seek the support and oversight of the vice chair for research to ensure that those on the paper deserve to be there.

As a rule, the principal writer should be the first author and the mentor the last. Other coauthors are listed after the first author in order of their level of contribution. Again, much unpleasantness can be avoided if these issues are discussed early in a group meeting.

In the final drafts, you will find the paper taking final form. This is the time to be fastidious, to strive for the persuasive expression of your ideas through well-manicured sentences. Before you send the paper out, force yourself to read it carefully one last time, making sure that the numbers all add up, that there are no gross misspellings or grammatical errors, and that the references are in the order of their callouts in the text. If your reviewers are faced with many errors, they are likely to give the project little credence.

Submit your paper for review when you think it is good enough. Do not strive for perfection or you will never send the paper out.

Submission: Abject and Otherwise

The selection of an appropriate journal turns on whether the study is suitable for a general radiology audience or a subspecialty audience. Do not overvalue your paper (which can lead to demoralizing rejections), but do not undervalue your paper either. If you think it might make it into one of the major radiology journals, send the paper with the foreknowledge that even seasoned investigators often have trouble publishing in these journals. If you get a rejection, pick yourself (and your paper) up, dust yourself off, reformat the paper for another journal, and use the critiques of the reviewers to improve your paper. Look critically at your study for ways that the presentation can be more transparent and your purposes clearer. Remember that if you make reviewers work too hard to understand your paper, they will not like it.

If your paper is accepted pending major revision, try to accommodate all or most of the requests as best you can. You want at least to appear to comply with the spirit of the criticism. A positive and conciliatory attitude in your response will likely engender a positive and conciliatory attitude in return; a pugnacious one will not. Quibbling with reviewers or the editor never endears you to them and rarely expedites progress to publication.

If your paper is not accepted, do not give up. Of all papers submitted to the *American Journal of Roentgenology*, 82% are eventually published there or in some other journal [11]. If you do not know how to improve your paper,

seek help from others who may not be in your subspecialty but know how to market their wares. These are usually the people in the department who have written and published many papers. Other good sources of advice on scientific writing are listed in Appendix 2.

Last Words of Encouragement

First attempts at writing up an investigation are challenging. The most important thing is to start. The next most important thing is to get the elements of the paper in some coherent order (Appendix 1). If these two objectives are fulfilled, you can usually count on an experienced writer or a mentor to help you guide the document to an acceptable state. What that mentor does not want is to have to take a completely disorganized document and rewrite the entire thing. And, of course, this is not what the junior researcher wants either. Considerable satisfaction will be gained in taking a project nearly to its conclusion as a published manuscript, and no one deserves that satisfaction more than the one who did most of the work.

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APPENDIX 1: Paragraph by Paragraph: Content and Order of the 18 Basic Paragraphs in the Typical Radiology Manuscript

Introduction
1. Statement of the issue
2. Why your paper is needed
3. Explicit purpose and hypothesis

Materials and Methods
4. Subjects
5. Procedures and techniques
6. Definitions and criteria
7. Data collection and validation
8. Statistical tests

Results
9. Descriptive statistics and baseline population comparisons
10. Procedural results and sorted outcomes
11. Measures of data validity
12. Results of statistical analyses (same order as in Materials and Methods; often > 1 paragraph)

Discussion
13. Your chief results
14. Your interpretation of your results
15. Your interpretation in the context of the literature
16. Clinical or pathophysiologic implications
17. Limitations
18. Summary and future directions

APPENDIX 2: Good Sources of Advice on Scientific Writing

1. Gopen GD, Swan JA. The science of scientific writing. *American Scientist* 1990; 78:550–558
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