

Writing well: lowering the barriers to success

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It is not enough to be a good scientist. One needs to be a good communicator. When publications are clear and a pleasure to read, they will advance both the field and the authors' reputation.

Communicating research is inherent to doing science. Researchers love to do research. They generally have less enthusiasm for writing about it. Too often, scientists view writing and publishing as a burden, an unwelcome add-on that slows their momentum and interferes with getting on to the next experiment. Why, then, do scientists write? There are two sets of reasons—content-related and career-related. Researchers disseminate findings to move their field forward, thus allowing others to add further knowledge. Without publications, the work would go unrecognized, and the field would not advance. Publications are also the currency of a career, valuable in acquiring visibility, demonstrating independence and advancing professionally. Like it or not, researchers are measured by what they write. They can have brilliant ideas, but if they do not communicate those ideas clearly, no one will know.

Writing is hard but not impossible

Writing in any form is hard. Under the rigorous peer-review system, publishing research manuscripts is a difficult mountain to climb. The energy of activation for a scientist to write a first draft can be high. How can one lower this energy barrier and even make writing fun?

Researchers are constantly writing, and many find it difficult to recognize any value

that does not directly lead to a manuscript. Like all things, to get better at writing, one must write. By producing a large volume of diverse written work, an author increases the chance that something previously thought irrelevant could be useful again. Also, with the increase in the use and acceptance of online resources, it is no longer necessary to rely on writing papers, reviews and grant applications to hone scientific writing skills. There are many opportunities to write for a scientific audience such as in professional society newsletters, blogs, webpage content, and by guest-writing pieces, expert opinions and article comments. Even thoughtful LinkedIn or Twitter updates can go a long way to increase not only writing experience but also visibility and status.

A more traditional tactic, however, is often closer at hand. There is never a shortage of other scientists who need help with their own writing. Offering to review papers for a journal, editing peer manuscripts and creating writing groups are effective means to build familiarity with the writing process. Scientists should not discount the value of reading the work of their colleagues because, among many things, they begin to recognize 'good' papers and emulate them while recognizing 'bad' papers and learning from them.

Perhaps the most effective way to practice without even having to write is by participating in or starting a journal club. There are many advantages to this approach, not the least of which is learning how to critically read an article. Journal club members also get valuable opinions and evaluations from peer scientists on interesting papers. Eventually, members learn how to craft better manuscripts because they have been able to critically view a research article from multiple perspectives: as a colleague (user), as a reviewer and as an editor.

Overview of the writing process

Scientists accept that experiments do not always go as planned. Writing is no different. Authors should approach writing like they would approach their research, by starting with a research question. How does one identify a good question? A good scientist knows the field, reads the literature and recognizes important challenges. With this in mind, scientists need to consider manuscripts before beginning the experiments. Outlining a project with manuscript(s) in mind promotes a systematic approach. In such an approach, benchmarking progress through achieving intermediate goals helps keep the project on track. As experiments progress, figures should be mapped out in a logical fashion. Writing and figure-making should be integrated with the collection of data. This process can be streamlined now that many data readouts are digital, thus allowing for the almost simultaneous production of results and figures. As this process repeats, the author must begin to assemble the results into a message, i.e., the answer to the question. Everything else flows from the message, and there must be only one message per paper. The author has to be brutally selective as to what must go in the paper to provide enough evidence for the answer.

Tackling certain sections of the growing manuscript will require more thinking and decision-making than others. Authors should build an outline of the entire paper, beginning with just the section headings and then adding subsections as needed. Once complete, the outline provides a framework to writing a draft in earnest. One of the most important steps to successful writing is to accept that the first draft will be far from perfect. The author must not fall into the trap of trying to write their first draft as if it is the only and final version. Authors should write the first draft by doing whatever it takes to get

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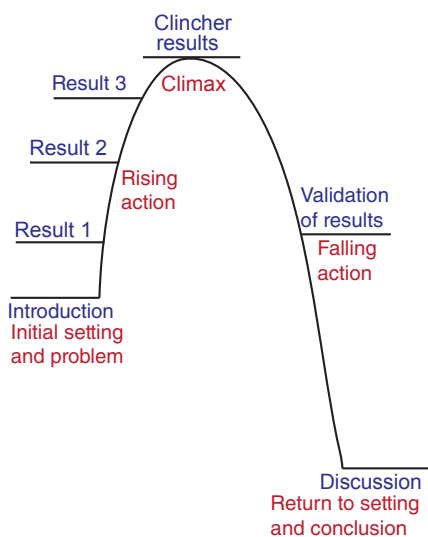


Figure 1 The dramatic arc of the scientific story. The data of the research can be summarized along an outline of a dramatic arc that resembles an energy-of-activation curve. This analogy resonates with the writing process, as scientists often struggle to reduce the energy barrier to writing. Adapted from ref. 2.

that first one done. Trying to please reviewers or readers at this point will only make it harder. Once the first draft is created, the process of revising and rewriting becomes easier. Revise for content by including only what needs to be in the paper and putting it in the proper order. The next round of revision should encompass writing style, organization of paragraphs, structure of sentences and word choice¹. Proofreading is often difficult for writers because they know the content well; thus scientists should not hesitate to reach out to other colleagues for a 'spare set of eyes' to help identify typographical, grammatical or linguistic errors.

What a manuscript does

Papers have both anatomy and physiology, structure and function. A manuscript is not just words on a page or a screen: the words are there for a purpose. Understanding what papers are for, and what the parts are for, makes it much easier to write them well. The title grabs the reader's attention. It must be both interesting and accurate, so that the reader's expectations are met. The introduction poses a research question. It shows the importance of the question and the need for the answer. It should build momentum and make the reader want to know more. The methods section does more than is commonly assumed. On the surface, the methods allow others to replicate and confirm published work. More deeply, this section demonstrates that the investigator has chosen the correct methods and used them appropriately.

The methods section convinces the reader that the data will be interpretable and the inferences will be valid. The results section answers the question and, notably, shows the evidence in support of the answer. For many, the discussion can be difficult to write for many. It places the answer in the context of previous published work. It may also tell the reader what to do with the answer and indicate the impact of the work.

Scientific storytelling

An author does not write a manuscript in isolation. Papers are usually group efforts, especially once the draft reaches a critical point. Producing a manuscript across a diverse authorship setting typically enhances the impact of the research, yet the process is often complicated. Each contributor has an opinion on how best to present the research story, often in his or her own field-specific language. How does a scientist harness the exciting results from a collective research effort and tell one cohesive research narrative to a broad scientific audience?

It is perhaps surprising that an age-old method, storytelling, can be repurposed as a tool for writing scientific manuscripts, as described in the book, *The Art of Scientific Storytelling*². Creating and resolving conflict works well in fiction, and even biography or history. The use of a similar structure can provide a rational framework for interdisciplinary, collaborative research manuscripts. The wealth of data generated in a research study can be systematically transformed into a story. The 'conflict' in research involves setting the stage, identifying a need or an unknown and building momentum so that the reader wants to know the outcome. The 'resolution' is describing the methods, showing the results and explaining how they meet the previously stated need. The responsibility is upon the investigator to tell this story in a logical fashion and make it clear to a scientific reader. It is important to remember that the logic and timeline of the manuscript are not necessarily the same as the timeline in which the experiments were performed. Applying the principles of logical storytelling to writing research manuscripts makes it easier for the reader to follow the text, grasp the point, and place the work in context.

Hypothesis-driven research progresses as scientists experiment, generate data and interpret the current literature. The first step in the storytelling process is to identify and justify the need for the research. Once this is done, the researcher can address the problem by conducting experiments on one important aspect of the gene, protein or chemical process (the 'protagonist') under study. Researchers control the independent variables in their experiments

and observe the effect of a manipulation on the dependent variable. Similarly, in storytelling, an event changes the protagonist and may affect the entire cast of supporting characters. A series of experiments allow the scientist to develop a narrative that describes the research phenomenon. This narrative is built on logic and reason. With a protagonist, conflict, resolution, antagonist and stakes, the author can assemble a story with variables, results, agreements, disagreements and wider implications.

A scientific story arc

The introduction sets up the situation and makes the reader care about the 'plot'. The introduction also introduces the 'characters'. The results are the backbone of the manuscript, the 'scenes' of the story. Figures and tables should be arranged in a logical sequence because they narrate the path of the identified protagonist in the data. The most important finding is the equivalent of a climax of the scientific story. After showing the data, it is imperative to provide evidence that the results are credible in the context of existing work. The discussion (conclusion) must, of course, be based on the data and explain what the data mean in the larger scheme. In a scientific story, the hypothesis is expanded into an abstract that follows a dramatic arc (Fig. 1).

For the writer (storyteller), the methods section requires few decisions and can be written upon finalizing the details of the study. Results can be written once the arrangement of figures is decided. The results section forms the foundation of the entire manuscript. The introduction will frame the question and focus the reader's attention, from the larger picture inward to the specific hypothesis. It calls for some decisions, guided by the results. The discussion should describe how the new results fit in the context of the current literature. The discussion is the mirror image of the introduction, proceeding outward from the specific answered question to larger implications for the field.

Keep the reader in mind

Papers serve a purpose, and anything with a purpose will have users. The readers are the users, so authors must ultimately write with their audience in mind. Reach the right audience by choosing the right journal. This sounds straightforward, but the choice of a journal can be yet another barrier to writing and publishing the paper. The time for authors to start thinking about where to submit a manuscript is before they start writing. Indeed, it is best to have an idea before they start doing the work. Different journals offer different choices of format. They may have requirements or limi-

tations that have bearing on the manuscript. Most importantly, they reach different groups of readers.

Authors should reflect on the reasons they read papers and on the journals they read themselves. This insight can reveal who they want to read their papers. Keeping in mind the scientific and career-related reasons to view a paper, the audience will be scientists who need the information, and individuals to whom the author wants to be more visible scientifically and professionally.

The audience will have multiple levels of interest. Close colleagues—and competitors—in the field will read the text and examine the figures in detail. They need to know the data that directly complement or counter their own research. Others in the same field but somewhat peripheral will find some of the data relevant to their work, so will read selectively. Investigators in unrelated fields may want to learn a new approach, incorporate the research findings to their work or even change direction. For students and fellows, publications are a way to reach potential employers for positions and jobs. For more established scientists, publications are a recruiting tool for their next students, postdocs and potential hires.

Consider the scope of the journal

With a sense of the audience, authors can think about what journals are likely to reach the desired readers. A good place to start may be the journals they read themselves; chances are that like-minded investigators read the same ones. The journal of field-specific professional societies could be an efficient way to target those in the field who should see the work. To reach viewers in other fields, consider a journal of more general interest.

With a few options in mind, the investigators should make an educated choice of where to submit. Edward J. Huth, the longtime edi-



Nature Publishing Group/Chris Sharp

The craft of writing is hard, but not impossible.

tor of the *Annals of Internal Medicine*, treated this topic elegantly in his classic book, *Writing and Publishing in Medicine*³. To ensure a well-informed and knowledgeable review of the paper, the list of the journal's editorial board members should contain familiar names.

At each possible destination, authors should read the instructions to authors and, where available, the instructions to reviewers. The latter can be invaluable in learning what manuscripts will be a 'good fit' for a given journal. Of course, the subject matter should be included in the journal's stated areas of interest, but that is not enough. Authors should examine the last few issues of the journal to determine whether work that is similar to their submission is published regularly or intermittently. Using this selective approach can increase the chance of the manuscript being accepted as a 'good fit'. Rejection may have nothing to do with the merit of the paper; it may simply be a matter of timing. Authors should be flexible and persistent, as cutting-edge research is published in many journals.

Logistical issues can affect the choice of a journal. A manuscript written in a particular format, such as a brief or rapid communica-

tion, can be submitted only to journals that accept that format. If the desired journal does not use that format, the authors will need to choose a different format or a different journal. An author under pressure to publish before graduation or a grant application due date will not have the luxury to recraft a rejected manuscript and submit it elsewhere. Word limits or restrictions on the number of authors, may further constrain the choice. Successful submissions to high-impact journals must be sufficiently interesting to a broad, general audience. Though this is beyond the scope of this Commentary, it is imperative that the research described is novel, is sufficiently mechanistic and demonstrates physiologic relevance.

Conclusion

Authors can lower the barriers to writing by adopting a few tools and habits: make the practice of writing part of daily life by taking opportunities to write short, enjoyable pieces; consider writing to be a part of the project, keeping manuscripts in mind from the start and as the research progresses; recognize the purpose of the paper and its parts, to produce a first draft, however imperfect; revise and then revise again; create a story around the need for the work, findings and conclusion; understand the intended audience to reach them most effectively. These steps can make scientific writing less stressful and more successful.

COMPETING FINANCIAL INTERESTS

The authors declare competing financial interests: details are available at doi:10.1038/ni.2923.

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