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is important to write down and follow ground rules on how the author list will be determined, the drafts composed and the editing and revision process carried out. It is especially important to maintain contact among collaborators and ensure that all co-authors are on board with changes to the manuscript. More generally, it is helpful to remember that ultimately your research paper should tell a compelling story — and that this story is the principal, tangible result of the group's work.

MAKE THE 'WRITE' DECISIONS

Once collaborators have agreed on ground rules and authorship questions (see 'First things first'), they immediately need to agree on a 'composing author' — the team member who is most familiar with the project details and most likely to have the deepest and broadest perspective. This teammate maintains the master copy of the manuscript and incorporates input from each co-author.

It is most effective if the same person serves as composing author from the project's launch to publication. There are usually many rounds of editing at each stage of the manuscript's life, and often the same points arise at different stages; if one person is shepherding the manuscript throughout, it is easy for them to recall the reasons behind various editing decisions if similar points are raised again. Having a single composing author also helps to establish a coherent, consistent voice.

Of course, life is complicated, and it may not be possible for one person to oversee the whole project. If the original composing author must step down, the team should explicitly agree on a replacement. The manuscript should be 'owned' solely by that person going forward.

We always urge our lab groups and collaborators to start writing before the research project is complete. A paper usually begins with an explanation of the motivation for the project and a survey of earlier related work. What better time to create this section than before you have fully plunged into the study?

Also, doing this bit at an earlier stage helps to delineate the paper's logical path and to provide a guide for the research ahead. When the survey of earlier work is prepared in advance, it is easier to foresee, for instance, what might need to be measured to choose between possible alternative interpretations of the data.

It is also useful to create an overall outline for the paper early on. The composing author should write it, discuss it with the team and reach consensus. ▶

COLUMN

Paper craft

Consensus with co-authors is vital when writing up research, say **Dmitry Budker** and **Derek Jackson Kimball**.

Most scientific manuscripts today have anywhere from two to thousands of co-authors. Large collaborations — generally defined as more than a couple of dozen members — usually establish formal structures to govern manuscript writing, but smaller groups often develop their writing rules in an ad hoc way. As a result, we have seen — and participated in — countless small collaborations that struggle with such

fundamental issues as editing their manuscript and deciding on the author list. Here we offer some general rules for small groups on how best to craft a scientific manuscript.

Writing a research paper is not necessarily formulaic, but we have learned some useful principles and guidelines from our own and others' experiences that will help to avoid many such obstacles and produce clear, engaging and readable text. From a practical standpoint, it

► Such a framework helps to crystallize the goals of the project, forces the group to address key scientific questions from the outset and keeps the work focused. More than once, we have completed a study and reconfigured the experimental apparatus for some new investigation, only to discover while writing the paper that we had overlooked a detail that requires more data. The outline can help to avert this misstep.

In some cases, it can work well if the first drafts of different manuscript sections are composed by different team members in accordance with their strengths — a theorist could write a section on calculations and an experimentalist could write a section on measurements, for example.

If your collaboration uses this model, the composing author should be the one to incorporate the different sections into a coherent story.

COMMUNICATION AND CONSENSUS

The decision on whether to add, delete or change existing content in the master copy calls for constant communication between the composing author and each co-author. As the composing author revises the master copy, he or she must send each new version to every co-author along with explanations of the changes. No one except the composing author should edit the master copy — co-authors need to send suggestions, corrections and extra pieces of text to that person.

By the same token, the composing author should acknowledge — although not necessarily incorporate — all such input from co-authors and, ideally, launch a discussion to reach agreement. From the co-author's point of view, it can be extremely frustrating to read an updated draft of the master manuscript and see the very problem that he or she had pointed out earlier — we have seen this happen often. When a co-author asks why the problem was not addressed, the composing author usually says only that he or she disagreed with the suggestion or did not find a good way to change the text. These are the very reasons to have a discussion.

The entire collaboration must agree on a first draft and on all subsequent drafts. We have both co-written papers that went through scores of serious revisions, a process that required a lot of patient, careful work over an extended period. In some of our collaborations, composing authors solicited and incorporated some edits from co-authors without sharing the final version of the manuscript with the entire team.

Co-authors have the right to expect and demand that the composing author follow the established ground rules during a collaboration. If they discover violations of those rules only after submission or publication, their response may well be to sever ties with the collaboration, which would be a calamitous and entirely avoidable result.

FIRST THINGS FIRST

The thorny problem of the author list

Who should be a co-author of the paper?

Two key questions we ask are: 'did the researcher make a meaningful contribution to the project?' and 'does the researcher understand the complete work well enough to explain and defend it to colleagues?'. Becoming a co-author of a paper is a serious commitment: that person's scientific reputation is now wedded to the validity of the paper. We have found that it makes sense to be reasonably inclusive: generally, people who feel that they do not meet the threshold for co-authorship will excuse themselves from the author list. It is much more damaging to the collaboration to leave someone off the author list who feels that they should be included than it is to include someone who has made marginal contributions. The omission can create hard feelings and possibly violate scientific ethics.

The order of authors on a collaborative scientific publication is often a source of

contention within the group, especially because different scientific communities have different and often unwritten rules. The high-energy-physics community, for example, tends to adhere to a strict alphabetical order of authors, whereas in atomic physics, students and postdocs who are central to the project are usually listed first and the principal investigator appears last.

Think about the author order from the start. What do you do if there is more than one student or a student and a postdoc who contributed equally? And what do you do if the work is a collaboration among several laboratories? Which laboratory goes first? Should the authors be grouped by laboratory, or should there be some other criterion?

Explicit descriptions of each author's role in the work can make author-order discussions less fraught. 'Author contribution' sections should be included even for journals that do not require them. These should spell out who did what on the project and who is responsible for which parts of the manuscript. When a collaboration cannot reach consensus about author order, the principal investigator should step in to make those decisions and provide detailed reasoning for the verdict. If there are multiple principal investigators, they must work out the order between them.

Ultimately, co-authors should not worry about this too much. We have witnessed heated arguments over who should be the first author; but 10 or 20 years later, we can see that it did not really matter that much in the end. **D.B. & D.J.K.**



In any case, if you are named composing author, you must consistently keep co-authors in the loop. Excluding them creates a lot of hard feelings and may also violate the norms of scientific ethics.

Everyone on the team needs to be available and responsive. Work comes to a halt when co-authors disappear into a 'black hole' in which e-mails and phone calls go unanswered.

We recommend defining a maximum response time — generally a few days — during which co-authors must at least acknowledge receipt of a communication. We also recommend that the composing author maintain consistent availability for the entire course of the writing project, which in some cases can be a year or longer.

Whether there are 2 authors or 22, each co-author should read the entire final manuscript and explicitly agree that the paper is

ready for journal submission or for posting to an e-print archive. The same holds true when a paper has been submitted and accepted, and is undergoing final edits — the full team needs to read and agree on the final version before publication. This is not only a courtesy to authors, it is also a cornerstone of scientific ethics, not to mention journal-policy and legal considerations.

We emphasize that these guidelines are not arbitrary: they originate from stressful and frustrating experiences that we have both lived through and witnessed. ■

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