

An Approach to the Writing of a Scientific Manuscript¹

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Objective. Writing a scientific manuscript is one of the most important tasks facing the academician, and may also be one of the most daunting.

Materials. The essentials of any paper include a description of what is known, an assessment of what is unknown, a clear statement regarding the question and hypothesis being addressed by the current study, and a discussion and summary of new information that has been learned as a result of the study.

Conclusions. A formulaic approach is provided to guide the author through this process. © 2005 Elsevier Inc.

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INTRODUCTION

Writing a scientific manuscript is one of the most important tasks facing the academician, and may also be one of the most daunting. There can be no greater satisfaction for the researcher than seeing his or her work undergo a peer review process and culminate as a printed article. By contrast, the relative frustration and potential anxiety involved with the publication process may prevent publication, thereby thwarting public debate and forcing other investigators to repeat experiments unnecessarily. To publish, one has to be able to write a scientific manuscript in a format that the readers—and the reviewers—can follow, and can learn from. Several authors have provided information

to assist investigators in this task [1–5], and there are certainly a large number of reliable and useful resources that explain how to write for the scientific literature [6–8]. The approach described in this manuscript is by no means the only way (and likely not the very best way) to write a research paper. However, it is hoped that it may provide researchers with a formulaic approach to make the task as straightforward as possible. See Fig. 1 for the overall approach to writing a scientific manuscript and a description of its major components.

THE INTRODUCTION SECTION

The introduction section of the manuscript has three essential purposes, which can be accomplished by addressing the following: What do we know (about this topic)? What don't we know? What are we now showing? Once these questions are answered, the reader will have a clear understanding of the nature of the current study, and will be clearly aware of the context in which the study is being performed.

The first question involves addressing what is known about the topic. To accomplish this, the author should provide a comprehensive review of the major findings in the current area of study. It is important to be complete, fair and balanced in your assessment of the current literature. The more completely written the section describing “what we know” is written, the easier it becomes to state, “what we don't know”. This paragraph should build the reader's attention and interest in your hypothesis.

The second question (“What don't we know?”) involves identifying what the gaps in our current understanding of the field are, and why it is important that these gaps be closed. It is important to identify and reference those studies in the literature that have addressed these or similar issues, so as to allow full disclosure regarding the novelty of the current work.

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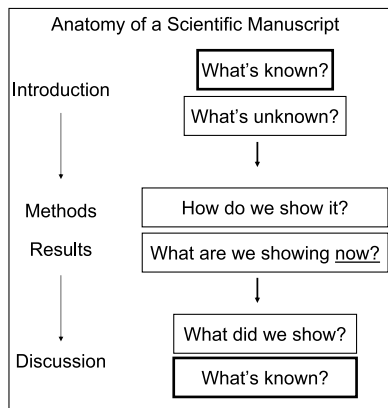


FIG. 1. Anatomy of a research manuscript. The essential components of a typical research manuscript are described.

Finally, the introduction section should end with a clear statement summarizing what's known, what needs to be learned, and what your paper aims to accomplish. Pitfalls in this section include omitting an important paper and thus overstating the novelty of the current study. This can be remedied by a careful literature review.

Some authors complete the introduction section with a short paragraph detailing the essential findings of the paper. Such a paragraph may start along the lines of "In the current study, we demonstrate that. . ." followed by a sentence (or two) in which the methodology and evidence in support of (or against) the hypothesis is clearly summarized. This focuses the manuscript, and facilitates the way in which the remainder of the paper is written.

METHODS SECTION

This section provides the reader with a detailed analysis of the methodology used in the conduct of the experiments. By definition, it should strike a balance between providing sufficient detail so that readers can repeat the experiments themselves, but is not expected to be a laboratory manual. The methods section should always provide information regarding each of the controls used, and should list all of the necessary sequence information used for the generation of oligonucleotides, antibodies, or siRNAs. It is the methodology section that reviewers turn to when critically evaluating the experimental design, and that subsequent investigators turn to when attempting to repeat the experiments. For this reason, the methods section provides a critical opportunity to build a "good name" for oneself in the scientific community, where attention to detail is extremely important.

Pitfalls in the completion of the methods section include failure to acknowledge the source of vectors, constructs, antibodies or key reagents, and in omitting a critical step in either the set-up or conduct of an

important experiment. When appropriately written, the methods section can provide an extremely useful resource for the scientific community.

RESULTS

The results section is truly the heart and soul of the manuscript. It contains all of the data to support (or refute) the hypothesis that was proposed in the introduction section. Many authors find it most useful to actually start the paper with this section and to build the rest of the paper around it. The results section serves to weave a coherent story and must communicate the findings to the reader in a logical, transparent manner. Therefore, it is perfectly appropriate to describe the results in a manner that makes sense, as opposed to describing the experiments in the temporal order in which they were performed. It may be helpful to use subheadings to introduce new paragraphs, and to devote a paragraph to individual or closely related figures. Useful phraseology to introduce new results include the following: "Having shown that . . ., we next examined whether. . .", "Given the results of the foregoing experiments, we therefore assessed whether. . .", "These results suggested that. . ., we therefore next tested the possibility that. . .". It is permissible to use the past tense when writing the results section, given that at the time of the writing, the experiments were indeed performed in the past (as opposed to the discussion section, where the present tense may be more appropriate).

Several potential pitfalls exist when writing the results section. When using figures, care should be taken to avoid simply repeating the findings in both the figure and the body of the text. It is important to avoid conjecture or speculation in the results section, unless one is writing a combined results/discussion section. Care should be taken to include appropriate statistical analyses, to indicate clearly the number of subjects or animals examined, and to carefully describe controls that are used. In general, one should take pains to avoid the use of the term "data not shown". If there are data that are worth describing in the results section, and if space is available, they should probably be shown.

DISCUSSION

The discussion section allows the writer to communicate the significance of his/her findings, to indicate how they support (or refute) the experimental hypothesis, and to describe how these results advance the field of study. Several authors begin the discussion section with a paragraph summarizing the main results, culminating in a statement describing the overall significance of the work. Subsequent paragraphs are devoted to expanding on themes that the authors

feel are important for the reader to understand the significance of the work. It is appropriate to use the present tense and the active voice when writing this section. Useful phraseology may include, “*One possible interpretation of the results in figure . . . includes the possibility that . . .*” or “*The results shown in figure . . . are in contradiction to the work of . . .*”.

One of the major pitfalls in writing the discussion section involves overstating the significance or novelty of results. It is perfectly appropriate to make inferences about the significance of a set of studies with regards to the experimental system (i.e., cell line, species, study population) that comprised the study. However, extreme care should be taken not to generalize the findings into other systems. This is particularly true when studies were performed *in vitro* on a limited number of cell lines, or when an animal model was used with no human data to ascribe clinical significance. When conjecturing, the writer should be up front about it, using phrases such as, “*we therefore speculate*”. It is also appropriate to use phrases that leave room for criticism or differences of opinion on the part of the reader. This indicates that the writer respects the reader’s insights and interpretation of the data presented. For instance, the phrase “*together these data strongly suggest that. . .*” is probably preferable to the bluntly stated “*this means that. . .*”.

FIGURE LEGENDS, REFERENCES, AND ACKNOWLEDGMENTS

The figure legends should provide a detailed description of the corresponding figure, within the space allocated. Care should be taken to ensure that each symbol in the figure (typically arrow heads, arrows, asterisks) is explained. All statistical analyses, where appropriate, should be described. If a legend contains a description of the methodology used to perform an experiment, care should be taken to avoid duplicating this description in the body of the text.

References are listed in the order (alphabetical *versus* order of appearance) as determined by the particular journal style. In general, it is important to be as inclusive as possible when referring to previously published work. Work that is in press should be indicated

as such. Certain journals have stylistic restrictions regarding a citation as “unpublished results” or “manuscript in preparation”.

The acknowledgment section allows for the publication of important individuals who made the work possible, and who are not co-authors. These may include mentors, administrative assistants, and individuals that proofread the manuscript. It is important to identify the sources of all reagents that were obtained as a result of collaboration. The sources of funding should also be acknowledged. In summary, the writing of a scientific manuscript is always a daunting task, and requires a great deal of planning, preparation and time. To convey the experimental results in the clearest possible way, it is essential that a logical approach be taken in the formulation of each of the sections of the manuscript. As stated earlier, the approach described in this manuscript is by no means the only way (and most certainly not the very best way) to write a research paper. However, it is hoped that it may provide researchers with a formulaic approach to make the task as straightforward as possible.

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