How to Write a Scientific Paper or Laboratory Report

Your instructor may occasionally ask you to submit written reports describing the work you did in the lab. Although these reports will probably not be published in scientific magazines or journals, they are important because they will help you learn to write a scientific paper. A scientific paper is a written description of how the scientific method was used to study a problem.

Understanding how to write a scientific paper (such as a lab report) is important for several reasons. Scientists become known (or remain unknown) by their publications in books, magazines, and scientific journals. Regardless of the presumed importance of a scientist's discoveries, poor writing delays or prohibits publication because it makes it difficult to understand what the scientist did or the importance of the work. Poor writing usually indicates an inability or unwillingness of a scientist to think clearly.

Scientific papers are the vehicle for the transmission of scientific knowledge; they are available for others to read, test, refute, and build on. Few skills are more important to a scientist than learning how to write a scientific paper.

Before you finish reading this section, go to the library and browse through a few biological journals such as *American Journal of Botany, Ecology, Journal of Mammalogy,* or *Journal of Cell Biology*. Make photocopies of one or two of the articles that interest you. As you'll see, scientific papers follow a standard format that reflects the scientific method.

PARTS OF A SCIENTIFIC PAPER

Almost all scientific papers have these parts:

- Title
- List of authors
- Abstract
- Introduction
- Materials and methods
- Results
- Discussion
- References

Understanding this format eases the burden of writing a scientific paper, because writing is an exercise in organization. Refer to the journal articles you photocopied in the library as you read this text.

Title

The title of a paper is a short label (usually fewer than 10 words) that helps readers quickly determine their interest in the paper. The title should reflect the paper's content and contain the fewest number of words that adequately express the paper's content. The title should never contain abbreviations or jargon (jargon is overly specialized or technical language).

List of Authors

Only those people who actively contributed to the design, execution, or analysis of the experiment should be listed as authors.

Abstract

The abstract is a short paragraph (usually fewer than 250 words) that summarizes (1) the objectives and scope of the problem, (2) methodology, (3) data, and (4) conclusions. The abstract contains no references.

Introduction

The introduction concisely states why you did the work. Avoid exhaustive reviews of what has already been published; rather, limit the introduction to just enough pertinent information to orient the reader to your study.

The introduction of a scientific paper has two primary parts. The first part is a description of the nature and background of the problem. For example, what do we already know (or not know) about the problem? This description is developed by citing other scientists' work, to give a history of the study of the problem, and by pointing out gaps in our knowledge. The second part of the introduction states the objectives of the study.

Materials and Methods

The materials and methods section describes how, when, where, and what you did. It should contain enough detail to allow another scientist to repeat your experiment, but it should not be overwhelming.

Materials include items such as growth conditions, organisms, and the chemicals used in the experiment. Avoid trade names of chemicals and describe organisms with their scientific names (e.g., *Zea mays* rather than "corn"). Also describe growth conditions, diet, lighting, temperature, and so on.

Methods are usually presented chronologically, and this discussion is often subdivided with headings. Examples of methods include sampling techniques, types of microscopy, and statistical analyses. If possible, use references to describe methods.

Experiments described in a scientific paper must be reproducible. Thus, the quality of materials and methods is judged by the reader's ability to repeat the experiment. If a colleague can't repeat your experiment, the materials and methods section is probably poorly written.

For most lab reports, do not copy the experimental procedures word for word from the lab manual. Rather, summarize what you did in several sentences.

Results

The results section is the heart of a scientific paper. It should clearly summarize your findings and leave no doubt about the outcome of your study. For example, state that "All animals died 29 hours after eating cyanide" or "Table 1 shows the influence of 2,4-D on leaf growth." Keep it simple and to the point.

Tables and graphs are excellent ways to present results but shouldn't completely replace a written summary of results. Tables are ideal for presenting large amounts of numerical data, and graphs are an excellent way to summarize data and show relationships between independent and dependent variables. The variable that the scientist established and controlled during the experiment is the **independent variable**. It is presented on the *x*-axis of the graph. Protein content of a diet might be an independent variable in an experiment measuring weight gain by an animal (fig. 2). Similarly, time and temperature are often independent variables.

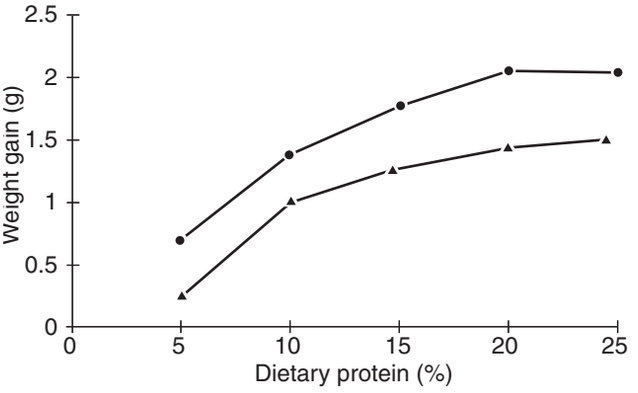

Figure 2
Sample graph from a scientific paper.

The **dependent variable** changes in response to changes in the independent variable and is presented on the *y*-axis of the graph. Weight and growth rate are examples of dependent variables that may change in response to light, temperature, diet, and so on. Graphs must also have a title (e.g., "Influence of Temperature on Root Elongation"), labeled axes (e.g., "Temperature," "Root Elongation"), and scaled units along each axis appropriate to each variable (e.g., °C, mm h^{-1}). Place tables and graphs on separate pages from the text.

Discussion

It's not enough to simply report your findings; you must also discuss what they mean and why they're important. This is the purpose of the discussion section of a scientific paper. This section should interpret your results relative to the objectives you described in the introduction and answer the question "So what?" or "What does it mean?" A good discussion section should do the following:

- Discuss your findings; that is, present relationships, principles, and generalizations. Point out exceptions and lack of correlations.
- Don't conceal anomalous results; rather, describe unsettled points. State how your results relate to existing knowledge.
- State the significance and implications of your data. What do your results mean? If your data are strong, don't hesitate to use statements beginning with "I conclude that . . . ."

References

Scientists rely heavily on information presented in papers written by their colleagues. Indeed, the introduction, materials and methods, and discussion sections of a paper often

contain citations of other publications. The format for these citations varies in different biological journals. The following citation for an article is in the format recommended by the Council of Biology Editors:*

White, H.B., III. Coenzymes as fossils of an earlier molecular state. *J. Mol. Evol.* 7:101–104; 1976.

A FEW SIMPLE RULES FOR WRITING EFFECTIVELY

Informative sentences and well-organized paragraphs are the foundation of a good scientific paper. Listed here are a few rules to help you write effectively. Following these rules won't necessarily make you a Hemingway, but it will probably improve your writing.

- *Write clearly and simply.* For example, "the biota exhibited a 100% mortality response" is a wordy and pretentious way of saying "all of the organisms died." Remember, keep it simple and straightforward.
- *Keep related words together.* Consider the following sentence taken from a scientific publication: "Lying on top of the intestine, you perhaps make out a small transparent thread." Do we really have to lie on top of the intestine to see the thread? The author meant that "a small transparent thread lies atop the intestine."
- *Use active voice.* Write "Good writers avoid passive voice," not "The passive voice is avoided by good writers." Here are some other examples of passive voice:

  Poor: My first lab report will always be remembered by me. (passive)

  Better: I'll always remember my first lab report. (active)

  Poor: Examination of patients was accomplished by me. (passive)

  Better: I examined patients. (active)
- *Write positively.* For example, write "The rats were always sick" instead of "The rats were never healthy."

  Use definite and specific sentences. For example, write "It rained every day for a week" instead of "A period of unfavorable growth conditions set in."
- *Be sure of the meaning of every word that you use, and write exactly what you mean.* Refer to a dictionary and thesaurus to ensure clarity and proper word usage. For example, you allude to a book, and elude a pursuer.
- *Delete unnecessary words.* For example:

Replace	*With*
The question as to whether	Whether
Advance notice	Notice
At this point in time	Now
Be that as it may	But
In the event that	If
General consensus	Consensus
Young juvenile	Juvenile
Student body	Students
Due to the fact that	Because
Chemotherapeutic agent	Drug

- *Use metric measurements* (see Exercise 2).
- *Be sure that each paragraph conveys a single major idea and has a topic sentence.* The topic sentence should state the main idea of the paragraph.
- *Have a friend or colleague read a draft of your writing and suggest improvements.*
- *Don't plagiarize.* Learn to summarize and be sure to cite all references from which you extracted information.

A neat and typed presentation is a must. If you use a word processor, remember to use the spell checker. Carefully proofread to catch mistakes. Put your work aside for at least 24 hours before you proofread. If you're interested in learning more about improving your writing, read *The Elements of Style* (4th ed.), by W. Strunk and E. B. White (New Jersey: Prentice Hall, 2000).

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* **Council of Biology Editors style manual: A guide for authors, editors, and publishers in the biological sciences. *5th ed. Council of Biology Editors; 1983.***