SCIENTIFIC WRITING: A GUIDE TO WRITING SCIENTIFIC PAPERS

All good writing involves two struggles: the struggle for understanding and the struggle to communicate that understanding to readers. Often reading good writing, especially technical or scientific writing, can help you become a better writer yourself. When you see good examples of scientific writing while researching related subjects, examine that writing to see what made it work. Use this handout as a way to organize the writing process as you prepare biology papers.

I. The Abstract

The Abstract is placed at the beginning of your paper following the title page, yet it should be the last thing that you write since it must completely summarize the entire report. The abstract is a short paragraph that reveals the "skeleton" of the study. Sentences should be concise, informative, and written in passive voice. A complete abstract will include:

1) Background stated in one or two sentences
2) Clear statement of specific question addressed and of specific hypothesis tested
3) Methods summarized in no more than three or four sentences
4) Major findings reported in no more than two or three sentences
5) Concluding sentence related to statement of specific question addressed

II. The Introduction Section

Many find the Introduction easiest to write after drafting the Materials and Methods, Results, and Discussion sections. In Introduction section, you briefly present background information that leads to a clear statement of the specific issue that will be addressed in the remainder of the report. Material in the Introduction often progresses from general to more specific statements, ending with the specific research objectives or hypotheses of the study. General rules for the Introduction are as follows:

1) **Support all statements of fact with a reference to a primary source or peer-reviewed journal.** Most scientific papers use indirect quotations rather than quoting the author verbatim with quotations marks. Refer to your reference within the text of the paragraph with the appropriate citation style. Remember that **plagiarism is a serious offense** and there are ways to avoid unintentional plagiarism, such as taking notes in your own words from the sources you intend to use or reading widely on the particular topic you are addressing (both of which help you to better understand the experiment and concepts!).
2) **Define specialized terminology**. This is often done with the help of outside research as well (cite these sources too). Give specific information on your study subject, study design, and purpose for the study.
3) **Do not make the Introduction too broad or detailed.** Every sentence should be designed to directly prepare readers for the statement of intent, which appears at the end of the Introduction section. Discuss only the most relevant concepts and references and get into the paper.

Often hypotheses or statements of intent are placed at the end of the Introduction section, but it may be helpful to write them first so you know what to be researching and how to organize all

the information in the section. Here you want to tell the reader what was the specific issue or question addressed in the study. Note that the following example is written in the past tense, since the study has already been completed:

> Poor: *In this study, we measured the metabolic rate of rats and mice.*
> Good: *In this study, the oxygen consumption of mice and rats was measured to investigate the relationship between metabolic rate, body weight, and body surface area.*

The first example did not tell the reader any important details pertaining to how the metabolic rates were measured and why the researchers went through the trouble of measuring those rates.

The Hypothesis

There are two main types of hypotheses, the null Hypothesis (H_o) and the alternative hypothesis (H_A). The null hypothesis is the one to be tested. The null hypothesis usually assumes that nothing unusual will happen in the experiment; that is, it assumes that the treatment will have no effect or that there will be no differences between the observed results and the expected results. The alternative hypothesis simply states that there *will* be a difference between the observed and expected results or that the treatment will have an effect. It is very important that **you do not set out to prove your hypothesis**; the hypothesis can only be discredited or supported.

Rules to remember when writing the Introduction:

1) Clear statement of specific question or issue addressed
2) Logical argument provided as to why the question or issue was addressed
3) Specific hypotheses are indicated, if appropriate, and a rationale for those expectations is provided
4) Every sentence leads to the statement of what was done in this study
5) All statements of fact or opinion are supported with a reference or example

III. The Materials and Methods

This section is almost always written first, though it is placed after the Introduction. It serves as a set of instructions for anyone wishing to repeat your study. It is written in past tense and often the passive voice is used. The final Materials and Methods itself is **not a list**; write it in paragraph form. But you can eliminate unnecessary details and highlight the important ones when it comes time to write by first making a list. Include in your list all materials used (including any special equipment, i.e. pipettes, spectrometers, etc.), the amounts used in the proper units (grams, millimeters, etc.), and the types of statistical analysis and programs used:

> Poor: *On January 5, I obtained 4 paper cups, 400 g of potting soil, and 12 radish seeds. I labeled the cups A,B,C,D and planted 3 seeds per cup, using a plastic spoon to cover each seed with about ¼ inch of soil.*

This is overly detailed and confusing to the reader. Did labeling the cups A-D or using a plastic spoon have any bearing on the results? Omitting the excess details, we obtain . . .

Good: *On January 5, I planted 3 radish seeds in each of 4 individually marked paper cups, covering the seeds with about 1 cm of potting soil.*

IV. The Results Section

Here you will summarize your findings using tables, graphs and words. The results section is:

1) **Not** the place to discuss why the experiment was performed
2) **Not** the place to discuss how the experiment was performed
3) **Not** the place to discuss whether results were expected or unexpected

Simply present the results, drawing the reader's attention to the major observations and key trends in the data, but **do not interpret them. Tell the reader exactly what you want them to see when they look at your graph or table.** The text should summarize, in past tense, the important findings in the data; it does not simply repeat raw data from the graphs or tables. If you are using graphs and tables, refer to them by Figure number or Table number within the text. Captions for figures go below the graph with a brief description of that figure; captions for tables will go above the table in the paper. Arrange them in the order in which you refer to them in the text of the results section.

Use words to draw the reader's attention to the key patterns in your data. First decide exactly what you want your reader to see when looking at each graph or table, and then stick the reader's nose right in it:

Temperature had a pronounced effect on seedling growth rates (Figure 1). In particular, seedlings at 25°C grew more rapidly than those at 20°C…

When presenting statistical data, place important values in parentheses immediately following the statement they pertain to. This is included almost any time you state that a result was significant or not. Note that the lead factual statement was supported by both a reference to a figure and by the results of statistical analysis in the following example:

Although individual specimens of Littorina littorea varied considerably in shell length at each tidal height (Figure 2), the mean shell length was significantly greater ($t = 26.3$; d.f. $= 47$; $p < 0.05$) for snails collected higher up the intertidal zone.

V. Discussion Section

In this section of the report, you must interpret your results in the context of the specific questions you set out to address in your experiment. Interpreting results requires that you thoroughly go over your data, find other sources to support your hypothesis, and come up with future questions based on the results. This may seem like a daunting task, but this is the section that can allow you to shine as a thoughtful science writer! The following is a list of what should go in the Discussion section:

1) What did you expect to find and why?

2) How did your results compare with those expected? If you set out to test a specific hypothesis, does your data support or reject that hypothesis? Explain your logic.
3) How might you explain any unexpected results?
4) How might you test those potential explanations?
5) Based on your results, what questions might you logically want to ask next?

A good Discussion section begins with a comparison between results expected and results obtained. The hypothesis or specific question is clearly restated with your conclusions and supporting references given. Always be careful to distinguish possibility from fact; the writer does not *conclude* anything, but merely *suggests* an explanation. Experiments cannot prove anything; they can only support or not support specific hypotheses. Evidence against the null hypothesis does not prove that the null is incorrect. Neither does it prove that an alternative hypothesis is correct. Similarly, failure to reject the null hypothesis does not prove the null is correct or that the alternative is incorrect. Thus, you must choose your words very carefully when presenting the results of hypothesis testing. Unexpected results are not always so easily explained away by human error alone, and these can often be used as suggestions for future research or technique and method refinements.

Rules to remember when writing the Discussion section:

1) Data should be clearly related to the expectations and hypotheses raised in the Introduction.
2) Facts are carefully distinguished from speculation.
3) Unusual or unexpected findings are discussed logically and thoughtfully.
4) All statements of fact or opinion are supported with references to the literature, data, or an example.
5) Discussion suggests additional questions that should be posed, future studies that could be conducted, or ways that the present study should be modified in the future.

Source: Jan Pechenik. *A Short Guide to Writing About Biology.* 6th ed. New York: Pearson Education, 2007.
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