

Research in Ecology

How to write a scientific paper

A good scientist also must be a good writer. All the research of a lifetime is useless if the investigator cannot effectively communicate new findings to his or her colleagues.

The exact format of a scientific paper will vary, depending upon the exact journal in which the paper is published. However, most journals use some variation of a format including the following components: **title, abstract, introduction, methods, results, discussion** and **literature cited**. You will be using this format when you write a scientific paper on your Team Research Project, as well as the paper describing an experiment you will do on caterpillars and their development. This outline instructs you how to write each of the six components of a scientific paper. When you write your paper, you should label each component (except the title) as shown below.

Title

The title of your paper will be read by the most readers, and it is the title that often will determine whether the rest of your paper will be read. It should describe *specifically* the contents of your paper. Generally, the name of the organism being studied is also included. Under the title, list the names of all investigators in the research team, the date and your institutional affiliation (In our case, it will be HHMI Research in Ecology Program 20XX.)

Abstract

The purpose of the abstract is to allow a reader to determine, with a very quick scan, what your report is about, how you did it and what you discovered. Although the abstract appears *first*, it is written *last*. In one double-spaced paragraph, offset from the rest of the paper, give a skeletal outline of your purpose (one sentence), methods, (one to two sentences), results (one to four sentences) and conclusions (one to two sentences). Do not cite literature references in the abstract.

The abstract is NOT merely an introductory statement. If you were actually to publish your paper, its abstract would appear in *Biological Abstracts*, a massive series of books containing nothing but the abstracts of scientific papers written in a given year. (The series is available in the reference area of the library, if you would like to see it.) An investigator searching for information on a particular subject can look up and read abstracts--rather than an entire paper--to determine whether a particular scientific study is relevant to his/her own work. If it is, s/he then can acquire the actual journal and the complete publication for a more detailed account of the study.

Introduction

This section can be written even before you begin your experiment. In one to several paragraphs, give *specific* background information on your project. Include a statement of purpose, the theory behind the experiment and what you are trying to demonstrate. Give background information on the species you are studying, if you are working on organisms.

When making a statement that is not common knowledge, you must cite the source of your information (see "literature cited" for instructions on the proper citation

format). Unless absolutely necessary, however, DO NOT USE DIRECT QUOTES! Instead, read, learn and *paraphrase* the knowledge.

The introduction is the proper place for you to state your **null and alternative hypotheses**. Include a summary of expected results (in terms of your hypothesis) and why you expect those results. If you have not *mentioned* predictions in your introduction, you cannot claim later "this was in agreement with my prediction."

Methods (a.k.a. Materials and Methods)

The purpose of your methods section is to enable a reader to duplicate your experiment exactly, and to test whether your results are reproducible. **Using past tense** (you are not writing a cookbook), you must describe all materials and procedures you used. **List concentrations, quantities, etc., of reagents in neat tables and refer to these tables in the text!** (Example: "Concentrations and amounts of enzyme and substrate used in Experiment #1 are listed in Table 1.") Do not describe the same procedure over and over for nearly identical experimental trials. Describe your general experimental procedure only once, then note any changes made in subsequent trials.

Caution! Don't get carried away with detail! It is not important that you used a #2 pencil to record your data in a spiral notebook on a slate table in a spacious laboratory. It *is* important that you were using *Vanessa cardui* as your study organism, and the precise temperatures, light regimens, etc. to which you subjected your organisms in your experiment. Also include the type of apparatus you used, and what statistical tests you performed on the data. Use your judgement and common sense! **Assume that your reader has some inkling of scientific procedures and knows good lab technique. DO NOT INCLUDE ANY DATA OR CONCLUSIONS IN THIS SECTION!!**

Results

Your results must be described in one to several **prose** paragraphs. *Never* give long lists of numbers in your prose text. List such results in neat tables or in clear figures. You **MUST** refer to every figure or table in the text. Example: "Increased reaction temperatures resulted in a higher rate of reaction (Figure 3)."

A **table** consists of neat columns of numbers or words. It should be referred to as "*Table 1*" (or 2, or 16, etc.) in your text and in its legend. The legend (prose explanation of the table) for a table should appear *above* the table.

A photograph, drawing, graph or other illustration is called a **figure**. It should be referred to as "*Figure 1*" (or 3 or 10, etc.) in your text and in its legend. The legend (prose explanation) for a figure should appear *beneath* the figure.

Do not alter your sacred data! Report exactly what happened in your experiment, even if it is not what you expected. You will have ample opportunity to explain deviations from the expected in the next section. **DO NOT INCLUDE ANY DISCUSSION OR CONCLUSIONS IN THIS SECTION!!**

Discussion

This is the main body of your paper and not merely a re-statement of your results. In your discussion, you must analyze and explain your results. Follow these simple guidelines to write a good discussion.

1. Link your results to your original hypotheses.

2. Do you accept or reject your null and alternative hypotheses? Why or why not?
3. Explain your experimental observations in *specific* terms. Describe what has happened in terms of molecular interaction, physics (kinetics), behavior, etc. DO NOT make statements such as: "The reaction was faster because it had a greater reaction rate." That's just redundant, and doesn't explain anything.
4. The world will not stop spinning if your results are not what you expected. Simply try to explain why your data show such unexpected results. Be logical and imaginative.
5. Discuss possible sources of error and how they might have affected your results.
6. Compare your results to those of similar experiments published elsewhere.
7. Draw overall conclusions--give summary statements.

This is your chance to show us your amazing capacity for creative, scientific thought. Refer to literature and other published material on the subject, but more importantly, offer your own insights and ideas about your observations. If you do not give detailed, intelligent explanations for your observations, you have *not* written a scientific paper.

Literature cited

"Literature cited" is exactly that. **When you state a fact that is not common knowledge, you must cite the source of that information.** What source, you ask? Papers from scientific journals . A text book. Your instructor. (But NOT the internet!)

The precise citation format used varies among scientific journals. For our purposes, please cite references in the format in the examples shown below. Write (in parentheses immediately after the cited fact) the author's last name and the year of the source material's publication. For example, you may state

Reaction rate may vary depending upon the pH of the solutions (Campbell, *et al* 2005).
(Note: "et al." is a Latin abbreviation meaning "and others." It is used only in the text reference when there are more than two authors. However, when listing the reference in your literature cited section, you must list every author's name--not "et al.") (Also note: In older journals, there is a comma between the name of the authors and the date. In more recent formats preferred by most journals, this comma is omitted.)

At the very end of your paper, after your discussion section, list references in alphabetical order in a section entitled "Literature Cited". **Include all citations mentioned in the text of your report, but DO NOT list a reference if you have not cited it in your report!** Use the format shown in the following examples.

FOR A BOOK:

Henderson, S. T. 1970. *Daylight and its spectrum*. American Elsevier: New York.

FOR A JOURNAL ARTICLE:

Schwalm, Patricia A., Priscilla H. Starrett and Roy W. McDiarmid. 1977. Infrared reflectance in neo-tropical leaf-sitting frogs. *Science* 196: 1225-1227.

Do not cite "personal communication" references in Literature Cited. If you include information you learned from your instructor during class, it should be cited where it appears in the text of your paper. For example: "Lemmings never jump off of cliffs during migration. The ones shown in that Disney film were actually herded off the cliff with flame throwers (D. Krempels, pers. comm.)."

Don't make common mistakes!

1. **DO** use correct grammar and spelling.
2. **DO NOT** write in the second person. Use either first or third person. RIGHT: "The investigators grabbed a flask and heated it until it blew up." WRONG: "You grab a flask and you heat it until it blows up."
3. **DO NOT** write in present or future tense. Write in past tense, since you already have performed this experiment. Use the same tense throughout your paper.
4. **DO NOT** pad your prose with flabby pseudoexplanatory phrases such as "It is important to do this because..." or "It is a fact that..." This is just poor style.
5. **DO NOT** use subjective adjectives ("*good* result" "*bad* result" "*clearly* demonstrates" "*extremely* obvious" etc.). Let the reader judge.
6. **DO NOT** state that your purpose is "to learn all about the phenomenon of..." It is **NOT**. Your purpose **IS** "to test the effect of on" You are writing a scientific report, not "What I did in school today."
7. **DO** write as though you had designed the experiment. Do not say, "We were required to..." or "The procedure required that we..." You are the scientist. You're in charge.
8. **DO** use your own words. Paraphrase sources **ONLY** when necessary. **Unless absolutely necessary, do not use direct quotes, even if placed in quotation marks (" ").**
9. **DO NOT** use chatty prose. RIGHT: "The results did not support our prediction." WRONG: "The results kind of surprised me."
10. **DO** type your report and store it in the appropriate location, as instructed in the Computer Workshop. No handwritten reports will be accepted.
11. **DO NOT** wait 'til the last minute to *write* your report. Give yourself time to edit your work. Once you've finished your first draft, let it rest for a day or two, then **GO BACK AND READ IT AGAIN.**
12. And finally, please be sure you don't make these mistakes (or others like them)
 - a. It's means "it is." Its is the possessive form meaning "belonging to it."
 - b. Data is the plural of datum. Data *are*; datum *is*.
 - c. Usually, **effect** is a noun and **affect** is a verb. Know the difference, and how to use the words correctly.
 - d. **Advise** is a verb ("to give advice"). **Advice** is a noun. Don't mix them up!

IF YOU FOLLOW THESE RULES AND TAKE THE TIME TO LEARN GOOD GRAMMAR AND STYLE, YOU WILL BE WELL ON YOUR WAY TO A LONG AND HAPPY CAREER IN SCIENTIFIC WRITING.