The Structure, Format, Content, and Style of a Journal-Style Scientific Paper

WHY A SCIENTIFIC FORMAT?

The scientific format may seem confusing for the beginning science writer due to its rigid structure, which is so different from writing in the humanities. One reason for using this format is that it is a means of efficiently communicating scientific findings to the broad community of scientists in a uniform manner. Most journal-style scientific papers are subdivided into the following sections:

Experimental process	**Section of Paper**
What did I do in a nutshell?	Abstract
What is the problem?	Introduction
How did I solve the problem?	Materials and Methods
What did I find out?	Results
What does it mean?	Discussion
Who helped me out?	Acknowledgments (optional)
Whose work did I refer to?	Literature Cited
Extra Information	Appendices (optional)

SECTION HEADINGS:

Each main section of the paper begins with a heading which should be capitalized, centered at the beginning of the section, and double spaced from the lines above and below. Do not underline the section heading OR put a colon at the end. Example of a main section heading:

INTRODUCTION

When your paper reports on more than one experiment, use subheadings to help organize the presentation. Subheadings should be capitalized (first letter in each word), left justified, and either bold italics OR underlined. Example of a subheading:

Effects of Light Intensity on the Rate of Electron Transport

TITLE, AUTHOR'S NAME, AND INSTITUTIONAL AFFILIATIONS

Your paper should begin with a title that succinctly describes the contents of the paper. Use descriptive words that you would associate strongly with the content of your paper: the molecule studied, the organism used or studied, the treatment, the location of a field site, the response measured, etc. For example, in a paper reporting on an experiment involving dosing mice with the sex hormone estrogen and watching for a certain kind of courtship behavior, a poor title would be:

Mouse Behavior

Why? It is very general, and could be referring to any of a number of mouse behaviors. A better title would be:

The Effects of Estrogen on the Nose-Twitch Courtship Behavior in Mice

Why? Because the key words identify a specific behavior, a modifying agent, and the experimental organism. If possible, give the key result of the study in the title, as seen in the first example. Similarly, the above title could be restated as:

Estrogen Stimulates Intensity of Nose-Twitch Courtship Behavior in Mice

The title should be centered at the top of page; the title is NOT underlined or italicized. The author's name and institutional affiliation are double-spaced from and centered below the title.

For example:

Ducks Over-Winter in Colorado Barley Fields in Response to Increased Daily Mean Temperature

Ima Mallard, Department of Wildlife Biology, University of Colorado – Boulder

ABSTRACT

An abstract summarizes, in one paragraph, the major aspects of the entire paper in the following prescribed sequence:

- *The question(s) you investigated (or purpose)*
  State the purpose very clearly in the first or second sentence.

- *The experimental design and methods used*
  Clearly express the basic design of the study.
  Name or briefly describe the basic methodology used without going into excessive detail
  Be sure to indicate the key techniques used.

- *The major findings including key quantitative results, or trends*
  Report those results which answer the questions you were asking
  Identify trends, relative change or differences, etc.

- A brief summary of your interpretations and conclusions
  Clearly state the implications of the answers your results gave you.

Whereas the title can only make the simplest statement about the content of your article, the abstract allows you to elaborate more on each major aspect of the paper. The length of your abstract should be kept to about 200-300 words maximum (a typical standard length for journals.) Limit your statements concerning each segment of the paper (i.e. purpose, methods, results, etc.) to two or three sentences, if possible. Use past tense.

How do you know when you have enough information in your abstract? A simple rule-of-thumb is to imagine that you are another researcher doing an study similar to the one you are reporting. If your abstract was the only part of the paper you could access, would you be happy with the information presented there?

The Abstract SHOULD NOT contain:

- lengthy background information
- references to other literature
- elliptical (i.e., ending with ...) or incomplete sentences
- abbreviations or terms that may be confusing to readers
- any sort of illustration, figure, or table, or references to them

Although it is the first section of your paper, the abstract, by definition, must be written last since it will summarize the paper. To begin composing your abstract, take whole sentences or key phrases from each section and put them in a sequence which summarizes the paper. Then set about revising or adding words to make it all cohesive and clear.

INTRODUCTION

The function of the Introduction is to:

- Establish the context of the work being reported. This is accomplished by discussing the relevant primary research literature (with citations) and summarizing our current understanding of the problem you are investigating;
- State the purpose of the work in the form of the hypothesis, question, or problem you investigated; and,
- Briefly explain your rationale and approach and, whenever possible, the possible outcomes your study can reveal.

Quite literally, the Introduction must answer the questions, "What was I studying? Why was it an important question? What did we know about it before I did this study? How will this study advance our knowledge?"

The structure of the introduction can be thought of as an inverted triangle – the broadest part at the top representing the most general information and focusing down to the specific problem you studied. Organize the information to present the more general aspects of the topic early in the Introduction, then narrow toward the more specific topical information that provides context, finally arriving at your statement of purpose and rationale. A good way to get on track is to sketch out the Introduction backwards; start with the specific purpose and then decide what is the scientific context in which you are asking the question(s) your study addresses. Once the scientific context is decided, then you'll have a good sense of what level and type of general information with which the Introduction should begin.

Begin your Introduction by clearly identifying the subject area of interest. Do this by using key words from your title in the first few sentences of the Introduction to get it focused directly on topic at the appropriate level. This insures that you get

to the primary subject matter quickly without losing focus, or discussing information that is too general. For example, in the mouse behavior paper, the words hormones and behavior would likely appear within the first one or two sentences of the introduction.

Establish the context by providing a brief and balanced review of the pertinent published literature that is available on the subject. The key is to summarize (for the reader) what we knew about the specific problem before you did your experiments or studies. This is accomplished with a general review of the primary research literature (with citations) but should not include very specific, lengthy explanations that you will probably discuss in greater detail later in the discussion. The judgment of what is general or specific is difficult at first, but with practice and reading of the scientific literature you will develop e firmer sense of your audience. In the mouse behavior paper, for example, you would begin the Introduction at the level of mating behavior in general, then quickly focus to mouse mating behaviors and then hormonal regulation of behavior. Lead the reader to your statement of purpose/hypothesis by focusing your literature review from the more general context (the big picture e.g., hormonal modulation of behaviors) to the more specific topic of interest to you (e.g., role/effects of reproductive hormones, especially estrogen, in modulating specific sexual behaviors of mice.)

What literature should you look for in your review of what we know about the problem? Focus your efforts on the primary research journals - the journals that publish original research articles. Although you may read some general background references (encyclopedias, textbooks, lab manuals, style manuals, etc.) to get yourself acquainted with the subject area, do not cite these, because they contain information that is considered fundamental or "common" knowledge within the discipline. Cite, instead, articles that reported specific results relevant to your study. Learn, as soon as possible, how to find the primary literature (research journals) and review articles rather than depending on reference books. The articles listed in the Literature Cited of relevant papers you find are a good starting point to move backwards in a line of inquiry.

Be sure to clearly state the purpose and /or hypothesis that you investigated. When you are first learning to write in this format it is okay, and actually preferable, to use a pat statement like, "The purpose of this study was to...." or "We investigated three possible mechanisms to explain the ... (1) blah, blah..(2) etc. It is most usual to place the statement of purpose near the end of the Introduction, often as the topic sentence of the final paragraph. It is not necessary (or even desirable) to use the words "hypothesis" or "null hypothesis", since these are usually implicit if you clearly state your purpose and expectations.

Provide a clear statement of the rationale for your approach to the problem studied. For example: State briefly how you approached the problem (e.g., you studied oxidative respiration pathways in isolated mitochondria of cauliflower). This will usually follow your statement of purpose in the last paragraph of the Introduction. Why did you choose this kind of experiment or experimental design? What are the scientific merits of this particular model system? What advantages does it confer in answering the particular question(s) you are posing? Do not discuss here the actual techniques or protocols used in your study (this will be done in the Materials and Methods); your readers will be quite familiar with the usual techniques and approaches used in your field.

MATERIALS AND METHODS

In this section you explain clearly how you carried out your study in the following general structure and organization:

- The organism(s) studied (plant, animal, human, etc.) and their handling and care. Include the source (supplier or where and how collected), size (weight, length, etc), how they were handled before the experiment, what they were fed, etc. In genetics studies include the strains or genetic stocks used. For some studies, age is important. Note that the term "subject" is used ONLY for human studies.

- When and where the study was carried out. Include the date(s) of the study (e.g., 10-15 April 1994) and the exact location of the study area. Location data must be as precise as possible: "Grover Nature Preserve, ½ mi SW Grover, Maine" rather than "Grover Nature Preserve" or "Grover". When possible, give the actual latitude and longitude position of the site (the WWW has sites which provide this service). It is most often a good idea to include a map (labeled as a Figure) showing the location in relation to some larger more recognizable geographic area. Someone else should be able to go to the exact location of your study if they want to repeat or check your work, or just visit your study area. For laboratory studies, if you have performed experiments at a particular location or lab because it is the only place to do it, then you should note that in your methods and identify the lab or facility.

- The experimental OR sampling design (i.e., how the experiment or study was structured. Describe your experimental design clearly. Be sure to include the hypotheses you tested, controls, treatments, variables measured, how many replicates you had, what you actually measured, what form the data take, etc. Always identify treatments by the variable or treatment name, NOT by an ambiguous, generic name or number (e.g., use "2.5% NaCl" rather than "test 1".) Foremost in your description should be the "quantitative" aspects of your study - the masses, volumes, incubation times, concentrations, etc., that another scientist needs in order to duplicate your experiment. When using standard lab or field methods and instrumentation, it is not always necessary to explain the procedures (e.g., serial dilution) or equipment used (e.g., autopipetter) since other scientists will likely be familiar with them already. It is appropriate to report, parenthetically, the source (vendor) and catalog number for reagents used, e.g., "....poly-L-lysine (Sigma #1309)." When using a method described in another published source, you can save time and words by providing the relevant citation to the source. Always make sure to describe any modifications you have made of a standard or published method.

- The protocol for collecting data, i.e., how the experimental procedures were carried out, and, how the data were analyzed (qualitative analyses and/or statistical procedures used). The information should include:
    - how the data were summarized (Means, percent, etc) and how you are reporting measures of variability (SD,SEM, etc)
    - data transformation (e.g., to normalize or equalize variances)
    - statistical tests used with reference to the particular questions they address
    - Any other numerical or graphical techniques used to analyze the data

Organize your presentation so your reader will understand the logical flow of the experiment(s); subheadings work well for this purpose. Each experiment or procedure should be presented as a unit, even if it was broken up over time. The experimental design and procedure are sometimes most efficiently presented as an integrated unit, because otherwise it would be difficult to split them up. In general, provide enough quantitative detail (how much, how long, when, etc.) about your experimental protocol such that other scientists could reproduce your experiments. You should also indicate the statistical procedures used to analyze your results, including the probability level at which you determined significance (usually at 0.05 probability).

The style in this section should read as if you were verbally describing the conduct of the experiment. You may use the active voice to a certain extent, although this section requires more use of third person, passive constructions than others. Avoid use of the first person in this section. Remember to use the past tense throughout - the work being reported is done, and was performed in the past, not the future.

The methods section is not a step-by-step, directive, protocol as you might see in a lab manual.

RESULTS

The function of the results section is to objectively present your key results, without interpretation, in an orderly and logical sequence using both text and illustrative materials (Tables and Figures). The results section always begins with text, reporting the key results and referring to your figures and tables as you proceed.

Organize the results section based on the sequence of Table and Figures you'll include. Prepare the Tables and Figures as soon as all the data are analyzed and arrange them in the sequence that best presents your findings in a logical way. A good strategy is to note, on a draft of each Table or Figure, the one or two key results you want to address in the text portion of the Results. Simple rules to follow related to Tables and Figures:

- Tables and Figures are assigned numbers separately and in the sequence that you will refer to them from the text.
    - The first Table you refer to is Table 1, the next Table 2 and so forth.
    - Similarly, the first Figure is Figure 1, the next Figure 2, etc.
- Each Table or Figure must include a brief description of the results being presented and other necessary information in a legend.
    - Table legends go above the Table; tables are read from top to bottom.
    - Figure legends go below the figure; figures are usually viewed from bottom to top.
- When referring to a Figure from the text, "Figure" is abbreviated as Fig., for example, Fig. 1. Table is never abbreviated, e.g., Table 1.

The body of the Results section is a text-based presentation of the key findings which includes references to each of the Tables and Figures. The text should guide the reader through your results stressing the key results which provide the answers to the question(s) investigated. A major function of the text is to provide clarifying information. You must refer to

each Table and/or Figure individually and in sequence (see numbering sequence), and clearly indicate for the reader the key results that each conveys. Key results depend on your questions, they might include obvious trends, important differences, similarities, correlations, maximums, minimums, etc.

Some problems to avoid:

- Do not present the same data in both a Table and Figure - this is considered redundant and a waste of space and energy. Decide which format best shows the result and go with it.

- Do not report raw data values when they can be summarized as means, percents, etc. Statistical test summaries (test name, p-value) are usually reported parenthetically in conjunction with the biological results they support. Always report your results with parenthetical reference to the statistical conclusion that supports your finding (if statistical tests are being used in your course). This parenthetical reference should include the statistical test used and the level of significance (test statistic and DF are optional). For example, if you found that the mean height of male Biology majors was significantly larger than that of female Biology majors, you might report this result and your statistical conclusion as follows: "Males (180.5 ± 5.1 cm; n=34) averaged 12.5 cm taller than females (168 ± 7.6 cm; n=34) in the 2009 pool of Biology majors (two-sample t-test, $t = 5.78$, 33 d.f., $p < 0.001$)."

- Avoid devoting whole sentences to report a statistical outcome alone.

- Two notes about the use of the word significant(ly).
  - In scientific studies, the use of this word implies that a statistical test was employed to make a decision about the data; in this case the test indicated a larger difference in mean heights than you would expect to get by chance alone. Limit the use of the word "significant" to this purpose only.
  - Present the results of your experiment(s) in a sequence that will logically support (or provide evidence against) the hypothesis, or answer the question, stated in the Introduction. For example, in reporting a study of the effect of an experimental diet on the skeletal mass of the rat, consider first giving the data on skeletal mass for the rats fed the control diet and then give the data for the rats fed the experimental diet.

- Report negative results - they are important! If you did not get the anticipated results, it may mean your hypothesis was incorrect and needs to be reformulated, or perhaps you have stumbled onto something unexpected that warrants further study. Moreover, the absence of an effect may be very telling in many situations. In any case, your results may be of importance to others even though they did not support your hypothesis. Do not fall into the trap of thinking that results contrary to what you expected are necessarily "bad data". If you carried out the work well, they are simply your results and need interpretation. Many important discoveries can be traced to "bad data".

- Always enter the appropriate units when reporting data or summary statistics. For an individual value you would write, "the mean length was 10 m", or, "the maximum time was 140 min." When including a measure of variability, place the unit after the error value, e.g., "...was 10 ± 2.3 m". Likewise place the unit after the last in a series of numbers all having the same unit. For example: "lengths of 5, 10, 15, and 20 m", or "no differences were observed after 2, 4, 6, or 8 min. of incubation".

DISCUSSION

The function of the Discussion is to interpret your results in light of what was already known about the subject of the investigation, and to explain our new understanding of the problem after taking your results into consideration. The Discussion will always connect to the Introduction by way of the question(s) or hypotheses you posed and the literature you cited, but it does not simply repeat or rearrange the Introduction. Instead, it tells how your study has moved us forward from the place you left us at the end of the Introduction.

Fundamental questions to answer here include:

- Do your results provide answers to your testable hypotheses? If so, how do you interpret your findings?
- Do your findings agree with what others have shown? If not, do they suggest an alternative explanation or perhaps a unforseen design flaw in your experiment (or theirs?)
- Given your conclusions, what is our new understanding of the problem you investigated and outlined in the Introduction?
- If warranted, what would be the next step in your study, e.g., what experiments would you do next?

Use the active voice whenever possible in this section. Watch out for wordy phrases; be concise and make your points clearly. Use of the first person is okay, but too much use of the first person may actually distract the reader from the main points.

Organize the Discussion to address each of the experiments or studies for which you presented results; discuss each in the same sequence as presented in the Results, providing your interpretation of what they mean in the larger context of the problem. Do not waste entire sentences restating your results; if you need to remind the reader of the result to be discussed, use "bridge sentences" that relate the result to the interpretation: "The slow response of the lead-exposed neurons relative to controls suggests that...[interpretation]". Be wary of mistaking the reiteration of a result for an interpretation, and make sure that no new results are presented here that rightly belong in the results.

You must relate your work to the findings of other studies - including previous studies you may have done and those of other investigators. As stated previously, you may find crucial information in someone else's study that helps you interpret your own data, or perhaps you will be able to reinterpret others' findings in light of yours. In either case you should discuss reasons for similarities and differences between yours and others' findings. Consider how the results of other studies may be combined with yours to derive a new or perhaps better substantiated understanding of the problem. Be sure to state the conclusions that can be drawn from your results in light of these considerations. You may also choose to briefly mention further studies you would do to clarify your working hypotheses. Make sure to reference any outside sources as shown in the Introduction section.

Although you might occasionally include in this section tables and figures which help explain something you are discussing, they must not contain new data (from your study) that should have been presented earlier. They might be flow diagrams, accumulation of data from the literature, or something that shows how one type of data leads to or correlates with another.

ACKNOWLEDGMENTS (include as needed)

If, in your experiment, you received any significant help in thinking up, designing, or carrying out the work, or received materials from someone who did you a favor by supplying them, you must acknowledge their assistance and the service or material provided. Authors always acknowledge outside reviewers of their drafts and any sources of funding that supported the research. Although usual style requirements (e.g., 1st person, objectivity) are relaxed somewhat here, Acknowledgments are always brief and never flowery.

LITERATURE CITED

The Literature Cited section gives an alphabetical listing (by first author's last name) of the references that you actually cited in the body of your paper. NOTE: Do not label this section "Bibliography". A bibliography contains references that you may have read but have not specifically cited in the text. Bibliography sections are found in books and other literary writing, but not scientific journal-style papers.

APPENDICES

An Appendix contains information that is non-essential to understanding of the paper, but may present information that further clarifies a point without burdening the body of the presentation. An appendix is an optional part of the paper.

Each Appendix should be identified by a Roman numeral in sequence, e.g., Appendix I, Appendix II, etc. Each appendix should contain different material.

Some examples of material that might be put in an appendix:

- raw data
- maps
- extra photographs
- explanation of formulas and worked example problems
- specialized computer programs for a particular procedure
- full generic names of chemicals or compounds that you have referred to in somewhat abbreviated fashion or by some common name in the text of your paper
- diagrams of specialized apparati