A GUIDE TO WRITING SCIENTIFIC PAPERS

Scientific experiments are demanding, exciting endeavors, but, to have an impact, results must be communicated to others. A research paper is a method of communication, an attempt to tell others about some specific data that you have gathered and what you think those data mean in the context of your research. The "rules" of writing a scientific paper are rigid and are different from those that apply when you write an English theme or a library research paper. For clear communication, the paper obviously requires proper usage of the English language and this will be considered in evaluating your reports. Scientific papers must be written clearly and concisely so that readers with backgrounds similar to yours can understand easily what you have done and how you have done it should they want to repeat or extend your work. When writing papers for the biology department, you can assume that your audience will be readers like yourselves with similar knowledge.

Although scientific journals differ somewhat in their specific requirements, a general format that would be acceptable for most biological journals is:

Title

*Abstract

Introduction

Methods and Materials

Results

Discussion

Conclusions

References

The actual words "Introduction", "Methods," etc. are used to head the sections of your paper. The section headings (Abstract, Introduction, etc.) should be **centered** and the body of each section should follow immediately below the heading. Do not begin each section on a new page. If one section ends part of the way down the page, the next section heading follows immediately on the same page. **Tables and figures are placed at the end of the text of the particular section in which it is referred.**

One important general rule to keep in mind is that a scientific paper is a report about something that has been done in the past. The paper should be written in the **PAST TENSE** (was, were). The paper should read as a narrative in which the author describes what was done and what results were obtained from that work.

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General Comments on Style

1. All scientific names (genus and species) must be italicized. (Underlining indicates italics in a typed paper.)
2. Use the metric system of measurements. Abbreviations of units are used without a following period.
3. Be aware that the word *data* is plural while *datum* is singular. This affects the choice of a correct verb. The word *species* is used both as a singular and as a plural.
4. Numbers should be written as numerals when they are greater than ten or when they are associated with measurements; for example, 6 mm or 2 g but *two* explanations of *six* factors. When one list includes numbers over or under ten, all numbers in the list may be expressed as numerals; for example, 17 sunfish, 13 bass, and 2 trout. Never start a sentence with numerals. Spell all numbers beginning sentences.
5. Be sure to divide paragraphs correctly and to use starting and ending sentences that indicate the purpose of the paragraph. A report or a section of a report should not be one long paragraph.
6. Every sentence must have a subject and a verb.
7. Avoid using the first person, I or we, in writing. Keep your writing impersonal, in the third person. Instead of saying, "We weighed the frogs and put them in a glass jar," write, "The frogs were weighed and put in a glass jar."
8. Avoid the use of slang and the overuse of contractions.
9. Be consistent in the use of tense throughout a paragraph--do not switch between past and present. It is best to use past tense.
10. Be sure that pronouns refer to antecedents. For example, in the statement, "Sometimes Cecropia caterpillars are in cherry trees but they are hard to find," does "they" refer to caterpillars or trees?

After writing a report, read it over, watching especially for lack of precision and for ambiguity. Each sentence should present a clear message. The following examples illustrate lack of precision:

1. "The sample was incubated in mixture A minus B plus C." Does the mixture lack both B and C or lack B and contain C?
2. The title "Protection against Carcinogenesis by Antioxidants" leaves the reader wondering whether antioxidants protect from or cause cancer.

The only way to prevent such errors is to read and think about what you write. Learn to reread and edit your work.

TITLE

Every scientific paper must have a self-explanatory title. By reading the title, the work being reported should be clear to the reader without having to read the paper itself. The title, "A Biology Lab Report", tells the reader nothing. An example of a good, self-explanatory title would be: "The Effects of Light and Temperature on the Growth of Populations of the Bacterium, *Escherichia coli* ". This title reports exactly what the researcher has done by stating three things:

1. The environmental factors that were manipulated (light, temperature).
2. The parameter that was measured (growth).
3. The specific organism that was studied (the bacterium, *Escherichia coli*).

If the title had been only "Effects of Light and Temperature on *Escherichia coli* ", the reader would have to guess which parameters were measured. (That is, were the effects on reproduction, survival, dry weight or something else?) If the title had been "Effect of Environmental Factors on Growth of *Escherichia coli* ", the reader would not know which environmental factors were manipulated. If the title had been "Effects of Light and Temperature on the Growth of an Organism", then the reader would not know which organism was studied. In any of the above cases, the reader would be forced to read more of the paper to understand what the researcher had done.

Exceptions do occur: If several factors were manipulated, all of them do not have to be listed. Instead, "Effects of Several Environmental Factors on Growth of Populations of *Escherichia coli* " (if more than two or three factors were manipulated) would be appropriate. The same applies if more than two or three organisms were studied. For example, "Effects of Light and Temperature on the Growth of Four Species of Bacteria" would be correct. The researcher would then include the names of the bacteria in the Materials and Methods section of the paper.

Abstract: Only required for YCSEF

The abstract is a one or two paragraph condensation (150-200 words) of the entire work described completely in the article. The abstract should be a self-contained unit capable of being understood without the benefit of the text. It should contain these four elements:

1. the purpose of the study (the central question);
2. a brief statement of what was done (Methods);
3. a brief statement of what was found (Results);
4. a brief statement of what was concluded (Discussion, in part).

Introduction:

The function of an introduction is to present the question being asked and place it in the context of what is already known about the topic. Background information that suggests why the topic is of interest and related findings by other scientists are usually mentioned here. In other words, **this section should contain:**

1. **a description of the nature of the problem and current state of knowledge or understanding at the beginning of the investigation (background);**

2. **a statement of the purpose, scope, and general method of investigation in your study;**

3. **hypothesis/hypotheses and predictions**.

Do not get lost in reviewing background information. Remember that the Introduction is meant to introduce the reader to your research, not summarize and evaluate all past literature on the subject (which is the purpose of a review paper). Many of the other studies you may be tempted to discuss in your Introduction are better saved for the Discussion, where they become a powerful tool for comparing and interpreting your results. Include only enough background information to allow your reader to understand why you are asking the questions you are and why your hypotheses are reasonable ones. Often, a brief explanation of the theory involved is sufficient. The statement of purpose expresses the central question you are asking and thus presents the variable you are investigating. **For example:** This study investigates the relationship between tree density and fruit size. The purpose of this study is to determine the effect of enzyme concentration on the reaction rate of...

The hypothesis is the explanation you are proposing for certain observations. It is a tentative answer to the question you have posed above. It should be accompanied by a prediction of results expected under certain conditions if the hypothesis is correct. "If competition lowers reproductive output, then fruit size should be smaller when tree density increases".

Methods and Materials:

The function of this section is to describe all experimental procedures, including controls. The description should be complete enough to enable someone else to repeat your work. If there is more than one part of the experiment, it is a good idea to describe your methods and present your results in the same order in each section. This may not be the same order in which the experiments were performed -it is up to you to decide what order of presentation will make the most sense to your reader.

1. **Explain why each procedure was done**, i.e., what variable were you measuring and why?

   Example: Difficult to understand: First, the frog muscle was removed and then Ringer's solution was poured on it. Next, It was attached it to the kymograph.

   Improved: The frog muscle was removed and then Ringer's solution was poured on it to prevent it from drying out. Then the muscle was attached to the kymograph order to determine the minimum voltage required for contraction.

2. **Experimental procedures and results are narrated in the past tense** (what you did, what you found, etc.)

3. **Mathematical equations and statistical tests are considered mathematical methods and should be described in this section along with the actual experimental work.**

DO NOT write this section as though it were directions in a laboratory exercise book. Instead of writing:

> First pour agar into six petri plates. Then inoculate the plates with the bacteria. Then put the plates into the incubator . . .

Simply describe how the experiment was done:

> Six petri plates were prepared with agar and inoculated with the bacteria. The plates were incubated for ten hours.

Also, **DO NOT LIST** the equipment used in the experiment. The materials that were used in the research are simply mentioned in the narrative as the experimental procedure is described in detail.

Results:

The function of this section is to summarize general trends in the data without comment, bias, or interpretation. **Statistical tests applied to your data are reported in this section although conclusions about your original hypotheses are saved for the Discussion section. Only the results are presented. No interpretation of the data or conclusions about what the data might mean is given in this section.** Data assembled in tables and/or figures should **supplement** the text and present the data in an easily understandable form. If tables and/or figures are used, **they must be accompanied by narrative text**. Do not repeat extensively in the text the data you have presented in tables and figures. But, do not restrict yourself to passing comments either. (For example, only stating that "Results are shown in Table 1." is not appropriate.) The text **describes** the data presented in the tables and figures and calls attention to the important data that the researcher will discuss in the Discussion section and will use to support Conclusions. (Rules to follow when constructing and presenting figures and tables are presented in a later section of this guide.)

Data may be presented in figures and tables, but this may not substitute for a verbal summary of the findings. The text should be understandable by someone who has not seen your figures and tables.
Example: Incorrect: The results are given in Figure 1.
Correct: Temperature was directly proportional to metabolic rate (Fig. 1).

1. All results should be presented, including those that do not support the hypothesis.
2. Statements made in the text must be supported by the results contained in figures and tables.
3. The results of statistical tests can be presented in parentheses following a verbal description.

Example: Fruit size was significantly greater in trees growing alone ($t = 3.65$, $df = 2$, $p < 0.05$).

Discussion:

The function of this section is to analyze the data and relate them to other studies. To "analyze" means to evaluate the meaning of your results in terms of the original question or hypothesis and point out their significance.

1. The Discussion should contain at least:

- **the relationship between the results and the original hypothesis, i.e., whether they support the hypothesis, or cause it to be rejected or modified.**
- **an integration of your results with those of previous studies in order to arrive at explanations for the observed phenomena. Make sure to cite all sources.**
- **possible explanations for unexpected results and observations, phrased as hypotheses that can be tested by realistic experimental procedures, which you should describe.**

2. Trends that are not statistically significant can still be discussed if they are suggestive or interesting, but cannot be made the basis for conclusions as if they were significant.

3. Avoid redundancy between the Results and the Discussion section. Do not repeat detailed descriptions of the data and results in the Discussion, but make sure to analyze relevant results

4. End the Discussion with a summary of the principal points you want the reader to remember. This is also the appropriate place to propose specific further study if that will serve some purpose, as well as possible applications, but do not end with the tired cliché that "this problem needs more study." All problems in biology need more study. Do not close on what you wish you had done, rather finish stating your conclusions and contributions.

CONCLUSIONS

This section simply states what the researcher thinks the data mean, and, as such, should relate directly back to the problem/question stated in the introduction. This section should not offer any *reasons* for those particular conclusions--these should have been presented in the Discussion section. By looking at only the Introduction and Conclusions sections, a reader should have a good idea of what the researcher has investigated and discovered even though the specific details of how the work was done would not be known.

Tables and Figures: All papers should contain at least one data table and one graph!

Tables and figures should be used when they are a more efficient way to convey information than verbal description. They must be independent units, accompanied by explanatory captions that allow them to be understood by someone who has not read the text. Do not repeat in the text the information in tables and figures, but do cite them, with a summary statement when that is appropriate. Whenever possible, use a figure instead of a table. Relationships between numbers are more readily grasped when they are presented graphically rather than as columns in a table.

1. **Tables :**

Do not repeat information in a table that you are depicting in a graph or histogram; include a table only if it presents new information.

It is easier to compare numbers by reading down a column rather than across a row. Therefore, list sets of data you want your reader to compare in vertical form.

Provide each table with a number (Table 1, Table 2, etc.) and a title. **The numbered title is placed above the table.**

2. **Figures:**

These comprise graphs, histograms, and illustrations, both drawings and photographs. Provide each figure with a number (Fig. 1, Fig. 2, etc.) **and a caption that explains what the figure shows**. **The numbered caption is placed below the figure.**

Figures submitted for publication must be "photo ready," i.e., they will appear just as you submit them, or photographically reduced. Therefore, when you graduate from student papers to publishable manuscripts, you must learn to prepare figures that will not embarrass you. Lines should be drawn with black ink (not ballpoint or marker). Symbols, letters, and numerals must be produced by stencil or mechanically, and should be large enough to withstand reduction.

Graphs and Histograms: Both can be used to compare two variables. However, graphs show continuous change, whereas histograms show discrete variables only. You can compare groups of data by plotting two or even three lines on one graph, but avoid cluttered graphs that are hard to read, and do not plot unrelated trends on the same graph. For both graphs, and histograms, plot the independent variable on the horizontal (x) axis and the dependent variable on the vertical (y) axis. Label both axes, including units of measurement.

Drawings and Photographs: These are used to illustrate organisms, experimental apparatus, models of structures, cellular and subcellular structure, and results of procedures like electrophoresis. Preparing such figures well is a lot of work and can be very expensive, so each figure must add enough to justify its preparation and publication, but good figures can greatly enhance a professional article, as your reading in biological journals has already shown.

References:

This is the last section of a scientific paper. Use current APA citation rules.
Papers are not referred to by footnotes as in literature papers but are cited within the body of the text.

SCIENCE FAIR GRADE SHEET

Title : 5 pts
Independent Variable
Dependent Variable

Introduction: 25 pts
Format: Grammar etc. (6pts)
Hypothesis (2 pts)
Variables (2pts)
Background Information (5pts)
Other research related to experiment(5pts)
Citations Format (5pts)

Methods and Materials 10 pts
Amounts/concentrations in SI units(3pts)
Detailed description (3pts)
Appropriate number of trials (2pts)
Control and constants (2pts)

Results: 20 pts
Tables /format(5pts)
Graphs/format (5 pts)
Results in words (5pts)
Specific details (5 pts)

Discussion: 25 pts
Comparison and analysis of specific results (10)
Compare to other research(3 pts) and citations (2 pts)
Error analysis (3pts)
Improvements (2pts)
Applications (3pts)
Further research (2pts)

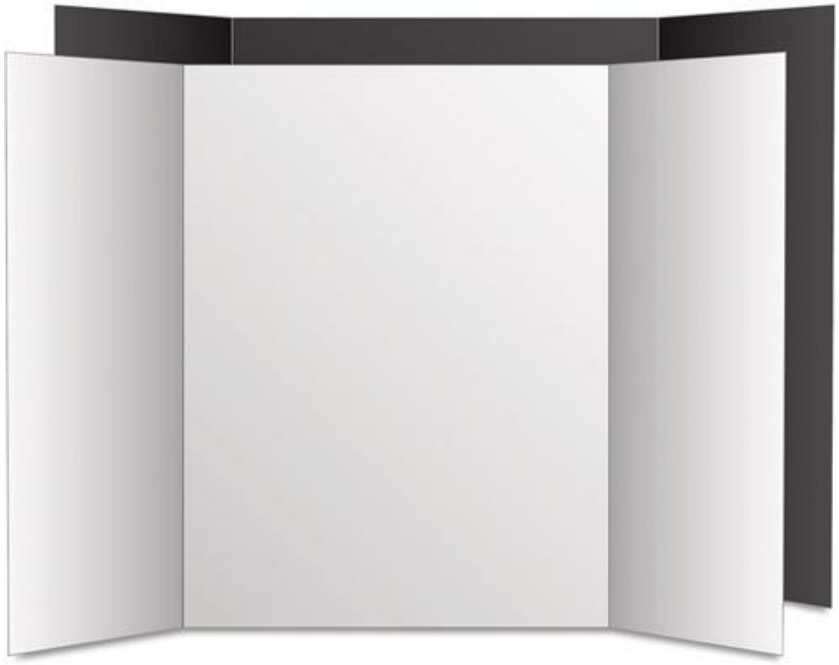
Conclusion: 5 pts
Summary of experiment (3pts)
Conclusion (2pts)

References: 10 pts
Format 5pts)
At least five sources (3pts)
At least two (2) non-internet (2pts)

TOTAL 100 PTS

Science Fair Poster Rubric

“A picture is worth a thousand words.” It is also an unfortunate fact of life that you are usually judged first by how you appear to others. Your science fair poster is a visual and written representation of the hard work and effort that you put into your science fair project. It is extremely important that you present yourself and your school with pride. To help guide you through the process, please utilize the below criteria. (Helpful hint: Be sure to collect artifacts and pictures that can put your poster on the next level. Although equipment is not allowed, crisp color photos and graphs make your poster look more professional… Yes that’s right: You might have to do this in your professional life, too.)



Component	Quality	Earned Points
Title (4)	Descriptive	
	Centered, Can be read from a distance of 10 feet	
Hypothesis (2)	Clearly posted	
Methods & Materials (4)	Clearly posted	
	Format is easy to understand	
Data Tables & Graphs (8)	Easy to understand layout, Appropriate format	
	Titles: Clear and concise	
	Column & row headings: Clear & concise Axis labels (with units)	
	Excel or other program	
	No "series" (unless you have more than one and specify what they are)	
Other Visuals (6)	Pictures are clear, titled and labeled	
	Drawings are clear, titled and labeled	
	Visuals are **meaningful** to hypothesis/conclusions	
Conclusion (6)	**Rewritten** to fit poster dimensions and purpose (not simply copied and pasted from your lab report)	
	Concise and easy to understand	
Neatness (10)	All components **neatly** cut out**, glued and arranged** on board	
	Font easy to read from 5 ft	
	Includes at least 5 visual elements	
	Flow of poster is logical	
	NO spelling errors NO grammatical errors	
	TOTAL	**/40**