How to Write A Paper in Scientific Journal Style and Format

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About This Guide

This guide has been compiled, edited, and revised by Greg Anderson and is intended to provide *general* content, style, and format guidelines for biology students learning to write papers in a standard, scientific journal style and format that can be easily adapted to specific journal requirements or disciplinary conventions. Much of the specific content has been shaped by the particular needs of the beginning scientific writers in our biology program. We therefore make no claims about completeness or depth for more advanced writers in the biological sciences, or those in other science disciplines. The guidelines presented here are largely based upon Huth et al (1994), and we provide suggestions as to other useful published writing guides.

How to Use This Guide

We provide this website as a introductory guide for writing a journal-style scientific paper in a standard format acceptable for most courses in the Biology Department. We suggest that you either have this document running in your browser while you are writing to provide quick answers regarding style and format, or to print a copy for easy reference anytime. To print hardcopy of the information use the File, Print option in your browser.

Each section is accessed from the Table of Contents and within each section you will find links to other relevant information. Link menus are provided at the top of each page to facilitate rapid access of the information for which you are looking. A menu at the bottom of each page allows quick return to the Table of Contents or to the On-Line Resources home page.

References

Huth J, Brogan M, Dancik B, Kommedahl T, Nadziejka D, Robinson P, Swanson W.1994. Scientific format and style: The CBE manual for authors, editors, and publishers. Cambridge: Cambridge University Press. 825 p.

Acknowledgments

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I welcome and encourage feedback from others who may use this guide and ask that it be directed to:

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Introduction to Journal-Style Scientific Writing

Overview

A critical aspect of the scientific process is the reporting of new results in scientific journals in order to disseminate that information to the larger community of scientists. Communication of your results contributes to the pool of knowledge within your discipline (and others!) and very often provides information that helps others interpret their own experimental results. Most journals accept papers for publication only after peer review by a small group of scientists who work in the same field and who recommend the paper be published (usually with some revision).

The format and structure presented here is a general one; the various scientific journals, and oftentimes specific disciplines, utilize slightly different formats and/or writing styles. Mastery of the format presented here will enable you to adapt easily to most journal- or discipline-specific formats. While this guide (a others like it) is a *necessary* tool of learning the scientific writing style and format, it is not *sufficient,* by itself, to make you an accomplished writer. This guide will not teach you how to write in the English language, i.e., it is not a grammar book. You, the writer, must **practice *writing* and *thinking*** within this structure, ***and***, learn by example from the writings of others; learning the nuances of this style and format will be enhanced as you **read the scientific literature - pay attention to how professional scientists write about their work**. You *will* see improvement in your own scientific writing skills by repeatedly practicing reading, writing, and critiquing of other's writing.

The guide addresses four major aspects of writing journal-style scientific papers:

(1) fundamental style considerations; **(2)** a suggested strategy for efficiently writing up research results; **(3)** the nuts and bolts of format and content of each section of a paper (part of learning to write a scientific paper is learning how to follow instructions precisely), and, **(4)** basic information regarding peer critiques of scientific writing. ALL journals have a set of instructions for authors which explicitly state how their paper should be formatted for submission. Consider this guide to be your instructions when writing lab reports for Bio 201, 270, and s42. We encourage you to follow the directions carefully and to make full use of this guide and the writing support system (TWAs, instructors, and Writing Workshop staff tutors) as you prepare your papers. Please ask for help if you have questions about format, style, or content. Above all, remember to write with **precision**, **clarity**, and **economy**.

Getting Started

The first task to accomplish as you begin the process of writing is to order and organize the information you wish to present. Some people work well from an outline, others do not. Some people write first to discover the points, then rearrange them using an after-the-fact outline. Whatever process you may use, be aware that scientific writing requires special attention to order and organization. Because the paper will be divided into sections, you need to know what information will go into each. If you don't normally work from an outline, this may be an occasion when you'll at least want to develop a list of the major points to be included in each section, before you begin to write. If the paper has multiple authors, then this is a good time to work (and negotiate!) with your collaborators to insure that all the points the group wants to make get listed.

Audience: Who will be reading your paper? Usually you will be writing to your peers. Simple advice: address your paper to another interested biology student, or lab group, in this course or major, and assume they have *at least* the same knowledge and expertise base as you. Knowing your audience helps you to decide what information to include--you would write a very different article for a narrow, highly technical, disciplinary journal vs. one that went out to a broad range of disciplines. Similarly, you would write a paper for an audience of other biology majors very differently than one you would write for a cross section of the college. **Do not** write your paper specifically for your instructor.

Prose

Your writing should be in complete sentences and easily understood. It should conform to the conventions of standard written English (sentence form, grammar, spelling, etc.). Your ideas will have little impact, no matter how good the research, if they are not communicated well. Remember always that scientific terminology very often has precise meaning. Be certain you choose your words correctly and wisely.

It is important to write clearly and concisely. **Make sure that every paragraph has a clear topic sentence and that the paragraph content supports the topic.** The goal is to report your findings and conclusions clearly, and with as few words as necessary. Your audience (other scientists usually) are not interested in flowery prose, they want to know your findings. **Remember:** Writing and thinking are closely linked enterprises - many people have noted that, "*fuzzy writing reflects fuzzy thinking.*" When people have difficulty translating their ideas into words, they generally do not know the material as well as they think.

Style Considerations

Be clear and concise: Write briefly and to the point. Say what you mean **clearly** and avoid embellishment with unnecessary words or phrases. **Brevity** is very important. Use of the active voice alone shortens sentence length considerably.

Precise word use is critical: Scientific terminology carries specific meaning - learn to use it *appropriately* and use it *consistently*. A critical function of technical terminology is to say a lot with a few words, i.e., ***economy***. This applies as well to appropriate *acronyms* (e.g., PCR) and *abbreviations*. Direct your paper toward the average reader in your intended audience. If writing for a highly technical journal, you will necessarily use the technical jargon. If writing for a general science audience you would limit the jargon.

Some things to avoid:

- You do not have to try to impress people by using words most people have never heard of. Many published articles are like this, and they are poor papers on account of it.
- *Do not* use colloquial speech, slang, or "childish" words or phrases.
- *Do not* use contractions: **for example**, "*don't*" must be "*do not*" and *"isn't"* must be "*is not*" etc.

Abbreviations: Do not use abbreviations in the text *except* for units of measure. Always abbreviate these when using them with data (2 mm; 10 min.). Except for temperature units (F,C, K) never abbreviate units of measure when using them in a non-data context (e.g., "we measured length in millimeters"; "time was recorded in minutes"; "temperature was measured in F (or C)"; "100 years have passed since Mendel did..."). A list of common abbreviations and conversions is provided.

Use Past Tense: Research papers reflect work that has been completed, therefore use the past tense throughout your paper (including the Introduction) when referring to the *actual work* that you did, including statements about your expectations or hypotheses. Use the past tense, as well, when referring to the work of others that you may cite.

First vs. Third Person: If there is one stylistic area where scientific disciplines and journals vary widely, it is the use of first vs. third person constructions. Some disciplines and their journals (e.g., organismal biology and ecology) have moved away from a very strict adherence to the third person construction, and permit limited use of the first person in published papers. Other disciplines, especially the biomedical fields, still prefer the third person constrcution. Limit your use of first person construction (i.e., " *I (or we) undertook this study ....*): usually it is most acceptable in the Introduction and Discussion sections, and then only to a limited extent. Use first person in the methods *sparingly* if at all, and avoid its use in the results.

Use Active Verbs: Use active verbs whenever possible; writing that overly uses passive verbs (is, was, has, have, had) is deadly to read and almost always results in more words than necessary to say the same thing.

ACTIVE: "*the mouse consumed oxygen at a higher rate...*"

PASSIVE: "*oxygen was consumed by the mouse at a higher rate..*"

The clarity and effectiveness of your writing will improve dramatically as you increase the use of the active voice.

Other specific comments on style are also included for each section of the paper. ***Remember***: precise word use, past tense, active voice, brevity.

References References to the research findings of others are an integral component of any research paper. The usual practice is to summarize the finding or other information in your own words and then cite the source. Any ideas or other information that are not your own must be substantiated by a reference that is cited in the text. **As a rule, in research papers, direct quotation and footnoting are not practiced - simply restate the author's ideas or findings in your own words and provide a citation.**

Ladd Library links:

Citation & Style Guides**--**

Plagiarism (use of others words, ideas, images, etc. without citation) is not to be tolerated and can be easily avoided by adequately referencing any and all information you use from other sources. In the strictest sense, plagiarism is representation of the work of others as being *your* work. Paraphrasing other's words too closely may be construed as plagiarism in some circumstances. In journal style papers there is virtually no circumstance in which the findings of someone else cannot be expressed in your own words with a proper citation of the source. Refer to: ***The Bates College Statement On Plagiarism and a Guide to Source Acknowledgment***.) If you are unclear about what constitutes plagiarism, please confer with your instructor.

A Strategy for Writing Up Research Results

Get Organized: **Lists, Outlines, Notecards, etc.** Before starting to write the paper, take the time to think about and develop a list of points to be made in the paper. As you progress, use whichever strategy works for you to begin to order and to organize those points and ideas into sections.

A. Balanced Review of the Primary Research Literature: Do an in-depth, balanced review of the primary research literature relevant to your study prior to designing and carrying out the experiments. This review will help you learn what is known about the topic you are investigating and may let you avoid unnecessarily repeating work done by others. This literature will form the basis of your Introduction and Discussion. Training in *on-line searches* is available through the librarians and is included in Biology 201. Do your search early enough to take advantage of the *Interlibrary Loan System* if need be.

B. Write the Introduction: Once your hypothesis has been refined for testing, you will draft the Introduction to your paper. In PI courses you will bring the Introduction to lab the day of the experiment for critique by an instructor or TWA (Technical Writing Assistant).

C. Design and Conduct the Experiment: Keep careful notes on procedures used during the experiment . You should write the Materials and Methods section upon completion of the experiment.

D Analyze and Interpret the Results: Once the data are collected, you must analyze and interpret the results. Analysis will include data summaries (e.g., calculating means and variances) and statistical tests to verify conclusions. Most scientists lay out their Tables and Figures upon completion of the data analysis before writing the Results section. Write the Table and Figure legends. It is good practice to note the one or two key results that each Table or Figure conveys and use this information as a basis for writing the Results section. Sequence and number the Tables and Figures in the order which best enables the reader to reach your conclusions.

E. Write the Results Section: Remember that the Results section has both text and illustrative materials (Tables and Figures). Use the text component to guide the reader through your key results, i.e., those results which answer the question(s) you investigated. Each Table and Figure must be referenced in the text portion of the results, and you must tell the reader what the key result(s) is that each Table or Figure conveys.

F. Write the Discussion: Interpretation of your results includes discussing how your results modify and fit in with what we previously understood about the problem. Review the literature again at this time. After completing the experiments you will have much greater insight into the subject, and by going through some of the literature again, information that seemed trivial before, or was overlooked, may tie something together and therefore prove very important to your own interpretation. Be sure to cite the works that you refer to.

G. Write the Abstract and Title: The Abstract is always the last section written because it is a concise summary of the entire paper and should include a clear statement of your aims, a brief description of the methods, the key findings, and your interpretation of the key results. The Title will probably be written earlier, but is often modified once the the final form of the paper clearly known.

H. Self-Revise Your Paper: Most authors revise their papers *at least* 2-3x before giving it out for peer review. Go back over your paper now and read it carefully; **read it aloud**. Does it say what you wanted it to say? Do any ideas, experiments, or interpretations need to be moved around within the text to enhance the logical flow of your arguments? Can you shorten long sentences to clarify them?

Can you change passive verbs to active forms? Do the Tables and Figures have sufficient information to stand alone outside the context of the paper? Use your dictionary to correct spelling and your spell checker to catch typos.

I. Peer Review: Have knowledgable colleagues critique your paper. Use their comments to revise your paper yet again.

Making Effective Comments on Peer Reviews
Peer Review Form.

J. Prepare the Final Draft: Carefully proof-read your final draft to make sure its as well done as possible. Double check that you've properly cited all your sources in the text and in the Literature Cited. Check the formatting one last time. The instructors LOVE to give full credit for format issues whenever possible, but will not hesitate to take points off for sloppy work.

Other Useful Resources

The content of this website is not exhaustive, and many topics related to writing research articles have not been discussed. The references listed below are a sampling of the numerous published resources on the topic of researching, writing and critiquing research papers.

Hult, Christine A. 1996. *Researching and Writing in the Sciences and Technology.* Allyn and Bacon, Boston, MA. 168 pp.
ISBN 0-205-16840-X

McMillan, V.E. 1997. *Writing Papers in the Biological Sciences*. 2nd Ed. Bedford Books, Boston 197 pp.
ISBN0-312-11504-0

Helpful Hints for Effective Peer Reviewing

by Seri Rudolph
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The Writing Workshop, Bates College

One of the hardest things about getting started with peer reviewing is dealing with your reluctance to give negative feedback. After all, we're all socialized not to say mean things to people, and purely negative commentary usually doesn't end up helping the writer anyway. The purpose of this document is to help you find ways to get around this problem by

1) remembering to **give positive commentary** where a writer has done well, and by,

2) **turning negative feedback into productive feedback**.

1. **When reviewing, it is always important to note a paper's strengths, so that the author will not lose these in the process of revision.** Never assume an author will automatically know which parts of a paper work well... remember, they have been immersed in it too long to be objective. The peer review form asks you to list the three major strengths of the paper in section VIIc - but remember to do this throughout the paper too, writing marginal comments like "good paragraph" when you read a part that flows well.

2. **But how to deal with the parts that really do have problems? The key is to make sure the comments you write are substantive comments.** As we read, we all have reactions to problematic parts of a paper: "Huh? This is unclear"... "Gosh, this is

disorganized!"... " What is this person trying to say here???". But these reactions are only the first step in the process of constructing helpful commentary, and writing down these initial reactions as comments is not usually useful to the writer.

How can you turn these unhelpful comments into helpful ones? You need to go a step beyond your initial reaction, and ask yourself *why* you are reacting negatively to that sentence or paragraph. Why, for instance, does a paragraph seem disorganized? Are several topics mixed together in one paragraph? Or is a single topic treated, but presented out of logical sequence, so that the reader is constantly grasping for information not yet given? Or does the writer seem to start with one idea or position, but then reverse him/herself later in the paragraph?

You can see that this process will take some work on your part, because you need to reflect on your reactions and read in a very involved way. Below are some examples of unhelpful "reaction-type" comments that have been turned into helpful comments by this process of reflection.

Example 1:

Unhelpful comment: "This section needs work."

Helpful Comment: Combine the related actions into a single sentence in Methods, eg, "Flies were assigned randomly to 5 treatment groups of 25, and were weighed, sexed, and marked with non-toxic paint before behaviorial trials began"

Example 2:

Unhelpful comment: "Disorganized!"

Helpful Comment: "This section discusses both animal-rearing conditions and experimental methods, but the two are mixed together. Could you separate each into its own paragraph?"

Example 3:

Unhelpful comment: "How are these references relevant?"

Helpful Comment: "The background and references given in poaragraph 2 don't seem directly relevant to our hypothesis. I think we need references on how light has been shown to affect flowering (in sunflower or any species), and less on other factors that promote or inhibit flowering."

Example 4:

Unhelpful comment: "Unclear."

Helpful Comment: "I'm not sure what your interpretation is after these two paragraphs: does the experiment show that mung beans cure cancer, or not? Which are we concluding? If the sample size is too small, we need to discuss that when we suggest future research, but that does not change our results here."

Revising Your Paper

Self-Revision by the Author(s)

Revision of your writing is an on-going process from the time you begin until the final copy is submitted. A strategy that works for many people is to write out an initial draft in total without substantial revision and then let it sit for a day. Come back to it then and begin revising your paper working from a ***global perspective*** (overall organization) to ***paragraph content and organization*** and finally down to ***sentence level line editing***. Implicit in these instructions is the assumption that you are checking the content for scientific correctness and accuracy.

- **GLOBAL**
  - check the sequence of ideas/background/content in each section for logical progression (*your topic sentences should do this*).
  - check for a strong relationship of ideas between the Introduction (*what we knew before our study*) and the Discussion (*how our study changes or supports our previous understanding*).

- **PARAGRAPH**
  - check that each paragraph has a **coherent topic sentence**, most often as the lead sentence.
  - in each paragraph do the **other sentences support the topic sentence**?
  - check the **transitions between paragraphs** to ensure they are *logical* and *smooth.*

- **LINE EDITING**
  - check for *consistent* and *correct* use of **terminology.**
  - can you change a passive verb construction to an **active verb**?
  - eliminate **superfluous lead phrases** (*Once that was done, ..*).
  - remove all **colloquial language.**
  - check for **redundancy** (i.e., places where you repeat what you have said elsewhere).
  - read each senetence closely for **clarity** and **brevity. Can you say the same thing with fewer words?**
  - **READ THE PAPER ALOUD** to find those quirky sentences that you wrote while still half asleep - if doesn't sound correct when spoken aloud, it will read even more oddly.

- **MISCELLANEOUS**
  - check that all of your **sources are cited correctly** in the text.
  - check the **numbering sequence of your tables and figures.**
  - check the **Literature Cited** for completeness and correct format.
  - check the **line spacing between headings and text**, and Tables and Figures and text.
  - check the **page breaks** to make sure you do not split tables or figures.
  - are the **authors' names** spelled correctly?
  - run spell check on the document to find **typographical errors** and read carefully for **spelling** and **grammatical errors**.
  - check your main headings and subheadings for proper case and placement.

Revision After Peer Critique

After reading carefully the comments and suggestions to improve your paper, discuss them with the reviewer (when possible) to get clarification or to argue your point, if you should disagree. In general, you will make the changes *as suggested* by the reviewer unless you have good, and justifiable, reasons not to.

Once you are clear on the changes to be made, approach the revision using the same *global*, *paragraph*, *line editing* strategy.

- Make the global changes first and recheck the items listed previously.
- Make the paragraph level changes and recheck list.
- Make the line edit changes and recheck the list.
- Recheck the miscelleaneous items.

Final Revision

If possible, have your reviewer examine the paper again (cookies help!) one last time. For PI courses, this is the opportunity for co-authors to check the final draft to make sure it satisfies their expectations. If all the changes have been made to everyone's satisfaction, make one last check of overall appearance of the document to catch recalcitrant page breaks, etc.

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. Another reason, perhaps more important than the first, is that this format allows the paper to be read at several different levels. For example, many people skim Titles to find out what information is available on a subject. Others may read only titles and Abstracts. Those wanting to go deeper may look at the Tables and Figures in the Results, and so on. The take home point here is that the scientific format helps to insure that at whatever level a person reads your paper (beyond title skimming), they will likely get the key results and conclusions.

The Sections of the Paper

Most journal-style scientific papers are subdivided into the following sections: Title, Authors and Affiliation, Abstract, Introduction, Methods, Results, Discussion, Acknowledgments, and Literature Cited, which parallel the experimental process. This is the system we will use. This website describes the style, content, and format associated with each section.

The sections appear in a journal style paper in the following prescribed order:

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:

Main 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

Subheadings: 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, Authors' Names, and Institutional Affiliations

1. **Function**: 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. A majority of readers will find your paper via electronic database searches and those search engines key on words found in the title.

2. **Title FAQs**

3. **Format**:

- The **title** should be centered at the top of page 1 (DO NOT use a title page - it is a waste of paper for our purposes); the title is NOT underlined or italicized.
- the **authors' names** (PI or primary author first) and **institutional affiliation** are *double-spaced from and centered below* the title. When more then two authors, the names are separated by commas except for the last which is separated from the previous name by the word "and".

For example:

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

Ima Mallard, Ura Drake, and Woodruff Ducque
Department of Wildlife Biology, University of Colorado - Boulder

The title is not a section, but it is necessary and important. The title should be short and unambiguous, yet be an adequate description of the work. A general rule-of-thumb is that the title should contain the **key words describing the work** presented. Remember that the title becomes the basis for most on-line computer searches - if your title is insufficient, few people will find or read your paper. 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

4. <u>Strategy for Writing Title</u>**.**

ABSTRACT

1. **Function**: An abstract summarizes, in one paragraph (usually), the major aspects of the entire paper in the following prescribed sequence:

- the ***question(s) you investigated*** (or purpose), (**from <u>Introduction</u>**)
  - state the purpose very clearly in the first or second sentence.
- the ***experimental design*** *and* ***methods*** used, (**from <u>Methods</u>**)
  - 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*** (**from**

Results)

- report those results which answer the questions you were asking
- identify trends, relative change or differences, etc.

- a brief summary of your ***interpetations*** and ***conclusions***. (from **Discussion**)
  - 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. The Abstract helps readers decide whether they want to read the rest of the paper, or it may be the only part they can obtain via electronic literature searches or in published abstracts. Therefore, enough key information (e.g., summary results, observations, trends, etc.) must be included to make the Abstract useful to someone who may to reference your work.

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?

2. **Style**: The Abstract is ONLY text. Use the active voice when possible, but much of it may require passive constructions. Write your Abstract using concise, but complete, sentences, and get to the point quickly. **Use past tense**. Maximum length should be 200-300 words, usually in a single paragraph.

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.

3. **Strategy**: 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. As you become more proficient you will most likely compose the Abstract from scratch.

4. **Check your work**: *Once you have the completed abstract, check to make sure that the information in the abstract completely agrees with what is written in the paper.*

*Confirm that **all** the information appearing the abstract actually appears in the body of the paper.*

INTRODUCTION

[strategy | FAQs | style | structure | relevant literature review | statement of purpose | rationale]

1. **Function**: 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?*"

2. **Style**: Use the active voice as much as possible. Some use of first person is okay, but do not overdo it.

3. **Structure**: 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.

Here is the information should flow in your Introduction:

- **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 acquianted with the subject area, do not cite these, becasue they contain information that is considered fundamental or "common" knowledge wqithin 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. Most academic libraries support the **Citation Index** - an index which is useful for tracking a line of inquiry *forward* in time. Some of the newer search engines will actually send you alerts of new papers that cite particular articles of interest to you. *Review articles* are particularly useful because they summarize all the research done on a narrow subject area over a brief period of time (a year to a few years in most cases).

- **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. If you are using a *novel* (new, revolutionary, never used before) technique or methodology, the merits of the new technique/method versus the previously used methods *should be* presented in the Introduction.

MATERIALS AND METHODS

This section is variously called **Methods** or **Methods and Materials**.

1. **Function**: In this section you explain *clearly* how you carried out your study in the following *general* structure and organization (details follow below):

- the **subjects used** (plant, animal, human, etc.) and their pre-experiment handling and care, and when and where the study was carried out (if location and time are important factors);
- if a field study, a **description of the study site**, including the physical and biological features, and precise location;
- the **experimental OR sampling design** (i.e., how the experiment or study was structured. For example, controls, treatments, the variable(s) measured, how many samples were collected, replication, etc.);
- the **protocol for collecting data**, i.e., how the experimental procedures were carried out, and,
- **how the data were analyzed** (statistical procedures used).

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. 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).

2. **Style**: 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 Methods section ***is not*** a step-by-step, directive, protocol as you might see in your lab manual.

3. Strategy for writing the Methods section.

4. Methods FAQs.

Describe the organism(s) used in the study. This includes giving the *source* (supplier or *where* and *how* collected), *size*, *how they were handled* before the experiment, what they were fed, etc. In genetics studies include the strains or genetic stocks used.

Describe the site where your field study was conducted. The description must include both *physical* and *biological* characteristics of the site pertinant to the study aims. 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.

- **NOTE: For laboratory studies you should *not* report the date and location of the study *UNLESS* it is relevant. Most often it is *not*.**

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% saline" rather than "test 1".) When your paper includes more than one experiment, use subheadings to help organize your presentation by experiment. A general experimental design worksheet is available to help plan your experiments in the core courses.

Describe the protocol for your study in sufficient detail that other scientists could repeat your work to verify your findings. 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. You may want to identify certain types of equipment by brand or category (e.g., ultracentrifuge vs. prep centrifuge). It is appropriate to give the source for reagents used parenthetically, e.g., "....poly-l-Lysine (Sigma #1309)." When using a method described in another published source, you can save time and words by referring to it and providing the relevant citation to the source. Always make sure to describe any modifications you have made of a standard or published method.

Describe how the data were summarized and analyzed. Here you will indicate what types of data summaries and analyses were employed to answer each of the questions or hypotheses tested.

The information should include:

- how the data were **summarized** (Means, percent, etc) and how you are reporting **measures of variability** (SD,SEM, etc)
  - this lets you avoid having to repeatedly indicate you are using mean ± SD.
- **data transformation** (e.g., to normalize or equalize variances)
- **statistical tests** used with reference to the particular questions they address, e.g.,

"A Paired t-test was used to compare mean flight duration before and after applying stablizers to the glider's wings."

"One way ANOVA was used to compare mean weight gain in weight-matched calves fed the three different rations."

- any other **numerical** or **graphical techniques** used to analyze the data

Here is some additional advice on particular problems common to new scientific writers.

Problem*: The Methods section is prone to being wordy or overly detailed.*

- *Avoid repeatedly using a single sentence to relate a single action*; this results in very lengthy, wordy passages. A related sequence of actions can be combined into one sentence to improve clarity and readability:

Problematic Example: This is a very long and wordy description of a common, simple procedure. It is characterized by single actions per sentence and lots of unnecessary details.

"The petri dish was placed on the turntable. The lid was then raised slightly. An inoculating loop was used to transfer culture to the agar surface. The turntable was rotated 90 degrees by hand. The loop was moved lightly back and forth over the agar to spread the culture. The bacteria were then incubated at 37 C for 24 hr."

Improved Example: Same actions, but all the important information is given in a single, concise sentence. Note that superfluous detail and otherwise obvious information has been deleted while important missing information was added.

"Each plate was placed on a turntable and streaked at opposing angles with fresh overnight E. coli culture using an inoculating loop. The bacteria were then incubated at 37 C for 24 hr."

Best: Here the author assumes the reader has basic knowledge of microbiological techniques and has deleted other superfluous information. The two sentences have been combined because they are related actions.

"Each plate was streaked with fresh overnight E. coli culture and incubated at 37 C for 24 hr."

Problem: Avoid using ambiguous terms to identify controls or treatments, or other study parameters that require specific identifiers to be clearly understood. Designators such as Tube 1, Tube 2, or Site 1 and Site 2 are completely meaningless out of context and difficult to follow in context.

Problematic example: In this example the reader will have no clue as to what the various tubes represent without having to constantly refer back to some previous point in the Methods.

"*A Spec 20 was used to measure A_{600} of Tubes 1,2, and 3 immediately after chloroplasts were added (Time 0) and every 2 min. thereafter until the DCIP was completely reduced. Tube 4's A_{600} was measured only at Time 0 and at the end of the experiment."*

Improved example: Notice how the substitution (in red) of treatment and control identifiers clarifies the passage both in the context of the paper, and if taken out of context.

"A Spec 20 was used to measure A_{600} of the reaction mixtures exposed to light intensities of 1500, 750, and 350 uE/m2/sec immediately after chloroplasts were added (Time 0) and every 2 min. thereafter until the DCIP was completely reduced. The A_{600} of the no light control was measured only at Time 0 and at the end of the experiment."

RESULTS

1. **Function**: The function of the Results section is to objectively present your key results, *without* interpretation, in an orderly and logical sequence using both illustrative materials (Tables and Figures) and text. Summaries of the statistical analyses may appear either in the text (usually parenthetically) or in the relevant Tables or Figures (in the legend or as footnotes to the Table or Figure). The Results

section should be organized around a series of Tables and/or Figures sequenced to present your key findings in a logical order. The text of the Results section follows this sequence and highlights the answers to the questions/hypotheses you investigated. Important negative results should be reported, too. Authors usually write the text of the results section based upon this sequence of Tables and Figures.

2. **Style**: Write the text of the Results section concisely and objectively. The passive voice will likely dominate here, but use the active voice as much as possible. Use the **past tense**. Avoid repetitive paragraph structures. Do not interpret the data here. The transition into interpretive language can be a slippery slope. Consider the following two examples:

- This example highlights the trend/difference that the author wants the reader to focus:

The duration of exposure to running water had a pronounced effect on cumulative seed germination percentages (Fig. 2). Seeds exposed to the 2-day treatment had the highest cumulative germination (84%), 1.25 times that of the 12-h or 5-day groups and 4 times that of controls.

- In contrast, this example strays subtly into interpretation by referring to optimality (a conceptual model) and tieing the observed result to that idea:

The results of the germination experiment (Fig. 2) suggest that the optimal time for running-water treatment is 2 days. This group showed the highest cumulative germination (84%), with longer (5 d) or shorter (12 h) exposures producing smaller gains in germination when compared to the control group.

3. Strategy for Writing the Results Section

4. Frequently asked questions (FAQs).

Things to consider as you write your Results section:

What are the "results"?: When you pose a testable hypothesis that can be answered experimentally, or ask a question that can be answered by collecting samples, you accumulate observations about those organisms or phenomena. Those observations are then analyzed to yield an answer to the question. In general, the answer is the " key result".

The above statements apply regardless of the complexity of the analysis you employ. So, in an introductory course your analysis may consist of visual inspection of figures and simple calculations of means and standard deviations; in a later course you may be expected to apply and interpret a variety of statistical tests. You instructor will tell you the level of analysis that is expected.

For example, **suppose you asked the question**, "*Is the average height of male students the same as female students in a pool of Biology majors*?" You would first collect height data from large random samples of male and female students. You would then calculate the descriptive statistics for those samples (mean, SD, n, range, etc) and plot these numbers. In a course where statistical tests are not employed, you would visually inspect these plots. Suppose you found that male Biology majors are, on average, 12.5 cm taller than female majors; this is the answer to the question.

- Notice that the outcome of a statistical analysis is not a key result, but rather an analytical *tool* that helps us understand *what is* our key result.

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 addess 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.,e.g., **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 things to avoid:

- **Do not** reiterate each value from a Figure or Table - only the key result or trends that each conveys.
- **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 (in blue) and your statistical conclusion (shown in red) 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 AY 1995 pool of Biology majors (two-sample t-test, $t = 5.78$, 33 d.f., $p < 0.001$)."

Note that the report of the key result (shown in blue) would be identical in a paper written for a course in which statistical testing is not employed - the section shown in red would simply not appear.

- 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.
    - If your parenthetical statistical information includes a p-value that is significant, it is unncecssary (and redundant) to use the word "significant" in the body of the sentence (see example above).

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. In either 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 <u>units</u> 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

1. Function: The function of the Discussion is to interpret your results in light of <u>what was already known</u> 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 <u>Introduction</u> 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?

2. Style: 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.

3. Approach: 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]".

You will necessarily make reference to the findings of others in order to support your interpretations.Use subheadings, if need be, to help organize your presentation. 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.

Do not introduce new results in the Discussion. 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, etc. For example, if you were studying a membrane-bound transport channel and you discovered a new bit of information about its mechanism, you might present a diagram showing how your findings helps to explain the channel's mechanism.

Acknowledgments (included 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 (in PI courses, this would be done *only* if an instructor or other individual critiqued the draft prior to evaluation) 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.

- Place the **Acknowledgments** between the Discussion and the Literature Cited.

Literature Cited

1. Function: 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. Instructions for writing full citations for various sources are given in on separate page. A complete format list for virtually all types of publication may be found in Huth and others(1994)**.**

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.

2. Format and Instructions for standard full citations of sources.

3. Literature Cited FAQs.

Appendices

| FAQs | Function | Headings | Types of Content | Tables and Figures

Function: 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, and is only rarely found in published papers.

Headings: 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 (not an exhaustive list):

- raw data
- maps (foldout type especially)
- extra photographs
- explanation of formulas, either already known ones, or especially if you have "invented" some statistical or other mathematical procedures for data analysis.
- 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.

Figures and Tables in Appendices

Figures and Tables are often found in an appendix. These should be formatted as discussed previously (see Tables and Figures), but are numbered in a separate sequence from those found in the body of the paper. So, the first Figure in the appendix would be Figure 1, the first Table would be Table 1, and so forth. In situations when multiple appendices are used, the Table and Figure numbering must indicate the appendix number as well (see Huth and others, 1994).

Almost Everything You Wanted to Know About Making Tables and Figures

Once your statistical analyses are complete, you will need to summarize the data and results for presentation to your readers. Data summaries may take one of 3 forms: text, Tables and Figures.

Text: contrary to what you may have heard, not all analyses or results warrant a Table or Figure. Some simple results are best stated in a single sentence, with data summarized parenthetically:

Seed production was higher for plants in the full-sun treatment (52.3 +/-6.8 seeds) than for those receiving filtered light (14.7+/- 3.2 seeds, $t=11.8$, $df=55$, $p<0.001$.)

Tables: Tables present lists of numbers or text in columns, each column having a title or label. Do not use a table when you wish to show a trend or a pattern of relationship between sets of values - these are better presented in a Figure. For instance, if you needed to present population sizes and sex ratios for your study organism at a series of sites, and you planned to focus on the differences among individual sites according to (say) habitat type, you would use a table. However, if you wanted to show us that sex ratio was related to population size, you would use a Figure.

Figures: Figures are visual presentations of results, including graphs, diagrams, photos, drawings, schematics, maps, etc. Graphs are the most common type of figure and will be discussed in detail; examples of other types of figures are included at the end of this section. Graphs show trends or patterns of relationship.

Organizing your presentation: Once you have done your analyses and decided how best to present each one, think about how you will arrange them. Your analyses should tell a "story" which leads the reader through the steps needed to logically answer the question(s) you posed in your Introduction. The order in which you present your results can be as important in convincing your readers as what you actually say in the text.

How to refer to Tables and Figures from the text: *Every* Figure and Table included in the paper MUST be referred to from the text. Use sentences that draw the reader's attention to the relationship or trend you wish to highlight, referring to the appropriate Figure or Table only parenthetically:

Germination rates were significantly higher after 24 h in running water than in controls (Fig. 4).

DNA sequence homologies for the *purple* gene from the four congeners (Table 1) show high similarity, differing by at most 4 base pairs.

<u>Avoid</u> sentences that give no information other than directing the reader to the Figure or Table:

Table 1 shows the summary results for male and female heights at Bates College.

Abbreviation of the word "Figure": When referring to a Figure in the text, the word "Figure" is abbreviated as "Fig.", while "Table" is not abbreviated. Both words are spelled out completely in descriptive legends.

How to number Tables and Figures: Figures and Tables are numbered independently, in the sequence in which you refer to them in the text, starting with Figure 1 and Table 1.

Placement of Figures and Tables within the Paper: In consideration of your readers, place each Table or Figure as near as possible to the place where you first refer to it (e.g., the next page.) For manuscripts (e.g. lab papers), Tables and Figures are usually put on separate pages from text material.

The "Acid Test" for Tables and Figures: Any Table or Figure you present must be sufficiently clear, well-labeled, and described by its legend to be understood by your intended audience without reading the results section, i.e., it must be able to stand alone and be interpretable. Overly complicated Figures or Tables may be difficult to understand in or out of context, so strive for simplicity whenever possible. If you are unsure whether your tables or figures meet these criteria, give them to a fellow biology major (not in your course) and ask them to interpret your results.

Descriptive Legends or Captions: To pass the "acid test" above, a clear and complete legend (sometimes called a caption) is essential. Like the title of the paper itself, each legend should convey as much information as possible about what the Table or Figure <u>tells the reader</u>: the subjects of the experiment, the treatment applied or the relationship displayed, location (if a field experiment), and sample sizes and statistical tests if they are not displayed elsewhere. <u>Do not</u> simply restate the axis labels with a "versus" written in between.

Example:

Figure 1. Height frequency (%) of White Pines (*Pinus strobus*) at Thorncrag Bird Sanctuary, Lewiston, Maine, before and after the Ice Storm of '98. Before, n=137, after, n=133. Approximately 16% of canopy pines were topped by heavy ice loads,

averaging 3.6 m stem length decrease. Four trees fell during the storm and were excluded from the post-storm survey.

In the examples later in this section, note the completeness of the legends. When you are starting out, you can use one of these examples (or an appropriate example from a published paper) as a model to follow in constructing your own legends.

Where do you place the legend?

- **Table legends** go above the body of the Table and are left justified; Tables are read from the top down.
- **Figure legends** go below the graph; graphs and other types of Figures are usually read from the bottom up.

The Anatomy of a Table

Table 4 below shows the typical layout of a table in three sections demarcated by lines. Tables are most easily constructed using your word processor's table function or a spread sheet such as Excel. Gridlines or boxes, commonly invoked by word processors, are optional for our purposes, but unlikely to be permitted in a journal.

Example 1: Courtesy of Shelley Ball.

Table 4. Population variation in hatch success (mean percent) of unfertilized eggs for females from populations sampled in1997. N = number of females tested. <--Table legend

Population	mean (%)	Standard deviation	Range	N
Beaver Creek [T]	7.31	13.95	0-53.16	15
Honey Creek [T]	4.33	7.83	0-25.47	11
Rock Bridge Gans Creek [T]	5.66	13.93	0-77.86	38
Cedar Creek [P]	6.56	9.64	0-46.52	64
Grindstone Creek [P]	8.56	14.77	0-57.32	19
Jacks Fork River [P]	5.28	8.28	0-30.96	28
Meramec River [P]	5.49	10.25	0-45.76	45
Little Dixie Lake [L]	7.96	14.54	0-67.66	71
Little Prairie Lake [L]	6.86	7.84	0-32.40	36
Rocky Forks Lake [L]	3.31	4.12	0-16.14	43
Wincgar Lake [L]	10.73	17.58	0-41.64	5
Whetstone Lake [L]	7.36	12.93	0-63.38	57

<--Column titles

<--Table body (data)

<--Lines demarcating the different parts of the table

[T] = temporary stream, [P] = permanent streams, [L] = lakes. <--footnotes

Example 2: Courtesy of Shelley Ball.

Table 2. Log-likelihood tests of deviation from 1:1 sex ratios for nymphs collected from each population in 1997 and 1998. Values are ratios of female:male; sample sizes are in parentheses. Bonferroni corrected probabilities are shown with an asterisks.

	Year	
Population	1997	1998
Beaver Creek[T]	9.00:1(20)***	2.67:1 (22)*
Honey Creek[T]	9.00:1(56)***	2.27:1 (98)***
Rock Bridge[T]	3.33:1(26)**	2.09:1 (68)**
Cedar Creek[P]	2.05:1(119)***	1.87:1 (198)***
Grindstone Creek[P]	-	2.26:1 (140)***
Jacks Fork River[P]	2.89:1(35)**	5.17:1 (37)***
Meramec River[P]	2.80 1(38)**	2.41:1 (58)**
Little Dixie Lake[L]	2.45:1(494)***	2.46:1 (384)***
Little Prairie Lake[L]	2.38:1 (71)***	2.08:1 (157)***
Rocky Forks Lake[L]	2.55:1 (213)***	2.93:1 (299)***
Winegar Lake[L]	3.41:1 (207)***	2.34:1 (204)***
Whetstone Lake[L]	2.69:1 (381)***	2.01:1 (268)***

* significant at $p < 0.05$; ** significant at $p < 0.005$; *** significant at $p < 0.001$.
[T] = temporary stream, [P] = permanent streams, [L] = lakes.

Example 3: Courtesy of Greg Anderson

Table 2. Planting date, mean planting density, and total number of seed clams planted in plots at Filucy Bay and Wescott Bay in 1979.

Location	Plot code	Planting date	Mean planting density in no. clams/m^2 ± 1 st. dev.(N)	Total no. clams planted
Filucy Bay	F10 x 30	5-16-79	994 ± 39(5)	298200
	F3 x 10	5-24-79	994 ± 39(5)	29820
Wescott Bay	W10 x 25	5-16-79	994 ± 39(5)	248500
	W3 x 10	6-2-79	895 ± 35(5)[a]	26850

[a]Calculated after clams were planted based on estimated 11% mortality of seed clams between 5-24 and 6-2-79.

In these examples notice several things:

- the presence of a period *after* "Table #";
- the legend goes *above* the Table;
- *units* are specified in column headings wherever appropriate;
- lines of demarcation are used to set legend, headers, data, and footnotes apart from one another.
- *footnotes* are used to clarify points in the table, or to convey repetitive information about entries;
- footnotes may also be used to denote statistical differences among groups.

The Anatomy of a Figure

The sections below show when and how to use the four most common Figure types (bar graph, frequency histogram, XY scatterplot, XY line graph.) The final section gives examples of other, less common, types of Figures.

Parts of a Graph: Below are example figures (typical line and bar graphs) with the various component parts labeled in red. Refer back to these examples if you encounter an unfamiliar term as you read the following sections.

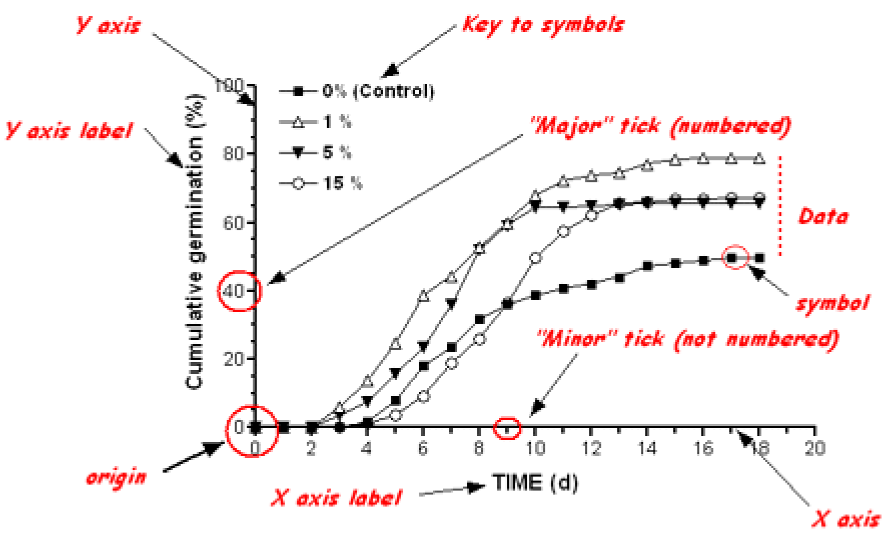


Figure 1. Cumulative germination of *Chenopodium* seeds after pregermination treatment of 2 day soak in NaCl solutions. n = 1 trial per treatment group (100 seeds/trial.)

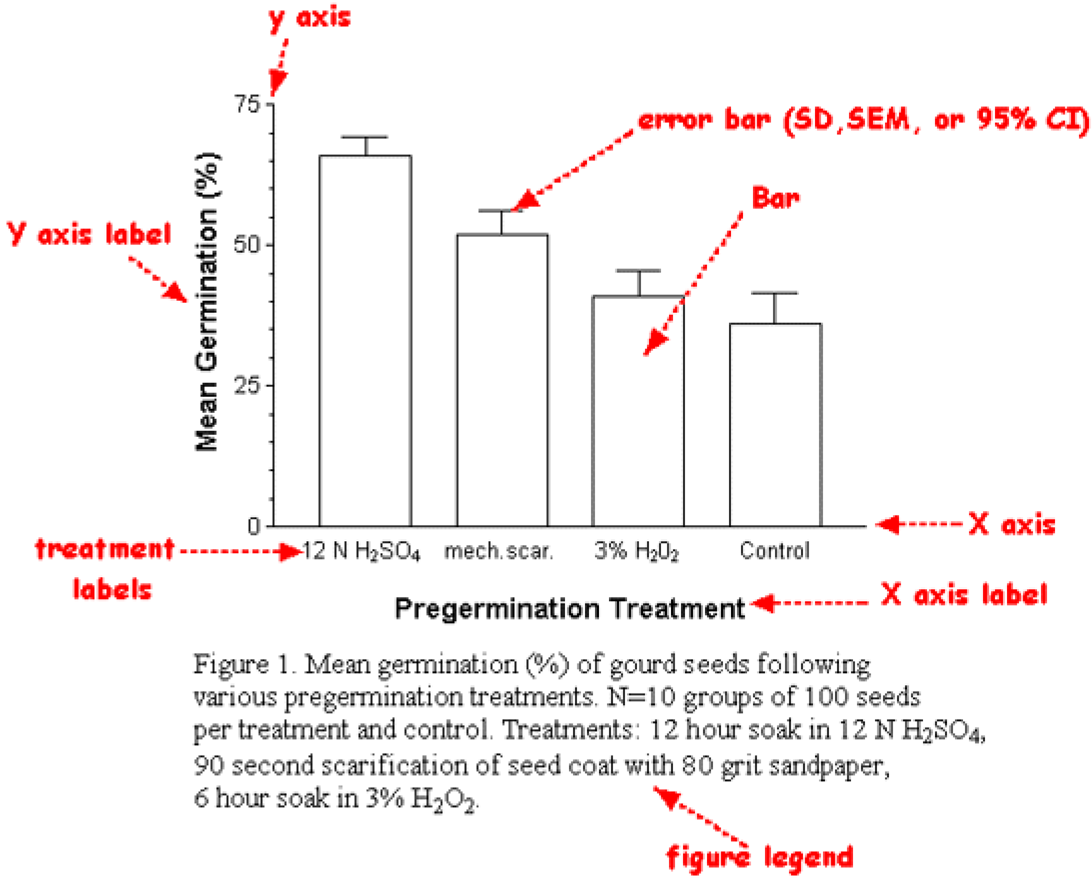


Figure 1. Mean germination (%) of gourd seeds following various pregermination treatments. N=10 groups of 100 seeds per treatment and control. Treatments: 12 hour soak in 12 N H_2SO_4, 90 second scarification of seed coat with 80 grit sandpaper, 6 hour soak in 3% H_2O_2.

Some general considerations about Figures:

- **Big or little?** For course-related papers, a good rule of thumb is to size your figures to fill about one-half of a page. Readers should not have to reach for a magnifying glass to make out the details.
- **Color or no color?** Most often black and white is preferred. The rationale is that if you need to photocopy or fax your paper, any information conveyed by colors will be lost to the reader. However, for a poster presentation or a talk with projected images, color can be helpful in distinguishing different data sets. Every aspect of your Figure should convey information; *never use color simply because it is pretty.*
- **Title or no title?** *Never use a title for Figures included in a paper*; the legend conveys all the necessary information and the title just takes up extra space. However, *for posters or projected images*, where people may have a harder time reading the small print of a legend, a larger font title is very helpful.
- **Offset axes or not**? Elect to offset the axes only when data points will be obscured by being printed over the Y axis.
- **Error bars or not**? Always include error bars (SD or SEM) when plotting means. In some courses you may be asked to plot other measures associated with the mean, such as confidence intervals.

Four Common Figure Types

Bar Graph

Bar graphs are used when you wish to compare the value of a single variable (usually a summary value such as a mean) among several groups. For example, a bar graph is appropriate to show the mean sizes of plants harvested from plots that received 4 different fertilizer treatments. (Note that although a bar graph might be used to show differences between only 2 groups, especially for class purposes, editors of many journals would prefer that you save space by presenting such information in the text.)

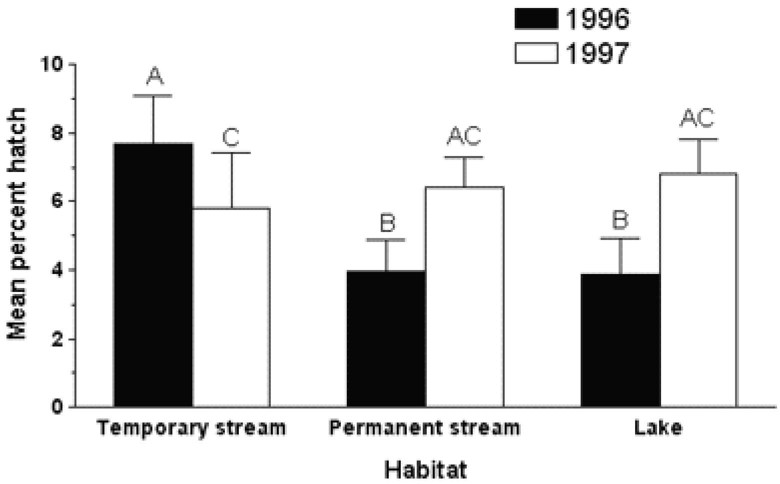


Figure 3. Effects of habitat and year on tychoparthenogenetic capacity (mean % hatching success ± 1 SD of unfertilized eggs) in mayflies. Means with different letters are significantly different (Tukey's HSD, $p < 0.05$).

In this example notice that:

- legend goes *below* the figure;
- a period follows "Figure 1" and the legend itself; "Figure" is not abbreviated ;
- the *measured* variable is labelled on the Y axis. In most cases units are given here as well (see next example);
- the *categorical* variable (habitat) is labelled on the X axis, and each category is designated;
- a *second* categorical variable (year) within habitat has been designated by *different bar fill patterns*. The patterns *must* be defined in a *key*, located wherever there is a convenient space within the graph.
- error bars are included, extending +1 SD or SEM above the mean.
- statistical differences may be indicated by a system of letters above the bars, with an accompanying note in the caption indicating the test and the significance level used.

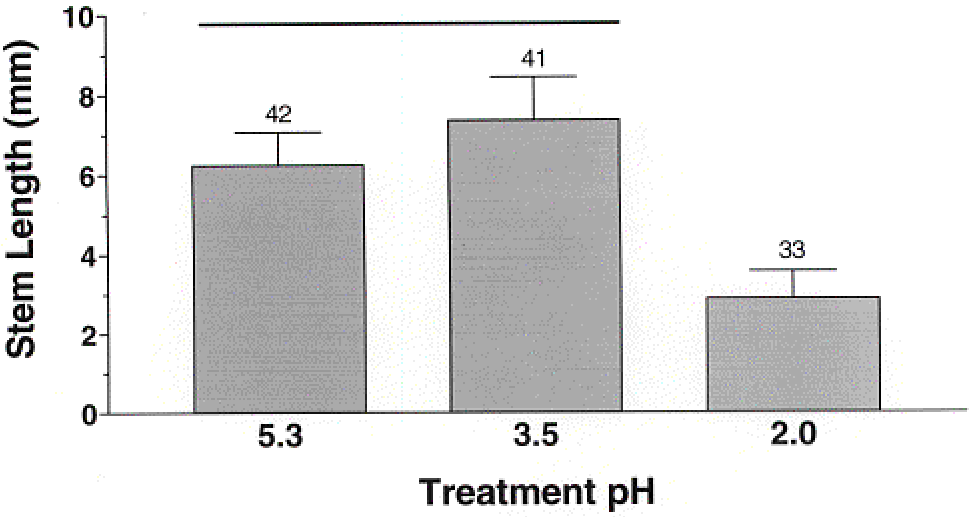


Figure 1. Mean stem length (± 1 SD) of seedling clover watered to soil saturation daily for 2.5 weeks with simulated acid rain of varying pH. The control (pH 5.3) was normal city tapwater. The pH 3.5 and 2.0 water was acidified with 2 M sulfuric/ 1 M nitric acid solution. Line over bars indicates groups which were not significantly different (Kruskal-Wallis Test and Dunn's Multiple Comparison's Tests). Number over bar indicates sample size.

Notice here:

- the completeness of the legend, which in this case requires over 3 lines just to describe the treatments used and variable measured.
- axis labels, with units;
- treatment group (pH) levels specified on X axis;
- error bars and group sample sizes accompany each bar, and each of these is well-defined in legend;
- statistical differences in this case are indicated by lines drawn over the bars, and the statistical test and significance level are identified in the legend.

Frequency Histogram

Frequency histograms (also called frequency distributions) are bar-type graphs that show how the measured individuals are distributed along an axis of the measured variable. Frequency (the Y axis) can be *absolute* (i.e. number of counts) or *relative* (i.e. percent or proportion of the sample.) A familiar example would be a histogram of exam scores, showing the number of students who achieved each possible score. Frequency histograms are important in describing populations, e.g. size and age distributions.

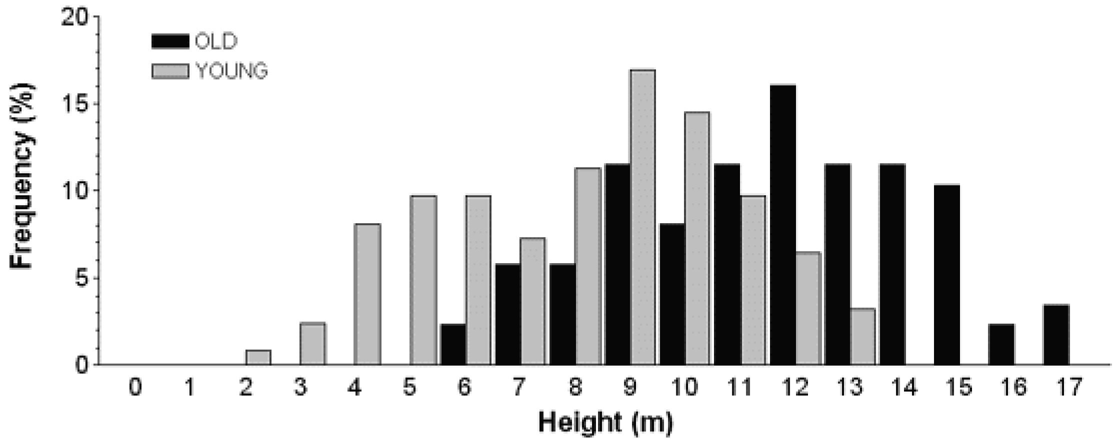


Figure 4. Height distribution in two recruitment cohorts of eastern white pine (Pinus strobus) near the eastern shore of Lake Auburn, Maine, in January 2001. N = 88 OLD and 123 YOUNG trees.

Notice several things about this example:

- the Y axis includes a clear indication ("%") that relative frequencies are used. (Some examples of an absolute frequencies: "Number of stems", "Number of birds observed")
- the measured variable (X axis) has been divided into categories ("bins") of appropriate width to visualize the population distribution. In this case, bins of 0.2 cm broke the population into 7 columns of varying heights. Setting the bin size at 0.5 cm would have yielded only 3 columns, not enough to visualize a pattern. Conversely, setting the bin size too small (0.05 cm) would have yielded very short columns scattered along a long axis, again obscuring the pattern.
- the values labeled on the X axis are the bin *centers*;
- sample size is clearly indicated, either in the legend or (in this case) the graph itself;
- the Y axis includes numbered and minor ticks to allow easy determination of bar values.

X,Y Scatterplot

These are plots of X,Y coordinates showing each individual's or sample's score on *two* variables. When plotting data this way we are usually interested in knowing whether the two variables show a "relationship", i.e. do they change in value together in a consistent way?

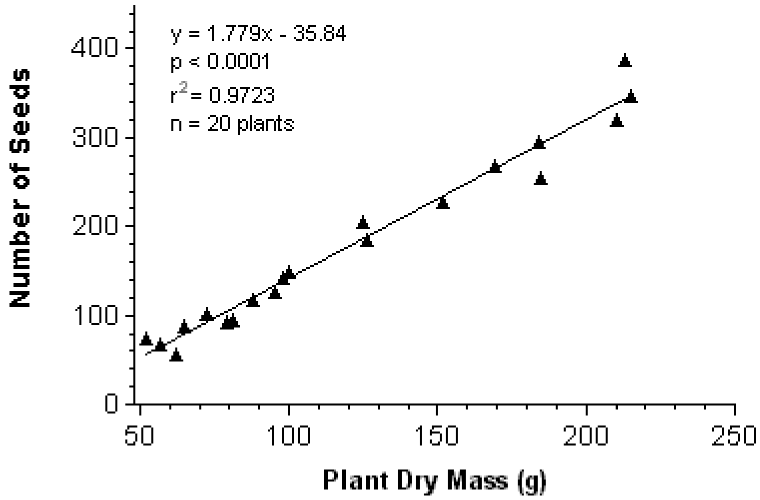


Figure 3. Seed production as a function of plant biomass in waterlilies (*Nuphar luteum*) harvested from Great Works Pond in Northern Maine in August, 2001.

Note in this example that:

- each axis is labeled (including units where appropriate) and includes numbered and minor ticks to allow easy determination of the values of plotted points;
- sample size is included in the legend or the body of the graph;
- if the data have been analyzed statistically and a relationship between the variables exists, it may be indicated by plotting the regression line on the graph, and by giving the equation of the regression and its statistical significance in the legend or body of the figure;
- the range of each axis has been carefully selected to maximize the spread of the points and to minimize wasted blank space where no points fall. For instance, the X axis is truncated below 50 g because no plants smaller than 52 g were measured. The ranges selected also result in labeled ticks that are easy to read (50, 100, 150…, rather than 48, 96, 144…)

Which variable goes on the X axis? When one variable is clearly *dependent* upon another (e.g. height depends on age, but it is hard to imagine age depending on height), the convention is to plot the **dependent variable on the Y axis** and **the independent variable on the X axis**. Sometimes there is no clear independent variable (e.g. length vs. width of leaves: does width depend on width, or vice-versa?) In these cases it makes no difference which variable is on which axis; the variables are <u>inter</u>-dependent, and an X,Y plot of these shows the *relationship* BETWEEN them (rather than the effect of one upon the other.)

In the example plotted above, we can imagine that seed production *might* depend on plant biomass, but it is hard to see how biomass could depend directly on seed production, so we choose biomass as the X axis. Alternatively, the relationship might be indirect: *both* seed production *and* plant biomass might depend on some other, unmeasured variable. Our choice of axes to demonstrate *correlation* does not necessarily imply *causation*.

X,Y Line Graph

Line graphs plot a series of related values that depict a change in Y as a function of X. Two common examples are a growth curve for an individual or population over time, and a dose-response curve showing effects of increasing doses of a drug or treatment.

When to connect the dots? If each point in the series is obtained from the same source and is dependent on the previous values (e.g. a plot of a baby's weight over the course of a year, or of muscle strength on successive contractions as a muscle fatigues), then the points should be connected by a line in a dot-to-dot fashion. If, however, the series represents independent measurements of a variable to show a trend (e.g. mean price of computer memory over time; a standard curve of optical density vs. solute concentration), then the trend or relationship can be modeled by calculating the best-fit line or curve by regression analysis (*see* A Painless Guide to Statistics) *Do not connect the dots* when the measurements were made independently.

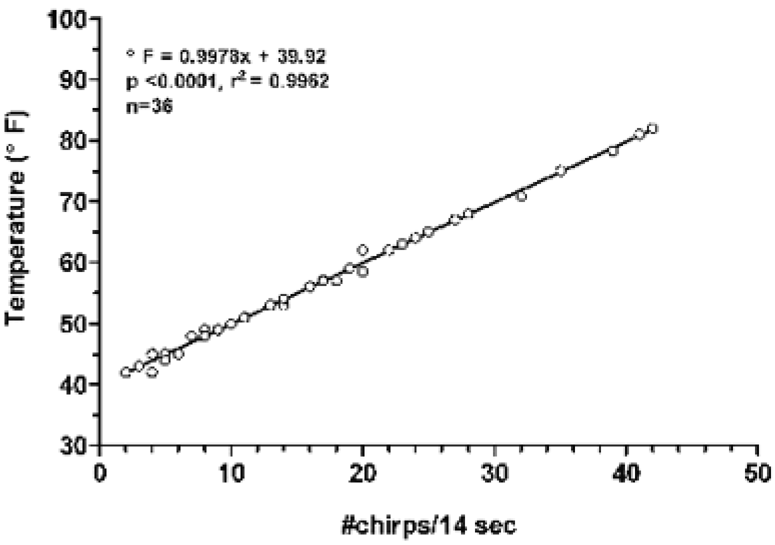


Figure 7. Temperature-dependence of cricket chirp frequency in south central Maine. Temperature (F) = #chirps in 14 sec + 40. n = 36 cricket chirp bouts.

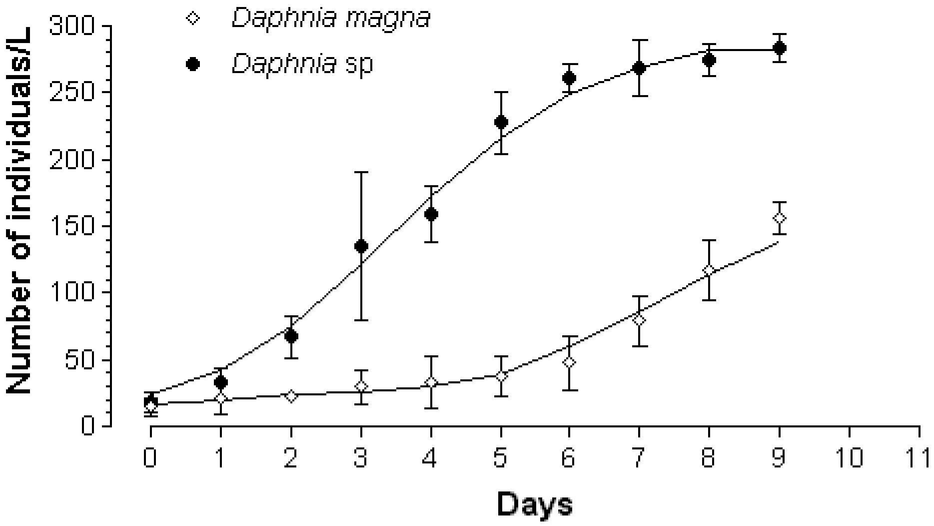


Figure 2. Mean population density (±1 standard deviation) of two species of *Daphnia* following artificial eutrophication of a small farm pond by application of organic fertilizer. Six replicate 1 L water samples were drawn from 50 cm depth at 1100 hr each day.

In this example notice:

- a different symbol is used for each group (species), and the key to the symbols is placed in the body of the graph where space permits. Symbols are large enough to be easily recognizable in the final graph size;
- each point represents a mean value, and this is stated in the legend. Error bars are therefore plotted for each point and defined in the legend as well.
- because measurements were taken on independent groups for each species, the points are NOT connected dot-to-dot; instead a curve is fitted to the data to show the trend.

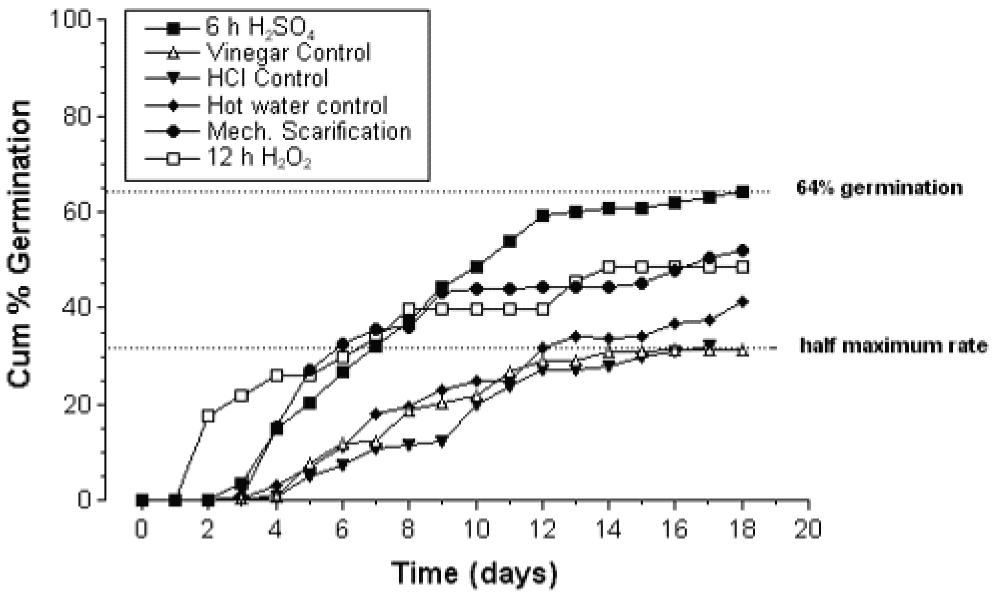


Figure 2. Cumulative germination of gourd seeds following various pregermination treatments. n = 100 seeds per trial.

Notice here that:

- this time the dots ARE connected dot-to-dot within each treatment, because cumulative percent germination was measured within the same set of seeds each day, and thus is *dependent* on the measurements of the prior days;
- a different symbol is used for each treatment, and symbols are large enough (and connecting lines fine enough) so that all can be easily read at the final graph size;
- in addition to the key to symbols, two other kinds of helpful information are supplied in the body of the figure: the values of the highest and lowest final cumulative percents, and a dashed line (baseline) showing the lowest cumulative % germination achieved. This baseline is defined in the legend.

Some Other Types of Figures

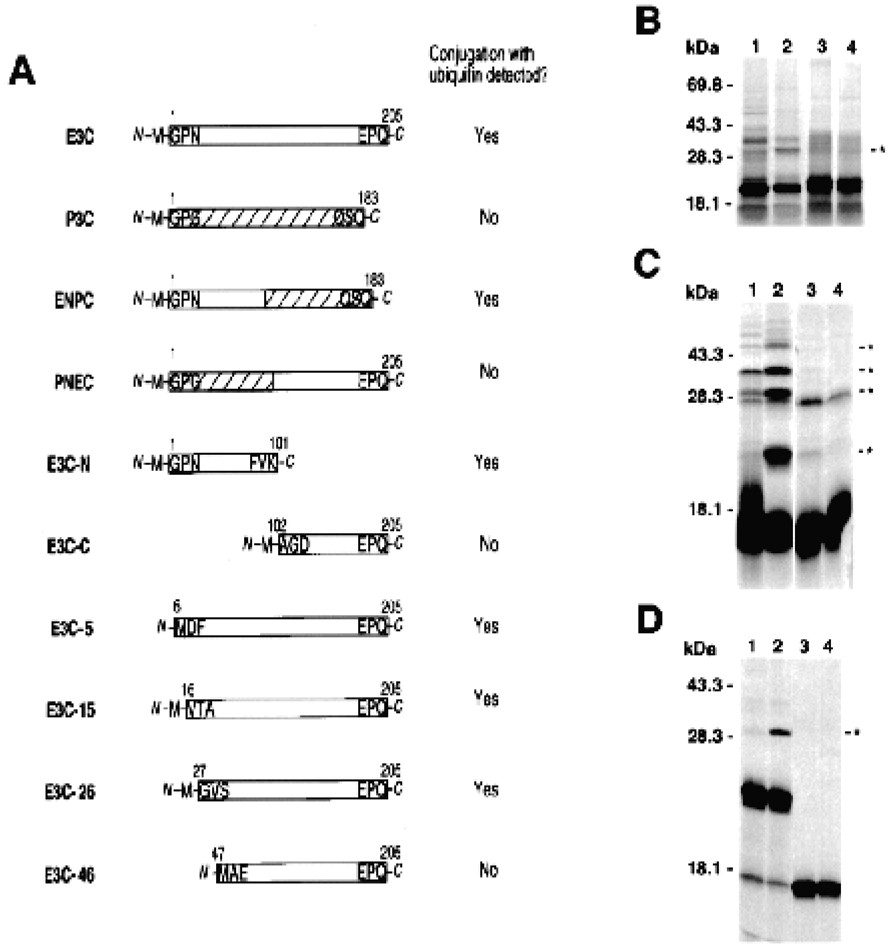
Photographs

Figure 9. Aerial photo of the study site ca. 1949 and in 1998 (inset) showing the regeneration of the forest. Photos courtesy of the USDA Field Office, Auburn, Maine.

Notice here that:

Gels

Source: Lawson et. al, 1999. J.Biol. Chem. 274(14):9871-9980. Used by permission of the authors.



Notice here that:

We are still under construction here, please bear with us.

Reporting Statistical Results in Your Paper

Overview

The results of your statistical analyses help you to understand the outcome of your study, e.g., whether or not some variable has an effect, whether variables are related, whether differences among groups of observations are the same or different, etc. Statistics are *tools* of science, *not* an end unto themselves. Statistics should be used to substantiate your findings and help you to say objectively when you have significant results. Therefore, when reporting the statistical outcomes relevant to your study, subordinate them to the actual *biological results.*

Reporting Descriptive (Summary) Statistics

Means: Always report the **mean** (average value) along with a measure of **variablility** (*standard deviation(s)* or *standard error of the mean*). Two common ways to express the mean and variability are shown below:

"Total length of brown trout (n=128) averaged 34.4 cm (*s* = 12.4 cm) in May, 1994, samples from Sebago Lake."

s = standard deviation (this format is preferred by Huth and others, 1994)

"Total length of brown trout (n=128) averaged 34.4 ±12.4 cm in May, 1994, samples from Sebago Lake."

This style necessitates specifically saying in the Methods what measure of variability is reported with the mean.

Frequencies: Frequency data should be summarized in the text with appropriate measures such as percents, proportions, or ratios.

"During the fall turnover period, an estimated 47% of brown trout and 24% of brook trout were concentrated in the deepest parts of the lake (Table 3)."

Reporting Results of Inferential Tests

In this example, the ***key result*** is shown in blue and the ***statistical result***, which *substantiates* the finding, is in red.

"Mean total length of brown trout in Sebago Lake increased significantly (3.8 cm) between May (34.4 cm ±12.4 cm, n=128) and September, 1994, (38.2 cm ±11.7 cm, n=114; twosample t-test, $p < 0.001$)."

NOTE: AVOID writing whole sentences which simply say what test you used to analyze a result followed by another giving the result. This wastes precious words (*economy*!!) and unnecessarily increases you paper's length.

How to Cite Other Papers in Your Paper

[Table of Contents]

| Citations in the body of the paper | Full Citation Rules in Lit. Cited | Journals | Books |

| Thesis | WWW | Personal Communication | DO NOTS

NOTE: Although you should use these citation formats in this and other biology courses, specific formats vary considerably for individual journals. If you are trying to publish a paper in a specific journal, you will be required to follow the format of that journal. Some journals,e.g., **Science**, use a number system to give the text reference. That system will not be presented here, but you should expect to encounter it in your reading of the literature. A complete listing of citation formats for published materials may be found in Huth et al (1994).

Citing References in the Body of the Paper

Throughout the body of your paper (primarily the Intro and Discussion), whenever you refer to outside sources of information, you must cite the sources from which you drew information. The simplest way to do this is to *parenthetically* give the author's last name and the year of publication, e.g., (Clarke 2001). When citing information from another's publication, be sure to report the *relevant* aspects of the work clearly and succinctly, IN YOUR OWN WORDS. Provide a reference to the work as soon as possible after giving the information.

Standard Text Citation Formats

There are exceptions among the various journals, but generally, in biological journals, the most frequent types of citations are shown in the following examples (in red):

"It has been found that male mice react to estrogen treatment by a reduction in phase three of courtship behavior (Gumwad 1952:209; Bugjuice 1970). Click and Clack (1974) demonstrated that mice treated with synthetic estrogen analogs react similarly. The reduction in phase three courtship behavior may also be linked to nutritional status (Anon. 1996; Bruhahauser et al 1973)."

Note the following:

- Typically, **only the last name of the author(s) and the year of publication are given,e.g.,** Bugjuice 1970. Your Literature Cited section will contain the complete reference, and the reader can look it up there.
- Notice that the **reference to the book has a page number** (Gumwad 1952:**209**). This is to facilitate a reader's finding the reference in a long publication such as a book (not done for journal articles). The paper by Bugjuice (1970) is short,

and if readers want to find the referenced information, they would not have as much trouble.

- For **two author papers**, give both authors' last names (e.g., Click and Clack 1974). Articles with more than two authors are cited by the first authors last name followed "and others" or "et al.", and then the year.
- When a book, paper, or article has **no identifiable author**, cite it as **Anon. Year, e.g.,** (Anon. 1996) (Anon. is the abbreviation for anonymous). See <u>Full Citation</u>.
- If you want **reference a paper found in another article**, do so as follows: (Driblick 1923, *in* Oobleck 1978).
- A <u>string of citations</u> should be separated by semicolons.
- Finally, you should note the **placement of the period** AFTER the parenthetical citation - the citation, too, is part of a sentence,e.g., "...courtship behavior (Gumwad 1952:209; Bugjuice 1970)."

Thesis: Theses and dissertatons should be cited as follows:

Mortimer, R. 1975. A study of hormonal regulation of body temperature and consequences for reproductive success in the common house mouse (*Mus musculus*) in Nome, Alaska. Masters Thesis, University of Alaska, Anchorage. 83 p.

World Wide Web/Internet source citations: WWW citation should be done with caution since so much is posted without peer review. When necessary, report the complete URL in the text including the site author's name:

".....(Gumwad, B. http://www.csu.edu/~gumwad/hormones/onlinepubs.html)"

Internet sources <u>should not</u> be inclkuded in your Literature Cited section.

For more information on citing internet sources, look at:
<u>http://www.councilscienceeditors.org/pubs_citing_internet.shtml</u>

For information on evaluating internet sources, look at:
<u>http://www.cbbnet.org/teaching/evaluation.html</u> and
<u>http://abacus.bates.edu/ils/web/research/evaluate.html</u>

For **unusual reference citations** such a government documents, technical reports, etc, refer to <u>Huth et al (1994)</u> for a complete listing of citation formats.

Personal Communications:

Suppose some of the information cited above was not gained from the Gumwad and Bugjuice publications, but rather in a personal conversation with or letter from an expert on the subject, Dr. Cynthia Mousse. When you have talked with, or written to someone, and gained some information or data that are not published, you should give credit to that person in the following way:

"It has been found that male mice .... phase three of courtship behavior (C. Mousse, pers. comm.)."

- No date is entered for a personal communication, nor will it be entered in your Literature Cited section. However, the source is usually thanked in your Acknowledgments for their contribution.

DO NOT DO THE FOLLOWING:

- **DO NOT USE FOOTNOTES**: Footnoting, although commonly done in books and other literary writing, is only *rarely* done in journal style papers. Cite references in the flow of the text as shown above.
- **DO NOT USE DIRECT QUOTES From Published Material:** In 99.99% of the cases, the information you want from a research article is an objective result or interpretation. How the author stated this information, i.e., *their prose*, is of little importance compared to the results or interpretations themselves. Take the information and *put it into your own words*; avoid paraphrasing since this can potentially lead to plagiarism.

Formats for Complete Citations used in the Literature Cited

In the Literature Cited you must provide complete citations for each of the published articles cited in your paper. The format for entries in the Literature Cited section differs for books and for journal papers because different kinds of information must be provided.

Some basic rules applicable to all formats:

- *All entries* are listed in *alphabetical* order of the first author's *last* name;
- If the same author(s) are cited for more than one paper, the papers should be listed in chronological sequence by year of publication. For example:

Bugjuice, B., Cratchet, R., and T. Timm. 1990. The role of estrogen in mouse xxxxcourtship behavior changes as mice age. J Physiol 62(6):1130-1142.

Bugjuice, B., Cratchet R., and T. Timm. 1994. Estrogen, schmestrogen!: Mouse xxxx(*Mus musculus*) as a dietary alternative for humans. J Nutrition 33(6):113 -114.

- If the same author(s) are cited for two or more papers published within the *same year,* place a small case letter after the year to denote the sequence in which you referred to them. For example:

Bugjuice, B. 1970a. Physiological effects of estrogen on mouse courtship behavior. ....x.J Physiol 40(2):140-145.

Bugjuice, B. 1970b. Physiological effects of estrogen analogs: Insincere courtship xxxxbehavior in female mice. J Physiol 40(8):1240-1247.

- If no author is listed, use the word Anonymous in place of the author name(s).

Anonymous. 1992. .....give rest of citation using appropriate format.

Specific Format Models

Journal Article: Single author

Bugjuice, B. 1970. Physiological effects of estrogen on mouse courtship behavior. .....J Physiol 40(2):140-145.

In the citation of Bugjuice's paper, note the following:

- **abbreviation** of her first name; no comma (if full name is given, *then* use a comma); if multiple authors, use commas between;
- **capitalization** of the words in the title is just as though it were a sentence;
- **abbreviation of the journal name**; usually the header on the article will list the appropriate abbreviation for the journal; no periods in abbreviated form of journal name;
- "40" is the **volume number** "(2)" is the number of the **issue**; if no issue is given, the colon follows the volume number;
- "140-145" is the **inclusive page numbers** of the article;
- **placement of periods** is standard;
- **indentation of the second line (and all susequent lines)** in the citation. This applies to all citations.

Journal: Two authors

Bugjuice, B. and T. Timm. 1989. The role of whisker length in mouse nose-twitch ......courtship behavior. J Physiol 61(3):113-118.

Journal: Multiple authors

Bugjuice, B., Cratchet, R., and T. Timm. 1990. The role of estrogen in mouse ......courtship behavior changes as mice age. J Physiol 62(6):1130-1142.

Author(s) Unknown or Not Named

If the authorship of a paper or other document is not provided, cite the author using the word "Anonymous" in the place of the authors name(s).

Anonymous. 1979. STD's and You: A Survival Guide for College Students in the 20th Century. Publ.#12-1979, Waazah County Health Department, Popville, Maine. 6 p.

Book: single author

Gumwad, G. 1952. Behavior patterns of mice. 2nd ed. New York: Harper & Row. 347 p.

Book: multiple authors

Huth, J., Brogan, M., Dancik, B., Kommedahl, T., Nadziejka, D., Robinson, P., and W. ....Swanson.1994. Scientific format and style: The CBE manual for authors, editors, and publishers. 6th ....ed. Cambridge: Cambridge University Press. 825 p.

Book: authors contributing a specific chapter

Kuret, J. and F. Murad. 1990. Adenohypophyseal hormones and related substances. In:
.....Gilman A, Rall T, Nies A, Taylor P, editors. The pharmacological basis of .....therapeutics. 8th ed. New York: Pergamon. p. 1334-60.

In the books citation, note the following:

- abbreviation of authors first name (one or both initials ok);
- capitalize title as if it was a sentence; the title is not underlined (contrary to literary format)

- "2nd ed." means second edition; if the book is a first edition; no entry is made, here, but if 2nd, 3rd, etc., then the notation is made;
- give city of publication, and the name of the publisher;
- year of publication follows authors' names;
- placement of periods is standard;
- indentation of all lines after the first.

How to Write Latin Names of Species

Binomial Nomenclature

The latin names for individual species are written using a system termed "binomial nomenclature" that was developed originally by Linnaeus. Quite literally, each species is identified by a combination of "two names": its *genus name* and its *specific epithet*. A familiar example is that of human beings, ***Homo sapiens***. Usually the latin name is followed by the last name of the person who first gave the name to the species (in parentheses, not italicized).

Simple Rules for Writing Latin Names in Papers

Here are some simple rules to follow when writing Latin names in your paper:

- The full name (e.g., *Homo sapiens*) should be written out in the Title, the first time it is used in the Abstract, and the first time it is used in the body of the paper. Thereafter the name may be abbreviated as the first letter of the genus name (capitalized) and the complete specific epithet (e.g., *H. sapiens*)
- The genus name is ALWAYS capitalized (e.g., *Homo*)
- The specific epithet is NEVER capitalized (e.g., *sapiens*)
- The entire name is always italicized in print (*Homo sapiens*); if italics are not possible, the alternative is to underline both names.
- If the name of the person who named the species is available, use it. (*Homo sapiens* Linnaeus; *Rana catesbeiana* Shaw, etc)

Use of common names for species

Most species that we encounter routinely are also given a common name which is usually somewhat less cumbersome than the latin name. If you need to mention the species name many times in your paper you may find it better to use the common name. A problem with common names is that a species which has a wide geographic range may be called by different common names depending on where you are. Further, some species may have different common names depending on their particular stage of life or size.

- You may use the common name in a paper so long as the latin name is given with it initially (e.g., in Title, Abstract, and first mention in Introduction) and you clarify which common name you are using for that species.

- When in doubt, use the latin name.

The Metric System, Abbreviations, and Conversions for Common Units of Measure

This page presents the most common abbreviations you will use in general biology, especially those for units of measure.

General Rules for Abbreviating Units of Measure

- Always abbreviate units when reporting numerical information.
- Unless otherwise noted, **singular** and **plural** units are abbreviated the same.
  - *Percent* is not abbreviated, but is symbolized by the familiar "%" symbol.
- Always put a space between the *number* and *unit*, e.g., **203.65 m, 457 um**
- When do you *abbreviate* units *vs. spelling out* the unit(s) as word(s)?
  - *abbreviate* units when you are reporting a numerical value:

"The maximum depth achieved by the ROV was 124 m approximately 2.3 km due south of Pt. Lobos."

  - *spell out* the unit as a word when using it in a non-numerical context, e.g.,

"All measurements were made in millimeters unless otherwise indicated."

  - When starting a sentence with a number and unit, both must be spelled out as words (this is something to avoid, if possible), e.g.,

"One thousand six hundred and eighty-seven kilograms of ground beef were randomly sampled and tested for *E.coli* contaminants between 21 August and 21 November, 1995."

The Metric System

The Metric System of measurement is the standard used by most scientific disciplines. The system is based upon measures of distance (in meters), volume (in liters), and mass (in grams). Scales of measurements increase or decrease as multiples of ten which facilitates expression of measurement values using the decimal system. The table below shows the most common prefixes and their relative magnitudes. Note that web browsers do not support use of superscripts and subscripts very well, so the notation 10^2 means "10 to the power of 2, or 10 squared". Similarly, the notation 10-2 should be read as "10 to the power of -2".

Prefix	Scientific Notation	Decimal equivalents	Example Units
kilo- (k)	= 10^3	= 1000	kilogram (kg); kilometer (km)
centi- (c)	= 10-2	= 0.01	centimeter (cm)
milli- (m)	= 10-3	= 0.001	milligram (mg); millimeter (mm)
micro- (u)	= 10-6	= 0.000001	microgram (ug) microliter (uL)
nano- (n)	= 10-9	= 0.000000001	nanogram (ng) nanoamperes (nA)
pico- (p)	= 10-12	= 0.000000000001	picogram (pg) picoamperes (pA)

Conversions

Units of Distance and Length

Metric Equivalents

1 km = 1000 m; 1 m = 100 cm = 1000 mm = 10^6 um = 10^9 nm

Metric Unit	multiplied by	= English Unit
millimeters	**0.0394**	inches (in)
centimeters	**0.394**	inches
centimeters	**0.0328**	feet (ft)
meters	**39.4**	inches
meters	**3.28**	feet
meters	**1.1**	yards (yd)
kilometers	**3,281**	feet
kilometers	**0.621**	miles (mi)

English Equivalents

1 mi = 1,760 yd = 5,281 ft; 1 yd = 3 ft = 36 in

English Unit	multiplied by	= Metric Unit
inches (in)	**25.4**	millimeters
inches	**2.54**	centimeters
inches	**0.254**	meters

feet (ft)	**30.48**	centimeters
yards (yd)	**91.44**	centimeters
yards	**0.9144**	meters
miles (mi)	**1.609**	kilometers

Units of Mass

Metric Equivalents

1 mt (metric ton) = 1000 kg = 2,205 lb

1 kg = 1000 g = 2.205 lb = 35.2802 oz

1 g = 1000 mg = 10^6 ng = 10^9 pg

Metric Unit	**Multiplied by**	**= English Unit**
gram (g)	0.035	ounces (oz)
kilogram (kg)	2.2	pounds (lb)
metric ton (mt)	1.102	ton (t)

English Equivalents

1 ton = 2000 lb = 907.2 kg or 0.9072 mt

1 lb = 16 oz = 0.4536 kg = 453.6 g

English Unit	**Multiplied by**	**= Metric Unit**
ounce (oz)	28	grams (g)
pound (lb)	0.4536	kilograms (kg)
tons (t)	0.9072	metric tons (mt)

Units of Volume

Metric Equivalents

1 cm^3 (or cc) = 1000 mm^3 = 0.061 in^3

1 m^3 = 10^6 cm^3 = 61,024 in^3 = 35.31 ft^3 = 1.308 yd^3

Metric Unit	**Multiplied by**	**= English Unit**
cubic centimeters (cm^3)	0.061	cubic inches (in^3)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters	1.308	cubic yards (yd^3)

English Equivalents

1 ft^3 = 1,728 in^3 = 28,317 cm^3 = 0.02832 m^3

1 yd^3 = 27 ft^3 = 0.7646 m^3

English Unit	Multiplied by	= Metric Unit
cubic inches	16.393	cubic centimeters
cubic feet	0.03	cubic meters
cubic yards	0.76	cubic meters

Units of Liquid Volumes

Metric Equivalents

1 L = 1000 ml = 2.113 pt (pints) = 1.06 qt (quarts) = 0.264 US gal

1 ml (or cm^3) = 1000 ul = 0.03 fl oz (fluid ounces)

Metric Unit	Multiplied by	= English Unit
milliliters (ml)	0.02957	fluid ounces (fl oz)
liters (L)	2.13	pints (pt)
liters (L)	1.0567	quarts (qt)

English Equivalents

1 US gal = 4 qt = 8 pt = 128 fl oz = 3.785 L

1 qt = 2 pt = 32 fl oz = 946.4 ml or 0.9464 L

1 pt = 16 fl oz = 473.2 ml or 0.213 L

1 fl oz = 29.57 ml

English Unit	Multiplied by	= Metric Unit
teaspoons (tsp)	5	milliliters (ml)
tablespoons (tbsp)	15	milliliters
fluid ounces (fl oz)	29.57	milliliters
cups (c)	0.24	liters (L)
pints (pt)	0.4732	liters
quarts (qt)	0.9464	liters
US gallons (US gal)	3.785	liters

Units of Area

Metric Equivalents

1 km^2 = 100 ha = 1,000,000 m^2 = 270 A (acres) = 0.3861 mi^2

1 ha (hectare) = 10,000 m^2 = 107,600 ft^2 = 2.471 A

1 m^2 = 10,000 cm^2 = 1,000,000 mm^2 = 1,550 in^2 = 1.196 yd^2

1 cm^2 = 100 mm^2 = 0.155 in^2

1 mm^2 = 1,000,000 um^2

Metric Unit	Multiplied by	= English Unit
centimeters squared	0.155	inches squared

meters squared	1.196	yards squared
kilometers squared	0.3861	miles squared

English Equivalents

1 mi^2 = 640 A = 27,878,400 ft^2 = 259 ha = 2.59 km^2

1 A = 4,840 yd^2 = 43,560 ft^2 = 4,407 m^2 = 0.405 ha

1 yd^2 = 9 ft^2 = 1296 in^2 = 8,361 cm^2 = 0.836 m^2

1 ft^2 = 144 in^2 = 929 cm^2

1 in^2 = 6.452 cm^2

English Unit	Multiplied by	= Metric Unit
inches squared	6.452	centimeters squared
feet squared	0.0929	meters squared
yards squared	0.836	meters squared
acres (A)	0.405	hectares (ha)
miles squared	2.59	kilometers squared

Units of Temperature

Temperature Equivalents

K = Kelvin || C = Celcius || F = Fahrenheit

0 K = -273.15 C = absolute zero (no molecular motion)

273.15 K = 0 C = 32 F = freezing point of water/ melting point of ice

373.15 K = 100 C = 212 F = boiling point of water

Fahrenheit (F) to Celcius (C) Conversion

(degrees F - 32) x 5/9 = degrees C

Celcius (C) to Fahrenheit (F) Conversion

(degrees C x 9/5) + 32 = degrees F

Units of Pressure

Units of Humidity

Units of Concentration

Concentration *usually* refers to a mass/volume relationship.

Percent (%)	= **grams solute / 100 ml solvent**; To convert to molar concentration multiply grams by 10, then divide by the formula weight (FW) of the solute.
Molarity (M)	= **moles solute per liter of solvent** **For example,** **1 M = 1 mole/liter**; where, 1 mole = 6.023 x 10^23 molecules = 1 molecular weight (MW) ~ 1 formula weight (FW) Molarity may also be expressed as mM (millimolar), where 1 mM equals 10-3 M, when working with low concentrations.
Salinity	= **grams *total solutes* per kg of seawater** Salinity is usually expressed as "parts per thousand" = ppt. Coastal seawater has approximately 30-32 g solutes per kg = 30-32 ppt salinity.

Units of pH

In contrast to other units, report pH with the unit before the number: e.g., **pH 8.2**

Units of Time

The most frequent units time used in the biological sciences are:

Years	yr
Days	d
Hours	h
Minutes	min
Seconds	sec or s
Milliseconds	msec