Appendix

Scientific Writing and Communication

For the scientific enterprise to be successful, scientists must clearly communicate their work. Scientific findings are never kept secret. Instead, scientists share their ideas and results with other scientists, encouraging critical review and alternative interpretations from colleagues and the entire scientific community. Communication, both oral and written, occurs at every step along the research path. While working on projects, scientists present their preliminary results for comments from their co-workers at laboratory group meetings and in written research reports. At a later stage, scientists report the results of their research activities as a poster or oral presentation at a scientific meeting. Then the final report is prepared in a rather standard scientific paper format and submitted for publication in an appropriate scientific journal. At each stage in this process, scientists encourage and require critical review of their work and ideas by their peers. The final publication in a peer-reviewed journal generally promotes additional research and establishes this contribution to current knowledge.

One of the objectives of every lab topic is to develop your writing skills. You will generate and write hypotheses, observations, answers to questions, and more, as one way of learning biology. Also, you will practice writing in a scientific paper format and style to communicate the results of your investigations. The scientific process is reflected in the design of a scientific paper and the format you will use for your laboratory papers.

A scientific paper usually includes the following parts: a **Title** (statement of the question or problem), an **Abstract** (short summary of the paper), an **Introduction** (background and significance of the problem), a **Materials and Methods** section (report of exactly what you did), a **Results** section (presentation of data), a **Discussion** section (interpretation and discussion of results), and **References Cited** (books and periodicals used). A **Conclusion** (concise restatement of conclusions) and **Acknowledgments** (recognition of assistance) may also be included.

Writing Program. *We propose that you practice writing throughout the biology laboratory program by submitting individual sections of a scientific paper.* Your instructor will determine which sections you will write for a given lab topic and will evaluate each of these sections, pointing out areas of weakness and suggesting improvements. By the time you have completed these assignments, you will have submitted the equivalent of one scientific paper. Having practiced writing each section of a scientific paper in the first half of the laboratory program, *you will then write one or two complete laboratory papers in scientific paper format during the second half of the laboratory program,* reporting the results of experiments, preferably those that you and your research team have designed and performed.

From Appendix A of *Investigating Biology Laboratory Manual*, Seventh Edition. Judith Giles Morgan, M. Eloise Brown Carter.
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Successful Scientific Writing

The following notes for success apply to writing throughout all sections of a scientific paper.

- Your writing should be **clear and concise** to communicate effectively with your audience. Write objectively in direct and informative sentences that explain what you mean with a minimum of words. **Avoid adjectives and adverbs** that can contribute to flowery language and have limited use in describing your work.
- **Write in short and logical, but not choppy, sentences.** Avoid run-on sentences and use grammatically correct English. Avoid long introductions. (See Appendix 4, "Sentences Requiring Revision," in Knisely (2009) for basic rules of writing and practice in editing for common errors.)
- **Write for your audience**: other student-scientists and your professor. Scientists read scientific papers to be current in the field, provide background information on a topic, and to develop or improve methodologies. Scientific writing must be factual and informative, rather than entertaining.
- **Support your writing with evidence**. Your interpretation of your work in the Discussion section will be based on the results of your research presented in the Results section. In the Introduction and Discussion sections you will provide support for your ideas by describing and referencing work of other scientists.
- **Locate sources related to your work early** in the research project. Read the sources carefully to understand the work. Then take notes in your own words. Make a complete record of the reference citation information to use in the References section of your paper.
- **Avoid quotations in scientific writing.** Unlike writing in other disciplines, scientific writing seldom includes direct quotes. You should summarize and explain the work of others in your own words. Then provide a reference citation to the work. *Do not use footnotes.*
- **Do not plagiarize.** When you restate or paraphrase the words of others, you must credit that work by including the source in a reference citation in the text. Simply changing a word or two in the sentence is still plagiarism. See Pechenik (2010) and Knisely (2009) for specific examples and suggestions for avoiding plagiarism.
- **Use the past tense** in the Abstract, Materials and Methods, and Results sections. Also use the past tense in the Introduction and Discussion sections when referring to *your* work. **Use the present tense** when relating the background information as you refer to other investigators' published work. Previously published research is considered established in the present body of knowledge.
- **Use the active voice** when possible. Doing so makes the paper easier to read and more understandable. However, in the Materials and Methods section you may use the passive voice so that the focus of your writing is the methodology, rather than the investigator.
- When referring to the scientific name of an organism, **the genus and species should be in italics or underlined.** The first letter of the genus

is capitalized, but the species is written in lowercase letters, for example, *Drosophila melanogaster.*

- **Pay particular attention to the rules for numbers.** Use metric units for all measurements. Use numerals when reporting measurements, percentages, decimals, and magnifications. When beginning a sentence, write the number as a word. Numbers of ten or less that are not measurements are written out. Numbers greater than ten are given as numerals. Decimal numbers less than one should have a zero in the one position (e.g., 0.153; not .153).
- **Include a heading for each section of the scientific paper** (except the title page), placing the heading of the section against the left margin on a separate line. Each section does not begin a new page but continues in order.
- **Revise, revise, and then revise!** For suggestions and examples of how to revise your work, see Chapter 5, "Revision," in Knisely (2009) and Chapter 6, "Revising," in Pechenik (2010).
- **A few points to remember.** Note the word *data* is plural. Remember the results cannot "prove" the hypothesis, but rather they may "support" or "falsify" the hypothesis.
- **Carefully proofread** your work even if your word processor has checked for grammatical and spelling errors. These programs cannot distinguish between "your" and "you're," for example.
- **Save a copy** of your work on a disk or USB flash drive, and **print a copy** of your paper before turning in the original.
- **Begin writing early, leaving time for literature search, analysis, revision and final proofreading.** Writing takes time and thought.

Locating Appropriate References

References are important to provide a context and evidence from the work of other scientists to support your explanations and interpretations. Scientific papers in general rely on **primary references,** *reports of original research that present the work of scientists in such a way that it can be repeated. Primary references are journal articles that have been reviewed by other scientists and the journal editor.* In addition to articles in journals (for example, *American Journal of Botany, Cell, Ecology,* and *Science*), primary references include conference papers, dissertations, and technical reports. Many scientific journals are available in a full-text version online; these are still primary references. (Websites are not primary references, because they are not required to participate in the peer review process.)

As you begin your study and literature review, it may be helpful to start with secondary references. Textbooks, review articles, and articles from popular science magazines are **secondary references,** *which generally provide a summary and interpretation of research* (for example, *Annual Review of Genetics, Science News,* and *Scientific American*). To develop fundamental concepts and terminology, consult books and review articles. For example, if your project is on plant hormones, you might consult a plant physiology textbook or search in the *Annual Review of Plant Physiology*. In general these secondary references do not provide the primary evidence needed for your scientific paper. They may include references to primary

articles that will be useful. (Also see the References section for each Lab Topic in this manual.)

Given the enormous number of scientific papers and journals available, searching for primary references on your research topic may seem to be a daunting task. The key to success is to use effective **search strategies** with **online databases and search engines** that specifically target scientific literature (for example, PubMed, Google Scholar, Biosis Previews, Science Direct, JSTOR, and Web of Science). You can compare these online resources and read about search strategies in Pechenik (2010) and Knisely (2009). Most databases and search engines provide a tutorial for searching under "Help" or "Advanced Searches."

As you read scientific papers, take notes by summarizing the work in your own words. Do not record quotes, since scientific writing does not use direct quotations. Record the complete citation information for any references at the time you read the article. Any information from these sources must be acknowledged with a citation in the text and inclusion in the References Cited section. *Refer to the citation format in the References Cited section of this appendix.* Your instructor will indicate the number of primary references required for your paper. Gillen (2007) and Knisely (2009) provide useful suggestions for how to read and evaluate scientific papers.

Plagiarism

Plagiarism is the use of someone else's words or ideas without acknowledging the source or author. Plagiarism is a serious offense and one that can and must be avoided. Many instructors are using Internet and software resources to detect plagiarism. The penalties for plagiarism are severe, ranging from a failing grade on the work to expulsion. All sources of information must be acknowledged even if you write about the work in your own words. Although you will work collaboratively on your laboratory investigations, *students must write and submit their papers independently.* Because performing the experiment will be a collaborative effort, you and your teammates will share the results of your investigation. The Introduction, Discussion, and References Cited (or References) sections must be the product of your own personal literature research and creative thinking. If you are not certain about the level of independence and what constitutes plagiarism in this laboratory program, ask your instructor to clarify the class policy. *In the most extreme case of plagiarism, a student presents another student's report as his or her own. However, representing another person's ideas as your own without giving that person credit is also plagiarism and is a serious offense.* To learn more about and to practice identifying plagiarism, see Frick's (2004) website.

Writing a Scientific Paper

The sections of a scientific paper and particular material to be covered in each section are described after the following table in order of appearance in a scientific paper. However, most scientists do not follow that sequence in the actual writing of the paper, but rather begin with the methodology. (See table, "Plan for Writing a Scientific Paper.")

Plan for Writing a Scientific Paper		
Order of Writing	**Section**	**Notes**
Begin 1st	Materials and Methods	The first draft of this section can be written before all the results are completed. Remember to review and carefully edit after completing all work. (See Materials and Methods.)
2nd	Results	Construct the **tables and figures** (see Lab Topic 1 Scientific Investigation). **Compose the text** for the Results section based on the tables and figures. (See Results.)
3rd	Literature Search—Continued	Consult references for background information and interpretation of results. **Locate and review primary and secondary references** for use in the Discussion and Introduction sections. (See References Cited.)
4th	Discussion and References	Write the **Discussion** section and begin the **References Cited** section. (See Discussion and References Cited.) Most scientists prefer to write the Discussion before the Introduction. Both sections require background information and a clear understanding of the results of the work. Remember to carefully check and revise your Discussion, if you write it first.
5th	Introduction and References	Develop the **Introduction** section and complete the **References Cited** section. (See Introduction and References Cited.)
6th	Abstract and Title	**Write the Title and Abstract**. The abstract is a short summary of all components of the paper. The title is a succinct statement of the objective of the research.
7th	Revise and Proofread	Leave the paper for a short time and then reread carefully. **Revise** to be clear, concise, and well written. Review your use of evidence and evaluate your sources. Revise accordingly. **Proofread carefully** for errors. Review a checklist, if available, before preparing the final version of the paper. Check for all formatting rules and suggestions.

Title Page and Title

The **title page** is the first page of the paper and includes the **title** of the paper, **your name**, the **course title**, your **lab section**, your **instructor's name**, and the **due date** for the paper. *The title should be as short as possible and long as necessary to describe the objective and significance of your research topic.* For example, if you are asking a question about the inheritance patterns of the gene for aldehyde oxidase production in *Drosophila melanogaster,* a possible title might be "Inheritance of the Gene for Aldehyde Oxidase in *Drosophila melanogaster.*" Something like "Inheritance in Fruit Flies" is too general, and "A Study of the Inheritance of the Enzyme Aldehyde Oxidase in the Fruit Fly *Drosophila melanogaster*" is too wordy. The words "A Study of the" are superfluous, and "Enzyme" and "Fruit Fly" are redundant. The suffix *-ase* indicates that aldehyde oxidase is an enzyme, and most scientists know that *Drosophila melanogaster* is the scientific name

of a common fruit fly species. However, it is appropriate to include in the title both common and scientific names of lesser known species.

The format for the title page. Place the title about 7 cm from the top of the title page. Place "by" and your name in the center of the page, and place the course name, lab section, instructor's name, and due date, each on a separate centered line, at the bottom of the page. Leave about 5 cm below this information.

Abstract

The **abstract** is placed at the beginning of the second page of the paper, after the title page. *The abstract concisely summarizes the question being investigated in the paper, the methods used in the experiment, the results, and the conclusions drawn.* The reader should be able to determine the major topics in the paper without reading the entire paper. The abstract should be no more than 250 words, and fewer if possible. Compose the abstract after the paper is completed.

Introduction

*The **introduction** has two functions: (1) to provide the context for your investigation and (2) to state the question asked and the hypothesis tested in the study.* Begin the introduction by providing background information that will enable the reader to understand the objective of the study and the significance of the problem, relating the problem to the larger issues in the field. Include only information that directly prepares the reader to understand the question investigated. Most ideas in the introduction will come from outside sources, such as scientific journals or books dealing with the topic you are investigating. All sources of information must be referenced and included in the References Cited (or References) section of the paper, but the introduction must be in your own words. Refer to the references when appropriate. Unless otherwise instructed, place the author of the reference cited and the year of publication in parentheses at the end of the sentence or paragraph relating the idea; for example, (Finnerty, 1992). Additional information on citing references is provided in the section on References Cited. *Do not use citation forms utilized in other disciplines. Do not use footnotes and avoid the use of direct quotes.*

As you describe your investigation, include only the question and hypothesis that you finally investigated. Briefly describe the experiment performed and the outcome predicted for the experiment. Although these items are usually presented after the background information near the end of the introduction, you should have each clearly in mind before you begin writing the introduction. It is a good idea to write down each item (question, hypothesis, prediction) before you begin to write your introduction.

Materials and Methods

*The **Materials and Methods** section describes your experiment in such a way that it can be repeated. This section should be a narrative description that integrates the materials with the procedures used in the investigation.* The Materials and Methods section is often the best place to begin writing your paper. The writing is straightforward and concise, and you will be reminded of the details of the work. The following notes apply to writing the Materials and Methods section.

- Write the Materials and Methods section concisely in paragraph form in the past tense. *Do not list the materials and do not list the steps of the procedure.*

- Be sure to include levels of treatment, numbers of replications, and controls.
- If you are working with living organisms, include the scientific name and the sex of the organism.
- Describe any statistical analyses or computer software used.
- Determine which details are essential for another investigator to repeat the experiment. For example, if in your experiment you incubated potato pieces in different concentrations of sucrose solution, it would not be necessary to explain that the pieces were incubated in plastic cups labeled with a wax marking pencil or to provide the numbers of the cups. In this case, the molarity of the sucrose solutions, the size of the potato pieces and how they were obtained, and the amount of incubation solution are the important items to include.
- Do not include failed attempts unless other investigators may try the technique used. Do not try to justify your procedures in this section.
- Results should not be included in the Materials and Methods.

Results

The **Results** section is the central section of a scientific paper. It consists of at least four components: *(1) one or two sentences reminding the reader about the nature of the research, (2) one or more paragraphs that describe the results, (3) figures (graphs, diagrams, pictures), and (4) tables.* The data included in tables and graphs should be summarized and emphasized in a narrative paragraph written in past tense. Draw the reader's attention to the results that are important. Describe trends in your data and provide evidence to support your claims.

Before writing the Results section, prepare the tables and figures. Remember to number figures and tables consecutively throughout the paper. Refer to figures and tables within the paragraph as you describe your results, using the word Figure or Table, followed by its number; for example, (Figure 1). If possible, place each figure or table at the end of the paragraph in which it is cited.

If you have performed a statistical analysis of your data, such as chi-square, include the results in this section.

Report your data as accurately as possible. Do not report what you expected to happen in the experiment nor whether your data supported your hypothesis. Do not discuss the meaning of your results in this section. Do not critique the results. Any data you plan to include in the Discussion section must be presented in the Results. Conversely, do not include data in the Results that you do not mention in the Discussion.

Write the Results section before attempting the Discussion section. This will ensure that the results of your investigation are clearly organized, logically presented, and thoroughly understood before they are discussed.

Discussion

*In the **Discussion** section, you will analyze and interpret the results of your experiment.* Simply restating the results is not interpretation. The Discussion must provide a context for understanding the significance of the results. Explain why you observed these results and how these results contribute to

our knowledge. Your results either will support or confirm your hypothesis or will negate, refute, or contradict your hypothesis; but the word *prove* is not appropriate in scientific writing. If your results do not support your hypothesis, you must still state why you think this occurred. Review the related work of other scientists and provide a summary of their research. Use this evidence to support your interpretation of the results of your study. State your conclusions in this section.

Complete the Results sections before you begin writing the Discussion. The figures and tables in the Results section will be particularly important as you begin to think about your discussion. The tables allow you to present your results clearly to the reader, and graphs allow you to visualize the effects that the independent variable has had on the dependent variables in your experiment. Studying these data will be one of the first steps in interpreting your results. As you study your data in the Results section, write down relationships and integrate these relationships into a rough draft of your discussion.

The following steps may be helpful as you begin to outline your discussion and before you write the narrative.

- Restate your question, hypothesis, and prediction.
- Write down the specific data, including results of statistical tests.
- State whether your results did or did not confirm your prediction and support or negate your hypothesis.
- Write down what you know about the biology involved in your experiment. How do your results fit in with what you know? What is the significance of your results?
- How do your results support or conflict with previous work? Summarize the findings and include references to this work.
- Clearly state your conclusions.
- List weaknesses you have identified in your experimental design that affected your results. The weaknesses of the experiment should not, however, dominate the Discussion. *Include one or two sentences only if these problems affected the results.* Remember the focus of the Discussion is to convey the significance of the results.
- You are now ready to write the narrative for the Discussion. Integrate all of the above information into several simple, clear, concise paragraphs. Discuss the results; do not simply restate the data. Refer to other work to support your ideas.

References Cited (or References)

A **References Cited** section lists only those references cited in the paper. A References section (bibliography), on the other hand, is a more inclusive list of all references used in producing the paper, including books and papers used to obtain background knowledge that may not be cited in the paper. Most references will be cited in the Introduction and Discussion sections of your paper. References may also be included in the Materials and Methods when acknowledging the source for a procedure or method of analysis. For your paper you should have a References Cited section that includes only those references cited in the paper. For additional assistance, see "Locating Appropriate References."

Constructing the References Cited Section

The **format for the References Cited section** differs slightly from one scientific journal to the next. How does an author know which format to use? Every scientific journal provides "Instructions to Authors" that describe specific requirements for this important section and all other aspects of the paper. You may use the format used in this lab manual and provided in the examples below, select the format in a scientific journal provided by your instructor, or use another accepted format for listing your references. Your instructor may provide additional instructions. Be sure to read the references that you cite in your paper.

Journal article, one author:

Gould, S. J. "Is a New and General Theory of Evolution Emerging?" *Paleobiology*, 1980, vol. 6, pp. 119–130.

Journal article, two or more authors:

Greider, C. W. and E. H. Blackburn. "Identification of a Specific Telomere Terminal Transferase Activity in *Tetrahymena* Extracts." *Science*, 1985, vol. 43, pp. 405–413.

Book:

Darwin, C. R. *On the Origin of Species.* London: John Murray, 1859.

Chapter or article in an edited book:

Funk, D. J. "Investigating Ecological Speciation," in *Speciation and Patterns of Diversity,* eds. R. K. Butlin, J. R. Bridle, and D. Schluter. Cambridge, UK: Cambridge University Press, 2009, pp. 195–218.

Government publication:

Office of Technology Assessment. *Harmful Non-indigenous Species in the United States.* Publication no. OTA-F-565. Washington, D.C.: U.S. Government Printing Office, 1993.

Citing References in Text

Scientific writing uses a different format than you may have used in other disciplines for acknowledging sources of information in the body of the paper. After referring to and describing the work of another scientist in your own words, place the author's name and the date in parentheses at the end of the passage. This date and year citation format is not the only one used in scientific writing, but it is the one used in this laboratory manual and many scientific journals. *Do not use citation formats from other disciplines.*

Example for one author:

The innate agonistic behavior of the male Siamese fighting fish has been widely studied (Simpson, 1968).

For two authors use both names:

Telomere terminal transferase was identified as the enzyme that adds nucleotide repeats at the telomeres (ends of chromosomes) during eukaryotic replication (Grieder and Blackburn, 1985).

For three or more authors use first author plus et al.:

Taxol, a bioactive compound extracted from the Pacific yew, inhibits cell replication at the metaphase/anaphase stage. The blocking of mitosis occurs in tissue culture cells as a result of stabilizing the microtubules so that the chromosomes cannot move to the poles of the cell (Jordan et al., 1993).

Information Sources and the Internet

The Internet can provide access to online search engines and databases including *Biological Abstracts, Current Contents, Medline,* and *Annual Reviews* among many others. These search tools provide access to a wide range of published papers, some of which may be available online as full text journals. For suggestions and examples of how to locate sources using the Internet, see Harnack and Kleppinger (2003) and Knisely (2009). Scientific papers published in professional journals have gone through an extensive review process by other scientists in the same field. Most scientific articles have been revised based on comments by the reviewers and the editors. Sources of information that lack this critical review process do not have the same validity and authority.

The Internet is an exciting, immediate, and easily accessible source of information. However, unlike traditional bibliographic resources in the sciences, the Internet includes websites with material that has not been critically reviewed. Your instructor may prefer that you use the Internet only for locating peer-reviewed primary references or as a starting point to promote your interest and ideas. You may not be allowed to use Internet sources at all. Consult your instructor concerning use of Internet information.

If you do use the Internet to locate information, you should be prepared to evaluate these sites critically. Remember always to record the online address (URL) for any site you use as a reference. Tate and Alexander (1996) suggest the following five criteria for evaluating Internet sources.

1. **Author and Publisher of Source.** Determine the author and publisher for the Internet site. What is the professional affiliation of the author? Are phone numbers and addresses included? Is there a link to the publisher's home page? Does the author list his or her qualifications? If the material is copyrighted, who owns the copyright?
2. **Accuracy.** Look for indications of professional standards for writing, citations, figures, and tables. Are there typographical, spelling, and grammatical errors? Are sources of information cited? Are the data presented or simply summarized?
3. **Objectivity.** Is the site provided as a public service, free of advertising? If advertising is present, is it clearly separate from the information? Does the site present only the view of the publisher or advertiser?
4. **Timeliness.** Determine the date of the site and whether it is regularly revised. How long has the site existed? When was it last updated? Are figures and tables dated? Some Internet sites disappear overnight. Always record the date that you visited the site and retrieved information.
5. **Coverage.** Is the information offered in a complete form or as an abstract or summary of information published elsewhere? Is the site under construction? When was the site last revised?

Below find a model format and examples for citing Internet sources in the References Cited section of your paper. Other formats may be suggested by your instructor or librarian.

Model:

Author's last name and initials. Date of Internet publication. Document title. <URL> Date of access.

Examples:

Professional site:

[CBE] Council of Biology Editors. 2010. CBE home page. http://www.councilscienceeditors.org. Accessed May 15, 2010.

e-journal:

Browning T. 1997. Embedded visuals: Student design in Web spaces. *Kairos: A Journal for Teachers of Writing in Webbed Environments* 3(1). http://english.ttu.edu/kairos/2.1/features/browning/bridge.html. Accessed May 15, 2010.

Government publication:

Food and Drug Administration, 1996, Sep. "Outsmarting Poison Ivy and Its Cousins." *FDA Consumer Magazine.* http://www.fda.gov/fdac/features/796_ivy.html. Accessed May 15, 2010.

Note: If using a Web search engine like Google Scholar, *do not include the entire search path.* Cite only the actual Web address or URL in the reference citation.

Oral and Poster Presentations

Oral Presentations

Scientists regularly present their work at scientific meetings in oral paper presentations. They can share preliminary findings and receive critical questions and comments from others in their field that are essential to scientific research. In this laboratory program you may be asked to give an oral report on your experiments in the laboratory or in a research symposium. For your 10- to 15-minute presentation, you need to capture the interest of your audience and make a convincing presentation of your results and conclusions. Following are suggestions to help you prepare and present oral reports.

- Include the components of a scientific paper, with an Introduction, Methods, Results, Discussion, and Conclusions.
- In the introduction, provide background information, state your hypothesis, give a brief description of your experiment, and state your predicted results.
- Briefly describe the experimental design and essential procedures.
- Emphasize your results with bold and clearly labeled figures and tables that have visual impact.
- Discuss and interpret your results providing supporting evidence from primary references.
- State your conclusions.
- Include references to sources of information and images.
- Be prepared to answer questions.

Pay attention to your presentation delivery. Use simple, bold visual aids that are easily visible from the back of the room. For information on preparing PowerPoint slides, see Knisely (2009) and www.Dartmouth.edu/~biomed/new.htmld/ppt_resources.shtml.

Below are suggestions for effective presentations.

- Slides should have a small number of bullets, not extensive text.
- Use a simple and consistent template or theme for slides.
- Minimize distracting transitions and sounds.

- Do not read the slides.
- Look at your audience (not the screen). Speak slowly and clearly, projecting your voice so all members of the audience can hear you.
- Keep your objective in mind—to clearly communicate your ideas.

A checklist and other suggestions for preparing successful oral presentations may be found in McMillan (2006). A copy of an evaluation form for oral presentations can be downloaded at http://www.sinauer.com/knisely/.

Poster Presentations

Another form of scientific communication that has become popular in recent years is the **scientific poster**, a document usually created on a single, large sheet. If a large printer is not available, a poster may be created on a multiple-paneled mat board. Most scientific societies are now organizing poster sessions at their annual meetings, often featuring undergraduate and graduate student research. Your instructor may ask you to model this form of communication by preparing a poster about your student-designed investigations or extended research projects as part of a poster symposium.

In many situations, posters may be a more effective method of presentation than writing a scientific paper or giving an oral report. A poster may be prominently displayed for a wider audience for an extended period. The presenters are then available at designated times to explain the research and engage in meaningful discussion.

Suggestions for preparing and presenting a poster follow.

- Present the essentials of your research with minimal text and maximum visual impact. Studies show that you have only 11 seconds to grab the attention of interested persons.
- Include the sections of a scientific paper—Title, Introduction, Experiment Summary (with brief methods), Results, Discussion, and References.
- Use a large typeface for headings and the content in abbreviated format under each heading. Use fonts that are easily readable from 3 to 6 feet. Title fonts should be 72 point; section headings 28 point; and text should be no smaller than 24 point (Knisely, 2009).
- Include simple, bold, and clearly labeled figures and tables.
- Before creating your poster, sketch the layout on paper, blocking out sections in two or three columns. Consider the location of text, images, tables, and figures.
- Consider the use of fonts, color, and images to highlight your poster and direct the viewer's eye.

You can design your poster in an electronic form using PowerPoint. This allows you to edit the text, images, and overall design. You can import sections from electronic files and insert digital images. You can effectively collaborate with your research team as you modify electronic versions of your poster. If your institution or community has a printing service, the electronic file can be sent to them for printing on large poster-sized paper. For detailed instructions see Chapter 7 in Knisely (2009).

Your instructor may give specific guidelines for your poster, or you may follow guidelines from other sources. There are several excellent websites with instructions for preparing posters. One of the most complete and well-designed

sites is http://www.swarthmore.edu/NatSci/cpurrin1/posteradvice.htm. This website includes a poster template, suggested layouts, and examples of good and mediocre posters.

References

The following sources are recommended to give additional help and examples in scientific writing.

Frick, T. 2004. "Understanding Plagiarism." Indiana School of Education. Available at: https://www.indiana.edu/~tedfrick/plagiarism/

Gillen, C. *Reading Primary Literature: A Practical Guide to Evaluating Research Articles in Biology*. San Francisco, CA: Benjamin/Cummings, 2007.

Harnack, A. and E. Kleppinger. *Online! A Reference Guide to Using Internet Sources,* 3rd ed. Boston: Bedford/St. Martin's, 2003.

Knisely, K. *A Student Handbook for Writing in Biology,* 3rd ed. Sunderland, MA: Sinauer Associates, 2009.

McMillan, V. E. *Writing Papers in the Biological Sciences,* 4th ed. Boston: Bedford/St.Martin's, 2006.

Pechenik, J. A. *A Short Guide to Writing about Biology,* 7th ed., New York, NY: Addison Wesley, 2010.

Style Manual Committee, Council of Biology Editors. *Scientific Style and Format: The CBE Manual for Authors, Editors and Publishers,* 6th ed. Cambridge, MA: Cambridge Univ. Press, 1994.

Tate, M. and J. Alexander. "Teaching Critical Evaluation Skills for World Wide Web Resources." *Computers in Libraries,* Nov/Dec 1996, pp. 49–55.

Websites

Evaluation forms for posters and oral presentations:
http://www.sinauer.com/knisely/

How to cite Internet sources:
http://www.bedfordstmartins.com/online/cite8.html

How to evaluate Web sources:
http://library.berkeley.edu/TeachingLib/Guides/Internet/Evaluate.html

How to prepare and present effective PowerPoint presentations:
http://www.dartmouth.edu/~biomed/new.htmld/ppt_resources.shtml

Purrington, C.B. 2006. Advice on designing scientific posters:
http://www.swarthmore.edu/NatSci/cpurrin1/posteradvice.htm