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Morgan, J. G. (Investigating Biology Laboratory Manual 5th edn.) New York: Pearson, 2005.

Appendix A

Scientific Writing

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 verbal and written, occurs at every step along the research path. While working on projects, scientists present their preliminary results for comments from their coworkers 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 in this manual 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.

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.

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. Delete unnecessary words—for example, adjectives and adverbs have limited use in describing your work. Write clearly 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 [2002] for basic rules of writing and practice in editing for common errors.)
- Your audience is your peers, other student-scientists. Write as though they are scientists: professional and knowledgeable.
- 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 investigator's published work. Previously published research is considered established in the present body of knowledge.
- Use the active voice whenever 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.*
- 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).
- Clearly label each section (except the title page), placing the title of the section against the left margin on a separate line. Each section does not begin a new page but continues in order.
- Begin writing early to allow time for researching your topic, analyzing your results, and revising your writing. Revise, revise, and then revise! For suggestions and examples of how to revise your work, see Chapter 5, "Revision," in Knisely (2002) and Chapter 5, "Revising," in Pechenik (2001).
- 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.

Plagiarism

Students will write 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 library 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.*

Plan for Writing a Scientific Paper

The sections of a scientific paper and particular material to be covered in each section are described in this appendix in order of appearance in the paper. However, most scientists do not follow that sequence in the actual writing of the paper, but rather begin with the methodology. A typical plan for writing a scientific paper follows.

- Begin writing the Materials and Methods section. 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 p. 767).
- 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 pp. 767–768)
- 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 pp. 769–770)
- Develop the Introduction section and begin the References Cited section. (See Introduction p. 766 and References Cited pp. 769–770) Most scientists prefer to write the Introduction before the Discussion. Both sections require background information and a clear understanding of the results of the work. Remember to carefully check and revise your Introduction if you write it first.
- Write the Discussion section and complete the References Cited section. (See Discussion pp. 768–769)
- Write the Title and Abstract. (See pp. 765–766)
- Review checklist, if available, before preparing final version of the paper.

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 time or section, your instructor's name, and the due date for the paper. *The title should be as short as possible and as long as necessary to communicate to the reader the question being answered in the paper.* 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.

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, if one is requested by the instructor, 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 reviewing 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 on p. 756, 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. Do not list the materials and do not list the steps of the procedure. Rather, write the Materials and Methods section concisely in paragraph form in the past tense. 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 if that information is relevant to the experiment. If you used computer software or any statistical analyses, include these in the Materials and Methods section.

The difficulty in writing this section comes as you decide the level of detail to include in your paragraphs. You must 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 the technique used may be tried by other investigators. Do not try to justify your procedures in this section.

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.

Results

The Results section 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 Results is the central section of a scientific paper.* Therefore, you should think carefully about the best way to present your results to the reader. The data included in tables and graphs should be summarized and emphasized in the narrative paragraph. Draw the reader's attention to the results that are important. Describe trends in your data and provide evidence to support your claims. This section also is written in the past tense.

Before writing the Results section, prepare the tables and figures. Remember to number figures and tables consecutively throughout the paper (*see Lab Topic 1, Scientific Investigation, for instructions on creating figures and tables and their presentation*). 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. For this reason, some scientists begin with the Results section when writing a paper.

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. Support your ideas from other work (books, lectures or outside reading of scientific literature). State your conclusions in this section.

Complete your Introduction and 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 the information in the Introduction section and 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? Include references to this work.
- Clearly state your conclusions.
- List weaknesses you have identified in your experimental design that affected your results. List any problems that arose during the experiment itself that affected your results. The weaknesses of the experiment should not 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 para-

graphs. 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. For your paper you should have a References Cited section that includes only those references cited in the paper.

Locating Appropriate References

Textbooks and review articles are an excellent starting place for developing background information for your independent investigations. Consult texts and books that are more specific than your general biology textbook. For example, if your project is on plant hormones, you might consult a plant physiology textbook to provide foundational information. Books will often have lists of articles and other references that may be helpful. (Also see the References section for each Lab Topic in this manual.) 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*).

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 (e.g., *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. However, websites are not primary references, because they are not required to participate in the peer review process. Your instructor will indicate the number of primary references required for your paper. Knisely (2002) and Pechenik (2001) provide useful suggestions for how to read scientific papers. Also Knisely (2002) has a helpful guide to searching for references using three computer databases: *Science Citation Index, Basic BIOSIS,* and *Article Finder.*

Record the citation information for any references, including online sources, at the time you read the information. Refer to the citation format to record the complete citation.

Examples of Reference Citations

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:

Whittaker, R. H. "New Concepts of Kingdoms of Organisms." *Science*, 1969, vol. 163, pp. 150–160.

Journal article, two or more authors:

Watson, J. D., and F. H. Crick. "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid." *Nature*, 1953, vol. 171, pp. 737–738.

Book:

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

Chapter or article in an edited book:

Baker, H. G. "Characteristics and Modes of Origin of Weeds" in *Genetics and Colonizing Species*, eds. H. G. Baker and G. L. Stebbins. New York: Academic Press, 1965, pp. 147–152.

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

In the text of the paper, cite the references using the author's name and the year. For example: "The innate agonistic behavior of the male Siamese fighting fish has been widely studied (Simpson, 1968)." "Simpson (1968) has described the agonistic behavior of the male Siamese fighting fish." If there are more than two authors, use the first author's name followed by *et al.* (and others). For example: (Simpson *et al.*, 1968).

Using Information Sources from the Internet

The Internet can provide access to online reference resources 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 (2001) and Knisely (2002). 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 locat-

ing 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 for any site you use as a reference. Tate and Alexander (1996) suggest the following five criteria for evaluating Internet sources:

1. **Authority.** Determine the author and sponsor for the Internet site. What is the professional affiliation of the author? Are phone numbers and addresses included? Is there a link to the sponsor'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 sponsor or advertiser?
4. **Currency.** 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> or other retrieval information. Date of access.

Examples:

(Professional site)

[CBE] Council of Biology Editors. 1999, Oct. 5. CBE home page. <http://www.councilscienceeditors.org>. Accessed Oct. 7, 1999.

(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 Oct. 4, 1999.

(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 Aug. 9, 2004.

References

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

Harnack, A. and E. Kleppinger. *Online! A Reference Guide to Using Internet Sources.* Boston: St. Martins, 2001.

Knisely, K. *A Student Handbook for Writing in Biology.* Sunderland, MA: Sinauer Associates, 2002.

McMillan, V. E. *Writing Papers in the Biological Sciences.* New York, NY: St. Martin's Press, 1997.

Pechenik, J. A. *A Short Guide to Writing about Biology,* 4th ed., New York, NY: Addison Wesley, 2001.

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

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