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READING SCIENTIFIC PAPERS

If you are not used to looking at biological journals, you may find research papers hard to read and understand. Here are some guidelines to help you get the most out of a scientific paper.

■ Acquire some background knowledge.

Papers reporting original research are written for a relatively specialized scientific audience and thus assume some knowledge of the subject matter and the vocabulary. You can't, of course, become an expert in any field overnight. However, you can acquire some familiarity with the major ideas and key terms before tackling the primary literature. If you build this foundation, you will be less likely to feel overwhelmed later. See pages 6–7 for suggestions about locating general, introductory references. Also useful in this regard are scientific dictionaries and encyclopedias.

■ Read the Abstract first.

The Abstract—a brief summary of the paper—will give you an overview of the study and help you decide whether to read the rest of the paper. Don't feel intimidated by abstracts containing unfamiliar terms or ideas. Often the Introduction and Discussion sections will provide much of the explanatory material you will need for a fuller understanding. Your main task, at this point, is to decide whether the paper might be useful to you. Note that in some papers the main text is followed by a Summary section rather than preceded by an Abstract.

■ Understand the basic aims of the study.

If the paper seems relevant, read the Introduction carefully. *Why* did the author(s) conduct the research? What were the major hypotheses or predictions? Authors generally end the Introduction with a brief statement of their objectives; some also include a succinct statement of the major findings.

■ Don't get bogged down in the Materials and Methods.

It is easy to become overwhelmed by the specialized terminology found in many Materials and Methods sections. However, unless your research requires close examination of the methodology, you need not

understand every procedural detail. Instead, work at grasping the author's basic approach. Try summarizing the methods in a few sentences, using your own words. Make sure you understand how the experimental design, use of controls, sampling techniques, or other methods relate to the specific objectives of the study. Once you have a sense of the major findings and conclusions, you can reread the Materials and Methods section, if necessary, to clarify selected points.

■ Read the Results carefully, focusing on the main points.

Do not panic if you don't understand the quantitative details. Focus first on the major qualitative findings and on the author's verbal summaries of quantitative data. These will lay the groundwork for understanding the more difficult material. The author may sum up main points in topic sentences (see p. 176) at the beginnings of paragraphs. Pay attention to comments in the text about figures and tables; they will help you pick out important quantitative trends or relationships. See Chapter 3 for a description of the common types of graphs used in biology and the sorts of information each is designed to convey.

■ Understand the author's argument.

Pay particular attention to the Discussion section, for it is here that the author attempts to tie together the various components of the study. Do the data support the author's conclusions, and if so, how? What does the author suggest is the major contribution of this study? What questions remain for further research? How can you use this paper in your own work?

■ Plan on rereading important papers, possibly several times.

Many of your sources may be too detailed or too difficult to understand in a single reading. Plan on returning to them once you have a firmer background and can better appreciate the specific contributions of each paper.

Also remember that when working with primary literature you can easily get sidetracked by the specifics of a particular study and thereby lose sight of the broader picture. Keep your own research in mind. Get a general grasp of each author's research, and then focus on whatever aspects are relevant to *your* objectives. The importance of a particular article may not be immediately apparent. You may need to skim through many papers at first to get your bearings and return later to those most central to your topic.

TAKING NOTES

■ Avoid plagiarism: take notes in your own words.

Plagiarism is the theft of someone else's words, work, or ideas. It includes such acts as (1) turning in a friend's paper and saying it is yours; (2) using another person's data or ideas without acknowledgment; (3) copying an author's exact words and putting them in your paper without quotation marks; and (4) using wording that is very similar to that of the original source but passing it off as entirely your own, even while acknowledging the source.

This last example of plagiarism is probably the most common one in student writing. Here is an example:

ORIGINAL PASSAGE

A very virulent isolate of *Alternaria mali,* the incitant of apple blotch, was found to produce two major host-specific toxins (HSTs) and five minor ones in liquid culture. The minor toxins were less active than the major ones, but were still specifically toxic to the plants which are susceptible to the pathogen.
(Kohmoto and others 1976, p. 141)

PLAGIARIZED PASSAGE

Kohmoto and others (1976) found that a very virulent isolate of *Alternaria mali*, the incitant of apple blotch disease, produced two main host-specific toxins, as well as five minor ones in liquid culture. Although the minor toxins were less active than the major ones, they were still specifically toxic to the susceptible plants.

Although the writer has altered a few words here and there, the second passage is strikingly similar to the original. *It is still plagiarism if you use an author's key phrases or sentence structure in a way that implies they are your own, even if you cite the source.* The only way to make this passage "legal" as it now stands is to enclose everything retained from the original wording in quotation marks. Better yet, you should first determine which facts or ideas in a source are relevant for your purposes, and then put these in your own words and word order.

Plagiarism of this kind is usually unintentional, the result of poor note taking and an incomplete understanding of the ethics of research and writing. Typically the problem arises when you lean heavily on notes that consist of undigested passages copied or half-copied from the original source. These become the source of all the information and ideas for your paper. When you sit down to write the first draft, it is all too easy for this

material to end up barely changed as the backbone of your paper. Thus your text becomes an amalgamation of other people's words disguised as your own. Even if you cite references for the facts and ideas, you are still guilty of plagiarism because the wording is not completely yours.

Another problem with this kind of note taking is that it reflects reading without thinking. It allows you to speed through a stack of references without necessarily understanding the material. It conflicts with your major purpose in conducting a literature review: to evaluate and interpret information on a subject. You need to start making judgments, comparisons, and contrasts while you are still working with the original sources; otherwise, your prose is just a mosaic of other people's material. Your own paper, like professional papers, should be more than just a sum of its parts.

Form the habit of taking notes mainly in your *own* words. If you are not used to doing this, you may be frustrated by the additional time it takes. However, once you start the first draft, these notes will save you much time and effort. You will have already worked through difficult material, weeded out many inconsistencies, responded to the conclusions of other authors, and made connections among related ideas. Much of the preliminary work will have already been done.

To take notes effectively you need to understand how to *paraphrase* and *summarize* material. A paraphrase expresses certain facts or ideas in different wording—your own—but in about the same number of words as the original. A summary expresses the important facts and ideas in fewer words than the original; for example, the Abstract of a research paper is a summary. Both paraphrasing and summarizing require that you understand material fully before you write about it. Although you will probably use both methods as you work through your sources, you'll find that learning how to identify and summarize the points that are *most* relevant to your particular needs is a highly valuable research skill. For example, the writer of the plagiarized passage above might have written the following in his or her notes, to be incorporated later in the final paper.

> *Kohmoto and others (1976) cultured the fungus Alternaria mali, which causes apple blotch, and isolated seven different toxins. Of these, two were particularly toxic to susceptible plants.*

■ Use an orderly system.

A common method is to use index cards, putting one idea or group of related ideas from a single source on each card. The cards thus contain manageable units of information and can be shuffled around at will as you organize your paper. However, such a method can be cumbersome, and many people feel constrained by the small size of the cards. Scientific topics often require longer, more detailed notes that cannot fit on index cards.

If you have a laptop computer, you may want to record notes directly into a computer file. Later you can cut and paste portions of your notes directly into your paper. An alternative method is to take notes on whole sheets of paper, writing on just one side so that you can cut, paste, and arrange notes later as you prepare the first draft.

Obviously, you need not take notes in complete sentences. In fact, if you try to restrict yourself to succinct phrases, you'll be even less likely to reproduce the exact wording of the original. If the author's own words *are* indispensable, enclose them within quotation marks along with the page number of the source. Do this for entire passages you wish to preserve, as well as for important words or phrases mixed in with your own notes:

> *J. concludes that "despite the predictive power and elegance" of the scientific method, it can give us only a "rough approximation" of what the natural world is like (Johnson 1933, p. 4).*

You also need a foolproof method to distinguish between an author's ideas and your own. For example, you might use a yellow marker to highlight your ideas or put your initials, the word *me,* or some distinctive symbol in front of any speculations and conclusions that are strictly your own:

> *B. suggests that light availability is the most important factor here. (me) What about moisture requirements? Not discussed.*

■ Be selective.

You will waste time and effort if you take copious notes on every source you encounter. Read first; take notes only when you have decided that the reference may be useful. Resist the temptation to photocopy *every* potentially useful source in its entirety; your research will be more productive if you try to make decisions, as you go along, about the relevance of each reference to your own objectives. If an article seems only peripherally connected or if you are not sure about its relevance, you may wish to photocopy the Abstract or other selected portions, but reserve your photocopying budget for those few papers that seem central to your work and that you may need to reread later.

■ Record full and accurate information about your sources.

Keep a master list of all the references you consult. Some people do this on whole sheets of paper or in a separate computer file; others list each source separately on index cards, so that when it is time to assemble the

Literature Cited (References) section, the cards can be shuffled and arranged in the proper order. Whatever system you use, be sure to separate the sources that you *cited* (referred to) in your paper from those you may have read but did not cite. Typically only cited sources are included in the Literature Cited section of biological papers.

Before you start your search, learn the kinds of bibliographic information you will need to report for each kind of reference you use (see Chapter 6). If you are not sure whether certain details are necessary, write them down anyway. It is easier to omit unneeded material when you eventually type your references than to spend time searching for missing publication dates or page numbers. If you photocopy part or all of an article, remember to write full bibliographic information about the source directly on the photocopy, so that you are never in doubt about its origin. Remember that Web sources need to be fully documented; see Chapter 6 for details.

CHAPTER 2

Handling Data and Using Statistics

Whether in the laboratory or the field, much of your training as a biologist involves learning how to collect, manipulate, and interpret both *quantitative* (numerical) and *qualitative* (nonnumerical) data. The usefulness of these data depends on such factors as your experimental design or sampling procedures, your choice of equipment and skill in using it, the statistical techniques used for analysis, and (in a field study) the environmental conditions. You cannot foresee all the problems that might detract from the validity of your results. However, you can anticipate and avoid many potential difficulties by thinking carefully about the kinds of data you want to collect and how best to handle them. Thorough coverage of statistics and experimental design is well beyond the scope of this book; however, the general guidelines below may help you in the initial stages of your work. (For more specialized references, see Additional Readings on pp. 253–255.)

GETTING STARTED

■ Start your research with questions leading to a specific prediction or hypothesis.

This may sound like obvious advice to anyone acquainted with the scientific method (see Introduction). Nevertheless, beginners sometimes plunge headlong into research with little sense of purpose. Most experienced biologists do considerable thinking, planning, and preliminary data