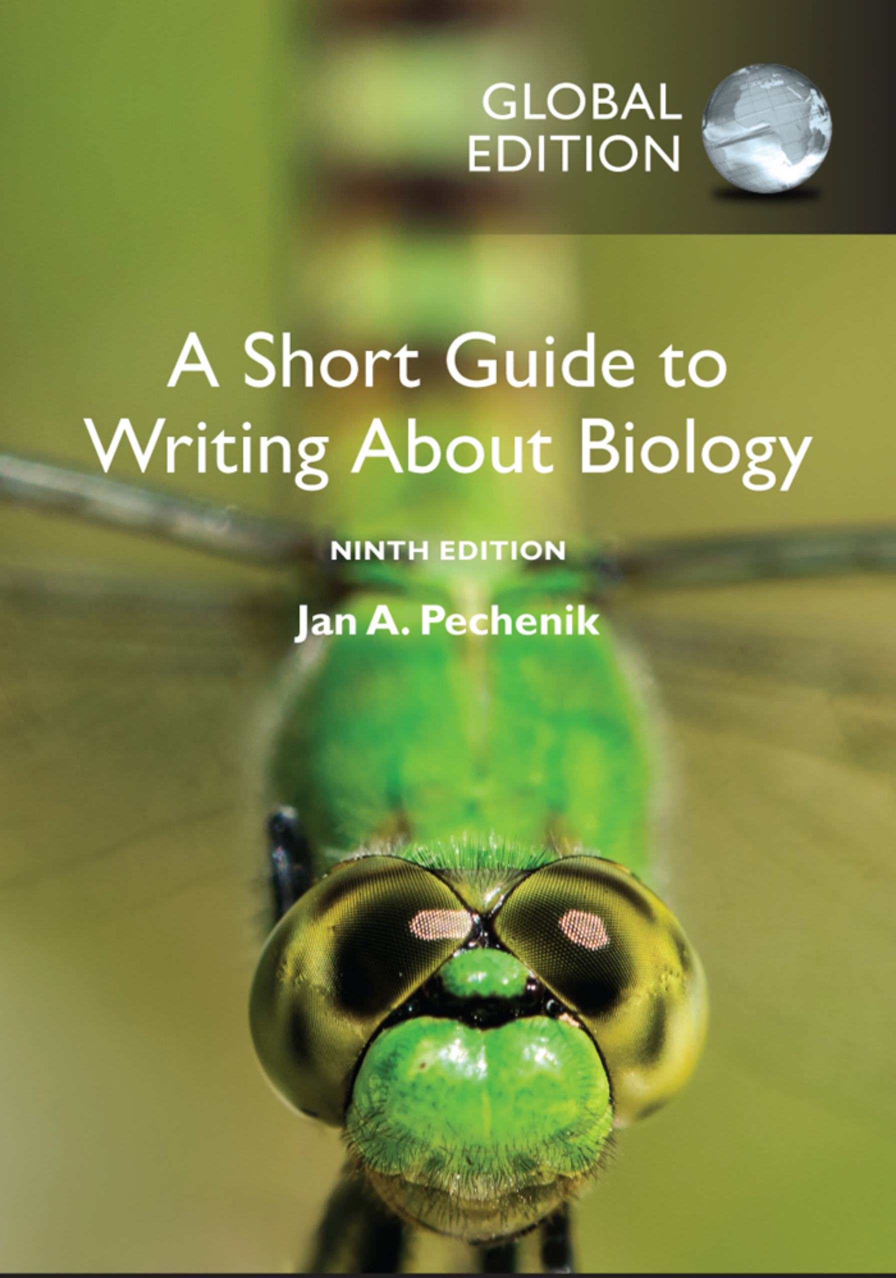
GLOBAL EDITION

A Short Guide to Writing About Biology

NINTH EDITION

Jan A. Pechenik



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A Short Guide to Writing about Biology

NINTH EDITION

GLOBAL EDITION

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Preface

Careful thinking cannot be separated from effective writing. Being a biologist is not just about memorizing facts and terminology or about mastering an increasing array of computer software and molecular techniques. Biology is a way of thinking about the world; it is about making careful observations, asking specific questions, designing ways to address those questions, manipulating data thoughtfully and thoroughly, interpreting those data and related observations, reevaluating past work, asking new questions, and redefining older ones. It is also about communicating information—accurately, logically, clearly, and concisely. The hard work of thinking about biology is at least as important as the work of doing it. Writing provides a way to examine, to evaluate, to refine, and to share that thinking. Writing is both a product and a process.

Biology instructors are increasingly concerned about their students' writing for two reasons. First, bad writing often reflects fuzzy thinking, so questioning the writing generally guides students toward a clearer understanding of the biology being written about. Second, effective communication is such a key part of the biologist's trade that our students really must learn to do it well. The difficulty, of course, is finding the time to teach both biology and presentation skills when there is barely enough time in the semester to cover the biology. This book allows instructors to guide their students' writing without taking up valuable class time. And as their writing improves, so, too, will the students' understanding of what they are writing about.

Although this book covers every sort of writing assignment that biologists face—both as students and as professionals—it is brief enough to be read along with other, more standard assignments and straightforward enough to be understood without additional instruction. The book is intended especially for undergraduate use in typical lecture and laboratory courses at all levels, but it is also widely used in undergraduate and graduate seminars. Many colleagues tell me they have also found much in the book that was new and helpful in their own writing, and in their teaching.

I have included examples from all fields of biology. However, because the book is intended for use even at introductory levels, I have avoided examples that assume substantial specialized knowledge or terminology. Instructors in advanced courses may wish to amplify basic principles with examples chosen from papers published in their own fields; students will benefit in particular from guided study of good models.

CHANGES MADE FOR THE NINTH EDITION

For this edition of the *Short Guide*, I have made the following major changes:

- I have added new content about avoiding plagiarism and have highlighted that issue further in Chapter 2.
- I have updated information about citing references and listing them in the Literature Cited section of reports, including information about adding digital object identifiers (DOIs) to references and citing online journals.
- In Chapter 8, I have added new material about in writing an effective Materials and Methods section, writing strong figure captions, and preparing manuscripts for online submission. I have also added new examples about building logical introductions that lead inexorably to the specific research question to be addressed.
- In Chapter 3, I have updated my advice about using indexes for online searches and have added Google Scholar screen shots.
- In Chapter 10, I have added new advice about organizing talks, and I introduce the idea of having students give short talks based on a single graph or table from a research paper.
- I now suggest using cloud storage for backing up drafts, and emphasize the importance of doing so.

For this ninth edition, I have retained the narrative style that has made previous editions so successful with students. We can't expect students to become better writers if we reduce everything to bullets and summaries for them. Students can learn a great deal by writing their own summaries but little of lasting value by reading or memorizing mine. I have, however, added more boldfacing to this edition, making it easier for students to locate advice of particular importance. Users of the previous edition will notice many smaller improvements in every chapter.

ORGANIZATION

The first 6 chapters cover general issues that apply to all types of writing (and reading) in biology. In Chapter 1, I emphasize the benefits of learning to write well in biology, describe the sorts of writing that professional biologists do, and review some key principles that characterize all sound scientific writing. Chapter 2 emphasizes the struggle for understanding that must precede any concern with how something is said. In it, I explain how to read the formal scientific literature, including graphs and tables; how to take useful notes; and how to take notes in ways that prevent unintentional plagiarism. In Chapter 3, I describe how to locate useful sources using computerized indexing services, online journals, and the Internet. Chapter 4 explains how to cite references and prepare a Literature Cited section. Chapter 5 talks about the use and interpretation of statistical analyses. Chapter 6 focuses on the process of revision—for content, organization, clarity, conciseness, grammar, word use, and spelling. It emphasizes the benefits of peer review, and it explains both how to be an effective reviewer of other people's writing and how to interpret criticism. Many readers have found Chapter 6 to be one of the most important chapters in the book. Most students learn little in preparing the first draft of anything. However, they can learn much—both about biology and about communicating their thoughts—through properly guided revision.

The rest of the book covers all of the specific writing tasks encountered in biology coursework and in professional life: writing summaries, critiques, essays, and review papers (Chapter 7); writing laboratory and other research reports (Chapter 8); writing research proposals (Chapter 9); preparing oral and poster presentations (Chapter 10); answering essay questions on exams (Chapter 11); and writing letters of application for jobs or for graduate school (Chapter 12). I encourage instructors to incorporate short oral presentations into their course design. Writing typically improves when students are first asked to give a short oral presentation on some aspect of what they are planning to write about: Writing, thinking, and speaking are all interconnected. Requiring brief oral presentations (based, for example, on a single figure from a published research paper) is a particularly good way to get students started on larger projects early in the semester.

My discussion of writing summaries and critiques is an especially important part of the book because most students seem not to have had much practice summarizing information accurately and concisely and in their own words. An inability to summarize effectively is a serious obstacle to both synthesis and evaluation. Writing summaries is also a particularly effective way for students to self-test their understanding and to prepare for examinations.

The chapter on writing research reports (Chapter 8) emphasizes that the results obtained in a study are often less important than the ability to discuss and interpret those results convincingly in the context of basic biological knowledge and to demonstrate a clear understanding of the purpose of the study. It emphasizes the variability inherent in biological systems and how that variability is dealt with in presenting, interpreting, and discussing data. This chapter will also be useful to anyone preparing papers for publication.

The checklists found at the ends of most chapters allow students to evaluate their own work and that of their peers. Most of the checklists include page numbers, helping students locate the text on which each item is based. Instructors can easily turn these checklists into grading rubrics, which should be shared with students well before the assignments are due. Sample rubrics, along with related materials, are available on my Website: http://ase.tufts.edu/biology/labs/pechenik/publications/books.htm

"Technology Tips" are scattered throughout the book, helping students take better advantage of the computer technology available to them for finding sources, writing, graphing, and giving oral presentations.

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This edition has benefited greatly from the suggestions of many people who took the time to read and comment on the previous edition, including Dr. Fredric R. Govedich, Southern Utah University; Valerie Haywood, Case Western Reserve University; Carl Smeller, Texas Wesleyan University; Dr. Kaci Thompson, University of Maryland; and Christopher M. Trimby, Ph.D., New Jersey Institute of Technology.

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I am grateful to all of these people for their comments and suggestions and am much cheered by their dedication to the cause. And who could ask for a more attentive reader than Victoria McMillan? "Oh, shame! Where is thy blush?"

It is also a pleasure to thank Regina Raboin, Science Research and Instruction Librarian at Tufts University, who was a great help in updating the material on conducting Internet and database searches.

Finally, I have learned much about writing and teaching from correspondence and conversation with enthusiastic readers of previous editions, from conversations with faculty in the many workshops that I've led over the past 20-plus years, and from working with colleagues from all disciplines in what was once the Writing Across the Curriculum program at Tufts University. I welcome additional comments from readers of the present edition, both instructors and students (**jan.pechenik@tufts.edu**).

JAN. A. PECHENIK

I GENERAL ADVICE ABOUT WRITING AND READING BIOLOGY

1

INTRODUCTION AND GENERAL RULES

What appears as a thoroughly systematic piece of scientific work is actually the final product: a cleanly washed offspring that tells us very little about the chaotic mess that fermented in the mental womb of its creator.

AVNER TREININ

What Lies Ahead? In This Chapter, You Will Learn

- The importance and benefits of learning to write well in biology courses
- Twenty-seven rules that characterize all good scientific writing—learn them, and follow them
- The perils of plagiarism and how to avoid them
- How to get the most from your computer in writing, data storage, data analysis, and data presentation

The logical development of ideas and the clear, precise, and succinct communication of those ideas through writing are among the most difficult skills that can be mastered in college—but among the most important ones, regardless of what your future career turns out to be. Effective writing is also one of the most difficult skills to teach. This is especially true in biology classes, which often require much writing but allow little time to focus on doing it well. The chief messages of this book are that developing your writing skills is worth every bit of effort it takes, and that biology is a splendid field in which to pursue this goal.

WHAT DO BIOLOGISTS WRITE ABOUT, AND WHY?

Most biologists write lectures; grant proposals; research papers; literature reviews; oral and poster presentations for meetings; letters of recommendation; committee reports; and even critiques of research papers, research proposals, and books written by other biologists. The writing that biologists do is similar in many respects to the writing of essays, literature reviews, term papers, and laboratory reports that you are asked to do while enrolled in a typical biology course. Basically, we must all prepare arguments.

Like a good term paper, research report, oral presentation, or thesis, a lecture is an argument; it presents information in an orderly manner, and it seeks to convince an audience that this information fits sensibly into some much larger story. Putting together a string of 3 or 4 lectures on any particular topic is the equivalent of preparing one 20- to 30-page term paper weekly.

In addition to preparing lectures, many biologists spend quite a bit of time writing grant proposals to fund their research and evaluating proposals submitted by colleagues. A research proposal is unquestionably an argument; success depends on our ability to convince a panel of other biologists that what we wish to do is worth doing, that we are capable of doing it, that we can interpret the results correctly, that the work cannot be done without the funds requested, and that the amount of funding requested is appropriate for the research planned. Research money is not plentiful. Even well-written proposals have a difficult time; poorly written proposals generally don't stand a chance.

When we are not writing grant proposals or lectures, we are often preparing the results of our research for publication or for presentation at meetings. Research articles are really just laboratory reports based on data collected over months or years. In research articles, as in laboratory reports, the goal is to make a strong case for doing the research, to present the data clearly, and to interpret those data thoroughly and convincingly in the context of previous work and basic biological principles. Preparing research reports typically involves the following steps:

1. Organizing and analyzing the data
2. Preparing a first draft of the article (following the procedures outlined in Chapter 8 of this book)
3. Revising and reprinting the paper
4. Asking one or more colleagues to read the paper critically
5. Revising the paper in accordance with the comments and suggestions of the readers
6. Reprinting and proofreading the paper
7. Sending the paper to the editor of the journal in which we would most like to see our work published

The editor then sends the manuscript out to be reviewed by 2 or 3 other biologists. Their comments, along with those of the editor, are then sent to the author, who must revise the paper again—often extensively. The editor may then accept or reject the revised manuscript, or the editor may request that it be rewritten yet again before publication.

Oral presentations involve similar preparation. The data are organized and examined, a draft of the talk is prepared, feedback on the talk is solicited from colleagues, and the presentation is revised.

College and university biologists also write about you. Letters of recommendation are especially troublesome for us because they are so important to you. Like a good laboratory report, literature review, essay, or term paper, a letter of recommendation must be written clearly, developed logically, and proofread carefully. It must also support all statements of opinion with facts or examples if it is to argue convincingly on your behalf and help get you where you want to go.

And then, there are progress reports, committee reports, and internal memoranda to write. All this writing involves thinking, organizing, nailing down convincing arguments, revising, retyping, and proofreading.

Clearly, being able to write effectively will help advance your career. Clear, concise, logical writing is an important tool of the biologist's trade: Learning how to write well is at least as important as learning how to use a balance, extract DNA, use a taxonomic key, measure a nerve impulse, run an electrophoretic gel, or clone a gene. And unlike these rather specialized laboratory techniques, **mastering the art of effective writing will reward you regardless of the field in which you eventually find yourself.**

In preparing the cover letter that accompanies a job application, for example, you are again building an argument: You are trying to convince someone that you understand the position you are applying for, that you have the skills to do the job well, and even that you want to do the job well. Similarly, in constructing a business plan, you must write clearly, concisely, and convincingly if you are to get your project funded. The fact that you may not become a biologist is no reason to cheat yourself out of the opportunity to become an effective writer. Remember this: While you're in college, you have a captive audience; **once you graduate, nobody has to read anything you write ever again**.

THE KEYS TO SUCCESS

It's always easier to learn something than to use what you've learned.

CHAIM POTOK, *THE PROMISE*

There is no easy way to learn to write well in biology or in any other field. It helps to read a lot of good writing, and not just in biology. Whenever you read anything that seems especially clear or easy to follow, examine that writing carefully to see what made it work so well for you. Reading well-written sentences aloud can also help plant good patterns in your brain. But mostly you just have to work hard at writing—and keep working hard at it, draft after draft, assignment after assignment. That will be much easier to do if you have something in mind that you actually want to say. Much of this book is about how to get to that point.

All good writing involves 2 struggles: the struggle for understanding and the struggle to communicate that understanding to readers. Like the making of omelets or crepes, the skill improves with practice. There are no shortcuts, and there is no simple formula that can be learned and then applied mindlessly to all future assignments. Every new piece of writing has to be thought about anew. Being aware of certain key principles, however, will ease the way considerably. Each of the following rules is discussed more fully in later chapters (note the relevant page numbers). This listing is worth reading at the start of each semester, or whenever you begin a new assignment.

Eleven Major Rules for Preparing a First Draft

1. **Work to understand your sources (pp. 31–43).** The only things we ever really learn are things we teach ourselves. When writing laboratory reports, spend time wrestling with your data until you are convinced you see the significance of what you have done. When taking notes from books or research articles, reread sentences you don't understand, and look up any words that puzzle you. Take notes in your own words; extensive copying or paraphrasing usually means that you do not yet understand the material well enough to be writing about it. Too few students take this struggle for understanding seriously enough, but all good scientific writing begins here. You can excel—in college and in life after college—by being one of the few who meet this challenge head on. Do not be embarrassed to admit—to yourself or to others—that you do not understand something after working at it for a while. Talk about the material with other students or with your instructor. If you don't commit yourself to winning the struggle for understanding, you will either end up with nothing to say or what you do say will be wrong. In both cases, you will produce nothing worth reading.
2. **Don't quote from your sources.** Direct quotations rarely appear in the formal biological literature. Describe what others have done and what they have found, but do so in your own words. Consider this sentence:

   > Shell adequacy was measured by the "shell adequacy index," defined by Vance (1972) as "the ratio of the weight of the hermit crab for which the shell was of preferred size to the actual weight of the hermit crab examined."

   When I see writing like this, I suspect that the writer did not understand the material being quoted; when you understand something thoroughly, you should be able to explain it in your own words. Perhaps I'm being unfair: Maybe this student just couldn't think of how to explain this better than the author already did. But if the student were explaining the shell adequacy index to a fellow student, would he or she have used that wording? I don't think so. Always think of yourself as explaining things to others, and do so using your own words. With practice and conscientious effort, you will find yourself capable of presenting facts and ideas in perfectly fine prose of your own devising.

3. **Don't plagiarize (pp. 23, 25, 30–44).** We all build on the work and ideas of others. Whenever you restate another writer's ideas or interpretations, you must do so in your own words and credit your source explicitly. You don't lose face by crediting your sources. To the contrary, you demonstrate to readers your growing mastery of the literature. Note, too, that simply changing a few words or changing the order of a few words in a sentence or a paragraph is still plagiarism. Plagiarism is one of the most serious crimes in academia: It can get you expelled from college or cost you a career later.
4. **Think about where you are going before you begin to write (pp. 138–140, 217–220).** Much of the real work of writing is in the thinking that must precede each draft. Effective writing is like effective sailing; you must take the time to plot your course before getting too far from port. Your ideas about where you are going and how best to get there may very well change as you continue to work with and revise your paper; the act of writing invariably clarifies your thinking and often brings entirely new ideas into focus. Nevertheless, you must have some plan in mind even when you begin to write your first draft. This plan evolves from thoughtful consideration of your notes. Think first, then write; thoughtful revision follows.

   Some people find it helpful to think at a keyboard or with a pen in hand, letting their thoughts tumble onto the paper. Others prefer to think "inside," writing only after their thoughts have come together into a coherent pattern. Either way, the hard work of thinking must not be avoided. If you still don't know where you are heading when you sit down to write that last draft of your paper, you certainly won't get to your destination smoothly, and you may well not get there at all. Almost certainly, your readers will not get there.
5. **Practice summarizing information (pp. 38–39).** The longer I work with writing issues, the more I realize the central importance of being able to summarize information effectively. If you can't summarize the results of one research paper in your own words, you can't possibly see the relationship between 3 or 4 such papers; summary is an essential prelude to synthesis. The more practice you get summarizing

information in your own words, the better. After you hear a lecture, take 10 minutes to summarize the major points in your notebook. After you see a movie or read a book, a short story, or even a newspaper article, try writing a short summary every now and then. From time to time, after reading even a single paragraph of something, try summarizing that paragraph in a single sentence (see p. 38 for an example). The ability to summarize is an underappreciated, largely neglected, but essential skill for professional life.

6. **Write to illuminate, not to impress (pp. 101, 200–201).** Use the simplest words and the simplest phrasing consistent with that goal. Avoid acronyms, and define all specialized terminology. In general, if a term was recently new to you, it should be defined in your writing. And if you can talk about "zones of polarizing activity" instead of "ZPAs," please do so. Your goal should be to communicate; why deliberately exclude potentially interested readers by trying to sound "scientific"? Don't try to impress readers with big words and a technical vocabulary; impress them by getting your point across.
7. **Write for your classmates and for your future self (pp. 95–96, 200–201).** It is difficult to write effectively unless you have a suitable audience in mind. It helps to write papers that you can imagine being interesting to and understood by your fellow students. You should also prepare your assignments so that they will remain meaningful to *you* should you read them far in the future, long after you have forgotten the details of coursework completed or experiments performed. Addressing these two audiences—your fellow students and your future self—should help you write both clearly and convincingly.
8. **Support all statements of fact and opinion with evidence (pp. 55–56, 57–61, 143–144, 184–187).** Remember, you are making arguments. In any argument, a statement of fact or opinion becomes convincing to the critical reader only when that statement is supported by evidence or explanation; provide it. You might, for instance, write the following:

   > Among the vertebrates, the development of sperm is triggered by the release of the hormone testosterone (Gilbert, 2013).

   In this case, a statement of fact is supported by **reference to a book** written by Scott Gilbert in 2013. Note that an author's first name is never included in the citation. In the following example, a statement is backed up by **reference to the writer's own data**:

   > Some wavelengths of light were more effective than others in promoting photosynthesis. For example, plants produced

> oxygen nearly 4 times faster when exposed to light of 650 nm* than when exposed to a wavelength of 550 nm (Figure 2).

Statements can also be supported by **reference to the results of statistical analyses**, as in the following example:

> The blue mussels produced significantly thicker shells in the presence of crustacean predators ($t = 4.65$; *d.f.* = 23; $P < 0.01$).

Here, the statement is supported by the results of a *t*-test. The meaning of the items in parentheses is further explained in Chapter 5.

9. **Always distinguish fact from possibility.** In the course of examining your data or reading your notes, you may form an opinion. This is splendid. But you must be careful not to state your opinion as though it were fact. "The members of species *X* lack the ability to respond to sucrose" is a statement of fact and must be supported with a reference. "Our data suggest that adults of species *X* lack the ability to respond to sucrose" or "Adults of species *X* seem unable to respond to sucrose" expresses your opinion and should be supported by drawing the reader's attention to key elements of your data set. Similarly, consider the following statement:

> The data suggest that ''vestigial wings'' is an autosomal recessive trait, whereas ''carnation eyes'' is a sex-linked recessive trait.

Adding that one phrase, "the data suggest," makes all the difference. Basing an opinion solely on his or her own data, the writer would be on far shakier ground beginning the sentence with "'Vestigial wings' is an autosomal recessive trait."

10. **Allow time for revision (pp. 87–89).** Accurate, concise, successfully persuasive communication is not easily achieved, and few of us come close in a first or even a second draft. Although the act of writing can itself help clarify your thinking, it is important to step away from the work and reread it with a fresh eye before making revisions; a "revision" is, after all, a re-vision: another look at what you have written. This second (or third or fourth) look allows you more easily to see if you *have* said what you had hoped to say, and whether you have guided the reader from point to point as masterfully as you had intended. Remember, you are constructing an argument. It takes thoughtful revision to make any argument fully convincing. Start writing assignments as soon as possible after receiving them, and always allow at least a few days between the

*nm, nanometers; that is, 10^{-9} meters.

penultimate and final drafts. If you follow this advice, the quality of what you submit will improve dramatically, as will the quality of what you learn from the assignment.

11. **Back up your drafts every few minutes** on your hard drive. At the end of each session, make another backup copy on a flash drive or external hard drive, or send a copy of the file to yourself as an e-mail attachment or as a Dropbox posting. Your institution may have its own cloud storage resource for you to use, with even more free storage capacity than that available on Dropbox.

Six Major Rules for Developing Your Final Draft

Once you have nailed together the basic framework of your presentation or argument, it is time to tighten the construction.

12. **Stick to the point (pp. 141, 201–202, 228).** Delete any irrelevant information, no matter how interesting it is to you. Snip it out and put it away in a safe place for later use if you wish, but don't let asides interrupt the flow of your writing.
13. **Say exactly what you mean (pp. 92–101).** Words are tricky; if they don't end up in the right places, they can add considerable ambiguity to your sentences. For example, "I saw 3 squid SCUBA diving last Thursday" conjures up an interesting image. Don't make readers guess what you're trying to say; they may guess incorrectly. Good scientific writing is precise. Sloppy writing often implies sloppy thinking. Figure out exactly what you mean to say, and be sure to say what you mean. It often helps to read aloud what you have written and to listen carefully to what you say as you read.
14. **Never make the reader back up (pp. 108–110).** You should try to take readers by the nose in your first paragraph and lead them through to the end, line by line, paragraph by paragraph, in a logical way. Link your sentences carefully, using transitional words such as *therefore* or *in contrast*, or by repeating key words so that a clear, logical argument is developed. Remind readers of what has come before, as in the following example:

    In saturated air (100% relative humidity), the worms lost about 20% of their initial body weight during the first 20 hours but were then able to prevent further dehydration. In contrast, worms maintained in air of 70–80% relative humidity dehydrated far more rapidly, losing 63% of their total body water content in 24 hours. As a consequence of this rapid dehydration, most worms died within the 24-hour period.

Note that the second and third sentences in this example begin with transitions ("In contrast," "As a consequence of"), thus continuing and developing the thought initiated in the preceding sentences. A far less satisfactory last sentence might read "Most of these animals died within the 24-hour period." A few words can make a big difference.

Link your paragraphs in the same way, using transitions to continue the progression of a thought, reminding readers periodically of what they have already read.

Avoid casual use of the words *it*, *they*, and *their*. For example, the sentence "It can be altered by several environmental factors" forces readers to go back to the preceding sentence, or perhaps even to the previous paragraph, to find out what *it* is. Changing the sentence to "The rate of population growth can be altered by several environmental factors" solves the problem. Here is another example:

> Our results were based on observations of short-term changes in behavior. They showed that feeding rates did not vary with the size of the caterpillar.

In this example, the word *they* could refer to "results," "observations," or "changes in behavior." Granted, the reader can back up and figure out what "they" are, but you should work to avoid the "You know what I mean" syndrome. Changing "they" in the second sentence to "These results" avoids the ambiguity and keeps the reader moving effortlessly in the right direction.

Do not be afraid to repeat a word or phrase used in a preceding sentence; if it is the right word and avoids ambiguity, use it. Repetition can be an effective way to keep readers moving forward.

15. **Don't make readers work harder than they have to (pp. 98–104, 183–186).** If there is interpreting to be done, you must be the one to do it. For example, never write something like:

> The difference in absorption rates is quite clearly shown in Table 1.

Such a statement puts the burden of effort on the reader. Instead, write something like:

> Clearly, alcohol was more readily absorbed into the bloodstream from distilled beverages than from brewed beverages (Table 1).

Readers now know exactly what you have in mind and can examine Table 1 to see if they agree with you.

16. **Be concise (pp. 103–108).** Give all the necessary information, but avoid using more words than you need for the job at hand. By being concise, your writing will gain in clarity. Why say:

    Our results were based on observations of short-term changes in behavior. These results showed that feeding rates did not vary with the size of the caterpillar.

    when you can say:

    Our observations of short-term changes in behavior indicate that feeding rates did not vary with the size of the caterpillar.

    In fact, you might be even better off with the following sentence:

    Feeding rates did not vary with caterpillar size.

    With this modified sentence, nearly 70% of the words in the first effort have been eliminated without any loss of content. Cutting out extra words means you will have less to type; you'll have your paper finished that much sooner. Finally, your readers can digest the paper more easily, reading it with pleasure rather than with impatience.
17. **Don't be teleological (p. 112).** That is, don't attribute a sense of purpose to other living things, especially when discussing evolution. Giraffes did not evolve long necks "in order to reach the leaves of tall trees." Birds did not evolve nest-building behavior "in order to protect their young." Insects did not evolve wings "in order to fly." Plants did not evolve flowers "in order to attract bees for pollination." Natural selection operates through a process of differential survival and reproduction, not with intent. Long necks, complex behavior, and other such genetically determined characteristics may well have given some organisms an advantage in surviving and reproducing that was unavailable to individuals lacking those traits, but this does not mean that any of these characteristics were deliberately evolved to achieve something.

    Organisms do not evolve structures, physiological adaptations, or behaviors out of desire. Appropriate genetic combinations must always arise by random genetic events—by chance—before selection can operate. Even then, selection is imposed on the individual by its surroundings and, in that sense, is a passive process; natural selection never involves conscious, deliberate choice. Don't write, "Insects may have evolved flight to escape predators." Instead, write, "Among insects, the ability to fly may have been selected for by predation."

Nine Finer Points: The Easy Stuff

18. **Abbreviate units of measurement that are preceded by numbers.** Do not put periods after unit symbols, and always use the same symbol for all values regardless of quantity: 1 mm (millimeter), 50 mm; 1 hr (hour), 50 hr; 1 g (gram), 454 g.
19. **Always underline or italicize species names, as in *Homo sapiens*.** Note also that the generic name (*Homo*) is capitalized whereas the specific name (*sapiens*) is not. Once you have given the full name of the organism in your paper, the generic name can be abbreviated; *Homo sapiens*, for example, becomes *H. sapiens*. There is no other acceptable way to abbreviate species names. In particular, it is not permissible to refer to an animal using only the generic name, because most genera include many species. (Note that the plural of *genus* is *genera*, not *genuses*.)
20. **Don't use formal scientific names to refer to individuals of a species.** For example, instead of writing that "*Chromys ludovicianus* is often considered an ecosystem engineer because it modifies its surroundings so extensively through its feeding and burrowing activities (Coppock et al., 1983)," write "Individuals of *Chromys ludovicianus* are often considered ecosystem engineers ...," or use the common name for the species like this: "Black-tailed prairie dogs (*Cynomys ludovicianus*) are often considered ecosystem engineers because they modify their surroundings so extensively...."
21. **Do not capitalize common names.** Examples include monarch butterfly, lowland gorillas, pygmy octopus, and fruit fly.
22. **When listing references at the end of a sentence, put the period after the references.** For example, "Most of what we currently know about how animals orient to magnetic fields is based on studies of vertebrates" (Able & Able, 1995; Phillips, 1996).
23. **Capitalize the names of taxonomic groups (clades) above the level of genus, but not the names of the taxonomic categories themselves.** For example, insects belong to the phylum Arthropoda and the class Insecta. Do not capitalize informal names of animals: Insects are arthropods, members of the phylum Arthropoda.
24. **Remember that the word data is plural.** The singular is *datum*, a word rarely used in biological writing. "The data are lovely" (not "The data is lovely"). "These data show some surprising trends" (not "This data shows some surprising trends"). You would not say, "My feet is very large"; treat *data* with the same respect.
25. **Pay attention to form and format: Appearances can be deceiving.** Your papers and reports should give the impression that you took the

assignment seriously, that you are proud of the result, and that you welcome constructive criticism of your work. Type or computer print your papers whenever possible; use only one side of each page. Leave margins of about an inch and a half on the left and right sides of the page and about an inch at the top and bottom of each page. Double-space your typing so that your instructor can easily make comments on your paper. Make corrections neatly. Never underestimate the subjective element in grading.

26. **Put your name and the date at the top of each assignment, and number all pages.** Pages should be numbered so that readers can tell immediately if a page is missing or out of order and can easily point out problems on particular pages ("In the middle of page 7, you imply that … "). Remarkably, most word-processing programs do not automatically number pages for you; you must tell the program to insert the page numbers.

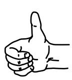
The Annoying But Essential Last Pass

27. **Proofread.** None of us likes to proofread, even though it is a crucial part of the writing process. By the time we have arrived at this point in the project, we have put in a considerable amount of work and are certain we have done the job correctly. Who wants to read the paper yet another time? Moreover, finding an error means having to make a correction. But put yourself in the position of your instructor, who must read perhaps 100 or more papers and reports each term. He or she starts off on your side, wanting to see you earn a good grade. Similarly, a reviewer or editor of scientific research manuscripts starts off wanting to see the paper under consideration get published. A sloppy paper—for example, one with many typographical errors—can lose you a considerable amount of goodwill as a student and later as a practicing scientist. For one thing, sloppy writing may suggest to the reader that you are equally sloppy in your work and in your thinking, or that you take little pride in your own efforts. Furthermore, failure to proofread your paper and to make the required corrections implies that you don't value the reader's time. That is not a flattering message to send, nor is it a particularly wise one. Never forget: There is often a subjective element to grading and to decisions about the fate of manuscripts and grant proposals. For all these reasons, shoddily prepared material can easily lower a grade, damage a writer's credibility, reduce the likelihood that a manuscript will be accepted for publication or that a grant proposal will be funded, or cost an applicant a job or admission to professional or

graduate school. Why put yourself in such jeopardy to save a mere half-hour? **Turn in a piece of work that you are proud to have produced.**

AVOIDING PLAGIARISM

The paper or report you submit for evaluation must be *your* work. **Submitting anyone else's work under your own name is plagiarism**, even if you alter some words or reorder some sentences. **Presenting someone else's thoughts or ideas as your own is also plagiarism.** Indeed, the Council of Writing Program Administrators considers plagiarism to occur "whenever a writer deliberately uses someone else's language, ideas, or other original (not common-knowledge) material without acknowledging its source." Consider the following 2 paragraphs:



Tytell (2001) suggests that this discrepancy in feeding rates may reflect differences in light intensities used in the two experiments. Fuchs (2014), however, found that light intensity did not influence the feeding rates of these animals and suggested that the rate differences instead reflect differences in the density at which the animals were held during the two experiments.

This discrepancy in feeding rates might reflect differences in light intensities. Tytell (2001), however, found that light level did not influence feeding rates. Perhaps the difference in rates reflects differences in the density at which the animals were held during the two experiments.

The first example is fine: Every idea is clearly associated with its source. In the second example, however, the writer takes credit for the ideas of Tytell and Fuchs; the writer has plagiarized.

As another example, consider this student's summary sentence based on the introductory paragraph presented on p. 41:

> The chemoreception of chemical cues that induce settlement and metamorphosis of marine invertebrate larvae is important for recognizing habitats that favor growth and reproductive success.

That's plagiarism in action. This is not:

> According to Biggers and Laufer (1999), marine invertebrate larvae typically metamorphose in response to chemical signals associated with environments that favor juvenile growth and reproduction.

The second student has *processed* information; the first student has not.

Here is another example, one that might surprise you. Suppose you hear a talk by an outside speaker on campus, hosted by the Biology department. You go because the speaker's research on reproductive isolation in the European corn borer relates to the topic of a paper or laboratory report that you are writing. Time well spent: You leave the talk with several pages of notes, and you even ask the speaker a few questions after the talk is over.

In writing your paper or report, you borrow a number of the speaker's ideas but don't attribute them to the speaker. Instead, you present the ideas as your own. You have plagiarized.

What you have done is not only immoral; it's also self-defeating. If you had credited the speaker with those ideas, you would have impressed your instructor fabulously: an undergraduate actually attends a departmental seminar without being required to do so and pays close enough attention to incorporate some of the speaker's information in the paper. You might be able to write something like this: "As Professor Dopman noted in his talk (October 12, 2011), the release of pheromones by females does not always result in courtship by males," and expand that thought in the next sentence or two. That would be impressive. Crediting ideas and working effectively with other people's ideas show your growing command of the field. That's a *good* thing. The Academic Resource Center at your institution may provide additional examples and guidelines.

Plagiarism is theft. It is one of the most serious offenses that can be committed in academia, where original thought is the major product of one's work—often months or sometimes years of physical and mental work. At the very least, an act of plagiarism will result in an F on the assignment or for the entire course, and a loss of credibility. Repeated plagiarism (but sometimes even a single offense) can get you expelled from college.

Here is some especially bad news for plagiarists: **Plagiarism is getting easier to detect.** Computer programs designed to detect plagiarism are now being used at more and more colleges and universities (and by more scientific journal editors). Such programs, for example, Turnitin, search enormous databases that include millions of pages from books and journals, millions of Web sites, and tens of millions of papers previously submitted by college students across the country.

Doing a Google search on the phrase "avoiding plagiarism" brought back more than 2,200,000 results; plagiarism is clearly a problem of great concern to many people. Intentional plagiarism (e.g., copying text directly from a Web site or putting your own name on a paper written by someone else) is easy to avoid: Just don't do it! But some plagiarism is unintentional; how do you avoid that? One approach is to read widely. If all you know about a particular topic is what you have read in your laboratory manual or textbook, your options for original thinking will be limited. The more you read, the more you will have to draw on in expressing your own thoughts. And **summarizing as you read (see**

Chapter 2) will help put you in command of the material. You also need to give yourself time to digest what you've read before you can begin putting the material together in an original way, in your own voice and with a clear sense of direction. If you wait until the last weekend to start reading, or you read without thinking, it's hard to avoid plagiarism in writing your paper.

Plagiarism can also occur unintentionally through bad note-taking practices. **Take notes in ways that minimize the likelihood of plagiarism**, as discussed in Chapter 2 (pp. 39–41). An added benefit of developing good note-taking techniques is that you will come away with a much greater understanding of what you read, and you will have much more substantive things to talk about and write about.

Another way to help avoid unintentional plagiarism is to write your first draft without looking at your notes. If you can't do this, you're probably not ready to write anyway.

ON USING COMPUTERS IN WRITING

With computers, perfection is within your immediate grasp. Instructors therefore find it increasingly annoying when students turn in computer-printed reports that are carelessly written and not proofread. Word processing has become a two-edged sword.

Let me also warn you about what you cannot expect a computer to do for you. Computers can do little to help you in that all-important first struggle—the struggle for understanding. Neither (unfortunately) can they think, organize, or revise for you. Computerized spelling checkers can catch some typographical and spelling errors, but you cannot expect them to catch all of your mistakes. Biology is a field with much specialized terminology, much of which is of no use to nonbiologists; these terms therefore do not find their way into the dictionaries that accompany computerized spelling programs. Although you can easily add words to the computer's dictionary, the terminology in your papers will be changing with every new assignment; many of the words you add for today's assignment will probably not be used in next week's assignment. Moreover, a spell-checker program will not distinguish between *to* and *too*, *there* and *their*, or *it's* and *its*, and the program will miss typographical errors that are real words. Suppose, for example, that you typed *an* when you intended to type *and*, or you typed *or* when you should have typed *of*, or you typed *rat* instead of *rate*. Grammar-checking programs also will not catch every error, and even when they recognize mistakes, they do not always suggest the proper correction. By all means, use spell- and grammar-checker programs for a first pass, but then use your own sharp eyes and keen intellect—moving word by word and sentence by sentence—to complete the necessary process of proofreading your work.

TECHNOLOGY TIP 1

Using shortcuts and AutoCorrect

The field of biology contains much specialized terminology; a number of abbreviations that require superscripts or subscripts; and many long, tongue-twisting species names (which always need to be italicized—Rule 19). Keyboard shortcuts and the AutoCorrect feature found in most word-processing programs can be helpful in dealing with these issues. For example, here are things you can do in Microsoft Word:

1. **For italicizing**, instead of highlighting and then clicking on the *I* symbol in the bottom line of the Word menu system (to the right of the **B** symbol, for boldfacing), press the Ctrl key and type an "i" before and after the word(s) that you want italicized; leave no space between the "i" and the letters of the word. You can **boldface** terms in a similar way, by typing Ctrl-b before and after the word.
2. **For superscripts**, hit Ctrl Shift = and then type the text that you would like superscripted. Repeat the process to exit superscript mode.
3. **For subscripts**, hit Ctrl = and then type the text you would like subscripted. Repeat the process to exit subscript mode.
4. **For long words**, such as complicated chemical names (e.g., fructose-1,6-diphosphate) that you need to type repeatedly, use the **AutoCorrect** feature of Word as follows:
   - Go to *Tools* in the tool bar menus and select *AutoCorrect Options*.
   - Decide on an abbreviation for the word you will need to type repeatedly. For "fructose-1,6-diphosphate," for example, you could use the abbreviation "frc." Type the abbreviation into the Replace space. Be sure that your abbreviation is not a combination of letters that appears frequently in other words; never use "the," for example.
   - Type the full version (e.g., "fructose-1,6-diphosphate" [without the quotation marks]) into the With space. **Double-check your spelling before proceeding!**
   - Click *Add*, and then click *OK*. Now, every time that you type the letters "frc" and hit the space bar, Word will automatically "correct" this to the name of the sugar that you programmed in.

5. For **italicized words that you will use repeatedly, such as the formal name of the sea urchin genus** *Strongylocentrotus*, do the following:
   - Type the complete word once in your text, italicize it, and highlight just that word.
   - Click on *Tools* and then select *AutoCorrec*t. Your highlighted word will appear in the With space.
   - Enter a simple abbreviation for that word (e.g., Sts) in the Replace space.
   - Be sure that the "Formatted text" circle is selected. Click *Add* and then click *OK*.
   - From now on, type Sts and you will instantly see *Strongylocentrotus* on your screen, spelled correctly and beautifully italicized, as soon you hit the space bar.
6. For automatic formatting of **subscripts and superscripts**, as in the expression K_m associated with enzyme kinetics, do the following:
   - Type the letters you want (in this case, Km) into your text.
   - Turn the "m" in our example into a subscript using the Format and then Font tools in the Tool Bar (check the subscript box, in this case) or by using one of the shortcuts mentioned previously.
   - Click *Tools* and then *AutoCorrect*. Your highlighted letters will appear in the With space.
   - Type K_m into the Replace space.
   - Click *Add*, and then click *OK*. From now on, whenever you type Km and hit the space bar, you will automatically see K_m on your screen.
   - You can play the same trick with **other specialized symbols,** such as µm (micrometer), °C (degrees Centigrade), and ‰ (parts per thousand, referring to salinity). AutoCorrect can be a writer's best friend!
   - Caution: Note that if you program "um" as a default abbreviation for µm, you may get "µmbrella" whenever you type "umbrella." The letters "umc" are a much safer choice. Choose your codes carefully, and make a list of the codes that you have programmed.