then order papers published by the same author in the same year alphabetically by title.

Works by two or more different authors with the same last name are arranged alphabetically according to the authors' first initials. For example, an article by E. J. Arnold would come before one by K. M. Arnold.

If you are using the CSE citation-sequence system, number and list the references in the order in which you *cite* them in the paper. However, if you are using the CSE citation-name system, list the references *alphabetically*, then number them, and use these numbers as the citation numbers in the text.

In CSE style, the reference list is titled "References." (In journals that do not use CSE style, the reference list is sometimes called "Literature Cited.") The first line of each entry is typed flush with the left margin, and successive lines are indented one-quarter inch (see sample student research paper, Chapter 4). For academic assignments, be sure to check with your instructor about his or her preferences regarding manuscript format. Individual journals also vary with respect to this feature of the reference section.

APA Style

As a biology student, you may sometimes encounter scientific papers using APA style for citing sources and listing references. This format, which has some similarities to the CSE name-year system, is based on recommendations by the American Psychological Association <http://www.apa.org>. APA format is used by many authors in psychology, nursing, and other behavioral and social science fields. Guidelines are described at length in the sixth edition of the *Publication Manual of the American Psychological Association* (2009).

Proofread your reference list for accuracy, completeness, and consistency.

Whichever documentation format you use, every entry must conform as closely as possible to the guidelines. Check that every source you cite is actually *listed* in the References section. Check that no source appears in the References list that is not *cited* in your text. You must also focus on minutiae, scrutinizing with meticulous care every punctuation mark, every space, every number, every capital letter. In the case of electronic sources, the URL must be reproduced exactly, and other information must be as thorough as possible. The entire task may seem tedious indeed. Just remember that all this time and effort is indispensable to the production of a well-received paper.

7

Drafting and Revising

Expect to write several drafts of your paper before you are satisfied with the final product. Good writing is generally the product of careful *rewriting*, or *revising*, in which you evaluate your early attempts at organizing and expressing your ideas. In the process, you end up scrutinizing the ideas themselves, as well as your own mastery of the subject. You may find that until you can express a concept clearly enough that others can understand it, you have not fully understood it yourself. Working through successive drafts also teases out *new* ideas, perhaps connections between disparate sets of data or new insights about the significance of your research. As you grope for more appropriate wording and a clearer structure, you give form and substance to thoughts still lurking in your subconscious. Gradually, and sometimes painfully, you discover what it is you really want to say.

The First Draft

Many people assign too much importance to a first draft. Think of it as just a rough version of the paper, an exercise in organizing your thoughts and getting down the main ideas. Focus on content, not on prose style or mechanics. Because much of what you write now may not end up in the final version, it is unproductive to tinker with commas, spelling, or sentence construction. First get down the basic information; in later drafts you can look more closely at your writing style and such matters as grammar and punctuation.

How do you shift from doing research or taking notes to composing the first draft of the paper? Experienced writers use a variety of methods. The following ones may help you get started.

■ Devise a working title.

The title should reflect your most important findings and your purpose in writing the paper. What is the main point you wish to make? What new information or perspective does your study contribute? Deciding on a preliminary title early in the writing process helps you focus your thoughts and start drafting the paper. If necessary, you can revise the title later as your ideas take shape.

■ Make an outline or a rough plan.

All writers need some sense of how the various points they want to make are logically connected to one another. However, people vary tremendously with respect to how organized their thoughts must be before they start to write. Some writers find that a detailed, point-by-point outline is absolutely essential before they start the first draft. Others prefer to work out a more general framework that leaves them considerable flexibility. Some writers find any kind of outline confining. Instead, they plunge directly from their notes into the first draft, doing most of the organizing in their heads as they go along.

Systematic planning may be more appropriate for some sections of the paper than for others. For example, the Materials and Methods section of a research paper is fairly straightforward and contains many details that must be organized in a logical manner. Once you plot it out carefully, it may practically write itself. The same may be true of the body of many review papers. By contrast, the complexities of a Discussion section may be difficult to pin down and categorize. In fact, you may not be sure of what you want to say until you start putting words to paper and have worked through one or two drafts.

It pays to experiment with different forms of planning. If you don't like outlines, try jotting down a rough list of the major topics or issues you need to discuss. You may find it easier to visualize the relationships between ideas if you make a flowchart with lines, arrows, or brackets linking groups of words or phrases. If you do rely on detailed outlines, remember that they should not be inflexible. They can be stretched or restructured to conform with your writing as it develops. An outline can be a valuable tool to get you started, but it should never be an end in itself. It should never keep you very long from that most important act of plunging into the paper.

■ Start the easiest writing first.

Don't feel you have to begin at the beginning. If you are writing a research paper, for example, it may not be productive to start with the Abstract or even with the Introduction. Begin with whatever part seems easiest and most straightforward. For many people this is the Materials and Methods section, which often can be drafted before the research is completed. The Results section also may be relatively easy to put together. Generally the Abstract is best written last, after all other major sections of the paper have been completed. The point is that once you start drafting *any* section of the paper, you have broken the barrier between you and the material, and the writing will gain momentum.

■ Remember your audience.

Readers of any piece of writing have expectations. If you understand these expectations, you will have a clearer sense of your own purpose as a writer. You'll also be in a better position to make informed choices about the appropriate content, format, tone, and diction of your paper. Many beginning writers struggle with their first drafts because they are unsure of their intended audience. It is difficult to write in a vacuum.

For academic assignments, of course, an important reader is your instructor. Nevertheless, think of your audience more broadly as including your classmates—in other words, people with biological backgrounds similar to your own. Your peers already have some common knowledge of your subject, so you do not have to explain every single term to them. Like other scientific readers, they expect that you will meet your stated objectives, communicate your ideas clearly, develop your main points in some depth, and follow scientific conventions in organization and documentation.

For some assignments, your instructor may ask that you compose the paper as if you were writing for scholarly journals in your subject area. If your paper is aimed at a particular journal, you'll need to study its instructions to authors (often available on the journal's Web site) and then follow these meticulously.

A good way to understand the general expectations of scientific audiences is simply to *read* as many scientific papers as you can. Read not just for content, but also for diction, tone, and format. If you are assigned a review paper, for example, then study examples of published reviews, even ones not directly related to your topic. Writers learn and grow not only by writing and rewriting, but also by analyzing how other writers deal with similar problems.

Finally, for works aimed at nonscientific or heterogeneous audiences, you'll need to make different decisions about style, tone, content, and organization. For example, a piece for your campus newspaper or an article in the style of a popular magazine would warrant a more informal tone. You might have a catchy headline or title. You would probably give more background information about your topic and avoid specialized terminology. Your writing might incorporate personal experience, anecdotes, direct quotes, or even dialogue—all depending on the specific venue for which you are writing. In these situations, too, it helps to study similar works by other writers. See Chapter 10 for more advice about writing for other types of audiences.

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Finally, for works aimed at nonscientific or heterogeneous audiences, you'll need to make different decisions about style, tone, content, and organization. For example, a piece for your campus newspaper or an article in the style of a popular magazine would warrant a more informal tone. You might have a catchy headline or title. You would probably give more background information about your topic and avoid specialized terminology. Your writing might incorporate personal experience, anecdotes, direct quotes, or even dialogue—all depending on the specific venue for which you are writing. In these situations, too, it helps to study similar works by other writers. See Chapter 10 for more advice about writing for other types of audiences.

■ Talk to others.

Brainstorming with other people about the project may help get you started by giving you an audience on which to test out your ideas. Professional scientists rely heavily on such feedback from their colleagues, both in the more formal settings provided by conferences and on a day-to-day basis during lunch or coffee breaks. Electronic mail and Internet discussion groups also provide a forum for informal conversation. Intellectual exchange with others helps scientists keep their work on track and instills it with fresh insights. If you read the Acknowledgments portion of several scientific papers, you will see how important such discussions are to research and writing processes.

Practical Suggestions for Revising

■ Break down the task into several successive steps.

First, consider the paper as a whole, checking overall content, organization, coherence, and consistency. Try to resist the impulse to make small-scale changes—for example, changes in punctuation—until you are satisfied with the main substance and structure of your paper. This is particularly important when you are composing on the computer. Because word processing makes it so simple to alter the surface features of your text, you may be tempted to make even your first draft "perfect," with every comma in place and every typographical error corrected. However, doing so will distract you from the more important job of articulating and organizing your main ideas.

Once you are satisfied with the paper's content and general organization, work on polishing your prose style, examining individual paragraphs and sentences closely for clarity, accuracy, and conciseness. Look for wordiness, awkward sentence constructions, improper word usage, faulty subject-verb agreement, excessive use of the passive voice, and other problems that may obscure your meaning and impede the flow of your writing. Finally, proofread the text for punctuation, spelling, and typographical errors, and inspect the final form of the manuscript.

In practice, of course, making revisions is not quite so orderly and mechanical a process. Also, "writing" and "revising" a paper are not totally separate activities: writers typically make changes as they are composing, not just after they have written a draft all the way through. Nevertheless, your writing may be more productive if you set some priorities for yourself, focusing on big changes first and on small changes later.

Finally, allow plenty of time for revising and proofreading your paper. Set each draft aside for several hours or several days; when you return to your writing you'll view it more objectively and work more productively. Try reading a draft out loud; you will be amazed at how useful this technique is for spotting awkwardly worded or ungrammatical constructions. Also, give your writing to others to read; see the discussion of peer reviews on page 156.

■ Find specific strategies that work for you.

Some writers work best if they do their early composing in longhand and save the later stages of revising and proofreading for the word processor. Others need the familiar feel of the computer right from the start and prefer to see their writing appear neatly on the screen in front of them. If you do write out early drafts in longhand, the "cut-and-paste" method saves time and effort when you need to move chunks of text from one place to another. Use scissors and tape to patch the new version together rather than write everything over again. Of course, word processing allows writers to move words, sentences, and sections of text and to make sweeping changes in the general structure of the manuscript.

Do not discard your early drafts; keep everything at least until you have submitted the final version of the paper. Sometimes parts of a first or second draft end up sounding better than later drafts. Put both the page number and the number of the draft on each piece of writing in case you mix up parts of different drafts.

Do not confine all your revising to the computer screen. The computer shows you only a small part of the manuscript at one time, but some problems may be more noticeable when you see several pages of the paper spread out in front of you. For this reason, it makes sense to print your work frequently and make additional changes by hand directly on the manuscript. Keep all the printouts even after you have incorporated the changes in your file. You may need to refer to an early draft before you are finished with the paper.

During the later stages of editing and proofreading, remember to use word processing features that will save you time. For example, "search and replace" features of word processing programs are invaluable for locating specific words or phrases in the text and allowing you to correct misspellings or other errors. Suppose you realize that throughout the paper you have typed the genus *Gomphus* incorrectly as *Gomphis*. On command the computer can locate every place where *Gomphis* appears and automatically make the necessary correction.

TECH TALK

Know the limits of spell-checking software.

Spell checkers are a great way to start looking for errors in your work, but they have limits. They can't detect typographical errors that are legitimate words, such as *the* instead of *then*. They also can't distinguish between the various spellings of words such as *two*, *to*, and *too* or *principle* instead of *principal*. They also may not include many of the words you use, especially specialized terms and proper nouns. Therefore, do not rely on spell-checkers to catch all errors and be sure to carefully proofread your final draft.

Finally, but most important, make sure you have two copies of your file—for example, one copy on your computer and a second, backup copy on a removable device such as a flash drive (thumb drive) or an external hard disk. Remember to update the backup file each time you make revisions.

Solicit comments from others.

Professional biologists rely heavily on advice from their colleagues as they prepare manuscripts. Once papers are submitted to journals, they are subjected to further scrutiny by editors and outside reviewers. This review process, as formidable as it may sound, gives authors invaluable feedback about their work and helps to ensure high standards for research and writing.

Ask one or more of your friends or classmates for feedback about your paper. Pick people who will give honest and thoughtful opinions and won't just say what they think you want to hear. Also, try to choose readers with some knowledge of science, preferably of your general subject, unless you are writing specifically for a lay audience. Here are some tips to make this peer review process work smoothly and effectively.

Responsibilities of the Author

- Give your readers some *context* for your paper by explaining the assignment, your instructor's expectations, and your own objectives.
- Work with a *rough draft*—don't ask readers simply to proofread your writing for "errors" half an hour before the paper is due. Later you may wish to ask someone to double-check for typos and other small-scale problems, but the best use of peer reviews is to help you during the early stages of the writing process, when you are still struggling with style, tone, content, and organization.
- *Orient and focus* your readers by listing your major concerns about your writing at this point. Doing so will direct their attention to key issues or places in the paper and help them give focused, specific feedback. Of course, they should also feel free to comment on other points you haven't raised.
- *Accept suggestions and criticisms graciously.* Don't get defensive. Your readers are simply trying to help. You may not agree with every piece of advice, and in fact you may receive conflicting advice. As the writer, you must take the ultimate responsibility for deciding which suggestions to follow.

Responsibilities of the Peer Reviewer

- *Understand the writer's chief concerns* as well as the context and purposes of the assignment.
- *Be focused and specific in your comments.* Avoid global statements such as "This is confusing" or "I think this is really good." What points are confusing? Where did you start to get lost? In what specific ways is the paper good? Is it clear and well organized? Does the writer write with authority? Are tone and diction appropriate for the assignment? Write specific comments directly on the draft at places where they are most appropriate.

- Unless directed otherwise, *focus on global issues* rather than on misplaced commas, typos, and the like. The writer is still composing big sections of text, not editing for grammar and punctuation in sentences that might be deleted anyway. However, if you notice recurrent problems—for example, sentence fragments or wordiness—that impede readability or are likely to persist in later drafts, then point these out.
- Resist the impulse to reword or otherwise "fix" the draft. Your role is to *identify possible problem areas*, not to rewrite or cowrite the paper.
- *Look for both strengths and weaknesses.* Most pieces of writing have both. The writer needs praise for successful parts of the paper as well as help identifying unsuccessful sections.
- *Be tactful* in your comments. Watch your tone; writers can have fragile egos. Give criticism in a supportive and courteous way.
- Supplement your specific in-text comments with a *brief summary of your responses* at the end of the draft. If you are one of several readers, add your name so that the writer can check with you later if he or she is confused about anything you wrote.
- Finally, *talk with the writer* informally about the paper. Listen to his or her concerns, and share your own responses orally.

Following is a sample peer-reviewed draft of the introduction to a student review paper, which follows the CSE citation-sequence style of documentation. Note how the reviewer has added specific notes in the text of the draft as well as summary comments at the end.

Too informal for scientific audience →

Picture scraping masses of foul-smelling zebra mussels off your new boat, or arriving at your favorite beach only to find it littered with huge piles of these decaying bivalves. The zebra mussel is native to the Black, Caspian, and Aral Seas in eastern Europe, but it is now found throughout the Great Lakes and connecting waterways in the eastern United States.[1,2] The species was probably introduced to habitats in the United States in 1988 by being carried in the freshwater ballast of European ships.[3] Since its discovery in 1988, it has spread throughout the Great Lakes and many other freshwater systems in the U.S. The mussels came in a variety of colors and patterns, and many of these are quite attractive.

Give spec name ←

Redundant—omit? →

Relevan Omit? ←

Use own words →

"Zebra mussels have the potential to foul municipal electric power and industrial water intake facilities, disrupt food webs and ecosystem balance, and interfere with fishing, navigation, beach use, and

d
sistent
umentation
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agricultural irrigation (Stand 2000)." The species was first noted in Lake St. Claire, Michigan.[3] Zebra mussels differ in many ways from native bivalves. This paper discusses various aspects of the biology of zebra mussels since their introduction into the United States.

Combine with 4th sentence?

In what ways?

What aspects?

Reviewer's comments at end of paragraph:

Zebra mussels (what is the species?) sound really interesting—but I'm not sure exactly what you are going to be discussing here. Differences between zebra mussels and native bivalves? (If so, what kinds of differences?) Environmental or other impacts? Do you plan to discuss possible control measures? Perhaps you could expand the statement of your aims and scope (last sentence). Have you thought of a possible title yet? I've noted places where you might omit some sentences because they are repetitive or seem (to me) unrelated to your topic. Also, for a scientific review, I think you need to have a more formal tone (I'd omit the first sentence), avoid direct quotes, and use the same documentation style throughout—are you using CSE citation-sequence format? Hope these comments help—I'll look forward to seeing your next draft.

Checking Content and Structure

■ Improve logic, continuity, and balance.

In a research paper, you need to keep track of your argument. What major question are you addressing? What hypotheses have you attempted to test? Do the data you present in your Results directly relate to these hypotheses and to the conclusions put forth in the Discussion? A good scientific paper is somewhat like a mystery story with the "solution" well supported by a carefully crafted body of evidence in the Results section. However, the scientific writer has also gradually prepared the reader for the major conclusions, which should come as no sudden surprise.

Although a review paper has a less formal structure, it also needs to be built around a logical train of thought. Readers need to understand your rationale for choosing the topic. They need a sense of movement as you develop your main points, and they need to see the paper end on a satisfying note through summarizing statements and conclusions.

Once you have completed a rough draft, try to visualize the paper as a unit. Is its structure clear? Do you lead readers along your line of reasoning point by point, paragraph by paragraph, making clear transitions from one topic to the next? Or do they have to grope their way along, guessing the connections? Are any topics underdeveloped or overdeveloped, throwing the paper out of balance? Do you maintain a consistent style and approach?

Compare your Introduction with the rest of the paper. Have you delivered to the reader what you promised at the beginning? Are your initial statements compatible with your concluding ones?

Sometimes large-scale revisions can be accomplished relatively effortlessly by moving sentences or even whole paragraphs from one place to another. Usually, however, you need to do substantial rewriting—paring down overwritten passages, modifying highly speculative comments, developing poorly expressed ideas, adding new clarifying material, and revising the beginnings and ends of paragraphs so that you can fit them into new contexts. Such revisions can be frustrating, even painful. However, they lead to a new product: a clearer, more organized version of the paper.

■ Omit unnecessary material.

Even when you feel you have "nothing to say," you may end up with more material than you anticipated, perhaps more than you really need. As you check the manuscript for logic and balance, be alert for places where you strayed off the topic. The Materials and Methods section may include procedures that do not pertain to any of the data discussed. The Results can easily become a grab bag of miscellaneous data, only some of which are important to the main story. The Discussion may be weighed down by predictions impossible to test in the near future or by rambling comments of only peripheral importance. Check that *every* point is relevant to your main objectives. Be ruthless. Cut any extraneous material—text, table, or figure—no matter how hard you worked on it.

■ Check for completeness and consistency.

Scientific writing requires you to keep track of many details. It is surprisingly easy to create inconsistencies or to leave out pieces of needed information. This is why it's important to leave enough time to put your work aside and return to it later for a fresh look. The checklists in Chapters 3, 4, 5, and 10 may help you check the contents of tables and figures, lab reports, research papers, review papers, oral presentations, and posters, all of which have specific requirements and formats of their own.

Improving Paragraphs

■ Present coherent units of thought.

Paragraphs are not just chunks of text; at their best, they are logically constructed passages organized around a central idea often expressed in a *topic sentence*. A writer constructs, orders, and connects paragraphs as a

You can use the same techniques for linking sentences *within* paragraphs for making transitions *between* paragraphs. These include the repetition of key words or ideas and the use of transitional "markers" (*furthermore, for example, a second point, by contrast, on the one hand . . . on the other hand*, and so on) to signal to the reader that you are either developing the same idea or moving on to a different one.

■ Vary your sentences.

Pay attention to the structure, length, and rhythm of your sentences. People "hear" writing as they read; if your prose is unvarying and one-dimensional, you will not get your message across as effectively. The following paragraph is dominated by short, choppy sentences:

> Many doves showed "nest-calling" behavior. They assumed a position with the tail and body axis pointing slightly upwards. In this posture they flicked their wings. This behavior was seen in both sexes. It was especially common in males. I saw it performed both on and off the nest.

We can make this passage more readable (and therefore more interesting) by combining related sentences. This eliminates the distracting, choppy style and makes the paragraph more effective as a unit:

> Many doves showed "nest-calling" behavior in which they assumed a position with the tail and body axis pointing slightly upwards and flicked their wings. This behavior, especially common in males, was performed both on and off the nest.

Writing Clear, Accurate Sentences

■ Use words that say precisely what you mean.

Do not give in to the temptation to use a word that "sounds right" unless you are absolutely sure it is appropriate. Sentences that are otherwise perfectly effective can be ruined by a single word or phrase that is wrong for the context. Here are some examples from student papers for a mycology class:

INCORRECT	Kohlmeyer (1975) sees the pit plug of red algae as being *heavily* related to the plug of Ascomycetes.
CORRECT	Kohlmeyer (1975) sees . . . *closely* related . . .
INCORRECT	Many mycologists have spent years *researching* for data suggesting a red algal ancestry with higher fungi.
CORRECT	Many mycologists have spent years *searching* . . .

INCORRECT	The evolutionary origin of the higher fungi has *harassed* scientists for many years.
CORRECT	The evolutionary origin . . . has *puzzled* scientists . . .

Take the time to consult a print or online dictionary if you're unsure about your wording. And before you use any technical term, make sure you fully understand its meaning. If in doubt, look it up in the glossary of an introductory text, or check the reference section of your library for specialized scientific encyclopedias and dictionaries, such as *McGraw-Hill Encyclopedia of Science & Technology* and *McGraw-Hill Dictionary of Scientific and Technical Terms*. Another useful tool is The Science Dictionary (http://www.thesciencedictionary.com), a Web site that provides links to a variety of online sources relating to specific search terms.

The following words are often used incorrectly in biological papers:

Affect: (as a verb) to influence or to produce an *effect*.

Effect: (as a noun) result; (as a verb) to bring about.

> Nutrient concentration was the most important factor *affecting* population size.

> Marking each ant on its thorax with enamel paint produced no apparent *effect* on its behavior.

> We hope that further studies of these endangered species will *effect* a major change in the allocation of funds by the federal government.

Comprise: to contain or include. Do not use *comprise* when you should use *constitute* or *compose*.

INCORRECT	The vertebrate central nervous system is *comprised* of the brain and the spinal cord.
CORRECT	The vertebrate central nervous system *comprises* the brain and the spinal cord.
CORRECT	The vertebrate central nervous system is *composed* of the brain and the spinal cord.
CORRECT	The brain and the spinal cord *constitute* the vertebrate central nervous system.

Correlated: In scientific writing, use in conjunction with certain statistical tests (correlation analyses) that provide a measure of the strength of relationship between two variables. (See also p. 85.)

Interspecific: *between or among* two or more different species.

Intraspecific: *within* a single species.

> Westerfield (2000), studying four species of sandpipers at a Minnesota lake, found marked *interspecific* differences in food preferences.

This plant shows little *intraspecific* variation in flower coloration; generally, the petals are pale yellow with a distinct orange spot at each tip.

Its/It's: *Its* is the possessive form of *it*. Do not confuse it with *it's*, a contraction of *it is* or *it has*.

Each calf recognized *its* own mother.

It's not clear whether rainfall or temperature is the more important factor.

Note, however, that contractions are generally avoided in formal biological writing.

Principal: (as an adjective) most important. Do not confuse it with *principle*, a noun, meaning a basic rule or truth.

The *principal* finding of this study was that excessive drinking by rats did not cause significant increases in blood pressure.

According to Heisenberg's Uncertainty *Principle*, we can never simultaneously determine the position and the momentum of a subatomic particle.

Random: In scientific writing, use to refer to a *particular* statistically defined pattern of heterogeneous values. (See also p. 86.)

Significant: In scientific writing, use to refer to *statistically significant* (or nonsignificant) results after having conducted appropriate statistical tests. (See also p. 85.)

That/Which: Use *that* to introduce *restrictive* or defining elements—phrases or clauses that limit your meaning in some way.

The rats *that had been fed a high calorie diet* were all dead by the end of the month.

Here the italicized portion restricts the meaning of *rats*; we are referring to *only* those specific rats that had been fed a high calorie diet.

Use *which* to introduce *nonrestrictive* or nondefining elements—word groups that do not limit your meaning but rather add additional information. Because this information is not vital to the integrity of the sentence, you can omit it without substantially changing the original meaning. The following sentence uses *which* instead of *that*; here the writer is speaking more generally, not calling attention to a *particular* group of rats.

The rats, *which* were fed a high calorie diet, were all dead by the end of the month.

Misuse of *that* or *which* may make a sentence confusing:

Plants, which grow along heavily traveled pathways, show many adaptations to trampling.

Here it sounds as if *all* plants grow along heavily traveled pathways. Actually the writer is referring only to a particular group of plants. The nonrestrictive clause needs to be replaced by a restrictive one limiting the meaning of *plants*:

Plants that grow along heavily traveled pathways show many adaptations to trampling.

Do *not* use commas with restrictive elements and *that*, as in the example above. Use commas to set off nonrestrictive elements introduced by *which*—a *pair* of them if the element appears in the middle of the sentence:

These data, which are consistent with those of other researchers, suggest several questions about the significance of wing positions in the thermoregulation of Arctic butterflies.

Unique: one of a kind. A thing cannot be *most*, *very*, or *quite* unique; it is simply unique:

INCORRECT	Females of this species have a *very unique* horny projection from the dorsal part of the thorax.
CORRECT	Females of this species have a *unique* . . .

■ Avoid slang.

Slang is the informal vocabulary of a particular group of people. Some slang words eventually make their way into Standard English; however, most soon become outdated and are replaced by others. Slang usually has no place in scientific writing, even if you put it in quotation marks.

SLANG	Histone-like HU proteins are at the cutting edge of research.
STANDARD	The intracellular functions of histone-like HU proteins have become the focus of much research.
SLANG	Barr's statement (2003) is a "cop-out" because he refuses to acknowledge that metals such as iron interact with prion proteins in mediating neurodegenerative disorders.
STANDARD	Barr's statement (2003) fails to acknowledge that metals such as iron . . .

■ Revise misplaced modifiers.

Modifying words, phrases, or clauses should relate clearly to the words they are meant to describe. If they do not, the sentence may be confusing, even ludicrous.

FAULTY After marking its hindwings with enamel paint, each damselfly was released within 1 m of the capture site.

REVISED After marking its hindwings with enamel paint, I released each damselfly within 1 m of the capture site.

Unless these insects were particularly clever at marking themselves, we need to make the intended subject of this sentence (the writer) more evident. Using the active instead of the passive voice helps here. (See also pp. 173–174.)

FAULTY After mating, the sperm are stored in a sac within the female damselfly's body.

REVISED After mating, the female damselfly stores sperm in a sac within her body.

Who is actually mating, the sperm or the damselfly? The revised version corrects the ambiguity.

FAULTY This behavior has only been reported in one other primate.

REVISED This behavior has been reported in only one other primate.

Modifiers such as *only*, *even*, *almost*, and *nearly* should be placed next to the most appropriate word in your sentence, depending on your meaning. In the first sentence, the position of *only* before the verb suggests that behavior may have been observed in more than one primate but *reported* in just a single species. If you really want to say that this behavior has been observed *and* reported in just this one species, then *only* must modify *one* as in the revised version. In the following sentence, *only* does limit the meaning of the verb in accordance with the writer's meaning.

This behavior has only been observed casually, not reported formally.

■ Avoid vague use of *this, that, it,* and *which.*

Do not use these pronouns on their own to refer to whole ideas; you may lose the reader. To avoid confusion, use clear, specific wording.

VAGUE We could not predict the number of adult males likely to visit each breeding site because male density in the surrounding forest varied greatly from day to day. This is typical of most field studies on this species.

What is "typical of most field studies"? Varying male densities, being unable to predict male numbers at the breeding site, or both? The revision eliminates this ambiguity:

SPECIFIC We could not predict the number of adult males . . . from day to day. Varying male density is typical of most field studies . . .

■ Make comparisons complete.

Add words if necessary to make comparisons or contrasts accurate and unambiguous.

AMBIGUOUS Average body length in *Libellula pulchella* is longer than *Plathemis lydia*.

Here you want to compare the body length of one species with the *body length* of another, as the revision clearly does:

UNAMBIGUOUS Average body length in *Libellula pulchella* is longer than that in *Plathemis lydia*.

AMBIGUOUS Bullfrogs were more abundant than any amphibian at Site A.

Because bullfrogs themselves are amphibians, you need to revise the wording to avoid confusion:

UNAMBIGUOUS Bullfrogs were more abundant than any other amphibian at Site A.

■ Make each verb agree with its subject.

Do not lose sight of the subject in a sentence by focusing on modifying words, such as prepositional phrases, occurring *between* the subject and the verb.

The *size* of all territories *was* [not *were*] reduced at high population densities.

A valuable *property* of restriction endonucleases *is* [not *are*] the specificity with which they cut DNA sequences.

The *zygote* of the Ascomycetes *develops* [not *develop*] into ascospores.

All of the sentences above have singular subjects and therefore need singular verbs.

Compound subjects are subjects with two or more separate parts that share the same verb. When these parts are connected by *and*, they need to be matched with plural verb forms.

The *color* and *shape* of the beak are [not *is an*] important taxonomic *features* [not *feature*].

When the parts of a compound subject are linked by *or* or *nor*, make the verb agree with the part that is closest to it. If one part of the subject is singular and the other plural, then put the plural part second and use a plural verb.

Under experimental conditions, *neither* the newly hatched chick *nor* its older siblings *were tended* by the parents.

Here the parts of the compound subject are *chick* and *siblings*; these are joined by *nor*. The second part, *siblings*, is plural and needs a plural verb (*were tended*).

Neither benzotriazole *nor* its brominated analogues *inhibit* helicase-catalyzed ATP hydrolysis.

In this example, too, the second part of the compound subject (*analogues*) needs a plural verb (*inhibit*).

Do not confuse a compound subject with a singular subject that is linked to other nouns by a prepositional phrase (such as *in addition to*, *along with*, or *as well as*). The following sentence has a singular subject and takes a singular verb:

The dominant *male*, along with his subordinates, *protects* [not *protect*] the offspring when the troop is threatened by predators.

When you refer to a particular quantity of something as a single unit, treat it as singular.

Before each experiment, *10 mL* of distilled water *was* added to each vial.

Many scientific terms have a Latin heritage and are used in both the singular and plural form, depending on the context. Make sure the verb agrees with the subject.

The *larva* of the monarch butterfly *feeds* [not *feed*] on milkweed.

Here are the singular and plural forms of some words commonly used in biology.

Singular	Plural
alga	algae
analysis	analyses
bacillus	bacilli
bacterium	bacteria
basis	bases
criterion	criteria
datum (rarely used)	data
flagellum	flagella, flagellums
focus	foci, focuses
formula	formulae, formulas
fungus	fungi, funguses
genus	genera
hypothesis	hypotheses
index	indices (for numerical expressions), indexes (in books)
inoculum	inocula
larva	larvae
locus	loci
matrix	matrices
medium	media, mediums
mycelium	mycelia
nucleus	nuclei
ovum	ova
phenomenon	phenomena, phenomenons
phylum	phyla
protozoan	protozoa, protozoans
pupa	pupae
serum	sera, serums
species	species
spectrum	spectra
stimulus	stimuli
stratum	strata
symposium	symposia, symposiums
taxon	taxa
testis	testes
villus	villi

Note that the word *species* can be either singular or plural: one species of cat, three species of toads.

■ Put related elements in parallel form.

When you link two or more words, phrases, or clauses in a sentence, put them in the same grammatical form. Such parallelism makes your writing easier to read and emphasizes the relationship between items or ideas.

FAULTY These two species differ in color, wingspan, and where they typically occur.

PARALLEL These two species differ in color, wingspan, and habitat.

FAULTY Both populations of plants had high mortality rates at sites that were dry, windy, and where there were frequent disturbances.

PARALLEL Both populations of plants had high mortality rates at sites that were dry, windy, and frequently disturbed.

FAULTY Male bluntnose minnows promote the survival of their offspring by agitation of the water over the eggs and keeping the nest free from sediment.

PARALLEL

Male bluntnose minnows promote the survival of their offspring by agitating the water over the eggs and keeping the nest free from sediment.

In the first example, the clause, *where they typically occur*, has been replaced by a single noun, *habitat*, for parallelism with the two preceding nouns (*color*, *wingspan*). Similarly, in the second example, parallelism has been achieved by putting *where there were frequent disturbances* into adjectival form, *disturbed*, to agree with *dry* and *windy*. In the third example, the noun *agitation* has been changed to a present participle (verb form ending in *-ing*), making two parallel phrases, "*agitating* . . ." and "*keeping*. . . ."

■ Write in a direct, straightforward manner; avoid jargon.

Scientific writing has the reputation of being dry, monotonous, and hard to understand. Consider the following passage from a published paper.

> The data of this study suggest that such a handling procedure not only effects a diminution of emotional behaviour as indexed by decreases in the duration of the immobility reaction, but also as indexed by other measures of fear (freezing and mobility in the open field). To the extent that the handled and nonhandled groups differed in the predicted direction with respect to these indices of fear, distress vocalizations in the open field were shown to be significantly less frequent in the relatively more fearful (nonhandled) group. (Ginsberg et al. 1974, p. 748)

A paper may contain exciting results or brilliant insights but still be tedious to read because of the author's unengaging prose. Whether your paper is a manuscript submitted for publication or a laboratory report for a biology class, an impenetrable style may keep it from getting the attention it deserves.

Frequently, the problem is the use of *jargon* instead of simpler, more straightforward writing. Broadly, jargon is the technical language of some specialized group, such as biologists. More specifically (and negatively), jargon is long-winded, confusing, and obscure language. Writers of jargon use esoteric terms unfamiliar to most of their readers. They rely heavily on long sentences, big words, a pompous tone, and ponderous constructions in the passive voice.

JARGON

One hour prior to the initiation of the experiment, each avian subject was transported by the experimenter to the observation cage. The subject was presented with various edible materials, and ingestion preferences were investigated utilizing the method developed by Wilbur (1965). When data collection was finalized, the subject was transferred back to the holding cage.

REVISED

One hour before the experiment, I put each bird in the observation cage, where feeding preferences were studied using Wilbur's method (1965). The bird was then returned to the holding cage.

The revised passage conveys the same information as the jargon-ridden one, but more simply, directly, and concisely.

Do not assume that to sound like a biologist you must write dry, stilted, and boring prose or that complex ideas must be couched in equally complex, convoluted sentences. Biology instructors, along with editors and readers of biological journals, prefer clear, straightforward writing—simple but effective prose that quickly illuminates the author's results and ideas.

Avoiding Wordiness

First drafts are usually labored and wordy because you have been focusing on just writing down your ideas. As you revise, examine each sentence carefully. Could you say the same thing more succinctly without jeopardizing the content? Lifting just one excess word from a sentence can enliven its rhythm and intensify its meaning, making your prose carry more weight.

■ Omit unneeded words; shorten wordy phrases.

WORDY

There is now an immunological method, first used by Hurt (1988), for localizing nucleoskeleton-like proteins at the nuclear periphery.

CONCISE

Hurt (1988) first used an immunological method to localize nucleoskeleton-like proteins at the nuclear periphery.

WORDY

It has been found that hepatitis C virus consists of a single strand of RNA.

CONCISE

Hepatitis C virus consists of a single strand of RNA.

WORDY

The sample size was not quite sufficiently large enough.

CONCISE

The sample size was not large enough.

MORE CONCISE

The sample size was too small.

WORDY

The root cap serves to protect the cells of the root meristem as the root is growing through the soil.

CONCISE

The root cap protects the cells of the root meristem as the root grows through the soil.

WORDY

The eggs were blue in color, and they were covered with a large number of black spots.

CONCISE

The eggs were blue with many black spots.

Common modifiers such as *very*, *quite*, and *rather* can often be cut from sentences. If you use such words routinely, ask yourself if they are essential to your meaning.

FAULTY	The data in Table 1 are *very consistent* with Sikola's model (2009).
REVISED	The data in Table 1 are *consistent* with . . .
FAULTY	Males guarding eggs are *quite aggressive* toward juveniles and females.
REVISED	Males guarding eggs are *aggressive* toward . . .

In summary, biological writing is plagued by countless wordy phrases, often placed at the beginning of a sentence, and by "empty" words and phrases that add little to the author's meaning. Some of these are listed below. You will probably think of many others to add to the list.

Wordy	Concise
a second point is that	second, secondly
more often than not	usually
it is apparent that	apparently
at the present time	now
in previous years	previously
owing to the fact that	because
because of the fact that	because
in light of the fact that	because
it may be that	perhaps
these observations would seem to suggest	these observations suggest
one of the problems	one problem
in only a very small number of cases	occasionally, rarely
in the possible event that	if
An additional piece of evidence that helps to support this hypothesis	Further evidence supporting this hypothesis
In spite of the fact that our knowledge at this point is far from complete	Although our present knowledge is incomplete
It is also worth pointing out that	[*omit it*]
Before concluding, another point is that	[*omit it*]
It is interesting to note that	[*omit it*]

Avoid repetition.

Some sentences or paragraphs are wordy because the writer has included the same information twice.

WORDY	In Weaver's study in 1997, she failed to account for temperature fluctuations (Weaver 1997).
CONCISE	Weaver (1997) failed to account for temperature fluctuations.

Because the author's name and the publication date are given in the literature citation (Weaver 1997), you need not give the same information at the beginning of the sentence. (See also Chapter 6.)

In the next example, the second sentence can be omitted because it merely repeats part of the first sentence using different wording.

> Male fathead minnows who were tending eggs spent the majority of their time rubbing the egg batches with their dorsal pads and preventing other fish from eating the eggs. They did not devote much time to other activities, but instead were chiefly occupied with behavior directed toward the eggs.

Use the passive voice sparingly.

In the passive voice, the subject of the sentence *receives* the action, whereas in the active voice, it *does* the action.

PASSIVE	Nearly half the seedlings *were eaten* by woodchucks.
ACTIVE	Woodchucks *ate* nearly half the seedlings.

Biological writing leans heavily on the passive voice even though the active voice is more direct, concise, and effective. Why this emphasis on the passive? Compare the following two sentences:

PASSIVE	Skin extract solution *was presented* to the fish through a plastic tube.
ACTIVE	*I presented* skin extract solution to the fish through a plastic tube.

Neither sentence is incorrect; however, the sentence in the passive voice shifts the reader's attention away from the writer and more appropriately to the materials he or she has been testing, observing, collecting, or measuring. This is why the passive voice is particularly common in the Materials and Methods section of biological papers. Shunning the passive altogether may result in prose that is "I-heavy" and monotonous because of too many first-person references. Prudent use of passive constructions gives variety to the text, and in a few situations such constructions may simply be more convenient.

Thus the passive voice has legitimate uses. Unfortunately, however, many beginning writers rely heavily on the passive because they think it makes their prose more formal, more important, and more "fitting" for a scientist. When used habitually, carelessly, or unintentionally, however, the passive voice results in a wordy and cumbersome style. Overuse of the passive is one reason that scientific writing has the reputation of being dry,

pompous, and boring. Usually the passive voice can easily be converted to the active voice, making sentences shorter and more forceful without any loss of meaning.

PASSIVE	Territory size was observed to vary with population density.
ACTIVE	Territory size varied with population density.
PASSIVE	From field observations, it was shown that virtually all tagged individuals remained in their original home ranges.
ACTIVE	Field observations showed that virtually all tagged individuals remained in their original home ranges.
PASSIVE	Brefeldin A was found to inhibit protein secretion in the Golgi apparatus.
ACTIVE	Brefeldin A inhibited protein secretion in the Golgi apparatus.

You will still find the passive voice in most of the scientific literature you read. As you write your own papers, you may see legitimate needs to use the passive voice. There are no firm guidelines about this in biological writing, and different journals and scientific fields vary in their use of the passive. However, the active voice generally does a better job. Use passive constructions deliberately and sparingly. For every sentence you put in the passive, ask yourself if you could express it more exactly and concisely in the active voice.

Verb Tense

Scientific ethics have given rise to the convention of using the *past* tense when reporting your own present findings and the *present* tense when discussing the published work of others. This is because new data are not yet considered established knowledge, whereas the findings of previous studies are treated as part of an existing theoretical framework. Therefore, in a research paper, you will need to use both the past and present tenses. Most of the Abstract, Materials and Methods, and Results sections will be in the past tense because you are describing your own work. Much of the Introduction and Discussion will be in the present tense because they include frequent references to published studies. Look at the following examples.

The reproductive success of yellow-bellied marmots (*Marmota flaviventris*) is strongly influenced by the availability of food and burrows (Andersen et al. 1976) [Introduction].

After inoculation, plants were kept in a high-humidity environment for 100 h [Materials and Methods].

Limpets occurred at all sampling sites [Results].

Diaptomus minutus was dominant in the zooplankton of Clinton Lake during both years of the study. This species is common on many other acidic lakes in the region (Lura and Lura 1985) [Discussion].

When you refer to an author directly, however, you may use the past tense:

Bauman (1959) found that this bacterium is highly sensitive to pH.

When you refer directly to a table, a figure, or a statistical test in your own paper, it is acceptable to use the present tense:

Table 3 shows that polychaetes were most abundant at depths of 10 to 16 m.

See the sample research paper at the end of Chapter 4 for other examples of correct verb tense.

Punctuation

Used correctly, punctuation marks help make your writing clear and understandable. Used incorrectly, they may distract, annoy, or confuse the reader. Buy a writer's guide with a detailed section on punctuation, and consult it frequently. The guidelines below address some of the most common punctuation problems in biology writing.

Comma

1. Use a comma to separate introductory material from the rest of the sentence.

Although egg cases were reared using Hendrickson's method (1977), none of the eggs hatched.

During the 1987 breeding season, bullfrogs were sexually active from early June to late July.

Nevertheless, these data suggest that mate selection in this species is based primarily on female choice.

A comma may be omitted after a very *short* introductory element that merges smoothly and unambiguously with the rest of the sentence.

Thus the data in Table 1 are consistent with those of Tables 2 and 3.

2. Use a *pair* of commas to set off insertions or elements that interrupt the flow of a sentence.

The situation is different, however, on isolated islands with lower species diversity.

This explanation, first proposed by Hess (1967), is still widely accepted.

3. Use a comma to separate all items in a series, including the last two.

Unlike mosses, ferns possess true roots, stems, and leaves.

4. Use a comma to separate independent clauses linked by a coordinating conjunction (*and, but, or, for, nor, so, yet*). (An independent clause is a word group that contains a subject and a verb and is able to function as a complete sentence.)

Many studies have been made of feeding preferences in spiders, but few have been done under natural conditions.

Do *not* use a comma on its own to join two independent clauses. Such an error is called a *comma splice*.

COMMA SPLICE Horsetails usually grow in moist habitats, some occur along dry roadsides and railway embankments.

A comma splice also results when you join two independent clauses with a comma followed by a conjunctive adverb (such as *however, moreover, furthermore, therefore, nevertheless*).

COMMA SPLICE Horsetails usually grow in moist habitats, however some occur along dry roadsides and railway embankments.

There are several ways to correct a comma splice. For example, you can use a semicolon (see p. 177) with or without a conjunctive adverb:

REVISION 1 Horsetails usually grow in moist habitats; however, some occur along dry roadsides and railway embankments.

REVISION 2 Horsetails usually grow in moist habitats; some occur along dry roadsides and railway embankments.

A comma splice can also be corrected by adding a coordinating conjunction after the comma:

REVISION 3 Horsetails usually grow in moist habitats, but some occur along dry roadsides and railway embankments.

Alternatively, you can make one of the clauses a dependent clause and separate the two clauses by a comma. (A dependent clause lacks either a subject or a verb and cannot stand alone as a complete sentence.)

REVISION 4 Although horsetails usually grow in moist habitats, some occur along dry roadsides and railway embankments.

Finally, you can make two sentences separated by a period:

REVISION 5 Horsetails usually grow in moist habitats. Some occur along dry roadsides and railway embankments.

Semicolon

1. Use a semicolon to join two independent clauses *not* linked by a coordinating conjunction (*and, but, or, for, nor, so, yet*).

Bacteria reproduce very rapidly; many species can divide once every 20 min under favorable conditions.

This statement could also have been written as two complete sentences separated by a period, but the semicolon suggests a closer relationship between the two ideas.

2. Use a semicolon to connect two independent clauses joined by a conjunctive adverb (such as *however, moreover, nevertheless,* and *furthermore*).

These data are consistent with those of Allen (2004); moreover, they suggest that pH may be a more important influence than previously believed.

3. Use a semicolon to clarify the meaning of a series of items containing internal commas.

Films were made of courtship and mating behavior; aggressive interactions between males, including chasing, butting, and biting; and parental behavior by females, particularly fanning and egg retrieving.

Colon

1. Use a colon to introduce items in a series.

Birds are distinguished by the following features: a four-chambered heart, feathers, light bones, and air sacs.

However, do *not* use a colon before a series unless the colon follows an independent clause.

INCORRECT Dandelions are in the same family as: daisies, chrysanthemums, sunflowers, and hawkweeds.

INCORRECT The most common insects at Site A were: mayflies, dragonflies, damselflies, and butterflies.

In both these examples, the colon should be deleted.

2. Use a colon between two independent clauses when the second clause explains or clarifies the first one.

The Cranston Lake study site was most suitable for incubation studies: nest sites were abundant, and brooding birds were rarely disturbed by road traffic.

3. Use a colon to formally introduce a direct quotation. (See p. 121.)

Dash

The dash is used to separate material abruptly from the rest of the sentence for clarity, emphasis, or explanation. (To type a dash, use two hyphens, one after the other, with no space on either side:—. Word processing programs can then convert these hyphens to dashes.)

Insects are distinguished by three body regions — head, thorax, and abdomen — and three pairs of legs.

Many writers use the dash when a comma, indicating just a slight pause, would be less distracting.

DISTRACTING Eggs with minor cracks and an intact inner membrane hatched normally — but severely cracked eggs failed to develop and soon rotted.

REVISED Eggs with minor cracks and an intact inner membrane hatched normally, but severely cracked eggs failed to develop and soon rotted.

When overused, dashes make your writing seem informal and careless, suggesting that you do not know how to use other types of punctuation. Use dashes sparingly, if at all, in biological writing.

Parentheses

1. Use parentheses to insert explanatory or supplemental information into a sentence.

The nests at Leland Pond were unusually large (at least 30 cm in diameter), but only one contained any eggs.

Juvenile monkeys raised in groups of three gained weight more rapidly than those raised in isolation (Fig. 2).

Like dashes, parentheses should be used sparingly because they interrupt the flow of your writing. Commas often work just as well as parentheses and are less distracting.

2. Use parentheses with a series of items introduced by letters or numbers, especially when you are listing many items or several long items.

Dragonflies are good subjects for studies of territorial behavior for these reasons: (1) many are easily identified and widely distributed, (2) most can be observed easily under natural conditions, and (3) much is known about the anatomy and life history of many species.

Quotation Marks, Brackets, and Ellipses

See pages 121–122 for uses of these punctuation marks to present quoted material.

Writing Papers in the Biological Sciences

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Victoria E. McMillan
Colgate University

***Statistics Consultant*, Robert Arnold**
Colgate University

***Library Consultant*, Charles F. Priore Jr.**
Carleton College and St. Olaf College

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