

Revising

Something that looks like a bad sentence can be the germ of a good one.

—Ludwig Wittgenstein

What a very difficult thing it is to write correctly.

—Charles Darwin

No one will ever criticize you for having written too clearly.

—Naj A. Kinehcep

Easy reading is damned hard writing.

—Nathaniel Hawthorne

WHAT LIES AHEAD?

In this chapter, you will learn ...

- The importance of completing a first draft early enough to allow at least several days for revision
 - How to revise for different sorts of problems in multiple passes through the manuscript
 - To revise initially for content and for the logical flow of information and ideas
 - How to give constructive criticism on another student's draft and how to interpret criticism of your own drafts
-

Much of this book concerns the reading, note taking, synthesizing, and organizing that permit you to capture your thoughts in a first draft—so they don't escape. This chapter addresses the next step—revising. You must examine your first draft critically and diagnose and treat the patient as necessary.

You can't do a thorough job of revising in a single pass. Once you fix the major problems (often relating to the organization of ideas), a whole new set of problems bubbles to the surface. These problems, in turn, become major ones that need attention, and spawn new difficulties.

This chapter presents revision as a multistep process. Draft by draft, the product gets better. I typically revise my own writing at least 4 or 5 times before letting anyone else see it—and several more times after it has been reviewed by others.

All writing benefits from revision. The acts of writing and then rereading what you have written typically clarify your thinking. Even when you finally know precisely what it is you want to say, you confront the universal difficulty of getting your points across (intact) to a reader. Revising your work improves communication and often leads you to a firmer understanding of what you are writing about—a process that, as a student, leads to a better grade. Here are the steps to follow:

HARDER

- Reorganize your ideas.
- Revise for content—be sure that every sentence says something important and substantive.
- Revise for clarity of expression—if readers have to stop to figure out what you are trying to say or if they misunderstand what you are saying, you have failed.
- Revise for completeness—be specific and complete in making your points.
- Revise for conciseness—say what you need to say in the fewest number of words.
- Revise for flow—link your ideas in a logical order and show that logic to readers.
- Revise for teleology, anthropomorphism, spelling, grammar, and word usage.

EASIER

It is difficult to revise your own work effectively unless you can examine it with a fresh eye. Without some distance from the work, you can't really tell whether you've actually said what you wanted to say. For this reason, *plan to complete your first draft at least 3 days before*

the final product is due to allow time for careful revision. Reading your paper aloud—and listening to yourself as you read—often reveals weaknesses that you would otherwise miss. It also helps to have one or more fellow students carefully read and comment honestly on your draft. Identifying writing problems—faulty logic, faulty organization, wordiness, ambiguity, factual errors, spelling and grammatical errors—is easier when reading the work of others. Forming a peer-editing group is a clear step toward more effective writing and clearer thinking. Be sure to tell the readers of your work that you sincerely want constructive criticism, not a pat on the back.

Remember, *your goal as a writer is to communicate*—clearly and succinctly—making it as easy as possible for readers to follow your argument. Your goal as a reader of someone else's draft is to help its author do the same. The less you make readers have to think as they read, the happier they will be—and the more likely they will be to continue reading. At the end of this chapter, you will find advice on how to be an effective reviewer.

Choose whatever system works best for you, but always revise your papers before submitting them. No matter how sound—or even brilliant—your thoughts and arguments are, it is the manner in which you express them that will determine whether they are understood and appreciated (or, in later life, whether they are even read). With pencil or pen at the ready, the time has come to edit your first draft. Even if you write your first draft on the computer, make at least your first set of revisions on printed copy rather than on screen; to reorganize effectively, you must see more than one screen of text at a time. Continue revising and editing, pass by pass, until your work is ready for the eyes of the instructor, admissions committee, journal editor, or potential employer. This chapter should help you know when have arrived at that point.

PREPARING THE DRAFT FOR SURGERY: PLOTTING IDEA MAPS

First drafts are often disorganized messes. They usually contain at least a few good ideas, and sometimes they are full of them. But often the ideas are not connected to each other in ways that will seem logical to all readers. In reorganizing material, some ideas can be connected by adding new ideas that will act as bridges between existing ideas. Some ideas cannot be readily connected to the other ideas, however, and do not belong in the same paper—or maybe they belong in different sections of the paper. One way to determine which ideas fall into which category is to sketch out an idea map (Flower and Hayes 1977).

For the following example, students were asked to write a newspaper article based on a research paper from the primary literature (Stickle et al 1984). Here is what one student's first draft looked like:

- 1 With their feathers bound by sticky tar, many seabirds could neither fly nor swim. An otter, washed up on the shore, was an unrecoverable black mess. A sudden oil spill killed these animals directly and swiftly. But it doesn't take a catastrophic spill of millions of gallons to cause such devastation.
- 2 Crude oil from boat engines, factory effluent, and runoff from city gutters enters the ocean, and takes a toll on some of the least suspected of animals exposed over a period of weeks to the deadly aromatic hydrocarbons that the oil delivers to water.
- 3 Using the carnivorous marine snail *Nucella lima* (formerly *Thais lima*), scientists have developed a faster, more sensitive method for assessing toxicity of aromatic hydrocarbons. By measuring growth rates, this method identifies sublethal effects of the toxin, predicting concentrations that will cause eventual death of the animal. A snail with negative growth rate loses more energy than it consumes, so it has none left over to convert to new body tissue. In fact, it starts to burn its own mass to pay the debt.
- 4 The traditional method used to determine the toxicity of a pollutant is to expose organisms to various concentrations of the pollutant. The concentration that kills half the organisms in a certain amount of time is called the LC-50, which stands for "lethal concentration causing 50% mortality." This has long served as a benchmark for determining toxicity of different compounds in the environment. The lower the LC-50 value, the more toxic the compound.
- 5 While better than short-term assays for predicting effects of pollutants that persist for a long time in the environment, such as aromatic hydrocarbons, long-term assays are costly and time consuming.
- 6 Scientists typically have exposed invertebrates to aromatic hydrocarbons for 3 days to determine LC-50 values. In this study by Dr. Bill Stickle and colleagues at Louisiana State University, snails were exposed for up to 28 days.
- 7 Concentrations of greater than 3,000 parts per billion (ppb) were required to kill half the snails in 3 days; concentrations of only about 800 ppb killed half the snails in 28 days. LC-50s declined with duration of exposure. This means that LC-50s measured after only 3 days give a false picture of animals being more tolerant than they are in the field, where pollutants can persist over much longer periods of time.

6 Growth rates, on the other hand, offer a quicker test for organism health in the presence of a pollutant. In this study, growth rate was determined indirectly by measuring energy intake by the snail (calories from mussel prey) and subtracting energy lost to respiration, feces, and metabolic waste. Growth rates are negative when energy lost is more than energy gained. In *Nucella lima*, growth rates were negative when hydrocarbon concentrations exceeded 200 ppb. This concentration is considerably less than 800 ppb determined to kill half the snails in 28 days. This finding suggests greater sensitivity of the growth rate assay than the LC-50 method to find negative effects of aromatic hydrocarbons.

7 This important study shows how determination of growth rates improves upon traditional measures of toxicity. Use of this technique could refine our knowledge of pollutant effects on marine fauna.

This draft isn't a complete disaster, but it certainly isn't easy to read. The ideas are there, but they aren't well organized. The first 2 paragraphs (1) concern the devastation caused by fuel oils and their components, whereas the third paragraph (2) discusses ways of measuring toxicity. The beginning of that third paragraph does not follow logically from the previous paragraph. Moreover, the third paragraph raises the issues of developing a faster method for assessing toxicity, whereas 3 paragraphs later (4) we learn that the "breakthrough" methodology requires 28 days instead of the normal 3 days. That's not faster! Finally, in the eighth paragraph (6) we get to the point of the article: growth rates provide a faster way to judge snail health by allowing us to predict whether the snails will eventually die. But it isn't a faster way to assess ecosystem health at all; it's a more sensitive method.

The student's eighth paragraph is confusing! The first sentence (6) implies that growth rates were determined. The second sentence (7) tells us that growth rates were not determined directly, and the third sentence (8) implies that growth rates were determined after all ("growth rates were negative")! In fact, the researchers did not really monitor growth at all; instead, they measured feeding, respiration, and assimilation rates over a short time and were then able to estimate the extent to which growth rates would be affected. The final sentence of the draft (9) is a giveaway. The vague wording shows that the student has not yet come to grips with what this paper is about. Writing effective newspaper articles is not as easy as it might appear.

A sentence-by-sentence revision of this piece would be pointless. Massive reorganization is called for. This draft would benefit immensely from idea mapping.

What are the major components of the student's draft?

1. Effects of pollutants
2. LC-50s: what are they?

3. Lethal versus sublethal responses
4. Study used the marine snail *Nucella lima*
5. LC-50 results: 3-day versus 28-day experiments
6. Growth rate measurements: importance; how long does it take to make them?
7. Measured by researchers: respiration rate, feeding rate, assimilation

To construct an idea map, scatter the main ideas on a piece of paper, as shown in Figure 6.1a. Now we need to find a good entry point. I have suggested that we begin by discussing the general issue of pollutant input into marine environments (see Fig 6.1b). From there we might discuss lethal versus sublethal responses—but how can we move smoothly between these 2 topics? One possibility would be to note the difficulty of determining the concentration at which any pollutant becomes toxic; this appears as a “bridge” topic in Figure 6.1b. At first I thought this might lead directly to a discussion of “lethal responses versus sublethal responses.” On further reflection, it seems to lead more logically to a discussion of LC-50s. How to determine toxic pollutant concentrations? Determine the time it takes to cause something to happen in 50% of the animals tested. But that depends on how long the experiment runs. So, we add an arrow from “LC-50s” to the next topic, “short-term versus long-term LC-50 results.” From there we can discuss the relative merits of measuring either time to death or to some sublethal response, which should be measurable at a lower pollutant concentration (thus increasing the sensitivity of the test). Increased sensitivity is an important point that wasn’t in our original list, so I have added it in Figure 6.1b. Proceeding in this fashion, I have managed to connect all of the ideas presented in Figure 6.1b to produce a coherent story. It isn’t the only way to link the ideas, but it’s one way that works. What we end up with is a simple flowchart that can be used to write the next draft of the paper, which should now be pretty easy to write because all of the hard thinking has already been done. You can also organize idea maps using index cards, putting one idea on each card and arranging the cards on a floor or tabletop.

Idea maps can also be used before starting a first draft, but for most people they seem to work best in preparing for the next draft. Once you finally have a coherent story to tell your readers, you can begin to fine-tune your presentation—to make it clear, concise and fully convincing. The rest of this chapter concerns that fine-tuning process.

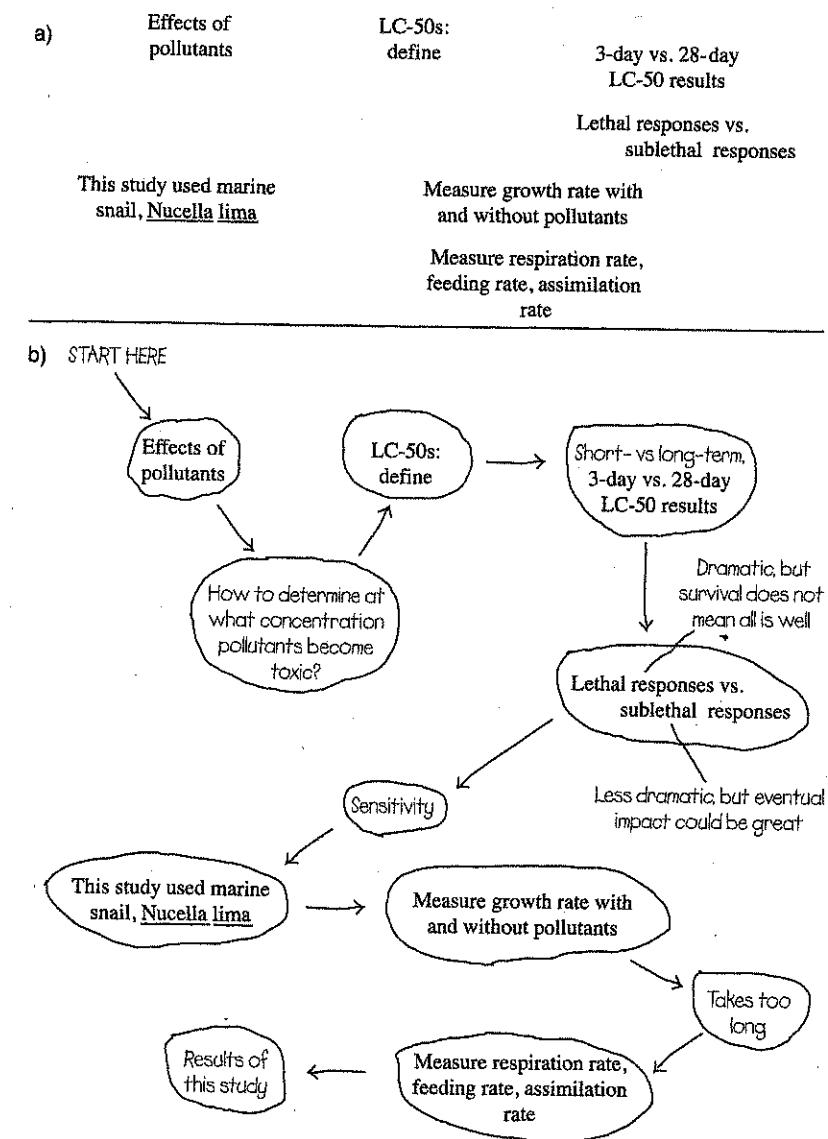


Figure 6.1 Organizing thoughts by creating idea maps.

- (a) The main ideas scattered at random, based on a student draft (pp. 86–87)
- (b) The ideas connected in one of several possible logical sequences.

REVISING FOR CONTENT

1. Make sure every sentence says something worth reading.

Consider the following opening sentence for an essay on the tolerance of estuarine fish to changes in salinity:



Salinity is a very important factor in marine environments.

What does this sentence say? Does the author really need to tell readers that the ocean is salty? What is important about salinity? The sentence is not substantive; it is really just a “running jump”—a sentence that may be on the way to something of substance. Let’s delete this sentence and replace it with one that says something worth reading. For example:



Estuarine fish may be subjected to enormous changes in salinity within only a few hours, especially during periods of heavy rain (Chaparro et al 2019).

The author of the revised opening sentence knows where the essay is headed, and so does the reader. While the original version got the writer started, the revision process focused the writer’s attention on a destination.

Take a careful look at the first sentence of each paragraph that you write for a first draft. You will often find “running jumps,” with the substance of the paragraph beginning with your second sentence. Consider the following example:



The damage associated with UV irradiation (280-400 nm wavelengths) on plant and animal populations is well documented. The UV irradiation in sunlight severely damages DNA and other biological molecules in a variety of marine plant and animal species (Gleason and Wellington 1995; Bingham and Reitzel 2000; Adams and Shick 2001).

That first sentence is a running jump if I ever saw one. Cross it out, and get the paragraph off to a much stronger start with a slightly modified form of the second sentence:



The UV irradiation (280-400 nm wavelengths) in sunlight severely damages DNA and other biological molecules in a variety of marine plant and animal species (Gleason and Wellington 1995; Bingham and Reitzel 2000; Adams and Shick 2001).

2. Insert figure references at the end of substantive sentences. Do not write “The results are shown in Figure 2.” Instead, write

something like “Extracts of fungal stains F2 and F14 inhibited the growth of at least 12 bacterial strains (Fig. 2).”

3. Use the word “relatively” only when making an explicit comparison. Consider this example:



Many of the animals living near deep-sea hydrothermal vents are relatively large.

The thoughtful reader wonders, “Relative to what?” Either delete the word and replace it with something of substance (e.g., Animals living near deep-sea hydrothermal vents can exceed lengths of 3 meters) or make a real comparison (e.g., Many of the animals living near deep-sea hydrothermal vents are large relative to their shallow-water counterparts, or Some animals living near deep-sea hydrothermal vents are many times larger than their shallow-water counterparts).

4. Never tell a reader that something is interesting. Let the reader be the judge. Consider this rather uninformative sentence:



Cell death is a particularly interesting phenomenon.

Is the phenomenon interesting? If so, ask yourself why you find it interesting, and then make a statement that will interest the reader as well. This example could, for instance, be rewritten as follows:



During the development of all animals, certain cells are genetically programmed for an early death.

5. Be cautious in drawing conclusions—but not overly so. It is always wise to be careful when interpreting biological data, particularly when you have access to only a few experiments or small data sets. For instance, write “These data suggest that . . .” rather than “These data demonstrate that . . .” or “These data prove that . . .”. But don’t get carried away, as in the following example:



This suggests the possibility that inductive interactions between cells may be required for the differentiation of nerve tissue.

Here, the author hedges 3 times in 1 sentence, using the words *suggests*, *possibility*, and *may*. Limit yourself to 1 hedge per sentence, as in the following rewrite:



This suggests that inductive interactions are required for the differentiation of nerve tissue.

If you are too unsure of your opinion to write such a sentence, reexamine your opinion.

6. **While revising content, keep in mind an audience of your peers, not your instructor.** In particular, be sure to define all scientific terms and abbreviations; it is not enough simply to use them properly. Brief definitions will help keep the attention of readers who may not know or may not remember the meaning of some terms. Brief definitions will also demonstrate to your instructor that you know the meaning of the specialized terminology you are using. **Try to make your writing self-sufficient;** the reader should not have to consult textbooks or other sources to understand what you are saying. For example:

 The advantages of outbreeding include reduced exposure of deleterious recessive alleles and increased heterosis, the increased fitness commonly associated with increased heterozygosity.

This would be a better sentence than:

 The advantages of outbreeding include reduced exposure of deleterious recessive alleles and increased heterosis.

Note that the author of the better example has cleverly defined the term heterosis within the sentence rather than devoting a separate sentence to its definition.

As always, if you write so that you will understand your work years in the future or so that your classmates will understand the work now, your papers and reports will generally have greater impact and will usually earn a higher grade.

REVISING FOR CLARITY

Taming Disobedient Sentences— Sentences That Don't Say What the Author Means

Be sure each sentence says what it's supposed to say; you want the reader's head to be nodding up and down, not side to side. Which way is the reader's head going in the following example?

These methods have different resorption rates and tail shapes.

Do methods have tails? Can methods be resorbed? This sentence certainly fails to communicate what its author had in mind.

Here is another sentence that does not reflect the intentions of its author:

From observations made in aquaria, feeding rates of the fish were highest at night.

How many observers do you suppose can fit into an aquarium? Aquaria usually contain fish, not authors; is the author of our example all wet? A revised sentence might read:

Feeding rates of fish held in aquaria were highest at night.
Or maybe something like this:

Fish held in aquaria fed the fastest at night.

Some biologists are clearly more dedicated to their research than most of us are:

Ferguson (1963) examined autoradiographs of sea star digestive tissue after being fed radioactive clams.

Perhaps we should feed the clams not to Ferguson but to the sea stars?

Ferguson (1963) fed radioactive clams to sea stars and then examined autoradiographs of the sea star digestive tissue.

In the preceding example, **note the advantages of summarizing a study in the same order as the steps undertaken.** Grammatical difficulties typically vanish, and the sentence automatically becomes clearer.

Sometimes sentences are confusing because the author tries to stuff too much into them, as in the following example:

The Coomassie blue stain, a nonspecific dye that binds to all proteins, was used to show all the proteins in the samples allowing analysis of induction of the appearance of a band after induction that is not found in the uninduced sample.

Whew! The goal of the experiment was to induce certain bacteria to express a cloned gene. The bacteria were then homogenized, and their proteins were separated on an electrophoretic gel. The gel was then stained with Coomassie blue to visualize the proteins present. If a new protein (the induced protein) was present, it would show up as a new, separate band. Now that's just too much work for any 1 sentence to accomplish!

Confusing sentences also inevitably arise when 3 or more nouns are lined up in a row. Consider this example:

Sleep study results show that tryptophan significantly decreases the time needed to fall asleep (Miller and Brown 2007).

At the first reading, the reader probably expects "results" to be a verb; instead, it is a noun preceded by 2 other nouns. The reader must stop and decode the sentence. Ah! The author is discussing the results of studies of people sleeping. We can rewrite the sentence to make this much clearer:

Recent studies show that tryptophan decreases the time needed for people to fall asleep (Miller and Brown 2007).

In revising your work, think twice *before leaving more than 2 nouns together.*

Here are 2 additional examples of unclear writing:

This determination was based on mannitol's relative toxicity to sodium chloride.

The surface area of mammalian small intestines is 3 to 7 times greater than reptiles.

With the first example, how can one chemical be toxic to another chemical? The author is probably trying to tell us that the 2 chemicals differ in their toxicity to some organisms or cell types. With the second example, one wonders how an intestinal surface area can be greater than a reptile; again, the author is not making the comparison intended.

Readers should never have to guess what the proper comparisons are; *the less you make your readers work, the more they will appreciate your writing.* Never invoke the "you know what I mean" defense. If a student writes, "A normal human fetus has 46 chromosomes," how can I assume the student understands that each cell of the fetus has 46 chromosomes? *It is your job to inform the reader; it is never the reader's job to guess what you are trying to say.*

Of course, it doesn't help that confusing sentences surround us in our everyday lives. Consider this example taken from a local newspaper:

Offer void where prohibited by law or while supplies last.

Apparently, no one can ever take advantage of this offer; the offer is either prohibited by law or, if permitted by law, is void while supplies last. Supplies can never run out because the advertiser seems unwilling to fill your order as long as the items are available. If stocks become depleted, perhaps by eventual disintegration of the product, the advertiser could then honor your request, but the company would no longer have anything to send you!

Then there are these gems:

It is illegal for school workers to say that children should take a psychiatric drug because they are not doctors.

Our nuclear reactors are as safe as they can possibly be. And we are constantly working to make them safer.

With practice, you can find similarly confusing or absurd sentences almost anywhere you look. If they appear in your own writing, revise them. Make each sentence state its case unambiguously. Here is a sentence that does not do so:

Sea stars prey on a wide range of intertidal animals, depending on their size.

Is the author talking about the size of the sea stars that are preying or about the size of the intertidal animals that are preyed upon? Don't be embarrassed at finding sentences like this one in early drafts of your papers or reports. Be embarrassed only when you don't edit them out of your final draft.

When referring to your results or to those of other authors, always use the past tense to avoid overgeneralizing beyond the data obtained. For example, "In our study, almost half of the 48 hermit crabs tested selected their original shell by the end of the 15-minute test period."

Finally, don't make readers think more than they have to! Nobody will ever criticize you for being too clear! Consider this example: "Reducing the salinity to 20 ppt increased the presence of American oyster larvae." Would you have a better understanding of an experiment if you read: "Reducing the salinity from 30 ppt to 20 ppt increased the presence of American oyster larvae, which are prevalent in field regions from 7.5 to 22.5 ppt.?"

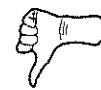
The Dangers of "It"

Frequent use of the pronouns *it, they, these, their, this, and them* in your writing should sound an alarm—probable ambiguity ahead. Consider the following example of the trouble *it* can cause



The body is covered by a cuticle, but it is unwaxed.

Which is unwaxed: the body or the cuticle? *It* makes the second part of the following sentence equally ambiguous:



The chemical signal must then be transported to the specific target tissue, but it is effective only if it possesses appropriate receptors.

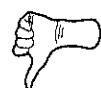
Are these receptors needed by the chemical signal or by the target tissue? I'm confused.

In the next example, *these* causes similar problems for readers:



Antigens encounter lymphocytes in the spleen, tonsils, and other secondary lymphoid organs. These then proliferate and differentiate into fully mature, antigen-specific effector cells.

Presumably the lymphocytes, not the tonsils, are proliferating, although the author has certainly not made this clear. The problem is easily repaired by substituting "The lymphocytes" for "These." In the next example, *their* is guilty of a similar offense:



Like fanworms and earthworms, leeches have proven very useful to neurophysiologists. Their neurons are few and large, making them particularly easy to study with electrodes.

Most readers are likely surprised to learn that neurophysiologists have so few neurons and are so easy to study.

Now let us consider the difficulties *they* can cause:

 Tropical countries are home to both venomous and nonvenomous snakes. They kill their prey by constriction or by biting and swallowing them.

How much clearer the last sentence could become by replacing *they* with a few words of substance and be deleting *them* entirely:

 Tropical countries are home to both venomous and nonvenomous snakes. The nonvenomous snakes kill their prey by constriction or by biting and swallowing.

And have you ever met researchers who glowed in the dark? One student apparently has:

 Harper and Case (1999) found that the plainfish midshipman, *Porichthys notatus*, experienced twice the rate of predation when they were not luminous.

If *they* have their way, the reader must guess who was glowing. Realizing that the sentence is in difficulty, we revise:

 Harper and Case (1999) found that luminous plainfish midshipman (*Porichthys notatus*) were twice as likely to be eaten as nonluminous specimens.

Finally, look what can happen when a variety of these pronouns are scattered throughout a sentence:

 Although *they* both saw the same things in *their* observations of embryonic development, *they* had different theories about how *this* came about.

A patient reader of the whole essay could probably figure out this sentence, eventually, but its author violated—in extreme fashion—one of our key rules, “*Never make the reader back up.*”

When revising your work, read it carefully and with skepticism, checking that you have said exactly what you mean to say. *Never make readers guess what you have in mind.* Never give them cause to wonder whether, in fact, you have anything in mind. Everything you write must make sense—to you and to your readers. As you read each sentence that you have written, ask yourself, “What does this sentence really say? What did I mean it to say?” Make each sentence work on your behalf, leading the reader easily from fact to fact, from thought to thought.

Please note that you need not be a grammarian to write correctly and clearly. With a little practice, especially if you read your work aloud, you can quickly learn to recognize a sentence in difficulty and sense how to fix it without even knowing the name of the grammatical rule that was violated.

Problems with “And”

The word *and* can sometimes obscure connections between ideas. Consider this example:

 Thorson (1950) suggested that sea star recruitment is often low despite the release of tens of millions of eggs because the probability of eggs encountering sperm in the plankton is low, and that most eggs are never fertilized.

The connection between the first and last parts of that sentence is unclear. A simple revision, in which *and* is replaced by *so*, clarifies the connection;

 Thorson (1950) suggested that sea star recruitment is often low despite the release of tens of millions of eggs because the probability of eggs encountering sperm in the plankton is low, so that most eggs are never fertilized.

The word *and* can also weaken a sentence by linking ideas that would be better left on their own, as in this example:

In two similar habitats, one with fish and one without fish, there was a negative correlation between the numbers of frogs and the numbers of fish and researchers believe that the accidental introduction of the fish is responsible for 60% of the variation in the distribution of frogs in these two regions (Knapp and Matthews 2000).

Try rereading the above sentence after replacing the *and* with a period and breaking it into 2 sentences. Now the second idea gets the attention it deserves.

Be sure that *and* is not being used to link weakly related or unrelated ideas.

Headache by Acronym

Overuse of acronyms can drive away potentially interested readers. Some acronyms, such as DNA, are widely known and are fine to use. But consider this sentence:

 Within 24 hours of induction by 5-HT, most cells in the AG showed signs of PCD.

Why would any author do something like this to a potentially interested reader? I would rewrite that sentence as follows:

 Within 24 hours of induction by 5-HT (serotonin), most cells in the apical ganglion showed signs of programmed cell death.

Avoid acronyms.

REVISING FOR COMPLETENESS

Make sure each thought is complete. *Be specific in making assertions.*
The following statement is much too vague:

Many insect species have been described.

How many is "many"? After editing, the sentence might read:

Nearly one million insect species have been described.

Similarly, the sentence

More caterpillars chose diet A than diet B when given a choice of the 2 diets (Fig. 2).

would benefit from the following alteration:

Nearly 5 times as many caterpillars chose diet A than diet B when given a choice between the 2 diets (Fig. 2).

Here is another kind of incompleteness:

If diffusion was entirely responsible for glucose transport, then this would not have occurred.

This rears its ugly head again; the author avoids the responsibility of drawing a clear conclusion and forces the reader to back up and attempt to summarize the findings. Even the beginning of the sentence is unnecessarily vague because—it turns out—the discussion is concerned only with glucose transport in intestinal tissue. Keep readers moving forward. Try to make your sentences tell a more detailed story, as in this revision:

If diffusion was entirely responsible for glucose transport into cells of the intestinal epithelium, transport would have continued when I added the inhibitors.

In the same way, "Cells exposed to copper chloride divided at normal rates" is a substantial improvement over "The copper chloride treatment was not affected."

Be especially careful to revise for completeness whenever you find that you have written *etc.*, which is an abbreviation for the Latin term *et cetera* meaning "and others" or "and so forth." In writing a first draft, use *etc.* freely when you'd rather not interrupt the flow of your thoughts by thinking exactly what "other things" you have in mind. When revising, however, *replace each etc. with words of substance*. In scientific writing, an *etc.* makes the reader suspect fuzzy thinking. Ask yourself, "What, exactly, do I have in mind here?" If you come up with additional

items for your list, add them. If you find that you have nothing to add, simply replace the *etc.* with a period; you will have produced a shorter, clearer sentence.

Consider the following sentence and its 2 improvements:

Original Version:

Plant growth is influenced by a variety of environmental factors, such as light intensity, nutrient availability, etc.

Revision 1:

Plant growth is influenced by a variety of environmental factors, such as light intensity, day length, nutrient availability, and temperature.

Revision 2:

Plant growth is influenced by such environmental factors as light intensity, day length, nutrient availability, and temperature.

In the original version, the author dodged the responsibility of clear, informative writing, forcing the reader to determine what is meant by *etc.* The sentence, although grammatically correct, is incomplete, waiting for the reader to fill in the missing information. The reader may justifiably wonder whether the writer knows what other factors affect plant growth. Both revised versions clearly indicate what the author had in mind. *Revising for completeness often requires you to return to your notes or to the sources upon which your notes are based.* As noted earlier, write in a way that keeps your readers moving forward.

REVISING FOR CONCISENESS

Make every word count. Omitting unnecessary words will make your thoughts clearer and more convincing. I have already talked about entire sentences that are really nothing more than running jumps, particularly at the beginning of paragraphs. *Often you can find running jumps at the start of the sentences*, too. Such phrases as "It should be noted that," "It is interesting to note that," "Evidence has shown that," "It has been documented that," "Analysis of the data indicated that," and "The fact of the matter is that" are common in first drafts but should be ruthlessly eliminated in preparing second drafts.

Consider an example:

There has been considerable work to show that when given the choice between a shell without symbionts and one with

symbionts, hermit crabs usually choose the unoccupied shell (e.g., Conover 1976; Li and Pechenik 2004).

That sentence doesn't really become substantive until we get to the symbionts, so let's remove the running jump and be more concise:

 Given a choice between a shell without symbionts and one with symbionts, hermit crabs usually choose the unoccupied shell (e.g., Conover 1976; Li and Pechenik 2004).

Running jumps often find their way into sentences presenting the results of statistical analyses, as in this example:

 Chi-square analysis of the samples collected at Fanghorn Wood, Middle Earth, indicated that there was no significant difference in the proportion of occupied intact pinecones compared to the proportion of occupied damaged pinecones ($\chi^2 = 0.26$; *d.f.* = 1; *p* = 0.61).

Everything preceding and including the words "indicated that" constitutes a running jump. Let readers dive right in:

 At Fanghorn Wood, Middle Earth, the proportion of pinecones occupied by weevils was not significantly affected by whether or not the pinecones were damaged ($\chi^2 = 0.26$; *d.f.* = 1; *p* = 0.61).

I have discussed writing about statistics more fully in Chapter 4.

Verbal excess can also take less conspicuous forms. How might you shorten this next sentence?

 Dr. Smith's research investigated the effect of pesticides on the reproductive biology of birds.

Who did the work: Dr. Smith or her research? A reasonable revision might look like this:

 Dr. Smith investigated the effect of pesticides on the reproductive biology of birds.

We have eliminated one word, and the sentence has not suffered a bit. Working on the sentence further, we can replace "the reproductive biology of birds" with "avian reproduction," achieving a net reduction of 3 more words:

 Dr. Smith investigated the effects of pesticides on avian reproduction.

The next example requires similar attention:

 It was found that the shell lengths of live snails tended to be larger for individuals collected closer to the low tide mark (Fig. 1).

A good editor would eliminate the first phrase of that sentence and prune further from there. In particular, what does the author mean by "tended to be larger?" Here is an improved version of the sentence:

 Snails found closer to the low tide mark had shells that were on average almost 19% larger than those collected higher up on the beach (Fig. 1).

Most wordy sentences suffer from at least 1 of 5 major ailments and can be brought to robust health by obeying the following Five Commandments of Concise Writing.

First Commandment: Eliminate Unnecessary Prepositions

Consider this example:

 The results indicated a role of hemal tissue in moving nutritive substances to the gonads of the animal.

Any sentence containing such a long string of prepositional phrases—"of hemal tissue," "in moving nutritive substances," "to the gonads," "of the animal"—is automatically a candidate for the editor's operating table. This sentence actually contains a simple thought, buried amid a clutter of unnecessary words. After surgery, the thought emerges clearly:

 The results indicated that hemal tissue moved nutrients to the animal's gonads.

Here is another example:

 The cells respond to foreign proteins by rapidly dividing and starting to produce antibodies reactive to the protein groups that induced their production.

The reader's head spins, an effect avoided by the following more concise incarnation of the same sentence:

 In the presence of foreign proteins, the cells divide rapidly and produce antibodies against those proteins.

By eliminating prepositions, "Karlson arrived at the conclusion that" becomes "Karlson concluded that"; "Grazing may constitute a benefit to" becomes "Grazing may benefit"; and "These data appear to be in support of the hypothesis that" becomes "These data support the hypothesis that."

Second Commandment: Avoid Weak Verbs

Formal scientific writing is often confusing—and boring—because the individual sentences contain no real action; commonly, the colorless verb *to be* is used where a more vivid verb would be more effective, as in this example:

 The fidelity of DNA replication is dependent on the fact that DNA is a double-stranded polymer held together by weak chemical interactions between the nucleotides on opposite DNA strands.

This patient suffers from *wimpy verb syndrome*, with a slight touch of excess prepositional phrase. There is potential action in the sentence, but it is sound asleep in the verb “is dependent.” Converting to the stronger verb “depends,” we read:

 The fidelity of DNA replication depends on the fact that DNA is a double-stranded polymer.

But why stop there? Let’s eliminate some clutter (“on the fact that”) and another weak verb (“is”):

The fidelity of DNA replication depends on DNA being a double-stranded polymer.

Along the same lines, can you find a potentially stronger verb for this next sentence?

 Activation of the immune response may be a trigger for disease progression (Bernheim 1980).

Why not replace “may be a trigger” [yawn] with “may trigger” [more exciting]? Then the sentence becomes:

 Activation of the immune response may trigger disease progression (Bernheim 1980).

Similarly:

 Plant vascular tissues function in the transport of food through xylem and phloem.

can be enlivened by converting the phrase “function in the transport of” to the more vigorous verb “transport”:

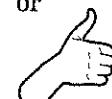
Plant vascular tissues transport food through xylem and phloem.

Note that by choosing a stronger verb, we have also eliminated 2 prepositional phrases (“in the transport” and “of food”). Step by step, the sentence becomes shorter and clearer. But, as often happens during revision, fixing one problem reveals an additional problem. In this case

a fundamental structural weakness makes the reader wonder whether the student understands that “xylem and phloem” are “plant vascular tissues.” Revising now for content, we might rewrite the sentence as:

 Plant vascular tissues (the xylem and phloem) transport nutrients throughout the plant.

or

 Plants transport nutrients through their vascular tissues, the xylem and phloem.

Third Commandment: Do Not Overuse the Passive Voice

Although passive voice has its uses, it is often a great enemy of concise writing—in part because the associated verbs are weak. If the subject (“Rats and mice,” in the following example) is on the receiving end of the action, the voice is passive:

Rats and mice were experimented on by the researchers.

If, on the other hand, the subject of a sentence (“They,” in the following example) is on the delivering end of the action, the voice is active:

They experimented with rats and mice.

Note that the active sentence contains only 6 words, whereas its passive counterpart contains 8. In addition to creating excessively wordy sentences, the passive voice often makes the active agent anonymous, and a weaker, sometimes ambiguous sentence may result:

 Once every month for 2 years, blue mussels (*Mytilus edulis*) were collected from 5 intertidal sites in Barnstable County, MA.

Who should the reader contact if there is a question about where the mussels were collected? Were the mussels collected by the writer, by fellow students, by an instructor, or by a private company? Eliminating the passive voice clarifies the procedure:

 Once every month for 2 years, members of the class collected blue mussels (*Mytilus edulis*) from 5 intertidal sites in Barnstable County, MA.

Similarly, “It was found that” becomes “I found,” or “We found,” or perhaps, “Karlson (1996) found.” Whenever it is important, or at least useful, that the reader know who the agent of the action is, and whenever the passive voice makes a sentence unnecessarily wordy, use the active voice:

Passive: Little is known of the nutritional requirements of these animals.

Active: We know little about the nutritional requirements of these animals.

Passive: The results were interpreted as indicative of . . .

Active: The results indicated . . .

Passive: In the present study, the food value of 7 diets was compared, and the chemical composition of each diet was correlated with its nutritional value.

Active: In this study, I compared the food value of 7 diets and correlated the chemical composition of each diet with its nutritional value.

Note in this last example that it has become perfectly acceptable to use the pronoun *I* in scientific writing; switching to the active voice expresses thoughts more forcibly and clearly and often eliminates unnecessary words.

Fourth Commandment: Make the Organism the Agent of the Action

Consider this example:



Studies on the freshwater hermaphroditic snail *Helisoma trivolvis* showed that whether or not individuals acted as males or females depended on their size (Norton et al 2008).

This is not a terrible sentence, but it can be improved by moving the action from the studies ("Studies . . . showed") to the organisms involved, the snails:



Smaller individuals of the freshwater hermaphroditic snail *Helisoma trivolvis* adopted a male role in mating more often than larger snails did (Norton et al 2008).

The revised sentence is shorter, clearer, and more interesting because now an organism is doing something. Along the way, a prepositional phrase ("on the freshwater hermaphroditic snail") has vanished. Note that I have also added more substance to the summary of the findings, by noting what the trend in mating was rather than simply saying that there was a trend.

Alternatively, one could include the researchers in the action:



Norton et al (2008) showed that certain hermaphroditic snails (*Helisoma trivolvis*) were more likely to act as males when they were small and as females when they were larger.

Similarly, redirecting the action transforms:



The reaction rate increased as pH was increased from 6.0 to about 8.0 and then declined between a pH of 8.5 and 9.0 (Fig. 1).

to



Trypsin was maximally effective at pHs between about 8.0 and 8.5 (Fig. 1).

Note that the author of the original version redrew a graph in words. We can easily picture the author staring at the graph and its axes while writing. In the revised version, the author makes the enzyme the agent of the action, and the message comes through much more clearly.

Fifth Commandment: Incorporate Definitions into Your Sentences

If you find yourself writing something like "Kairomones are defined as . . ." you're on your way to writing a wordy and boring sentence. Instead, try to incorporate definitions into substantive sentences that move your presentation forward. For example, you might write something like this:

Chemicals (known as "kairomones") that are released by predators can sometimes induce morphological changes in their crustacean prey.

REVISING FOR FLOW

A strong paragraph—indeed, a strong paper—takes the reader smoothly and inevitably from a point upstream to one downstream. Link your sentences and paragraphs using the appropriate transitions so that readers move effortlessly and inevitably—logically and unambiguously—from one thought to the next. Minimize turbulence. Remind readers of what has come before and help them anticipate what is coming next. Consider the following example:



Since aquatic organisms are in no danger of drying out, gas exchange can occur across the general body surface. The body walls of aquatic invertebrates are generally thin and water permeable. Terrestrial species that rely on simple diffusion of gases through unspecialized body surfaces must have some means of maintaining a moist body surface or must have an impermeable outer body surface to prevent dehydration; gas exchange must occur through specialized, internal respiratory structures.

This example gives the reader a choppy ride and cries out for careful revision—not of the ideas themselves but of the way they are presented. In the following revision, note the effect of 2 important transitional expressions, *thus* and *in contrast to*. The first connects 2 thoughts; the second warns the reader of an approaching shift in direction.



Since aquatic organisms are in no danger of drying out, gas exchange can occur across the general body surface. Thus, the body walls of aquatic invertebrates are generally thin and water permeable, facilitating such gas exchange.

In contrast to the simplicity of gas exchange mechanisms among aquatic species, terrestrial species that rely on simple diffusion of gases through unspecialized body surfaces must either have some means of maintaining a moist body surface or must have an impermeable outer body covering that prevents dehydration. If the outer body wall is impermeable to water and gases, respiratory structures must be specialized and internal.

In the first draft, the reader must struggle to find the connection between sentences. In the revised version, the writer has assisted the reader by connecting the thoughts, resulting in a more coherent paragraph.

Here is one more example of a stagnating paragraph that carries its readers nowhere:

 The energy needs of a resting sea otter are 3 times those of terrestrial animals of comparable size. The sea otter must eat about 25% of its body weight daily. Sea otters feed at night as well as during the day.

Revising for improved flow, or coherence, produces the following paragraph. Note that the writer has introduced no new ideas. The additions underlined here are simply clarifications that make the connections between each point explicit:

 The energy needs of a resting sea otter are 3 times those of terrestrial animals of comparable size. To support such a high metabolic rate, the sea otter must eat about 25% of its body weight daily. Moreover, sea otters feed continually at night as well as during the day.

The following transitional words and phrases are especially useful in linking thoughts to improve flow: in contrast, however, although, for example, thus, whereas, even so, nevertheless, moreover, despite, in addition to. The use of such words can also help readers see connections between adjacent paragraphs, as in the following example (connecting words are underlined):

 Decreased fecundity due to inbreeding depression is well documented in plants. [The student then gives several examples]... and in *Trillium erectum*, self-pollinated plants produced 71% fewer seeds than outcrossed plants (Irwin 2001).

Similar effects of inbreeding on fecundity have also been reported in a number of bird species. For example,...

Repetition and summary are highly effective ways to link thoughts. Repetition was used to connect the first 2 sentences of the revised example about sea otters; “To support such a high metabolic rate” essentially repeats, in summary form, the information content of the first sentence. Repetition was also used to link the paragraphs about

inbreeding that you just read. In reminding readers of what has come before, the author consolidates the information and then moves on. Use these and similar transitions to move the reader smoothly from the beginning of your paper to the end. Be certain that each sentence—and each paragraph—sets the stage for the one that follows and that each sentence—and each paragraph—builds on the one that came before.

A Short Exercise in Establishing Coherence

Your sentences should lead so logically and smoothly from one thought to the next that should the wind scatter individual sentences of a paragraph, someone who collects the windblown sentences should be able to reassemble the original paragraph. For example, I have deliberately disassembled a paragraph (from Lee et al 1999) into the following isolated sentences:

- a. It is becoming clear, however, that although wave propagation is a common feature of activation, there are both subtle and significant differences in this response when comparing eggs from different species.
- b. It appears that all vertebrate, invertebrate, and perhaps even some plant eggs are activated by the generation of calcium transients in their cytoplasm (Roberts et al 1994; Lawrence et al 1997).
- c. In contrast, activation triggers a series of repetitive calcium waves or oscillations in annelids (Stricker, 1996), ascidians (Albrieux et al. 1997), and mammals (Kline and Kline 1992), including humans (Homa and Swann 1994; Tesarik and Testart 1994).
- d. For example, in fish (Gilkey et al 1978), echinoderms (Stricker et al 1992), and frogs (Busa and Nuccitelli, 1985; Kubota et al 1987), a single calcium wave is propagated across the activating egg.
- e. In most cases these transients take the form of propagating calcium waves (Jaffe 1985; Epel 1990; Whitaker and Swann 1993), which appear to be essential for activating the eggs.

Try reconstructing the original paragraph. Clearly, sentence “a” can’t be the opening sentence of the paragraph. Why not? What sentence most likely precedes sentence “a”? What sentence most likely follows sentence “a”? What words provide the clues that allow you to answer these questions? Which sentence provides the most general statement of the problem? I nominate that sentence as our best candidate for the opening sentence of the paragraph. The correct sentence order is shown at the end of this chapter. Try to make your own paragraphs as easy to reconstruct—in part by using the tricks of repetition and summary and by using appropriate transitional words and phrases.

Improving Flow Using Punctuation

Judicious use of the semicolon can also ease the reader's journey. In particular, when the second sentence of a pair explains or clarifies something contained in the first, you may wish to clarify the logical connection between the 2 thoughts by using a semicolon. Consider the following 2 sentences:

 This enlarged and modified bone, with its associated muscles, serves as a useful adaptation for the panda. With its "thumb," the panda can easily strip the bamboo on which it feeds.

The reader probably has to pause to consider the connection between the 2 sentences. Using a semicolon, the passage would read:

 This enlarged and modified bone, with its associated muscles, serves as a useful adaptation for the panda; with this "thumb," the panda can easily strip the bamboo on which it feeds.

The semicolon links the 2 ideas and eliminates an obstruction in the reader's path.

Similarly, a semicolon provides an effective connection between thoughts in the following 2 examples:

 Recently we demonstrated the rapid germination of radish seeds; nearly 80% of the seeds successfully germinated within 3 days of planting.

 Recombinant DNA technology enables large-scale production of particular gene products; specific genes are transferred to rapidly dividing host organisms (yeast or bacteria), which then transcribe and translate the introduced genetic templates.

ADDITIONAL REVISIONS

Revising for Teleology and Anthropomorphism

Remember, most organisms do not act or evolve with intent. Consider the following examples of teleological writing and learn to avoid it in your own work:

Barnacles cannot move from place to place and therefore had to evolve a specialized food-collecting apparatus in order to survive.

Squid and most other cephalopods lost their external shells in order to swim faster, and so better compete with fish.

Many animals use antipredator behaviors to increase their chance of survival.

Revise all such teleology out of your writing. Don't have nonhuman animals thinking and planning.

Also beware of anthropomorphizing, in which you give human characteristics to nonhuman entities, as in this example:

The existence of sage in the harsh climate of the American plains results from Nature's timeless experimentation.

Again, this conveys a rather fuzzy picture about how natural selection operates. The author would be on a firmer ground by writing something like this:

Sage is one of the few plants capable of withstanding the harsh, dry climate of the American plains.

Revising for Spelling Errors

Misspellings convey the impression of carelessness, laziness, or perhaps even stupidity. These are not advisable images to present to instructors, reviewers, prospective employers, or the admissions officers of graduate or professional programs.

It helps to keep a list of words that you find yourself using often and consistently misspelling. *Desiccation* and *argument* were on my list for quite some time; *proceed* and *precede*, and *stationary* and *stationery*, are still on it. When in doubt, use a dictionary or a Google search. And if you add technical terms to your computer program's dictionary, be careful to enter the correct spellings.

A few peculiarities of the English language are worth pointing out:

1. *Mucus* is a noun; as an adjective, the same slime becomes *mucous*. Thus, many marine animals produce mucus, and many marine animals produce mucous trails.
2. *Seawater* is always a single word. *Fresh water*, however, is usually 2 words as a noun and 1 word as an adjective. Thus, freshwater animals live in fresh water. The Council of Science Editors no longer insists on this usage, however, and different publishers are setting their own rules.
3. *Species* is both singular and plural: 1 species, 2 species. But the plural of *genus* is *genera*: 1 genus, 2 genera.
4. The plural forms of alga, bacterium, and hypothesis are algae, bacteria, and hypotheses.
5. When writing about insect larvae, *worm* is never written as a separate word because insect larvae are not true worms (i.e., they are not annelids). One studies *silkworms*, for example, not *silk worms*. Similarly, for 2-part insect names, the second part (e.g., *fly* or *bug*) is never written as a separate word when it is not correct systematically; otherwise it is written as a separate word. We

write, for example, about *butterflies* (which do not belong to the order Diptera, containing true flies) and about *house flies* (which are true flies) and *bed bugs* (which are true bugs, members of the order Hemiptera).

See also the distinction between *effect* and *affect* (discussed below). And *don't forget to underline or italicize scientific names*: *Littorina littorea* (the periwinkle snail), *Chrysemys picta* (the eastern painted turtle), *Taraxacum officinale* (the common dandelion), *Caenorhabditis elegans* (a nematode worm, the first animal to have its entire genome sequenced), *Homo sapiens* (the only animal that writes laboratory reports).

Spelling Issues That Need Attention

1. Capitalize formal common names of all organisms: e.g. "This research concerns the impact of xxx on Largemouth Bass."
2. Capitalize genus names but not the specific epithet; e.g. "Crepidula spp." "Crepidula fornicata"
3. Capitalize the formal names of taxonomic groups (e.g., phyla, classes, and orders); e.g., "Gastropoda" or "Echinodermata", but not the common names, e.g., "Many gastropods."
4. Capitalize terms such as "table" and "figure" when referring to specific tables and figures; e.g., "as seen in Table 4 and Figure 3."

REVISING FOR GRAMMAR AND PROPER WORD USAGE

While on the lookout for sentence fragments, run-on sentences, faulty use of commas, faulty parallelism, incorrect agreement between subjects and verbs, and other grammatical blunders, you should also be on the lookout for violations of 12 especially troublesome rules of usage when revising your work.

1. *between* and *among*. *Between* (from *by twain*) usually refers to only 2 things:

The 20 caterpillars were randomly distributed between the 2 dishes.

Among usually refers to more than 2 things;

The 20 caterpillars were randomly distributed among the 8 dishes.

2. *which* and *that*.

This fish, which lives at depths up to 1,000 m, experiences up to 101 atmospheres of pressure.

A fish that lives at a depth of 1,000 m is exposed to 101 atmospheres of pressure.

In the first example, *which* introduces a nonrestrictive (nondefining) clause. The introduced phrase is, in effect, an aside—adding extra information about the fish in question. The sentence would survive without the aside. On the other hand, the *that* in the second example introduces a restrictive (defining) clause; we are being told about a particular fish, or type of fish—one that lives at a depth of 1,000 m. Most of your *whichs* should be *thats*.

Improper use of *that* and *which* can occasionally lead to ambiguity or falsehood. Consider the following sentence about the production of proteins from messenger RNA (mRNA) transcripts:



This difference in protein production is due to different amounts of mRNA that translate and produce each particular protein.

Here, *that* correctly introduces a restrictive clause. Which mRNA molecules? The ones coding for these particular proteins. The writer is telling us that proteins are produced in proportion to the number of mRNA molecules coding for them within the cell. Replacing *that* with *which* drastically changes the meaning of the sentence:



The difference in protein production is due to different amounts of mRNA, which translates and produces each particular protein.

The sentence has lost clarity because *which* now introduces a non-defining clause that should be explaining only what mRNA does in general. In the following sentence, using the word *which* conveys information that is actually wrong:



In squid and other cephalopods, which lack external shells, locomotion is accomplished by contracting the muscular mantle.

Here, the writer asserts that no cephalopods have external shells; however, some species *do* have external shells. The correct word is *that*:



In squid and other cephalopods that lack external shells ...

Now the writer correctly refers specifically to those cephalopods without external shells.

As in the examples given, *which* is preceded by a comma. When deciding between *which* and *that* in your own writing, read your sentence aloud. If the word doesn't need a comma before it for the sentence to make sense, the correct word is probably *that*. If you

hear a pause when you read, signifying the need for a comma, the correct word is probably *which*.

3. *its* and *it's*. *It's* is an abbreviation for *it is*. If *it is* does not belong in your sentence, use the possessive pronoun *its*:

When treated with the chemical, the protozoan lost its cilia and died.

It's clear that the loss of cilia was caused by treatment with the chemical.

While we're at it, let's revise that last sentence to eliminate the passive voice:

It's clear that treatment with the chemical caused the loss of cilia.

In general, contractions are not welcome in formal scientific writing. Thus, you can avoid the problem entirely by writing *it is* when appropriate.

It is clear that treatment with the chemical caused the loss of cilia.

4. *effect* and *affect*. Effect as a noun means a "result" or "outcome":

What is the effect of fuel oil on the feeding behavior of sea birds?

Effect as a verb means "to bring about":

What changes in feeding behavior will fuel oil effect upon sea birds?

Affect as a verb means "to influence" or "to produce an effect upon":

How will the fuel oil affect the feeding behavior of sea birds?

Used as a verb, *effect* can, indeed, be replaced in the preceding example by *bring about* but not by *influence*. *Affect* can, indeed, be replaced by *influence* but not by *bring about*. *Affect* and *effect* are so similar in meaning that determining the correct verb can be difficult. Memorizing the definitions of the 2 words as well as memorizing the examples above may help you choose the correct word.

5. *rate*. "Rates" have units of "something per time": moles of substrate degraded per minute, numbers of centimeters (cm) moved per second, numbers of births per year, and so forth. If you are writing about something that does not have units of "per time," then do not use the word *rate*.
6. *i.e.* and *e.g.* These 2 abbreviations are not interchangeable. The abbreviation *i.e.* is an abbreviation for the Latin *id est*, meaning

"that is" or "that is to say." Use this abbreviation to introduce a specific explanation or clarification. For example:

Data on sex determination suggest that this species has only two sexual genotypes, i.e., female (XX) and male (XY).

The embryos were undifferentiated at this stage of development; i.e., they lacked external cilia and the gut had not yet formed.

In contrast, *e.g.* stands for *exempli gratia*, which means "for example." This abbreviation introduces general examples, as illustrated below:

During the precompetent period of development, the larvae cannot be induced to metamorphose (e.g., Crisp 1974; Bonar 1978; Chia 1978; Pires 2020).

However, the larvae of several butterfly species (e.g., *Papilio demodocus* Esper, *Papilio eurymedon*, and *Pieris napi*) are able to feed and grow on plants that the adults never lay eggs on.

In the first case, the writer uses *e.g.* to indicate that what follows is only a partial listing of references supporting the statement. The parenthetical means: "for example, see these references." In the second case, the writer uses *e.g.* to indicate only a partial list of butterfly species that do not lay eggs on all suitable plants.

7. *However*, *therefore*, and *moreover*. These words are often incorrectly used as conjunctions, as in the following examples:



The brain of a toothed whale is larger than the human brain, however the ratio of brain to body weight is greater in humans.



The resistance of mosquito fish (*Gambusia affinis*) to the pesticide DDT persisted into the next generation bred in the laboratory, therefore the resistance was probably genetically based.



Protein synthesis in frog eggs will take place even if the nucleus is surgically removed, moreover the pattern of protein synthesis in such enucleated eggs is apparently normal.

These examples all demonstrate the infamous comma splice, in which a comma is mistakenly used to join what are really 2 separate sentences. *Reading aloud, you should hear the material come to a complete stop before the words however, therefore, and moreover.* Thus, you must replace the commas with either a semi-colon or a period, as in these revisions of the first example:



The brain of a toothed whale is larger than the human brain; however, the ratio of brain to body weight is greater in humans.



The brain of a toothed whale is larger than the human brain. However, the ratio of brain to body weight is greater in humans.

8. **concentration and density.** People often use *density* when they mean concentration, as in the following example:

Larvae were more active at the highest of the 3 food densities.

Although “density” *can* refer to the number of things per unit volume (e.g., cells per milliliter [ml], as in this example, or moles per liter), it can also mean mass per unit volume. To avoid ambiguity, it would be better to write about the 3 food “concentrations.”

9. **weight and mass.** Although biologists often use these terms interchangeably, the units kg, g, mg (and pounds) are actually units of mass, not weight. Mass is an intrinsic property of matter, whereas weight varies with the force of gravity. An object with a mass of 127 g at sea level on Earth will have the same mass on the moon but a substantially smaller weight. Thus, it is best to follow this model:

The juveniles used in this study varied in mass between 64 and 72 g.

10. **varying and various.** *Varying* means “changing over time” or with changing circumstances, whereas *various* means “different.” Consider the following example:

We also examined feeding rates among animals maintained at varying temperatures.

It is certainly possible that temperature was caused to change over time during the study. However, the authors maintained animals at each of 4 constant temperatures. A revised version of the sentence might read:

We also examined feeding rates among animals maintained at 4 different temperatures over the range of 15–29°C.

Misuse of the word *varying* sometimes adds a bit of amusement to an otherwise dreary day:

Five shells of varying sizes were then selected for each hermit crab.

You can almost visualize each shell pulsating and undulating as it waits to be inspected by the hermit crabs. What the student meant

to write, of course, was “shells of various sizes” or “shells of different sizes.”

11. Proper use of commas in writing species names. Use commas to set off formal species names only when the formal names are preceded by specific common names. For example, you would use a comma before the species name here:

We extracted genomic DNA from embryos of the common blue mussel, *Mytilus edulis*.

but not here:

We extracted genomic DNA from embryos of the mussel *Mytilus edulis*.

12. Using scientific names as adjectives. According to the Council of Science Editors (2024), it is acceptable to use scientific names as adjectives, but only in the following ways. You can talk about “streptococcal infections” or about “streptococcus infections” as long as the genus name (*Streptococcus*) is not capitalized and is not italicized or underlined (i.e., it’s acceptable to use the generic name in the vernacular). You can use the formal genus name as an adjective only if you are referring to all species within the genus, as in “We included all known *Photinus* firefly species in our analysis.” You can use an organism’s complete scientific name (the binomial) as an adjective when you are referring only to members of that particular species, as in “*Photinus ignitus* fireflies were studied . . .”

13. And don’t forget: the data *are* . . .

A Grammatical Aside: Rules that Are Not Rules

[S]ome grammarians have invented rules they think everyone should observe. . . . But since grammarians have been accusing the best writers of violating these rules for the last 200 years, we have to conclude that for 200 years the best writers have been ignoring both the rules and grammarians.

—Joseph Williams

Here are some of the rules-that-are-not-rules that Williams is referring to:

Never begin a sentence with *And*.

Never begin a sentence with *But*.

Never begin a sentence with *Because*.

Never write a paragraph with fewer than 3 sentences.

Never end a sentence with a proposition.

Never split an infinitive.

"To boldly go where no man has gone before?" Problem? I don't think so. You can't split an infinitive (e.g., to go, to see, to conquer) in Latin, or Spanish, or Italian, or French, because the infinitives in those languages are a single word. In English, they're 2 words, so they can be split. The renowned linguist Steven Pinker puts it this way: "[F]orcing modern speakers of English to not split . . . an infinitive because it isn't done in Latin makes about as much sense as forcing modern residents of England to wear laurels and togas" (Pinker 1994 p 386).

Most of the rules-that-are-not-rules were taught to us in grade school for good reasons—for example, to keep us from making real grammatical mistakes or to encourage us to develop our ideas more logically and fully. But they were training wheels; it's okay to take them off now! Certainly, it would irritate your readers to begin too many sentences with *but*, and you don't want to write so *cutely* that you give readers the impression you don't take your work seriously. Did you notice that I started a sentence with the word *But* two sentences back? Used every now and then, violating the "rules" about *and*, *but*, and *because* can be a very effective way of making an important point stand out.

A Strategy for Revising: Pass by Pass by Pass

As noted previously, fixing one set of problems usually brings other problems to the surface. *Don't try to fix everything at once.* Instead, plan to make a series of passes through your work, fixing different sorts of problems with each pass. *The more time you allow for revision and the more revisions you complete, the more effective your writing will become.*

First, look carefully at content. Second drafts commonly arise from only a small portion of the first—perhaps a few sentences buried somewhere in the last third of the original. In such a case, you must abandon most of the first draft and begin afresh, but this time you are writing from a stronger base.

Now, read your paper again and look for organizational problems. Once you are happy with the order in which ideas are presented and have created convincing, logical connections between them, make another few passes through your paper to revise for completeness, conciseness, clarity, and flow. Use lots of strong verbs! Warning—as you improve the clarity and conciseness of the writing, you will sometimes find problems with the ideas themselves. As noted at the start of this chapter, thoughtful revising is extremely useful in developing your thinking.

Finally, revise for spelling and grammatical mistakes. You might try using an artificial intelligence program to do this; let me know how that works for you! And don't forget to proofread carefully before you turn in your work.

BECOMING A GOOD REVIEWER

You don't always have to chop with the sword of truth. You can point with it, too.

—Anne Lamott

The best way to become an effective reviser of your own writing is to become a critical reader of other people's writing. Whenever you read a newspaper, magazine, research paper, or textbook, watch for ambiguity and wordiness; think about how the sentence or paragraph might best be rewritten. You will gradually come to recognize the same problems, and the solutions to those problems, in your own writing.

Encourage fellow students to give you drafts of their work to look over at least several days before the final piece is due. *Be concerned first with content and organization.* Until you are convinced that the author has something to say, it makes little sense to be overly concerned with how something is said—for the same reason it would make little sense to wash and wax a car that was headed for the auto salvage.

Take an especially careful look at the title and the first few paragraphs. Does the title clearly indicate the topic of the paper or laboratory report? Do the title and first paragraph seem closely related? In the first 1 or 2 paragraphs, do the sentences flow logically to establish a clear direction for what follows? Can you tell from the first or second paragraph exactly what this paper, proposal, or report addresses, and why the issue is of interest? Or are you reading a series of apparently unrelated facts that seem to lead nowhere or in many different directions? Does the first paragraph head in one direction, the second in another, and the third in yet another? If so, focus your comments on those issues.

If you are examining a laboratory report, study the results section first. Does it conform to the requirements outlined in Chapter 9? Does the materials and methods section answer all procedural questions that were not addressed in the figure captions and table legends? Should some of those issues (e.g., experimental temperature) be addressed in the captions and legends, or directly on the graphs or in the tables? Does the introduction section state a clear question and provide the background information needed to understand why that question is worth asking? Does it provide a compelling rationale for the work that

was done? Does each sentence make sense, and does each one lead in logical fashion to the next? Does each paragraph of the Introduction follow logically from the previous paragraph? Does the concluding paragraph address the issue raised the first paragraph? Does the discussion section interpret the data or simply apologize, and does the discussion clearly address the specific issue or issues raised in the Introduction? Are the author's conclusions supported by the data? Does the author suggest what issues should be addressed in future studies?

Only when you can answer yes to these questions should you worry about commenting on conciseness, grammar, and spelling. When examining a first draft, it may be most useful to write a few paragraphs of commentary to the author and not write directly on the paper at all. Don't feel compelled to rewrite the paper for the author; your role is simply to point out strengths and perceived weaknesses and to offer the best advice you can about potential fixes. Here is an example of how this might be done; the student is making comments about the first draft of a research proposal written by a fellow student:

Jim, I think you have a good idea for a project here, but it's not reflected in your introduction (or the title, but that can wait). The question you finally state in the middle of p. 4 caught me completely by surprise. At least until the bottom of p. 2 I thought you were interested in the effects of electromagnetic fields on human development, and by the end of p. 3, I wasn't sure what you were planning to study! On pp. 2-3 especially, I couldn't see how the indicated paragraphs (see my comments on your paper) related to the question you ended up asking. Or perhaps they are relevant, and you just haven't made the connections clear to me. The entire introduction seems to be in the "book report" format we discussed in class, rather than a piece of writing with a point to make (I'm having this trouble, too). The information you present is interesting, but a lot of it seems irrelevant. Try to make clearer connections between the paragraphs, perhaps by leaving some things out. As the Pechenik book says, "Be sure each paragraph sets the stage for the one that follows"—isn't that a great book? Here is a possible reorganization plan: Introduce the concept of electromagnetic fields in the first few sentences (what they are, what produces them); then mention potential damaging effects on physiology and development (at present it's not clear why the question is so important until one gets to p. 6!); then state your question and note why sea urchins are especially good animals to study. Will that work?

Also in the Introduction, I would expand the paragraph on gene expression effects; discuss one or two of the key experiments in some detail, rather than just tell us the results. I think this is important because your experiments are a follow-up on those.

Table 1 seems redundant because you present the same information in Figure 1. Delete Table 1.

Your experimental design seems sound, although I'm not sure the experiments really address the exact question you pose in your introduction (see my comments on the draft; probably you just need to rephrase the question). But I didn't see any mention of a control; without the control, how will you be sure that any of the effects you see were caused by the electromagnetic field? Also, won't your treatment raise the water temperature? If so, you will need to control for that as well.

Finally, you might want to ask Professor Romero about this, but I think you should write for a more scientifically advanced audience. Your tone seems a bit too chatty and informal. And watch those prepositions—you use them almost as freely as I do! I enjoyed reading your paper and look forward to seeing the next draft!

Notice that this reviewer points out the strengths of the piece without overlooking the weaknesses and deals with the major problems first. ***Be firm but kind in your criticism; your goal is to help your colleagues not to crush their egos.*** Be especially careful to avoid sarcasm. Write a page of constructive criticism that you would feel comfortable receiving.

To help you give your classmates helpful criticism on drafts of their assignments, your instructor may provide you with, or ask you to develop, a peer-review sheet. You can also use such forms to self-criticize drafts of your own writing.

Receiving Criticism

I have probably learned more about the business of conducting research from referee comments than from any other single source.

—Phil Clapham

Be pleased to receive suggestions for improving your work. A colleague who returns your paper with only a smile and a pat on the back does you no favor. It is good to receive some positive feedback, of course, ***but what you are really hoping for is constructive criticism.*** On the other hand, you need not accept every suggestion offered. Examine each one honestly and with distance; decide for yourself if the reader is on target. ***Reviews are advisory,*** giving you a chance to see how other people interpret what you have written. Sometimes a reader will misinterpret your writing, and you may therefore disagree with the specific criticisms and suggestions leveled at you. However, if something was unclear to one reader, it may be equally unclear to others. Try to figure

out where the reader went astray and modify your writing to prevent future readers from following the same path.

It is hard to read criticism of your writing without feeling defensive, but learning to value constructive comments puts you firmly on the path to becoming a more effective writer. After all, you want to communicate. If you are not communicating well, you need to know it—and you need to know why.

Fine-Tuning

Once the writing has a clear direction and solid logic, it is time to make 1 or 2 final passes to see that each sentence is doing its job in the clearest, most concise fashion. As a first step in developing your ability to fine-tune your writing, read the 25 sentences that appear below to verbalize the ailment afflicting each one; then revise the sentences that need help. Pencil your suggested changes directly onto the sentences, using the guide to proofreader's notation presented in Table 6.1, as in the following example:

Hermaphoditism is commonly encountered among invertebrates. For example, the young East Coast oyster, *Crassostrea virginica*, matures as a male, later becomes a female and may change sex every few years thereafter. Sequential hermaphrodites generally change sex only once, and usually change from male to female. In contrast to species that change sex as they age, many invertebrates are ~~simultaneous hermaphrodites. Self-fertilization is rare among~~

Problem	Symbol	Example
1. Word has been omitted	caret	study describes effect
2. Letter has been omitted	caret	that bok
3. Letters are transposed	~	form the sea
4. Words are transposed	~	was only exposed
5. Letter should be capitalized	(three short underlines)	these data

6. Letter should be lowercase	/ (slash)	These data
7. Word should be in italics	— (underline once)	<u>Homo sapiens</u>
8. Words are run together	(draw vertical line in between)	edit carefully
9. Word should be deleted	— (draw line through)	the nee -data
10. Space should not have been left	○ (sideways parentheses)	the e nd
11. Wrong letter	/ (draw line through and add correct letter above)	f emale
12. Wrong word	— (draw line through and add correct word above)	These This data
13. Need to begin a new paragraph	¶ (paragraph symbol)	female. In contrast
14. Restore original	STET	the energy needs

Table 6.1 Proofreader's symbols used in revising copy

Sentences in Need of Revision

- To perform this experiment there had to be a low tide. We concluded the study at Blissful Beach on September 23, 2023, at 2:30 PM.
- In *Chlamydomonas reinhardi*, a single-celled green alga, there are two mating types, 1 and 2. The 1 and 2 cells mate with each other when starved of nitrogen and form a zygote.
- Protruding from this carapace is the head, bearing a large pair of second antennae.
- The order in which we think of things to write down is rarely the order we use when we explain what we did to a reader.

5. The distance at which a given marine animal may be able to hear the sound generated by a vessel or wind turbine is very difficult to answer.
6. Swimming in fish has been carefully studied in only a few species.
7. One example of this capacity is observed in the phenomenon of encystment exhibited by many fresh water and parasitic species.
8. An estuary is a body of water nearly surrounded by land whose salinity is influenced by freshwater drainage.
9. The carbon-to-nitrogen ratio of the microbial films gives an indication of the film's nutritional quality. (Bhosle and Wagh 1997).
10. In textbooks and many lectures, you are being presented with facts and interpretations.
11. The human genome contains 25,000 genes, however, there is enough DNA in the genome to form nearly 2×10^6 genes.
12. It should be noted that analyses were done to determine whether the caterpillars chose the different diets at random.
13. These experiments were conducted to test whether the condition of the biological films on the substratum surface triggered settlement of the larvae.
14. Various species of sea anemones live throughout the world.
15. This data clearly demonstrates that growth rates of the blue mussel (*Mytilus Edulis*) vary with temperature.
16. Hibernating mammals mate early in the spring so that their offspring can reach adulthood before the beginning of the next winter.
17. This study pertains to the investigation of the effect of this pesticide on the orientation behavior of honey bees.
18. The results reported here have lead the author to the conclusion that thirsty flies will show a positive response to all solutions, regardless of sugar concentration (see figure 2).
19. Numbers are difficult for listeners to keep track of when they are floating around in the air.
20. Those seedlings possessing a quickly grown phenotype will be selected for, whereas . . .
21. Under a dissecting microscope, a slide with a drop of the culture was examined at 50 X.
22. Measurements of respiration by the salamanders typically took one-half hour each.

23. The results suggest that some local enhancement of pathogen specific antibody production at the infection site exists.
24. Usually it has been found that higher temperatures (30°C) have resulted in the production of females, while lower temperatures (22–27°C) have resulted in the production of males. (e.g., Bull 1980; Mrosousky 1982)
25. Octopuses have been successfully trained to distinguish between red and white balls of varying size.

TECHNOLOGY TIP 5

Tracking changes made to documents

When coauthoring a paper, one person generally writes the first draft and other authors then suggest modifications. For group work, you might draft the materials and methods section, for example, whereas another student drafts the results section. You can email a draft of your section or paper (as an attachment) to another student. If you composed your paper in Word, track changes is a very useful feature for making and identifying suggested changes. The reviewer makes the change directly on the document, and the original author can see what changes were made.

To use this feature in Word, open the document, click Review on the menu bar, and then select Track Changes. All additions to the text will appear in a different color, and deleted text will be indicated on the side (there are options for how additions and deleted items are shown).

You can accept or reject changes one by one or accept all changes in the document at once.

You can also add comments, suggestions, and questions using Insert and then Comment from the menu bar. Be sure to accept all changes and to delete all comments before submitting the document to the course instructor or journal editor.

Don't send your draft to other students until you have revised it a few times yourself. The closer the draft is to final form, the more useful reviewers can be in giving suggestions.

There are several ways to improve each of these sentences. Be sure that you can identify the specific problem in each original sentence, and that your revision solves the problem (and does not introduce any new difficulties).

Checklist

- Allow adequate time for revision.
- Read your paper aloud slowly; listen for problems as you read.
- Don't worry about problems within individual sentences until your paper or report has a beginning, middle, and ending—with

each idea leading logically into the next. Use idea maps to help organize your thoughts.

Revise for content, clarity, and completeness:

Make sure that each sentence says something of substance and says what you intend it to say.

Be cautious in drawing conclusions.

Keep an audience of interested peers in mind as you revise.

Use *it*, *they*, *their*, and other pronouns sparingly; be sure they don't create ambiguity.

Make each statement as specific as possible.

Revise next for conciseness:

Delete "It is interesting to note that . . ." and other running jumps. Just dive right into the issue being presented.

Eliminate unnecessary prepositions.

Replace weak verbs with stronger ones.

Try to have organisms, enzymes, and molecules DOING something.

Revise next for flow (coherence). Improve the logical connections between sentences and paragraphs using appropriate transitional words, summary and repetition, and occasional semicolons.

Incorporate definitions into sentences.

Eliminate teleology and anthropomorphism.

Proofread for spelling and grammatical errors.

Turn in work that you are proud to have completed.

Practice finding problems with other people's writing—including the writing in published papers.

Give criticism to others that is substantive and honest but also be constructive and not insulting.

Answer to a short exercise in establishing coherence (pp. 107): the correct sentence order is b-e-a-d-c.

PART II

Guidelines for Specific Tasks

PRELUDE:

WHY ARE YOU WRITING PAPERS AND PROPOSALS AND GIVING TALKS?

Every time you are asked to write a summary, a critique, an essay, a review paper, a lab report, or a research proposal, your instructor commits to many hours of reading and grading. There must be a good reason to require such assignments; most instructors are not masochists.

Writing papers benefits you in several important ways. First, you end up teaching yourself something relevant to the course you are taking. *The ability to self-teach is essential for success in graduate programs and academic careers; in fact, self-teaching is a skill worth cultivating for success in almost any profession.* In addition, you gain experience in reading the primary scientific literature, as discussed in Chapter 3. Textbooks and many lectures present you with facts and interpretations. By reading the papers on which those facts and interpretations are based, you come face to face with the sorts of data, and with the interpretations of data, on which the so-called facts of biology are based. You gain insight into the true nature of scientific inquiry. *The data collected in an experiment are always real; interpretations, however, are subject to change.*

The writing assignments discussed in the rest of this book will help you move away from the unscientific, blind acceptance of stated facts and toward the scientific, critical evaluation of data and ideas.