Revision, of course, is important to all writing, not just scientific writing. Most of the advice in chapter 21 is therefore universal. In the remainder of Part V, I focus on the journal paper and the process of journal publication. It won't be difficult, though, for you to extrapolate much of that advice to help you with other writing forms.

TWENTY-ONE

Self-Revision

You've just written the final sentence of your Conclusions (or whatever you tend to do last). There it is, on the screen in front of you: a complete manuscript. You have to admire your deft writing touches (if you do say so yourself). It even looks really good, thanks to the wonders of word processing—that's a lovely font you've chosen, and the italics make the subheads stand out effectively. Is it time to share your accomplishment with the world at large?

No! A few writers produce "first drafts" that are ready for public consumption (chapter 2), but most of us will never join their ranks. Nearly everything written by nearly every scientist goes through three more stages before it's ready for its readers: self-revision, friendly review (comments from colleagues and friends), and finally formal review (journal peer review or its equivalent). These stages have distinct functions and follow different processes, so I treat them in separate chapters.

Friendly and formal reviews (chapters 22 and 23) are invaluable tools for improving the clarity and quality of your writing. However, the kindness and patience of your reviewers are not inexhaustible resources. If you send them manuscripts that aren't the best-polished you can manage, you'll find they become less willing to help you with your next offering. If you've ever read a manuscript for someone else, and found yourself muttering under your breath "How is it *my* job to catch such obvious mistakes?," then you know exactly what I mean. And if you haven't yet muttered along those lines, before long you will.

So before you ask anyone else to help you edit your draft manuscript, you owe it to them and to yourself to do as much self-revision as you can. If you do this well, you'll send out something that reviewers will be

happy to read, happy to help you improve further—and, ultimately, happy to accept for publication.

When Not to Self-Revise

While it's important to know when (and how) to self-revise, it's also important to know when *not* to. In particular, you should avoid self-revision **while you are writing your first draft** and also **immediately after you've completed that draft.** The first point was a major message of chapter 6; remember to storm the beach. The second point is equally important. Avoid the temptation to start self-revision as soon as you've finished a draft. Actually, you might not face this temptation—upon completing the first draft, you may be so sick of the project that you can't bear to look at it for a while. But if you *are* fired up and ready to dive into self-revision right away, fight the urge. Instead, put the draft away and don't think about it for a week or so. Your draft won't change in that week, but your ability to look at it critically will. In particular, the major challenge of self-revision is to see the text as a reader rather than as its writer—a psychological trick that is difficult at the best of times, but nearly impossible if the draft is too fresh in your mind. Meanwhile, if you're champing at the bit to keep writing, that's great—just turn to another piece of writing. Momentum, after all, is too precious to waste.

Taking Self-Revision Seriously

Beginning writers—and even senior ones—often struggle with self-revision in an interesting way: they *fail* to struggle with it. Instead, they give their draft a quick once-over, fix the inevitable grammatical errors and typos, and pronounce it much improved. Writers for whom this will suffice are rare (and unlikely to be reading this book). For the rest of us, self-revision doesn't mean a little polishing. Instead, it means grappling seriously with every sentence and every word in your draft. It means critical self-destruction and reconstruction. It means fixing material that doesn't work or removing material that doesn't fit, no matter how much blood, sweat, and tears it took to produce it.

Deleting material you toiled over can be heartbreaking, but delete you must. "Murder your darlings," Sir Arthur Quiller-Couch (1916) famously advised. Quiller-Couch[1] was referring in particular to excesses of style. More completely, his advice ran, "Whenever you feel an impulse to perpetrate a piece of exceptionally fine writing, obey it—wholeheartedly—and delete it before sending your manuscript to press. *Murder your darlings.*" (Whether there might be a place in scientific writing for *some* "exceptionally fine style" is something I take up in chapter 28.)

Quiller-Couch's advice applies to content just as aptly as to style. You'll find that it's routine to labor over a paragraph, a figure, or an analysis, only to find upon critical rereading that it just doesn't belong. Perhaps the story you're telling has shifted during writing, or what seemed relevant in your mind seems unnecessary on paper. As an example, in a recent paper (Heard and Kitts 2012) I dealt with the impact of an herbivorous insect on two species of goldenrods. In the Introduction I brought up the notions of resistance to, and tolerance of, herbivory. In a nutshell, *resistance* means plants fighting off insect attack, and *tolerance* means plants growing despite attack. But each concept is more slippery than that, and I found myself providing detailed definitions and adding a figure and half a dozen citations. At this point I converted the passage to an Appendix, which grew to several pages of text with even more citations. All this took about three days of solid writing effort—but during self-revision I realized that the material was tangential to the manuscript, and that some fine reviews of resistance and tolerance were already in the literature. With an anguished sob, I deleted the whole thing, and not a word survives in the published manuscript. When you find a passage like this in your own work, take it out!

If you waver in your ruthlessness, hesitating as your finger approaches the Delete key, consider a bit of self-deception. This is how I soften the blow: rather than just deleting excess material, I cut-and-paste it to a

[1] The deliciously-named Sir Arthur Quiller-Couch was a Cornish novelist, poet, critic, and anthologist. His 1916 *On the Art of Writing* doesn't stand up terribly well today, but his incitement to "murder your darlings" is widely quoted. *Murder Your Darlings* is also the name of an Ohio metal-punk band who describe their music as "displaying the darkness of the downtrodden working man and an entire generation of Southern rockers, kick[ing] it up with Northern hardcore-punk nihilism and finish[ing] with a touch of Midwest noise-rock buzzsaw gravy" (http://www.murderyourdarlings.com/index.html). I suspect this would have puzzled Sir Arthur as much as it delights me.

separate document that I name "cuts_to_maybe_restore." I can't remember ever actually restoring something from one of my "cuts" files, but somehow the theoretical possibility of resurrection makes it easier for me to murder my own darlings.

Getting Out of Your Head and Into Your Reader's

The key to effective self-revision is a mental trick that's probably the single most important piece of the writing craft: getting out of your own head, and into the reader's. In order to assess your writing—to find where your bid for telepathic clarity fails, and decide how to fix it—you need to read your draft **as if you were the reader you're trying to reach**. Of course your draft is perfectly clear to *you*: you wrote it, and you know what you meant to say. But communicating telepathically with your *own* mind isn't an impressive trick! To really evaluate your draft you need to achieve, or at least simulate, a mental state in which you have access only to the information a reader does: to your text, and to whatever background knowledge you can legitimately assume from your intended audience. This means forgetting what you meant to say, and forgetting all those things you know but didn't put in the text. For instance, "reader-you" should get confused by a pronoun that lacks an obvious antecedent, even though "writer-you" knows perfectly well what's intended.

We can call the necessary mental trick "reader simulation," and it's a specific case of a more general mental ability that psychologists call having a "theory of mind." Theory of mind is your ability to simulate (or work out) what another person is thinking, independently of your own mental state. This includes the ability to realize that the other person lacks knowledge that you have (Box 21.1).

Box 21.1 Theory of mind

Theory of mind is a bit abstract and can be hard to grasp without a concrete example. There's a classic experiment that makes it concrete. Imagine that I tell you this story:

> Alice and Bai were watching TV together. Bai watched Alice put the TV remote on the end table, and then went to the kitchen to get more snacks. While Bai was gone, Alice moved the TV remote to the bookcase. After returning to the room, Bai wanted to change the channel.
>
> I diagnose your theory of mind by asking you where Bai looked for the remote. If you say "on the bookcase," you fail to realize that Bai lacks knowledge that you possess (that Alice moved the remote while he was gone). But if you say "on the end table" you have constructed a simulation of Bai's mental state, and this simulation differs from your own. You have an effective theory of mind.
>
> In revision, you need this ability to simulate the reader's mental state independently of your own, in order to see your text as a reader will see it. You need to set aside your own knowledge of what you meant to say, realizing that it's inaccessible to your reader—knowledge equivalent to your realization, unavailable to Bai, that Alice moved the remote.

Achieving reader simulation is not a trivial task. Deploying one's theory of mind takes effort, and we tend not to bother without a conscious decision that doing so is necessary. You know this if you have a friend who loves oysters or Brussels sprouts or peaty Scotch, and keeps offering them to you no matter how many times you explain you don't like them. It doesn't mean your friend has a defective theory of mind; rather, without conscious resolve otherwise, most of us tend to project our own thinking onto others. The same conscious resolve is necessary during self-revision.

Fortunately, with practice you can improve your ability to slip deliberately into reader simulation. In the meantime, there are a number of simple techniques you can use to help keep you thinking as the reader, rather than as you:

- **Read for self-revision in a different place or time than you wrote your draft.** Memory is strongly keyed to the context of learning, so it's much easier to remember something if you are exposed to the same environment in which you learned it (Godden and Baddeley 1975). For instance, facts painstakingly memorized while studying in a coffee bar may be distressingly elusive when you're writing a final exam in a gymnasium—unless you're lucky enough to catch a whiff of your

instructor's cappuccino passing by. In the educational and psychological literature, this phenomenon is normally seen as something that can be exploited to improve memory, but in writing you can exploit it in reverse as a way to help *disrupt* memory. If you wrote your draft on weekday afternoons in your office, you may want to begin self-revision on weekend mornings in the library or in your child's treehouse. The difference in sights, smells, and sounds will make it easier for you to leave your own head and get into the reader's. And if every now and again you ask yourself what on earth you're doing working in the "wrong" place or at the "wrong" time, answering the question can help with your conscious focus on reader simulation.

- **Read for self-revision at the time of day you think least clearly**. All of us have circadian rhythms in physiology, including in aspects of mental performance (Carrier and Monk 2000). You probably know whether you're an early bird like me (pretty smart in the morning, but dumber than a rock by suppertime) or a night owl whose thinking is muddled before noon. You probably even take advantage of this by taking on mentally demanding tasks at your clearest-thinking time of day. But achieving reader simulation may be easier if you turn this logic on its head, and read for self-revision when you *don't* think so clearly. This isn't about trying to simulate stupid readers; rather, you are looking to counterbalance your overfamiliarity with what you meant to say with a bit of useful mental fog. If your draft is clear to you even when you're not thinking your best, great—and if it's not, you've found something to fix.
- **Convert your draft to an unfamiliar font or medium**. A simple trick to achieve the unfamiliarity you're after is to change to a font different from the one you usually write in. If the strangeness of the font gives you an odd sensation of reading someone else's words, you're succeeding at reader simulation. Similarly, if you normally read on the computer screen, print out your draft and read on paper.
- **Read your draft out loud**. When you read familiar text quietly to yourself, it's very easy to read what you meant to write, not what you actually wrote. It's much harder to make the same mistake when you hear your work read out loud. Mind you, if you have oratorical or dramatic experience, this is a good time to forget it—your aim is not to make the text sound its best, but rather to lay bare its flaws. Read what you wrote as simply as you can, with each word pronounced and each punctuation mark interpreted as it lies. Listen for awkwardness, repetition, and unclear meaning. As you find these issues, mark them for later and keep reading aloud.

- **Post a reminder**. The four techniques above are aimed at weakening your unconscious tendency to think as the writer. But you should not neglect the converse: opportunities to strengthen your conscious decision to think as the reader. Any time that you can explicitly ask yourself "How would a reader take this passage?," you have a chance to assess your progress toward crystal clarity. The problem is that it's difficult to maintain conscious reader-simulation, and natural instead to slip back into being writer-you. So post a reminder: make a sign that says "Be the Reader" in large, friendly letters, and hang it directly over your workspace. Move it around, too, so it won't get too familiar and recede into your mental background. Print it in the margins of your draft, if that helps. Each time you notice it, reinforce your conscious reader-simulation.
- **Target typical problems of writer familiarity.** Some particular writing problems are likely to arise, or to be overlooked, precisely because you know what you meant to say. In self-revision, you can target these deliberately. Most of these have been covered in more detail in earlier chapters, so brief reminders will suffice here. Problems closely linked to writer familiarity include:
  - **Unclear pronoun antecedents**. Check every pronoun (especially the demonstrative *this*, *that*, *these*, and *those*), asking "if I knew nothing more than the words on paper say, what could I reasonably think this pronoun refers to?" If there is more than one answer, or if the answer differs from what you intended when you wrote, fix the problem.
  - **Misaligned topic sentences**. You know how your argument flows, and how each paragraph is intended to contribute. But your reader may not. For each paragraph, ask whether the topic sentence clearly signals the content to follow.
  - **Missing transitions**. It may be obvious to you why topic B immediately follows topic A, but you've been thinking about the relationship between A and B for years. Make sure you've made transitions between ideas, paragraphs, and sections smooth for the reader.

- **Assumed knowledge**. It's surprisingly easy to leave important information out of your draft. I once read a manuscript in which the author supplied the Latin name of the study organism—but neglected to tell me that it was a plant, something that mattered quite a bit but didn't become clear from the context for some time. Particular trouble spots for the assumed-knowledge problem are the Abstract, the beginning and end of the Introduction, and the Methods, so scan these especially carefully and ask yourself if your intended audience can be counted on to know everything your text assumes they do.

Decomposing the Process

The sort of major overhaul that I've called for may sound like a daunting task. It can be even more daunting—and unlikely to succeed—if you just start doing it. It's a much better idea to break the process down into a series of smaller steps that you can tackle one at a time. This has at least two big advantages. First, bite-size pieces of the self-revision project are psychologically easier to begin (chapter 5), and completing the first one or two can give you momentum that makes it easier to keep going (chapter 6). Second, most of us greatly overestimate our multitasking ability (e.g., Bowman et al. 2010, Wang et al. 2012). If you are reading to look for overall logical flow, for example, your mind tends to skip over spelling errors, citation accuracy, or wordiness. Successfully targeting one of the latter, on the other hand, pretty much requires a willful disregard of the former.

Multiple rounds of self-revision, each with a specific aim in terms of changes to content or style, are thus the way to go. But how many rounds, with how many aims? You will have to discover what works best for you, but earlier in your writing career the number is likely to be larger. In fact, you may be startled to discover just how large. With experience you may find you can combine some, but you'll probably always go through enough rounds of self-revision to become heartily sick of what you've written. Don't worry. We all get sick of what we've written. As a starting point, I recommend you try at least five rounds of self-revision, with distinct aims as follows:

- **Revision for content**. The first step is to ask yourself again what story you're trying to tell (chapter 7). Once you know the answer to that (and it may have changed since you began work on the draft), then you can ask whether all the pieces of your draft really belong. If a paragraph, a figure, or even a sentence isn't necessary for the reader to understand the story you're telling, take it out. No less important, although usually easier in terms of self-motivation, is to ask what elements of your story might be missing and to put them in. Finally, make sure the story promised in your Introduction is the same one delivered in your Discussion. Read the first and last few sentences of your Introduction, and skip directly to the last paragraph of the Discussion (or Conclusions). Is the major point presented the same in each place? If not, adjust.

  This should be your first round of revision, because you will nearly always remove material at this step—and you might as well remove it before you waste effort polishing it. The order of the remaining rounds is up to you.
- **Revision(s) for problems of writer familiarity.** Now that the basic content is fixed, use all the tricks outlined above to put yourself into the reader's mind and read to assess the crystal clarity you're aiming for. You may be able to do this in one pass, or you might want to break this down into several substeps: for instance, a round strictly to check pronoun antecedents and one strictly to check topic sentences.
- **Revision for brevity.** Even if you wrote your first draft with brevity firmly in mind (chapter 20), it's virtually certain that you can do better. So you should always work to shorten your first draft. Most writers, even very experienced ones, make quite substantial cuts in self-revision, although of course the time to stop is when further cuts would make your writing cryptic. In my experience most writers should target at least a twenty percent reduction in overall length from the first draft. In time, you'll learn whether your own writing style needs more ruthless tightening, or whether you can get away with a bit less.

  If you find revising for brevity difficult or tedious, think of it as a game you're playing with yourself. Call it "character-count limbo," and ask "how low can I go?" Or set yourself some targets with promised rewards: a doughnut if you can hit twenty thousand characters or

a walk in the woods if you can cut eight hundred words. Remember as you do this that excising material isn't evidence of unsuccessful writing—it's evidence of successful revision. So celebrate your cuts, and don't feel bad about the need to make them.

- **Revision(s) for citations.** This is deadly dull, but has to be done: check your use of literature citations. Do you have all the citations you need? Do you need all the citations you have? Do the cited papers actually say what you think they do? Have you used a consistent format? Does every citation in your text appear in your References section, and vice versa? (In my own self-revision, I have a separate round just for that last issue.) Use of bibliographic software while you write can reduce the number of citation problems, but it can't entirely replace your sharp eye.
- **Revision(s) for your personal bad habits.** Finally (or at least in my own self-revision this is the final round), you should do a special focused search for bad writing habits you just can't seem to stamp out. All of us have them. I use parentheses, for instance, as if I'd gotten an irresistible deal on a bulk purchase of water-damaged ones. My only way of fighting this seems to be a special round of self-revision in which I do nothing but search-and-destroy parentheses. Perhaps you are in love with the semicolon, can't suppress use of the passive voice, or overuse a word like "utilize" or "manifest." As you gain practice writing, you will develop a list of your involuntary writing tics, and you'll know what to look for in your own drafts.

A Final Polish

Once you've made it through all the steps outlined above, take a deep breath. Better yet, take a breather—put the manuscript away again, at least for a day or two. Then give it a final read-through with a fresh eye. It's almost certain that you'll find a few problems that you introduced while fixing other ones. But don't let fear of the next step—letting a friendly reviewer see the manuscript you've produced—trap you in an endless cycle of ever-tinier revisions. Your job in self-revision is not to achieve absolute perfection by yourself, but rather to make it as easy as possible for friendly and formal reviewers to help you improve further. It's now time to put your work out there.

Chapter Summary

- Every manuscript requires serious, extensive self-revision.
- The major challenge of self-revision is "reader simulation": forgetting what you know, and seeing the draft as a reader would.
- Reader simulation is eased by reducing familiarity with what you've written. Put the manuscript aside for a while, then work with it in a new place, a new medium, a new font, etc.
- Because we don't multitask well, self-revision works best with multiple rounds targeted at different problems.