Writing in Science & Medicine:

The Investigator's Guide to Writing for Clarity and Style

Principal Investigators Association™

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Best Regards,

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Retired Founder: Leslie C. Norins, MD, PhD

PREFACE

"There is no form of prose more difficult to understand and more tedious to read than the average scientific paper."

Francis Crick, the co-discoverer of the structure of DNA, wrote this in 1994 in his book *The Astonishing Hypothesis.* Crick and many of his colleagues were acknowledging then what every scientist knows today: many scientific communications are largely unreadable.

Dr. Crick and others of his generation witnessed the transformation of scientific prose from reasonably understandable to largely unreadable—papers and grants filled with a jungle of jargon that even the most astute reader cannot untangle, errors in logic, repetition, and misuse of the English language that masks the meaning. This has caused known problems for scientists world-wide, for their careers and for the delay in disseminating their unique findings to the world. The rapid increase in science specialization, complexity, and new language have been largely to blame. But I believe that scientists largely lack the training needed to simplify their language. As science becomes increasingly more specialized and complex, for many scientists, it becomes even more difficult to communicate with their readers in clear and simple terms.

But why? Certainly, you as the expert in your field know and understand the science better than anyone and should be able to explain it to anyone because of this. I believe it becomes more difficult partly because scientists become more mired down into the complexities of their science, and their thinking becomes tangled and confused in the details. They find it more difficult to look at the complexity from a higher level, think clearly, and translate those thoughts clearly to their reader. But it's also that scientists just have not learned ways to simplify and organize their writing. The writing is weighed down by a tradition of pompous academic writing that has been perpetuated in the literature—in the fear of appearing too simplistic by their esteemed colleagues—they write things like *Prior to the initiation of our present analysis* when they could simply write *Before our study began.*

And learning how to write clearly, directly, more simply, is undoubtedly one of the most important and valuable skills any scientist can learn. In college, we had a notion that scientists had to learn the technical skills of their field but not how to write. And that is the biggest falsehood you could possibly perpetrate on young people. I believe that writing and rhetoric are the most valuable skills across any discipline in any field, especially science and medicine.

Let me explain more completely from my own experience.

Your thoughts are like a string of pearls the man said as he looked up at me sternly over his wire-rimmed glasses. This was his reaction to the first draft of my research paper. The man was a former Senior Editor of one of the most esteemed medical journals, for whom I apprenticed on my first job out of academia.

I smiled and enthusiastically thanked him—after all, I worked <u>hard</u> on that paper!

You misunderstand! By that, I meant that your thoughts are like a string of loosely unconnected sentences without any transition, much the same in form throughout, and, well, otherwise boring and difficult to follow, and therefore to understand.

The words cut into me, the young scientist-apprentice. After all, I was a trained scientist, and had already written a few journal articles and one grant in academia. Surely, I had learned something about writing from this experience. I struggled for some comprehension— was it possible I didn't know how to write? Perhaps my editor could be wrong and another opinion would be more favorable. But he wasn't wrong and another opinion would have just confirmed the diagnosis—bad writing!

The physician-editor sat me down and meticulously went through his marks—there was a sea of red on every page (yes, this was before computers!). Through the often painful lessons, I had obviously forgotten some basic principles from my freshman writing classes.

Omit needless words! Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts!

This was the advice essayist and editor E.B. White took from his Cornell English professor William Strunk. *The Elements of Style*, was one of the first books I had read in writing class my freshman year. I had forgotten its advice. My thinking and subsequent prose had become overly complex, redundant, muddled, and confused.
The editor continued.

No good editor will accept this paper! But with enough work, you'll learn how to write well the first time...now, go back and start over with an outline!

I walked away with my proverbial tail between my legs. I thought, *an outline, start over…why should I do that?* Underneath, however, I felt somehow hopeful that he was willing to help me. I was bound not to repeat the failure. But I did. Many times. *This could be a big problem for my career,* I thought. *Why can't I express my thoughts clearly?*

Eventually and slowly, I learned how to write more clearly and directly through much laborious practice and making mistakes repeatedly—especially, I learned by how easily my readers could…or could not…grasp what I had meant to communicate. I learned how to simplify my complex sentences and clarify the complex science. But it was hard work. I tried reading books on writing; there were so many of them, but I quickly learned that they were mostly not helpful.

In the many intervening years working with young (and experienced) students and faculty on their writing, I learned that many investigators never had a mentor that helped them with their writing—or, the advice given to them was simply misleading and not helpful. In fact, I have been told by some investigators and students that their mentors believe that writing can't be taught, and you either sink or swim on your own in academia. This large misconception stems from an ignorance about writing that has been pervasive in academia since I can remember.

Over the years during which I have taught courses about scientific writing in academic homes, it continues to amaze me how many scientists struggle with even the basics of writing, many aspects of which can be taught. I have frequently pondered why scientists write poorly. One universal tenant of writing is that scientists often equate long, complex sentences and paragraphs with deep thinking—a subject we discuss in Chapter 1. But the simple fact is that academic puffery—stilted, complex, and confused writing—is misunderstood by the reader and doesn't serve the author. For example, consider this sentence, part of an abstract, sent to me by a prominent scientist (their <u>final</u> version):

The influence of age (younger vs. older) has been reported recently for multiple sclerosis disease in the context of a more rapid clinical response.

This sort of poor writing from an already confused author confused also the reader (me), who tried to guess what the author really meant. When I asked her to clarify this sentence, she said:

Well, I think it was clear! Our patients who had multiple sclerosis that were younger, under 55 years, showed a faster clinical response compared to the older patients. That's what it says!

Her stubbornness and emphatic stance confirmed for me what I already knew: many authors are insecure and defensive about their writing because it is such a personal activity, and, in an attempt to make it sound erudite, they copy the academic language that they see in many journals and other scientific forums— much of which is confusing and difficult to understand. Unfortunately, this author ignored my advice and the abstract ended up being rejected by the editors of the scientific congress because the message was unclear and her meaning obscured and partially misunderstood. She realized her tenable position and together, we rewrote the abstract, which was eventually published. And it read:

We found that our younger multiple sclerosis patients—those under 55 years—had a more rapid clinical response compared to our older patients, over 55 years.

And in writing like this, she learned the value of simplifying her thoughts, a much more valuable lesson. Unfortunately, many like-minded scientists end up with rejections from a journal or from a funding agency because of confused and disorganized writing, which delays the dissemination of important scientific findings to their colleagues.

This problem is altogether avoidable.

In this guide, I offer some of my advice from experience of working with students and investigators at all levels at many different institutions. It's advice that most respected journal editors and good writers will also give you.

Chapter 1:
The Causes of Obscurity in Scientific Writing

This guide relies on 2 fundamental principles:

1. It is important for scientists to write clearly
2. Anyone can learn it

The first principle is self-evident, particularly to those who read writing like this:

An understanding of the causal factors involved in excessive drinking by students could lead to their more efficacious treatment.

but can't seem to write:

We could more effectively treat students who drink too much if we understood why they did so.

And the second principle eludes many scientists who struggle with their writing but believe that writing cannot be taught.

This is a problem for generations of scientists who have, unfortunately, learned to write in a way that obscures their meaning from their readers, and I would even suggest from themselves. Scientists use language they copy from the literature, the jargon-filled writing perpetuated from paper to paper, grant to grant. They believe the writing is understandable, even erudite. But for the people that matter—journal editors, peer reviewers, and the like—their meaning is often confused, obscured, and misunderstood, which reflects poorly on the writer.

This guide is intended to help you—the scientist—to learn simple ways to overcome this academic obscure style and learn to write clearly, simply, and directly. The principles herein are taken from real-life experiences in working with hundreds of principal investigator scientists, both experienced and novice. It is intended for the early-stage investigator and the established investigator alike—anyone who wants to become a better writer.

The Causes of Obscurity

If you want to learn how to improve your writing, you first need to understand why medical and scientific writing has been historically unclear. Here, we examine some of the causes of obscurity in thought and writing.

First, obscurity in scientific and medical writing isn't a new problem. In 1975, Dr. Michael Crichton—the famous writer of *Jurassic Park* and *The Andromeda Strain* and *ER*— took writers to task when he published a blunt essay "Medical Obfuscation: Structure and Function" in the New England Journal of Medicine.

He wrote:

Medical writing in general is weak...the general tone is one of utmost timidity, going far beyond sensible caution…it is striking that so many powerful members of the profession—heads of departments, professors, and deans—should choose to express themselves in so hesitant a fashion. They certainly don't talk that way. Weak writing is hard to read. In fact, the general consequence of all these writing errors is to make medical prose as dense, impressive, and forbidding as possible. Even the simplest concepts are re-stated in unrevealing forms. The stance of authors seems designed to astound and mystify the reader with a dazzling display of knowledge and scientific acumen.

Crichton argued that dense and forbidding medical prose is designed as a *display of scientific profundity, and not as an attempt to communicate experience.*

Why do scientists write like this?

Writers pump up their prose, hoping that complicated long sentences with big words indicate deep, erudite thought. And, when we want to hide the fact that we don't know what we're talking about, we typically throw up a tangle of abstract words in long, complex sentences and phrases.

One of the biggest reasons scientists write poorly is because they often cannot anticipate when readers will think their message is unclear, much less why. When we read what we write, our prose always seems clearer to us than to others (your audience). Thus, instead of revising our writing to meet our readers' comprehension, we write it to meet ours. But you are not writing it for yourself, as much as you might like the 'sound' of your own writing—you're writing it for the reader, who must get through the tangle of confused thoughts, paragraphs, and sentences.

Studies on writing and understanding show that authors who are unclear about their material often write unclearly and confuse the reader. Many scientists who read complex, long sentences believe that the writing is deep and erudite and they imitate the style—often called "academic" or pompous writing. It's a scholarly work, after all, and should sound important, deep, and intellectual. But the audiences that matter—journal editors and peer reviewers—are confused by such writing, which immediately signals that the author is also unclear and disorganized.

Does the Standard of Writing Matter?

Most scientific and medical journal editors and peer reviewers believe it does. Editors and reviewers continually point out that unclear writing is one essential reason that papers are rejected and grants are not funded. Stated another way, anything that gets between the writer's scientific message and the reader's comprehension of that message, derails the paper or grant and upsets the reviewer, who has to stop and go over and over the message to understand the writer.

Many scientists have argued that if a paper (or grant) represents sound work and is significant enough to publish or be funded, no damage is done if it's published or submitted for review with ungrammatical constructions, confused and illogical thoughts, ambiguity, concealed hedging, or poor punctuation and spelling. And that the function of journal editors, after all, is to attend to such mundane matters. Investigators shouldn't have to worry about this.

This couldn't be more wrong. I am amazed by the patience with which some academic reviewers and editors plow through horribly blemished articles. The spirit in which these articles are often written—to impress the reader with the author's command of language—is completely opposite of what it should be. If what you write—which is all the editor or peer reviewer has to go on for months of your planning, designing, and executing your studies—is confused, vague, ungrammatical, and illogical or otherwise unclear, you've accomplished the opposite of what you set out to accomplish: confusing the reader. It also reflects poorly on you, your institution, and your colleagues because readers of careless, confused writing will wonder whether a similar lack of care was exercised in taking histories, examining patients, collecting data, or keeping lab notebooks.

There is clear evidence that the writing in medical and science journals and grants exerts a corrupting influence on young scientists—on their writing, on their reading, and especially their thinking.

When a student enters graduate or medical school from their undergraduate days, they often have had comparatively little exposure to the scientific literature and often write with admirable directness and clarity of purpose like this:

To determine the molecular size and shape of A and B, I measured their sedimentation and diffusion constraints. The results, shown in Table 1, shows that A is a spherical molecule with a molecular weight of 36 kD. The molecular weight of B remains uncertain because the sample seems to be impure; however we estimate it to be approximately half the molecular weight of A. This is being further investigated.

Years later, their writing is verbose, pompous, full of illogical paragraphs, and incorrect constructions:

In order to evaluate the possible significance of certain molecular parameters at the sub-cellular level and to shed light on the conceivable role of structural configuration in spatial relationships of intracellular macromolecules, an integrated approach to this problem of cellular diffusivity has been devised and developed herein. The results, which are in a preliminary state, are discussed herein in some detail in terms of their possible implication in mechanisms of diffusivity in a wider sphere.

The student can no longer write. Why is this? What has happened in the intervening years of his work? First, the student is among learned and very critical colleagues and often feels insecure in his writing and therefore borrows these erudite-sounding pompous phrases from other papers they have read. As they move through their career, they continue to copy these phrases and words from other literature, and it eventually becomes their own style —their simple, direct, and clear style is lost. It has changed not only their style but their thinking to the point they cannot express themselves simply. They believe what they have written sounds important. But often, it's confused and they really don't understand what they are writing about.

Also, the student's powers of reading are changed. They have to wade through the obscure writing in the literature and cannot comprehend what is intended. As one assignment in a writing class at Stanford University, I asked my students to write a 150-word abstract of a very clearly written short paper about how people's brains change on MRI as they look at faces of people expressing different emotions. First, many of them spent half of the abstract writing details (often copying directly from the paper) of the methods, sometimes copying them incorrectly. They also missed the point of the study—that making eye contact enhances the appeal of a pleasing face, irrespective of gender—and they wrote instead about how brain regions differ when stimulated by happy and sad faces. A couple of students referred to the *ventral striatum*, a region of the brain that was studied—as part of the MRI apparatus! Many provided details of the article that were irrelevant to the study's conclusion and missed describing the importance of the study and what it meant. If scientists cannot think clearly, they cannot write clearly, because the two are intricately bound.

Clear Writing=Clear Thinking=Clear Writing

So, we are left with one guiding principal: **to write clearly, you have to first think clearly.**

Writing well requires that the writer deals with putting forth complex scientific ideas with logic, precision, and clarity. In this guide, we address such aspects, and show you how to produce good sentences and paragraphs, but before you embark on writing scientific prose, you must first be abundantly clear in your thinking about your science. To attempt to write a paper or grant with some notion of your research studies starting from a blinking cursor on a blank page is impossible for most, if not all, writers. Even the most seasoned or talented writers run into a dangerous minefield of conflicting ideas and complex arguments without some prior thought and preparation about what they are going to say on the page. I liken this to building a house without a blueprint—you end up with a poor construction, which has to be torn down and reconstructed from plan.

Writing to clarify thinking is a concept most scientists do not appreciate fully. Simply writing ideas down even into an outline and examining those ideas can clarify the writer's thought. Once the writer's ideas have been written, even in outline form, they can be analyzed critically later. Often when the writer starts putting sentences down on the page, they start thinking about how their colleagues will view their paper and if it seems scholarly and deep. The writer has now become immersed in the details of words and structure of sentences.

As an illustration, I often would have the scientists I work with just *talk* to me about the concepts they want to explain. When relaxed and not feeling threatened, they are many times able to explain it clearly and easily. But when it comes time to write it for their colleagues, it becomes another language altogether!

As one example, on an elevator, Jane asks her colleague Bill (Dr. Smith) about what he found in his recent study on the medical curriculum. She asks him *What did you find in your study?* Bill replied:

Overall, we found that our clinical teachers of undergraduates tend not to let students look after the difficult patients.

However, later that evening, Bill (or rather Dr. Smith) sits down at his computer and writes:

Our investigation has confirmed the primary hypothesis that clinical instructors for undergraduate medical students would use specific instructional techniques limiting active student interactive involvement in patient care activities upon facing problematical interactive clinical situations.

Bill has now become Dr. Smith, and he pontificates about the study to his colleagues. Leaning back in his chair, staring at his wonderful writing, he is satisfied that he has produced an academic piece that his colleagues will be proud of. Too bad *Bill* didn't get to write the paper—the journal editor would have been more inclined to accept it.

Science writers should begin by developing their ideas in outline form on the blank page and realize what they write in a series of sentences in bullets or numbered outline will NOT be read by their colleagues. The writer develops their thoughts by writing down ideas and arguments in outline form and concentrates on getting down their basic ideas without being mired down in the details of wording the piece. Once the ideas are developed, reread, reviewed, reworked and made clear though clarified thinking of the writer, then, <u>and only then</u>, should the writer start writing their first draft. This is the only way that the piece can be solid. Trying to wrangle a disorganized and poorly constructed paper or grant, often times with multiple authors, is a nightmare and always results in an inferior product that often cannot be rescued without swiping through whole paragraphs and sections and hitting the **DELETE** button on your keyboard.

In conclusion, communication is not something added onto science—it is the essence of science. Unclear writing signals unclear thinking. To write clearly, we need to understand all the nuances and aspects of the subject before we begin wordsmithing the article or grant. Writing down the ideas even in outline form helps to clarify thinking. We imitate the academic, obscure writing that is seen in some medical and scientific journals and in grants, attempting to impress the reader with complex, long, and unclear phrases and paragraphs. If you want to write more clearly, let go of this style and develop your own clear way of communicating. Always think of your reader who needs to understand what you are intending to communicate.

Chapter 2: Concision and Misused Words and Terms

Concision, the Art of Being Concise

Being concise means that you use an economy of words that are the most effective in conveying your ideas. Most writers particularly have difficulty being concise and often fill their writing with unnecessary redundant words and phrases that do not add anything to the sentences or paragraph. In this section, we discuss the art of concision.

Omit Needless Words!! This advice, often quoted from Strunk and White's *The Elements of Style* is apropos to any writing, particularly medical writing, as the majority of papers and grants are at least 20% to 40% redundant and unnecessarily wordy. Strunk and White write:

Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell.

In this chapter, we will give you advice on how to be concise in your thinking and writing and use words and terms correctly in your writing.

Before we examine sentences and paragraphs and the entire document, we should begin with the fundamentals—concision, or being concise and clear.

Being concise reduces length—and most scientific documents are too wordy and long—and increases comprehension. Most scientists have great difficulty distilling their message not only because they don't know the writing principals involved (which I will show you) but they believe that the shorter message misses important points. For example:

In order to reduce the cellular growth, which was too rapid, of the HeLa cells in our culture conditions, we added the inhibitor HA-119 to the culture. In employing this agent, we found a large reduction of at about half in the cell growth over the period of 24 hours after initiating the agent (54 words).

The sentence is too wordy and, in some instances, vague. Editing out redundancies and being direct, we get:

To slow HeLa cell growth in our culture, we added the inhibitor HA-119, which reduced cell growth by 52% within 24 hours. (23 words, 42% shorter).

Does it convey the same thought? Yes. But here, a disclaimer. In this guide, I offer suggested edits to illustrate different points. They are all taken out of context—thus, one can argue that it may not convey what was meant in the larger context. However, it is necessary to look at examples in isolation to illustrate the point and trust that I am showing you one good way of eliminating needless words and phrases.

The general principals of concision are:

First, delete words that convey little or nothing, words that repeat the meaning of other words, or unnecessary adjectives and adverbs. Second, replace a phrase with a word.

We'll examine each of these.

Delete Meaningless Words

Some words are just useless verbal ticks we use in speech that have no place in writing:

Such meaningless words are seen commonly in writing:

It is of interest to note	*In a sense*
Interestingly	*That said…*
In order to	*Clearly*
Due to the fact that	*Basically*
Draw your attention to the fact that	*Indeed*
It goes without saying	*As already stated*

These phrases do not belong in writing—they are meaningless yet commonly used.

Other meaningless words seen in medical writing are *essentially, process, basis, and grounds:*

Essentially, cellular growth of our HeLa cells was dependent upon the culture temperature and level of CO_2.
becomes
Cell growth of HeLa cells depended upon the culture temperature and CO_2 *levels.*

Also, do not use process:
*...disease **process**…cancer **process**...inflammatory **process**…aging **process.***

Yes, they are processes, but we don't need to be told that.

*Asphyxia is a low-frequency event in the birthing **process.***
becomes
Asphyxia during birth is uncommon.

*Patients examined on a daily **basis** (regular **basis**).*
becomes
Patients examined daily (regularly).

*Each patient was studied on a one-to-one **basis.***
becomes
Each patient was examined individually.

*...a heterogeneous group of tumors on epidemiological **grounds.***
becomes
This is an epidemiologically heterogeneous group of tumors.

Delete Double-Meaning Words

Part of the problem here is that scientists don't sometimes think they get the point across unless they use paired words:

Final outcome	*Skin rash*
Red in color	*Soft in consistency*
Small in size	*Important essentials*
Add together	*Fewer in number*
Entirely complete	*Audible to the ear*
Combine together	*Interval of time*

For example, note the redundancies in:

The patient's skin rash appeared blue in color
The interval of time of the experiment was 2-4 weeks
The 3 dB noise was audible to the ear

The **bolded** items in this sentence show common redundancies:

Here, we ***measured the*** *weight of the agent drug, dissolved it at* ***a level of*** *0.5 µg/L in saline, and* ***then it was*** *stored at 0°C for* ***a period of*** *10 days.*

You should eliminate the redundancies in bold and make it a parallel sentence using the verbs weighed, dissolved, stored:

We weighed the drug, dissolved it in 0.5 mg/L in saline, and stored it at 0°C for 10 days.

Replace a Phrase with a Word

Using unnecessarily long phrases when a word will do is common in scientific writing. You should learn to spot opportunities to edit the sentence down. This editing will be illustrated in the principle of *nominalization* in which strong verbs like *measure* is turned into the noun *the measurement*. This will be discussed in Chapter 3.

Here are common superfluous phrases and words that can be used to mean the same thing:

Phrase	**Replace with**
It is clear that	*Clearly*
In the event that	*If*
At the present time	*Now*
Due to the fact that	*Because*
Subsequent (prior) to	*Before*
Due to circumstances that	*Because or since*
In a careful manner	*Carefully*
Have an effect on	*Affect*
In order to	*To*

For example, here are commonly found phrases in writing:

Despite the fact that *the data were checked, errors occurred.*
becomes
Even though (or Although) we checked the data, errors occurred.

We have noticed ***a decrease in the number of*** *errors.*
becomes
We have noticed fewer errors.

Prior to the initiation of the present study*, a calibration of the instruments was performed.*
becomes
Before we began our study, we calibrated the instruments.

I want to say a few words ***concerning the matter of*** *genetic mutation.*
becomes
*I want to say a few words about genetic mutation…*or *I now will discuss genetic mutation.*

Delete Adjectives and Adverbs of No Clear Limit

Writing is filled with:

Very	*Quite a few*
Many	*Long-term*
Multiple	*A lot*
Numerous	*Clear (clearly)*
A large (small) number	*Fairly*
Various	*Only*
Sort of	

*The magnitude of change was **very** large.*
becomes
The change was 10-fold larger than…

*Figure 1 **clearly** shows.*
becomes
Figure 1 shows.

In particular, the use of the word ***only*** is problematic in writing science. It is one of those vague words that have no reference. If you say *findings were positive in **only** 20 patients*, the reader is left to think that 20 patients is not a large number, but compared with what? For example,

*Animals receiving drug A had **only** a 4% incidence in bleeding.*
becomes
Animals receiving drug A had a 4% incidence in bleeding compared with animals receiving drug B.

***Few** of the animals showed signs of joint pain by the XYZ test.*
becomes
Of the 50 mice studied, 5 displayed joint pain by the XYZ test.

Jargon

Certain phrases used in medical writing are specialized slang that many physicians and scientists perpetuate in the literature:

Jargon	**Preferred Format**
Cardiac diet	*Diet for a patient with cardiac disease*
Gastrointestinal infection	*Gastrointestinal tract infection or infection of the gastrointestinal tract*
Left heart failure	*Left ventricular failure*
Therapy of Down syndrome	*Therapy for Down syndrome*
Patients on Cardene	*Patients receiving (or taking) Cardene*

Some examples:

Two thousand patients were imaged; of these, 292 had positive cancers.
becomes
We studied 2000 patients with magnetic resonance imaging (MRI) and found that 292 had cancers.

No pathology was noted from the patient.
Becomes
The patient had no pathological findings.

Commonly Misused Words, Phrases

Scientific and medical writing should always be as precise as possible to avoid misinterpretation. Many writers of journal articles and grants make common errors in correct usage of common words and phrases.

Abnormal/Normal, Negative/Positive

These adjectives are incorrectly used to refer to test results or examinations, which cannot be described using this way.

The patient’s physical exam was normal.

becomes

The findings of the patient’s physical exam were normal.

The cultures were negative.

becomes

The cultures were negative for beta hemolytic streptococci.

The electrocardiogram was positive.

becomes

The electrocardiogram showed abnormalities in the short S and T waves.

Acute, Chronic

Avoid these adjectives in describing treatments or drugs or medical conditions.

Incorrect:

Acute administration of drug

Chronic care

Chronic aspirin therapy

Correct:

Long-term dialysis

Long-term drug users

Immediate administration of drug

Affect, Effect

Affect, as a verb, means to have an influence on. *Effect*, as a verb, means to bring about or cause. These two words cannot be used interchangeably.

Ingesting massive doses of ascorbic acid may affect his recovery.
(influence the recovery in some way)

Ingesting massive doses of ascorbic acid may effect his recovery.
(produce his recovery)

Affect as a noun (pronounced *ah*-fect) refers to a person's emotional expression, and is often used in psychiatric diagnosis.

Mr. Smith's general lack of affect was a direct effect from his recent head trauma.

Age, Aged, School-Aged, Teenage, Teenaged

The adjective form *aged*, not the noun *age*, should be used to designate a person's age. Similarly, *school-aged* and *teenaged* are preferred to *school-age* and *teenage*. In referring to participant's or patient's ages, it is usually preferred to give the actual ages or range in ages.

The patient, aged 75 years, had symptoms of cognitive decline.
Or
The 75-year-old patient had symptoms of cognitive decline.

Also, it is redundant to add *of age* after the number of months, years because it is implied in the adjectives *younger* and *older.*

These vaccinations are not appropriate for infants under 6 months.

Age and Gender Referents

Investigators often do not use the correct terminology to refer to a person's age.

Neonates or *newborns* are persons from birth to one month.
Infants are aged one month to one year (12 months).

Children are persons aged from 1 to 12 years. Sometimes, children may be used more broadly to encompass persons from birth to 12 years of age. These persons are called *boys* and *girls*.

Adolescents are from 13 to 17 years; they may also be called *teenagers* or *adolescent boys* or *adolescent girls*, depending on context.

Adults are persons aged 18 years or older and be called *men* or *women*.
Persons aged 18 to 24 years may also be called young *adults*.

Note: if you give the age of someone, it may be written as a mixed function (for example, *6 ½ years*, or as *six years six months* but to express age as a mean, use a decimal: *Mean patient age was 12.5 years* (not 12 ½ years).

Whenever possible, patient or participant in a study should be referred to as *a man, woman, boy, girl*, or *infant*, not as a *male* or *female*. Occasionally, the study group may comprise children and adults of both sexes. Then, use male and female as nouns. Male and female are also used as adjectives.

Our study enrolled 222 adolescent boys, aged 14-16 years, as well as 224 women, aged 34-38 years (mean age 36.3 years). This is in contrast with the study by Reiss that enrolled mostly adolescent boys and girls (mean age 16.3 years).

As, Because, Since

These are often incorrectly interchanged. They can all be used when *for the reason that* is intended. However, the word *as* should not be used when it could be construed to mean *while*.

She could not answer her phone as she was examining a patient.
becomes
She could not answer the telephone because she was examining a patient.

Also, *since* implies *from the time of* or *from the time that* and should not be used in place of *because.*

She had not been able to respond since she was in the clinic (implies incorrectly from the time she was in the clinic).
becomes
She had not responded to the page because she was in the clinic (since yesterday) or
Because she was in the clinic, she could not respond to the page.

Assure, Ensure, Insure

These verbs are used incorrectly in many contexts and often one to represent the other. *Assure* means to provide positive information to a person or persons and implies the removal of doubt (*assure* the study's participants that their test results will be protected under HIPPA regulations). *Ensure* means to make sure for certain (*ensure* the statistical power of the study). *Insure* means to take precaution beforehand (*insure* his possessions).

*The **insurance** company **assured** workers' families that their policies <u>ensure</u> that workers with few assess would get a permanent burial.*

The investigators ensured (not assured) that the cells had 50% confluence before adding the growth inhibitor.

Case, Participant, Subject, Patient

These terms are quite commonly misused, and worse, mixed when describing studies in medical research. For clinical studies, a *case* is an instance of a disease (*a case of diabetes*) but <u>not</u> a human being. *Patient* is a person under medical care and usually being treated for a condition or disease. If a clinical trial studies a drug or devise in people with a medical condition, they are *patients*. A research *participant* (referred to as a *subject* sometimes) is a person with a particular characteristic or behavior, or a person who undergoes an intervention as part of the scientific investigation, usually a case-controlled study or randomized controlled trial. Thus, children with autism who are being treated with a certain agent, are *patients*; if the study is controlled by using age-matched children without autism, they would be the *participants* in the same study (or c*ase-controlled participants*, but not *normal controls*). In case-controlled studies, it is usual to refer to *patients in the case-control group, case patients, controls, participants in the control group, or control patients.*

Subject is impersonal, as it implies a person in a subservient role. Similarly, <u>never</u> refer to a human being as a *case*.

However, a *case* can be evaluated, documented, reported. A *patient* is examined, undergoes testing, and is treated. A *research participant* is *recruited, selected*, sometimes *subjected to experimental testing*, and *observed*.

In this Phase II trial, participants received drug A and control cases received drug B.
becomes
In this Phase II trial, patients received drug A and control participants received a matching placebo.

Use, Usage, Utility, Utilize

Use is always preferable to *utilize*, which has the specific meaning "to find profitable or practical use for." Utilize is a different meaning to find a new or practical use for something:

*Researchers **utilized** the lab's sterilized plastic garbage containers for growing the large cell cultures in lieu of 20-liter glass bottles.*

Usage refers to acceptable, customary, or habitual practice.

The correct usage of 'patient' versus 'participant' is discussed on the following pages.

Utility means fitness for some purpose, or usefulness – should never be changed to the noun use, and <u>never</u> use the verb ***employ***—it means *to hire*—use instead ***use.***

Redundancy and Metadiscourse

Medical and scientific writing are not only filled with redundant phrases and superfluous phrases, as we have seen in this chapter, but writers often use metadiscourse, in which the writer will comment on what is in the sentence, usually as an introductory clause. For example, here are common examples:

To show their intention: *to sum up, candidly, I believe*
To direct the reader: *note that, consider now, as you see*

Metadiscourse is sometimes needed to keep the reader grounded to where they are in the document: *first, second, third, finally, therefore, last.*

Here are some metadiscourse examples that show how to edit out this sort of redundancy:

Pointing Your Ideas to a Source

Don't announce that something has been *observed, noticed, noted:*

High mutation rates ***have been observed*** *to occur in areas that* ***have been thought to have*** *higher population densities.*
becomes
High mutation rates occur in areas with high population densities.

Topic Announcement

You don't need to tell your audience what the topic is about:

This next chapter points out another *problem, that of noise pollution.* ***The first observation I would like to make about this is that*** *noise pollution exists not only...*
becomes
Another problem is noise pollution. First, it exists not only…

Other examples:

In regards to *vigorous style, the most important feature is a short, concrete subject followed by a forceful verb.*

In so far as *genetic mutation rates are concerned, it will take several years before…*

Having said this*, we still believe that mutation rates are higher in this population…*

Hedging

Writers often will reflect their uncertainty about their research. Hedges limit certainty and influence how your readers judge your research.

Commonly used hedges:

actually, often, sometimes, almost, virtually, possibly, allegedly, arguably, perhaps, apparently, to some extent, somewhat, in some aspects

And you might see hedges in the form of verbs:

may, might, can, could, seem, tend, appear, suggest, indicate

Eliminate these from your writing. The reader is going to think you cannot stand by your findings if you write:

There seems to be some *evidence to* ***suggest*** *that* ***certain*** *cellular mutations like those we have seen* ***could be*** *derived from other sources such as radiation…*

In academic writing, one hedge of uncertainty is common:

This evidence ***suggests*** *that cellular mutations like those we have shown are derived from other sources such as radiation…* or

Our evidence shows that ***certain*** *cellular mutations like those we have seen are derived from other sources such as radiation…*

These are <u>different</u> meanings, so be precise in how you wish to present your findings.

Other Redundancies in Writing

In addition to using repetitive phrases, redundant words, and metadiscourse, it is also common for writers to repeat themselves throughout the structure of a document. For example, writers repeat points in the introduction and discussion section of a manuscript, repeat figure legends, table titles, or contents of the tables or figures themselves. This sort of redundancy results in documents (grants, papers) that are at least 20% to 40% too long.

As an example, if you are writing the results of your research and refer to a figure with the title:

Figure 3. Mean Overall Survival (OS) and Progression-Free Survival (PFS) For Lymphoma Patients Receiving Drug A and Placebo.

and you write:

Figure 3 illustrates the mean OS and PFS for lymphoma patients receiving active drug A and placebo…

This states the obvious and is redundant. This also angers the reader (and the editor!). It shows that you did not critically think about what the reader needs to know.

Similarly, researchers often regurgitate the results from tables and figures, which not only insults readers' (and editors') intelligence, it illustrates lazy writing and results in documents that are not only uninformative, but too long. For example, in a demographics table, the writer tells the reader:

As shown in Table 1, the mean age of participants was 20.4 ± 2 years, and 80% of patients were Caucasian. Treatment group contained 40 patients, whereas control group contained 45 patients. Table 2 shows the demographics of women in these groups. There were 24 women in the control group, and 33 women in the treatment group...

This information, obvious from the table, regurgitates the results, providing no useful information to the reader and wastes valuable words and ideas. A more informative result might be:

There were no significant differences in treatment and control patient intake demographics (Table 1), although a significantly greater number of patients in the treatment group dropped from the study for a variety of reasons, mostly relating to adverse reactions. However, analysis of patients in this group later revealed that those dropped patients had significant disease at intake (Table 2). In comparing the two treatment groups (Fig. 1), we found that...

Another example—the writer refers to a figure below with the text:

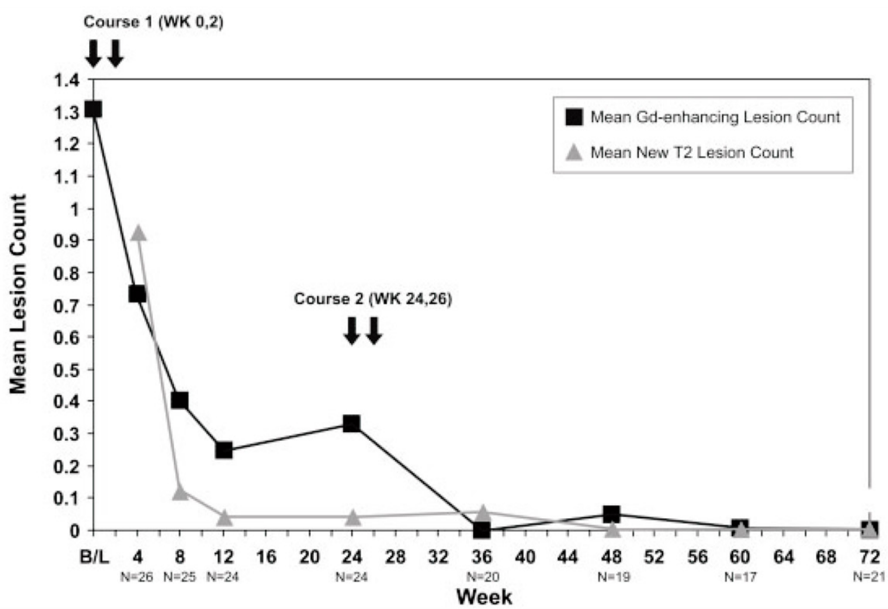

Figure X is a line graph illustrating the mean gadolinium (Gd)-enhancing lesion count and mean T2 lesion count over study week 72. Course 1 of drug was given at weeks 0 and 2 and course 2 was given weeks 24 and 26. The mean Gd-enhancing lesions dropped dramatically beginning week 2 and stayed at a low level through-out the 72-week study...

This states what is obvious from the figure and is of little or no use to the reader. A more informative result might have been this:

In Figure X, mean number of new T2 lesions decreased over 72 weeks from 0.892 at week 4 to 0.001 at week 72. The T2 lesion volume was 8,429.2 mm^3 at baseline but decreased by 120.1 mm^3 at 48 weeks and by 280.1 mm^3 by the last study week 72.

Finally, although much repetition and metadiscourse can be removed from writing, it sometimes may be intentional to make the point for emphasis:

Although the mutation rates in this population varied, ***we wish to re-emphasize*** *that this was not a genome-wide association study, and the methods we used were…*

In conclusion, be concise and delete filler and extra words and expressions of no limit. Be careful of using metadiscourse, particularly in those areas of your document that contain repeated information. If you outline your work, you will discover places to eliminate redundancies.

Exercises, Chapter 2

Edit the following sentences to make them more concise.

1. Recent research suggests that these two disorders may not be as distinct as previously was thought and the degree of overlap may be considerable.

Edited version: ____

____

2. Discharges of these hazardous substances occur through spills when loading vehicles, spills and over-spills when filling the tanks, leaks from supply pipes and pipe joints, rust holes and cracks in the seams of the tanks themselves.

Edited version: ____

____

____

3. In this experiment, we measured the weight of the sample drug, dissolved it at a level of 0.5 µg/L in saline, and it was then stored at a temperature of 0°C for a period of 10 days.

Edited version: ____

____

4. The primary route of lithium elimination from the body is through renal lithium excretion.

Edited version: ____

____

5. It is estimated that one in 500 college students is infected with HIV, according to the health center, also provides condoms at one forth the cost of stores.

Edited version: ____

____

6. Next, the copper solution was prepared. This procedure was done by weighing out 0.1821 grams of copper nitrate and diluting it in 10 mils of tap water.

Edited version: ____

____

7. In these patients, water consumption increase was observed after drug A was given and the patients on drug B were observed to have no change in water consumption.

Edited version: ____

____

8. Interestingly, the results showed that in order to achieve full blood pressure, patients had to take the full dosage of 100 mg/day of drug X for the entire 7 days, an unexpected finding.

Edited version: ____

____

9. The two results are found to be in agreement.

Edited version: ____

____

10. There is enormous variety of clinical presentation, as symptoms vary depending on the tumors' location, size, and malignant versus benign behavior.

Edited version: ____

____

See suggested answers on page 87.

Chapter 3:
The Sentence—Short and Clear

Writers often form overly complex sentences containing several different ideas in a passive construction using weak verbs and unclear subjects. At the simplest level, a good sentence should be immediately understood on first read. If you have to stop and re-read the sentence, it is not clear and needs to be rewritten. And to be clear, sentences must first contain a clear and identifiable subject followed immediately by a strong active verb.

Subjects and Verbs

The measurement of the atomic mass of the new element was made by the researchers.
versus
Researchers measured the new element's atomic mass.

The first sentence is a passive construction (versus active construction, more on that later), has an indirect subject (*The measurement*), and a weak verb (*was*). The writer was not clear on the important subject—*the researchers*—and took a strong verb (*measured*) and made it the noun subject *The measurement* (a nominalization, more on that later in this chapter), which forced the writer into a longer, less direct construction.

Language research shows that readers will interpret a sentence quickly if they encounter a verb immediately after a clear subject. Anything that gets in between the two will be glossed over because the reader scans the sentence looking for the action.

A good example of this is a sentence appearing in a paper (Joy DA *et al*, Science 2003; 300: 318) about the origins of *plasmodium falciparum*, the organism carried by mosquitos that causes malaria. The writer intended to tell the reader about what caused the organism's emergence:

The emergence of virulent Plasmodium falciparum in Africa within the past 6,000 years as a result of a cascade of changes in human behavior and mosquito transmission has recently been hypothesized.

Here, the subject of the sentence is *The emergence* and the verb modifying the noun doesn't appear until the sentence's end: *has recently been hypothesized*. The reader scans the sentence looking for the action and misses the important information buried in the middle, giving it little or no attention. However, the writer intended for the reader to understand that the organism emerged in Africa because of changes in human behavior and mosquito transmission. These central points are buried in the middle of the sentence. The sentence begins with the subject *The emergence* (a nominalization of the verb *emerged*) and ends with even less important information *has recently been hypothesized*. And, sentence end, we will discover, is the **stress position**, where the writer should make the points they want the reader to remember.

Accordingly, Dr. Joy would have gotten her point across more directly and effectively by writing:

According to a recent hypothesis, virulent Plasmodium falciparum emerged in Africa within the past 6,000 years as a result of a cascade of changes in human behavior and mosquito transmission.

This new active direct sentence contains the intended subject (*Plasmodium falciparum*) followed by the strong verb *emerged*, and the opening contains the least important information (*According to a recent hypothesis*). The sentence ends with the stressed information (*changes in human behavior and mosquito transmission*). The sentence is now clear to the reader that this organism emerged because of changes in human behavior and mosquito transmission.

Sentence Constructions

The sentence finish—the stress position. What readers read last is what they remember. Thus, your sentences should end with what you want to stress and have the reader remember. You saw this previously in the sentence about malaria. In that example, we assumed the writer wanted to emphasize the reasons for the rise in the organism *Plasmodium falciparum* by writing:

According to a recent hypothesis, virulent Plasmodium falciparum emerged in Africa within the past 6,000 ***years as a result of a cascade of changes in human behavior and mosquito transmission.***

However, if Dr. Joy's argument was directed at discussing the timing of *Plasmodium* emergence in Africa, she might have emphasized that point by writing instead:

According to a recent hypothesis, because of a cascade of changes in human behavior and mosquito transmission, virulent Plasmodium falciparum ***emerged in Africa within the past 6,000 years.***

How you manage the emphasis in a sentence stress helps to establish the voice readers hear in your prose—if you end it with less important information that carry little meaning, your sentence will fail and not be remembered.

Old Before New Information

Research on how sentences are constructed for maximum clarity emphasize two points:

1. **Begin sentences with information your readers already understand or know.** Readers remember ideas and words from the sentences they just finished reading or understand from general knowledge.

2. **End sentences with information new to your readers.** Reader always expect to read what's new after they read what's familiar or old information.

Therefore, the beginning of a sentence grounds the reader with established information for the leap that follows. It might refer to previous material presented in other paragraphs or sentences. Then, the new information is introduced at the end. The more closely the structure matches the reader's expectations, the more they will immediately comprehend it.

In the previous paragraph, we demonstrated that PET and fMRI are useful neuroimaging methods to study patients with brain injury. In this section, we show that further resolution of disordered neural circuits is possible with a new method called diffusion tensor imaging (DTI)…

Nominalization—Turning Verbs Into Nouns

Writers of technical documents, especially those in the scientific and medical field, have unfortunately learned to take strong action verbs like *react* and turn them into nouns *The reaction* because they think it sounds more erudite to use that form. Here are some common verbs turned into nouns:

react → reaction
neutralize → neutralization
inhibit → inhibition
eliminate → elimination

Some examples you may recognize in your own writing:

The human immune system is responsible not only for the ***identification*** *of foreign molecules, but also for the actions leading to their* ***immobilization, neutralization****, and* ***destruction****.*

Now, uncover the hidden strong verbs, eliminating the weak verbs *is*:

The human immune system not only ***identifies*** *foreign molecules, but also* ***immobilizes, neutralizes****, and* ***destroys*** *those molecules.*

Scientists seem to think it sounds more important to say:

The ***inhibition*** *of the reaction was carried out by…*

When they mean simply:

The reaction was ***inhibited*** *by…*

This is an important concept that is very common in science writing, so other examples show you how this works:

Our results indicate that the ***interpretation*** *of this data should be taken with caution.*
becomes
Our results indicate that data should be ***interpreted*** *cautiously.*

In this animal, the ***infusion*** *of glucose followed a timed course of every 3 hours.*
becomes
In this animal, glucose was ***infused*** *every 3 hours.*
(And notice that *a timed course* is redundant when you write *3 hours*.)

The ***neutralization*** *of the toxic proteins was carried out by the B cells.*
becomes
B cells ***neutralized*** *the toxic proteins.*

When editing your work, look for the nominalizations and hidden verbs, which will be evident when you see the verbs "to be" (*is, are, were*) and the article *the* in front of the word (*the reaction, neutralization, inhibition*), indicating the noun form. Making these changes makes the sentence more active, shorter, and easier to follow.

Passive and Active Voice

Although the passive voice is sometimes appropriate and necessary in science writing, using the passive voice throughout a paper is not appropriate—not only is it boring, it forces the reader into indirect constructions with weak verbs and therefore often leads to ambiguity. Many scientists I have taught in the past several years have told me their advisors told them to write exclusively in the passive, not the active, voice. This is bad advice.

The behavior of children was studied (passive)
versus
We studied the behavior of children (active)

Notice the weak verb in the first sentence (*was*) and the strong verb in the second (*studied*). When you write in the passive voice, the subject names the goal of the action, and it forces the writer to use a weak verb form such as *am, is, was, were, are,* or *been*; in the active voice, the writer puts the subject as the actor and uses a strong, active verb, eliminating the weak verb forms. Passive voice throughout an entire paper is not only monotonous, it shows a lack of conviction, requires more words, extends reading time, and can often be confusing.

In the present study, an increase in sugar consumption was observed both in female and male children 1-2 hours after drug A was taken. However, there was no significant sugar consumption increase 3 hours after taking drug A. (39 words)

We observed that girls and boys ate more sugar 1 to 2 hours after taking drug A; within 3 hours, their sugar intake decreased. (24 words)

However, passive voice is sometimes acceptable. Passive voice makes sense when the agent performing the action is obvious, unimportant, or unknown or when a writer wishes to postpone mentioning the agent until the last part of the sentence or to avoid mentioning the agent at all. The passive voice is effective in such circumstances because it highlights the action and what is acted upon rather than the agent performing the action. The Methods section of the paper is one place where passive is appropriate.

The proponents of this theory did not consider newer genetic findings…

Subjects were scanned using a novel functional MRI method…

Patients were excluded from the study…

In this experiment, three liters of fluid was filtered through porous glass beads…

While this is true, active voice is preferred for much of scientific writing. Scientists often don't like using "we" or "I" in a paper because they feel the need to distance themselves from the reader and remain neutral. I believe that many scientists do this because they may be unsure of their findings and want to remove themselves from the writing. As Dr. Michael Crichton said in his NEJM article cited earlier: *The general tone* (of medical writing) *is one of utmost timidity, going far beyond sensible caution.*

But your name is on the paper and it's your opinion. To say *In my (our) opinion*… or *We believe this to be false because*… is preferred by readers (and by many journal editors) rather than *It is concluded that the treatment is not effective*… because we don't know who made the conclusion. In their famous paper published in 1953, Crick and Watson began their paper with:

We wish to suggest a structure for the salt of deoxyribonucleic acid (DNA)…

This is active, direct, and clear. If Crick and Watson had written:

In this paper, a structure is suggested for the salt of deoxyribose nucleic acid (DNA).

This emphasizes rather the structure as the subject and the sentence is unclear because we don't know who made this suggestion. The passive voice also forced the writer into using a weak verb *is*.

Many medical and bioscience journals request that authors write in an active voice and be direct:

British Medical Journal: "Please write in a clear, direct, and active style....Write in the active [voice] and use the first person where necessary."

The Journal of Neuroscience: "Overuse of the passive voice is a common problem in writing. Although the passive has its place—for example, in the Methods section—in many instances it makes the manuscript dull by failing to identify the author's role in the research....Use direct, active-voice sentences."

The Journal of Trauma and Dissociation: "Use the active voice whenever possible: We will ask authors that rely heavily on the use of the passive voice to re-write manuscripts in the active voice."

Nature: "Nature journals like authors to write in the active voice ('we performed the experiment...') as experience has shown that readers find concepts and results to be conveyed more clearly if written directly."

Ophthalmology: "Active voice is much preferred to passive voice, which should be used sparingly. Passive voice...does not relieve the author of direct responsibility for observations, opinions, or conclusions (e.g., 'The problem of blood flow was investigated...' vs. 'We investigated the problem of blood flow...')."

Science: "Use active voice when suitable, particularly when necessary for correct syntax."

Tenses

In scientific writing, the present, past, and future tenses are used, depending upon context and meaning. Here are some general rules for using tenses in a paper.

Present Tense. Use when describing established knowledge in a paper's Abstract, Introduction, Discussion:

Lesions of the midbrain cause…

Use present tense also for presenting figures/tables in results/methods:

Table 1 illustrates… *Table 5 shows …*

Past Tense. Use in Methods and Results:

We used… *We measured … We tested…* *Our results showed…*

For attribution of other's work in the paper's Introduction and Discussion:

Smith reported…this was also found by Jones….Reiss confirmed these findings…

Future Tense. Used only to describe work yet to be done in the future:

In our next series of studies, we will examine this population in conjunction with …

To avoid confusion, do <u>not</u> use the **perfect tenses** in scientific writing:

Smith <u>has</u> reported the presence of … Present perfect

Jones <u>had</u> described the action of drug A… Past perfect

Unfortunately, scientists make mistakes in tense by writing:

Figure 1 has shown that cell growth was inhibited…
We have reported earlier that…
In this study, cell death is decreased…

In addition, scientists often mix tenses, which confuse the reader about what was attribution and what was found in the study.

In conclusion, your sentences should be short, with clear subjects and strong action verbs, using the active voice. Often, sentences are too long and too full of several ideas, making it difficult for the reader to digest important ideas and interpret information. Arrange your sentences to emphasize most important information or new material at the end, starting with less important or old information. But above all, the sentence should be short, strong, and interesting!

Exercises, Chapter 3

Rewrite the following sentences to remove any redundancies and simplify.

1. The increase in the reaction was observed after the addition of the copper solution.

Edited version: ____

____

____

2. It has been observed in the past century that genetic mutation rates have been increasing in north American Indian tribes, according to a recent study by Smith et al (Smith and Jones, 2011).

Edited version: ____

____

____

3. The investigation of the craft's engine bolt fragments was performed by the engineers in order to understand the origin of the crafts failure.

Edited version: ____

____

____

4. Anti-inflammatory agents may be protective for the occurrence of Alzheimer's disease and may reduce the progression of the disease.

Edited version: ____

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5. Baby walkers are devices that provide preambulatory infants with postural support in addition to offering them the opportunity to experience bipedal locomotion. They are intended to simulate the infant's independent locomotion and by so doing, it is argued, encourage and even accelerate the early acquisition of this skill.

Edited version: ____

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6. An increase in blood pressure rates were observed in rats, which occurred after employment of the lithium compound in food.

Edited version: ____

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7. The mature adult sheep muscle protein iron levels were studied in this investigation.

Edited version: ____

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8. The human endocrine system is responsible for the secretion of hormones and also for the regulation and the metabolism of hormones throughout the human body.

Edited version: ____

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9. To confirm this finding, we did experiments in rats in which we removed the ovaries and replaced the hormones with injections of estrogen in the animal.

Edited version: ____

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____

10. The supplementation of zinc in mothers during pregnancy to observe changes in birth parameters such as weight was our primary objective in this study.

Edited version: ____

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See suggested answers on page 88.

Chapter 4: The Paragraph—Organized and Coherent

The Importance of Paragraphs

Dr. Liane Reif-Leher, in her "Confessions of an NIH Grant Application Reviewer" (*The Scientist*, September 5, 1998, p. 19), made the following observation when reviewing a research grant:

It was clear to me that bad organization could mislead the reviewer. If the topic sentence of a paragraph was full of unimportant words, I would move on to the next paragraph. This was sometimes detrimental for the applicant—as well as embarrassing for me when I learned from my peers that important information had been buried in one of those paragraphs. My suggestion to proposal-writers: Once you think that it's finished, go through it again to see if you have told the reviewer up front what is in each paragraph.

As a journal editor, one of the main problems I observed with papers was their disorganization in paragraphs and lack of logical thought throughout the piece. Paragraphs in grants and papers were often full of disconnected thoughts and the reader (me) could not follow a clear line of logic. This caused me to constantly stumble over the sentences and paragraphs, which took my focus off the science. It is very frustrating to a journal editor to read paragraphs like this:

Tetracyclines have been in use since 1948. Their side effects, however, are still a problem. Photosensitivity and tooth discoloration as well as overgrowth of nonsusceptible organisms in the gut must be considered when drugs are prescribed. It has been found that such drugs as gentamycin are only somewhat useful in eliminating gram-negative organisms. Tetracyclines are derived from Streptomyces and semisynthetic derivatives...

This paragraph is poorly organized and confusing because it contains a series of sentences that do not flow logically but rather skip from one idea to the next without context. Its topic sentence does not reflect the ideas contained in this paragraph. It begins by discussing that tetracycline drugs, despite being around since the 1940s, still have persistent side effects. Then it switches to the fact that gentamycin is only somewhat useful in eliminating gram-negative bacteria and then a completely different idea on the origins of tetracyclines.

To rectify this, the writer should outline their argument first before writing. Then they might come up with the following, which contains the 3 ideas in separate paragraphs:

Tetracyclines have been in use since 1948. Their side effects, however, are still a problem. Photosensitivity and tooth discoloration as well as overgrowth of nonsusceptible organisms in the gut must be considered when drugs are prescribed. Photosensitivity may cause…

It has been found that such drugs as gentamycin are useful in eliminating gram-negative organisms. However, some gram-negative bacteria are resistant to some tetracyclines, and it has been proposed that the outer cell membrane in gram-negative bacteria has as a protective mechanism against antibiotic selection pressure.

The classical tetracyclines were derived from Streptomyces, but the newer derivatives are semisynthetic as is generally true for newer members of other drug groups. The semisynthetic drugs …

Principles of Clear Paragraphs

All clearly constructed paragraphs contain an opening topic sentence that introduces the paragraph's concept to support the writer's arguments, clear transitions from one idea to another, a consistent order of terms and ideas, and parallel thoughts. Most effective paragraphs should be no longer than 10 sentences, and as short as 1. Each of these concepts are discussed below.

Topic Sentences

Every paragraph should start with a topic sentence that tells the reader the main idea of the paragraph. A paragraph's topic sentence must be general enough to express the paragraph's overall subject. But it should also be specific so that the reader can understand the paragraph's main subject and point. Once the topic is clear to the reader, you have given them the paragraph's main idea and they will follow clearly what you put forth as long as it follows the lead idea. Here's an example:

*The **incidence and demography** of Anorexia nervosa have been extensively characterized (1-21). Anorexia nervosa occurs in roughly 1% of adolescent and young adult females (1-3). Most cases (90%) are female (4-8), and the majority are Caucasian and come from middle-class or higher socioeconomic groups (9-14). Anorexia nervosa is more prevalent in industrialized countries that share a western view that thinness is ideal (15, 16). It develops most frequently during adolescence; mean age of onset is 17 years with bimodal peaks at ages 14 and 18 (17-19). The prevalence of anorexia nervosa has remained constant over the past few decades; one notable change is the higher incidence in women over age 30, although this still represents a minority of cases (20, 21).*

Persons with anorexia nervosa often present with varying ***symptoms of depression****. Among these symptoms are depressed mood, loss of interest, social withdrawal, insomnia, difficulty in concentrating and anxiety. Depressed mood (aka depression) is present in over 80% of women with anorexia (22) and this is often associated with alogia or loss of interest in life (23-25). In one series of 500 young women aged 20-25, 83% scored significantly higher on the Adams Depression scale compared to nondepressed women of the same age and 90% expressed they had lost an interest in their lives (26). The social withdrawal that follows…*

Here, the first sentence of the first paragraph announces the subject of incidence and demography of anorexia, and every sentence following that is about incidence and demography, nothing else. The second paragraph starts with a new idea, that anorexia patients manifest symptoms of depression, and that announces a new topic that will follow.

Unfortunately, scientists start writing from a blinking cursor on a blank page trying to navigate through many complex concepts only from memory. It is common for them to become tangled through their thoughts, so they often end up with disconnected ideas and redundancies, which produces a mess of illogical sentences through a series of tangled paragraphs.

This can easily be avoided by outlining your argument, in which the first point ("I. Incidence and demography of anorexia") is the topic sentence and ideas that connect to that (A, B, C, etc.) in your outline are linked to that one main idea:

I. Incidence and Demography

- A. One percent of adolescent, young women (Blass, Everly, Smith)
- B. Most are female (Michaels, Smith, Jones, Reiss)
- C. Most Caucasian from middle- higher-class socioeconomic groups (Michaels, Gerlach, Dant, Smith, Enayati) Etc.

With the complexities of science and the many ideas put forth in a paper and especially a grant, it is impossible for anyone to translate the thoughts from their brain to page without some structure. Thus, without an outline, writers are bound to stumble over their thoughts and arguments and end up with a mixture of different ideas that don't follow a logical line. Once the tangled mess of sentences are put forth, much like a house being built without a blueprint, it is extraordinarily difficult to untangle them and end up with a logical series of arguments (or a nicely designed house).

I cannot emphasize this enough: outline your paper or grant!

Here's another good example of disorganization:

Deaths from ovarian cancer are increasing in the United States. Postmenopausal estrogen use is associated with increased risk of hormone-related cancers. Endometrial cancer incidence increases rapidly with use of estrogen (ref). Breast cancer incidence, however, increases only following long-duration estrogen use (ref). Hormone-related cancers include endometrial and breast cancers. Recent and larger case-controlled studies have suggested an increased risk (ref), particularly with long-duration of estrogen use. Earlier case-controlled studies report decreased risk (ref), no association (ref), or increased risk (ref). Although there is evidence that pituitary and/or sex hormones play an important causal role in ovarian cancer (ref), epidemiologic studies of the association between postmenopausal estrogen use and ovarian cancer have yielded inconsistent results (ref). Small clinical studies have not yielded useful information regarding the incidence of breast cancer and long-term estrogen use (ref). However, even the largest studies have reduced statistical power to assess the risk associated with long-duration estrogen use.

Anyone reading this will throw up their hands in frustration! It's disconnected with many different ideas one after the other. To clarify the thoughts requires that you take each sentence and put it into its right place—this is NOT the job of your editor or especially your reader! The first sentence (presumably the topic sentence) is about ovarian cancer so the reader assumes that's what this paragraph is about. But that's not what the paragraph is about—it's about the association of postmenopausal estrogen use with hormone-related cancers and the evidence for that. And, the paragraph contains a series of sentences in which the evidence is not presented logically. First, we need a sentence after the topic that tells us what hormone-related cancers are—that's buried down in the 3rd sentence. Then, we are told about endometrial and breast cancers incidence and the influence of hormones on those diseases. Then comes the description of the studies. It starts with case-controlled studies, switches to earlier case-controlled studies (and in the middle, a sentence about pituitary/sex hormones, which is out of place) and then onto other studies. If you were to outline these sentences and put them in logical order, you might come out with this more logical paragraph:

Postmenopausal estrogen use is associated with an increased risk of hormone-related cancers, which include endometrial and breast cancers. Endometrial cancer incidence increases rapidly with use of estrogen (ref); breast cancer incidence, however, increases only after long-duration estrogen use (ref). Although there is evidence that pituitary and/or sex hormones play an important causal role in ovarian cancer (ref), epidemiologic studies of *the association between postmenopausal estrogen use and ovarian cancer have yielded inconsistent results (ref). Earlier case-controlled studies report decreased risk (ref), no association (ref), or increased risk (ref). More recent and larger case-controlled studies have suggested an increased risk (ref), particularly with long-duration of estrogen use. However, even the largest studies have limited statistical power to assess the risk associated with long-duration estrogen use.*

Now the paragraph (and writer) is clear! Outlining your arguments beforehand will save you major headaches down the line and you will end up with a logical, cohesive paragraph.

Use Consistent Order

In describing several ideas or items, keep them in the same order.

To study the effects of drug A on decreased estrogen production, we measured anterior pituitary luteinizing hormone (LH), follicle-stimulating hormone (FSH), adrenal cortisol, and posterior pituitary oxytocin in premenopausal women. The effect of drug A on oxytocin was negligible. However, whereas drug A decreased cortisol, it increased FSH…

Here, the reader gets confused when moving from the first sentence to the next sentence because they have first described the effect of a drug on four different hormones listed in a certain order—but the second sentence tells us the findings on the hormones listed in a different order, and the reader is wondering what happened to the luteinizing hormone, the first on the list before they move on. Thus, the author should have written:

To study the effects of drug A on decreased estrogen production, we measured anterior pituitary luteinizing hormone (LH), follicle-stimulating hormone (FSH), adrenal cortisol, and posterior pituitary oxytocin in premenopausal women.. LH decreased in response to drug A, but FSH significantly increased in …

Parallelism

Use consistent construction and ideas throughout to clarify your thoughts.

*This research follows four distinct phases: (1) **establishing** reliable instruments (2) **measuring** patterns (3) **developing** interventions and (4) **disseminating** successful interventions to other settings and institutions.*

Our specific aims are to: (1) ***identify*** *immune mechanisms of B-cell depletion, (2)* ***measure*** *patterns of CD-20 cell growth, and (3)* ***develop*** *interventions for neuronal-based destruction.*

Cardiac output ***increased*** *by 40%, and blood pressure* ***decreased*** *by 10%.*
Rather than
Cardiac output ***increased*** *by 40%, but blood pressure was* ***reduced*** *by only 10%.*

You would, for example, present several actions in a sentence in parallel form:

In this experiment, we ***lavaged*** *the excised rabbit lungs twice with saline to obtain the pulmonary macrophages,* ***suspended*** *the macrophages in minimal essential medium,* ***exposed*** *them for 4 min to the filtered-gas phase of cigarette smoke, and* ***incubated*** *them under CO_2 at 37°C.*

Parallel form in a paragraph also applies to ideas that should be presented in parallel fashion. Here's one example.

*To determine whether cholinergic or adrenergic nerves mediate release of glucocorticoids from the adrenal gland, we did experiments on glands excised from white rats. T**o induce release of hormone**, we stimulated the tissue both electrically and pharmacologically.* ***To inhibit the hormone****, we added an inhibitor to the bathing solution.*

The author, in an attempt to abbreviate the idea, or just not seeing the mistake, used the bolded words to describe how first, they induced the hormone's release by stimulating the tissue…and then, in the next sentence, to inhibit the hormone's release, they added an inhibitor…but the two ideas are different—they are discussing how they induced and inhibited the hormone's release and the last sentence says they inhibited the hormone itself, something different. Thus, the paragraph should read:

To determine whether cholinergic or adrenergic nerves mediate release of glucocorticoids from the adrenal gland, we excised whole adrenal glands from white rats to study them in vitro. We ***induced secretion*** *of hormone by stimulating the tissue both electrically and pharmacologically. We* ***inhibited secretion*** *of hormone by adding the inhibitor B to the bathing solution.*

And, as an added point—note the first example says *we did experiments on glands excised from white rats.* This is grammatically incorrect—the scientist *excised whole adrenal glands*—be precise and accurate in what you write.

To conclude, outline your work first! When you begin to write those paragraphs, use your outline to guide your topic sentences and arguments and make one main point in each paragraph. Use transitions to help the reader to the next paragraph. Use headers to help them navigate through your argument. And allow plenty of time for revisions, which is at the heart of good writing.

Exercises, Chapter 4

Improve the following 3 paragraphs by editing and rearranging the elements.

1. Headache is an extraordinarily common pain symptom that virtually everyone experiences at one time or another. As a pain symptom, headaches have many causes. The full range of these causes were categorized by the International Headache Society (IHS) in 1988. The IHS distinguishes two broad groups of headache disorders. These are primary headache disorders and secondary headache disorders. Secondary headache disorders are a consequence of an underlying condition, such as a brain tumor, a systemic infection or a head injury. In primary headache disorders, the headache disorder is the fundamental problem, and it is not symptomatic of another cause. The two most common types of primary headache disorders are episodic tension-type headache (ETTH) and migraine.

Edited version: ____

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2. In the present study, benzene pollution was monitored from each of the European towns of Antwerp, Athens, Copenhagen, Murcia, Padula, and Rouen, using 100 benzene sampling sites that were located over a city multi-scale grid map that was drawn directly onto the town map. Regularly, every 2 months, from September 1997 through September 1998, these same sites were sample measured for benzene substance pollution during the week from Monday morning to Friday afternoon through the use of a radial symmetry passive sampler measurement device. This measurement device was termed a radiello.

Edited version: ____

____

3. Our research team investigated the effects of glue, epoxy resin, on the activation of brain patterns in thirty patients. The results of the present study suggest that in addition to the immediate aberrant activation patterns seen in brain activation of patients following the presentation of the noxious the glue substance (epoxy resin), there was other abnormal patterns observed that were longer lasting up to a week. These subsided over time. Importantly, it can be said that these latter effects are due to damage to the myelin of the nerve cell that affect the transmission of patterns seen in the current brain activation study and that are likely reversible due to myelin regeneration abilities. However it is also likely that the shorter term changes seen here reflect other structural damage in addition, but this was not investigated. At the present time, the mechanism of action is unknown that causes damage from this noxious material.

Edited version: ______________________________

See suggested answers on page 89.

Chapter 5: Mechanics and Style

In this chapter, I provide essential information about mechanics and style, including grammar and punctuation, how to use numbers and units, and information on using figures and tables, all important in constructing clear, concise, and accurate scientific documents. Many journals maintain their own style, particularly for units and numerals, but here, I am using the *AMA Manual of Style* 10th Edition as an often-cited style used by authors and editors.

Grammar Basics

Understanding the basics of grammar is essential to good writing. Here, we focus on how to avoid common grammatical mistakes in writing rather than provide a primer on grammar.

Dangling Participles and Referents

This is a verb form that usually ends in *–ing* and shows up in places where it doesn't belong and often refers to the wrong thing. When you spot a phrase starting with an *–ing* verb, beware—make sure it modifies what it's supposed to.

After closing the incision, the dog was moved to the kennel.
(Obviously, the dog did not close the incision). This can be easily corrected to:
After we (the veterinarians) closed the dog's incision, we placed it in a kennel.

Using the Kjeldahl method, nitrogen was determined…
versus
We used the Kjeldahl method to determine nitrogen…

Spit Infinitives and Verb Phrases

This construction happens when a word or phrase, usually an adverb or adverbial phrase, comes between the marker to and the infinitive form of a verb.

*The authors planned **to promote** exercising vigorously.*

Is it the exercising or the promotion of exercising that is vigorous? It's ambiguous. To clarify the meaning, write:

*The authors planned **to vigorously** promote exercising.*
Or
*The authors planned **to promote** vigorous exercise.*

Subject-Verb Agreement

The subject and verb must agree by number.

Plural verbs should follow plural nouns, and singular verbs follow singular nouns. This rule is true even when a phrase ending in a plural noun follows a singular subject or a phrase ending in a singular noun follows a plural subject.

*A **review** of all patients with Stage II adrenal tumors **was** [*not ***were***] undertaken in the university hospital.*

The subject in this sentence is review. Ignore all modifying prepositional phrases that follow a noun when determining verb agreement.

*This patient, together with her nurse and her family, **makes** [*not ***make***] this decision.*

*The investigator, in addition to all participants, **was** [*not ***were***] expected to abide by the institution's safety guidelines.*

<u>Common plural nouns</u>. A few plural nouns like *data, agenda, bacteria* are used so commonly as singular that they are often used with a singular verb.

*The agenda **has** [*not ***have***] been set for our next meeting.*

This is true with words like *bacteria, criteria, phenomena.* When the singular is intended, use *bacterium, criterion, phenomenon.*

Also, *data* is often used as a singular when used as a plural (collective) noun and, it takes the singular verb in this way.

In the final analysis, few data ***were*** *[*not ***was****] available to support our hypothesis.*

When you need to use -*s* or -*es* in parentheses to express the **possibility** of a plural, use a singular verb.

The risk factor(s) for these patients ***was*** *(*not ***were****)* not *always clear.*

Collective nouns. When you name more than one person, place, or thing meant as a unit, use the singular verb.

Ten percent of Dr. Smith's time **is** *[*not ***are****] spent on lecturing medical students. [Ten percent* is thought of as a unit with a singular verb.*]*

The emergency paramedic crew ***responds*** *[*not ***respond****] to these accidents.*
Here, *Crew* is thought of as a unit here, so it takes a singular verb.

Compound subjects. When 2 words joined by *and/or* are the subject, either the singular or plural verb form is used—depending on whether the words joined are singular or plural and on the connectors used.

Joined by *and*. With *and*, a plural verb is usually correct.

The nurse ***and*** *the physician* ***are*** *discussing my case.*

A singular verb should be used if the 2 elements are thought of as a unit:

Chemotherapy and radiation ***was*** *suggested in this patient.*

or refer to the same person or thing:

The last author and co-investigator in charge of budget ***takes*** *responsibility for the financial analysis.*

Compound Subject with *or/nor.* Use a plural verb if both elements are plural or singular verb if both are singular. When one is singular, the other plural, the verb should agree with the noun closer to the verb.

*The nurse or physician **makes** the decision on patient care.*

*The nurses or physicians **make** the decision on patient care.*

Which Versus That

A phrase introduced by "that" is <u>restrictive</u> and cannot be omitted without changing the meaning of the sentence. Such essential material should <u>not</u> be set off by commas.

*Animals **that** were treated with antibiotics recovered.*

This means that those animals treated with antibiotics recovered. It implies that animals not treated with antibiotics did not recover.

A <u>nonrestrictive</u> phrase adds information, but does not limit what it modifies. Because it can be omitted without changing the sentence meaning, it is <u>always</u> set off by commas. *Which* should be used to introduce a <u>nonrestrictive</u> phrase.

*Animals, **which** were treated with antibiotics, recovered.*

This means the animals recovered—and that they were all treated with antibiotics (a parenthetical phrase). This is quite different than the first sentence.

As another example, suppose a doctor gave this instruction to a nurse:

Do not give steroids that are diabetogenic.

This would mean don't give the steroids that cause diabetes, but you can give those steroids that don't cause diabetes.

Or, instead, if the instruction came as:

Do not give steroids, which are diabetogenic.

This means all steroids cause diabetes, a **very different instruction.**

Punctuation

Comma (,). Commas produce a pause between words or phrases. When you read the sentence, if you find yourself pausing, it probably signals a comma. For example, if you were to read the unpunctuated sentence:

Although drug A was discontinued after 9 days the tumors regressed.

This is ambiguous and could be interpreted at least 2 very different ways:

Although drug A was discontinued, after 9 days, the tumors regressed.
Or
Although drug A was discontinued after 9 days, the tumors regressed.

Make certain your meaning is intended when working with <u>dependent clauses</u> (those clauses that are dependent on the meaning) versus <u>independent clauses</u> (those clauses that are not dependent on the meaning). For example:

*A study was made of all patients with signs of infection. The patients with tuberculosis **who did not miss doses** were more likely to remain culture-negative.*

This clause "who did not miss doses" is not set off by commas and thus signals a dependent clause—the sentence means that the tuberculosis patients who did not miss doses—as opposed to the tuberculosis patients who <u>did</u> miss doses—were more likely than other patients to be free of infection (i.e., culture-negative for bacteria).

Compare this with:

*A study was made of all patients with signs of infection. The patients with tuberculosis, **who did not miss doses,** were more likely to remain culture-negative.*

This means that none of the tuberculosis patients missed doses, and that the tuberculosis patients were more likely to remain culture negative than patients with other signs of infection.

Use commas to set off a clause that is not required (a parenthetical clause) in the sentence to make it clear. You can think of such a parenthetical clause as being in parentheses or set off by a dash:

These 10 experiments, 4 of which were from our first series of studies, were designed to investigate the PL1 gene function.

Serial commas. In a series of 3 or more actions with a single conjunction (*and*), use a comma after each term and the *and*.

Before resuspending the HeLa cells in Delbecco's medium, they were treated with 10 mL trypsin, centrifuged, and washed with physiological saline.

Heart disease is commonly increased in persons who smoke, are overweight, and inactive.

Positive, negative, and neutral leads were used in the EKG studies.

Do not use a comma between a subject and verb:

Analysis of the results obtained after one minute, indicates that...

Awareness and recall during anesthesia and surgery, have been reported...

An example of this, is the treatment…

Semicolon (;). If the series just mentioned contains commas that set off a parenthetical phrase, use semicolons to separate the actions. That is, use the form:

Item 1, which is first; item 2, the second item; and item 3. As in:

Deep vein thrombosis was the highest in patients who smoked cigarettes, but did not use other tobaccos; who were overweight by at least 10 kg; and who did not exercise more than once a week, which we termed "inactive."

Treatment consisted of graded exercises, which were supervised by a physical therapist; beta-blockers, chiefly Cardene; and avoiding fatty acids and cigarettes.

Use semicolons to link two independent clauses and to connect closely related ideas.

Mutations of the pRAS gene block the RAS pathway in breast cancer cell lines; the pFRA gene turn on the RAS pathway but block the IDJ pathway in ovarian cancer cell lines.

Colon (:). Use a colon to introduce an explanation or an example of something.

In these experiments, we accomplished 3 objectives: (1) to test the hypothesis that …., (2) to determine …, and (3) to show that... .

Apostrophe ('). Use the apostrophe to denote possession.

The study's protocol;
The investigator's background.

Using an apostrophe to denote possession of a person's name that normally ends in an "s" (e.g., Chris), add an ***'s*** as in:

*Chris**'s** pen was broken.*
*Thomas**'s** brother was injured in the accident.*
*Charles**'s** mother died of ovarian cancer.*
But not:
The doctors's collective diagnosis …. This should be
The doctors' collective diagnosis

You can use an apostrophe to show the plurals of single letters:

*I've dotted the i**'s** and crossed the t**'s.***
*Find all the p**'s** in this sentence.*

Use an apostrophe to show the plurals of numbers:

*Find all the number 7**'s.***

Do not use the apostrophe to form the plural of nouns, names, abbreviations, or numerical dates (as in incorrectly stating: *Those early trials were all conducted in the 1980**'s***).

Hyphen (-). Hyphens are commonly used in scientific writing to form compound modifiers, and they are commonly used incorrectly or worse, often omitted, which can make the sentence misleading, ambiguous, or wrong. Modifiers are often composed of more than one word, usually two-word adjectives modifying a noun.

Correct examples of hyphenations in science writing:

Low-quality suture material
100 foot bandages vs. 100-foot bandages (**very** different meanings)
Man eating shark vs. man-eating shark (first is a man in a restaurant, second is a fish)
Long- and short-term memory
2-, 5-, and 10-hour experimental trials
Endocrine therapy-resistant breast cancer vs. endocrine therapy resistance in breast cancer
T cell-based therapy
Fixed-duration, constant-rate infusions vs. infusions of constant rate and fixed duration

Dash (—). The dash is sometimes used to mark off information or ideas that are not essential to an understanding of the rest of the sentence. It can be thought of like the parentheses. Be sure you do not use a hyphen to designate a dash. You produce a dash on your keyboard by typing *option shift hyphen* (mac keyboard) or *alt shift hyphen* (PC keyboard).

The transformed HeLa cells—similar to the type of cell used in our experiments—were all found to lack the KJL gene.

Also, you may use the dash to show other kinds of breaks in a sentence, for which a comma, semicolon, or colon would be used traditionally:

Such genetic studies have changed in the last 20 years—mainly for the better.

Measures and Numbers

I recommend the *American Medical Association's Manual of Style* as a strong and complete source for units of measure and numbers, some of which are summarized here.

The international system of units (SI) is used in all scientific writing. The base units of the SI system:

Quantity	Base Unit Name	SI Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	Centigrade	C
Luminous intensity	candela	cd
Substance amount	mole	mol

Although not included in these base units, the liter (L) is a fundamental measure of capacity or volume. The liter is the recommended unit for volume of liquids and gases, whereas the cubic meter (written m^3) is used to designate the volume of solids.

Prefixes are used with base units to form multiples of units. The common factors designated by prefixes are powers of 10. Common prefixes are:

Factor	Prefix	Symbol
10^{12}	Tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Examples: *terabytes (TB), megabytes (MB), picometers (pM), millilitres (mL), microliters (μL), centimoles (cmol), nanometers (nm).* Note the capital *"L"* in *"mL."*

Capitalizing Units. When spelling out the unit (i.e., *kilogram*) in writing, use lower case, except for Celsius (as in *degrees Celsius*), which is capitalized because it denotes the name of the man who invented the scale. The symbols for SI units are also written lowercase, with the following exceptions:

Abbreviations derived from proper names should be capitalized (*N* for *newton* or *K* for *kelvin*), but when spelling these out, they are not capitalized (e.g., *newtons, kelvin*). Or, *A* for *ampere*.

The uppercase letter *L* is used for liter to avoid confusion with the lowercase letter *l* and the number *1*.

Some prefixes are capitalized to distinguish them from singular lowercase abbreviations:

M used for *mega* (10^6), whereas *m* is used for *milli* (10^{-1})
P is used for *peta* (10^{15}), whereas *p* is used for *pico* (10^{-12})

Products of unit symbols. The product of 2 or more SI units should have a space between them or a raised multiplication dot (·) positioned properly to distinguish it from a decimal point. When unit is the product of ≥2 units, use abbreviations (symbols) or nonabbreviated units:

Preferred	Newton meter is written as *N m* or *N · m* as in *50 N · m*
Avoid	*Newton · m* or *N · meter*

SI unit symbols in designating "per" may be expressed by the forward slash (/) or negative exponents. Do not use the word per.

$\mu g/L$ or $\mu g \cdot L^{-1}$
but not
µg per L or *µg per liter*

However, when spelling out the unit names in a quotient or in text, the word *per* is used.

The power output was measured in joules per second.
but not
*The power output was measured in joules/second [*or *J/s].*

Expressions with 2 or more units of measure require the forward slash, dot products, negative components, or parentheses:

$mL \cdot kg^{-1} \cdot min^{-1}$ or $mL/kg/min$
$m^2 \cdot kg \cdot sec^{-2} \cdot A$ or $(m^2 \cdot kg)/(s^2 \cdot A^2)$

Format, Style, Punctuation of Units

Exponents. Exponents like square (^{2}) and cube (^{3}) are used in scientific writing rather than *cu* (cubic) and *sq* (square):

m^2 not *sq m*

m^3 not *cu m*

however, in the text, you could write:

223 square meters but it also acceptable to write *223* m^2 as long as you consistently refer to the measurements in text using the same convention throughout. All tables and figures would use the symbol.

Plurals. Units are always singular, so that you use the same symbol for single and multiple quantities:

70 L not *70 Ls*

500 g not *500 gs*

400 lb not *400 lbs*

2.3 m not *2.3 ms*

Singular vs. Plural. Units of measure are treated as collective singular nouns and require a singular verb:

To control the patient's fever, 500 mg of acetaminophen ***was*** *[*not ***were****] administered.*

Beginning sentences and titles. A unit of measure that follows a number at the beginning of a sentence or a title is not abbreviated, even though the same unit of measure is abbreviated if it appears elsewhere in the same sentence:

Six-hundred forty eight grams of drug was processed by ion-exchange chromatography.

Not

648 grams of drug was processed by ion-exchange chromatography.

Or sometimes using *A total of* can circumvent this:

A total of 648 grams of drug was processed by ion-exchange chromatography.

Punctuation. Symbols or abbreviations of units are not followed by a period unless they occur at the end of a sentence:

The patient's weight was 80 kg [not 80 kg.] and had increased by 10%.

Hyphens. A hyphen is used to join 2 spelled-out units of measure:

The time was 1008 pascal-seconds.

A hyphen is used to join a unit of measure and the number associated with it when the combination is used as an adjective (modifying a noun):

We used 8-L containers for storing cells.
The 10-mm strip was used for the experiment.

Hyphens are often misused and can produce confusion or the wrong meaning:

10 foot bandages means there were a quantity of 10 foot bandages.
versus
10-foot bandages means the bandages were 10 feet long.

Hyphenate all terms in a list if they modify the same word. Do not repeat the word that modifies the unit.

The 10-, 15-, and 30-minute assays.
The epinephrine- and isoproterenol-induced responses.
The drug-sensitive and -insensitive cells were compared.

Purple-labeled tubes means the labels on the tubes were purple.
Red labeled tubes means the tubes were red and also labeled, but the label is not red.
The green-labeled purple tubes means the tubes were purple with green labels.

Adverbs always modify verbs or adjectives, so they don't need special treatment when used that way. Words ending in "*-ly*" are adverbs and never hyphenated:

A newly established pathway.
A highly regarded expert in the field.

A good example of hyphenations and meaning:

An insulated Styrofoam container.

This phrase means the container is insulated and it's also made of Styrofoam; the Styrofoam is not insulated—the container is (i.e., it's an insulated container).

Compare this with:

A Styrofoam-insulated container.

This phrase means the container is insulated—and the insulation is Styrofoam.

If written out, compound numbers are hyphenated:

Thirty-three patients were enrolled or *We enrolled 33 patients.*
One-hundred percent of the knock-out animals were used or *We used 100 percent of the knock-out animals.*
The cost of each infusion was over three-thousand dollars or *Each infusion cost over $3000.*

Spacing. With the exception of the percent sign (%) and the degree sign (° for temperature and angles), a full space is always put between the numeral indicating the quantity and the unit of measure:

140 nmol/L not *140nmol/L*
135-140 nmol/L
40% acceptance rate
45° trajectory
Temperature was 95.1°C
not
95.1° C nor *95.1 °C*

Here is an example of what your writing should look like with numbers and units:

The drug levels were 95.3 ± 15.1 pmol/L in controls (n=50) and test cells (n=55). We treated cells with 300 µM cAMP for 10 min and at 37°C, and 88% survived the final assay. The test animals weighed 55 kg. All control and test animals had an initial fever of 38.3°C. The test cells were incubated in a 95% CO_2 *incubator that was 5.1* m^2.

Using Numerals with Units

Use only numbers between 1 and 1000 and use the appropriate prefix for quantities. For example, 0.003 mL is expressed as *3 µL* and 15,000 g is *15 kg*.

Some measures are expressed in quantities and units that may have numbers outside this range:

20,000,000 A
may be expressed
as *20 million amperes*
or as *2 x 107 A*

Decimal. The decimal format is used for numbers with units of measure. Values less than 1 require placement of a "0" before the decimal marker:

0.125
$P<0.05$

This is because in printed material or even PDF files that are smaller when viewed on a computer screen, the decimal mark is difficult to see and a P value of 0.05 written as *.05* may not be clear. Thus write:

$P<0.05$

Fractions should not be used with units:

2.5 kg not *2½ kg*
*After 7.5 years (*not *7½ years) of investigation, our efforts were abandoned.*

Numbers Used in Text

This is often confusing for writers who cite styles in which one should spell out all numbers between one and nine and use numerals 10 and above. However, this rule is not used commonly, and numerals should be used in text when expressed as a value. However, journals may have their own style—check a current journal article to see how the specific journal uses numbers in text. Some examples commonly seen:

In the second phase of our study, 3 of the investigators administered the 5 tests to the 7 remaining participants… test scores showed a 2- to 2.5-fold improvement over those of the first phase. Of the 10 tests we tried, only 2 were validated.

In 2 of the 17 patients that showed signs of the disease.
In patient 3, we observed…
Groups 1 and 3 were similar for demographic characteristics (Table 1).
Tables 3 and 4 list the test names.
The 4 tests that were given included the 10-listed questionnaire.
A 3-member committee visited the laboratory.
Of the 45 tests studied, 15 were deemed plausible.
Of the 10 patients studied, only 1 had clear signs of infection.

For idiomatic expressions such as the word *one* (to mean being a person, thing, or individual instance), which appears in running text without referring to a quantity, the word should be spelled out. Also, *zero* can be spelled out to avoid confusion with the letter oh (*o* or *O*). Generally, large numbers should not be spelled out unless they begin a sentence, which is not preferable. Examples:

Any one of the 12 individuals.
or to avoid confusion,
Any of the 12 individuals.
One might confuse this with…
The study was plagued by one problem after another.
Models were developed to allow for the inclusion of one-time variable.
The variable was zero.

Ordinals. Ordinals express order or rank, not a precise quantity and are nontechnical aspects (i.e., third, first, ninth) in writing. The numerical expression of these (1^{st}, 2^{nd}, 3^{rd}) may appear jarring in a sentence, and interrupt flow of ideas, so spell out the ordinals *first* through *ninth.*

The third patient was not available for reevaluation.
In the series of 10 patients, the second was…the ninth was...
The 10^{th} in the series of 12 tests were studied.
The fourth patient in the series was re-examined for inclusion criteria.

However, if the sentence contains 2 or more ordinals, at least one of which is greater than *ninth*, all should be numerical to avoid confusion:

Patients in the 4^{th} and 10^{th} series of tests were included in our survey.
The first and third patients were treated with placebo.
Of the 15 analysis groups, the 2^{nd} and 10^{th} were eliminated from statistical consideration.

Large rounded numbers. Numbers starting with million should be expressed with numerals and words:

Rheumatoid arthritis affects 5 million to 6 million people (million is repeated to avoid ambiguity).

The projected budget is $8.5 million… This is sometimes written *$8.5M*

Consecutive numerical expressions. When 2 or more numbers appear consecutively in a sentence, either reword it or spell out 1 of the numbers for clarity:

In the cohort of fifteen hundred, 690 were men.
better:
In the cohort studied, 690 of the 1500 individuals were men.
but not:
In the cohort of 1500, 690 were men.

Use numerals consecutively if they refer to items in an array:

The life expectancy of groups 1, 2, and 4 was 50, 83, and 85 years, respectively.

The word *respectively* can be problematic. In the previous sentence, you could write instead:

Life expectancy of group 1 was 50 years, of 2 was 83 years, and of 4 was 85 years.

If abbreviations or symbols follow numbers, reword the sentence to avoid confusion:

There were 2 D2 dopamine receptor isoforms
should be rewritten to:
The D2 dopamine receptor has 2 isoforms…

If the journal requires superscripts to indicate references, be careful to place it so that it is not confused for an exponent:

Increased mortality has been associated with a BMI less than 18^{2} *and greater than* 27^{3}.

This should be changed to:

Smith et al[2] *also found a BMI <18 was associated with increased mortality; and a year later, these authors also found that patients with a BMI >27 had increased mortality.*[3]

<u>Hyphens to indicate spans of years, pages.</u> Digits should not be omitted when indicating the span of years or page numbers in the text.

The students participated in the study during the 1994-1995 academic year.
not
the 1994-5 academic year.

The test procedure was included on pages 22-25.

To avoid ambiguity, use the word "*to*" instead of a hyphen if necessary. The word "*through*" is only used when the final digit is included in the span, but "*to*" is used when the final digit is not included in the span. A hyphen generally means "through."

The participants ranged in age from 28 to 86 years.

Means participants were aged 28 years up to 86 years, but not 87 years of age or older.

The trial enrolled 334 patients from December 10th through June 4th.

Means they enrolled patients from December 10$^{\text{th}}$ through the day of June 4$^{\text{th}}$.

<u>Numbering items in a list.</u> To show a list of enumerated items, use numerals run in and enclosed within parentheses in the text:

The testing format focused on (1) strength skills, (2) memory recall, and (3) cognitive ability.

If the list is short, you would not need to number the items:

We tested for language skills, memory, and cognition.

If the list is long, use a table or a bulleted list:

Anorexia nervosa includes the following:

- *Low body weight with refusal to maintain a normal weight*
- *Fear of being overweight*
- *Disturbed body image*
- *Denial of being underweight*
- *Poor self image*
- *Absence of menstrual cycle*

Tables, Graphs, and Redundancy

Although many authors know how to depict complex concepts and data into tables and graphs, which should be constructed while the paper or grant is being outlined, they commonly invite redundancy. For example, some figures and tables contain identical information, which an editor will find and believe that the author did not proofread their paper. In addition, authors, in writing results, will refer to a table or graph and repeat obvious information that is contained in them rather than provide the reader with information not obvious from the table/graph, which is important in interpreting the data.

In deciding whether your data should be put into a table or figure, you should read the sentence to decide if too much data in the text obscures the meaning. The following text requires a table because it is too difficult for the reader to visualize in a sentence:

Kaplan-Meier estimates for DOR, inclusive of the 48-week dose-response trial and ongoing extension study, showed that the drug idelalisib was associated with a median DOR of 2.7 months (95% CI, 1-8.1; range, 0.3-28.2) in the 16 responding patients that had disease progression of 5.3 months ± 3.2 days (median of 5.7 months, Mann-Whiney U test statistic=-1.34, p<0.001). Of the 40 patients entering the 48-week dose-escalation trial, 5 received 50 mg bid, 7 received 100 mg bid, 7 received 150 mg qd, 5 received 150 mg bid for 21 days, 4 received 300 mg qd, 6 received 150 mg bid, 3 received 200 mg bid, and 3 received 350 mg bid.

However, the following text does not require a table or figure because it is using data to compare two groups:

As compared with patients in the placebo group, the number of patients in the treatment group with relapses was reduced at treatment week 24 (14.5% vs. 34.3%, p= 0.02) and week 48 (20.3% vs. 40.0%, p=0.04).

Examples of figures and tables illustrate some of these points. This particular example was taken from the public domain article *Goldberg RL, Tamura T, Neggers RL et al. The Effect of Zinc Supplementation on Pregnancy Outcome. JAMA 274 (6): August 9, 1995.*

Table 2 (following) was taken from this article to show the main findings. The table is very clear. It contains a straightforward table title and the data are organized by groups and further within each group by treatment of zinc vs. placebo. Each of the outcomes are organized further by maternal characteristics (age of mother, her BMI, smokers), pregnancy outcomes (baby data), baby anthropomorphic measures, and outcome of baby (sepsis, hospital stay).

You can immediately see where the big differences in groups lie. The reader does not need any immediate regurgitation of the data, just a summary of the main findings—as you see by the actual text in the article.

Table 2.—Selected Pregnancy Outcomes and Neonatal Measurements in the Zinc Supplement and Placebo Subgroups by Body Mass Index (BMI) Categories

	BMI ≥26			BMI <26		
	Zinc Supplement (n=155)	Placebo (n=145)	P	Zinc Supplement (n=134)	Placebo (n=134)	P
Maternal Characteristics						
Age, y	24.8	24.2	.32	22.9	21.2	.01
BMI, kg/m²	33.4	33.0	.64	22.3	22.2	.57
Current smoker, %	7.7	5.5	.44	3.0	3.0	.98
Pregnancy Outcome						
Birth weight, g	3240	3241	.99	3190	2942	.005
Gestational age, wk	39.0	38.7	.47	38.6	37.9	.08
Preterm birth <32 wk, %	3.2	5.5	.33	3.0	6.8	.15
Birth weight <1500 g, %	3.9	3.5	.84	2.3	6.0	.12
Anthropometric Measurements						
Crown-heel length, cm	50.2	49.8	.41	50.3	49.7	.20
Head circumference, cm	34.3	34.0	.50	34.1	33.4	.005
Abdominal circumference, cm	33.3	33.1	.64	32.8	32.6	.58
Arm length, cm	9.9	9.7	.27	9.9	9.6	.03
Subscapular skinfold, mm	4.2	3.9	.05	3.9	3.6	.06
Neonatal Outcome						
Neonatal hospital stay, d	3.9	4.5	.47	3.1	4.9	.10
Neonatal sepsis, %	0.7	1.4	.52	0	2.2	.08

The text associated with this table reads:

"In women with BMI <26 kg/m², zinc supplementation was associated with a significant increase in birth weight of 248 g (P=0.005), an increase in head circumference of 0.7 cm (P=0.005), and increase in arm length of 0.3 cm (P=0.03). The other outcome measures all favored the zinc supplement group but the differences were not statistically significant (Table 2)."

Yes, there is data repeated from the table in these sentences, but it summarizes only the 3 main outcomes of the study that the authors wanted to focus on. It's to the point and brief and the table easily understood.

However, if the author was not thinking clearly they might have instead written:

In Table 2, we show the two groups of women with BMI ≥ 26 kg/m² and those with BMI <26/m², each divided into placebo and zinc supplementation subgroups. The data show that there was no significant difference in the ages of mothers in the first group, but, in the second group, mothers' ages were significantly different (P<0.01). In both groups, the BMI of zinc and placebo subgroups were not statistically different (P=0.64 in group BMI ≥ 26 kg/m² and P=0.57 in group BMI >26 kg/m²)....

This sort of writing, regurgitating what is in the table, is a disservice to readers and a common flag for journal editors that there might be other problems with the paper. It also does not provide the reader with information important for them to interpret the findings of the study.

Another table from that study with its associated text shows how brief and to the point your results can be:

Table 3.—The Effect of Maternal Zinc Supplementation on Birth Weight by Body Mass Index (BMI) Categories

	Zinc Supplement Group		Placebo Group		Difference	
BMI Category, kg/m^2	No.	Birth Weight, g	No.	Birth Weight, g	Birth Weight, g	*P*
<19.8	20	2997	23	2572	425	.11
19.8-26.0	116	3224	109	3038	186	.04
26.1-29.0	46	3279	37	3227	52	.74
>29.0	108	3223	108	3267	−44	.60

Table 3 shows the mean birth weight by the BMI categories recommended by the NIH Institute of Medicine. The lower the BMI, the greater the effect of zinc supplementation on birth weight.

That's all that was said for this result. Direct, to the point, and simple.

In conclusion, scientists must master basic grammar and the correct use of punctuation marks to make their meaning clear. Correct use of numbers and units in writing science is also vital to avoid confusion and incorrect interpretation. Tables, graphs, and illustrations should be carefully considered so that they enhance rather than confuse the reader's understanding of the research. To learn more about tables, figures, and graphs, I recommend the *American Medical Association's Manual of Style*, which also addresses whether specific data are better presented in a table or a figure.

Exercises, Chapter 5

Edit the following to correct the mistakes, if any:

1. The 10 µM copper sulfate solution was added to 3 10 mL tubes containing EDTA buffer at 37 ° C.

Edited version: ______________________________

2. Fifty four patients were enrolled in the study.

Edited version: ______________________________

3. The average cost per run was over 3 thousand dollars.

Edited version: ______________________________

4. The drug induced side effects of aspirin include GI distress.

Edited version: ______________________________

5. The Ca++ and phospholipid dependant enzyme reactions were studied.

Edited version: ______________________________

6. The inhibitor genistein which is selective for tyrosine kinases inhibited this serine kinase mediated response.

Edited version: ______________________________

____

7. The control cells showed modest internalization, but, drug treated cells showed less internalization contrary to our hypothesis.

Edited version: ______________________________

____

8. Treatment of deep vein thrombosis includes the use of anticoagulant drugs, frequent walking, cessation of smoking, which is often difficult, and wearing full leg compression stockings 2x weekly.

Edited version: ____

____

9. Since C3 toxin is a highly selective Rho inhibitor we avoided it's use in these metabolism studies.

Edited version: ____

10. The drug which we used to block redox signaling was tempol.

Edited version: ____

11. In the Boyan assay, 10^5 cells were added on 6.0 mm diameter filter cups (8 µm pore, Cambridge Corporation), with 100-µL of serum free DMEM and incubated at 37° C for 6 hrs in the presence and absence of 1 µM LPA.

Edited version: ____

____

____

12. In this 2nd group of 2000 patients, 690 were ineligible for inclusion.

Edited version: ____

13. Following the appropriate guidelines, the abstracts were much clearer.

Edited version: ____

14. The first author and principal investigator take responsibility for the data analysis.

Edited version: ____

15. The number of participating centers in the study was 130.

Edited version: ____

See suggested answers on page 90.

Chapter 6: Shape—Looking at the Whole

The Rules of Good Writing and Revision

Here, I offer advice from my experience in working with students and investigators at all levels at many different academic institutions as well as private companies. It is advice that most respected journal editors, peer reviewers, and good writers will likely give you.

1. Know your audience—your reader. Most writers write for themselves, ignoring the reader. Without considering who will read your article, you will not first consider how fully you should explain more difficult concepts, what figures or tables to include, or what terms and concepts you need to define. In some highly specialized journals, this may seem obvious. However, with readership world-wide and science becoming increasingly cross-disciplinary, writers must consider a more common audience than might seem obvious. Before you start typing from that blinking cursor, consider your audience—many journals publish this information in their instructions online. Talk to an experienced peer reviewer of the journal, if possible, to better understand the readership. It will serve you well.

2. Outline your work. I have emphasized this throughout this book. You remember how to outline from your freshman English class. Without an outline, you will walk through a minefield of disorganized and wayward thoughts. Starting to write a paper with that unforgiving blinking cursor is nothing short of trying to build a house without an architect's blueprint. The end product ends up with a mess of disorganized and illogical and poorly connected thoughts, redundancies, and irrelevant material— all of which makes the work much harder for the writer, sometimes impossible.

One of my wise mentors at Stanford, an outstanding writer, told me "the best way to edit a disorganized paragraph is to just swipe through it and hit DELETE." Many of the papers and grants I receive for review often require substantial rewriting to untangle a mess of long, illogical paragraphs, redundancies, and confused concepts. Unfortunately, once the ideas are put down for consideration, untangling them and reorganizing the paper takes far longer, is tortuous, and often results in an inferior product than if they had written it from an outline—just like the poorly designed house with disorganized spaces, layout, wiring, and plumbing. Some of the paragraphs just have to be torn apart and reordered, compounding the writer's problems, creating a patchworked nightmare, and costing the writer valuable time.

3. Never write the research paper in the same order it is presented. Starting with your abstract and moving to introduction, methods, etc., is a mistake and will create more work for you. In the process of writing a paper, especially in making the outline, authors discover new ideas and may take different directions. Thus, my advice, and that of many journal editors I have worked with, is to start with your figures and tables. Consider your data, talk to your colleagues, think about what the data is telling you, and then create your results. I often print my figures and tables and spread them out in front of me—what are they telling me? In your outline, you start framing your findings carefully. I say carefully because so many writers take the lazy route and end up regurgitating what is obvious from a figure or table, wasting valuable space but more importantly, insulting the reader's intelligence. If you have carefully crafted your figures and tables—and this means going through many revisions—your reader will be able to immediately understand them. Point out for them what is not obvious.

Look through some top-level journals in your field—or better yet, outside of your field and see how they do it. You will see some pretty sophisticated figures and tables that stand on their own and are clear at first read—they have gone through countless edits by the authors and journal editors alike. Once you frame your findings using your figures and tables, and from your outline, frame your discussion and introduction next. The methods section often can be put together anytime, but it usually will need refining once you finish your results. The discussion is critical to a paper, and so many investigators make the mistake of going off on sidetracks not relevant to their central hypothesis and findings, and many times, authors will make conclusions not supported by their findings. This is a dealbreaker for journal editors, and can often be a central reason for the paper's rejection. Discussions should put your findings in the context of other research findings, discuss weaknesses, and especially tell the reader: what's next?

Research is not carried out in a vacuum—your findings always suggest future studies, and it is important to tell your reader what you plan to do next now that you have gotten these results. Also, the introduction often suffers, largely because writers have not outlined their thoughts first, and they end up writing an exhaustive and disorganized background, some of which is not relevant to the problem. Your introduction should be short and strong—a precise background and significance that follows a logical framework. What is the problem? What do we know about it? What are our gaps in knowledge? What is my hypothesis? And how am I going to fill that knowledge gap to help solve the stated problem? And, most importantly, why is this important?

Take a clue from the NIH—the new grant structure now must include a separate section, Significance, in which you must detail why this problem is important to human health and disease. You then end the introduction with a clear and short statement of objective like "Here, our objective was to…". Abstracts are written last. Also, do not wordsmith your title until the end. Start with a working title if necessary, but you will refine it once you finish so it can be more sculpted to your paper's subtle purpose.

4. Revision is at the heart of good writing. Put the paper draft away for a couple of days. When you re-read it, you will find basic errors, many redundancies (which should have been minimized by your outline), and confusing sections. Think of your reader when you are revising—who are my readers and what do they need to know? Also, give your paper to a colleague—it is a necessary part of revision. A different point of view, whether you agree with it or not, always refreshes your perspective. You may think of yourself as an "independent" investigator, but that does not mean you work in a vacuum. Do not exclude your colleagues' ideas! And, in revising your work, learn to cut ruthlessly. Most papers I edit are 20% to 30% too long, with many redundancies and convoluted sentences that the author did not see—the track changes help them to see, but learn to carefully edit your own work. Sometimes, swiping through a tangled paragraph and hitting the DELETE button is necessary!

5. Take some lessons from seasoned writers. Scientists often ask me how I write. I find the time—usually I schedule the time—then pick a quiet place to write, free from distractions, close my door, and decide on a goal. Today, I will write my results and discussion from my outline might be a good goal. But under no circumstances will I open my paper when I have only a few minutes and try to do any serious work. Good writing requires dedication and concentration, and TIME. Unfortunately, many scientists try to write a paper in a weekend, in one sitting, go through one or two cursory edits on their own, and send it into the journal, all within a few days. Most good papers require weeks to write and will undergo many revisions—sometimes 5 or 6 drafts and other authors' input and consideration. But remember, if you are the paper's first author, it is your responsibility to take all authors' input, consider them for inclusion or not, and assure that the paper holds together with all the additions and deletions that are part of revising. I have seen some big papers turn into a nightmare of confused paragraphs and differing styles that sometimes are unrecoverable and they had to be rewritten from scratch. Do not go there.

6. Devote time. It doesn't matter when you write—some writers like writing first thing after they awaken, as they claim their mind is clear; others like writing late at night after their day's work. Whatever works for you, stick to a schedule and devote at least 2 to 3 hours, more if possible, to writing. However, writing for too long, like 6 hours, becomes counterproductive for most writers. I can't think clearly for that long and I often start making mistakes after 2 to 4 hours of writing. If you find yourself frustrated and angry at your writing, stop immediately! It is a universal truth that giving that troublesome draft an overnight rest cures many problems. Looking at work with fresh eyes is amazing—you will discover many problems and mistakes. And giving time between drafts does something else amazing—it's in between those drafts when you're out walking your dog or doing errands when the best ideas come to you. Sometimes in the moment before sleep. If you suddenly think of some great idea, or realize something you forgot that was important, write it down immediately for consideration in your next writing session. Nobody—I mean nobody—can sit down and write a manuscript or a major section of a grant (like an entire research strategy) in one sitting! Yes, you always should be working from an outline and you want to try and construct big sections as quickly as possible, but the human mind cannot contain all the aspects of a complete scientific argument in one period of time.

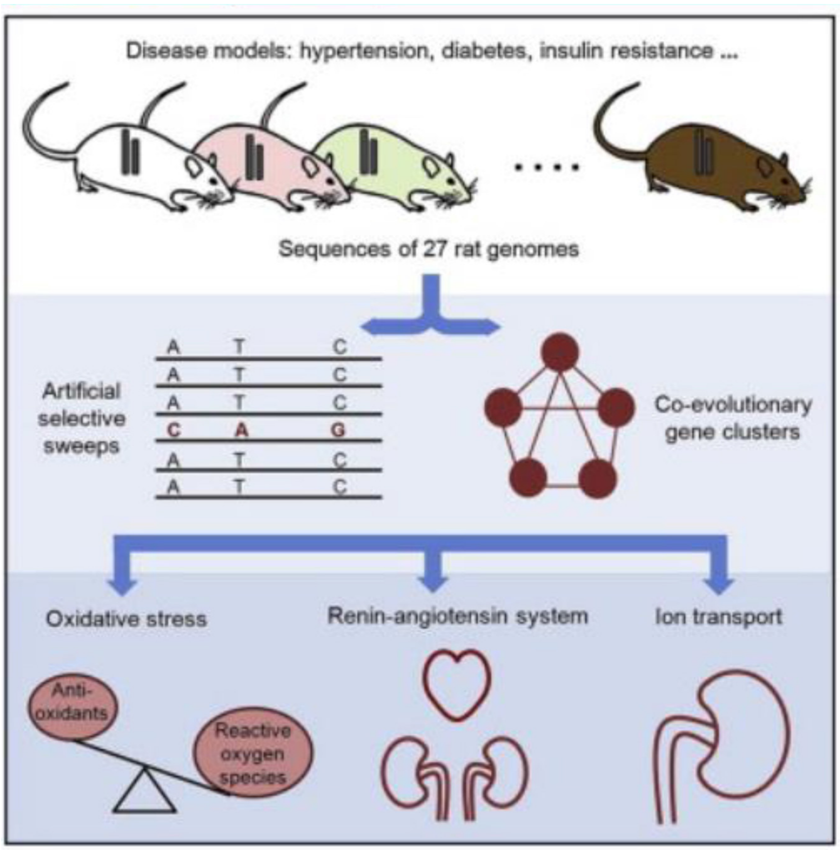
Most writers will also suggest that you **start with the previous day's work.** Writers struggle with where to start. Trying to drop yourself down into your story by writing a new section doesn't usually work well. Take the material you wrote yesterday or the day before and start re-reading that to re-familiarize yourself with the material. You'll come up with many changes and ideas for where to go from there. It works well that way. **Don't delete your previous files.** My experience is that you usually can use some previous piece of writing for another purpose.

7. When faced with problematic passages and confused writing, read it out loud to yourself or a colleague. Linguistic research confirms that seeing and hearing what you have written will help clarify the difficulties and confusion. And, when speaking your thoughts before they are put on paper, especially because the writer is not trying to wordsmith the writing to impress their reader, the thoughts often flow more naturally. Often, scientists can more easily express their thoughts through speaking. Writing down those verbalized thoughts usually makes it easier to navigate through the many complex ideas and thoughts, especially when they have already been outlined. So, the next time you are navigating through your cumbersome prose, stop and read it aloud. You will more clearly see the problems.

8. A second set of eyes is invaluable. Give your work to a trusted colleague to read—even if they are not exactly in your field. This will be very helpful because many of your reviewers will not be in the exact field you are in, and their feedback will often be valuable in seeing the flaws in arguments and confusing flow of ideas. Don't be defensive about other people's edits—you don't have to use them but more than often, they will give you insights you don't have as a writer.

9. Learn to be visually literate. From the beginning of time, humans have communicated visually and have learned to interpret, negotiate, and make meaning from complex information presented in the form of an image. Visual literacy is based on the idea that pictures can be "read" and that meaning can be communicated through a process of reading. I believe that in communicating science, particularly in an increasingly complex word of subspecialized ideas and language, becoming more visually creative will serve you well.

One of the first telling aspects of a manuscript or a grant to a reviewer is its figures and tables. But many investigators think only of the obvious ways to display complex information. There are many creative ways to simplify or convey complex mechanisms of action, study designs, and other concepts visually. Here is the "graphical abstract" from an article entitled "Genome Sequencing Reveals Loci under Artificial Selection that Underlie Disease Phenotypes in the Laboratory Rat" [Image retrieved from www.cell.com.]



This has been recognized by some journals as paramount. The highly respected journal *Cell* has launched a new format for their online presentation of all research articles. This "Article of the Future" offers a visual display of the authors' complex ideas in a visual abstract that help readers easily grasp the points of the paper. I believe it is the future of publishing. Such visual literacy, I believe, also helps writers think through complex ideas. Drawing it in some sort of graphical format will help to clarify your thought. And clear thinking is a prerequisite for clear writing. Without it, we have seen, a writer remains tangled in their own muddled thoughts.

10. Think like a peer reviewer and journal editor. Peer reviewers are busy scientists with many papers and grants to read. They are overworked, pressured, but always wanting to do a good job. They want to read well-constructed, well-organized and clear papers and grants. Anything that gets in the way of them getting the central scientific argument in your grant or paper—unclear sentences; illogical arguments; mistakes in spelling, grammar, punctuation—stop their brain from assimilating the material and they become upset. The lack of clarity reflects directly on you, the writer. Dr. Liane Reif-Lehrer, in her article in The Scientist (Confessions of an NIH Grant Reviewer, 1988, September 4, p 19), puts it this way:

"…psychological mechanisms came into play…once I lost patience with an applicant for writing a disorganized section, I was much more likely to notice other faults in the proposal. Also, when a proposal was sloppy, it was difficult not to extrapolate that the applicant's labwork was sloppy as well.

At the other extreme, the easier the applicant made it for me to get the information necessary to assess the application, the more likely I was—if the science was sound—to have a positive feeling about the proposal."

Journal editors face the same problems. As a former editor, I would read through papers that initially looked promising in terms of the science, but once I spotted mistakes in punctuation and English, sloppy academic writing, my red flags came out. I began to find other problems with the paper. It would most often present itself in the form of poorly organized paragraphs and disorganized sections, tables, and figures that were not standalone and difficult to interpret, and tons of redundancies, leading to excessive word count. In the middle of reading through a paper, I would ask myself *why didn't this investigator proofread their paper more carefully or have a colleague read it?* And, I wondered whether a similar lack of care was exercised by the investigator when they were designing their studies, in collecting and analyzing their data, or carrying out their experiments.

You should save the editor's and reviewer's time and make their life easier by presenting them with a stellar paper or grant that in every respect presents your arguments clearly, logically, concisely with **NO** English errors!

11. Get feedback on your writing from an independent editor. Edits of your work showing where you could have cut extra material (concision) and how to reword sentences and paragraphs to make them flow better are invaluable to writers. A good MD- or PhD-trained medical editor can often see the flaws in a manuscript or grant better than you can because they are removed from the work and look at the piece from the perspective of your audience. And, I recommend you use someone trained in the sciences—someone with a doctorate in the medical sciences (or with a medical degree) who has written grants and manuscripts as part of their training. There are often too many "medical" editors with a degree in English or Journalism who might help copy edit your work but they won't be able to rewrite, substantially edit, or reorganize your complex scientific ideas. This won't help you write better. I recommend the services of my own group, Medcom Consulting (http://medcomconsulting.org/MedCom.html).

Looking at the Big Picture: Significance, Impact, Innovation

When you write any scholarly work in medicine and science, you need to continually step back and **look at the big picture.** Manuscripts and grants, in particular, are works that should be a contained piece that tell a story from the problem statement, how you set out to solve it, what you found, and what that means. Too often, papers and grants ramble on without the cohesiveness necessary to tell the reader your story. The most important parts of that story are background and significance, innovation, and the impact of the work. And, again, without an outline, you will not see the big picture. If you have a cohesive outline, you can hold the entire story in your head and look at it from a higher level than when you're down in the trenches wordsmithing complex ideas and missing the whole. You should concentrate on the concepts of **significance**, or why is my research important; **impact**, or how will my research findings impact the work on my field, i.e., how will it change the direction of research; and **innovation**, or how is my work novel?

These concepts are central to an NIH grant application, and important in any scientific and medical writing. The goal of medical research is to improve human health, and all studies ultimately are funded for the purpose of diagnosing, treating, and ultimately preventing human disease. In describing their research to peer reviewers and editors, whether it be in a manuscript or grant or in a oral presentation, scientists must clearly describe and convey the importance of the problem they are studying, how it is novel or innovative, and what impact the work will have (in a grant) or has had (in a manuscript) on the field(s) and ultimately to human health. While this seems obvious, too often, scientists do not clearly convey the essence of their research to their reader in writing. Too often, either the message isn't clear or is buried, or is not stated at all. It is important to understand how to deliver these concepts in a convincing and clear way.

Here, we provide NIH grant examples available at the NIAID.

Significance

From their SF424 instructions, the NIH asks grant writers to:

1. Explain the importance of the ***problem or critical barrier*** *to progress in the field that the proposed project addresses.*

2. Explain how the proposed project will ***improve*** *scientific knowledge, technical capability, and/or clinical practice in one or more broad fields.*

3. Describe how the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field ***will be changed*** *if the proposed aims are achieved.*

These 3 points are the essence of significance, and the last point describes impact. Too often, scientists equate significance with disease burden. For example, in a grant that focused on identifying lymph node metastases in patients with resectable lung cancer, the PI, in his opening statement of the grant, writes:

Lung cancer is the leading cause of cancer deaths among both men and women in the US. In 2008, 109,643 men were diagnosed with lung cancer, and 88,329 died; in addition, 93,893 women diagnosed with lung cancer, and 70,354 died…etc.

This is the sort of material that many scientists are tempted to write in their attempt to convince the reader how important this research will be. However, it fails at that because it doesn't describe the importance of the problem nor does it highlight the gap of knowledge on the issue. This sort of writing states the obvious, is not focused to the problem, and doesn't tell the reader why this is an important problem. This rewrite gets closer to the significance:

Failure to identify regional lymph node metastases in the 40,000 US patients/year with surgically resected lung cancer is associated with a 3-fold increase in recurrence and decreased overall survival… This research will develop novel nanotechnology methods to identify and prevent lymph node metastases…

Now, we have a more focused significance, as it identifies a problem they are studying.

With this understanding, let's look at a good example of significance from an NIH grant in the public domain from NIAID:

The developing human immune system faces a balancing act that must be carefully timed. On the one hand, it must tolerate the presence of the surrounding mother and her non-inherited maternal alloantigens (NIMA) or otherwise risk the potential of engaging a fatal "graft vs. host" disease. On the other hand, novel antigens must be recognized as foreign when encountered after birth, triggering a vigorous adaptive immune response (e.g., with cytolytic T cells and neutralizing antigens) against them. Otherwise, the newborn will be susceptible to diseases caused by multiple infectious agents.

In ongoing experiments, we have obtained preliminary data (see below) indicating that this switch from a fetaltype to an adult-type immune response is dependent upon the stage-specific appearance of distinct multilineage hematopoietic stem/progenitor cells (HSPC). Nonetheless, infection remains a leading cause of death and morbidity in newborns. Not only are neonates susceptible to more severe forms of disease caused by human pathogens such as herpes simplex virus 1, respiratory syncytial virus, Bordetella pertussis and Staphylococcus aureus), they are also subject to serious infection by microbial entities that are commensal flora in adults. For example, even after implementation of intensive screening and prevention practices, the estimated rate of Group B Streptococal sepsis in the first week of life is 0.34 per 1000 live births, resulting in 60-70 deaths per year. Thus, in utero, hematopoiesis in the first and second trimester is largely sustained by a fetal-type HSPC that gives rise to tolerogenic Tregs; later, an adult-type HSPC instead gives rise to immunoreactive T cells. The timing of this switch coincides with birth and normally allows the newborn to move from a stance of tolerance to one of active defense against all foreign antigens. In this manner, the "immune privileged" aspect of mammalian pregnancy is preserved while the ability of the newborn to fight infections is also permitted. In addition to the immediate impact of neonatal illness and death, the long-term disability resulting from these infections represents a profound public health burden. Premature infants, in particular, are predisposed to more severe infections from all pathogens and can also succumb to fatal infection by microbes that infrequently cause severe disease in adults, such as Staphylococcus epidermidis. Compared with adults and older children, newborns produce less, and generally less effective, antibody in response to most immunizations. They are also less able to generate T cells that mediate effective antimicrobial responses. Together, these deficiencies render the neonate a vulnerable target for a host of invading pathogens.

If the switch to an "adult-type" immune system is incomplete or overly slow after birth, two other problems may also arise. First, the neonate may respond less well to immunizations provided during the first months of life, either generating low levels of an effective response or polarized features of a non-effective response. Secondly, those neonates that are most likely to develop atopic disorders after birth are also those who are most likely to generate suboptimal (and/or strong Th2-type) response to vaccination. Since fetal Tregs may suppress Th1-type (or other) immune responses to vaccines in a manner that is different than adult Tregs, we speculate that strong Th2 polarization of childhood responses to vaccines may in part be due to a higher than normal proportion of fetal Tregs at birth.

We hypothesize that the immune system "layering" that is necessary for effective in utero development and postnatal protection of the human fetus occurs at a dissimilar pace in different individuals, predisposing some at birth to less effective immune responses to childhood immunizations.

This specific aims page gives a **focused significance** about reducing deaths in children by understanding the timing and mechanisms of fetal-childhood adaptive immune responses as currently, there is a high rate of deaths per year occurring from sepsis in the newborn. We see that this is a clear definition of a gap in knowledge that once addressed will help physicians alter the ratio of fetal to adult T cells and therefore lower infection rates.

Impact

While the significance of the research describes the importance of the problem, the impact assumes (in the case of a grant) that the study will be successful and answer the aims of the grant, as well as describe the impact the work will have on the field. The NIH asks the PI to address:

1. What are my **expected outcomes?** What are your **long-term objectives** with this research?

2. What is the probability my study will be successful and exert a powerful sustained influence on the field(s) specifically and more generally **(impact)**?

In the example above, the PI then writes:

We anticipate that this study will reveal normal variation in the ratio of fetal to adult T cells at birth and that such variability in this ratio will be directly related to – and possibly causal of – a Th2 skew that results in a poor response to childhood vaccines and a heightened predisposition to childhood infections and to atopic disorders. If so, then modalities aimed at changing this ratio more towards the adult lineage at birth may provide benefit to a substantial number of newborns.

This is key to their study because it clearly tells the reviewer what they expect to find and how the findings will have a major impact on the field of childhood infections and vaccines.

This is of **utmost importance** to a reviewer because it is often the pivot point of whether the grant is worth funding (or the paper worth publishing), and therefore, you must clearly and specifically make the case and make certain that your impact statement is clearly visible in the document.

Innovation

For satisfying the innovation aspect of a grant, the NIH SF424 instructions ask the PI to:

1. Explain how the application challenges and seeks to ***shift current research or clinical practice paradigms.***

2. ***Describe novel*** *theoretical concepts, approaches or methodologies, instrumentation or intervention(s) to be developed or used, and any advantage over existing methodologies, instrumentation or intervention(s).*

3. Explain any ***refinements, improvements, or new applications*** *of theoretical concepts, approaches or methodologies, instrumentation or interventions.*

Innovation is difficult for most investigators to understand. Beyond the obvious use of new methods and instruments and interventions, there can be a novel combination of known non-innovative methods that has never been tried to produce an end result.

It's safer to not travel too far into an unknown realm. To be innovative for NIH's purposes, it's enough to show how the work you propose is new and unique and will add significantly to knowledge—move its frontier forward, as our graphic above shows. Your research should move the frontier of knowledge forward. Striving for a true paradigm shift is not advisable.

In the same grant we have discussed earlier, the innovation section reads:

Previous experiments have demonstrated that similar "layering" of the immune system can occur in avian and murine models. In these species, however, the timing and/or anatomic constraints are entirely different. In particular, the murine immune system develops at a markedly different pace than does the human immune system, e.g., with very few Tregs detectable until three days after birth as compared to the late 1st trimester in the human. This study is innovative in two respects: this is the first time that human immune system layering has been studied in utero and at birth; in addition, we have identified and validated a set of genes that are uniquely expressed in fetal or adult T cells, allowing us to quantitatively and qualitatively study the kinetics of the two populations as a function of time. The proposed research has the potential to improve prevention (through improved vaccine strategies) and treatment of neonatal infection (by providing a better understanding of normal human fetal immune development), and should teach us how the developmental state of the fetus and newborn affects their ability to respond to pathogens or vaccines.

This clearly states aspects of innovation.

If you fully understand the aspects of significance, innovation, and impact, I believe you will be better prepared to write a strong grant or paper because this is what the reviewers and editors are looking for in their reviews.

In conclusion, if you follow the rules of good writing and always keep an eye on significance, innovation, and impact, you will deliver your scientific message clearly while emphasizing the central messages of your research.

Writing is a very personal activity, much like playing a musical instrument—the writer and musician learns much the same way: trying different approaches, making mistakes, and ultimately through practice, becoming more and more proficient. The scientist who wishes to communicate through the written word must also practice frequently, but they must have help, much like from a music teacher, to point out their mistakes and help them improve. Unfortunately, not all scientists have a mentor to help them.

It is my hope that this advice helps you to improve and gives you a push to do more. I would suggest that you find a trusted colleague and work together to read each others' work, form a journal writing club, anything to get feedback on your writing. This is vital. Writing is hard work for the novice and experienced writer alike. With daily practice, you'll eventually get to that more confident place, a place in which your writing really sings with simple and lucid sentences and paragraphs, and clearly tells your reader exactly what you intended.

Answers to Exercise, Chapter 2

1. Recent research suggests that these two disorders overlap considerably.

2. Hazardous substances are spilled when loading vehicles and filling tanks, and from leaks through cracks, open seams, and holes caused by rust in supply pipes.

3. We weighed the drug, dissolved it at 0.5 µg/L in saline, and stored it at 0°C for 10 days.

4. Lithium is primarily excreted through the kidneys.

5. The health center estimates that one in 500 college students is infected with HIV; they provide condoms at one quarter the retail cost.

6. We prepared the copper solution by dissolving 0.1821 g of copper nitrate in 10 mL of tap water.

7. Patients drank more water after taking drug A, but those taking drug B had no change in water consumption.

8. Unexpectedly, we found that to achieve normal blood pressure, patients had to receive drug X at 100 mg/day for 7 days.

9. The two results agreed.

10. Symptoms varied depending on the tumor's location, size, and whether it was malignant or benign.

Answers to Exercise, Chapter 3

1. After adding the copper solution, we observed an increase in the reaction (of what?).

2. In the past century, genetic mutation rates have increased in North American Indian tribes (Smith and Jones, 2011).

3. To understand why the craft failed, engineers studied bolt fragments found in the engine.

4. Anti-inflammatory agents may protect a patient against Alzheimer’s disease and retard disease progression.

5. Baby walkers allow babies who are still at the crawling stage to stand up and practice walking. Some researchers believe that such devices encourages and even speed up a baby’s ability to walk independently.

6. Rats who were fed the lithium compound had increased blood pressure (compared to rats who were not fed the compound).

7. We studied iron levels in the muscles from adult sheep.

8. The human endocrine system secretes, regulates, and metabolizes hormones.

9. To confirm this finding, we removed rat ovaries and injected estrogen replacement hormone.

10. Our primary study objective was to evaluate whether zinc supplementation during pregnancy in mothers’ diet affects infant birth measures like weight.

Answers to Exercise, Chapter 4

1. Headache is a pain symptom that almost everyone experiences. The International Headache Society (IHS) groups headaches into two types based on cause: primary headache disorders and secondary headache disorders. In primary headache disorders, the headache itself is the main complaint. The two most common types of primary headache disorder are episodic tension-type headache (ETTH) and migraine. Secondary headache disorders result from an underlying condition, such as a brain tumor, a systemic infection, or a head injury.

2. We monitored benzene pollution at 100 sampling sites in each of the European towns of Antwerp, Athens, Copenhagen, Murcia, Padula, and Rouen. These sites were distributed over a multiscale grid drawn onto the town map. Every two months (from September 1997 to September 1998), these sites were sampled from Monday morning to Friday afternoon using a radial-symmetry, passive-sampler device (a radiello).

3. We investigated the short- and long-term effects of glue (epoxy resin) sniffing on brain activation patterns in 30 participants. Following inhalation of the glue, participants showed both immediate and longer-lasting (up to one week) aberrant brain activation patterns. Although the immediate activation patterns were likely a result of structural changes in nerves, this was not investigated. However, the longer-lasting brain activation patterns that subsided after one week were likely a result of the regeneration of myelin. We do not know the mechanism by which epoxy resin produces these brain changes.

Answers to Exercise, Chapter 5

1. The 10-µM copper sulfate solution was added to three 10-mL tubes containing EDTA buffer at 37°C.

2. Fifty-four patients were enrolled in the study OR We enrolled 54 patients in the study.

3. The average cost per run was over $3,000.

4. The drug-induced side effects of aspirin include GI distress.

5. The Ca++- and phospholipid-dependent enzyme reactions were studied.

6. The inhibitor genistein, which is selective for tyrosine kinases, inhibited this serine kinase-mediated response.

7. The control cells showed modest internalization but, contrary to our hypothesis, drug-treated cells showed less internalization.

8. Treatment of deep-vein thrombosis includes the use of anticoagulant drugs; frequent walking; cessation of smoking, which is often difficult; and wearing full-leg compression stockings twice weekly.

9. Because C3 toxin is a highly selective Rho inhibitor, we avoided its use in these metabolism studies.

10. We used tempol to block redox signaling.

11. In the Boyan assay, 105 cells were added on 6.0-mm-diameter filter cups (8-µm pore, Cambridge Corporation), with 100 µL of serum-free DMEM and incubated at 37°C for 6 h with and without 1-µM LPA.

12. In this second group of two thousand patients, 690 were ineligible for inclusion OR Of the 2000 patients in the second group, 690 were ineligible for inclusion.

13. The abstracts were much clearer once we followed the appropriate guidelines.

14. The first author and principal investigator takes responsibility for the data analysis.

15. There were 130 participating centers in the study.

About the Author — Christopher Dant, PhD

Christopher Dant is a faculty instructor at Dartmouth Medical School and the Norris Cotton Cancer Center. His PhD was concentrated in cellular and molecular biology. Early in his postgraduate career, he apprenticed with a Senior Editor at Journal of the American Medical Association (JAMA), and went on to work as a biomedical writer for life sciences investigators in academia, private industry, and government agencies. Before coming to Dartmouth, Dant was a Projects Manager at the Stanford Medical School for grants and manuscripts and served as the Director of Medical Publications at Genentech in San Francisco, where he worked with many thought leaders in medicine. He regularly presents at national and international medical meetings on writing. At Dartmouth, he works with investigators in developing grant proposals and programmatic initiatives, and educates faculty in grant and manuscript writing skills. He is owner of Medcom Consulting (http://medcomconsulting.org/MedCom.html), a medical and scientific communications company for academic investigators writing grants and manuscripts. Christopher is also a published author of fiction and lives in Vermont with his wife Maureen and dog Chauncey.