Chapter 1

Writing
The Most Vital – and Neglected – Skill

Introduction

Every hour of every working day – and in the deserted hours and weekends after the rest of the university has scattered from campus – thousands of well-educated, seasoned researchers procrastinate, flounder, and make mistakes that cost them years of time and untold millions of dollars in grant funding. In North America, researchers in the biomedical sciences typically dedicate as much as a decade and a half to education, residencies, fellowships, and post-doctoral training. And yet, only a vanishingly small percentage of them ever receive so much as an hour's formal training on the one currency now necessary for promotion or for the creation and maintenance of basic science laboratories. That currency is writing.

Despite its importance, writing today is a task that most researchers delegate to the least-seasoned member of their unit. These junior team members are, if anything, even more in the dark about the entire cycle of writing, submission, and revision than the rest of the team. Perversely, we treat the most challenging aspect of research as gruntwork best passed off to the individuals who cannot refuse to do it. Perhaps, if researchers knew the logistics of good writing and the gauntlets we all run through in getting work published or funded, they would spend more time mentoring their teammates and even less time delegating.

The long and short of writing in the biomedical sciences is simple to describe: writing is hard work. The act of writing carries with it high cognitive overhead and the need to juggle multiple constraints on documents. You must shape your research to the aims, scope, and conventions of specific journals. Even as you struggle with your first draft, you had better anticipate the myriad ways in which your peevish peer reviewers will give your manuscript a sound drubbing because your argument reduces the significance of their own research.

The past decade has witnessed dramatic shifts in publishing in the biomedical sciences, making this decade into a Dickensian best-of-times-worst-of-times

scenario. Submissions to biomedical journals have risen dramatically as researchers from India, China, and other developing countries swell the ranks of scholars submitting articles, driving down the ratio of accepted to submitted articles at established journals. However, more journals debuted, with many available via databases with broad distribution – albeit not always available via the gold-standard, PubMed. (For more caveats on selecting journals, see Chapter 4). At the same time, websites such as ResearchGate and Academia.edu and the relaxing of the Ingelfinger rule embargo on publishing preliminary data can make your publications available to a wider array of researchers now than ever before. These options represent alternative paths to gaining acceptance for your research, provided you persist in revising and resubmitting your paper to suit the aims and scope of multiple journals and to help ensure your grants get funded via data published in a PubMed-indexed journal, a topic we cover in Chapter 4.

Beyond IMRaD

A handful of books address how to write in medicine and the biomedical sciences, from handling a structured abstract to writing your first grant proposal – and the standard organization of scientific papers: Introduction, Methods, Results, and Discussion (IMRaD). But no book to date has covered the science, psychology, strategy, and tactics of writing in the biomedical sciences. In contrast, we set out to write this book precisely because we recognized the science behind writing effectively and the psychology necessary to anticipate and pre-empt reviewers' and study sections' objections to our work. Moreover, we were also painfully aware of lost opportunities, productivity, and funding stemming entirely from young researchers' ignorance of the strategy and tactics inherent in submitting manuscripts and proposals. As a result, *The Biomedical Writer* bases its principles on science-based studies, empirical data, and interviews with successful principal heads of basic and clinical divisions.

In *The Biomedical Writer*, we cover the dozens of writing strategies, tactics, and principles that we learned the hard way, through rejections and hours of lost productivity. These things include, first, anticipating the two audiences every research manuscript and grant proposal face along the multiple steps en route to publication or funding: (1) non-specialist gatekeepers and (2) subject-matter experts. Before you ever get to specialists who understand the role the interstitial cells of Cajal play in delayed gastric emptying, you must first run a gauntlet of editors and grants-making staff who most likely need convincing that delayed gastric emptying, known as gastroparesis, is an issue deserving wider clinical attention, diagnosis, and intervention. Second, this gauntlet also includes implicitly targeting the journal's or grant program's aims and scope in your submitted document and explicitly addressing those aims in your letter of submittal whenever possible. Third, every writer must master the science of writing – and, yes, writing relies on science far more than it does on art. And,

fourth, any research team working on a proposal must reverse-engineer the focus of the proposal, based on both the aims of the grants-making agency and on the projects it has previously funded. Fifth, never underestimate the importance of creating a peer network, but not merely a mentor in the nudge-your-career-along way that other books suggest. Instead, we focus on the necessity of identifying peer reviewers for grants and manuscripts. This mandatory step in the submittal process of most online journals and many proposals can land you either rejection or a favorable review – the latter most likely when a member of your network reviews your work.

To address the multifaceted demands of writing in the biomedical sciences, you need a nodding acquaintance with research in areas as diverse as organizational behavior, linguistics, psychology, rhetoric, and neuroscience. Moreover, you also need a grasp of the demands of handling basic, translational, and clinical research. As the head of a basic research laboratory at the University of Alabama-Birmingham (formerly at the University of Florida and Indiana University–Indianapolis-Purdue University), Professor Grant has also spent more than thirty-five years in medicine as a clinician, a division chief, and a basic researcher. Her passion is to bring exciting advances in stem cell therapy from the "bench to the bedside." Her laboratory program is committed to fostering teamwork, training the science and healthcare workforce of the future, and continuing to improve and deliver novel, cutting-edge therapies that can offer cures for patients who currently have limited options. Her research on stem cells for repair and regeneration has earned her fourteen R01 grants and authorship of over 200 peer-reviewed publications. At the opposite end of the spectrum, as a teacher, consultant, and researcher, Professor Douglas has taught writing in virtually every field in the biomedical sciences for fifteen years, written, collaborated, or consulted on manuscripts and grants in over a dozen biomedicine disciplines, and handled advertising, public relations, and marketing for biotech clients including GlaxoSmithKline, AstraZeneca, Abbott Laboratories, Alere, and Janssen Biotech. She has also held faculty positions in sociology, English, management communication, and clinical and translational science. In other words, between the two of us, we have performed the research, as well as learned the lessons stretching across disciplines for you.

In the chapters that follow, we address many of the approaches and understandings you need to succeed as a researcher. The chapters contain steps to help you succeed in every aspect that involves writing in biomedicine, in addition to worked examples as well as expert tips, advice for facing specific challenges, and even the occasional secret weapon – usually involving technology. For those researchers facing looming deadlines, we end each chapter with a summary of takeaways to remember and apply.

Chapter 2

Writing for Your Reader's Brain

In this chapter, you will learn how to:

- understand the three stages of comprehension in reading
- appreciate how word choice and sentence structure impact the clarity of your writing
- create sentences that read as though mortared together seamlessly
- leverage priming, primacy, and recency effects to impact your readers' recall of content
- use paragraph and document structure to make your writing easy to read – no matter how complex the topic.

Making Your Writing Clear, Effective, and Efficient

Since antiquity, writing has occupied a position antithetical to science. Writing is an art, pundits from Aristotle through Erasmus to Steven Pinker have argued. Yet, despite scores of journal articles on writing and countless books on writing the perfect sentence and paragraph, the advice remains the same. And the advice remains just that: advice. Of all the arts and humanities, no other subject offers such a striking dearth of core knowledge – and nothing remotely approaching the evidence-based methods science demands. Small wonder, then, that writing receives scant attention in curricula in the biomedical sciences. Or that the researchers and clinicians who received mentoring in writing can generally only describe an approach to "mastering" writing that resembles the "see one, do one, teach one" instruction of clinical residencies, only without the "see one" bit.

Yet for over four decades, research on the reading brain has given us abundant insight into its workings with direct implications for writing. This data invaluably provides evidence-based principles for writing, principles that enhance the odds that your next manuscript will be accepted and that your grant proposal wins funding. These principles specifically target the three phases in reading comprehension – lexical, syntactic, and

inferential – and build off the mechanisms that enable us to comprehend written content easily and efficiently. This same body of research also identifies the principles you can use to facilitate stronger recall of key findings or values in your research while also minimizing its weaknesses. Moreover, Douglas tested this approach to teaching writing for over fifteen years in programs for faculty in the biomedical sciences at the University of Florida. She wrote *The Reader's Brain* (2015) after a former post-doctoral student contacted her to urge her methods be made more widely available, since the former post-doc had, in eight years, become a professor, director of her school, and the author of over fifty peer-reviewed publications, which were accepted so readily, she claimed, because of the writing principles Douglas had taught her.*

Recognizing Reading's Three Challenges: Lexical, Syntactic, and Inferential

Although we read daily and can scarcely stop ourselves from reading billboards and labels, reading is actually hard work. When you slog through an article on, say, endothelial sheer stress, you are likely to find the reading hard going, but not because the subject matter is unfamiliar or the hypothesis difficult to grasp. Instead, your pace of reading slows, and you end up rereading sentences and entire paragraphs because the writers have ignored the gauntlets that reading throws at us with every paragraph: the challenges of identifying words, grasping how sentence structure endows words with meaning, and spotting connections between sentences.

Whether you're reading an article in *The Wall Street Journal* or *Cardiovascular Endocrinology*, reading is challenging. Readers simultaneously identify word meanings, the roles each word plays within a sentence, the relationships between sentences, and the points made by entire paragraphs. Moreover, as we read, we are also comparing the content we encounter now with everything we already know about the topic. And we decide on the fly whether to retain particular pieces of content, transferring them from short-term memory to long-term memory. All this activity happens unconsciously, even when we're struggling with content that makes for thorny going, involving multiple rereadings. However, to understand how to write effectively, we first need to understand how our brains make sense of a paragraph that might not, at first, seem particularly challenging – which brings us back to *Cardiovascular Endocrinology*.

* Sherrilene Classen, Ph.D., personal communication to Douglas, December 2013.

Consider the second paragraph of a review article published in *Cardiovascular Endocrinology* in 2015. Read the paragraph below and time yourself how long you needed to read it.

> According to a National Center for Health Statistics report, during the period 2001–2006, 32 and 8% of the US population had serum 25-hydroxyvitamin D [25(OH)D] levels <20 and <12ng/ml, respectively. In five large cities in China, the prevalence of severe vitamin D deficiency (< 10 ng/ml), vitamin D deficiency (10–20 ng/ ml), and vitamin D insufficiency (20–30 ng/ml) was 5.9, 50.0, and 38.7%, respectively. Low vitamin D level was associated inversely with several cardiometabolic risk factors, such as waist circumference, systolic blood pressure, and homeostatic model assessment-insulin resistance (HOMA-IR) index, and risk of death from cardiovascular disease (CVD). 1α,25-Dihydroxyvitamin D_3 [$1,25(OH)_2D$; calcitriol] manifests diverse biological effects through binding to the vitamin D receptor (VDR) in most body cells, including T-lymphocytes, macro-phages, monocytes, islet and endothelial cells, and vascular smooth muscle cells. There is growing interest in the nonskeletal action of vitamin D, including in inflammation, glucose metabolism, and atherosclerosis. Hence, vitamin D supplementation may be a new therapeutic approach in the already expanding range of options for the management of diabetes and CVD. The latest advances in the anti-inflammatory effects of vitamin D from experimental, observational, and interventional studies are discussed in the following sections. (Su and Xiao, 2015)

The content is not particularly challenging for anyone with even a slender acquaintance of either cardiovascular medicine or endocrinology, and the paragraph does not contain any writing errors that jump out at us. However, you likely found yourself reading increasingly slowly from the second sentence onward. In fact, even the first sentence contains items that will slow down any reader. We can begin to understand the challenges of reading – and the three stages of reading comprehension – when we read a paragraph like the one above, one that seems comprehensible on the surface but surprisingly challenging when you start reading it.

The hiccup in the first sentence involves the fundamental engine that enables us to make sense of sentences and paragraphs: prediction. We understand sentences by unconsciously predicting how they will play out structurally, based on our knowledge of likely millions of sentences. And prediction is always forward-looking. Reading is most efficient and writing most effective when we read uni-directionally, always looking ahead. As a result, the instant you require the reader to look backward, you have sent them in the wrong direction. You have also required a wasted effort from readers, as we should only look backward – known as retrospecting – when we realize we have misread a sentence (Britton and Pradl, 1982). Now look back at the first sentence of the paragraph above:

> According to a National Center for Health Statistics report, during the period 2001–2006, 32 and 8% of the US population had serum 25-hydroxyvitamin D [25(OH)D] levels <20 and <12ng/ml, respectively.

To discover what percentage of the US population had serum 25-hydroxyvitamin D levels at <20ng/ml and which, <12ng/ml, every reader must dart glances back to the percentages on the second line: 32% and 8%. (Incidentally, the omission of the % from "32" also sends some readers backward, depending on the amount of data they take in at a glance, which ranges from a single word to an entire line, a phenomenon we describe on the next page). That innocuous "respectively," an adverb most researchers use in sentences without giving the word a thought, sends readers scuttling crab-wise backward, in search of which quantity needs pairing with which measurement. For most readers, that darting glance backward and forward, between 32% and <20ng/ml, represents a significant hitch in reading speed, as well as unnecessary rereading. This sentence is also an excellent illustration of how common practices in writing in the biomedical sciences can lead to less-than-stellar writing. In addition, you should now have at least a fleeting acquaintance with the role prediction and direction play in reading.

The First Two Stages in Reading: Lexical and Syntactic

The first stage in cognitive processing begins when we recognize individual words, based on familiarity with words from our previous encounters. Skilled readers take as little as 300 milliseconds (ms) to identify individual words – evident in the length of pauses in eye movements, known as saccades (Perfetti, 1999). However, the speed of our eye movements depends entirely on the constraints the sentence imposes on each word's meaning.

In English, word meanings depend on the role the word plays in the sentence structure or syntax. As a result, even the same word may have multiple meanings within a single sentence. For example, *A rebel can rebel by giving a rebel yell*. The first *rebel* is a human being and a noun. In contrast, the second *rebel* is a verb, while the third *rebel* is an adjective. In speech, we use inflection to differentiate the different meanings each word has, so our ears can differentiate the meaning as we hear the words spoken. Thus, the noun is REB-ell, while the verb is re-BELL. The different inflections tell us just how important identifying a noun and verb are to comprehending a sentence's meaning. When a reader misidentifies a noun or a verb, the entire sentence's meaning is usually altered, resulting in a misreading or what linguists term a *garden path* sentence, meaning readers will misinterpret the sentence on a first reading and only grasp their error in assigning roles to words as nouns or verbs when the sentence's syntax fails to play out when they reach the end. We can see this process at work in a sentence written by a faculty member in a course Douglas taught at the University of Florida's College of Medicine:

> *Thirteen of the 27 genes significantly up-regulated at short reperfusion but not at long reperfusion encode for known transcription factors or inflammatory cytokines, suggesting roles in gene transcription and regulation at this early reperfusion time point.*

If you needed to reread this sentence at least twice, you are hardly alone. Nearly all readers will seize on the word *up-regulated* as the sentence's main verb. But, when we reach *encode*, the second verb form promptly makes a hash of our initial guess about the sentence's structure. The core of the sentence is *Thirteen of the 27 genes encode for known transcription factors*, not *Thirteen of the 27 genes [were] significantly up-regulated at short reperfusion*.

This sentence contains a valuable illustration of the power of prediction and of the constraints sentence structure places on meaning – the tight coupling of lexical and syntactic stages in reading. The more constrained a word's role, the more rapid and accurate our identification of the word. Perhaps more importantly, this tight coupling of lexical and syntactic stages in reading comprehension also show how central our correct identification of nouns and verbs prove to efficient reading (Graesser, Millis, and Zwaan, 1997). Note that, despite the word *rebel* cropping up in three different roles – and with slightly different meanings – in a single sentence, the sentence was hardly a garden-path-level challenge. Instead, the concreteness of the words helped make identifying their roles within the sentence easy.

Clarity: Making Sentences Easy to Read

Cognitive psychologists long ago identified causation as central to our perception of events in the world around us. In one well-known experiment, subjects described circles and squares moving randomly in an animated film in entirely causal terms (Michotte, 1963). Conventional wisdom suggests that our ability to perceive causation is central to our survival. But our apparent hard-wiring to perceive causation also impacts our perception of language. Moreover, English is a subject–verb–object ordered language, which nicely reflects what linguists dub the *iconicity assumption*: we expect events in English sentences to unfold in the order in which they occurred (McWhorter, 2001). Nevertheless, a surprising number of sentences do precisely the opposite. Instead, they invert the order in which events happened, or, worse, entirely obscure it. Fortunately, we have a name for these sentences – we call them passive or, more precisely, we say that these sentences rely on passive construction.

Clarity Principle #1: Prefer Active to Passive Construction

For over a decade, journals in the biomedical sciences have encouraged writers to avoid passive construction for good reason. In a passively constructed sentence, the action runs counter to the way it unfolded in the world. An outcome occupies the grammatical subject, and the sentence contains a non-action verb that merely represents a state of being. In addition, passively constructed sentences are less concrete, less efficient, less memorable, and slower to read than their actively constructed counterparts (Ferreira, 2003). Remember that earlier paragraph from *Cardiovascular Endocrinology*? That paragraph contained a variety of sins against clarity that would have

contributed to the lack of speed with which you almost certainly read it, among them, a sentence containing passive construction:

> Low vitamin D level was associated inversely with several cardiometabolic risk factors, such as waist circumference, systolic blood pressure, and homeostatic model assessment-insulin resistance (HOMA-IR) index, and risk of death from cardiovascular disease (CVD).

The two words, *was associated*, imply that somebody did something. However, the actors are conspicuously absent from the sentence, with the outcome reported in the grammatical subject, *low vitamin D level*. If you can ask *Who is doing the [insert verb here] ing?*, and the answer isn't the grammatical subject of the sentence, you are looking at passive construction. To make a sentence active, find an actor or concrete object for your grammatical subject. In this sentence, you can use either *researchers* or even *we* as your actor/grammatical subject. The revised version not only uses active construction but invites more rapid reading because the revised sentence handily incorporates clarity principles 1, 2, and 3.

> **Before:**
> Low vitamin D level was associated inversely with several cardiometabolic risk factors, such as waist circumference, systolic blood pressure, and homeostatic model assessment-insulin resistance (HOMA-IR) index, and risk of death from cardiovascular disease (CVD).
>
> **After:**
> In our meta-analysis of 160,309 patients we discovered an inverse association between low vitamin D levels and several cardiometabolic risk factors, including waist circumference, systolic blood pressure, index of homeostatic model assessment-insulin resistance (HOMA- IR), and risk of death from cardiovascular disease (CVD).

Clarity Principle #1 Caveats

In methods sections, your sentences would endlessly repeat the same agents – your research team or, simply, *we*. As a result, you can shift back into using passive construction in this section only to avoid endlessly repeating *we* as your grammatical subject. In addition, when an entire section features sentences that uniformly use passive construction, your readers experience less fall-off in reading speed than if they continually shift between active and passive (Olson and Filby, 1972). So, while you can use active construction in a methods section to write,

> [T]o evaluate further the therapeutic potential of interactors that influenced ΔF508 CFTR maturation in CFBE41o− cells in the RNAi screen, we assessed rescue of ΔF508 CFTR channel function for eight interactors that bind preferentially to ΔF508 CFTR and/or were dynamically regulated by temperature shift and HDACi.

You can also use passive construction, as the authors did here in the same research article in *Nature:*

> Primary human bronchial epithelial cells from healthy donors or patients with CF, and CFBE41o– cells, were differentiated into epithelial cultures at an air–liquid interface (ALI) and ΔF508 CFTR channel function was determined by electrophysiology in an Ussing chamber (Pankow, Casimir Bamberger, Calzolari et al., 2015).

Clarity Principle #2: Prefer Actors or Concrete Objects as Grammatical Subjects

When you use an agent or actor (in the non-theatrical sense) as your grammatical subject, your writing immediately enjoys two distinct benefits. First, the more concrete a noun is, the easier your readers' task of disambiguating its meaning and role in the sentence (Clark and Sengul, 1979), as we saw with the simple illustration of *rebel*, a word with a clear-cut role and meaning, despite its occupying no fewer than three roles within a single sentence. And, second, an agent builds your sentence around cause and effect, turning it into a micro-narrative, which speeds reading and comprehension alike.

Clarity Corollary 2A: Avoid Using Isolated Pronouns as Grammatical Subjects

Since prediction enables comprehension, you want your readers always looking forward, not backpedaling three clauses or two sentences from the one they have just read. But, when you rely on isolated pronouns like *this, that, these, those,* and *it* as your grammatical subjects, you force your readers to scan back several clauses or even entire sentences. Why? Pronouns, by their nature, are indeterminate – they offer meaning only relative to an earlier noun, thus significantly slowing down reading speeds (Stallings, MacDonald, and O'Seaghdha, 1998). But the pronoun referent can be an entire sentence or even crop up several sentences earlier. In some instances, sentences also bristle with a host of candidates for a pronoun's referent, leaving your reader to wonder which noun *it* refers to. Instead, always anchor these pronouns to nouns: *this meta-analysis, these outcomes, that intervention*. Also, avoid ever using *it* as a grammatical subject, since the pronoun seldom refers to a single noun and usually functions simply as a placeholder before the sentence's real meaning begins, as in *It was found that the VDR physically interacts with NF-κB p65 in osteoblasts, fibroblasts, and colonic epithelial cells*. Whisk away both the meaningless pronoun subject, *it*, and the passive construction, *was found*, and simply begin the sentence where the authors say something meaningful: *VDR physically interacts with NF-κB p65 in osteoblasts, fibroblasts, and colonic epithelial cells.*