Education 2013, 3(2): 130-133
DOI: 10.5923/j.edu.20130302.04

An Essay on Scientific Writing

Fred M. Menger[1,*], Syed A. A. Rizvi[2]

[1]Department of Chemistry, Sanford S. Atwood Chemistry Center, Emory University, 1515 Dickey Drive, Atlanta, GA 30322, USA
[2]Department of Pharmaceutical Sciences, College of Pharmacy, Nova Southeastern University, 3200 South University Drive, Fort Lauderdale, FL 33328, USA

Abstract The essay deals with sentence structure, style, and logical flow when writing scientific text. Ten suggestions for optimizing sentences are presented followed by ten published examples of stylistic variations. Although the emphasis is on chemistry, the recommendations are applicable to all areas of non-fiction writing.

Keywords Scientific Writing, Shorter Sentences, Logical Flow, Variety, Readability

1. Introduction

Generally speaking, a scientific article embodies two stages: (1) the design and execution of the actual experiments; (2) the writing up of the results so that they may be understood and appreciated by interested scientists elsewhere. Thus, chemistry requires both laboratory and communication skills. Unfortunately, students are often short-changed with regard to training in the latter, a problem that can reveal itself well into their subsequent careers. I (F. M) was such a deprived student. As a result, even a short paragraph forced me to spend hours of writing and rewriting until the paragraph finally expressed my thoughts with reasonable clarity and conciseness. Although the task has become somewhat easier over the years, I must still devote a considerable amount of time optimizing my sentences. In fact this very paragraph has been recast many times over 2-3 weeks. Good writing is clearly a struggle even for an experienced author. Yet I have never resented the effort. Why would a scientist, especially after two or three years of toil at the bench, risk annoying or (worse) confusing the readership with careless writing? An abundance of books and articles on scientific writing testifies to its relevance to the chemical enterprise[1-11].

During the course of our writing, we use ten simple suggestions, listed below, as a guide. The rules may seem elementary, but it has been observed that exposing the rules to students can dramatically improve their writing without necessitating their reading an entire book on the subject. This list of technical suggestions will be then followed by a more subtle topic: style. It is here where personality and individuality enter the picture.

* Corresponding author:
menger@emory.edu (Fred M. Menger)
Published online at http://journal.sapub.org/edu

2. Suggestions

1) Minimize forms of “to be” (is, was, will be etc.) as the main verb especially in long sentences where the verb is located in the middle. “Strong” verbs (reinstate, attenuate, furnish, infuse, delay etc.) are far preferable.

Poor: The class of reactions in which proton transfer occurs in the rate-determining step is important to chemistry and biology.

Better: Rate-determining proton transfers pervade chemistry and biology.

2) An improved rewriting of a sentence almost always leads to a shorter sentence. (See the examples in Rule 1).

Poor: We should also note that this molecule has a center of symmetry as well.

Better: Note that this molecule also has a center of symmetry.

3) Limit the number of prepositions (except for the experimental section). (See the example in Rule 1 where four prepositions…of, in, in, and to…have been eliminated).

Poor: The objective of the synthesis of naturally occurring mitomycins is a source of considerable interest.

Better: Synthesizing naturally occurring mitomycins has attracted considerable interest.

Note that the improved sentence is shortened, has eliminated “of” three times, and no longer uses “is” as the main verb.

4) Insert variety in various ways: (a) Sentence length; (b) First word; (c) Simple, compound, and complex sentences; (d) No strong word non-technical word repeated more than once per paragraph; (e) Use of “?”, “:”, “;” a quote or metaphor.

Examples: Note how in the first paragraph of this essay a short sentence (“I was such a deprived student.”) was embedded between two longer sentences. The word “the” does not initiate any of the sentences. A sentence beginning with "Although…" introduces a complex sentence into the text. The penultimate sentence provides variety via posing a question. Several strong verbs have been used: embodies, requires, reveal, forced, expressed, devote, optimizing, recast, resented, risk, and testifies. The verb "to be" was used several times but only in short sentences with the verb near the subject. No strong non-technical word was used more than once in the paragraph (e.g. note that "deprived" avoided the need to repeat the strong word "short-changed").

5) You should be able to read the paper aloud without stumbling.

Poor: For the electrocylic reaction catalysts are not needed.

Better: a) For the electrocyclic reaction, catalysts are not needed. b) Catalysts are not needed for the electrocyclic reaction.

When reading the poor version, the eye does not automatically separate "reaction" from "catalysts" as is accomplished in the two better versions. Troubles of this sort are detected by an oral reading of the text.

6) End a sentence with an important word or phrase rather than a word or phrase of peripheral importance.

Poor: The ketone was converted into an exo alcohol and into an endo alcohol after several days reaction.

Better: The ketone was converted after several days of reaction into exo and endo alcohols.

Unless "after several days reaction" was the main point of the statement, it is best not the end the sentence with this phrase. Authors should take advantage of the fact that the eye and mind tend to focus on the beginning and end of a sentence while down-playing its center.

7) Use the present tense for statements that are generally true.

Poor: We found that the melting point was 65℃.

Better: We found that the melting point is 65℃.

8) Write the text, put it aside for several days or more, come back and rewrite it. Repeat as necessary (a dozen times not being unusual).

9) Avoid verbal assaults on the reader (grammatically correct writing is not necessarily good writing).

Poor: In Figure 5, the $\Delta G_0(CH3,T^+)$ values are plotted against $\Delta G_0(HT^+)$ values for the 25 anions in Table I where least-squares lines with slopes near unity were drawn through the points for the carbanion and oxanion families, and a line of similar slope was drawn through the closely spaced points for the nitranion family, thereby showing that the intrinsic carbon basicity at the same hydrogen basicity decreases in the order $H^- > C^- > S^- > N^-$, the total range being almost 15 orders of magnitude.

10) To assess the quality of the writing, write in the margins adjacent to each sentence: (a) the number of words in the sentence; (b) the kind of sentence (simple, compound, or complex); (c) the first word of the sentence; (d) the main verb; and (e) the number of prepositions.

If, for example, your marginalia reveal that too many sentences begin with "the", or that the sentences are all lengthy, or that the verb "to be" is over-used, then a rewrite may be in order. Sentence-structure is, of course, only one of many considerations when preparing a scientific text. Another is "style"…a concept that is difficult to define let alone scrutinize. Let me put it this way: One would like, as much as possible, to impart a joy and liveliness to the text. Consider, for example, dull writing as occurs in a paper beginning with the words: "As part of a continuing study of…. we decided to explore….".

3. Examples of Good Scientific Writing

By way of contrast, we present below several introductory paragraphs from our own writing. In no way are we claiming that this style should be emulated. Indeed, some might outright dislike it. But the point is that style allows a scientist to personalize and enliven the text in an attempt to make the science not only informative but more enjoyable to read.

[1] F. M. Menger, "Macro and Multimoleculer Systems", in Bio-Organic Chemistry, E. E. van Tamelen (ed.), New York, Academic Press, pp. 139, 1977.

"Thomas Lincoln (Abe's father) once remarked that it is time to move when one can see the smoke from a neighbor's chimney. Chemists of similar temperament may feel that it is time to enter a new field when the reviews begin to appear. Although such feelings have merit, I hope that this review of micellar chemistry and previous reviews of the subject will attract rather than repel. The vast amount of information published on micellar bioorganic chemistry in recent years has served more to define problems than to solve them."

[2] F. M. Menger, L. H. Gan, E. Johnson, D. H. Durst, Phosphate ester hydrolysis catalyzed by metallomicelles, Journal of the American Chemical Society, vol. 109, no. 9, pp. 2800-2803, 1987.

"In Reston, VA, 1980, a gathering of American chemists was challenged to devise methods for destroying some of the most noxious compounds known to man, compounds which a saner world would never produce. These are the phosphate esters and related phosphorus (V) materials known as nerve agents (e.g. GD or "Soman") and used in chemical weaponry. Owing to our interest in catalysis, especially in reactions of biologically important systems such as phosphate esters, we undertook the challenge and began developing catalysts that hydrolyze phosphorus(V) substrates. The first of these, dubbed Atlanta-1 or A-1, operates by (a) binding noncovalently a phosphate ester, (b) accepting the phosphoryl group on one of its hydroxyls, and (c) dephosphorylating to produce an aldehyde that immediately regenerates the original A-1. Thus, true catalysis or "turnover" was achieved, one of our major goals. The overall rate enhancement with 8 mM A-1 was substantial (1800-fold), yet we set our sights on attaining even greater reactivity. This led to the synthesis of an entirely different catalyst, A-2, whose remarkable properties are described below."

[3] F. M. Menger, H. B. Kaiserman, Decarboxylation of isatoic anhydride in the crystalline state, The Journal of Organic Chemistry, vol. 52, no. 2, pp. 315-316, 1987.

"Sometimes one pursues a laboratory observation that is unrelated to any personal interest or experience of the past. Intuition, memory, analogy, and testimony play no role; mere curiosity motivates the decision to experiment further. Thus we were curious about an unexpected observation made during the course of our work: Isatoic anhydride decarboxylates when heated at temperatures below its melting point of 245℃. Crystals eject CO_2, often shattering in the process. What is the main product of this solid-state reaction? What are the mechanistic details? Is the solid-state reactivity different from that in solution? These and other questions are addressed herein."

[4] F. M. Menger, M. Ladika, Fast hydrolysis of an aliphatic amide at neutral pH and ambient temperature. A peptidase model, Journal of the American Chemical Society, vol. 110, no. 20, pp. 6794-6796, 1988.

"Human beings admire speed whether it be animal, mechanical, or chemical in origin. Within the chemistry area, fast reactions signify milder conditions and reduced energy consumption. But the desire to achieve speed is motivated by more than economics. Chemists are challenged by a rival, the enzyme, that outpaces us with a perplexing regularity. α-Chymotrypsin, for example, hydrolyzes amides rapidly at neutral pH and ambient temperature. In contrast, a typical chemical procedure for hydrolyzing amides calls for a 10-h reflux in 8 N HCl. Although "models" attempting to duplicate α-chymotrypsin-like rates have been successful with p-nitrophenyl esters, rate enhancements often vanish when less reactive ("natural") carboxylic acid derivatives are employed. In the present article we describe cleavage of an aliphatic amide under biological conditions free from transition metals. Neither a substituent (such as a p-nitrophenyl group on the nitrogen) nor ring-strain (as in a β-lactam) nor amide-twisting (as in a bridgehead amide) artificially activate the substrate. To our knowledge, the reaction constitutes the fastest peptidase "model" at pH 7 on record."

[5] F. M. Menger, M. G. Wood, S. Richardson, Q. Zhou, A. R. Elrington, M. J. Sherrod, Chain-substituted lipids in monolayer films. A study of molecular packing, Journal of the American Chemical Society, vol. 110, no. 20, pp. 6797-6803, 1988.

"There is a growing need for chemists, particularly those with biological leanings, to understand the principles governing noncovalent interactions. Host and guest, sensor and activator, channel and permeant, receptor and drug, enzyme and substrate, antibody and antigen, DNA and carcinogen: all partners recognize each other by means of noncovalent forces. Since intermolecular association and organization are involved in so many vital process, we initiated a study of "molecular packing" using lipids as the main focus. Three weak brothers of covalency (hydrogen bonding, hydrophobic association, and electrostatics) assemble lipids into a community of molecules. As with human communities, the individual species dictate the behavior of the group while, concurrently, the group imposes constraints upon the individuals. Our goal is to understand the interrelationship in greater detail."

[6] F. M. Menger, N. Balachander, E. Van der Linden, G. S. Hammond, Microscopic observation of a polyaphron transforming into a microemulsion, Journal of the American Chemical Society, vol. 113, no. 12, pp. 5119-5120, 1991.

"Organic reactions are usually conceptualized in terms of single molecules or pairs of molecules. However, many reacting systems, and virtually all physical properties, require consideration of multimolecular assemblages in order to model their behavior. A living cell is a wondrous example of a system that operates via a molecular cooperation that cannot be understood by extrapolating the properties of individual species. Indeed, there is a growing suspicion that the collective and holistic features of complex systems can display new and unforeseen modes of behavior that are not captured by the Newtonian and thermodynamic approaches. Widespread interest in self-assembling systems illustrates the desire to explore multimolecular phenomena at a relatively simple level. We ourselves have in the past studied molecular communities such as micelles, vesicles, films, pools, and laminates. This work led us to examine, by optical microscopy, the transformation of one molecular assemblage, a polyaphron, into another, a microemulsion."

[7] F. M. Menger, M. E. Chlebowski, A. L. Galloway, H. Lu, V. A. Seredyuk, J. L. Sorrells, H. Zhang, A Tribute to the Phospholipid, Langmuir, vol. 21, no. 23, pp. 10336-10341, 2005.

"Proteins and nucleic acids receive so much attention and hype that a third biological building block, the phospholipid, might well be suffering from an inferiority complex. Phospholipids have a trivial structure (Figure 1), and this has certainly not added to their self-esteem. Moreover, phospholipid molecules cannot fold into interesting coils, cannot catalyze reactions, cannot duplicate themselves, and cannot transport oxygen. Nonetheless, one should feel no pity for the seemingly mundane phospholipid. Living systems could not have evolved until their biochemistries had been enclosed within lipid membranes. This is not to relegate the membrane merely to a "sausage casing with the interesting stuff inside." Actually, the cell membrane is a remarkable community of molecules, embedded in a structural motif called a bilayer (Figure 2), where multiple types of dynamic events take place. Motions of proteins and nucleic acids might seem rather dull when compared to those within phospholipid self-assemblies, as briefly summarized below."

[8] F. M. Menger, H. Lu, Addressing the regioselectivity problem in organic synthesis, Chemical Communications, pp. 3235-3237, 2006.

"Organic synthesis is winning the war against its challenges. The reactions available to the synthetic organic chemist number in the countless thousands. Natural products with over sixty chiral centers have been constructed. Chiral catalysts and auxiliaries giving enantiomeric excesses greater than 90% abound. We hear occasionally that "If you can draw it, you can make it." Although this statement is no doubt hyperbole, it does serve to drive home the impressive successes in the field of organic synthesis. Nevertheless, there remains a major problem in organic synthesis that has not been solved. In fact, it has only rarely been addressed: enzyme-like regioselectivity."

[9] F. M. Menger, J. L. Sorrells, Chronology of a Difficult Synthesis, Journal of Chemical Education, vol. 86, no. 7, pp. 859-863, 2009.

"One cannot help but marvel at the planning and execution evident throughout the vast literature in synthetic organic chemistry sometimes encompassing twenty or more steps. If problems are encountered on the way, they are often side-stepped, giving the impression of a smooth and almost inevitable progression toward the ultimate goal. Of course, any practitioner of synthetic organic chemistry knows that these published accounts largely understate the problems experienced during a synthesis. For one thing, space limitations may not permit full disclosure of experiments that failed to work. For another, difficulties may, rightly or wrongly, imply poor planning or lack of laboratory skills, so why advertise them when they would only detract from the main theme?"

[10] F. M. Menger, L. Shi, S. A. A. Rizvi, Self-assembling systems: Mining a rich vein, Journal of Colloid and Interface Science, vol. 344, no. 2, pp. 241-246, 2010.

"Self-assembling amphiphiles (or "surfactants") are compounds that possess both polar and non-polar sections. The synthesis and examination of new self-assembling compounds have drawn international attention, as illustrated here via an incomplete and arbitrary listing: Argentina (amphiphilic cyclodextrins)[1]; Australia (amphiphilic dendrimers)[2]; Brazil (sugar-based surfactants)[3]; Canada (amphiphilic copolymers)[4]; China (chiral surfactants)[5]; France (noncovalent amphiphiles)[6]; Germany (bolaamphiphiles)[7]; India (multiple-headgroup surfactants)[8]; Italy (gemini surfactants)[9]; Iran (cleavable surfactants)[10]; Japan (π-electronic amphihpiles)[11]; Korea (T-shaped amphiphiles)[12]; The Netherlands (carbohydrate-based gemini surfactants)[13]; Portugal (amino acid-based amphiphiles)[14]; Spain (urea-based surfactants)[15]; Sweden (heterogemini surfactants)[16]; United Kingdom (light-sensitive surfactants)[17]; and United States (redox-active surfactants)[18]."

One last point will be made in this brief essay on scientific writing. Sentences in a paragraph should flow logically from one to the next. This goal may be achieved by imagining that one is telling a short story. Humans have a long history of story telling. Since the skill may even lie in our genes, appealing to the story format seems like a natural thing to do. In a child's story, such as Little Red Riding Hood, every sentence follows smoothly from the previous one; otherwise young listeners would, we suspect, lose interest. A scientific article might profitably emulate this narrative mode of presentation.

5. Conclusions

In summary, we would advise scientific writers to pay attention to sentence structure, style, and logical flow. Since room to manipulate language is obviously open-ended, writing offers a freedom that is both a challenge and a pleasure.

REFERENCES

[1] C. Potera, The basic elements of writing scientific paper: The art of scientific style, Journal of Chemical Education, vol. 61, no. 3, pp. 246-248, 1984.

[2] N. P. Shires, Teaching writing in college chemistry: A practical bibliography 1980-1990, Journal of Chemical Education, vol. 68, no. 6, pp. 494-495, 1991.

[3] M. S. Robinson, F. L.Stoller, J. K. Jones, Using the ACS Journals Search To Validate Assumptions about Writing in Chemistry and Improve Chemistry Writing Instruction, Journal of Chemical Education, vol. 85, no. 5, pp. 650-654, 2008.

[4] S. S. Zimmerman, Writing for chemistry. Food for thought must be appetizing, Journal of Chemical Education, vol. 55, no. 11, pp. 727, 1978.

[5] T. Spector, Writing a Scientific Manuscript: Highlights for Success, Journal of Chemical Education, vol. 71, no. 1, pp. 47-49, 1994.

[6] G. Piel, Writing general science articles, Journal of Chemical Education, vol. 31, no. 1, pp.20-22, 1954.

[7] M. S. Robinson, F. L. Stoller, M. Costanza-Robinson, J. K. Jones, Write Like a Chemist: A Guide and Resource, Oxford University Press, USA, 2008.

[8] H. B. Davis, J. F. Tyson, J. A. Pechenik, A Short Guide to the Writing about Chemistry, Longman, USA, 2010.

[9] J-L. Lebrun, Scientific Writing: A Reader and Writer's Guide, World Scientific Publ. Co, Singapore, 2007.

[10] M. Cargill, P. O'Connor, Writing Scientific Research Articles, Chichester, UK, 2009.

[11] M. Alley, The Craft of Scientific Writing, Springer-Verlag, New York, 1996.