

Writing a Scientific Manuscript

Highlights for Success

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Many scientists are far more comfortable performing scientific experiments than they are reporting their findings. Although they could benefit from the excellent books available on scientific writing, they may not have time to read these comprehensive articles. As a result, considerable data either are not reported or are published in ways that inadequately express their significance.

This article was written to complement the extensive reviews. It presents techniques for optimally relaying the content and meaning of scientific studies and for avoiding common problems. It begins with simple strategies to construct succinct sentences that are easy to read and understand. It then discusses key features of the standard journal sections, tables, and figures and suggests strategies for their effective construction.

Writing Style

Succinct Sentences

Well-constructed sentences are succinct. They are easy to read and understand. Succinct sentences unambiguously relay content and meaning. The five topics of this section describe methods for writing succinct sentences. I recommend constructing the major part of manuscripts with succinct sentences. Less succinct sentences may be used for emphasis or to break up a string of succinct sentences that have become monotonous.

Tangible noun subjects

The following suggestion is probably the most important recommendation in this article. **Use a tangible noun as the subject of the sentence.**¹ The key to writing a succinct sentence is to select the proper subject for that sentence. Tangible noun subjects are meaningful subjects. They immediately direct the reader to the focus of the sentence. Whenever possible and appropriate, use a tangible noun as the subject of the sentence.

The following examples demonstrate the advantages of switching the subject (italicized) to a tangible noun. Notice the ease of reading and understanding the "succinct" sentences. In contrast, the subjects of the "original" sentences cause the reader to search for the intended meaning.

1. *Original:* In the rat, the *metabolism* of 1 x 80 is characterized by the formation of three-polar compounds.
Succinct: *Rats* metabolize 1x 80 to three polar compounds.
2. *Original:* Another *issue* that concerns the authors focuses on the interpretation of the *in vitro* data.
Succinct: The *authors* are also concerned with the interpretation of the *in vitro* data.
3. *Original:* The *modification* of the method of Smith (ref) led to the generation of acceptable data.
Succinct: Acceptable *data* were generated by modifying the method of Smith (ref).

¹A tangible noun represents something that is touchable or concrete. The subject of a sentence does the action (active), is acted upon (passive), or is described or identified.

²Example from Day (3).

4. *Original:* Elevation of intracellular ATP was observed following i. v. administration of compound Q. *Succinct:* Intracellular *ATP* was elevated following i. v. administration of compound Q.

Several words are giveaways for detecting convoluted sentences with weak subjects.

1. Excess prepositions: Note that three prepositions eliminated by changing the above Example 1 to the succinct form.
2. *It* and *there* used as false subjects; Examples:
 - (a) It is of concern to the authors . . .
 - (b) There exists in the rat. . .

Subject-Verb Location and Agreement

People are easily lost in the forest between the subject and the verb. Keep your readers on track by placing the verb as close to the subject as possible. Go pen and Swan (i t discuss how intervening words interrupt the reader's expectations. In addition, subjects and verbs must agree in number (singular and plural forms). I refer the reader to Dodd (2) for a discussion of this topic.

Active I Passive Voice and First Person

Although the active voice is more succinct than the passive voice (3), many scientists prefer the latter. They believe that the passive voice is more objective and, therefore, more suitable for scientific writing. I suggest using the active voice wherever appropriate. Using active voice in Example 1 under "Tangible noun subjects" added to the clarity of the sentence.

Sentence 1 (below) is an appropriate use of the first person active voice. Here, the authors are drawing the conclusion. However, overuse of "we" or "I" can seem obnoxiously egocentric. Sentences 2 & 3 are examples of active and passive voice, respectively.

1. We conclude that the mechanism must be concerted.
2. Neutrophils generate superoxide radical.
3. Mice were treated with methotrexate.

Dangling and Misplaced Modifiers

Make sure that modifiers actually modify what they are intended to modify. Otherwise, they may distort the meaning of a sentence. The following dangling participial phrases (italicized) lead the reader to wonder how the centrifuge turned the dial and who was incubated or was lying on the intestine.

1. *Original:* *Turning the dial to 60,000 rpm*, the centrifuge started.
Corrected: The centrifuge was started by turning the dial to 60,000 rpm.
2. *Original:* *Having incubated for 30 min at 37*, we placed the vials on ice.
Corrected: The vials were placed on ice after they had incubated for 30 min at 37.
3. *Original:* *Lying on top of the intestine*, you will perhaps make out a small transparent thread.²
Corrected: You may see a small transparent thread lying on top of the intestine.

The misplaced modifier and phrase (italicized) in these sentences substantially alter the intended meaning.

1. *Original*: The cells *only* secreted small amounts of peptide X.
Corrected: The cells secreted only small amounts of peptide X.
2. *Original*: A large mass of literature has accumulated *on cell walls of staphylococci*.²
Corrected: A large body of literature on cell walls of staphylococci has accumulated.

Wordiness

Words that don't enhance content or meaning may bog down the reader. For example, the boldface words in the following sentence are either superfluous or redundant and should be deleted.

1. *Original*: We plan additional studies in the future in order to confirm previous experiments where replicate determinations consistently showed the pool size to essentially increase.
Improved: We plan studies to confirm experiments where replicate determinations showed an increase in pool sizes.
Better: We plan to confirm the experiments that repeatedly showed an increase in pool sizes.

The next sentence also becomes more readable as it is shortened. It is converted to a succinct sentence by replacing the false subject with a tangible noun and by using active instead of passive voice.

2. *Original*. It has been reported (ref) that hydroxyurea selectively decreases purine deoxynucleotide pools.
Improved: Hydroxyurea was reported (ref) to selectively decrease purine deoxynucleotide pools.
Better: Hydroxyurea selectively decreases purine deoxynucleotide pools (ref).

Empty phrases can often be reduced to simple words. For example, the phrase, in the vicinity of, means "near". A list of "empty phrases" and "words to avoid" are reported by Huth(4) and Day(3).

Verb Tense

Many authors struggle with the use of past and present verb tense. The rules, however, are simple.

1. Use the present tense to describe experiments and data that have been established and exist in the literature, e. g. Compound 6 is inefficiently degraded by guanosine hydrolase (ref).
2. Use the past tense to describe experiments and data of your present manuscript, e. g. Compound 6 was inefficiently degraded by guanosine hydrolase. (See the table on the next page.)

Word and Number Selection

The following items frequently surface as problems in scientific manuscripts.

Affect / Effect

Stick to the most common and least troublesome use of these words. Use *affect* as a verb meaning "to change or influence", and *effect* as a noun meaning "a result or consequence".

1. Excess acid will *affect* the yield.
2. He studied the *effect* of excess add.

That/Which

People seem to be agreeing that *that*, which appears without a comma, should be used to introduce restrictive clauses, and that *which*, which appears with a comma, sets off nonrestrictive clauses. Strunk and White (5) advise to "go on a which hunt" to make articles more readable. The

restrictive clause italicized in Sentence 1 is necessary to the meaning of the sentence; whereas, the nonrestrictive clause underlined in Sentence 2 is not.

1. Only drugs *that stop the virus from integrating into the human genome* prevent chronic infections.
2. The mechanism, which may be concerted, is difficult to prove.

IC₅₀/ID₅₀; EC₅₀/ED₅₀

The "C" OF IC₅₀ and EC₅₀ abbreviates the "concentration", and the "D" of ID₅₀ and ED₅₀ abbreviates the "dose" of agents that inhibit (I) the effect by 50 percent or produce 50 percent of the maximum effect (E). Therefore, ensure that the correct units are connected with the correct terms, for example, an ED₅₀ reported as "μ.M" is meaningless.

In Vitro / In Vivo

The term "in vitro" refers to experiments performed in an artificial environment with tissues, cells, organs, enzymes, fluids, etc. removed from living organisms. In vivo experiments are performed within living organisms. Thus, experiments with parasites and viruses in cultured cells are in vitro studies, or studies in culture, and differ from in vivo studies of infected animals or plants.

Jargon

Either carefully define or delete any laboratory terms that are not well established in the literature. Some examples of *jargon* follow. A correction appears in parentheses after the jargon.

1. *Microsomal* (endoplasmic reticulum) enzymes metabolize Compound Z in mice.
2. *Reactions* (reactants) were mixed in a glass vial.
3. *Proteins were* (protein concentration was) determined by the Bradford assay (ref).

Auxiliary Verbs in Compound Sentences

Auxiliary verbs should not be omitted when subjects change in compound sentences. The auxiliary verb "was" is needed in the second part of the following sentence to prevent the voice from switching from passive to active. Obviously, radioactivity cannot count. This type of error is commonly found in methods sections.

Original: Scintillation fluid *was* added and the radioactivity counted.

Corrected: Scintillation fluid *was* added and the radioactivity *was* counted.

Significant Digits

The number of significant digits in data should not exceed the precision of the determination. Because errors denote the magnitude of uncertainty, they should be presented with only one significant digit. Furthermore, this digit determines the least significant digit of the reported value. Thus, the left-most place of the error determines the right-most significant digit of the value. Accordingly, theism for Compound 1 in the table is 15 ± 1, and not 15.32 ± 1.27, and the *K_m* of Compound 6 is 120 ± 10, and not 122 ± 11.

Editing

I recommend having several colleagues comment on the content, construction, and style of your manuscript. Even accomplished writers benefit by critical reviews of their manuscripts. Peer reviewers are easy to find. Some not-so-highly skilled writers may be clever reviewers. Remember

³Day (3) and Dodd (2) condone the use of (split infinitives such as 'to selectively decrease', but caution to preserve the intended meaning.

to encourage your reviewers to be frank. Honesty may be more valuable than politeness.

The review process also allows you to distance yourself from your article. Writers often are too close to their writing. You may not adequately describe complex material for the uninitiated, or you may not present a clear overall picture. Your colleagues' perspectives can be useful, but don't let too many cooks spoil the broth. Weigh all the opinions before making changes.

Manuscript Sections

General comment. I suggest that you read your selected journal's instructions to authors before writing your manuscript. Each journal has different ways of including specific parts. Editors appreciate receiving properly formatted manuscripts.

Title Page

Although the details of the title page are specified in the instructions for each journal, suggestions for title selection may not be adequate. Titles should be short, revealing, and enticing, but generally do not contain an active verb. Because most people scan titles by looking at their beginning and ending, the most important words should be located in these places. A bold phrase or name (heading) ending with a colon and followed with a descriptive phrase (subtitle) provides initial recognition plus crucial information. For example, *Human Sulfite Oxidase: Irreversible Inactivation by Futile Chloride*, readily draws attention to key elements when it appears as:

Human Sulfite Oxidase:

Irreversible Inactivation by Futile Chloride

Summary/Abstract

Present the important findings. Include values and methods that are crucial to their understanding and interpretation. Omit other details. *The summary is easier to write after Results and Discussion are completed.*

Introduction

This is the most important section for manuscript construction. It provides background information that describes and justifies the need for or advantage of the scientific study. It then clearly defines the purpose or problem, explains the approach taken, and may end with a brief summary of the findings. Thus, a well-written introduction structures the entire manuscript. *Authors who write this section first usually find that the rest of the manuscript readily flows from it.*

Substrate Specificity of Canine Guanosine Hyffrolase

Substrate	$K_m \pm$ S.E. (μ M)	V_{max}, \pm S.E. (μ mol/min/unit)	V_{max}/K_m (relative)
Guanosine ^a	30 2	1.30 0.07	100
Compound 1	15 1	1.2 0.1	190
Compound 2	5 1	0.17 + 0.03	78
Compound 3	6 1	0.19 + 0.02	73
Compound 4	66 6	0.19 0.01	6.6
Compound 5	200 20	0.029 0.004	0.33
Compound 6	120 10	0.00097 0.00006	0.019

^aReference substrate; specific activity was 450 mol/min/mg.

Materials

Most material acquisitions are straightforward. The following example demonstrates an economical style for grouping and listing.

Acetaminophen, chloramphenicol, zomepirac, and probenecid were purchased from Sigma Chemical Co. (St. Louis, MO); Coomassie Blue reagent was from Pierce Biochemicals (Rock-ford, IL); HPLC grade ammonium phosphate (monobasic), acetonitrile, and water were from Mallinckrodt (St. Louis, MO).

Methods

General methods belong in this section; whereas, specific details of particular experiments belong in the result section. Labels, as "Standard Assay" and "Buffer B", for general procedures or items described here avoid repetition of lengthy wording. *The term "modified method" should be accompanied by a list of the modifications and the reasons why they were made.*

Results

This is usually the most straightforward and easiest section to write. Results should contain an objective and clear description of the experimental findings presented in a logical sequence that unravels the story and aids the reader's understanding. This sequence is not necessarily the chronological order in which the experiments were performed.

Add a bit of explanation and this section is finished. An occasional conclusion may be appropriate here, but save most interpretation for the discussion section.

Tables

The table in the left column is an example of a well-constructed table.

- The title is simple and clear.
- The column headings are accurate and contain the units.
- The uncluttered data are easy to read and understand with out reference to the text.
- The data are sorted (after the reference compound) in decreasing value by the most important column (V_{max}/K_m).
- The absolute value of the reference compound is reported.
- The number of significant digits in the values do not exceed the precision of the determination.

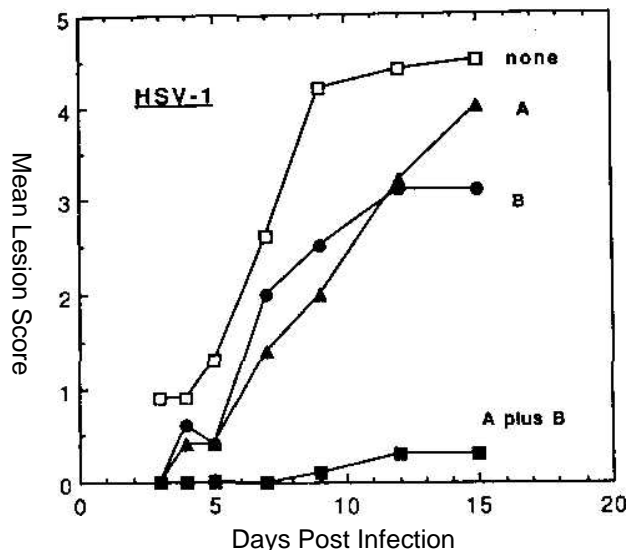
Figures

The sample figure shown on the next page exemplifies an easily understood figure.

- The purpose of the figure is readily discernible by visual inspection.
- The title of the figure is clear, simple, and relevant.
- The legend contains adequate information to understand the figure.
- The uncrowded figure contains adequate and balanced white-space.
- The curves are labeled within the figure (if acceptable by the journal) to avoid the need to Flip visually between the graphic and the legend.
- The curves don't extend beyond the data points.
- The symbols clearly distinguish the curves.
- The axes are labeled clearly and have meaningful values with appropriate intervals.
- The text remained legible after photographic reduction.

Discussion

This section brings out the significance of your work and relates it to the literature (and to your introduction). Although a brief rehash of results maybe appropriate, this is not the place to present results. Discuss, interpret, and comment on all significant findings and discrepancies of



Synergistic antiviral therapy by drugs A and B. Mice (10 per group) were infected on the dorsum with herpes simplex virus type 1 (HSV-1) and were treated on days 1-5 with the indicated drugs. Drugs A and B were dosed orally at 2 and 4 mg/kg, respectively. Standard deviations were less than 20% of the means. Lesions were scored on a 0-5 scale as described in Methods.

the manuscript. Discrepancies are better discussed here than left as fodder for potential critics.

I recommend writing a preliminary outline of the points to be discussed. This approach keeps the manuscript flowing in a logical way and prevents rambling.

Readers tend to remember best what they read first and last. So cover the most important items first, and don't try to bury items of doubt by saving them for last. End your discussion with a positive and optimistic conclusion concerning the most favorable aspect of your study.

Literature Cited Section

Consult the particular journal's instructions to authors for the reference format. Almost all are different. They also locate citations to unpublished data in different sections. Because this is an error-prone section, **proofread and verify the references**; neither the reviewers nor the technical editors have the time to do this for you. Some libraries and technical information departments provide this service.

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