

Short communication

Structural outline of an archival paper for the Journal of Biomechanics

Richard A. Brand^{a,*}, Rik Huiskes^b

^aDepartment of Orthopaedic Surgery, The University of Iowa Hospitals, 01029 JPP, 200 Hawkins Drive, Iowa City, IA 52242, USA

^bDepartment of Biomedical Engineering, Eindhoven University of Technology, Wh-4.131, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Writing is a demanding, personal task. Any piece of writing, scientific or not, assumes the personality and philosophy of the writer. All writing styles are more or less arbitrary, and preferences vary widely. One cannot argue that a single style or approach is best, for the variations (even with “good” writing) are infinite. However, all agree that clear, concise writing most effectively communicates ideas.

Few scientific writers, in fact, practice clear and concise exposition. Seemingly, few know the principles of such writing, and fewer still practise them. (Most traditional scientific curricula fail to demand adequate courses and practice in expository writing.) The two most critical principles are: logical flow and brevity.

Logical flow occurs by observing the following elements of paragraph construction:

1. Each paragraph discusses only one major topic.
2. The first sentence of each paragraph introduces the topic, and the remaining statements merely expand and/or modify the first.
3. The critical elements of the topic appear in that first sentence.
4. Either the final sentence in the paragraph connects the logic from that paragraph to the next, or the topic sentence of the new paragraph relates back to the previous; that is, paragraphs are connected by “transitional” statements.

Brevity arises by: (1) Concisely stating ideas once; (2) Minimizing repetition (with a few exceptions to be noted below); and (3) Proper grammar.

Most concise scientific (archival) journals utilize a traditional form: Introduction, Methods, Results, Discussion. This format is neither always essential, nor always the best. However, one should have clear justification for discarding it in favor of another. Complexity of material is rarely, if ever, adequate

justification—in fact, complex material is best presented with simple structure. I usually find sub-headings distracting, and often a poor substitute for clear writing; if the first sentence of each paragraph introduces a new topic in an appropriate fashion a sub-heading is redundant. On the other hand, a sequence of more or less unrelated material (particularly in a long Methods and Materials section) may flow better with sub-headings.

One can rarely justify an archival manuscript of more than 3000–4000 words. If one has difficulty communicating the *essentials* in 4000 words, then I suggest the problem generally resides in the communication or failure to clarify issues, not in the material. The tendency of many authors is to include non-essential information (frequently owing to unfocused questions or hypotheses, or often because painstakingly accumulated information is not easily discarded by authors).

1. Introduction—500 words or less

The Introduction states an issue, briefly notes what we know (or do not know) about the issue, and poses appropriate questions or hypotheses or approaches. It focuses upon the rationale (motivation) for the study. The flow of logic should be so compelling that the reader has absolutely no reason to doubt the rationale. In a hypothesis- or question-driven paper, the first paragraph typically introduces and justifies systematic exploration of some issue. The second and/or third cite past observations leading one to an explanation for the issue or problem. The third and/or fourth pose critical (experimentally verifiable) predictions of the postulated explanation or pose specific hypotheses (or questions). In such papers, it is critical to focus on concepts or observations, not on methods or past investigators. One does this by constructing sentences in which subjects or objects refer to observations and in which authors are parenthetically referred. Imagine critical observations as premises of Aristotelian logic leading to a conclusion: If *a*, and *b*, and *c*, and *d*, then we logically conclude *x*, or *y*,

*Tel.: +1-319-356-3472; fax: +1-319-384-9419.

E-mail address: dick-brand@uiowa.edu (R.A. Brand).

or z (where x , y , or z represent hypotheses to be tested). A useful tool for constructing the most critical questions or hypotheses is to suppose a question which can be unambiguously answered “yes” or “no” by the experimental design or a hypothesis which can be unambiguously supported or refuted. Formulating questions or hypotheses in terms of independent and dependent variables helps insure lack of ambiguity. (Hypotheses posed in other terms may lend heuristic value as “thought experiments”, but cannot be tested.)

In reports of a new method (e.g., experimental technique, numerical model), the approach is modified. One must justify a new approach, which means outlining the limitations of past approaches. This should be accomplished in a tactful manner so as to avoid deprecating past works (and investigators); as concepts and technical capacities advance, past approaches usually seem simplistic or naive. However, it remains critical to begin the first paragraph in a similar manner as the hypothesis-based paper—outlining and justifying the class of problems necessitating study. The first paragraph, then, outlines the issues. The second and/or third paragraphs focus on past methods and their limitations for a particular set of problems. The final paragraph compellingly outlines the problems or classes of problems for which a new method will provide new and critical information.

As a matter of preference, I choose not to state what will be done in the Introduction: this immediately follows in Methods. Further, a concise summary of method will have been already offered to the reader in a Summary or Abstract. Thus, stating what will follow is redundant.

2. Methods—500–1500 words

In a hypothesis-based paper, this section provides the experimental design and details of the approach. It is often difficult to know exactly how much detail should be provided. On the one hand, one would ideally provide enough detail so that an independent investigator could repeat the work; on the other hand, such detail would unnecessarily lengthen a manuscript, so that one should cite, rather than repeat the published material. Practicality, however, dictates that the fundamentals of published methods be briefly noted, so the reader unfamiliar with past works (particularly those which are difficult to locate) can follow the logic. Previously published details (as contrasted to fundamentals) may merely be cited. Sometimes, the balance of brevity versus detail becomes a matter of personal or editorial preference.

In a methods-oriented paper, all critical details must be provided. Less critical (but new) details often fit best in an appendix, since small details may disrupt the

greater flow of logic. The Methods section should contain a complete description of all statistical methods, usually at the end. The inevitable assumptions of the statistical tests should be justified based upon the nature of the data. In many biological experiments, choice of level of statistical (rather than biological or clinical) significance requires justification (see comments below).

3. Results—500 words

The Results section typically contains only that information bearing on the questions raised. If the investigator finds substantially new, critical, and unexpected information in the course of an investigation, a separate paper may be warranted. Begin each paragraph in Results with a clear statement of a key result (parenthetically referring to all data figures or tables) within the framework of the prediction, question, or hypothesis posed in the Introduction. Each statement (and paragraph) should contain a key argument for or against the approach (methods paper) or answering the question or testing a hypothesis (hypothesis-based paper). While normally one can construct as many paragraphs as there are questions or hypotheses, at times additional paragraphs are needed for material needed to convince the reader of the validity of the approach, or to report unexpected findings. List results in approximate order of importance. If the reader considered only the first sentences of each paragraph in Results, he or she should know all important information. Avoid sentences containing a figure or table as subject or object as a figure of speech (e.g., “Figure 3 shows the results of...”); these statements convey little useful information, and place emphasis on data per se, rather than interpretation of data. A Results section should contain only results of the current study, and not previously published results. Avoid description of methods (“To determine whether or not X related to Y we computed correlation coefficients...”).

When noting that one parameter statistically differs from another, I prefer stating “ X is greater ($p = 0.039$) than Y ”, or “the treatment increased ($p = 0.024$) the response of Z ” with the p values parenthetically noted. There is no “standard” of statistical significance: in biological problems (with inherent variability and major sampling problems) or in clinical problems (with a need to balance risk and benefit) a p value of 0.01 may be insignificant, while a p value of 0.1 may be significant. Given no level of statistical significance necessarily denotes any “true” biological significance, I think it best to state the actual p value (rather than $p < 0.05$) and let the reader decide whether the level of significance seems reasonable for the specific situation. (I acknowledge that there are legitimate differences of opinion on this point, since some would argue that once a level of statistical

significance is established, groups would be either different or not different and the level of p value would make no difference. With this philosophy, however, an author must justify the selected level of significance based upon the particular problem, rather than merely stating or implying a “standard” p value less than 0.05.)

4. Discussion—1000 words

The discussion should reflect rather more of a synthesis than a reiteration of results. No new results should be discussed. Begin with a concise restatement of the rationale for the question or hypothesis stated at the end of the Introduction. In a methods paper, one should restate the rationale for the new approach.

Then, briefly explore the major assumptions and/or limitations of the approach or methods. In biologically-oriented papers, this should include the adaptation of the living system to altered conditions over time or with disease. The reader should be convinced that the limitations do not seriously jeopardize the conclusions within an explicitly stated range of conditions. If the reader (and more importantly, the author) does not know the conditions for which methods allow reasonable conclusions, then both author and reader can be seriously misled.

Next, compare and/or contrast data with observations or data in the literature. Include all relevant observations. Quantitative comparisons best convince the reader that results are “in the ballpark.” Figures or tables most effectively convey large numbers of comparisons and add to the value of the paper. However, comparisons need not be merely quantitative; often comparison of new data or observations with past (qualitative) observations or even opinion suffices. Discrepancies should be explained in so far as possible, and noted when they cannot be explained.

Finally, synthesize the results of the current paper and observations or data in the literature into a coherent whole, and within the framework of the prediction, question, hypothesis, or objective posed in the Introduction. “Synthesis” means that all known observations correspond to the framework (failure of an established “fact” to correspond falsifies the hypothesis).

5. Captions

All data (figures and tables) should provide some key argument for or against the prediction, question, or hypothesis, and that argument should be succinctly stated in one or two sentences. The reader should immediately grasp the significance of the data to the questions posed. *Journal of Biomechanics* policy suggests a maximum of 10 total data figures for an original

article, or four for a technical note. More become distracting and difficult to digest. Further, if an author cannot convince a reader of critical points in 10 sets of data, then the data are likely to be inefficiently conveyed, or less important data included, or the questions vaguely formulated. Imagine that the reader only examined the Introduction, then looked at the figures, and finally read the captions: all critical questions and answers would be obvious.

6. Abstract

A substantive abstract will begin with the issues or questions posed, and then describe the method in a few brief statements. Even key quantitative results draw greater reader attention and likely enhance the exposure of the material through web-based citation searches. Finally, the author expresses his or her answers to the question (or statement of support for or refutation of a prediction or hypothesis) in one or two concise statements. In general, the abstract is best written last, both in an initial and revised submission.

7. Convey the message

To make a message most effective, some repetition is important, despite the need for brevity. Specifically, the questions should be repeated in the final paragraph of the Introduction, the beginning of the Discussion, and the beginning of the Abstract. The answers should be repeated in the first line of each paragraph in Results, the end of the Discussion (with appropriate synthesis from the literature), the figure Captions, and at the end of the Abstract.

In summary, logical flow and brevity throughout a manuscript provide effective communication. Once a draft is completed, quickly reading through only the first sentence of each paragraph throughout allows a quick check of logical flow: if all critical information does not appear in these topic sentences, the reader is likely to have difficulty following the logic. Brevity is maintained by stating most key elements only once. However, repetition of the questions and the answers in two or three places emphasizes the message.

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Further reading

- Day, R.A., 1979. *How to Write and Publish a Scientific Paper*. ISI Press, Philadelphia.
- Huth, E.J., 1982. *How to Write and Publish Papers in the Medical Sciences*. ISI Press, Philadelphia.
- Katz, M.J., 1985. *Elements of the Scientific Paper: A Set-by-Step Guide for Students and Professionals*. Yale University Press, New Haven.
- King, L.S., 1991. *Why Not Say It Clearly: A Guide to Expository Writing*. Little, Brown and Company, Boston.
- Shertzer, M., 1986. *The Elements of Grammar*. Macmillan, New York.
- Strunk Jr., W., White, E.G., 1979. *The Elements of Style*, 3rd Ed.. Macmillan, New York.