

WHAT IS A GOOD SCIENTIFIC PAPER?
(And how to write an abstract)

by

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Scientific findings are reported in many different ways. Scientific information might be conveyed in research papers, short communications, science notes, popular articles and the like. Therefore, it is necessary to distinguish a scientific paper - by which is meant a research paper - from other types of publications conveying scientific data.

A scientific paper is the outcome of a well-completed research investigation. It should thus essentially follow the same logical sequence that led to the investigation. Such a paper is not simply an attractive piece of literary writing built on unrelated facts and events. On the contrary, its essence is its ability to convince the reader of the conclusions reached by the scientists solely on the basis of critical argument. Here critical argument implies a careful examination of the evidence for its validity and a rejection of what is not applicable.

A comprehensive research paper normally follows the sequence of Title, Introduction, Materials and Methods, Results, Discussions, Acknowledgements and Bibliography. Summary might be added at the end but in most journals an abstract is provided at the beginning.

Title The title itself is often an indication as to whether the article is a research paper or an article in a popular journal. For example, if I were to report on an investigation with Azolla on rice in a research paper it would probably be entitled "The effect of Azolla on the growth and yield of rice". If the same results were to be published in a popular magazine the title is more likely to be, "Azolla biofertilizers bring better rice yields".

In writing a research paper it is best to prepare the first draft with a tentative title and to reconsider the title once the paper is completed. The title should be short, specific and accurate but as informative as possible. It must contain the essential key words for correct indexing.

Introduction The introduction must capture the reader's attention and focus it on the problem that has been investigated. It must state the problem accurately and, as far as possible, justify the investigation. It is best to cite only a few pertinent references at this stage leaving detailed citations for the discussion.

While the opening statement in the introduction of a popular article should attract curiosity, this is not a requirement in a scientific paper addressed to a restricted readership which is assumed to have some background knowledge and interest in the subject. Thus the introduction of a popular article on nitrogen fixation in Soybean might start with a statement like, "Twelve million metric tons of Soybean are produced in Brazil annually without the assistance of any chemical nitrogen fertilizer". A research paper on the

other hand could start with a more formal sentence such as, "Methods for the accurate quantitative estimation of nitrogen fixation under field conditions have been slow to develop".

In the introduction, the problem investigated is best presented as a verifiable hypothesis. Where this is not possible it would be posed simply as a question. The justification for the investigation could be provided by showing why the research was started. Alternatively some indication of the gap in knowledge which could be filled by the investigation might be indicated. However, it is not necessary to explain at length here things that can be found in a standard textbook though a few references to the relevant literature might be made.

Materials and Methods This section should provide details sufficient for a critical reader to comprehend exactly how the investigation was made. When well accepted standard methods are used, references to relevant publications will be adequate. Any modification in the method, if adopted, must be described. The protocol followed should be stated clearly indicating the treatment and the control groups (if any). All living organisms (plants, animals and micro-organisms) should be referred to by their scientific names and perhaps the authority should be cited, eg. Azolla pinnata, R Brown. In certain cases, especially with microorganisms and crop plants, it might be necessary to give the strains, varieties and cultivars as well.

Experiments conducted under controlled conditions in laboratories are generally well described in scientific papers. The description of field experiments is more difficult but even here the variations in the environmental parameters such as pH, temperature, light intensity and humidity should be clearly indicated. In experiments with soils, their types and basic characteristics must be stated. Where special equipment and/or specific chemicals (enzymes, vitamins, antibiotics) are used it is essential that models and the names of manufacturers are given. Statistical analyses are now commonly applied to results and a description of the experimental design with replications of the treatments is necessary to understand such analyses.

The section on Materials and Methods should be so written as to enable the reader to judge whether the findings reported have been obtained by a reliable method of inquiry. It should also provide adequate information to the researcher interested in repeating the investigation to verify the validity of the results.

Results This is the section which details the evidence in support of the conclusions. The evidence is best presented in a logical sequence which might not necessarily be the same order in which it was obtained. A good scientific paper would clearly distinguish the evidence obtained from opinions and theories related to it.

Numerical results are best presented either as tables or as graphs. A good table is a complete unit of communication by itself. It helps to make the text shorter and more precise. A bad table will force the reader to refer to the text several times before he is able to understand it. For easy comprehension a table should contain as little data as possible.

Graphs are essentially used to show relationships among data and to condense several points on to a single illustration. For example a graph showing a correlation might contain up to 50 or 60 points which data if presented as a table will appear formidable. A good graph should have only a few curves. This can be achieved either by increasing the number of illustrations or by deleting the less important graphs. In the section giving results the text can be made short and more precise by having adequate illustrations (tables, graphs, histograms, diagrams, photographs etc) which summarise statistically significant correlations and differences and point out the absence of such relationships.

The results section should provide clear answers to the question addressed and papers having vague phrases such as 'tended to be lower' or 'showed promising trends' are weak in character.

While the results section should essentially contain the data obtained during the investigation, it could also include results reported by others to support your critical argument.

Discussion and Conclusion

To most readers this section is the most stimulating and interesting and should be presented in a manner to satisfy the curious mind. Reading a good discussion should be like listening to a judge summing up the evidence for and against a case. The discussion should be built upon critical arguments, based on the data presented in the results section. Such evidence need not be confined to those obtained during the investigation reported. Support could also be obtained from additional evidence derived from other publications. References to relevant literature is absolutely essential in this section. In a well written paper, reference is made not only to publications that support the results, but also to counter evidence which have to be assessed in view of the findings.

A good discussion presents all the facts investigated, a critical examination of the results for and against the hypothesis and the conclusion arrived at. A conclusion is often not universally accepted, but would rather stimulate further investigation.

In essence, a good scientific paper should raise a question, give the methodology to verify it, present the relevant data obtained, critically argue the case on the available data and arrive at an answer which leads to a sound conclusion (Table 1).

Writing the Abstract

There are different types of abstracts such as author abstracts, access abstracts, critical abstracts, computer-based abstracts etc., but for the present discussion we will consider only the author abstracts. According to the American National Standard's Institute, an author abstract is "an abbreviated, accurate representation of a document preferably prepared by its authors, for publication with the document".

For most papers and parts of monographs, an abstract of fewer than 250 words is adequate, whereas for short communications fewer than 100 words would suffice. However, the exact length of the abstract would be determined by the journal in which the paper appears. The style of an abstract is best when it conveys the necessary information quickly but accurately. Clarity is essential and brevity is measured by the amount of information presented in a given space.

Good reading habits are a necessary pre-requisite for any form of effective writing. For the writing of abstracts, analytical reading and editing and adherence to certain rules and conventions are also required. Analytical reading is best done in three sequential steps: retrieval reading, creative reading and critical reading.

During retrieval reading the abstractor rapidly reads through the text to identify information on the purpose, scope, methods, results, conclusions and/or recommendations (Table 2), and marks the text accordingly (Table 3). In creative reading, the material identified during retrieval reading is re-read in order to select,

extract, organize and write the most relevant information in an orderly manner (Table 4). In the final critical reading stage, the written material is read analytically and edited for unity and brevity and to agree to the style and convention required by the particular journal to which the paper is submitted (Table 5).

A few guidelines that would be useful in writing a good abstract is given in Table 6.

References

- 1 Calnan, James and Andras, Barabas (1973) - Writing Medical Papers : A practical guide. Bath, William Heinemann Medical Books Ltd; The Pitman Press. 121 pp.
- 2 Cremmins, Edward, T. (1982) - The Art of Abstracting. Philadelphia, ISI Press. 150 pp.
- 3 Huth, Edward, J. (1982) How to write and publish papers in the medical sciences. Philadelphia, ISI Press. 203 pp.

TABLE 1. *Structure of the research paper*

Sequence of the research	Format and content	Elements of critical argument
The question to be answered	Introduction	The problem (question)
How the answer was sought	Materials and Methods	Credibility of evidence
Findings	Results	Evidence (the data); initial answer
Findings considered in the light of the findings of other investigators; the answer	Discussion and Conclusion	Supporting evidence (other papers), contradictory evidence (other papers) Assessment of conflicting evidence Answer

SOURCE : HURT , J, EDWARD - HOW TO WRITE AND PUBLISH PAPERS IN THE MEDICAL SCIENCES

Retrieval-Reading Rules

There are two rules for retrieval reading. They should be observed in conjunction with the general reading rules given in Chapter 5. Retrieval reading is ideally done once, non-stop, with a minimum of regressions and fixations. In practice, it may be necessary to repeat portions of this reading process.

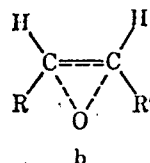
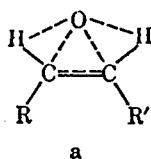
Rule 1. Read quickly but attentively through the text of the material to be abstracted to identify passages containing information with potential for inclusion in the abstract.

Rule 2. While reading, mentally or in the margin of the copy note which parts of the material contain information on purpose, methods, findings, or conclusions and recommendations. (If you mark in the margins on manuscripts or published copies of materials being abstracted, write lightly in pencil so that the markings may be erased without damaging the copy.)

MARKING OF A TEXT DURING RETRIEVAL READING

Sample Article A

● assumption of this interaction arises from the observation that, for both *cis*- and *trans*-2-butene, the ratio of *cis*-2,3-epoxybutane to isobutyraldehyde, as well as that of *trans*-2,3-epoxybutane to 2-butanone, remains constant. The relationship holds over a wide temperature range (77–300°K), despite large differences in the ratios of *trans*- to *cis*-2,3-epoxybutane produced from *cis*- compared to *trans*-2-butene (1.25–8.3). Observations on 2-butenes have been extended to several more straight-chain, internal olefins in the low-temperature region. The results are given in Table I. Comparison of the *trans*-epoxide to ketone ratios from the *cis*- vs. the *trans*-olefin with increasing size of the olefin indicates that these ratios diverge. However, the larger olefins show greater stereospecificity in their reactions. Thus, *cis*-3-hexene gives about 2.5 times as much *cis*-3,4-epoxyhexane as the *trans*-epoxide. Even a relatively small quantity of 3-hexanone from the *cis* intermediate could easily account for the difference in the *trans*-epoxide/ketone ratio between the reactions of *cis*- and *trans*-3-hexene. It is noted that the recently proposed "epoxide-like" transition complex implies that, although only one form of the complex is possible from the *trans*-, two forms are possible from the *cis*-olefin



Of these, form b could readily lead to the ketone, because of easy migration of H, but form a would be expected to preponderate from the energetic viewpoint.

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An indication of the importance of these forms, within the framework of the transition states specified and the assumption that form a gives only the aldehyde in its rearrangement to the carbonyl end product, whereas form b gives mostly ketones, is obtained from the data of Table I. The *trans*-olefin compounds, as may be noted, produce epoxides that contain 90–97% of the *trans* form. If the same ratio of *cis*-epoxide to aldehyde obtained from the *cis*-3-hexene is maintained in the *trans*-3-hexene products, the residual aldehyde presumed to arise from the *trans* intermediate may be calculated. Accordingly a ratio of 50:1 for the *trans*-epoxide/aldehyde compounds derived

- Background information
- ▼ Purpose, scope, and methods
- RESULTS
- ▶ CONCLUSIONS AND RECOMMENDATIONS

SOURCE : CREMMIM, T. EDWARD - THE ART OF ABSTRACTING

TABLE -4-

RULES FOR CREATIVE READING

Rule 1. (*Step A*) Reread all of the information on purpose, scope, and methods that you identified during the retrieval-reading process. While reading, mentally index the primary and secondary themes described in this material, using your own choice of arbitrary terms or phrases. (Beginning abstractors or those writing an abstract for a complex document might find it helpful to jot down their arbitrary index terms or phrases on note paper.) (*Step B*) Write the primary annotative part of the abstract (the first sentence).

Rule 2. From the remaining information on purpose, scope, and methods, extract appropriate materials and write the secondary annotative sentence or sentences.

If your instructions are to write an indicative abstract, you have now completed the creative-reading stage and are ready to begin the critical-reading stage for self-editing of the completed abstract. If you are writing an informative abstract, continue on to Rules 3 and 4.

Rule 3. (*Step A*) If you are writing an abstract of a document reporting on experimental research, tests, surveys, or case reports, reread the textual materials on the results or findings. While reading, condense this information mentally or write it on note paper, to aid your judgment of its relevance and significance. (*Step B*) Extract the most relevant results and write them in sentence form, concisely, in descending order of significance.

Rule 4. (*Step A*) Reread the conclusions and recommendations that were identified during the retrieval-reading process in a manner similar to that described in Rule 3. (*Step B*) Extract the most relevant conclusions and recommendations and write them in sentence form, tersely, in descending order of significance. (Application of this rule depends on whether it is required by publishers or managers of access-information systems.)

SOURCE : EDWARD T. CREMMIM - THE ART OF ABSTRACTING

Rules for Critical Reading

There are three rules for the self-editing of completed abstracts by use of critical reading. Experienced abstractors should have no difficulty applying the rules simultaneously during a single analytical reading of the text of most of their abstracts. Novice abstractors are advised to follow the rules separately in sequence. The rules are interrogatory.

Rule 1. Is the abstract properly structured and unified?

Rule 2. Is the content of the abstract complete, coherent, and concise?

Rule 3. Does the abstract conform to both general style rules and conventions for abstracts and those special ones contained in the publisher's or information-system manager's instructions on the type and length of abstracts?

Hints for Writing Good Reader-Oriented Informative Abstracts

Do:

scan the document purposefully for key facts
 slant the abstract to your audience,
 tell what was found
 tell why the work was done
 tell how the work was done
 place findings early in the topical sentence
 put details in succeeding sentences
 place general statements last
 separate relatively independent subjects
 differentiate experiment from hypothesis
 be informative but brief
 be exact, concise, and unambiguous
 use short, complete sentences

Don't:

change the meaning of the original
 comment on or interpret the document
 mention earlier work
 include detailed experimental results
 describe details for conventional apparatus
 mention future work
 begin abstracts with stock phrases
 use involved phraseology
 use questionable jargon
 waste words by stating the obvious
 say the same thing two ways
 use noun form of verbs
 over-use synonyms
 use a choppy, telegraphic style

SOURCE : CREMMIUM , T, EDWARD - THE ART OF ABSTRACTING