UNIVERSITY COLLEGE OF RHODESIA

A GUIDE TO WRITING SCIENTIFIC PAPERS

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CONTENTS

OUTLINE OF A PAPER

CONTENTS

WRITING THE PAPER

OUTLINE OF A PAPER

THE RESEARCH PROBLEM

When the investigation of a scientific problem has been completed it must be described in writing. This must be done in such a way that a reader of similar experience can readily understand what the writer has to say. Often the process of writing is regarded as a chore because few of us have a natural ability to write well. However, scientific writing is an art which can be learnt through guidance and practice. It is important that scientists learn this art so that their efforts to contribute to knowledge may be made known to other investigators. A paper which is poorly written and presented detracts from the value of research work and gives a poor impression of the author. Scientists are busy people with a growing literature to read. They are unlikely to bother with a paper when the author has not taken the trouble to make it easily readable.

The purpose of this paper is to give a brief account of the way in which scientific information should be presented and to comment on the style in which it should be written. Clearly, no single suggested arrangement will be suitable for every paper. The method of presentation must be made to fit the nature of the subject, the purpose of the article and the interests of probable readers. However the outline which follows may be used in the presentation of a wide variety of papers and can be adapted for special requirements.

CHOICE OF INQUIRY

The investigator should choose a problem within the field of knowledge in which he has most interest and competence. He should then prepare a tentative plan which outlines the object of the inquiry, the observations which are to be made, the equipment necessary to make them and the kind of information he expects the investigation to provide. This synopsis should then be discussed with people who know the subject. It is particularly important to ascertain whether the information provided by the experiment will require statistical analysis. The advice of a biometrician should be sought at an early stage. Much time and effort can be saved if this plan is followed.

OUTLINE FOR A PAPER

Some journals, in their directions to authors, specify a standard arrangement for papers so that this paper should be read in conjunction with the instructions issued by the journal in which the author hopes to publish. In this connection the directions to contributors in, for example, the "Journal of General Microbiology" and the "Proceedings of the Nutrition Society" are well worthy of study. A general outline for the scientific paper follows together with notes which describe the main sections.

TITLE A brief indication of the main contents.

ABSTRACT A brief summary of the whole paper.

INTRODUCTION:

(i) Outline of problem.
(ii) State of present knowledge on the problem.
(iii) Derivation of knowledge.
(iv) Plan of investigation—in relation to (i) - (iii).

METHODS:

(i) Equipment and materials.
(ii) Experimental design.
(iii) Observations.
(iv) Method of analysis.

RESULTS

Information which investigation has provided. Presented in tables and graphs where possible. Text used to draw attention to main features.

DISCUSSION:

(i) The main findings of the experiment.
(ii) Reasoned conclusions.
(iii) Theories opposed to the conclusions.
(iv) Comparison of results with existing knowledge.
(v) Further research and practical implications.

ACKNOWLEDGEMENTS

REFERENCES

TITLE

The title should indicate what the paper contains and should be as concise as possible. However it is always better to sacrifice brevity for clarity in order that the exact contents of the paper may be described. Remember that eventually the paper will be indexed in journals and libraries so that the title should include the important nouns under which the paper must be indexed. If these nouns are listed the author can then join them together into a descriptive title.

While I was collecting information for this article I wished to refer to a letter which had been published in *Nature* some time between 1952 and 1957. Looking through the indexes under "authorship", "scientific papers" and "writing" I was unable to find what was wanted. Consequently I had to examine the contents page of each of the weekly issues up to 1955—about four hours work. The letter was entitled "Independence in Publication" and was indexed under "independence" and "publication". It made a plea for an end to unnecessary acknowledgements in scientific papers. These last five words would have made a more appropriate title, ensured that the letter was correctly indexed and made it easy to find.

The title of the paper should be followed with the authors' names and the full name and address of the institution at which the work was carried out. If an author has moved it is customary to provide the new address in a footnote. Journals vary in these requirements so that the journal in which the paper is to be published should be consulted and its procedure adopted.

ABSTRACT

Purpose

It is becoming the custom to follow the authors' names and addresses with an abstract of the paper rather than to provide a summary at the end. The abstract should be used to bridge the gap between a title of a few words and a paper of several pages. It should summarise the experiment, the results, the main conclusions and indicate the relevance of the work. Workers in the same field as the author are almost certain to read the paper. A carefully written abstract helps workers in related fields to decide whether the paper has sufficient relevance to their own interests to warrant their reading it. The abstract should be modelled on those which appear in the abstract journals and if carefully prepared may be copied for such purposes. Two pertinent articles on the scientific abstract have been written by Jacks (1961, 1963). As editor of "Soils and Fertilizers" he makes a plea for the abstract to be "brief, informative, brief, complete and brief." Such abstract is not only what is required by the reader but it is likely to expedite the work of the abstracting journals—a consideration of increasing importance as the size and numbers of journals increase.

Preparation

These points should be kept in mind when the abstract is written. The author should read the article and make notes as he does so. The notes should reveal the purpose of the investigation, how it was carried out and the principle new facts and conclusions which result from the work. New techniques and theories should also be indicated. From these notes sentences can be written to provide an abstract which is clear, concise and readable. When carefully pruned it should not exceed 200 words.

INTRODUCTION

Introductory paragraphs should be used to state the purpose of the article, to describe the problem which has been studied, and how it has been investigated. The exact form in which a paper is introduced depends on the particular topic of the paper although, in general, four main parts may be recognised.

(i) **Outline of problem.** This should comprise a clear statement of the subject of the paper and the reasons for its investigation.

(ii) **The state of present knowledge.** This is presented as a brief review of papers which contain valid results and which are relevant to the introduction. Today it is unfashionable to give a long, comprehensive review of literature in the introduction. Most references should appear in the discussion where the results of the investigation can be compared with those of previous work and where appropriate interpretation can be made. Where the problem is new a simple statement of an observation which occasioned the investigation is all that is required. On the other hand a problem may have been investigated many times and the findings of the various investigators may conflict. If so the author is justified in presenting a more comprehensive review in order to justify his work. Sometimes the author can save valuable time and space if the problem has been reviewed competently elsewhere. Here he may draw attention to the review and briefly mention the main points that have emerged and which are relevant to his own investigation.

(iii) **Derivation of knowledge.** The choice of method may materially affect experimental results and their interpretation. This happens when other workers in a particular field have not agreed on a common method of investigation or of laboratory procedure. It is often the reason for the conflicting findings mentioned in (ii) above. This should be made clear in the introduction.

(iv) **Plan of investigation.** This is a brief description of the method by which the experiment was carried out and should be a logical development based on the information provided in paragraphs (i), (ii) and (iii) above. Where several methods of investigation are available the author should give the reasons for his choice. The details of the experimental method should appear elsewhere.

METHODS

Detail

Because results depend on the precise way in which an investigation is carried out, it is important to describe clearly the materials and methods used. This should be done so that a reader can judge for himself how valid the results are likely to be. There should be sufficient detail to enable a competent worker to repeat the experiment. This can be particularly valuable to workers in developing countries who may not have ready access to extensive libraries and may have to depend on correspondence for information.

Completeness

When a generally accepted method of investigation has been used it is sufficient to quote the original reference. Authors should be careful, however, not to state that the methods were described in a previous publication when, in fact, several papers may have to be consulted. When this happens a reader cannot assess results accurately until he has seen the preceding papers. This can become a long and expensive project

for those who must rely on inter-library loans for access to scientific publications. When several papers must be consulted, to find out the method that has been used, it is preferable for the author to consolidate this information in the current paper.

Outline

Materials and methods can be described from four main aspects depending on the nature of the investigation in hand.

(i) **Equipment.** When living organisms are used, their kind, number and environment should be given together with a note of any special feature which has a bearing on the investigation.

(ii) **Experimental design.** This can be explained briefly in simple experiments. In more complex trials, where for example breeds, diets and treatments are involved, the information may be more easily understood if it is presented in a table.

(iii) **Observations.** The observations recorded provide the raw material from which the results of the experiment are derived. Methods of sampling, sub-sampling and so on should be described clearly.

(iv) **Methods of analysis.** The methods of laboratory analyses should be given together with the way the resulting information was treated statistically. Any new method should be described and special features emphasised, e.g. if chemicals of a particular purity are required then this should be stated and their source of origin given if necessary.

RESULTS

Presentation

This section should contain only a factual statement of the information which the investigation has provided. No attempt should be made to interpret the results or to discuss them in any way. This is done at a later stage in the paper. If the loss of a replicate has occurred the action taken should be given. So far as possible the results should be presented in tables or figures which should be comprehensible without reference to the text. The text should be used to draw attention to the contents of tables and figures so that the main experimental findings emerge in a logical sequence. There is no point, of course, in having tables and graphs if their contents are detailed in the text.

The metric system should be used for the expression of weights and measures and other data because of its world-wide comprehension. An increasing number of editors of scientific journals insist on its use. Similarly decimals should be used in place of fractions and the centigrade scale instead of the Fahrenheit. Never use more than one system e.g. British measures in one place and metric in another. It is permissible to give both together e.g. 10°C. (50°F.) but this is unnecessary.

A table's contents needs no description in the text. We all know that it is likely to contain the experimental results together with some indication of their variability and significance. Consequently, the first sentence in the following example is unnecessary:

> "Table 2 presents the mean results of Experiment 1 together with standard errors of the means, co-efficients of variation and an indication of these differences which were significant at the 5% level of probability.

> There were no significant differences between pigs receiving water *ad libitum*, or at rates of 2.5 lb. and 1.5 lb. per 1 lb. meal in any of the characters measured."

All the reader needs for his attention to be directed to the correct table is for "(Table 2)" to be inserted after " . . . characters measured."

Results and Discussion

While presentation of the results without comment is desirable, because of the clarity it lends to a paper, it may not always be possible to follow this recommendation. When an investigation is composed of a series of experiments, or consists of a large volume of descriptive material, it is preferable to combine the results and their discussion in one section. The section will then consist of a series of sub-sections in which results are presented and then discussed for each experiment. There should be no question, however, of interweaving results and discussion in such a way that a reader cannot readily distinguish between what an author found out, what other writers have written about the subject and accordingly, how the author has interpreted his own findings.

General Discussion

A combined section of results and discussion must be followed by a "general discussion" so that the main points from the whole series of experiments can be brought together for interpretation.

DISCUSSION

Purpose

The discussion provides the investigator with an opportunity to put his results into perspective. In it he should describe how his new facts are related to existing knowledge and what inferences may be drawn from them. The ability of the writer to do so competently serves as a criterion of his scientific worth. Consequently the discussion is of major importance. The developing writer may find this to be the most difficult section of the paper to deal with. It is, however, much easier if he knows the relevant literature and has planned and executed the experiment carefully. The pattern outlined below will serve as a guide to the logical development of the discussion. Each main topic should be treated separately according to the following aspects.

(i) **The main findings** should be stated although long repetition of the results must be avoided.

(ii) **Conclusions** should be drawn logically from the evidence provided.

(iii) **Opposing theories** should be explained in relation to the conclusions.

(iv) **Comparison** of results with existing knowledge. The results contained in the paper should be compared with those of other research workers and interpreted in relation to their findings.

For clarity of exposition the discussion has been shown to have four aspects but obviously these should not be separate sections. Each main finding of the experiment should be discussed separately in one or more paragraphs constructed on the outline given in (i) to (iv) above.

(v) **Implications.** When all the main findings have been discussed the problem investigated may still be unsolved. It is then appropriate to suggest what further research should be carried out. On the other hand a problem may have been solved and in an applied science may have a practical application. This should be clearly but briefly stated.

Finally, remember that rambling discussions are tedious to read. Authors should stick to the point, deal with it concisely and then proceed to the next point to be discussed. Statements of personal opinion should be kept to a bare minimum and should be written in such a way that they cannot be mistaken for facts—by the author as much as by anyone else.

ACKNOWLEDGEMENTS

Help or advice given by colleagues at any stage of the research work reported should be given in a brief statement at the end of the report. Hill (1955) has much to say on unnecessary acknowledgement.

REFERENCES

Most scientific journals follow a common method for quoting references but it is the duty of authors to ascertain exactly how this should be done for the journal in which they wish to publish. The least common method of quoting references in scientific publications is to use a number in brackets when attention is to be drawn to other work.

> "Baker (1) abominates grandiloquence, Cox (2) and Tucker (3) genteelism and Hill (4) unnecessary acknowledgement."

This system can be used without drawing attention to names of authors.

> "Attention has been drawn to grandiloquence (1), genteelism (2, 3) and unnecessary acknowledgement (4)."

Few, if any, complications arise with this method. References are merely numbered as they are used and then listed in numerical order at the end of the paper.

The method adopted for most scientific publications is to quote the name of the author and year of publication and to list these references alphabetically. Some authors have difficulty in setting-out references correctly with this system. This happens most frequently when there is more than one author for a publication. The main problem seems to arise according to whether authors names are used in a sentence or whether they are grouped together in brackets, usually at the end of a sentence. The real difference in setting-out is one of punctuation.

The case of the single author is quite easy:—

> " . . . quoted by Jacks (1961)." or
> " . . . have been quoted (Jacks, 1961)."

Note that when reference is made to Jacks (1961) the only punctuation required is brackets about the year. This applies irrespective of the position of the reference in a sentence. When the reference is given in brackets, the first bracket is moved in front of the author's name and it is replaced by a comma. If reference is made to two publications by the same author the years are merely separated by a comma.

> " . . . quoted by Jacks (1961, 1963)." or
> " . . . have been quoted (Jacks, 1961, 1963)."

References which contain a group of names should be handled in the same way.

" . . . quoted by Casey, Perry, Berry & Kent (1966)." or
" . . . have been quoted (Casey, Perry, Berry & Kent, 1966)."

A further point on group authorship is that most journals require all names to be given when the reference is used for the first time. Thereafter only the first named author should be quoted and the other names replaced by "*et al.*" This does not apply when authorship is by two people when both names are always given.

" . . . quoted by Casey *et al.* (1966)."
" . . . have been quoted (Casey *et al.*, 1966)."

Note there is no punctuation needed before a date when it is in brackets but, when the reference is in brackets, a comma should follow the last author's name. The full stop after "*al.*" is used to indicate that the word "*alia*" has been abbreviated.

When several references are quoted together they should be arranged in datal order and in alphabetical order within dates. When a group of references are quoted in a sentence each should be separated from the other by a comma.

" . . . in publications by Baker (1955), Cox (1955), Hill (1955), Tucker (1955), Brooks (1961), Jacks (1961, 1963), Leitch (1961) and Stielau & Hunter (1965)."

A semi-colon should be used for separation when references are grouped together inside a common set of brackets and a comma inserted after the last author's name.

" . . . in publications (Baker, 1955; Cox, 1955; Hill, 1955; Tucker, 1955; Brooks, 1961; Jacks, 1961, 1963; Leitch, 1961 and Stielau & Hunter, 1965)".

Sometimes an author or a group of authors may publish a number of papers in the same year. It is customary to distinguish these by a small letter after the year in question. No example of this occurs in the list of references to this paper so that a hypothetical example is given.

" . . . in publications by Baker (1955a, b)" or
" . . . in publications (Baker, 1955a, b)."

Setting-out the list of references at the end of the paper is a straightforward task. It is customary for references to be listed alphabetically and in datal order where an author has published more than one paper. In some journals the reference list is comprised of author(s), year, abbreviated title of the journal in which the article appeared, volume number and pages.

"Baker, J. R. (1955). *Nature*, Lond. **176**, 851-852."

Other journals insist that the title is given as well.

"Baker, J. R. (1955). "English style in scientific papers." *Nature*, Lond. **176**, 851-852."

The inclusion of the title of an article is becoming increasingly used and is helpful to anyone who is searching the literature for titles on a specific subject. Whatever method is used for setting-out references the author should check the correct abbreviated title of each journal quoted in "World List of Scientific Periodicals" by Brown & Stratton (1964).

WRITING THE PAPER

PRELIMINARY INFORMATION REQUIRED

Need to Understand the Problem

The prelude to a research project is the identification of a problem worth investigation. In an applied field such as agriculture this may arise simply because farmers are unable to obtain an economic yield from a given crop. This may be due to disease, parasitism, inadequate nutrition, inherently low productivity of the variety and so on. The problem may be simple and solved by a change in husbandry. On the other hand it may be complex with interactions between two or more factors obscuring the basic cause of low productivity. Usually the more complex the problem the greater the depth of knowledge of a subject that is required. This knowledge is usually derived from the scientific journals and without it neither an appropriate introduction nor a logical and critical discussion of results can be written. It is fitting to discuss methods of recording the salient features of papers to which an author may wish to refer when the paper is in preparation.

Abstracting Articles

Although the modern trend is for scientific articles to contain an abstract which summarises the information in the paper, this is usually insufficient for a research worker's card index. The abstract is a condensation of the author's views and while these must be recorded in the reader's own words, further vital information is needed for future reference. For example, it has been pointed out already that the experimental methods, laboratory, field and statistical, have a controlling effect on the results. The reader should note his own comments on the methods. Again, the results and discussion represent the author's views and the reader may have a different interpretation. Consequently a reader's abstract may often be longer than that of the author. Careful notes by the reader arising from the questions "What did the author have to say? What are my own views?", are the basis of personal abstracting. They often save a great deal of time when properly written and should obviate the need to consult the original text again. This is particularly important to people who do not have ready access to a well-stocked library.

Card Indexing

A few people have exceptional memories and are able to remember author, date, title, contents and the journal in which an article was published. Most of us can learn to do this for a limited number of key papers but must rely on a card index or some other form of recording system for reference purposes. Punched card index systems are used for a wide variety of purposes and a number of systems have been described (Casey, Perry, Berry & Kent, 1958; Clapp, Davis & Owens, 1961; Leitch, 1961; Stielau & Hunter, 1965; Berry, Cleaver, Nelder & Salter, 1966). Each individual tends to modify a well known system to suit himself. The beginner, particularly if he intends to write a thesis, where a comprehensive review of the literature is normally desirable, should adopt a manual punched card system. The simplest kind of card is made with a standard series of holes punched all round the card near the edge.

To use these cards a master is prepared on which each hole is designated to represent a particular aspect of a subject. This may be done alphabetically although grouping according to main subdivision is more usual. A separate card should be prepared for each paper to which reference may have to be made. On it will be recorded just enough information to recall the main points of the paper to the abstractor.

Holes representing subjects covered in the paper concerned are converted into notches by clipping away the edge of the card. When all the cards for a specific aspect of a subject are required, a needle is pushed through the appropriate holes of the entire card collection, lifted into the air and the cards which have been clipped over that aspect, will drop out. The procedure can be repeated one or more times on the fallen cards depending on the number of sub-divisions involved.

Some people prefer to abstract on to plain cards and to file these according to subject. At first sight this system appears to be simpler to operate than punched cards. However most scientific papers deal with several subjects, e.g. the effect of plane of nutrition on lactation and fertility in sheep. In this hypothetical example three distinct aspects of animal production are mentioned and three separate cards are required if the references are to be easily found.

THE FIRST DRAFT

Level of Presentation

Most journals prefer papers to be written for the moderate specialist, i.e. an author should write, not solely for the limited number of people in the world who are working in exactly the same field of enquiry, but for the large numbers working in related fields who wish to keep abreast of new knowledge. For this reason it is wise to avoid so far as possible the jargon terms which all branches of science tend to develop.

Basis of Scientific Writing

The four basic requirements of scientific writing are that the paper should be clear, precise, logical and brief. These essentials should be borne in mind at every stage in preparation although to implement them may be a difficult task for some writers. Sheridan wrote:

"Easy writing's curst hard reading."

The statement has been parodied by the editors of the Journal of General Microbiology to emphasise the fact that good writing comes only as a result of much practice;

"Easy reading's curst hard writing."

Although we must recognise that style is usually achieved through hard work and much practice we none of us need to be discouraged. The late Sir Winston Churchill, who probably earned more money with his pen than any other man in history, often found it to be necessary to write, rewrite and write again his speeches and prose in order to find the most suitable words and phrases for his particular purpose. Most of us have need of this Churchillian technique if we wish to achieve clarity, precision and brevity. The fourth essential, writing logically, depends on the ability of the writer to think in a logical way and this is, or should be, one of the results of a scientific training.

Initial Draft

The initial draft of a paper should be made as soon as possible and can be started while the experimental work is still going on. Substantial progress can be made with the 'introduction' and 'methods' sections but obviously the results and discussion of them, must await the completion of the work.

Introductory Review

The procedure of the beginner in writing an introduction may well differ from that of the experienced writer. The latter should have acquired some expertise in deciding on the few references needed to give a clear exposition of the problem. The beginner has yet to learn the art of presenting a problem in a nutshell which will capture a reader's interest. Consequently he would be well advised to write a rather comprehensive review of papers dealing with the subject. This should be critical where possible rather than a repetition of other people's views and should comprise principles and major findings rather than tedious details. Experience of writing a review in this way, particularly if it is submitted to an experienced colleague for criticism and discussion, helps to clarify ideas, develop logical and deductive reasoning, and the ability to pick out what is important from what is not. Once such a review is written it should become fairly obvious to the writer which parts will suffice for the introduction and which will be needed for a discussion of his own results. The relevant parts can then be summarised appropriately as the first draft of the paper is written. If the review is to be published as such then it will serve as a first draft to be pruned and polished in due course.

STYLE IN WRITING

This section is not meant to be concerned with creative writing nor does it pretend to provide a key to style in scientific writing. However, long experience in guiding post-graduate students in the preparation of papers for publication, has brought to my notice the common errors of inexperienced authors. These are given in somewhat gruesome detail. At the same time I must not give the impression that my students were particularly poor writers. They were not. Most of the errors described are continually encountered in some of the most reputable journals. Where possible I provide references to others who have encountered similar errors.

A short bibliography is provided. All of the books listed have been chosen because particular sections of each seem to me to be of special value. The list is far from complete. Anyone who wishes to make a detailed study of scientific writing can do so by consulting the references listed in those books included in the bibliography.

Principles

The need to be clear, precise, logical and brief in scientific writing was explained earlier. Lack of these essentials usually arises from clumsy sentence construction, ponderous phraseology, indirectness, verbosity, padding, jargon, failure to use words correctly, repetition, the use of emotional words and so on. These faults make a paper cumbersome and dull and prevent the author from presenting his information in a crisp and interesting way.

Gowers' "The complete plain words" is an excellent guide to avoiding the common pitfalls of writing. Although written specifically to improve the style of English used by Civil Servants in the United Kingdom, it is of great value to all authors. Gowers had an enquiring mind and an amusing style of writing. Fortunately for many scientists one may profit from his remarks without an extensive knowledge of English grammar. I can recommend this small book for the instruction and amusement of all authors.

Tense

Indiscriminate changes of tense are confusing and can give a meaning to a statement which does not accord with the facts. The introduction may be written in both the *present* and the *past* tense. For example:

> "Hammond *showed* that the eye *is* more fully developed at birth than other organs."

Materials and methods should be written in the *past* tense, e.g.

> "The experimental design *was* a 6 x 6 Latin square."

Remarks about results should be mainly in the *past* tense, e.g.

> "When N was applied at ear emergence leaf area was increased."

When the results are discussed *both present* and *past* tense may be used to make the meaning clear. For example:

> "The greatest liveweight gain *is* shown by group 3 which *received* a fish meal supplement to the diet."

However, any conclusions drawn from the data should be made in the *past* tense. For example:

> "Calves *grew* most rapidly, in these trials, when fish meal *was* added to their diet."

It is erroneous to state

> "Calves *grow* most rapidly when fish meal *is* added to the diet."

Such a statement confuses conclusions drawn from the special conditions of the experiment with a general pronouncement for all circumstances.

Sentence Construction

The first draft may have been written so quickly that little attention has been given to sentence construction. The purpose of any paper is to convey information and ideas. This cannot be done with long and involved sentences. Keep sentences short—if possible no more than thirty words in length. This is an aid to both clear thinking and ready understanding. If some sentences are too long, split them up. Consider if each sentence can be shortened or even omitted.

> "The steers in the trial gained at an average of 2.25 lb. per day for the first two months of summer, and only averaged 0.75 lb. gain per day for the remainder of summer until they reached their peak weights from the end of April to June, depending on the season, showing that high levels of production on this veld type are only possible during the first two to three summer months."

This sentence is difficult to follow. Not only is it too long but the key information appears in the final clause. Consequently the sentence must be read again to find out what justifies the final concept. Changing the order of phrases and turning them into sentences clarifies the argument.

> "On this type of veld steers gain weight rapidly only in early summer. In the first two months the average daily gain was 2.25 lb. and thereafter 0.75 lb. Steers reached maximum liveweight from the end of April to June although this varied seasonally."

Choice of more suitable words and avoidance of repetition has reduced the length of the passage by one third. Many first drafts can be improved in this way. Moderation in all things is often a counsel of perfection. Nevertheless authors should beware of becoming too brief otherwise the effect is staccato, which is almost as irritating as sostenuto.

Choice of Words

Once the plan and its development in the paper has taken shape and the sentences revised to make them crisp, attention should be given to choice of word. Words have precise meanings and to use them correctly adds clarity and precision to prose. A standard dictionary and Roget's "Thesaurus of English words and phrases" should be consulted throughout the preparation of a paper. Gowers has written four pithy chapters on the choice of words. Consequently only a few of the common errors of choice and usage need be mentioned here.

Abstract. Use the concrete and not the abstract to achieve clarity and precision.

> "A cessation of plant growth operated in some plots over the period in which the trial was conducted."

Obviously a cessation cannot operate. It is simpler, clearer and shorter to write:

> "Some plots of plants did not grow during the trial."

The abstract noun *basis* is commonly overworked.

> "Measurement of storm intensity involves recording staff to be available both day and night on a 24-hour basis."

The use of 'basis' in this way has led to a clumsy construction. Again 'involves' is hardly the appropriate word to use.

> "To measure storm intensity recording staff have to be on duty throughout the day and night."

Emotional words. The basic essentials of writing are described by Gowers, but a special note is needed on avoiding words which have an emotional meaning. We are all aware that no logical argument can be developed if emotional words or concepts are used. For example, a man who introduces new farming practices may be called "progressive" by his admirers, and a "reckless experimenter" or even "a crank" by his detractors. These descriptions make no contribution to systematic knowledge which is the foundation of science. Words which are commonly used in an emotional sense by some scientists are "sound", "good", and "correct". These words can be used in a precise way in certain circumstances but this implies definition. If we say examination results are to be classified as "excellent" (+75%), "good" (60-74%), "fair" (40-59%) and "poor" (below 40%) these words are given a scientific meaning. Too often, unfortunately, words like sound, good and correct are used to reflect the author's opinion. Consequently we frequently read about "sound veld management" and so on and are left to imagine precisely what the author means. Usually it is the kind of management the author advocates.

Gerunds. The use of these words often gives a wrong meaning to a sentence and Baker (1955) states they are best avoided. Here is an example:

> "There is a great deal to be learnt about milking technique: the kind of building in which a cow is milked, the ways in which she may be stimulated to eject her milk, the properties of the milking machine—after learning all this milking technique still appears more of an art than a science."

Obviously milking technique did not "learn all this". This error would not arise if the author had written—"—after we have learnt all this . . ."

Superlatives. The words *very*, *quite*, *more* and *much* have a place when used economically. As super-superlatives they are out of place in scientific writing. Some words express a precise attribute or state and consequently to precede them with a comparative adverb blunts their cutting edges. A petrie dish is either sterile or it is not sterile. It cannot be very sterile or quite sterile or more sterile and so on.

Loose expressions. These are the opposite of what is precise and are the result of muddled thinking.

If authors test their work sentence by sentence, asking themselves whether or not their meaning is simply and clearly stated, loose expressions can be avoided. Here is an example in the schoolboy howler class.

> "Another reason is the fact that bulls with high milk yield—and which consequently increase farmers' incomes substantially—tend to have fat percentages below average."

We can guess, of course, what the author means but what he has written is ridiculous nonsense.

The Active Voice

The active voice of verbs is to be preferred to the passive in all scientific writing because it is usually more direct and vigorous than the passive. The simplest construction of a sentence is:

Subject	Verb	Object
The Sheep	ate	the lucerne

In this sentence the verb is said to be in the *active voice* since the subject performs the action. When, however, the subject suffers the action the verb is in the *passive voice.*

Subject	Verb	Object
The lucerne	was eaten	by the sheep

When a sentence is made stronger by use of the active voice it usually becomes shorter. Indeed, brevity is a by-product of vigour in scientific writing.

Abominations of Style

Some authors seem to go out of their way to be obscure and, consequently, irritating. When we consider the growing quantity of literature scientists must read today then anyone who does not write clearly, precisely and briefly, is, at best, inconsiderate, and at worst, impertinent. Baker (1955) abominates grandiloquence and Germanic constructions, Cox (1955) and Tucker (1955) genteelism, and Hill (1955) unnecessary acknowledgement. There are other errors of style which make papers hard work instead of pleasant reading.

Grandiloquence. Baker (1955) describes this delightfully. "Long words derived from Greek or Latin roots are often used for expressing very simple ideas. When a man wants to say that something is visible to the naked eye on merely opening the body cavity he can make it sound grand by saying:

> "this phenomenon can be macroscopically observed upon laparotomy."

Genteelism. Ponderous circumlocutions arise from the abhorrence with which most authors evade the use of the first person pronoun. This may be done in the mistaken belief that to use "I" is immodest in a research worker. The implication is that where "I" is used a personal note is introduced to the scientific composition

which should be entirely impersonal. However clarity is more to be prized than false modesty because clarity and word economy go together. The following flabby phrases should be replaced by "I":

"the present writer"
"the author of this communication"

Genteelism of this kind appears to be a foible of the egoist. By ostentatiously avoiding the appearance of egotism a writer can easily draw attention to his supreme egotism. Genteelism has been discussed by Cox (1955) and Tucker (1955).

Germanic construction. Most scientists are able to discuss their work intelligibly but some fail to do so in writing. Baker (1955) has drawn attention to the increasing use of Germanic phrazeology in scientific writing. He points out that no one would think of saying 'a tea containing cup' for 'a cup containing tea'. Baker gives the examples which follow:

"iron containing globules"
"a hyaluronidase treated area"
"non-formation containing fixations"
"adenosine triphosphate activated actomysin contraction"

As Baker states: "These words are put together without the slightest attempt at clarity or any consideration for the reader." In his opinion, and I agree with him, the phrases are worse than merely illiterate, they are rude.

Overuse of "the". This fault is particularly irritating. It is quite unnecessary to place the definite article in front of every noun in a sentence. To do so is clumsy and produces a soporific effect.

> "*The* collection of *the* samples from *the* ewes on *the* various pastures was facilitated by *the* use of *the* portable races and *the* pens."

Each "the" may be omitted from this sentence unless "various pastures" are specific. In such a case use of "the" before "various" reminds us of particular pastures to which, presumably, reference has been made earlier.

Ititis. Finney (1951) pungently has drawn attention to the excessive use of the indefinite pronoun IT. Undoubtedly the impersonal and indefinite "it" should be dispensed with because the expression is weak and pompous. A few simple examples together with corrections illustrate the point.

"It would thus appear that . . ."	(Apparently)
"It will be seen that . . ."	(omit)
"It is evident that . . ."	(Evidently)
"It is interesting to note that . . ."	(omit)

The construction becomes monstrous, states Finney, "when it is adopted by the author who wants either to avoid explaining ideas that he has not fully thought out for himself or to insinuate his opinions without accepting responsibility for them."

For example:

"It is to be expected that it will be difficult to apply A unless it is accompanied by B, for which reason it is generally preferable to use C in spite of its other disadvantages."

Brevity, clarity and strength are achieved and the author has no longer evaded his duty of thinking out exactly what he wants to say, by the following:

> "In spite of its disadvantages, I recommend the use of C. because application of A without B is difficult."

Jargon. Some writers have a tendency to use made-up terms which are understood in their own field but are unintelligible to others. Each branch of enquiry has its own technical terms and usually these have arisen because new concepts sometimes demand new words. Such terms are justified, of course, when they have been coined to act in place of a phrase or when a common word cannot convey the precise meaning intended. Words of this description are not usually regarded as jargon and no objection attaches to them. What is abominable is the slovenly word thrown into a text by the writer who cannot be bothered to find the appropriate word required. Even worse is the use of accepted technical terms in such an obscure way that even scientists, who know the meaning of the individual words, cannot grasp their meaning when they are strung together into a phrase. Here is an example:

> ". . . within which are anteroposteriorly orientated anastomosing fibres."

This might mean, but no one can be sure:

> ". . . posterior directed fibres anastomose with anterior directed fibres on meeting."

REVISING THE MANUSCRIPT

Once a first draft of a paper has been prepared it is ready for revision. It is worth while to write drafts on alternate lines of close-ruled foolscap paper (51 lines a page) so that it is easy to rewrite between the lines. Usually the draft will have to be revised several times. It is best to do so for one particular purpose at a time.

Order and Development

The first revision should be concerned with the order and development of the main sections together with the paragraphs they contain. At this stage the author should ask himself: "Is the arrangement logical? Have the main ideas been developed clearly? What details, though interesting, are irrelevant and can be omitted? Are the arguments in the discussion consistent with the results of the investigation? and are they assessed correctly in relation to the findings of other workers?"

Final Revision

Once the manuscript has been corrected for order and development, sentence construction and choice of words, it should be ready for final revision. At this stage the text should be clear and concise and contain no unnecessary repetition of information. A check should be made on punctuation. The use of relatively short and simple sentences facilitates this. Avoid having several sentences with similar beginnings or word groups. Modifying the beginnings of the last three sentences above illustrates these points:

> "At this stage the text should be clear . . . "
> "At this stage a check should also be made on . . . "
> "This stage is facilitated if relatively . . . "

Repetition of word groups, as distinct from repetition of information, makes reading tedious and can be avoided with a little ingenuity. Words which rhyme should be eliminated as well as repetitions of the same word. For example:

> "The supply of protein requirements by a food is a first requirement of a food for feeding to pigs. Foods containing fish meal supply the protein requirements required in proportion to the supply of fish meal the food contains."

A less clumsy and more precise way of presenting this information is:

> "The first requirement of a diet is to supply a pig's protein needs. Foods containing fish meal do so in proportion to the amount included."

Submission for Comment

When the author is satisfied that he can make no more improvements to the draft, it should be typed and copies submitted to colleagues for comment. Errors of interpretation may arise if some important detail in the literature has been overlooked. To avoid such errors someone who knows the subject well can be particularly helpful. If the author does not know anyone like this he should write to the editor of the journal in which the article is to be published. The editor will be able to suggest an authority who can help. Comment from a person with some experience of writing scientific papers can be invaluable. This is particularly true if the scientist has only a general knowledge of the subject of the paper. He can criticise the paper from two important aspects, i.e. suitability of outline and comprehension. While scientific accuracy must be the first essential in a paper there can be no doubt that comprehension is a close second. Thus if a scientist from another field of study can readily follow the logic of the paper, the author can be confident that his information and arguments are clear.

Comments from the scientist with only a general knowledge of the subject has another great value. The specialist, through an intimate knowledge of his subject, may omit a concept and so give a meaning which is opposite to that which is intended. Such omission can escape the notice of other specialists in the same field because the missing concept may be elementary. Again, although an author may not agree with the criticism of a colleague, at least he will have to think hard about what he has written.

THE FINISHED MANUSCRIPT

Typing

A legible copy of the manuscript must be written out for the typist when the last revisions have been made. The headings of sections, sub-sections and so on should be clearly indicated to ease the task of both typist and reader. This is illustrated by the list of contents at the beginning of this paper and by the system adopted throughout.

The manuscript should be clearly typed on a machine which has 10 characters to the inch. The lines should be double spaced for the whole of the manuscript. Attention to these details eases the task of all who must read it. Authors should consult the instructions to contributors which are usually printed inside the cover of a journal. Some journals specify the size of paper for manuscripts, the width of margins and the number of copies to be submitted to the editors. Otherwise it is customary to type on plain white foolscap (8 in. x 13 in.). Margins of $1\frac{1}{2}$ inches on the left, 1 inch on the right, and 1 inch at the top and bottom of the paper should be left clear. The ribbon copy should be sent to the editor.

Checking

The typed manuscript must be compared with the original for errors. Every letter and figure must be checked because it is easier to correct mistakes on the typescript than on the galley proof. The best way to do this is to have a colleague read the original aloud slowly while the author corrects the typescript. All corrections must be made by means of standard proof-readers symbols (British Standards Institution, 1958).

Galley Proofs

When an article has been accepted for publication the editor sends it to the printer to set up the type. The first run from the press is made on long slips of paper which are known as galley-proofs. These are sent to the author who must check them for accuracy against the carbon copy of the manuscript submitted. Again this is simplified if another person reads aloud while the author checks. Only errors of copying may be corrected on the galley-proof. If even a small insertion or deletion is made it might involve the printer in resetting all the lines which follow. This is expensive and some journals charge a fee when this happens. If the author discovers an error of substance then he must put this right even if he has to pay for the change.

REFERENCES

BAKER, J. R. (1955). English style in scientific papers. *Nature*. Lond. **176**, 851-852.

BERRY, G., CLEAVER, T. J., NELDER, J. A. & SALTER, P. J. (1966). Methods of recording data in the laboratory and field. *Expl. Agric.* **2**, 69-80.

BRITISH STANDARDS INSTITUTION. (1958). Proof correction and copy preparation. (B.S. 1219: 1958). Lond. *B.S.I.* 28 p.

CASEY, R. A., PERRY, J. W., BERRY, M. M. & KENT, A. (1958). Punched cards. Their application to science and industry. *Ind. ed.* New York, Reinhold.

CLAPP, C. E., DAVIS, R. J. & OWENS, L. D. (1961). A punched card system for soil scientists. *Agron. J.* **53**, 397-399.

COX, E. G. (1955). English style in scientific papers. *Nature*. Lond. **176**, 1250.

FINNEY, D. J. (1951). Ititis. *Biometrics* **7**, 306-307.

GOWERS, SIR E. (1962). *The complete plain words*. Harmondsworth, Penguin Books.

HILL, A. V. (1955). Independence in publication. *Nature*. Lond. **175**, 266.

JACKS, G. V. (1961). The summary. *Soils & Fert.* **24**, 409-410.

JACKS, G. V. (1963). Summary, Part II. *Soils & Fert.* **26**, 379-381.

LEITCH, I. (1961). Nutrition: a scheme for classification and coding of information for machine retrieval. *Nutr. Abst. Rev.* **31**, 1099-1107.

ROGET, P. M. (1956). *Thesaurus of English words & phrases*. Lond. Longmans.

STIELAU, W. J. & HUNTER, G. L. (1965). A punched card subject index for animal science. *Proc. S. Afr. Soc. Anim. Prod.* **4**, 185-188.

World List of Scientific Periodicals; 4th ed. edited by BROWN, P. & STRATTON, G. B. Lond. Butterworth, 1963-65. 3 v. p. 1824.

TUCKER, D. W. (1955). English style in scientific papers. *Nature* Lond. **176**, 1251.

BIBLIOGRAPHY

CONFERENCE OF BIOLOGICAL EDITORS, COMMITTEE ON FORM AND STYLE, (1960). Style manual for biological journals. *Am. Inst. Biol. Sci.* Washington. 92 p.

STRUNK JNR., W. & WHITE, E. B. (1959). *The elements of style*. New York, Macmillan. 71 p.

BROOKES, B. C. (1961). *Editorial practice in libraries*. Lond. Aslib. 204 p.

FIESER, L. F. & FIESER, M. (1960). *Style guide for chemists*. New York, Rheinhold. 668 p.

HENN, T. R. (1960). *Science in writing*. Lond. Harrap. 248 p.

KAPP, R. O. (1948). *The presentation of technical information*. Constable.

WILEY & SONS (1958). *Authors Guide*. New York: John Wiley & Sons; London: Chapman & Hall. 80 p.

UNIVERSITY OF CHICAGO PRESS. *A manual of style*. Chicago University of Chicago Press. 534 p.