Chapter One
Writing a scientific paper

Before you write

Here are four suggestions about what you might do before writing a paper.

1. If notebooks are used, good notebook discipline is helpful. When an experiment is finished, try to record your conclusion in words, together with your findings and on the same page. Make tables. Draw graphs and stick them into the book. Keep a file in which to record summaries of results from many experiments, and group them by subject. Some experiments will each provide results for various summaries. Number each book and each right-hand page. Then, even after some years, an experiment can be found from the file as e.g. 9;43 (book 9; p. 43). Write the date at the top of the page.

Prompt recording of a summary for each experiment compels you to give critical thought to the experiment at the best time, and may move you to repeat a control test while you still have the materials. Clark (1960) makes an eloquent appeal for keeping adequate notes. Write every digit unmistakably. Think: ‘I must so write my notes that another person can read them if I am ill, or worse’. Then you should understand them yourself when you come to write the paper.

2. *Speaking makes you think out arguments*; and listeners’ criticisms may prevent your publishing a clanger. Some institutes operate a regular tea club or occasional seminar at which researchers tell colleagues about their work. If your institute has no club, or the programme is filled, invite colleagues to your room to listen to you. Display diagrams. If you have no projector, use a felt-tip pen to draw diagrams and tables on the back of a roll of wallpaper. Hang the paper over a chair on the bench. Do – speak – slowly.

(1) Nothing clarifies ideas in one’s mind so much as explaining them to other people.

(2)
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3. The third suggested pre-writing activity is based on Woodford's (8 (3)) 'reservoirs'. Take 8 sheets of paper. Boldly label them Title Summary Intro Mat Meth Results Disc Ref
Write ideas for your paper, whenever they come to you, as notes on the appropriate sheets (reservoirs). Use differently coloured sheets if possible. Carry a card everywhere – even to bed. Jot down ideas as they occur. Transfer the notes to the reservoirs and put a fresh card in your pocket or handbag. Rewrite a cluttered reservoir from time to time; if you wait too long, you may forget what some of your notes meant. Hold the reservoirs in a clothes peg (pin), not in a wire clip which may catch on other papers.

Some writers construct a skeleton, an outline scheme, before they start to write. Should you do this it is still advisable first to prepare the reservoirs. In particular, a skeleton for the Discussion may help you to muster your ideas in the best order and to avoid repetition.

4. Prepare tables and figures.

Honesty & accident

If the result of an experiment seems ‘wrong’, record it none the less, and watch for a repeat. Many a discovery has been made by accident: serendipity is alive and productive. However, people have been known to manipulate or 'doctor' their 'wrong' results. Manipulators may have regrets later.

When to begin writing

My research supervisor said 'Writing a paper is as important as experiments. Is it unreasonable, then, if it takes as long?' Oft-repeated advice is 'Set aside your paper for some weeks, then read it. You may be amazed at what you wrote.' You may even discover a passage you yourself cannot understand. If you follow this advice, and believe that supervisor, you must start writing early. Writing as the work proceeds reveals gaps in knowledge, gaps that should be filled while laboratory facilities are still available.

Arrangement of a scientific paper

The commonest arrangement for a research paper is that indicated by the order of the reservoirs mentioned above. Some investigations are suitable for results and discussion to be written together in narrative form. If you use this form, write your Conclusion as a separate section.
Where to start

Even though you have enough material, you may have postponed writing a projected paper. Perhaps you find it difficult to start. I do. You do not have to begin with the Introduction. Begin with the easiest section. This may be Methods, for you should know what you did. Use the ‘reservoirs’, and cross out the notes as you consume them.

Next, perhaps, you might start on the Results. Write the first draft ‘in your own words’ just as though you are telling a friend about your discoveries. Don’t worry – yet – about grammar, aptest words & style. The immediate objective is to get going. You can polish the style later. This paragraph was so written, and the needless words and hackneyed phrases have not yet been polished out.

The Conclusion of a paper is so important that you should make its first draft in time to allow for re-draftings.

Stocktaking

Now take stock. The outline is complete, diagrams and tables are ready, the Discussion is planned, the Conclusion is drafted and Methods are written. Oh joy! the paper is half finished. A happy author writes better than a worried one.

Title & key words

Some searchers may read only a paper’s Title and Summary. So both are supremely important parts. Compose trial versions of the title as early in your writing as you can; re-examine them later.

On your first reservoir sheet write key words for the Title. Let the Title’s first word be a key word if possible; in lists of titles such a word is better than ‘The’. Remove other waste words such as ‘on’, ‘study’, ‘investigation’. . . . The Title should be short yet specific, not general: a reader, attracted by a title, may be disappointed to find that the paper is about only one specialized aspect of the subject promised. Have you experienced such a disappointment?

Many journals require a Headline or Running title as well as the Title. An ingenious paraphrase of the Title can supplement the latter. For example, the Latin name of a species might appear in the Title and the common name in the Running title.

If the journal needs key words, you can provide them from your reservoir.
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Summary

If the editor permits, compose the Summary in numbered paragraphs. The first should state – briefly – what you did. Then come the main results. Lists of values may be indigestible for your readers; so use words, supplemented by a few key values. State your conclusion in the last paragraph. If you have no succinct conclusion, you might write ‘The effect of A upon B is discussed’.

If a summary is long, readers may look only at the first and last paragraphs. Although a well-written summary may be lifted by abstractors, a long summary will be shortened, perhaps by the omission of what you consider vital parts.

Write the Summary in the past tense, except perhaps the last paragraph.

Some journals print the Summary in small type. How odd!

Introduction to a paper

The Introduction should state the problem, and perhaps ask a question. The objective must be clear. If you modified your objective after you began the work, give the current version. Do you still think you asked the right question?

The quoting of numerous papers in the Introduction is no longer good practice. [If much has been published, and you think it warrants a review, write that separately and submit it to an editor.] Refer to papers that, taken together, show that a problem exists. If another paper gives many references, refer to that. However, beware of lifting references – from that paper – together with misquotations of information from the original papers. That has been done . . . For example, one abstractor supposed that Kaninchen meant little dog; and Yamane’s work on the rabbit [Kaninchen means rabbit] has gone into the literature as being on the dog. For this and other cautionary tales, see Hartree (1976). Roland (1976) reports that J. Hlava, a Czech, wrote an article ‘On dysentery’ and added a Czech translation of the title: ‘O. Uplavici’. An abstractor cited the author as O. Uplavici; so an author who never lived went into the literature for 50 years.

In the last sentence of the Introduction, it is accepted practice to state the conclusion. A reader can better appreciate the evidence that follows if it is clear what conclusion is being supported. However, this version of the conclusion must be brief. Some authors repeat much of the Summary in the Introduction. That is not an acceptable practice.
Materials & Methods

If the description of materials is short it may be included in Methods. Avoid trade names if practicable, not to avoid advertising, but because they may not be understood abroad. [Do you know what Klampits or Barbisters are? or what Skellysolve means?] If you use a local name for polymethylmethacrylate or other compound, give the chemical name at first mention of the trade name.

Write what you did in operational order. Invert ‘The urn was dated after restructuring’ to ‘The urn was reconstructed, then dated’. You should so describe the methods you used that others can repeat the experiments. You must be concise, yet you must not omit essential detail. If you used ‘alcohol’ say which alcohol. If you controlled, or even measured, the humidity and ventilation in an animal room, say so: they may be nearly as important as temperature. If you centrifuged a suspension, say whether supernatant or pellet was used for the next operation. Similarly, if you filtered a suspension, say which part was retained; it has not always been easy for a reader to conjecture.

If you used control experiments, permit no doubt about their nature. The reader may not be able to guess what you omitted for each control.

If your paper is about a new method, ask a visitor or a technician to test your description by applying the method in your absence. The result of the omission of one detail can be illuminating.

Results

Before you write about your Results it may be advisable to study Units and quantities (p. 25) and Tables (p. 24).

Replicate observations should not usually be given. Instead, offer the mean and a measure of the variability if you can. The range is not satisfactory; if there are enough replicates for the range to be of use then there are enough for estimating the standard deviation (s.d.) of one observation, the standard error of the mean (s.e.m.) or the coefficient of variation (c.v.). Give the number of observations or the degrees of freedom within parentheses: 12.65 ± 0.22 (n = 12). Perhaps you can make a pooled estimate of the variance (or other statistic) from the whole study. You can then give individual uncluttered values.

Journals ask for tables and figures to be clear without reference to the text. This requires concise explanation in legends, an explanation of abbreviations, and care in the avoidance of repetition in the text and in other legends, as well as consistency between text and legends.
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Discussion

The Discussion must not be so long as to deter a reader, yet it must contain logical argument. Do not repeat descriptions of other people’s findings if they are in the Introduction; refer to that. Avoid summarizing your results in the Discussion. Mention them, take them as read or refer to a table or even to the Summary (quote a paragraph number, if used). Enlarge upon the significance of your new results and explain how they add to existing knowledge. You may have formulated your problem as a question in the Introduction. If you can now give the answer, that facilitates discussion.

Think critically, not only about other people’s work but about your own. For example, ask yourself ‘Can my hypothesis be refuted? Can my results have another explanation?’ Maier (1933) told the students in one of two large groups that, were they unable to solve the problem given to them, they should try to ignore their first approach and seek an altogether different line. (The other group, the control, was not told.) This worked – in the ‘told’ group a larger proportion solved the problem than in the control group – yet it is difficult to achieve such ‘lateral thinking’, as de Bono (1967) calls the modern development. The following example shows how important is such ‘no-prejudice rethinking’. Two authors published graphs to prove their thesis that xanthine oxidase and the Schardinger enzyme (aldehyde oxidase) are distinct enzymes. Later, their graphs were used by another author to confirm the opposite (now accepted) view that the enzymes are identical. Had those first authors given their results more thought, they too might have reversed their conclusion. The literature contains abundant examples of inconclusive thinking. Writers should take care not to add to them by publishing in haste.

W. Pauli wrote ‘I don’t mind your thinking slowly: I mind your publishing faster than you can think.’ [Translated by Mackay (1977).]

Conclusion

If you are fortunate, your Message (or part of it) may survive in textbooks – although you may not be given a whole sentence! So the Conclusion needs precise wording. Your Conclusion may appear three times: in the Discussion, the Summary and the Introduction. Do not repeat the wording; paraphrase it. If the reader has not understood one version, another may help. Use the shortest version for the Summary.
Parting remarks. Perhaps you have not yet reached a conclusion, but have contributed towards one. You may like to end with ‘Parting remarks’. Make them short, but do not bring ‘final’ into the heading. One paper concluded with ‘We admit we have raised more questions than we have solved.’

References, Bibliography or Literature cited

Write each reference on a card. Arrange the cards in order and give them to the typist at the final typing of your paper when you have checked them against your revised text. This scheme leads to fewer errors than does retyping the references at every retyping of the paper, although the advent of word processors has made ‘editing’ the References a much easier job. Each journal arranges references in a particular style, which should be followed. Give the typist a copy of the journal to provide an example of style. If references in the text are made by superior digits, avoid ‘the value was 24\textsuperscript{2}; change to ‘the value was 24 (ref. 2)’.

Check the typed list against the original papers. Also check that the spelling of names in text and Bibliography agree. Errors are very common in papers submitted to editors. (See Numbering, p. 48.)

Written English

Good written English is nearly the same as good spoken English. Grandiloquence has no place in scientific writing. We need to convey ideas effectively, to make it easy for the reader to understand what we write, not to exhibit our vocabulary. Indeed, those who use pompous language may even be suspected of having nothing important to say! Try to envisage the reader; write in a manner not too technical, not too elementary. Write as though you are talking to a reader, relating your experiments, but restrain colloquialisms.

Clear English. Ask yourself often: would T. W. Fline [p. xiv] understand what I write? Write short sentences, but not all of them so short as to produce a staccato effect. Cure a staccato passage by linking two sentences (as I have done here with a ‘but’), but do this only seldom, so as to keep to ‘one idea per sentence’ with occasional exceptions. A satisfying sentence has two main verbs (Pertunen, 1975).

If you train yourself to speak well, that will help you to develop a good written style. In conversation, choose words with care, speak deliberately and clearly.
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Grammar

English grammar is simpler than that of many languages, yet some writers are careless about the small amount that does exist. People abroad who learn English as a foreign language mostly learn it grammatically because they are used to complex grammar in their own languages. So when they meet doubtful grammar in a published work, or at a conference, they may be confused. On their behalf, I appeal to you to persuade emergent authors to follow rules of grammar and to punctuate carefully.

In English, the same word can sometimes be used as a noun (*tin*), an adjective (*tin can*) and a verb (to *tin* the copper wire). Indeed, almost any noun may be ‘verbed’ and any adjective ‘nounded’: medical, high, sabbatical. But this freedom is needlessly abused. Consider the phrase ‘the book was authored’. Why not say ‘written’? ‘Authored’ gives no special shade of meaning. Where a verb is needed but none exists, it is practical to use a noun (to program, to chromatograph); but ‘to gift’ (mineral samples were gifted by Dr Fob) is unnecessary.

Mutual editing

In courses on rapid reading, one is told not to go back to re-read a passage. A trained reader may not return to a sentence whose meaning was not grasped. How can you discover such passages in your own writing? One way is to put the paper away for a month, then read it afresh. This may be impractical. Another is to have colleagues read your paper. Ask them both to make general comments and to mark every sentence they had to read twice. If they are critical, thank them nevertheless, for, if they fail to understand you, others might fail too and your Message will be lost.

For nearly 2000 years it has been known that we see other people’s faults more easily than our own. (Parable of the mote and beam, Matthew 7, iii.) Moreover, it is fun to cross out needless words in other people’s papers. Therefore, make a deal with your colleagues; if they will let you ‘correct’ their papers, you will let them correct yours. Do not use red ink, which is offensive to some; green is more soothing.

You may have noted a repetition above. That is deliberate, because emphasis is needed. Hundreds of the errors I have seen, in papers that had already been accepted but not yet edited, ought to have been seen by a critical colleague and then corrected – before submission.

However senior you be, ignore the ‘statuskline’, or hierarchy, and
ask for constructive criticism, not flattery, from your juniors. Such editing should be good training for them.

**Literary style**

(7) *Noun adjectives*. In English, nouns may be used as adjectives; that is, as modifiers of a true noun. One might write ‘an oil engine needs engine oil’ or ‘glass bottles are made of bottle glass’. But the use of nouns as adjectives may lead to confusion unless made with care. For such terms as ‘dog meat’ or ‘cat fish’ make it clear which of the two meanings is intended. ‘Rapid gas apparatus deterioration’ is better written as ‘Rapid deterioration of gas apparatus’, and ‘product treatment’ as ‘treatment of the product’. Even the simple ‘drug dose’ seems clumsy. If you dislike recurrent ‘of’, the occasional genitive case may be used.

There is no suggestion here that nouns should never be used adjectivally. Many are so used satisfactorily, including hydrogen bond, gold size, oak tree, steel plate, SI units.

Take care to avoid confusion. *We* may know that a spring washer is a sprung washer, not a machine for washing springs, but would T. W. Fline know that? And would the title ‘Cancer in rubber workers’ be understood?

When two or more nouns are used as adjectives of one noun, the phrase may become inelegant. Consider the following: isotope dilution assay results; pH 6.8 phosphate buffer; multiple conductor galvanized angle steel pylon system; we devised a new short chain fluorocarbon aerosol can valve. Such phrases are difficult to comprehend; the reader finds that each successive noun is not the real noun; words have to be stored mentally until the substantive being modified is reached. Therefore, avoid long adjectival phrases, or stacked modifiers as Woodford (8 (3)) calls them (see also p. 54). Even if the modifier contains no noun adjective, it may be troublesome, as this example shows: a frequently heated and therefore deeply coloured viscous solution . . . . The use of hyphens may lead to improvement of some phrases, but rewriting is usually best.

Note that *in vivo*, *excess* and *de novo* are not adjectives, but that *subliminal*, *optimal*, *minimal* and *maximal* are. Write ‘test *in vitro*’ not *in vitro* test. People would not write ‘in glass test’.

*Comparatives*. A passage that contains a comparative sometimes causes difficulty: what does ‘lions eat more than antelopes’ mean? Make clear
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what is more than what, and only compare things that are comparable. Instead of ‘starch yielded more glucose than maltose’ write either ‘. . . than did maltose’ or ‘starch produced a greater yield of glucose than of maltose’. Do not omit ‘those in’ from ‘bearings in steam engines lasted longer than those in diesel engines’.

Wrongly attached participle. A verb in the active voice needs a subject, an operator, either actual or understood. One of the most common errors submitted for publication is exemplified by ‘having completed the observations the telescope . . .’ or ‘a bend was observed in the bridge using a strain gauge’. Was the bridge really using a gauge? Phrases such as the following make people laugh. After standing in boiling water for 2 h, examine the flask; electronic devices should be made safe before leaving the laboratory; and goggles are required to do the experiment. Yet such errors (aberrations, faults, lapses . . .) are often submitted to editors. Read what Fowler [8 (9)] or the authors of style books listed in Chapter Eight have written on Unattached, Wrongly attached or Dangling participles and infinitives.

Gerund. A participle may become a kind of noun (called a gerund), as in ‘Writing a paper’. If the adding of ‘the’ and ‘of’ (e.g. before and after ‘adding’ in this sentence) makes grammatical sense, the -ing word is a gerund. Applying this test, you can see that ‘Using a dynamometer, the tractive effort was measured’ is not allowable because ‘Using’ is a wrongly attached verb here, not a gerund, being wrongly attached to ‘effort’. Change the sentence to ‘Using a dynamometer, we measured . . .’ or to ‘A dynamometer was used for measuring the tractive . . .’ or add ‘By’ → ‘by using a . . .’. In ‘Applying this test, you . . .’ (see 6 lines above) the ‘you’ was the subject, and the phrase is allowable.

Be alert for dangling verbs. So many sentences start with ‘Judging by’ or ‘Based on’ that these participles are becoming accepted for use in that way. Even so, let other words that end in -ing or -ed warn you to ensure that each is either a gerund or is properly attached to an operator.

Using is written and spoken so often without an expressed operator that it may eventually become a preposition (compare providing). Even if you accept that event, you will be wise to ensure that the operator is always clearly understood. The phrase ‘He could not stop the mill using