Duplication

Now is also the opportune time to discover and eliminate unnecessary duplication. The danger points for repetition are usually found in the Introduction and the Discussion, and the Results and the Discussion.

Points developed in the Introduction are often redeveloped needlessly in the Discussion. Where this happens, it is usually possible to amend the Discussion so that the reader is reminded of the argument in the Introduction but is not obliged to re-read it. Results are very frequently repeated in the Discussion. As we saw earlier, the remedy is to refer in the Discussion to appropriate tables and figures, not to repeat text. If this cannot be done you should re-examine the way in which the results have been composed and reorganise the presentation so that you can refer to the sections in question easily and concisely.

Having organised the overall layout of the paper so that it flows logically, we can now begin to examine ways of improving the writing itself.

3

Third Draft—Readability

ENGLISH is the international scientific language. It is frightening to realise that many foreign scientists' only contact with our language is through reading English language scientific journals. In writing English, therefore, we have two responsibilities: to communicate our research findings, and to set an example for fellow scientists, foreign and native-English-speaking. The key to meeting both responsibilities is to construct readable sentences and, ultimately, clear paragraph units. Readable sentences are the elements that generate fluency and coherence in writing. They are sentences that can be read in one pass and understood by someone of average intelligence and with no special knowledge of the subject matter. 'In one pass'; that is the key to readability. The English language is versatile enough to allow us generally two or more options for expressing the same thought. The decision as to which to use should rest on readability. The sentence that can be read and absorbed without having to backtrack or to stop and select between alternatives is the one to choose. Even sentences that are grammatically perfect and unambiguous are sometimes constructed in a way that requires several attempts by the reader to find their exact meaning. Such sentences should be reconstructed in a way that no longer distracts the reader. After all, the words you use are merely the vehicle to carry your thoughts. If the words are unobtrusive but, at the same time, convey the thought accurately the reader has the privilege of only having to concentrate on one thing. Different readers often seek different information from an article and therefore their trains of thought will not be identical. So, it is impossible to meet the criterion of perfect readability 100 per cent of the time. But, at the other end of the scale,

an article that requires reading and re-reading, sentence after sentence, becomes a total failure because the reader gives up.

Strangely, when readers find themselves in the midst of a particularly difficult piece of text their first reaction is to think that their inability to seize its meaning is their own fault. 'I can't seem to concentrate to-day'; 'I've too many other things on my mind'. Often the cold truth is that the author is the sole culprit.

Many writers in attempting to meet the constraints of scientific truth and exactitude become tense and stifle their writing style and terminology to produce a heavy, ponderous result. They abandon a conversational style, presumably to convey an impression of the seriousness of science. They may tell you that they think Smith's results are wrong but will sit down and write 'The present authors believe that their results and those of Smith are at variance', because they think that sounds more scientific. If you are writing and find yourself in agony trying to sort out the wording for one or two sentences your problem can often be resolved in seconds when a colleague unexpectedly asks 'Tell me, what do you really want to say?' The conversational reply to that question can supply the answer that has been so elusive; a simple direct statement of what you wanted to say. The momentary drop in tension starts the breakthrough. If we can overcome, as a matter of course, the magnetic attraction of 'scientificese', one of the great barriers to clear writing disappears.

Scientists are not alone, of course, in their attempts to develop a style of writing that they think befits their calling. Lawyers, clerks, journalists and others have all contributed to the convolution of the English language. If you wrote to your local council and said:

> I can't see the traffic when I back out of my garage because of a tree in the street in front of my house. Would you please remove it?

Do you think they would understand you? Many people apparently think not, because they try to help out the poor people on the council by constructing something more 'councilish'.

> The writer wishes to make a request in respect of an obstruction on the border of the thoroughfare in front of the writer's residence. The obstruction—viz. a large tree—impairs vision of vehicles on the said thoroughfare in relation to entry and exit from the writer's residence. I hereby request that the council take steps to immediately remove the said object at the first available opportunity.

Surely the council staff are ordinary people capable of understanding simple English.

Scientists, too, are ordinary people and neither need nor appreciate contorted English.

There are, therefore, two sources of errors of style in scientific writing. The first stems from the writer's lack of understanding of English syntax either because English may be a second language or because grammar was a weak subject at school. This is a deep-seated problem for which the reasons are obvious and cannot quickly be overcome.

The second stems from the tension of simply trying to be scientific. This tension expresses itself in two ways. The writer inserts cumbersome expressions into the individual sentences of the text in attempts to make each sentence a scientific mini-masterpiece. Then, having expended so much effort on individual sentences, he or she fails to recognise that those sentences must relate logically and fluently to each other.

Cumbersome expressions

Our concepts of writing style are learned largely from what we read in scientific journals. Unfortunately, what we read is not always the best example on which to base what we write.

Here are ten common examples of convolution of English that demonstrate a sort of scientific style but which do not result in a clear communication of facts. In each case, the offending construction is bad because it interferes with readability. The reader has to stop, untangle what is written, decide what is meant, and only then, read on. Look up your most frequently used scientific journal and see how long it takes you to find two examples of each of the ten problems illustrated below. It won't take long.

1 Clusters of nouns

Noun-noun-noun sequences are probably the most common form of scientific jargon: for example:

Random leaf copper analyses

Difficult child psychology problems
Amino acid digestion analyses.
Chemical healing suppression figures
Third generation portfolio planning

These expressions pose two problems. They are always cumbersome to read and they are often imprecise. Sometimes they are used in the belief that valuable space is saved by eliminating prepositions such as 'of', 'on', 'in', 'for' and others, and sometimes writers have become so used to thinking of a certain group of nouns as one, that they do not realise that a reader trying to assimilate them for the first time will be floundering. Occasionally, as in the case of 'third generation portfolio planning', they are deliberately designed to confuse with words that imply that the writer has some privileged knowledge that is not available to the reader.

Omitting prepositions may be permissible where the missing word is clearly understood. But, does 'chemical healing suppression' mean 'suppression of healing *by* chemicals' or 'suppression *of* chemical healing' by something else?

Where several nouns are clustered and there is also a real adjective in the cluster the reader can often confuse the noun to which the adjective refers. To illustrate, in the first example, are we dealing with random leaves or random analyses?; or in the second, difficult children or difficult problems?

There are three possibilities here.

a Replace one or more of the nouns used as an adjective by the real adjective; for example, 'psychological problems', not 'psychology problems'.

b Use the appropriate prepositions; for example, 'random analysis of copper in leaves', or, of course, 'analysis of copper in random leaves'. By a happy coincidence, prepositions are among the shortest words in the English language. Inserting an extra one or two to be more accurate will not lengthen your article significantly.

c Where words seem particularly appropriate together—and this is comparatively rare—use a hyphen to indicate that they should be read as one composite noun, for example, 'healing-suppression'.

2 Adjectival clusters or adjectival clauses

For example:

The analysis was carried out to find *the maximum net returns above feed cost ration.*

Research in the manufacturing industries has operated on a 'grant' culture rather than *an innovation based return on investment culture.*

These produce the same problems in readability as clusters of nouns. They are generally the result of an over-familiarity with the field and generally confuse readers who see them for the first time.

3 Sentences beginning with subordinate clauses

These sentences are the hallmark of pseudo-scientific writing. They seem to be used to indicate that the writer has taken care to clarify the main clause by first declaring all reservations about it, thereby implying precision. The impact is entirely lost because no one knows what is being clarified until they get to the main clause which may be several lines further on. Our short-term memory just can't handle it. The most important part of any sentence is the beginning and that is where the most important message should be placed; for example:

> Thus, although there were too few plots to show all of the interactions which we sought [subordinate clause, apologetic], under the conditions of the experiment [subordinate phrase conditional], copper and zinc acted additively.

Compare that with:

> Thus, copper and zinc acted additively under the conditions of our experiment although there were etc . . . ,

which is much easier to follow because we know what the sentence is about (or the topic) from the first few words.

Other examples are sentences beginning with: 'Despite the fact that . . . '; 'Notwithstanding the fact that . . . '; 'While . . . '; 'Whilst . . . ' (meaning although). These words signal the beginning of a sentence that is likely to be difficult to comprehend in one pass.

Occasionally, a condition or reservation may be the key issue in a sentence. In this case you are justified in placing the conditional clause

first. For example, after a statement about the value of fertilisers you may say: 'If there is insufficient rainfall it is uneconomical to apply supplementary fertilisers'. Nevertheless, on the rare occasions when you put a subordinate clause first, be sure you do so for the right reason.

4 Nouns instead of verbs from which they are derived

For example:

'Weights [noun] of the animals were taken';

'Low temperatures caused a reduction [noun] in the rate of the reaction';

'Recording [noun] of pulse rates was made';

'Temperatures showed an increase [noun] during the day'.

One of the most successful methods of repairing such sentences, all of which seem cumbersome, is to look at each noun in the sentence and see if it has a verb derivative. If so, simply use the verb. Thus:

'The animals were weighed' [verb] or 'we weighed' [verb] the animals';
or
'Low temperatures reduced [verb] the rate of the reaction'.

You will notice that by creating a new verb from a noun we have done three useful things. We have automatically dispensed with the original verb, which indicates that it didn't have much value in the first place. We have shortened the sentence and we have sharpened its impact. Replacing nouns with verbs is one of the most simple and yet most powerful ways to improve the clarity and directness of your writing.

5 Use of 'filler' verbs

Verbs in this category are often added to complete a sentence in which the appropriate verb has been wasted because it is in its noun form. For example, in the statement:

'We conducted a study of pathogenic insects.'

we can use the verb 'to study' ('We studied . . . ') and the verb 'to conduct' disappears. 'To conduct' was a 'filler' verb.

'An improvement in digestibility occurred when an increase in the protein content of the diet was made.'

This becomes:

'Digestibility improved when the protein content of the diet was increased.'

The sentence is shorter and clearer in the absence of the two filler verbs 'to occur' and 'to make'.

There are many verbs in this category, of which some of the most common are 'to occur . . . '; 'to be present . . . '; 'to be noticed . . . '; 'to obtain . . . '; 'to take . . . '; 'to perform . . . '. They are so non-specific that you can often substitute one for another and make no real difference to the meaning of the sentence. Whenever you see them in a sentence, look for a noun in the sentence whose verb derivative you might use instead. The modified sentence will invariably be clearer and you will notice that there will be no other verb that you can satisfactorily substitute for the new word that you used.

6 Use of passive rather than active voice

Passive voice is useful when the doer of an action is not known or when it doesn't matter who or what performed the action. In all other cases it makes the expression wordy and vague when compared with the more direct and straightforward active voice. When you use passive voice in a scientific article to describe your methodology, or to express an opinion, one could cynically suggest that it implies that you do not want to be held responsible for doing the work or having that opinion. For example: 'Patients were observed [passive voice] by two people for signs of abnormal behaviour . . . '; 'It is believed [passive voice] that, in this case, chemical analysis is better than bioassay'. Changing to the active voice they read: 'Two people observed the patients . . . ' and, 'I believe that . . . '

Many people, when using the active voice, see the use of the first person—'I' or 'we'—as a problem . They think that it destroys objectivity and that more distant words like 'the author' are somehow preferable. So, we get sentences like 'The author disagrees with Bloggs (1989)'. One or two journals frown on the use of the first person but

most do not. I believe that the use of the first person and active voice gives a refreshing sense of directness and involvement and sometimes avoids the necessity for some remarkable verbal gymnastics. 'He was told by the author that the lake should be jumped into by him.'!

If it is immaterial to the sense of the sentence whether it was you or anyone else who performed the action then, by all means, use the passive voice.

7 *Use of imprecise words*

These are words like, 'considerable', 'quite', 'the vast majority', 'a great deal', 'rather', 'somewhat', 'etc.' and 'and so forth'. Each of these words can convey a different meaning to different readers. Considerable could mean anything from a few per cent to ninety-nine per cent. It is invariably more specific and more useful to give the exact figure or a rounded version of it. Thus, instead of 'A considerable number of plants responded' we should use 'Seventy-four per cent of plants responded', or even 'About three-quarters of the plants responded'. The rounded version should be used only if the precise figure is given in an accompanying table or figure.

Words like 'etc.' and 'and so forth' are often used when the writer cannot think of anything more to complete a sequence of words. This is the very antithesis of scientific precision. 'The data were treated statistically to take account of changes in temperature, humidity, daylength, etc.' Can you guess what 'etc.' means here? Avoid 'etc.' as a matter of course. If you insist, then the only time that you should use it is when the identity of the 'etc.' is absolutely clear. 'The 20 aliquots were labelled 1,2,3,4, etc.'

8 *Use of compound prepositions*

For example, 'in the case of', 'in regard to', 'as to whether', 'in respect of'. These are simply padding and dilute the meaningful parts of the sentence. They are the stock-in-trade of speech makers, university lecturers and politicians who use them to gain valuable seconds while thinking of the next thing to say.

9 *Use of multiple negatives*

For example, 'it is not uncommon', 'it is unlikely, that it won't work', 'not unreasonably inefficient'. Two negatives make a positive in both English and mathematics. Why not save the reader the trouble of calculating and be positive in the first place?: 'it is common', 'it is likely to work'. I defy anyone to be certain that they have the right meaning for 'not unreasonably inefficient' without hesitating and recalculating several times. As someone once said, 'People who use double negatives make me not unill!'

10 *Use of unfamiliar abbreviations, symbols and references*

Included in this category are all those things over which readers are likely to stumble, and which might be expected to break their train of thought.

Abbreviations

Abbreviations frequently require a moment or more of consideration even if they have been explained earlier in the article. Abbreviations can certainly be useful—especially if expressions that could be abbreviated are to be used many times in a paper. Even so, they should be written out in full in the title and in headings to graphs or tables. In short, anywhere that they might be encountered separately from the text in which they are defined. This also allows the reader more opportunity to assimilate them.

But don't go wild with abbreviations because they can be particularly annoying and distracting. If an expression is not used more than three or four times, the saving in space through abbreviation will in no way compensate for the readers' lost time and concentration while they verify the meaning of the abbreviation. Commonly accepted and well-known abbreviations—which may not be as commonly accepted or as well-known as you imagine—are usually difficult enough for most readers. For example, AA means 'amino acid' to biochemists and 'atomic absorption' to physicists but it is also familiar as 'Automobile Association' to motorists, and 'Alcoholics Anonymous' to others (presumably not motorists!). Abbreviations

that you invent yourself should be avoided except as a last resort because they invariably disrupt readability.

If you are an endocrinologist you might understand this: 'FSH and LH were measured by RIA and E2, was extracted with RTC, purified by TLC, and measured by CPB'. If not, you would need several minutes at least to begin to comprehend what was being said. There has been a trend in recent years for government documents and consultants' reports to include a large table of abbreviations at the beginning for the benefit of the reader. I cannot think of a more obvious way of signalling that the document is going to be ponderous to read. In effect, readers are being warned that they will be obliged to stop reading each time that they encounter one of these monstrosities, refer to the table at the front for clarification and then try to pick up the thread of the article again in the body of the text.

On the same criterion of readability, expressions like 'kg day-l' instead of 'kg per day' seem unhelpful. We say 'kilograms per day', not 'kilograms day to the power-1'. Therefore, it seems preferable to write what we say no matter how mathematically correct the other expression. A venerable colleague of mine when he first saw that cows were being fed a ration at the rate of 10 kg day-l suggested that they were probably being fed at night.

Referencing

We have seen already that the positioning of references to published work in the text can convey subtle differences in emphasis, but references should not be allowed to break the flow of sentences unless for a special reason. Consider this sentence:

> The number of stomates per leaf may increase in geraniums (Brown 1937), decrease in petunias (Black 1978) or remain constant in sweet peas (White 1990) when manganese is deficient.

The construction makes sure that each fact is accorded its appropriate author but the sentence is difficult to read because the authors have intervened unnecessarily. A more acceptable statement, because it is more fluent, is:

> When manganese is deficient the number of stomates per leaf may increase in geraniums, decrease in petunias, or remain constant in sweet peas (Brown 1937; Black 1978; White 1980).

Note also that the key to the sentence—'When manganese is deficient'—has been placed at the beginning even though it is a subordinate clause. This way the reader immediately grasps the perspective of the writer.

Footnotes

Very few scientific journals encourage, and fewer still allow, footnotes with explanatory statements or references at the bottom of each page. In my opinion, that is a very good thing. Even where such major distractions are permitted, you should avoid them in the interest of your reader. Certainly, they provide extra information at a particular point in the text but at what cost and to what end? The reader is lured from the mainstream of the thought process to a side issue, with potentially disastrous consequences for his or her comprehension of the major text. But, was the side issue worth pursuing anyway? The fact that you, the writer, considered it unworthy of a place in the main body of the text suggests immediately that you, the writer, should consider very seriously leaving it out entirely. If it is important enough, then put it in the main part of the article; if it isn't, then leave it out. Messing around with footnotes on the assumption that some people may be glad of the extra information is effectively admitting that you don't know why people are likely to read what you have written. That, in turn, means that you don't know why you are writing the article in the first place.

Organising sentences so that they are readable

Helpful rules in organising your writing

1 Power of position

The English language is remarkably flexible. Most sentences contain a series of pieces of information or ideas and there are many ways in which these can be expressed. The choice of the best of the many ways depends on which of the facts or ideas is most important to the development of your story.

> Fleming, in 1929, discovered penicillin after a bacterial plate he was culturing became contaminated with a spore of the fungus *Penicillium*.

Some of the many facts and ideas in this sentence are:

1 The discoverer of penicillin.
2 The date of discovery.
3 The way it came to notice.
4 The name of the organism involved.
5 What it contaminated.

It is likely that one or other of these pieces of information would be more important than the rest depending on your objective in writing the sentence. For example, if you wished to emphasise that it was Fleming who made the discovery, you would probably be happy with the sentence as it stands. However, if you were emphasising the historic implications, the date would be your main consideration. The sentence would be slightly modified to 'In 1929 Fleming discovered penicillin . . . ' If you were in the process of describing the various antibiotics, you would want the drug penicillin to be emphasised and so your sentence would read 'Penicillin was discovered in 1929 by Fleming after . . . ' If you were describing the role of accidental discoveries in science you would construct your sentence in another way: 'After a spore of the fungus *Penicillium* contaminated a bacterial plate he was culturing, Fleming . . . ' You will have noticed that, in each case, the desired emphasis has been conveyed by placing the major element first in the sentence.

The most powerful position in any sentence is the beginning

The beginning of the sentence should be held sacrosanct and reserved for orientating your reader. The beginning of the sentence gives readers their bearings and enables them later to pick up new concepts or the less essential details that follow, easily and without any irritation. It is the 'topic' part of the sentence. Bearing in mind that your aim is to keep the reader as close as possible to your thought path, a knowledge of this simple rule is one of the most powerful tools you can have in your repertoire. We have already seen that the concept of the beginning being the most powerful position applies equally to sentences, titles, paragraphs and to whole sections of the scientific article.

A scientific article that presents all of the data and all of the scientific discourse that the author intended to present is not necessarily a successful article. It only becomes one when most of the people who read it can perceive accurately what the author really meant. For this to happen the author has to be aware of what makes things easy to read. As Gopen and Swan[1] (1990) observed, 'If the reader is to grasp what the writer means, the writer must understand what the reader needs.' Gopen and Swan describe a methodology to achieve this based on the concept of 'reader expectations'.

Basically, all information that we receive by the written word is either 'new' or 'old'. That is, it provides us with fresh concepts and ideas or else it consolidates ideas that we have already received. In most cases, we can find both of types of information in the same sentence. The key to rapid comprehension is to use the 'old' information to let readers know where they are in relation to what they have just been reading, and then present the 'new' information.

New thoughts are grasped much more readily when they are perceived from the comfort of what is already understood. So, the first part of the sentence should usually be used to get readers comfortable by linking them to previous information before the rest of the sentence discloses the new idea. The order is most important and we can often make great changes in the readability and the clarity of passages simply by getting the order right. If, at the same time, we take care to provide linking words that signal to what our next idea is going to relate we can almost work miracles with seemingly difficult text. The value of this idea of generating in the reader an expectation against which he or she can compare new information cannot be stressed enough. The concept works at the level of the whole article, the section, the paragraph or, in this case, the sentence.

Consider the following paragraph which describes how fat is broken down in our small intestine. It is taken from a published textbook on Physiology.

> The main fat that we eat is the ester of long chain fatty acids and glycerol. The small intestine is the site of digestion and absorption of fat. Under normal conditions we do not excrete fat in the faeces because almost all of the fat that we eat is absorbed. Fat leaves the stomach as large droplets within an aqueous solution of chyme. If it remained in this form the water

soluble lipase which digests it would have great difficulty in getting into contact with most of it. Bile salts can emulsify large droplets and break them down into smaller ones and the lipase can come in contact over a much larger area. Agitation within the duodenum helps break up the large droplets, the lipid part of the bile salt molecule dissolves in the fat and the electric charge on the polar part of its molecule faces outwards towards the aqueous phase of the mixture preventing the droplets from coalescing.

Most people would describe this paragraph as heavy going. Yet none of the sentences within it is particularly difficult to read. They are grammatically correct, they don't contain large and obscure words except those that are appropriate scientifically and, apart from the last one, are not inordinately long. The problem is that when taken together they make us work too hard to follow their overall sense. Each sentence assaults us with new material without regard to what the sentences around have been telling us. We haven't had an opportunity to get 'comfortable' with old material before new material is thrown at us. Our minds have difficulty in pigeon-holing the information in a logical way and this leads to at least two unsatisfactory consequences. The first is that readers are obliged to store a lot of information on 'hold' while they backtrack and re-read to find more clues about what to do with it. The second, as a direct result of this confusion, is that the material is likely to be interpreted by different readers in different ways.

What are the new bits of information in each sentence of this paragraph?

The main fat . . .

We don't normally excrete fat . . .

It is in large droplets . . .

Lipase can't get to it . . .

Bile salts emulsify large droplets . . .

Agitation helps . . . so do electrical charges

In most cases these new pieces of information are being made at the very point in the sentence where the reader is unprepared to receive and absorb them—at the beginning. The sentence needs to be made

more 'user friendly' to allow the reader's mind to tidy up and put away the material from one sentence and prepare for the next. Here is my attempt to apply these concepts:

The main fat that we eat is the ester of long chain fatty acids and glycerol. We digest this fat in the small intestine and absorb it almost totally because we normally do not excrete fat in the faeces. When fat enters the small intestine *from the stomach* it is in the form of large droplets within an aqueous solution of chyme. The aqueous layer acts as a barrier to the water soluble *enzyme*, lipase, preventing it from contacting most of the fat and digesting it. *So the barrier must be broken down and this is done in three ways. First*, large droplets are emulsified and broken down into smaller ones by the salts in bile *which is excreted in the small intestine.* The lipase can now come in contact with fat over a much larger area. *Second*, agitation within the small intestine helps break up the large droplets. *Third, the bile salt molecule has a lipid part and a polar part that is electrically charged.* The lipid part dissolves in the fat and the electrically charged part of its molecule faces outwards towards the aqueous phase of the mixture preventing the droplets from coalescing.

This is easier to read because it now has a structure that presents new information only when the reader has been made ready to accept it.

The first sentence has not been changed because, in the absence of a preceding paragraph we have no 'old' information on which to build. It serves as a topic sentence for the new paragraph. But, in the second sentence the new information about the small intestine is not raised until we have linked it with the old information from the first sentence. The modified sentence now begins by establishing that it is going to continue to tell us about fat. Similarly, the third sentence now orientates us towards the now familiar small intestine before introducing new material about fat droplets. A logical flow from one sentence to the next has been built up and continues throughout the paragraph.

The modified paragraph is longer than the original because some new material, highlighted in italics, has been deliberately introduced. This is the direct result of considering the sequence of events as the reader might perceive them. In the original, the author had neglected to tell us about some of the logical connections so they have to be assumed by the reader. In the new version, these omissions have

become obvious and have had to be inserted. The author was probably so familiar with the fact that food enters the small intestine from the stomach, that lipase is an enzyme, and that bile is actually excreted into the small intestine that it seemed unimportant to say so. Certainly, some readers may agree, but many others would not. Unless the author can be sure that all readers are as informed as he or she is, then it is a wise assumption that they might need a little help.

A further invaluable aid to developing the expectations of the reader is illustrated in the last part of the new paragraph. It has been made clear that there are three ways of breaking down fat droplets. The simple, short sentence saying so is a map that keeps the reader orientated through a relatively complex passage of information and keeps each piece of that information in perspective.

2 Checking the tense

The rules for the choice of tense of verbs are relatively simple. In almost all scientific articles only two tenses are used, the past, most of the time, and the present, sometimes. The only exception is when a sequence of events in time is to be described and each event has to be placed relative to the others. Then the pluperfect or the past continuous tenses might be used. For example:

> After the patients had had [pluperfect tense] a barium meal they returned [past tense] to the operating theatre.

> While the plants were wilting [past continuous] they lost [past tense] their nutritive value for livestock.

Otherwise all descriptions of what you did and your results are described in the past tense. The reason is that your experiment is now finished.

The present tense is reserved for two conditions. Conclusions, generalisations and principles that you believe are still valid at the time of writing, and 'housekeeping' within your article where, for example, you refer to tables or figures. 'Figure 3 shows [present tense] that . . .'

When describing the work of others the same rule applies. For example:

> MacSpratt found [past tense] that when sheep were [past tense] deficient in nitrogen the rate of mitosis in wool follicles was [past tense] sixty-three per cent of normal and concluded [past tense] that nitrogen is [present tense] essential to normal growth of wool. This is [present tense] shown graphically in Figure 4.

Each of the verbs in the past tense describes a specific event or result; the first verb in the present tense is part of a generalisation and the second involves a piece of housekeeping. In this example, the verb 'is' in the generalisation could be replaced by 'was' if, in fact, later work had proved the conclusion to be false.

Let us look at another example:

> Infestations with aphids reduced [past tense] the yield of raspberries by 18 per cent and treatment of the aphids with pyrethrum was [past tense] 98 per cent effective. Pyrethrum is [present tense] cheap so that it can be used [present tense] to increase yields of raspberries economically.

Again the distinction between the descriptions of events, which take the past tense, and principles, which use the present tense, is clear.

3 Precision, clarity, brevity

These three criteria, more than any others, distinguish scientific writing from other forms of literature. Not only must they constantly influence how a scientist writes, but they must always be considered in that order. It is good to be brief but if, in so doing, you do not express yourself clearly then brevity should be sacrificed to achieve clarity. Similarly, precision should never be sacrificed in order to make it easy to say something clearly or more briefly.

The colleague test

Despite your efforts, it is unlikely that you have been entirely objective in your appraisal of your own work. It is equally unlikely that expressions and explanations that seem adequate to you will be equally clear to someone else. Now is the time to seek help from some sympathetic and respected colleague. Ideally, find at least two people who will read your manuscript and make frank comments about it.

Ask them to read the paper quickly, as you did, marking difficult passages in passing without attempting to fix them. A reader who is familiar with the field of work or who may even have had a small part in the experiment should be able to make constructive comments about the substance of the paper and the correctness of your arguments. If possible find a second reader who is familiar with scientific literature but not with your field of work. His or her comments on the fluency of the paper, its comprehensibility and the presence of jargon and awkward abbreviations should be taken very seriously. If they say that they do not understand a section you should take the view that this is your fault and not theirs. It is not enough to show them where they misinterpreted you or failed to grasp the meaning of something. The fact that they did not grasp your meaning at the first attempt probably means that it was not expressed as well as it could have been. Therefore, you should try to reconstruct the offending passage to prevent other readers from having the same difficulty.

Note

[1] Gopen, George D., and Swan, Judith A., (1990) The Science of Scientific Writing, American Scientist 78, 550-558.

4

Final Draft—Editing

Meeting requirements of the journal

EACH JOURNAL has its own 'house style'. That is, it requires abbreviations of commonly used units to be uniform, headings to be set out in a particular way, references to be cited in the style of the journal and so on. This information is given periodically in the journal itself or in the case of some journals in a separate 'Guide to Authors'. Some of the points appear trivial but editors are looking for uniformity in their journals and insist that their format be followed carefully. To be certain that you take nothing for granted it is a good idea to make a photocopy of the journal's instructions to authors and keep it beside you at this stage. In addition, as you, or a typist, prepare the final draft a copy of the journal itself on the desk can often solve minor problems as they arise.

Checking

The next job is verification. Spelling-checkers in word processing programmes can help you pick up some misspelt words and typographical gaffes. There are programmes that can check your grammar and syntax. These are certainly helpful at this stage of the writing process, but they do not and cannot substitute for meticulous checking of both the text and the figures.

Your scientific credibility depends on many things but above all on your exactitude. There are many sources of error in science associated with variability, chance, and limitations of available techniques. Statistical techniques have been developed to preserve your credibility in the face of these but if you introduce another source of error—plain