SCIENTIFIC WRITING FOR GRADUATE STUDENTS

A MANUAL ON THE TEACHING OF SCIENTIFIC WRITING

EDITED BY F. PETER WOODFORD

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A COUNCIL OF BIOLOGY EDITORS MANUAL
Prepared by the CBE Committee on Graduate Training in Scientific Writing

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Clearing Away the Underbrush

Timing:
Allow about 15 minutes for this introductory material, and plan to go well into Chapter 2 during your first session.

Most of the students who have signed up for your course will have done so because they are afraid of and dislike writing: they have no instinctive feeling for the power and beauty of words and no gift for putting them together tellingly. They like science because it is full of experimental action and definite, verifiable facts; writing, on the contrary, seems to be a less exciting activity requiring intuition, for which they have small use, and taste, for which they have no use at all.

Your first job is to convince them that scientific writing is an activity they will enjoy. It demands exactly the same qualities of thought as are needed for the rest of science: logic, clarity, and precision. A sense of literary “rightness” is definitely not necessary (although the few who have such a sense should not feel disadvantaged). Assure your students that if they will only apply scientific principles to the planning, design, and execution of scientific writing, they will surely master it. For scientific principles are, in essence, merely guidelines for keeping thought logical, clear, and precise; and the outstanding characteristics of successful scientific writing are that it is logically constructed, clearly expressed, and precisely worded.

Your students will have spent most of their university careers studying scientific principles, and their minds have been developed, therefore, in just the direction needed for good scientific writing. Urge them to get rid of the notion that because they are scientists they must of necessity be inferior writers. Quite the reverse is true, at least for the kind of writing with which this book is concerned. At its best, such writing is straightforward, con-
crete, exact, rigorous, clearheaded, and concise. Are not these the qualities most of us associate with scientists? Are they not the qualities your students are proud to possess to a highly developed degree?

Tell them how lucky they are. Both training and inclination predispose them to succeed in scientific writing, which is the only kind they need produce. Conversely, the "literary style" they dread, and for which they are neither suited nor trained, is not called for in scientific writing. In earlier courses in English composition they may have come to loathe all considerations of imponderable taste and nuance, to detest all subtle questions of balance and rhythm, and to distrust from the bottom of their hearts the phrasemaker and all his works. Emphasize that you are not qualified to teach literary style, and that they have not been assembled to learn it. For the task in hand—scientific writing—they need only be honestly, completely, and thoroughly scientific.

Do not be tempted, however, to go a step further and rhapsodize about how easy scientific writing is. It is not. To keep to a straight and narrow path through a thicket of complex and intertwining ideas can be extremely difficult. But it is no more difficult than keeping a line of research straight in the face of obstructive practical difficulties and tempting byways of investigation. And it is equally important.

If your students have been recruited not by the force of attraction (the desire to write well) but by that of compulsion (the desire of others that they write well), some may be less interested in whether they can improve their writing than in why they should. Tell such students that if they go into research—academic or industrial—they will, as a matter of course, be obliged to write papers for publication, and if they express themselves badly their papers will not be accepted in reputable journals. If they do succeed in publishing—in journals with lower standards—papers that are difficult to understand or that do not present arguments and results convincingly, their work will be disregarded and their scientific abilities will go unnoticed. Most established scientists, tolerant as they are of some faults of writing, recognize that consistently poor writing either betrays the inability to think clearly or reveals an unwillingness to take the trouble to do so. If the budding scientist wants to do himself justice, therefore, he simply must learn to write as well as he thinks.

Having made these points, ask your class to name the various kinds of writing that a scientist is called upon to produce. These include a disserta-

tion at the start of his career; progress reports and survey papers for his close colleagues; case histories, if he is a medical man; journal articles for an audience of specialists; review articles for the less specialized; book reviews to be savored by the cognoscenti; project proposals and grant applications to be judged both by his peers and by laymen; and articles for a nonscientific but informed public. He will also have to write when he prepares talks for various types of audience. Stress that the good writer is like a well-mannered man: he is considerate of others. He must know who his readers or listeners are and aim, with this knowledge in mind, for the most rapid and comfortable communication possible.

Remind your students that writing is not extrinsic to research: it is inevitably a part of it, since research is not complete until it is published. At the same time you should, perhaps, reassure them by saying that although the first paper is notoriously the most difficult, you hope to take the sting out of even that most traumatic experience.

In this manual we suggest that you teach scientific writing not by enunciating abstract principles but, more concretely, by showing your class how to write a journal article. If you teach the course in this way, the major assignment will require the students to write up some portion of their recent or current research in the form of a journal article. Tell them this in the first session so that they may select a suitable set of experimental results by the time you next meet with them. The program presupposes that your students already have a year or more of research experience, and indeed we believe that this is the earliest stage at which students can profit from the kind of training described here. If the assignment suggested is impossible or inappropriate for your students, the "Notes on Major Assignment," p. 14, may help you to modify it.

The same belief in concreteness has led us to the piece of advice given at the head of this chapter: keep the introductory material short and get on to the steps in Chapter 2 within your first session. Those who have come unwillingly or skeptically to sample your course will not be won over by abstract argument about the importance of writing, but will almost certainly be intrigued by the first steps, especially the discussion of "What Is the Most Suitable Journal?", and will come back for more. Eager students will already be convinced that they want to improve their writing, and will be impatient to begin.

The instruction on the journal article (Chapters 2-8) has been designed
according to the cardinal principle of Logic Before Language. There is a
great deal more to writing an article than arranging well-chosen words in
a clear, concise way. Before you introduce the dread word Style you must
dwell long and thoroughly on how to define and delimit a topic, how to
select some and exclude other experimental results, how to group ideas,
how to arrange tables and figures, and how to write an outline. Some of
these topics will be familiar to you from general treatises on writing; others
are relevant to scientific writing only, and even for the more general topics
many of the approaches suggested here for teaching them are unorthodox.

The order in which the topics are dealt with has been deliberately
designed for palatability to the scientist. He is interested primarily in logical
connections, so talk about logic and organization first. No one will be
surprised as you develop the theme that only logical reasoning can produce
a satisfying structure for the article. Then, when you have your students’
full confidence, lead them gradually to the realization that the same kind of
logical reasoning can yield precision and clarity in each sentence of the
finished manuscript. In this way they will come, via paths that appeal to
them, to an interest in words and their relationships. They will come to
recognize that words are the coin in which we exchange thought, and
that discussion of words in this context constitutes not a literary exercise,
but a truly scientific activity.

2

The Ground Plan

**You will need:**

Copies of a few leading journals, some of wide scope (e.g., *Science,
Nature, Journal of Biological Chemistry*), some of greater specialization
(any high-quality subspecialty journals appropriate to your class).
Choose the issues containing the Instructions to Authors or obtain
copies of these for each journal.

One or two copies of *Current Contents* (Institute for Scientific Informa-
tion, Philadelphia, Pa.).

Williams and Wilkins Co., Baltimore. (Paperback edition: The M.I.T.
Press, Cambridge, Mass., 1969.) Recommend this as a textbook that
deals best with logical considerations in scientific writing. Of the many
books on this subject that are in print, this is by far the pithiest, the
most profound, and above all the most scientific. It is not surprising to
discover that it was written by a scientist. All page numbers in Trelease
given in later chapters of this manual refer to the 1958 hard-cover
edition.

Since Trelease’s own writing is highly condensed, students may
find it a little indigestible if read at a sitting. A good plan is, therefore,
to send them to the relevant passage only after you have expounded it
vividly, with examples, in class.

**You should read:**

Rosenblum, M. 1965. “Information Handling for the Biomedical
Sciences.” In *A National Program to Conquer Heart Disease, Cancer
2:410–437.

Biological Sciences Curriculum Study. 1965. *Biological Science: Inter-
action of Experiments and Ideas.* Prentice-Hall, Inc., Englewood Cliffs,
N.J. 77–97.

**Timing:**

With Chapter 1, this chapter up to the end of Step 3 (including dis-
cussion) takes one hour.
Assignments:
Writing an abstract of a major article in a field appropriate to the students’ interests. It is desirable to select an article that has either an unsatisfactory published abstract or no abstract at all.

Obtaining the Instructions to Authors (containing “Purpose and Scope”) for a journal of the student’s choice.

Any complex, large-scale task, which may be overwhelming to the beginner in its entirety, becomes more manageable when broken down into parts. The task of writing a journal article has therefore been broken down into about two dozen small steps, each of them rather quickly completed, which are described in this and subsequent chapters. Obviously, you may wish to increase this number, to skip lightly over some steps, or to rearrange them according to your own experience. They are listed in Table 1, page 9.

Stress the Two-Way Relationship Between Thinking and Writing
As you will inevitably find yourself constantly returning to one principle throughout the course, it might as well be discussed at the outset. It is that thinking and writing mutually interact. Good scientific writing is, of course, impossible without clear thinking. What is less obvious and less widely appreciated is that careful writing can actually assist in developing logical scientific thought. Somehow the discipline of crystallizing a thought into a grammatical sentence with a beginning, a middle, and an end clarifies, sharpens, and defines the thought. You will find ample opportunity to demonstrate this useful feedback effect of writing (see, for example, Steps 2 and 5 below), and will be astonished how rapidly your students’ power of clear, precise thinking will develop as they utilize it.

Several of the steps, including the first four, take the form of questions that the student is to ask himself.

Step 1: What Is the Right Time to Publish?
Graduate students who have not yet published find this an unexpected question. All the better, for one cannot impress upon them too early or too forcibly that good reasons must be given before they add a single drop to the flood of publication. Some scientists seem to believe that the world will be perpetually grateful to them for keeping what amounts to a public diary

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<td>Reread the “Purpose and Scope” in the chosen journal</td>
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<td>Think of the article as a unit; write the first draft continuously from beginning to end</td>
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<td>Construct the list of references as you go along</td>
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<td>Materials and Methods section(s): include the right amount of detail</td>
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<td>Write title and abstract in final form</td>
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<td>Reread the journal’s instructions to authors before having the manuscript typed</td>
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to your class. If you suspect that they may be more moved by considerations of ambition than of altruism, stress that in the councils whose opinions really matter in the furtherance of their careers, a few good papers count far more than an infinitude of shameful "potboilers."

Actual evidence of the unfavorable effects of rushing into print is presented in Allen's article "Why Are Research Grant Applications Disapproved?" (Allen, E. M. 1960. Science. 132: 1532), which reveals that 12.6 per cent of the rejected proposals in the sample examined were disapproved because the investigator's previously published work did not inspire confidence. Let your students weigh this against the witty but oversimplified catchphrase "Publish or perish," by which they are all too easily impressed. Remind them that the printed word is indelible and that, even in the face of pressure from superiors, their first duty is to safeguard their future reputations. You will, of course, give special and different consideration to the rare, reticent creature who actually must be encouraged to publish his excellent research.

Well, what is the right moment to publish? Ideally, when a research question of some importance has been asked and a convincing answer found. Sometimes the complete answer cannot be expected within five or ten years; then publication is justified when a sizable step toward that answer has been taken. Perhaps the best criterion is: has a significant advance in knowledge been made? Remind the members of your class that on this point they will have to satisfy not only their own consciences but also a group of critics who may be even sterner: the editors, editorial board, and reviewers of the scientific journal to which the article is submitted. A young scientist's first contact with publishing can be a shattering experience; try to transform it into an educational one by preparing him for the cold-eyed appraisal of his peers. More on the kind of preparation to provide is given in Chapter 9.

**STEP 2: What Question Has Been Asked, and What Are the Conclusions?**

Step I has been occupied with pondering these questions, and now we apply the device of writing down the answers in order to tether the thoughts to solid ground. The device establishes exactly what the article will be about. Failure to do this leads to the kind of publication that is, alas, only too frequent—the one that impels the exasperated reader to ask "What on earth is the man driving at?" Furthermore, the written sentences define the article's limits. Frequently the researcher is occupied with a number of closely related questions. It is imperative that he decide which question or questions will be discussed; which data are relevant, therefore, and which must be excluded.

Emphasize especially the form of the heading of this section: "What question has been asked?" (or alternatively, "What hypothesis has been examined?"); not "What was the purpose of the research?" The latter question can lead to the formless "purpose" of "investigating such-and-such a process" or "gathering data concerned with such-and-such a phenomenon," which advances nobody in the pursuit of explicitness and definition.

**Assignment** You can help your students read, as well as write, more effectively if you encourage them to ask "What was the question, and what are the conclusions?" of every article they study. Your first assignment can give them practice in this—and simultaneously convey that this course is concerned more with scientific thinking than with niceties of literary style—if it consists in having them make an abstract of a published paper. To convey the full meaning and significance of a major paper in a stringently limited number of words (say between 100 and 200) constitutes a challenging intellectual exercise. Usually you will be able to select a paper that will be sufficiently comprehensible, for the purposes of the exercise, to all members of the class. A list of well-written articles in several biological fields is given in *BioScience*, 1964, 14:22–23. Perhaps the students should aim at improving on the informativeness of the published abstract, where there is one, in a version that is only two-thirds as long. The assignment should be completed before the second class meets.

Much fruitful discussion can arise out of this assignment. Students are eager to exercise their critical judgment, and will come up with many (real or imagined) faults of omission and commission even in a fairly good article. Encourage them to turn this critical faculty on their own writing and to resolve never to commit these faults when their turn comes to publish. You will almost certainly find instances in which the students have misread the article. Sort out with them who was at fault—they or the author—and stress the importance of critical, accurate reading. You can, perhaps, circulate your own version of the abstract and ask them to improve upon it.

Alternatively, you may choose not to comment on this assignment in detail, but to give the same assignment at the end of the course.
in order to assess (and have the students judge for themselves) what progress has been made in critical reading and thinking, as well as in writing, as a result of the course.

**STEP 3: What Is the Most Suitable Journal?**

With the precise knowledge of the contents and scope of the proposed article gained in Step 2, the author is ready to consider where he will submit it. I realize that the advice to consider this question so early is unorthodox. Yet it is a commonplace that the effectiveness of any piece of writing is directly related to the writer's knowledge of the audience to whom it is addressed. Nothing is more discouraging, demoralizing, and time-wasting than to prepare an article for a journal that rejects it for inappropriateness of content. Conversely, nothing saves more time at every stage of the article's preparation than the clear knowledge of where it will be submitted and who is likely to read it.

**Assignment** Point out that all journals publish a statement of their purpose and scope, although not necessarily in every issue. Have your students name the journal in which they expect to publish their next (or first) article and require them to obtain and study the "purpose and scope" of that journal and of possible alternatives before embarking on their Major Assignment.

Ask your students by what criteria they would choose one journal over another. You will elicit (or may have to supply) such answers as the following, and can expand them by means of the questions in parentheses.

1. General quality and prestige. (How is this judged? Does the composition of the editorial board provide a clue? What are your supervisor's and colleagues' opinions? Can you judge by critical appraisal of the contents?)

2. Size of audience. (A statement of circulation appears annually in most U.S. journals; those that carry advertising usually have a circulation of 5,000 or more.)

3. Type of audience. (Are you interested in reaching specialists only, or a wide audience? Is this determined solely by the journal, or do present methods of scanning lists of titles and selecting articles from any journal make this consideration unimportant?)

4. Speed of publication. Point out the distinction between date of receipt of manuscripts by a journal and the date of their acceptance for publication. Many journals publish both dates, from which one can deduce the time taken for the editorial process, including any necessary revision by the author; further, by comparing the date of acceptance with the date of publication of the issue one can deduce the time taken for the "production" phase—composition, proofreading, printing, and binding.

5. Quality of photographic reproduction. (In what types of work is this important?)

At this juncture it is useful to review and expand the students' knowledge of primary journals and of their place in the whole scientific information process. Such knowledge facilitates students' use of the literature and of the library at all stages of their work. It also enables them to write a primary journal article more intelligently, because they are aware that it is the fundamental unit of scientific communication, which is built into a more complex system by several means (publication of the abstract, discussion in other journal articles, citation in reviews, incorporation into textbooks). Excellent background for your handling of this subject is Rosenblum's source paper on the biomedical information system (see the beginning of this chapter). Your students should read the section "Guides to the Literature" in Trelease's book, pp. 11-25. The elementary but exceptionally clear description of the scientific literature in Biological Science: Interaction of Experiments and Ideas (see beginning of this chapter) may suggest some questions to test your students' knowledge, and your own experience will supply others. What do they think are the criteria by which submitted manuscripts are judged? (In general, these include relevance to the journal's field, importance of the questions asked and the conclusions reached, strength of the experimental evidence, and clarity of presentation.) Do journals differ in the strictness with which they apply the criteria? What other considerations might be of overriding importance?

You can pull this discussion together, perhaps, by a practical suggestion for seeking a suitable journal in which to publish: scanning of Current Contents. The names of journals listed at the front of that publication will suggest that some of them should be examined further; since the titles of articles appearing in the current issue of those journals are reproduced inside, this can be conveniently done without extensive search in the library.
Notes on Major Assignment

It is unlikely that every member of your class has material ready to be published when your course begins. Encourage those who are not so far along either to select a small group of experiments, which is complete but which they would not normally consider (Step 1) a sufficiently important advance in knowledge to publish as a full paper; or to choose a portion of the work in progress that is incomplete, but for which a probable result can be predicted arbitrarily and appropriate conclusions drawn. The less artificial the exercise is, of course, the more effective it will be, but there need be nothing artificial about the second alternative I have described; in many types of experiments the experimenter knows beforehand that result A must lead to one conclusion and result B to another. Another possibility is to make the major assignment the description of a research proposal (see Chapter 12) concerned with work the student is embarking upon. Your important task is to ensure that the subject matter of the major assignment is research with which the student is personally involved.

Offer to discuss the choice of material for the assignment if the students have any difficulty in selecting it. Make sure that the choice is made early in the course and that the projected paper is small in scope, otherwise the student will have great difficulty keeping up with the steps as they are discussed in class. Once the material has been chosen, the student will require three weeks to complete Steps 1-12, when he will be ready to submit to you his sentence outline (see p. 21).

STEP 4: How Are the Findings Related to the Existing Body of Knowledge?

Once again, this is a step in which the author writes down what is presumably already fairly clear in his mind in order to clarify it further. What he writes specifies the exact area in which his advance has been made, where the work of others stopped short, and what the future developments could be. It eliminates irrelevant aspects of the field and prepares the ground for the Introduction and Discussion sections. Emphasize how precise you want this piece of thinking to be: one describes not the whole jigsaw puzzle of (say) amino acid metabolism, but only the pieces immediately surrounding the new knowledge concerning aspartate oxidation that is now to be fitted in.

STEP 5: Write the Title and Synopsis

What a surprising piece of advice, your students will exclaim. People usually tell us to devise the title last! Furthermore, as to the synopsis, how can we give a general view of something that is not yet written? Explain that this is another piece of writing to clarify thinking. Although the title may well have to be revised when the article is finished, and the synopsis will almost certainly have to undergo a transformation before it can serve as an abstract, writing both of them at this point is invaluable to the author who is aiming for a tightly constructed article that is free from all irrelevance. And the student is, in fact, already perfectly well equipped to produce a working title and synopsis. He has a clear idea of what he has to say (Step 2), how it relates to previous knowledge (Step 4), and what constitutes his experimental evidence (in his notebooks); he is therefore in an excellent position to expound his projected paper in definite and concise terms, as though to a friend who asks him at some chilly street corner what he has been up to recently. The synopsis should be a logical chain of reasoning ("What was the question?"); observation ("What is the evidence?"); and deduction ("What are the conclusions?") without a single weak link in it. The author really defines the subject of his article and the limits he has set for it only when he has written a satisfactory title and synopsis. When this is done, he can feel that he has properly pegged out his ground plan and is free to move about comfortably within its well-defined limits as he plans the article in more detail and proceeds to its construction.
The Master Plan

You will need:

Copies of the Instructions to Authors in journals you deem appropriate.

Timing:

Together with the last two steps in Chapter 2, a full hour.

Assignment:

Steps 1–5 of the student's journal article (Major Assignment). Possibly, the reduction of a published article to outline form.

Step 6: Reread the "Purpose and Scope" in the Chosen Journal

Now, with the subject matter firmly delineated on paper in the form of title and synopsis, the student should match it once more against the subject area of the journal he has chosen. This is his last chance to change his mind about the journal, for from here on all his words will be directed to that journal and to its readers. Because every line of communication has a receiving end as well as a transmitter, the successful writer is acutely aware of his audience. He must often decide, for example, "Should I explain this, or will my readers know it so well that they will be irritated by an explanation? On the other hand, can I find two or three words to bring in the less well-informed or less specialized reader without antagonizing the more sophisticated?" Such questions of judgment can be decided only if the student knows who his readers are likely to be. Study of the "Purpose and Scope" will aid his intelligent guesswork in that direction.

Step 7: Read the Instructions to Authors

Ask your students what sort of information is contained in the Instructions to Authors that appear in most journals. Much of it is concerned with such mechanical matters as the number of copies to be submitted, spacing of lines, treatment of footnotes, etc., which will become important to the student only later. Nevertheless, even at this stage, it is necessary to know such things as whether there is a page limit (as in, for example, Proc. Nat. Acad. Sci. U.S. and J. Exp. Med.); whether any style manual or other standard is adhered to for abbreviations; whether there are any special rules on nomenclature; and so on. Much time and patience can be needlessly expended on these matters if they are ignored until a later stage.

Step 8: Decide on the Basic Form of the Article

Most scientific articles, at least in the life sciences, are arranged in four main sections: (a) Introduction, (b) Materials and Methods, (c) Results, and (d) Discussion. There are those who deplore this standardization, either because all uniformity is deadening or because it gives a false impression of an unimaginatively logical approach to scientific questions. Yet no one has authoritatively laid down this form; it evolved, early in the twentieth century, as scientific publication became more voluminous. It represents, I submit, a survival of the fittest among the various possible forms, where "fittest" means the most streamlined and efficient means of conveying information. It should be discarded, then, only when circumstances are absolutely compelling.

Obviously, material should not be forced into this mold when it does not fit—for example, a theoretical treatment of previously published results or a piece of work in which the reader must know the results of one portion before being introduced to the methods and experimental design of another. But the best advice to students is: use the conventional form whenever possible; if you adopt another one, do it in the conscious knowledge that some proved advantages of the conventional form will inevitably be lost, and satisfy yourself that there will be a net gain beyond the satisfaction of being unorthodox.

This is a good point at which to discuss the advantages of combining the Results and Discussion sections, together with the dangers. Any special forms, such as taxonomic descriptions, that are of special interest to your students should, of course, also be examined critically. You may also like to comment on how the Methods section has moved, at least in biochemical journals, from its former position as a sort of necessary appendix at the end of a paper to its present prominence near the beginning, and to explore the
reasons. One is that the type of methods employed and the purity of substances used often have a profound effect on the results and on their interpretation. So important is this information that a further subdivision of the experimental section may become necessary, into a section headed "Materials" (in which the sources of both chemicals and biological tissue are stated and their purity is discussed) and another section headed "Methods."

In what follows, I have assumed that the conventional form has been adopted, but I do not mean to imply that no other is possible.

**STEP 9: Stock the Section Reservoirs**

A fundamental mistake of the inexperienced writer is to sit down with a rough mental outline of what he has to say, seize a pen with desperation and a groan, and start writing. At the end of the first page of botched sentences and confused thoughts, he is, not unnaturally, discouraged; only by great effort of will can he return to that distasteful pursuit—writing—and make another attempt.

It will by now have become apparent that this method is not the one advocated in this course. Because those scientists who are not "born writers" have no inherent pleasure in constructing a balanced sentence or a well-turned phrase, they should concentrate first on the things they do enjoy: facts, ideas, and logical connections. Tell your students, therefore, to take five sheets of paper; head them Introduction, Materials and Methods, Results, Discussion, and References; and into these reservoirs put—in any order they like—brief indications of facts, experiments, thoughts, and observations that belong in each. Naturally, the student's notebooks, graphs, card index, etc., should all be at hand to refresh his memory. The following considerations should influence his decisions on the items that are being added to the reservoirs:

(a) Is the item necessary? This is decided by reference to the title and synopsis, constructed in Step 5.

(b) In what section does the item belong? Some items may seem to have connections with two sections or even more; such items should be prominently marked, and the writer should consider carefully at this stage where they will be developed in most detail.

(c) Are all necessary items included?

**THE MASTER PLAN**

As the work on the reservoirs continues, the structure of each section and its relationship to the other sections begin to emerge. More than one possible structure for the article may suggest itself, and if the student numbers the items he can readily experiment with different logical arrangements. But before the topic outline is attempted, another extremely important step must be completed.

**STEP 10: Construct the Tables and Figures**

The student will protest that he has already tabulated his data and drawn his graphs; this was how he knew that he was ready to publish (Step 1). Explain to him that he is now going to draw them up in a way that will be completely intelligible to others. This includes composing full titles and footnotes for the tables as well as legends for the figures and labels for the axes of graphs. The step has three objects.

First, if tables are cleverly designed and have informative titles and complete footnotes, and if figures can be comprehended at a glance and have intelligible legends, the reader can glean not only the results but also a great part of the experimental design without any reference to the text. In the final paper the tables and figures, together with the title and the abstract, should form a coherent story. Ask your students in what order they look at the various parts of a published article, and many of them will give you: title, abstract, figures, tables, introduction, discussion, results, methods. Now, if it is true that figures and tables are often examined before the text, they should not be dependent on the text for comprehensibility. Few authors seem to realize this; put your students among those few by training them to design tables and figures in full before a word of the text is written. The first object of this step is, then, to make tables and figures fully informative in themselves and to banish from their vicinity the irritating and usually unnecessary inscription "see text."

Second, the tables and figures give the author a sort of extended synopsis of the paper. This may modify ideas developed in Step 9 as to the best order of presentation and therefore be useful for the writing of the topic outline, Step 11.

Third, matching the data thus tabulated and graphed against the items in the Section Reservoirs will reveal whether the conclusions must be modified (or abandoned!) and whether more experimental work should be done before the work is ripe for publication. In either of these two cases, time
will not be wasted in writing a paper that may never see the light of day or that will reflect no credit on the author if it does.

These points about tables and figures are further elaborated in Chapter 10, but I think they are best discussed in detail after the students have already made mistakes and scored successes in designing tables and figures in the course of writing their major assignment.

Class discussion of Step 10 and its purposes will bring home to the students how useful it is to begin "writing" a journal article (using Steps 1–10) when a piece of research is nearing completion instead of when it seems to be finished. The steps reveal more concretely than vague daydreaming just what further evidence remains to be garnered. Recommend this to your students as a useful technique of research.

**STEP 11: Construct the Topic Outline**

Let us assume that all is well and that further experimental work seems unnecessary. Now, I think, the author will be straining at the bit to put the items down in logical order—for it is really exciting to see the paper assume definite and logical form in the mind’s eye. I defy anyone who is the least interested in his results to be untouched by this excitement as all the items in his reservoirs, tables, and figures seem to be jostling another in eagerness to be put in place.

The topics should be arranged, within each section, in a logical order. What does this mean? Obviously, many different things. In Methods, perhaps a chronological handling of samples; in Results, the most important and explicable findings first, less clearcut differences later, or a gradation from simple to complex systems, or a discussion organ by organ, chemical class by chemical class; and so on. Some of these possibilities will be touched upon in subsequent steps, but, in general, scientists are strong in and proud of their logical thinking, and your students should be encouraged to display their prowess to the full. Point out the usefulness of headings, subheadings, and sub-subheadings as initial guides in writing even if they are scrapped in the final version; and stress how important it is to ensure that the ranking is logically correct, i.e., that a topic given a heading is really on the same level of importance as another that has been assigned a heading of the same magnitude. The longer the article, the more need there is for subheadings to guide both author and reader. You might add, parenthetically, that the doctoral dissertation must be strictly ordered by means of them, and that erroneous ranking is one of the major sources of confusion both in expository writing and in thinking.

The writer should make certain that he has included in his topic outline everything that was in his reservoirs and that repetition has been eliminated or minimized before he goes on to expand this outline in the next step.

**STEP 12: Construct the Sentence Outline**

Not all writers agree that a sentence outline is necessary, but its construction can be a further aid in clarifying thought for the neophyte. "How does it differ from a topic outline?" the students (rather to my surprise) ask. Whereas the topic outline defines what subject will be discussed in each section or paragraph, the sentence outline expresses what the writer has to say about that subject. Ideally, each sentence summarizes one paragraph in the finished article—shorn, of course, of all detail and supporting arguments—and the succession of sentences should make some sense to another person (allowing for the fact that transitional sentences may be necessary for complete intelligibility).

A sentence outline confers many benefits. It may, for instance, reveal gaps in the logic, even though the topic outline seemed perfect: perhaps a new heading should be inserted or the material rearranged. Sentences in the outline sometimes turn out to be so informative and pithy that the author delightedly extracts them bodily and uses them as key sentences in paragraphs of the final article. Finally, the construction of sentences prepares the writer for the phase of more continuous writing that is to come. Despite all these potential benefits, however, some writers find the sentence outline cumbersome and constricting. I ask my students to try it out experimentally, but not to force themselves to use it if it does not seem to help.

**Assignment** Description of these steps goes more quickly than their execution, and your students will be ready at this stage to tackle only the Ground Plan on their major assignment. I suggest that you give them three weeks in all to reach Step 12 (first week, Steps 1–5; second week, Steps 6–10; third week, Steps 11 and 12). Only at Step 12 is it meaningful for you to examine their work (a Topic Outline is virtually incomprehensible to anyone but its author). In my experience, science students perform well in the "outline" assignments, and for this reason you may like to bolster their confidence by giving them an additional
one to prepare. Ask them to take a published article (perhaps the one they have already abstracted at Step 2) and break it down into topic and sentence outlines.

You will realize that this assignment, like the abstracting one, is just the reverse of composing something as a preparation for writing a full text. Like a chemical compound, writing is more fully understood after it has been both analyzed and synthesized than after either analysis or synthesis alone.

4

The First Draft

You will need:

Copies of a good Introduction to hand out: either the one given on p. 25 or one of your own choosing.

Copies of a description of experimental methods, to be condensed into a form suitable for journal publication.

You should read:

Trelease, pp. 36-42.


Timing:

About 1½ one-hour sessions.

Assignments:

Condensation of a description of experimental methods.

Steps 6-10 of the student’s journal article.

Step 13: Think of the Article as a Unit; Write the First Draft Continuously from Beginning to End

A prime object of good style is unity. Unity should not be difficult to achieve in a journal article, written as it is around a single theme or research problem. If you know what you have to say, the article will flow best and be most coherent if it is written with one swing from beginning to end. Of course, no writer can achieve perfection as he goes along: the precise word, the clinching phrase are not at one’s beck and call—sometimes, in the heat of composition, one cannot even decide how to end a sentence grammatically, let alone tellingly! But such obstacles should not deter the writer of a
first draft. He should plunge forward, intent on the mainstream of his message, comforting himself with the thought that careful revision will smooth out the rough passages. In later drafts, the passage may be jetisoned altogether—why streamline something you will throw away? The main objective should be to get down some sort of account of each of the essential points, in the order indicated by the Sentence Outline. Some steering aids are offered in the following steps, which give specific help in different sections of the journal article.

Sometimes the reluctant writer is advised differently. He is encouraged to tackle the easiest sections first, complete them, and experience the satisfaction of having them safely under his belt. But the easiest sections are undoubtedly the Methods and Results, and as these are preceded only by a short Introduction, which serves to orient the writer as well as the reader, I believe that this advice is not so different from mine after all. The danger of writing separately conceived sections is that of producing a "patchwork quilt" of unrelated parts that no amount of patient stitching will unify.

Most of this advice applies exclusively to short articles with a single theme, such as will be forthcoming from your students at this stage. Long articles are perforce written in several sessions, but if the student has acquired the habit of writing his first drafts quickly, without editing, he stands a better chance of reducing the number of those days when writing goes painfully and unsatisfactorily. He will be relying on a method and not on inspiration.

**Step 14: The Introduction**

The key direction to give here is: keep it short. Some scientists deplore the disappearance of the scholarly historical introduction from scientific articles. Certainly the young scientist's frequent lack of historical perspective may be partly due to the brevity of most present-day introductions—and this may be a good moment to disabuse your students' minds of the notion that science began ten years ago. But most readers, and certainly all editors, have tired of the lengthy account of the glorious advances of the past, to which the author's modest contribution seems to be attached in the hope of gaining luster by association. With the proliferation of review articles, the necessity for an extensive introductory survey has passed. The writer must, of course, know the history of his subject thoroughly, but his knowledge will be revealed by the way he describes his own work; there is no need to demonstrate it in any other way. He should select from that knowledge just enough to orient the reader adequately and to place the work to be described in appropriate perspective.

Good introductions often fall into three parts, be they sentences or paragraphs. The first states the general field of interest. The second presents, in main lines only, the findings of others that will be challenged or developed. The third specifies the question to which the present paper is addressed. The third part may indicate by what means the question has been examined, especially if the methods are new or unfamiliar, and may or may not state the conclusions, as the author wishes. The aim throughout should be to excite and interest, not bore, the reader, and answer the question: "Why was this work embarked upon?"

Choose one or two good Introductions to distribute and discuss. Here is one (Dobbing, J. 1963. "The Entry of Cholesterol into Rat Brain During Development." J. Neurochem. 10:739. Reproduced by permission of the author and of Pergamon Press).

"Previous experiments have shown a remarkable persistence of cholesterol laid down at the time of myelination in the chick and rabbit brain. In these experiments cholesterol-4-14C was injected into the yolk sac of day-old chicks and intraperitoneally into 17-day-old rabbits (1, 2). It was recovered from the brain up to one year later, labeled in the same place in the molecule and at no other (3).

"An incidental finding was that the cholesterol molecule itself could enter the developing brain, although brain cholesterol has hitherto been considered to be entirely derived from synthesis within the organ. This new finding has recently been challenged in experiments with rats (4).

"In the present work rats have again been used in case there should be an unexpected species difference. The experiments were undertaken to determine (a) whether cholesterol as such could enter the brain; and if so (b) whether its rate of entry was as dependent on the timing of myelination as is the entry of other myelin-sheath constituents and their precursors."

**Step 15: Construct the List of References As You Go Along**

This piece of advice can be interjected here because the student is now actually writing the text of his article, albeit only in first draft. An unfortu-
nately common practice is to mutter "I shall refer here to that article of so-and-so's in 1963" and to leave the "library work" to the very end. I have seen this cause more anguish than it is possible to describe. With the deadline for submission of the article two days away, the distracted author finds that half the necessary volumes are lost, borrowed, or at the bindery. All this is avoided if the writer, every time he refers to others' work, makes sure that he has the necessary reference in his files. Then, as soon as the mo- mentum of his writing slackens, he must put down on a separate sheet, headed References, the full bibliographic details with all the authors' names, initials, and so on (is the title also required by the journal?), in the style adopted by the journal of choice. The references can be renumbered and rearranged later, if necessary, and their accuracy can be checked at any time, without panic, by consultation of the original in the library as the first draft nears its completion. Emphasize the importance of absolute accuracy, and make sure that your students know what the essential constituents of a reference are, namely:

For a journal reference: all authors with initials, journal title appropriately abbreviated (as recommended by the U. S. A. Standards Institute; see Biological Abstracts. 48 (24), 15 December 1967), volume, year, initial page (some journals require inclusive pagination), sometimes title of article. For books: author(s) with initials, title of book, editor(s) if any, number of the edition if applicable, publisher, city and year of publication, volume number if necessary, page number or inclusive pagination.

**Step 16: Materials and Methods Section(s)**

The editors of some journals dislike, as I do, the word "Experimental" as a section heading. In no other circumstances is an adjective used as a heading, so why here? Most journals will accept the more specific heading Materials and Methods, even if their usual custom is to use the unfortunate "Experimental."

Common sense dictates—when Materials and Methods should be described in separate sections, for example when the materials used are numerous and their purification is complex or particularly important. When experimental animals are used, the species and strain should be specified accurately. "Monkey" is an insufficient description in a scientific article.

Considerable delicacy of judgment is required to decide exactly how much information should be offered in the Materials and Methods section. All scientists are agreed on the principle that sufficient detail must be provided to permit the reader to repeat the experiments if he wants to. However, we must define carefully who "the reader" is. For these purposes, he must be assumed to be a trained investigator with considerable experience; otherwise, the article will become intolerably long and begin to resemble a manual of laboratory practice. The writer should ask himself constantly: "Is the average reader who is likely to want to do this work already familiar with this kind of manipulation? Are these details essential to the success of the experiment?" That the author may make the wrong decision on such questions does not absolve him from asking them and giving the best answer he can. Train your students to include the right amount of detail.

Apart from this, the Methods section is an easy one. The logical sequence has already been decided in the Outlines. It often follows a chronological pattern, e.g., chemical reaction conditions—purification of the product—analysis; or, treatment of animals—dissection of tissues—incubation conditions—assays—statistical methods for examination of results. Sometimes a succession of techniques, such as different types of chromatography, can form the different subheadings. Warn your students, however, of the perils of this approach if it conflicts with a chronological description, and point out how confusing it is to describe the analysis of a mixture which has yet to be extracted, or measurements on a substance of which the purification has yet to be described.

A frequent question is: "If I have used someone else's method for doing something, should I describe it or merely give a reference?" I believe that, unless the method is widely familiar (such as the method of Lowry, Rosebrough, Farr, and Randall for protein determination), the reader always appreciates being told at least the principle on which the method is based. Similarly, if the author has modified the method quoted he should give at least the outline of the modification. Modifications too trivial to be described are also too trivial to be mentioned.

**Assignment** Practice in exercising judgment about what to include and what to leave out when writing the Methods section can be provided in the following assignment, which also brings out a potentially useful distinction between the traditional "dissertation style" and that of a journal (see, however, Chapter 11). Ask your students to
condense the methods section of a dissertation to which you have access into a form suitable for a journal article. Good examples of this exercise in the field of preparative organic chemistry, in extended and condensed form, are given in Gensler and Gensler (see bibliography at the head of this chapter).

You may like to explore one technique for stimulating fruitful discussion of this assignment. Divide the class into groups of about five students and have them select and defend to the rest of the class what they consider to be the best condensed version. The critical analysis that is required brings home vividly the strengths and weaknesses of the version selected.

**STEP 17: Results Section**

The Results section should also be an easy one. The commonest fault here is to repeat in tedious prose what is already clear to the reader from a cursory examination of the tables and figures. If these have been well constructed, they will expose both the results and the experimental design (see Step 10). Little remains, then, but to make the object of each experiment clear in the text; to point out salient features, e.g., that A is greater than B (without giving the values), that something is linear over a certain range of concentration, or what the pH optimum is; and to connect the results with one another. In short, advise your students to **allow the data to speak for themselves** and to remember that the busy reader will be grateful for a guiding hand but should not be led as through blindfolded.

Authorities differ on whether the Results section should contain any conclusions. Some readers prefer to draw their own conclusions, without being prejudiced by the author, and compare them with the author's when they come to the Discussion section. If, however, the author keeps his Results section untainted by conclusions only to be forced to restate his findings in order to make the Discussion intelligible, he has avoided Scylla only to be drawn into Charybdis, for repetitiveness is a sin indeed. The best guide to offer is, perhaps, that the Results section must be comprehensible on its own and should indicate at least the trend of the author's reasoning, but that any extended discussion of the observations or comparison with others' work is best deferred until the last section. If no extended discussion is contemplated, the sections should be combined.

**STEP 18: Discussion Section**

This section is often the heart of a paper, the section in which the author assesses the meaning of his results. One can understand, then, why howls of protest go up when an editor suggests shortening it. However, the author should recognize that the minute consideration of every aspect of his work may not be as intensely interesting to others as it is to him, and there is a grave danger, if he indulges himself in a too-particular contemplation of nonessentials, that his reader may leave him before he has reached the nub of his argument. Again, he should realize that his natural desire to score off another investigator is only of marginal interest to the reader (unless he be that investigator) and, anyway, the pages of a journal are not the best place for personal rivalry. Try this as a piece of advice, then: **watch for symptoms of megalomania**.

Controversial issues should be discussed lucidly and fairly. Where results differ from previous ones, an explanation rather than a refutation should be sought. Anomalous results for which no explanation is readily available should be stressed rather than concealed, and the anomalies frankly admitted. Most interesting and valuable to science are the results which open up new possibilities of exploration, and these should be brought to the fore. Of course, speculation is in order in a Discussion, but it must be reasonable, firmly founded in observation, and subject to test, if it is to get past a responsible editorial board. A single hypothesis to explain results is almost mandatory, but piling hypothesis upon hypothesis is bad for the reader's digestion and the author's reputation. Sometimes the claim is made that some reader, somewhere, may be stimulated by the groping theories of an author, who should therefore not be forced to be too cut-and-dried. I think this notion is often grossly exaggerated. Only a very conceited man will seriously consider that science cannot advance unless his haphazard conjectures are enshrined in hallowed print.
5
The First Revision:
Structural Alterations

You will need:
Short versions of the “Condensation of Methods Section” assignment.

You should reread:
Trelease, pp. 44–46.

Timing:
½–¾ hour.

Assignment:
Steps 11, 12 of the student’s journal article.

Revision of the first draft is best carried out in two distinct stages, described in Steps 19 and 20. In general, the less experienced the author, the more revisions are likely to be necessary; possibly, each of the following fractions of steps (subsumed under 19 and 20) may lead to a fresh draft. Teach your students not to be ashamed of four, five, or even more drafts—the greatest authors, whose prose looks as if it flowed effortlessly onto the page, have confessed to anywhere from 8 to 39 drafts before they were satisfied. Since perfection in the subtleties of literary style is not our aim, less revision than this should suffice, especially if it is logically directed and systematically undertaken.

STEP 19: Are Major Alterations Necessary?
Offer here four pieces of advice, given in the following order.

(a) Seek Out Logical Flaws
The ways in which a scientist can delude himself into believing that a cher-
ished hypothesis has been proved are many and various. Trelease, pp. 44–46, trenchantly describes the most common ones. Of course, the purpose of all the hard thinking that went into the construction of the outlines was to avoid the possibility of any catastrophic failure of logic, so we shall expect the major argument to stand up without trouble. But there may be minor lines of reasoning that will not survive close scrutiny. Advise your students, therefore, to read those three pages of Trelease’s book with the closest possible attention (the passage is so succinctly written that each sentence yields its full import only if one reads it two or three times and ponders it well). They should then consider every statement and inference in their first draft, sentence by sentence, for faults of logic. Few things give a better training in scientific method than the ruthless examination of one’s own statements in the light of well-defined principles.

(b) Correct Any Misquotations
The writer should inspect with particular care his statements about others’ work. Impress on your students that they must reread at this point the papers or passages of papers cited in the first draft and acquaint themselves of any suspicion of misinterpretation—for an author’s prejudices only too readily distort his remembrance of an earlier worker’s conclusions. Students should guard even more carefully against the common tendency to cite a finding that has no true bearing on the point under discussion but merely relates to the same complex of ideas. Quoting out of context to give an impression different from that intended is, of course, universally condemned.

I doubt very much that the writer who commits these offenses does so in a deliberate attempt to deceive. The errors come from self-deception and wishful thinking, from a false recollection, or from notes that are too sketchy. Above all, the writer should recognize that his frame of reference has almost certainly changed since he first planned his research and read the articles cited. He owes it to his readers, and even more to himself, to read the articles again in the light of his present knowledge and attitudes and to assure himself that he is not quoting them incorrectly in either the letter or the spirit. For whatever the motives or reasons behind misquotation, the consequences are always unfortunate: knowledgeable readers (including editors and reviewers) lose confidence in the writer’s competence, while the ignorant are misled.

To those who grumble that it is immense labor to read all that literature
again, be merciless. Scholarship is not compatible with laziness, and science cannot progress where sloppy thinking is condoned. To put forward a hypothesis without checking the accuracy of the supporting arguments is like determining the composition of reaction products without being sure that the starting materials are pure.

You may wish to suggest this examination of the cited literature at an earlier stage—Step 11: Construct the Topic Outline. But I believe that this advice is valuable only to scientists with considerable experience in writing journal articles. Indeed, in planning the Introduction and Discussion, such writers should reexamine the leading sources of the arguments they will employ there. Novices, though, are all too easily distracted and discouraged from the task of writing their first drafts, and this rereading of published work may provide merely another tempting excuse for procrastination. If the reevaluation comes after the first draft has been written, the author has gained some confidence in his ability to write and is therefore willing to face the task of remodeling, should this seem called for.

(c) REEXAMINE THE ORDER OF PRESENTATION

Even if no changes under (a) and (b) seem necessary, and even though Topic and Sentence Outlines were constructed and dutifully followed, make the student take a long, hard look at the first draft and consider whether it is soundly designed. He should ask himself in particular: "Will the function of each section be clear to any reader on his very first approach?"

Since clarity of purpose is the key to unity and coherence, the student should now refresh his memory about the exact intent of the article he is preparing, by reference to his title and synopsis. His main object at this stage is to ensure that the paths of reasoning in the first draft, rough and stony though they may be at present, at least point resolutely toward the goals he has defined.

If work on the Outlines has been thorough, shifting of material from one section to another should not, of course, be necessary. But miscalculations are always possible. The very process of writing the first draft may have revealed that a more logical development would result if facts and ideas were rearranged within the original framework. If so, now is the time for the scissors and paste—not later, for then the arduous dovetailing of each sentence to fit its context would have to be undertaken twice.

(d) COMBINE OR SIMPLIFY TABLES WHERE NECESSARY

A closer look at the tables drawn up in Step 10 may now reveal that portions of them are irrelevant to the point being made, or that two or more of them can be combined to increase comprehensibility. Similarly, graphs may profitably be reconstituted to convey their message more directly or vividly. Some principles that should underlie this revision are given in Chapter 10.

Step 19 has been largely concerned with logic and structure. When any major alterations necessitated by this step have been made, and not before, the student can proceed to the correction and improvement of style.

STEP 20: Polishing the Style

Style is probably what your students expected, in a course on writing, to hear about from the start. A few will have been disappointed not to have heard it mentioned, but most will have been relieved that you have been primarily concerned with something familiar and dear to them—scientific method. These need not feel they are entering foreign territory even now, if you emphasize that good scientific style consists of these qualities:

- rational construction of sentence and paragraph (logic again);
- absolute accuracy of expression (precision);
- ready comprehensibility (clarity);
- directness; and
- brevity.

Thus the scientific writer need strive only to be logical, precise, clear, direct, and brief. Most desiderata of literary style—for example, grace, mystery, urbanity, wit, lightness, word-music, rhythm—are, although not necessarily undesirable, inessential here. I think you will have little difficulty in persuading your students of the importance and desirability of good style as thus defined. For their greater comfort, stress that good scientific style can be learned: it is a craft rather than an art—by which I mean that it demands no special inspiration, or genius, that stamps a man as different from all others. Such inspiration, in a scientist, will have manifested itself at an earlier stage of the work: in the choice of problem, the experimental design, and the deductions. These you do not pretend to teach.

The discussion of scientific style (Chapter 6) will occupy at least three complete sessions, so it will constitute a considerable apparent digression from the numbered series of steps. You may like, therefore, to state at this time what the remaining steps will be (Chapter 8), in order to convey the feeling that completion of the task is somewhere in sight.
Further Revision: 
Polishing the Style

The over-all plan for the sessions on style that constitute Step 20 is as follows.

First session: consideration of the true aims of style in scientific writing; enunciation of four principles of scientific style, with examples; assignment of sentences and phrases for correction.

Second session: consideration in class of answers to the assignments; discussion of points of special difficulty and any necessary amplification; discussion of the recommended reading list; and distribution of the "editing assignment"—a complete, badly written paper for correction (see Chapter 7).

Third session: correction of the "editing assignment" in class, preferably with the help of an overhead projector. After this, students should be able to proceed to apply the stylistic principles to the revision of their First Draft.

This schema should be flexible: four sessions may be needed.

You will need:

First Session
1. Copies of the book list, p. 56 (to be discussed in the Second Session; you will, however, refer to it in the first). This is a suggested short list to be handed out to your students; for full bibliography for your own reference, see the beginning of each chapter and the Bibliography of Further Reading, p. 179.
2. Copies of assignments related to each of the principles of style discussed (for suggested assignments see pp. 42, 48, 52, and 54).
3. Desk copies of (for full bibliographic details see p. 56): Fowler (Modern English Usage); Fowler and Fowler (The King's English); Gowers (The Complete Plain Words); Strunk and White (The Elements of Style); Quiller-Couch (The Art of Writing); Baker, J. R. 1955. "English Style in Scientific Papers." Nature. 176: 851-2.

Second Session
1. As above, plus copies of Baker's article for distribution.
2. Duplicated lists of the "Warning Words," see p. 51.
3. Copies of the Editing Assignment (see Chapter 7; have only the faulty text on the left-hand pages duplicated, with the superscript numbers omitted and with each line numbered for easy reference. See pp. 55 and 57 for preparation of alternative editing assignments).

Third Session
Transparent (Diops) copies of item 3 under Second Session.

You should read:
All the books on the students' book list, p. 56.
The recommended passages on p. 42.
Fowler (Modern English Usage): entries headed "Unattached participles"; "Participles"; "Fused participles."


Step 20: [First Session]

The Aims of Scientific Style

All that you have told your students up to now has laid a firm foundation for good scientific style, for it has been concerned with clear, logical thinking. Getting one's thoughts in good order is one of the hardest tasks in the world, especially if they are complex, novel, and exciting, and there will have been little chance during the preparation of the first draft to hunt and trap the telling word or to perfect the economical phrase. Now comes the time to polish the style.

Make it plain from the start that "style" is not an ornament applied to the outside of something essentially simple in order to dress it up for greater impressiveness. Stylistic improvement in scientific writing goes, generally, in quite the opposite direction. Explain that you will first bring to your students' notice some of the common faults of style in scientific literature, and then show how they can be avoided.

Define here what you mean by faults of style: impediments to the transfer of ideas. Ideally, sentences should be smooth; but if the price of smoothness is ambiguity, something clumsier but unequivocal is better. Brevity, we have said, is desirable; yet a long, precise statement is always preferable
to a concise one that is inexact. In other words, the students should aim not at superficial graces but at functional beauty. To do so they must know what the function of scientific prose is: to convey logically ordered ideas exactly, concisely, and clearly.

There are many excellent books full of advice on how to achieve clarity in writing (see the bibliography, pp. 179–184). You will do well to commend Strunk's classic above all others. Strunk is concerned also, as are Gowers and Quiller-Couch, with directness and vigor. These are indeed admirable qualities in expository writing. But a goal that is rarely stressed in general books on writing, one that is of particular importance in science and of particular appeal to scientists (for obvious and good reasons), is precision. You should not hesitate to stress this special quality in scientific writing, both as a desideratum and as a strong suit in the scientist's hand.

However excellent the texts that you encourage your students to read may be, the words of wisdom will not take root unless their meaning is brought home by a great deal of practice. Numerous assignments that will provide this practice are offered to you here. Elementary faults are dealt with first, in single sentences or phrases, and more subtle and interesting ones are presented later in the Editing Assignment (Chapter 7), in which the student edits an entire article.

Obviously, the discussion of style must have a well-defined structure if it is not to degenerate into the consideration of a multitude of single instances from which no precepts emerge. I suggest a framework of four stylistic principles to supply this structure. A detailed description of each of them is given below. These principles have not been conceived in vacuo, but have emerged from my own experience in editing scientific articles. They are not infallible, and can and should be violated when there are overriding reasons for doing so. For that reason they are best regarded as principles rather than rules, although it is simpler and shorter to refer to Rule 1, Rule 2, and so on.

Make clear that you do not mean that the "rules" should impose some restriction on the author's style from without; rather, good style grows from within as the principles are first understood, then applied, and finally transcended. The principles do not by any means supply the answer to every stylistic problem, but if the student learns and understands them thoroughly he will have acquired a writing technique that has a firm basis. Most important of all, by studying and applying these principles the student learn a method for criticizing their own writing. The method involves rational consideration of the purposes of writing, the application of well-defined principles, and the constant reappraisal of "rules" given here and elsewhere. What could be more congenial to a research scientist?

First, warn your students not to aim for the currently accepted style of scientific writing. They should not study the leading journal in their specialty and attempt to imitate the writing it contains. Unfortunately, there has grown up among scientists a ritualistic mode of expression that is at once grandiose and alien to science's grand purpose—which is surely explanation, not obsfuscation. To combat this false style, arm your students for the fray with these firm intentions: to think straight, to say what they mean, and to ensure by constant consideration of their audience that what they say will be understood. Encourage them to treasure their native directness, and to spurn, not imitate, the tortured prose of others.

Fowler and Fowler begin their classic, The King's English, with this powerful sentence: "Any one who wishes to become a good writer should endeavour, before he allows himself to be tempted by the more showy qualities, to be direct, simple, brief, vigorous, and lucid." This admonition applies to all expository writing, but as we have seen, scientific writing demands one other quality: precision. The following enunciation and discussion of four principles of scientific style show, with examples, how Fowler and Fowler's five characteristics—and the additional characteristic, precision—can be attained in scientific writing. The resultant prose is, in functional beauty, as far beyond the tortured outpourings of current scientific writing as the buildings of Mies van der Rohe are beyond those of the Smithsonian.

Rule 1, Be Simple and Concise, works toward being "direct, simple, brief" and combats the tendency of the immature writer to be bombastic and verbose. Rule 2, Make Sure of the Meaning of Every Word, aims at precision; the rigorous application of this simple principle can not only increase accuracy of thought but also eradicate most of the grammatical faults common in scientific writing. Rule 3, Use Verbs Instead of Abstract Nouns, enables your students to write more vigorously. Finally, their writing becomes both more precise and more lucid if they Break Up Noun Clusters and Stacked Modifiers (Rule 4), which creep so insidiously into the hasty or thoughtless writer's work. Let us see, then, how these rules can be imparted and how they work out in practice.
RULE 1: BE SIMPLE AND CONCISE

This most fundamental rule of expository writing can be introduced, if you will, by a delightful anecdote from Plutarch. It illustrates that from ancient times thoughtful men were aware of the danger of letting their tongues run away with them. "Anacharsis, when he had been feasted and entertained at Solon's house and lay down to sleep, was seen to have his left hand placed upon his private parts, but his right hand upon his mouth; for he believed, quite rightly, that the tongue needs the strongest restraint."

What was Anacharsis afraid of? That if he allowed himself to babble, some secret might be revealed. If a writer allows himself to babble in print, an even greater secret may come out: that he is not quite sure what he is talking about. He may have become so lost in impressive, orotund phrases that he is no longer able to face the issues squarely. One sure way to come to grips with a line of reasoning and examine whether it is logical is to express it in the simplest possible terms. For his own sake, then, as well as for the reader's, the writer should check through the first draft of his text—word by word and sentence by sentence—with these questions: "What can be shortened or simplified? What can be eliminated altogether?" The time and hard work it takes to substitute the simple expression for a long-winded circumlocution are well invested, for the more practice the writer gets in simplifying his expressions, the clearer and more forceful become his vocabulary and his thinking.

One of the worst faults of current scientific writing is a kind of hypnotic prolixity. The reader of a scientific article often gets the uneasy feeling that it describes a rite, in which the investigators Jones, Smith, and Robinson circle solemnly among the crucibles, ecstatically intoning

"Optimal reaction conditions are approximated when...";

"In studies pertaining to the identification of phenolic derivatives, drying of the paper gives less satisfactory visualization";

and

"Insufficient data are at present available to completely negate the possibility that removal of the abovementioned substances from the circulation is not a factor of importance."

These are (real, not invented!) examples of jargon, the kind of magniloquent utterance that the specialist falls into when he forgets to strive for simplicity. The etymology of "jargon" is revealing: it is derived from a medieval French word meaning the warbling, twittering, and chattering of birds, and has the same root as "gargle." Jargon consists, then, of sounds that are meaningless. It often results when words are borrowed from one scholarly vocabulary, where they have a precise meaning, and used, in another discipline, in a pseudo-scholarly way. Thus "to approximate" has a precise meaning in mathematics, but the first of the above examples ("Optimal conditions are approximated when...".) does not use this meaning (of continuous approach to an ideal, or ultimate value); the ornamental flourish actually says no more than "The reaction goes fastest when..." (Or does the phrase mean "The reaction goes most nearly to completion when..."? Simple language enforces accurate thinking.) Thus, the writer is not merely verbose; he is inaccurate.

Impress upon your students with all the vigor at your command how dangerous an inflated style is, not merely in obscuring meaning for the reader but in so veiling the issue from the writer that the chances of his making a blunder are greatly increased.

The second ritualistic example,

"In studies pertaining to the identification of phenolic derivatives, drying of the paper gives less satisfactory visualization."

may seem innocuous to those of your students whose sensibilities have already become calloused by daily contact with scientific writing at its present low standard. Ask them if they don't prefer

"Phenolic derivatives are more easily seen and identified if the paper is left wet."

Some may be so far corrupted as to be shocked by the "bluntness" of the restatement. Others will admit that they prefer it, but object that it may not be what the author meant. This objection brings out a prime justification for simplifying high-flown passages: they are usually ambiguous. Still others may feel that although the simpler form communicates more easily and vividly, the difference is slight. Get these objects to realize that a writer who permits himself one such pompous sentence will almost certainly persist in his stylelessness, constantly being complex where he could be simple. Each small, unnecessary effort of comprehension the reader must

* Writers have become so careless in thinking about the meaning of words that I have recently seen "The amount of X was approximated by..." when the writer meant "estimated" or "determined!"
make tires and frets him, and lessens his receptiveness even if he escapes being consciously bored.

You can draw here an analogy between the writer and an archer who points his bow at a target (the reader's comprehension) a hundred yards away. It is the archer's responsibility to trim his arrows and take his aim, not the target's to swell so that it can be hit. An error of a centimeter at the firing end means a yard off the bull's eye. The real danger is that complacency about such poor aim, such small lapses into unnecessary complexity, quickly leads to monstrosities like the "insufficient data" sentence above or to:

"A variety of stimulatory hormones, irrespective of their chemical nature, are characterized by their ability to influence the synthesis of messenger RNA as a prerequisite for the secondary biologic events characteristic of the particular target organ."

Have your students rewrite this sentence in simple prose, and discover for themselves how little they understand it, how wide of the mark its author was.

At this point, you may have to counter students' protestations that you seem to be opposed to the use of technical terms. Naturally, you are not. Technical terms are often polysyllabic, yet they are concise because they have precise (if often complex) meanings that would require many more words to convey in any other way. But in habituating ourselves to these polysyllabic terms we become inclined to use other polysyllabic words and phrases that sound dignified but that turn out on examination to be merely pretentious. In the bad sentence above, the only technical term is "messenger RNA"—and this is the clearest feature of the whole sentence! Give your class a common example of fuzziness induced by nontechnical verbiage: "under conditions of high pH." This says no more than "when the pH is high." Why bury pH, which says so much so succinctly, under the woolly blanket-word "conditions"? Encourage your students to develop and use a "thinking man's vocabulary," not the jargon of the pseudo-intellectual. "A man of true science uses but few hard words, and those only when none other will answer his purpose; whereas the smatterer in science thinks that by moulting hard words he proves that he understands hard things." (Herman Melville)

You may also have to counter another kind of objection. Certain fields engender a special terminology, which, the students say, is perfectly well understood and indeed is a useful shorthand way of conveying information within the charmed circle of its most active practitioners. They admit that it may be misunderstood by outsiders, but suspect that they may not become accepted members of the "in-group" if they fail to follow the leaders' example. Calm their fears on this score. Even "club members" are susceptible to the appeal of clear, simple English and will never even notice when jargon is missing. Ask your students if they want to reach only the members of the in-group. Are they bent on repelling others? Do they want their papers to have lasting value, or are they content to see them become quickly outmoded because of the perishable cargo of vogue words they bear? Disourage them, too, from the propagation of neologisms. A little thought, and a little dictionary work, will often produce an exactly equivalent, already existing, English word to substitute for their uncalled-for brain-child.

I have, in contrast to the authors of many books on style, put simplicity and conciseness together under one heading, for I believe they should be aimed at simultaneously. Otherwise a whole group of students will produce, in a laudable attempt only to be simple, this kind of verbose passage:

"The numbers of enucleated cells in vaccinated and nonvaccinated mice were determined both at four and eight days after inoculation and (or) the beginning of fasting. The number of enucleated cells in vaccinated mice was seen to be greater than in nonvaccinated mice and to increase from four to eight days after inoculation, whereas the number of such cells examined under the same conditions in nonvaccinated mice actually decreased during the first part of the experimental period and then increased from four to eight days, but not to the same extent as they did in mice that were both vaccinated and fasted. Consideration of the numbers of enucleated cells in all four groups, see Table 1, reveals that the effect of fasting seems to have been superimposed upon the effect of prior vaccination, at least in the second portion of the experimental period."

As Strunk puts it, "conciseness requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell" (his Rule 13, p. 17). Few words tell in this "simple" passage, which is therefore as tedious to read as if it had been wrapped up in polysyllabic elaborations.

Further invaluable reading on what constitutes nontechnical jargon is to be found in the following (for complete references see p. 56):
1. Gowers, *The Complete Plain Words*. Recommend that your students read at least case (pp. 91–2), *position, situation, conditions, and level* (pp. 138–141). The last-named has acquired enormous popularity with the development of molecular genetics (use of such phrases as *at the transcription level* has led to absurd imitations like *at the membrane level*, where *level* is completely superfluous). Ask them what they would think if you told them that you are dealing with writing *at the ideational level*.

2. Strunk, Rules 12 (p. 15) and 13 (p. 17).

3. Quiller-Couch, Chapter V, "On jargon." This classic deserves to be learned by heart.

4. Baker’s two-page paper, see beginning of this chapter.

Show your students, by requiring them to read these short excerpts, how entertaining books on style can be. It is not sufficient to place the books on a "recommended reading" list—you must whet the students’ appetite for them.

A list of complicated sentences for simplification and condensation is given below. Indubitably you can supplement this list from your current reading.

**Exercises on Rule 1** (with suggested corrections)

This phenomenon is associated, in a causative or accompanying way, with . . .

(This phenomenon causes or accompanies)

At the termination of the experiment . . .

(At the end of the experiment)

. . . has the capability of . . .

(can, is able to)

. . . at a high speed level . . .

(quickly, rapidly)

This result would seem to indicate the possible presence of . . .

(This result indicates that . . . may be present.)

Effectiveness of the oral inoculum in producing caries varies widely with the strain of rat; in some cases, rats may become highly caries active, whereas in other strains, the oral inoculum has much less adverse influence.

(delete everything after the semicolon)

X produced an inhibitory effect on the formation of Y.

(X inhibited the formation of Y.)

It was possible to obtain semipreparative (100 µg) quantities of substance X.

(100 µg of X could be made.)

X formed Y at least an order of magnitude faster when . . .

(X formed Y at least ten times faster when)

**Polishing the Style**

Computations were conducted . . .

(Calculations were made; or, X was calculated)

. . . in a state of protrusion . . .

(protruding)

. . . subsequent to their entry into the cell . . .

(after they have entered the cell)

. . . occupies a juxta-nuclear position . . .

(is next to the nucleus)

Solvents were pre-cooled at 0°C prior to use.

(What does "pre-cooled" have over "cooled," or "prior to" over "before"?)

One lot contained particles greater than 74 µ, and this material was shaken on a sieve prior to use to remove particles in excess of this size.

(One lot contained particles *larger* than 74 µ; these were removed by sieving.)

Figs. 1–3 are photographs of thin-layer chromatograms developed in the solvent system described and are typical of the separations achieved with this chromatographic method.

(Figs. 1–3 show typical chromatograms.)

**Rule 2:** Make Sure of the Meaning of Every Word

"Alice had not the slightest idea what Latitude was, or Longitude either, but she thought they were nice grand words to say."

Science is full of nice grand words, and very tempting to tongue and pen they are. But if a major objective of our writing, as of all our scientific activity, is precision, we must use them with the greatest care. If we try to write without understanding their meaning *exactly*, it is like trying to obtain a result with uncalibrated equipment, while revision is like trying to find a fault in the equipment without understanding the basic principles of its construction. Insist, then, that your students calibrate their equipment by frequent recourse to dictionaries (for words of general meaning) and to textbooks (for definitions of technical terms).

Be patient with your students. They entered quite suddenly, at college, a world of ideas peopled with a vast number of new words, some of which were never adequately explained, many of which are inaccurately used in the articles they read. The only adequate corrective is constant vigilance and a conscious appraisal of each word that they write. Ask them to consider (as examples of precision in word usage) whether enzyme reactions are studied in solutions of *varying enzyme concentration* or in solutions of *various enzyme concentrations*. Is a *variety of improvements* reported, or are *various improvements* described? Did the clinician administer *varied* treat-
ments or merely different ones? Are two values equivalent or equal? What is wrong with "Both methods yielded similar results," or with "The adsorption is completed in 15 minutes. This greatly reduces previously reported adsorption times."

Your students may not be as patient with you as you are with them. "Oh, for pity's sake," they cry, "we know just what the fellow means, why all the pedantic fuss?" Convince them that this apparently robust, commonsense attitude is, in fact, a nonscientific one, analogous to that of a housewife who cannot conceive that an ounce of butter one way or the other is going to make the slightest difference in her cooking, whereas the scientist frequently encounters the case in which a milligram and even a microgram makes all the difference in the world. Anyway, is the reader so sure what "the fellow means"? If the writer's prose abounds in minor inaccuracies like this, we cannot be confident that when he refers to "10 mM glucose . . . in a total of 3 ml" he actually used 3 ml of a 10 millimolar solution. The carelessness of his style makes it distastefully likely that he made a common error of abbreviation and actually meant "10 millimoles of glucose per 3 ml of solution." The 300-fold difference might well be crucial in an experiment.

For precision of diction, a knowledge of definitions is (of course) not enough. Besides the meanings of individual words, the writer must examine words in context to ensure that the correct meaning is conveyed. An intelligent university student without any formal knowledge of grammar can actually correct most faults in grammar simply by analyzing his sentences logically. Can anyone fail to spot the error in "This value was found by Smith in rabbits who reported that . . ." provided he is examining the meaning of every word and its context? Nevertheless, an awareness of common pitfalls is helpful. One such pitfall is the unattached or dangling participle; another, the dangling infinitive; a third, the omission of auxiliary verbs. A brief discussion of these points is worthwhile (although you may feel that continuity is best preserved if you defer this to the second style session). A treatment such as the following is suitable.

Dangling participles. Scientific writing abounds in dangling participles because it is difficult to combine successfully the frequently used (and useful) passive voice with a participial construction. As you know, a verb-form (participle or infinitive) is said to "dangle" when the (unstated) subject of the verb in question is not the subject of the main clause of the sentence.

A dangling participial construction may be unobjectionable ("The experiment was performed using redistilled solvents"), misleading ("Chromatography fractions were sampled, followed by UV measurement, and dried."), or downright ludicrous: "After closing the incision, the animal was placed in a restraining cage" (skillful surgeons, some of these laboratory animals!). Baker, in the article in Nature cited at the head of this chapter, states that "anyone who is intelligent enough to carry out scientific research at a university can easily grasp everything that is it essential to know about the use of present participle and gerunds in fifteen minutes." Although Dr. Baker may be optimistic, do give your students fifteen minutes of instruction on the point. As source material use Fowler on Unattached participles, the excellent example given by Baker, and horrid examples you have collected yourself. Recommend these simple precepts to be applied in revision of the first draft:

(a) In each sentence, establish the subject of every verb (in whatever form the verb may appear—active or passive voice, participle, infinitive). Ensure that the subject, if present, is unequivocally in the right context or, if absent or represented by a pronoun, is unambiguously implied.

(b) Distract all words that end in "...ing" and examine their context for correctness (see Fowler on Participles, esp. Fused participles). Particularly avoid following, which is usually a clumsy elaboration for after but which sounds distressingly like a participle, to the confusion of all ("The miliness of the intestinal lymphatics of a dog following a fat meal. . ."). Poor, starved animal! "Following the meeting in Paris, the editors visited London. How vague about a rendezvous can you get?"

Dangling infinitives. These are almost as common as dangling participles. Take, for example, the sentence "The flask was flushed with nitrogen to remove ozone." The intended subject of the verb "remove" is "the experimenter," but this subject is not mentioned. Grammatically, therefore, the implied subject of that verb must be the subject of the main clause—"flask"—and the nonsensical inference to be drawn is that the flask wanted to remove its excess ozone. The fault is not corrected by inserting "in order," since these words merely elucidate that the infinitive is an infinitive of purpose and do not essentially change the grammatical structure. Nor is the fault corrected by inverting the sentence to "Excess ozone was removed by flushing the flask with nitrogen," for then we have a dan-
gling participle, "flushing" (grammatically, the ozone must be doing the flushing).

The best correction in most instances of this kind is to insert the true subject of all the verbs, namely "we," and transform the sentence into the active voice. "We flushed the flask with nitrogen (in order) to remove excess ozone" or "We removed excess ozone by flushing the flask with nitrogen." If the passive is considered essential, the possibilities (cumbersome but correct) are: "The flask was flushed with nitrogen and the excess ozone thereby removed"); "Flushing the flask with nitrogen removed excess ozone" (here the notion of purpose is not expressed, but is rather obvious; "flushing" in this sentence is not a participle but a gerund or verb-noun); and "In order that excess ozone might be removed, the flask was flushed with nitrogen."

Omitted auxiliaries. Avoidance of the repetition of "was" or "were" in a sentence—a device applied by many writers, perhaps in an unconscious attempt to decrease wordiness—requires careful handling if the sentence is to emerge grammatically correct. The following classification of omitted auxiliaries is readily understood and applied:

(a) Invariably incorrect. Two different verbs and two different subjects, one of which is singular and the other plural, e.g., "The rats were killed and their blood pooled." (Blood were pooled??)

(b) Sometimes correct, rarely advisable. Two (or more) verbs, each with its own subject, all subjects being singular (or all being plural): "The dog was anesthetized, blood drawn through a long needle provided with anticoagulant, and serum separated by centrifuging." Although grammatically correct, this kind of sentence plunges the reader into a succession of uncertainties. Are we supposed to read "blood drawn through a long needle was provided with anticoagulant" or "blood was drawn through a long needle [that had been] provided with anticoagulant"? Did the serum separate or was it separated? Insertion of "was" at two points would remove all doubts.

(c) Always correct and desirable. One subject, and a string of verbs, e.g., "The solution was warmed, stirred, decanted, and evaporated."

The writer (and reviser) can guard against errors that result from omitting auxiliaries if he again follows the advice (see above): establish the subject of each verb and ensure that its context is correct.

In general, it is not appropriate to deal with any other points of grammar in a course of this sort. Individual students who need grammatical help or study can be directed to such textbooks and workbooks as those by J. M. Walsh and A. K. Walsh, Archibald C. Jordan, or W. Paul Jones (see the bibliography, p. 179). Jones, Chapter 19, provides particularly appropriate examples and exercises on parallel construction, agreement of subject and verb, reference of pronouns, dangling, trailing, and misplaced modifiers, and other grammatical problems. Tichy (see students' book list, p. 56) deals with the matter of grammar sensibly, by reviewing only the kinds of mistake that are common in scientists' writing. It may amuse you to discover what a large proportion of the faults she lists can be detected by a conscientious reviser who applies Rule 2—to take two common examples, the unidentified or ambiguous antecedent of pronouns (detected by "what is the meaning of it or this here?") and the nonagreement of subject and verb (detected by "what is the meaning of the context of this verb, i.e., what is its subject?"). Your whole approach should be, I think, to get your students to rely on logical analysis for the removal of blemishes, rather than to give a full review of formal grammar.

Detailed analysis for meaning will often turn up scientific solecisms such as the following:

"The solvents were evaporated in vacuo at 40°C under a stream of nitrogen."

Here the author has been too lazy to examine the meaning of the words "in vacuo" that are daily on his lips—shouldn't this phrase be banished forever in favor of "at reduced pressure" if there is any danger of its leading to the absurdity of specifying that a vacuum shall be composed of nitrogen? Unmasking blunders such as this constitutes, surely, the whole justification for detailed criticism of one's writing.

Urge your students, then, to combine common sense with their not-so-common intelligence and to acquire an ingrained habit of ruthless word-by-word criticism. The ultimate object will be to make every sentence (as Quintilian put it) not merely capable of being understood, but incapable of being misunderstood. No writer, least of all a scientist, should lay himself open to the kind of reprimand that Alice received:

"Speak English!" said the Eaglet. "I don't know the meaning of half those long words, and, what's more, I don't believe you do either."
EXERCISES ON RULE 2
Ferric chloride was deleted from the color reagent.
(simple malapropism of "deleted" for "eliminated" or "omitted")
Glycerol ethers of varying degrees of unsaturation...
(The continuous "varying" is inappropriately used instead of "various.")
A method is described for use on unfractionated human plasma that is superior to that now in use.
(Is the plasma superior to that now in use?)
The composition of the lymph of the fasted rat is also unlike depot fat.
(Is the composition unlike fat? This is a very common type of fault, eliminated by inserting "that of" before "depot fat").
The addition of hexokinase decreased palmitate oxidation and was therefore not included in the incubation medium.
(The addition was not included?)
The optimal conditions for transesterification approximate those for phospholipase activity.
(not "approximately," which means "approach," but "are about the same as")
The two major components analyzed very close to that expected for the mono- and diacetate structures.
(1. Did the components analyze, or were they analyzed? 2. What is antecedent of "that"? 3. What is the use of the word "structures").
The problem of diffusion constants of almost insoluble substances...
(Are diffusion constants a problem?)
Due to the low resistance of the plate, a 100-ohm resistance was placed in series with it.
("Due to" is often advantageously replaced by "because of." Try inverting the sentence: it makes sense with "because of" but not with "due to.")
Following the incubation, the remaining fluid was poured off and the slices washed.
(1. Was the fluid following the incubation? Use "after." 2. The auxiliary verb "were" is omitted.)
The tubes were shaken, followed by centrifugation, and the upper phase withdrawn.
(Were the tubes followed by centrifugation? Were the upper phase withdrawn?)
Fasting blood was drawn.
(Can blood fast?)
In view of the colored nature of retinol...
(What is a colored nature? Can it come into view, as a color can?)
Based on electrophoretic patterns, hyperlipoproteinemia has been classified.
(Were hyperlipoproteinemia based on electrophoretic patterns?)

POLISHING THE STYLE
Other investigators have reported large populations of lactobacilli in fecal contents. Reference 7 presents a recent review dealing with this problem.
(Are large populations—at least in this context—a problem?)
In the steady state, the daily fecal excretion of neutral plus acidic steroids of endogenous origin should approximate the daily synthesis of cholesterol.
(... should approximately equal ...)
Contrast this correct usage:
When radioactive cholesterol is given to patients with every meal, the specific activity of biliary bile acids approximates that of plasma cholesterol after some days.
and point out the strength and utility of precise vocabulary and usage.

RULE 3: USE VERBS INSTEAD OF ABSTRACT NOUNS
So far we have talked about being simple, brief, logical, and precise. Writing that has these characteristics can still be unappealing: noble and virtuous, perhaps, but lifeless. The Fowler brothers knew what they were about when they commended vigor as a prime characteristic of good writing. Lucas, too, remarks that it is not much use making your reader see, if you also make him yawn.

What is it that makes most scientific writing so preeminently dull? I believe it is the failure to use expressive verbs, for the best way to bring a piece of flabby writing to life is to use richly meaningful, telling verbs. Yet scientists seem to want to weaken the verb in every possible way. They show an inexplicable urge to use gerunds, abstract nouns derived from verbs, or noun-phrases—anything but a verb, in fact—to do the work in a sentence, which then has to be grammatically completed (since a sentence, by definition, demands a verb) by some pale shadow of a verb like "affected." Thus, instead of the vigorous "A was separated from B" we have to suffer "The separation of A from B was affected." The force of the verb "separate" has been dissipated by its transmutation into "separation." Your first task is, then, to train your students to recognize and then release the hidden verb, that sleeping beauty so often locked up in a bland ivory tower of an abstract noun.

Mention of the abstract noun brings up a second aspect of this principle of using verbs: it enables the writer to substitute concrete action for hazy abstractions, which, as every professional writer from antiquity to the present knows, is vital to holding your readers' interest. In scientific writing we are often dealing with, and necessarily writing about, abstract concepts,
All the more reason, then, to write concretely when no abstract idea is being put forward.

"Isolation of the tertiary component was accomplished and its identification achieved by the following sequence of manipulations."

Here the scientist is not thinking, like some yearning recluse, of the accomplishment of isolation; he is thinking, and should be writing, about isolating a particular compound. Nor is he concerned, like a spiritual guru, with the ultimate achievement of identification; he just wants to identify a single chemical. When actions are earthbound, their description should be earthy—and vigorous.

The technique of releasing the hidden verb leads, as your best students will already have realized, not only to greater vigor but also to simplicity and brevity. Circumlocution is often the result of burying verbs in other, longer parts of speech (not "explain" but "is explanatory of"; not "results from" but "is the resultant of"). In addition, using verbs instead of nouns can lead to greater precision, because the proper use of a verb forces the writer to specify subject and object unequivocally. Abstract nouns allow the subject to remain unnamed and insubstantial, which is why the writer of official documents loves them so (see Gowers). In one example I encountered, I was able to conclude only after diligent search of the context that the sentence "Repeat aspiration was necessitated" probably meant "The upper layer had to be siphoned off twice"; I remained uncertain, however, since the subject "the upper layer" had not been specified.

Your advice will be, then, to release hidden verbs wherever feasible; but you will find that your students need much practice before they can recognize nouns (and other parts of speech) derived from verbs. A useful aid in doing so is to compile and keep at hand a list of "warning words" which usually indicate a nearby trapped verb in distress. These warning words are the colorless shadows of verbs I mentioned above as being necessary to complete the sentence in which an abstract verb-noun lurks: "carried out," "effected," "achieved," "facilitated," and the like. A list of them appears in Table 1. I suggest distributing this list in the Second Session, but you may prefer to do so here. Do not call them "forbidden words," because in some contexts they are inevitable and right. But they should be memorized as warning signals. When the student finds one of them as he revises his first draft, he should stop at once and examine the sentence closely. Can it be expressed more succinctly, precisely, directly, vigorously? Almost always he will discover that it can.

| accomlished | experienced | obtained |
| achieved    | facilitated | occurred |
| attained    | given       | performed |
| carried out | implemented | proceeded |
| conducted   | indicated   | produced |
| done        | involved    | required  |
| effected    | made        |          |

**Woolly words** (sometimes these have a precise meaning; more often, they are an indication that the thought has to be sharpened)

- area
- character
- conditions
- field
- level
- nature

**Words incorrectly used as synonyms**

- amount
- concentration
- content
- level

- alternate
- alternative
- slight

- minimal
- negligible
- varied

- varying
- various
- different

**Dangling words**

All words that end in "ing" or "ed" and all infinitives

**Danger words**

- this (obscure antecedent)
- it (obscure antecedent)

**Vague qualifiers** (can usually be omitted, since they add nothing)

fairly quite rather several very much
EXERCISES ON RULE 3

Protein determinations were performed as described above.

(Proteins were determined as described above.)

Hydriodic acid attack on unsaturated ethers proceeds at olefinic bonds.

(Hydriodic acid attacks unsaturated ethers at olefinic bonds.)

Conversion of acetates to iodides was effected.

(Acetates were converted to iodides.)

Primary and secondary particle separation was obtained by performing electrophoresis.

(Primary and secondary particles were separated by electrophoresis. “Performing” is both dangling and redundant.)

Injection of the protein was more difficult of achievement in older animals due to the frequency of occurrence of thrombosis.

(It was more difficult to inject the protein into older animals because thrombi often formed.)

Preferential release of monoenoic acids would also appear to be the case in man.

(Monoenoic acids seem to be preferentially released in man also.)

The separations were checked frequently to ensure that quantitative recovery of cholesteryl esters, uncontaminated by triglycerides, was being achieved in the second fraction.

(Frequent checks established that cholesteryl esters, uncontaminated by triglycerides, were recovered quantitatively in the second fraction.)

The paper lost its integrity.

(The paper disintegrated.)

There was predominantly protein formation . . .

(Proteins were mostly formed . . .)

RULE 4: BREAK UP NOUN CLUSTERS AND STACKED MODIFIERS

A factor that contributes significantly to the flexibility of English is that one noun can be used to modify another without any inflection. Thus, “disease of the liver” can be perfectly satisfactorily rendered as “liver disease” even though an adjectival form for liver, “hepatic,” exists. When more than two nouns are gathered together, however, trouble begins. In “adult liver disease” we become uncertain which words are substantive and which modifying: is the writer referring to liver disease in the adult, or to disease of the adult liver? Here, perhaps, it does not greatly matter; the phrase makes sense whichever way you group the words, just as in “rabbit ear skin” or “serum cholesterol level.” But when we encounter “liver disease plasma” the case is different. Does this mean “disease(d) plasma flowing through the liver,” “hepatic plasma in disease”? No, the only meaningful combination seems to link the two first nouns to form a complex adjective and make

the phrase mean “plasma obtained from patients with liver disease.”

The meaning of these noun clusters can, then, usually be puzzled out—although sometimes a real, unresolvable ambiguity results, as in “heavy beef heart mitochondria protein” (which is heavy—the beef, the heart, the mitochondria, or the protein?). The major objection to noun clusters is that the writer has shown discourtesy in using a shorthand designation that may be convenient for him but is highly inconvenient for the reader.

The difficulty is compounded when not only a couple of nouns, but a whole string of modifiers, is carelessly flung down before a single noun. Here real uncertainty arises as to what is meant to modify what. Except to an expert in the field, the meaning of “a radium containing argon ionization chamber” is totally obscure. Perhaps you think that a little reflection will unscramble this: the chamber, which contains radium, is a device for ionizing argon—why bother to add words spelling it out? My answer is twofold. First, the onus of making the translation should not be on the reader. Second, the translation is wrong: the chamber does contain both argon and radium, but the “ionization” is of organic vapors that enter the chamber and react with the electrically excited argon. So much for the attitude “Oh, they’ll all know what I mean!”

If the reader is in as much of a hurry as the writer of such careless phrases, understanding may never be reached. In a paper in which a reader has become used to translating “silica gel coated glass fiber paper chromatography” into “chromatography on paper that is made out of glass fibers and coated with silica gel,” “nonglucose light experiments” into “experiments carried out in the light in the absence of glucose,” and “light glucose cells” into (believe it or not) “cells grown in the light in the presence of glucose,” he will almost certainly be waiting for the main verb in “The presence of glucose delayed daughter cell release in 80% of experiments . . . ,” only to discover after much cogitation that the main verb is actually there! The noun cluster consists of only three words, daughter cell release, and the sentence is meant to be read: “The presence of glucose delayed the release of daughter cells in 80% of experiments.” Readers with this degree of perseverance are more than such an author deserves.

How should one detect clusters of nouns and modifiers, judge whether they impede communication, and correct them if they do? Detection is easy, if tedious. The student should pick out every noun in his draft and count the number of modifiers it bears. A useful rule of thumb to ensure lucidity
is to allow the coupling of two nouns ("palmitate oxidation") but not the addition of a third ("sheep palmitate oxidation") nor even of a modifier of the two-noun cluster ("enhanced palmitate oxidation"). And the correction is also rather simple: decide the precise relationship of the modifiers to one another, and express this relationship by inserting prepositions and verbs. Some loss of brevity is inevitable, but lucidity is too important a commodity to be sacrificed on the altar of conciseness, and you should not allow your students to defend their clusters with Rule 1 as their banner. This is one example, out of many you will encounter, of the need to overrule one principle because of the greater importance of another.

**Exercises on Rule 4**

The monoamine oxidase inhibitor insensitive agent

(The agent that is insensitive to the inhibitor of monoamine oxidase)

Radioactive glycerol-labeled triglyceride metabolism

(Metabolism of triglycerides labeled with radioactive glycerol)

Anomalous stability constant order

(Anomalous order of stability constants)

... in order to obtain high purity, high yield aldehyde

(... in order to obtain aldehyde in high purity and high yield)

Highly purified heavy beef heart mitochondria protein

(Protein from the highly purified heavy fraction of bovine heart mitochondria)

Proteolipid protein-free lower phase lipids

(Lipids contained in the lower phase, free from proteolipid protein)

Cellulose acetate electrophoresis procedure

(Electrophoresis on cellulose acetate)

The minute analysis of imperfect prose that is necessary to illustrate principles such as the ones I have given may seem irksome. Elaboration of these points is indeed unnecessary to a naturally gifted writer, who instinctively avoids the kind of solecism I have discussed. But it is to the less gifted that our attention is directed, to the student who senses that something is wrong, but who does not know why, or how corrections can be made. He needs clear-cut principles—principles he can see the point of, and believe in—to guide his hand and brain. If you can demonstrate that by application of these simple principles a passage is markedly improved, the student rapidly discovers that the process is exciting rather than tedious, and develops a style that is a worthy vehicle for the liveliness of his thought.

**STEP 20: [Second Session]**

After the students have wrestled with the short assignments, it is advisable to discuss the four principles again, with the aid of further examples, in order that the students not only grasp them but become thoroughly familiar with them. You can distribute the "Warning Words" (Table 1) as a basis for this amplification. The first part of the table lists colorless verbs and is to be related to Rule 3; the rest of the table refers to various aspects of Rule 2.

The grammatical points I discussed under Rule 2 (dangling constructions and omitted auxiliary verbs) can also now be considered.

Discuss the short book list (p. 56), distinguish between books to be read thoroughly and those to be used for reference, and ensure that the students have embarked on some reading of them. The "highly recommended" books can be described with enthusiasm to those of your students who have some literary bent and appreciation and who have already mastered the Four Rules, but do not launch into this eulogy too early; the student must tangle with and overcome the fundamental difficulties before he can appreciate these elegant and eloquent pleas for better style. Even the lively book by Tich, which is specifically directed toward scientists, should be regarded as the basis of further refinement of style rather than as an introductory text. One great strength of this appealing book is the wealth of examples in which scientist-writers have succeeded, in contrast to the many I have quoted who have failed, in the task of scientific communication.

Distribute the Editing Assignment (examples are provided in Chapter 7) and explain to your students that it is so loaded with faults that they will certainly have to rewrite every sentence, at least in part, and reorganize some of the paper as well. In particular, they should examine the Table for possible simplification, and consider whether any material should be moved from the Results to the Methods section or vice versa. Tell them that you will go over this paper in detail in the next session, but that they should correct it, as far as they are able, before then. Emphasize that they should read the faulty article right through before giving way to the natural urge to start correcting; only if the point of the article is understood will the editing be soundly based.

"Editing assignments" such as the examples I have given can be com-
BOOKS ON (SCIENTIFIC) WRITING

Essential textbooks:

Reference works:
A good collegiate dictionary. Webster's is the most often referred to but is the most permissive; Random House is a better authority for educated usage. British writers will prefer the Oxford Dictionary.
Roget's Thesaurus. Innumerable versions, including paperback editions. (First published 1852.)

Highly recommended:

Recommended:

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posed very easily. You may want to prepare one whose subject-matter has closer appeal for your particular class. Just take any short, well-written, published paper—one of your own, for instance—and inject into it examples of all the faults that have been discussed in the preceding pages plus others that you find especially objectionable. This can be done rapidly if you have before you a list of “Warning Words”; the exercises on the Four Rules; and compilations of circumlocutions, passive constructions, malapropisms, and clichés such as are contained in the tables, pp. 17-20, of the Author's Guide for Technical Reporting (see bibliography at the beginning of this chapter). Everything in this excellent booklet is worth studying, for possible use with your students later.

STEP 20: [Third Session]

YOU WILL NEED:
A copy of the “editing assignment” distributed at the end of the Second Session, identical with the students' copies except that it is made on transparent Diops (sheets of clear plastic); a supply of sharpened wax pencils; and an overhead projector that throws onto a screen an image of the sheet and of your pencil as you make corrections.

If you do not have the facilities to have such Diops made, use an ordinary copy of the assignment and a projector such as is used for projecting an image of a page in a book. You will not be able to make corrections on the projected image, but you will be able to point to the offending words or passage. Make provision, in this case, for an illuminated blackboard, if possible, so that you can use it while the image of the page is still being projected in the darkened room.

Because the object of this exercise is not so much to arrive at an improved version of the faulty paper as to teach general principles of style, work out beforehand which of the corrections you will spend most time on and ensure that each one either makes a major point or can be related to one of the Four Rules already enunciated. It is discouraging for students to watch you make many minor corrections that seem to have no general application and no relationship to an over-all scheme. For the same reason, control the extensive discussion that inevitably results from this exercise in such a way that the framework of principles and the categorization of errors remain clearly in the foreground. Defend nothing on the grounds of personal taste; if you can refer neither to a principle of scientific
style nor to an unequivocal rule of grammar, concede the point. Try to avoid being either pedantic or apologetic.

Your students will have detected and corrected many of the errors already, and will be heartened by seeing you treat them in the same way. Other points will be new to them. In some places, content yourself with indicating what is wrong, and why—and let your students provide the correction. As a final exercise on Style, have them extend and complete the editing of the assignment in the light of what they have learned during this session, and hand in their final version of it a few days later. A brief examination of these versions will show where each student still needs guidance or further study, and you will be able to direct him to appropriate authorities. Try not to involve yourself in detailed correction at this stage; such correction will be much more telling in the revised draft of the student’s Major Assignment, to which he is more deeply committed both intellectually and emotionally.

STEP 20: [Fourth Session]

You may or may not consider a fourth Style Session to be necessary; but it is wise to allow for it if possible. Your students will almost certainly be bursting with questions: they may want you to explain one of the principles again or to provide a more elegant solution than theirs to one of the problems in the editing assignment. On your side, you may want to elucidate something that they apparently have not grasped. Perhaps you should stress again the enjoyment and profit to be gained from careful reading of the books in the book list (p. 56) and the importance of critical reading of everything that comes their way for the continuing development of good scientific style.

After the editing assignment and subsequent session(s), return to the sequence of steps, in which Step 20: Polishing the Style has been a lengthy one, and fill in the details of Steps 21–25 as indicated in Chapter 8. You may wish to end your course there, or to extend it with the material in Chapter 9 or any of the chapters in the second half of this book that fit both the needs of your students and your own time schedule.
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The Final Steps

You will quote:
Trease, p. 39 ("Choice of Title")

This chapter contains the remaining steps in writing a journal article. You may want, as suggested in Chapter 5, to give your students a "preview" of them before plunging into the detailed consideration of style for which the framework is given in Chapter 6.

Step 21: Give Drawings to Illustration Department

Revision of the text sometimes shows that corresponding changes are needed in the figures, designed at Step 10. It is not wise, therefore, to have drawings made professionally before one is sure of the final form. Now, however, the illustrators should be given as much time as possible to complete their work while the author works on the final steps in writing. Emphasize the importance of consulting the Instructions to Authors and of sending to the illustration department any special requirements of the journal (e.g., type of drawing paper, size of lettering) relating to the drawings to be submitted.

Step 22: Write Title and Abstract in Final Form

You and your students gave a lot of thought to the title and the early form of the abstract (the synopsis), back at Step 5. Why should these parts of the manuscript need revision? Because now a different objective must be considered. The purpose of writing title and synopsis at that early stage, you will remember, was for the author to clarify for himself his aims and intentions. Now he must think of the title and abstract from the reader's point of view. He must check that they accurately reflect the contents of the article as it has emerged after all the modifications we have discussed. He must also ensure that the title, especially, is an effective guide for scientists rapidly scanning lists of titles for information relevant to their interests. Of all the parts of the article, the title will surely enjoy the widest circulation; all the more reason, then, that it should be a fitting and worthy representative of the article's contents.

The title should be long enough to be fully informative, but it should contain no unnecessary words like "On the..." and "Studies in...". The tersest form of expression is always the most telling; furthermore, automatic indexing systems reject parts of excessively long titles, and may retain insignificant words at the expense of more important ones. Here you have an opportunity, invoking these considerations, to discourage the "serialization" of articles—publication of a series of numbered articles, all under a general title. This practice is objectionable for another reason also: its patent self-advertisement antagonizes rather than informs.

A title should not suggest too much through too broad a generalization (e.g., "Extraction of Proteins from Tissues," when the article deals with the extraction of only one class of protein from certain mammalian tissues) or through vagueness ("Some Photosynthetic Reactions"), but neither should it attempt to be an abstract in itself ("Conversion of Tetra cyclic Terpenes to Derivatives of Geranyl Geraniol and Some Unidentified Oxidation Products Under the Influence of Broad-Spectrum Light at Temperatures Below 0°C and High Pressures"). Much information can be given in a short title, with the aid of a little ingenuity and ruthless suppression of nonessentials ("Light-Induced Conversion of Terpenes to Geranyl Geraniol at Low Temperatures and High Pressures")... the last six words can be omitted if the main novel achievement was the conversion, whereas they are needed if the conversion was already known under other conditions). See Trease, p. 39, for further guidance on this matter, and provide good and bad examples from your own reading.

Making an abstract from the finished paper will resemble the assignment at the end of Chapter 3. Refer to Trease, pp. 42-43, for principles to be followed, and recommend that the spirit of the synopsis written at Step 5 be studied and as far as possible retained—for the abstract will be the reader's first encounter with the paper, and his mind will be as unclouded by familiarity with its contents as was the writer's at that early stage.
Clarify at this point the difference between an abstract and a summary (on this matter, Trelase, p. 42, is at variance with present usage). An abstract must stand alone and be intelligible without reference to the text (especially as it may be reprinted unchanged in a secondary publication, quite divorced from the text). A summary serves only to bring together, for a reader who has already read the paper, the article’s salient points; it often gives only conclusions, without indicating the experiments that have led to them or the purpose and significance of the work performed. An abstract therefore appears at the head of an article and a summary at the end. Information specialists nowadays are urging that, of the two, abstracts are far more valuable to many users, and that summaries have had their day.

A further distinction is between indicative and informative abstracts. The former are descriptive and often omit all numerical data, whereas the latter try to give all the results of the paper itself and are often accepted as substitutes for the original paper when it is, for example, in an inaccessible language. Informative abstracts clearly call for great skill and experience on the part of the abstracter and are usually entrusted to professionals. This does not mean, however, that the author’s indicative abstract can be a sloppy, amateur affair. The writer must attempt, within the space allowed, to convey the purpose, general experimental design, conclusions, and, if possible, significance of his work—not merely list his results in a dull, meaningless catalogue.

**STEP 23:** Reread the Journal’s Instructions to Authors Before Having the Manuscript Typed

In view of all the time and effort expended on organization, content, and style, we have at least the hope that the draft resulting from the revision steps will be the final one, fit for transmission to the journal. Before it is typed, therefore, both the typist and the author should reread the Instructions to Authors of the journal to which the article is to be submitted—not, this time, in order to get a general impression of the journal’s scope and procedures but to study and apply all the minutiae of convention adopted by the chosen journal. In particular, you could mention the following points to be watched for: position and length of abstract, style of headings and subheadings, paragraphing, numbering (Roman or Arabic?) of tables and figures, layout of tables, authorities given for nomenclature, form of bibliographic references, and number of copies to be submitted. You will find it useful to keep a file of Instructions to Authors from several journals to show to your class.

You may or may not care to go into any more detail on these mechanical matters, which constitute “publisher’s style.” Trelase, pp. 52–66, has some useful tips for the uninitiated. The essential point to be made is that these details are not to be dismissed as unimportant fiddle-faddle beneath the notice of the gifted scientist who is fully occupied with pushing back the frontiers of knowledge. Attention to such matters is a mark of scrupulous care, which cannot fail to make a good impression on editors and reviewers. If your students show a tendency to charge editors and publishers with being too compulsively devoted to points of mechanical consistency, ask them whether they consider it important, in any series of experiments, to make up solutions with chemicals of a consistent grade of purity, or whether they use tap water in one experiment and sterile, triple-distilled water in the next, or whether they think it proper in a paper to give dimensions in inches or meters, fractions or decimals, indiscriminately and whimsically. In my experience, the correlation between excellence of preparation of a manuscript and the chances of its ultimate acceptance is high, because fastidious presentation is a mark not only of good manners but of good training. It is an indication of careful and reliable work in all phases of the investigation.

When the manuscript has been typed, it must be proofread (before Step 24) by the author, preferably with the aid of a colleague or assistant who reads aloud from the original while the author notes any corrections on the top copy and simultaneously on each carbon copy.

**STEP 24:** Departmental Review

When the final draft is ready, the author will do well to offer it, before formal submission, for informal review to three types of critic, who may be personified as: the man in the same laboratory, the man down the hall, and the author’s wife. By the “man in the laboratory” I mean someone intimately involved with similar work, who can criticize the methodological details and perhaps suggest alternative interpretations of the results; the ideal adviser here may actually be in another institution, hundreds of miles
away. The "man down the hall" represents a fellow scientist who will be able to point out where the text is unintelligible to anyone outside the sub-specialty or limited circle to whom the paper is primarily addressed. For "wife" one may substitute—in this context only!—any nonscientific friend who cares enough for the author to stumble through the technicalities to discover what seems to be a disjointed sentence, a word with undesirable or risible overtones, an overlong paragraph, an apparent failure in logic, or an awkward transition. These three critics give the author something he is unable to provide for himself: distance. Whether he chooses to take their advice is a matter of judgment based on whom he wants to reach with the article and how he wants to influence his audience. In order to avoid offending these kind advisers, he can ask them to write their suggestions down for him to study, and thank them after due time for reflection. And he should not continue to ask advice indefinitely, or confusion and despair will surely seize him.

STEP 25: Shelve the Manuscript for a While

Again in the interests of obtaining distance, the author should put the last draft of the manuscript away for at least a week and then read it critically before submitting it for formal review by the journal. This enables him to look at it with a fresh eye, as though he were a reader coming upon it for the first time (and this is the frame of mind he should aim for).

Now the paper is ready to go. After a final check that the pages are correctly numbered and are all present, together with tables and figures, in all copies, the manuscript can be mailed. Tell your students not to forget the brief covering letter of submittal—which shows (among other things) with whom the editor should correspond and the date the manuscript left the author's desk—or the protective cardboard for the figures, if this seems necessary. Some Instructions to Authors stipulate using registered or certified mail; in any case, the author should, of course, retain at least one complete and accurate copy in his files just in case anything should go wrong. Suggest that authors enclose a postcard for the editor to acknowledge the paper's arrival, but warn them not to count on a decision in less than six weeks. Sober and thoughtful review can easily take that long, although it sometimes requires much less. A polite letter of inquiry at the end of this time is not out of place. If the postcard acknowledging receipt is not re-
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Responding to the Editor

This part of the course is optional, but I think you will find that your students are extremely interested in what happens to a paper after it reaches the editorial office. If most of them go on to research work as a career they will probably publish several papers and will need to know how to cope with editors' and reviewers' suggestions. This chapter may help them, too, to be systematic as well as sympathetic reviewers themselves when the time comes for them to judge others' work.

Before beginning to talk about corresponding with the editors of journals, you may have to explain that the system of editorial review varies from journal to journal, but almost always involves consideration of the manuscript by at least one expert in the field besides the editor. Description of the systems from your own knowledge and experience will constitute the most vivid possible exposition, so I have not attempted one here.

The editor's letter to the author will contain one of three decisions:

1. **Outright Acceptance**. This decision, the author's dream, is rare. Scientists are, by nature and training, critical, and it is unusual for them to find that anything is perfect, even when they believe that it is important and well executed. For a few journals, however, outright acceptance is routine: for example, the Proceedings of the National Academy of Sciences of the United States and of many other countries. The high standards of these journals are maintained by reason of the caliber of the authors who are permitted to publish in them, namely the members of the Academy. No response to a letter of acceptance is strictly necessary, although a gracious note of thanks cannot be taken amiss.

2. **Outright Rejection**. If the tone of the editor's letter makes it clear that he and his reviewers have fundamental objections to the manuscript and if the letter does not explicitly offer further consideration of the matter, the author is usually well advised to accept the decision with as much grace as he can muster. According to the reasons for rejection given, he should:

   a) Consider sending the manuscript, suitably modified as to "publisher's style" (see Step 23), to another journal. This course should usually be followed only if the reason given for rejection is that the article is too specialized (or not specialized enough) for the journal first chosen and would be more appropriately published elsewhere. Step 3 (What Is the Most Suitable Journal?) should have obviated this response, but we all make mistakes.

   b) Consider modifying the content and perhaps the length of the article, taking advantage of the criticisms offered, and submit it to another journal. If the experts in charge of the first journal so clearly disliked the manuscript on first submission, they are unlikely to view a modified version with any great relish, but a new editorial board may be more charitable or work within another frame of reference.

   c) Consider withholding the manuscript until he has obtained more extensive data and better support for his conclusions. Steps 1 (What Is the Right Time to Publish?) and 24 (Departmental Review) should have saved the author from this humiliation; but again, he and his friends may easily have underestimated the strictness of reviewers.

   d) Consider contesting the editor's decision. If the author feels that the reviewers have shown incompetence, have misunderstood a major issue, or have been unjust (and since reviewers are human beings, all these things happen), he has every right to urge the editor to reconsider his decision. Letters written in anger—and still worse, telephone calls—have little chance of success. Calm, reasoned rebuttals are almost always considered sympathetically, for editors are rarely complete fools or inflexible tyrants. They are busy, though, so tell your students to keep such rebuttals succinct and to the point. One copy of the manuscript should accompany the letter unless it is clear that the editor still has one in his files. Politeness is always well received.

3. **Request for Revision**. The "decision letter" often contains this request. The author should first determine whether the revisions requested are major or minor and then examine whether the letter states that the article would be acceptable if thus revised or only offers further consideration by the editorial board. This distinction may decide whether the revisions are worth the trouble.
Above all, the author should realize that the recommended revisions are suggestions, generally put forward by responsible scientists anxious only to further science. They are not commands or conditions of acceptance. He must make up his mind whether they will improve his paper or not, and adopt them or not accordingly. Pages on which any changes have been made (beyond a few words inserted or deleted) should be retyped, and the revised manuscript should be returned together with (a) a letter of thanks to the editor and the reviewers for their help; (b) a copy of the original manuscript if this will help the editor; (c) a list of responses to the reviewer's comments, giving reasons for not accepting the recommendations where appropriate; and (d) a list of changes made in the manuscript. All these considerate actions will assist and expedite the handling of the revised manuscript.

Correspondence concerning publication of a paper is often, unnecessarily, the cause or the product of anger. It should not be. Mature authors are those who have learned to value the constructive criticism of fellow scientists and to appreciate the sacrifice of anything up to 20 hours of time and (unpaid) effort on behalf of an unknown colleague. The young scientist will reach that maturity more quickly if the mechanism of the procedure, and especially the motives of those who participate, are well explained at an early stage of his career. Any sensible person will concede that it is preferable to receive criticism in private, before the publication of his paper, than after, when it has entered the public forum.

Above all, discourage your students from guessing at the reviewers' identities. Editors agree that such guesses are—surprisingly, perhaps—usually wrong. If the review is unfavorable, this inevitably leads to completely unfounded antagonism. The best approach may be to believe that every review is written by God; if this seems impossible or unlikely, tell your class to imagine its author to be a highly intelligent, though fallible, archangel whom they are unlikely ever to encounter in real life.
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Oral Presentation of a Scientific Paper

Editor's Preface:
Some justification may seem necessary for including a chapter about speaking in a book about writing. We do not intend, however, to be apologetic about this inclusion because no one will dispute that formal talks at local, national, or international meetings are often closely linked—as elements in the transmission of knowledge—with publication of the same work in an archival journal. From an organizational point of view, planning an article and planning a talk are identical up to a certain point, while the same principles of scientific style apply throughout. Didactically, the juxtaposition of a course on writing with a subsequent short course on oral presentation is excellent for teaching the similarities and differences between the two modes of communication. Finally, the writing that is necessary in the early stages of planning a talk provides yet another concrete example for your students of the postulate (see Chapter 2) that writing clarifies thought.

Timing:
Three to four one-hour sessions are sufficient. Principles can be dealt with, and exemplified by a 10-minute talk of your own, in the first two hours; in each subsequent hour three ten-minute talks can be given by the students and critically discussed, as explained in the chapter. These "rehearsal" sessions can be continued as long as you think them useful to the nonperformers (they are always useful to the performers).

You will probably find the following material useful:
American Chemical Society. 1961. Suggestions on How to Organize, Present and Illustrate a Technical Paper. Bulletin 8, available ($1.00, or 50c each on orders of 10 or more copies) from the Society at 1155 16th Street, N.W., Washington, D.C. 20036.


Oral communication plays an important part in the exchange of scientific information. The main purpose of a congress—oral discussion between participants—can be achieved only if a contribution is heard and understood. Scientists often travel thousands of miles to a congress, and each participant should feel duty-bound to be informative, interesting, and concise.

A delivered paper can have a dismal reception for many reasons, but often the main one is that because the proceedings of the conference are to be published, the speaker mistakenly regards his talk as a form of publication. He prepares the talk carefully, and dutifully reads it word for word from his manuscript. Students may be very ready to accept your statement that this is not recommended, but it is well worth the time to discuss with them why it is a bad practice. Point out the differences between oral and written communication—the finite attention span of a listener, the frequent presence of distractions in the auditorium, the inability of a listener to go back over a difficult sentence or to request that an inaudible one be repeated—and show how these considerations should induce the potential speaker to:

1. Capture the full attention of the audience at the very beginning.
2. State the underlying objectives of the research with even greater clarity and emphasis than in written articles.
3. Concentrate on concepts, and eliminate confusing details.
4. Discuss the purpose of each experiment, the conclusions drawn from it, and its connection with the main argument at the time that the results are shown, rather than in a separate "Discussion" section.
5. Present important ideas in several different ways, even at the risk of repetition (an undesirable trait in written presentation).

6. Use slides of lesser complexity than published figures and tables.

This chapter suggests some of the ground rules for an effective oral presentation. Most of what follows is applicable to a 10- or 15-minute presentation, since such short periods are frequently allotted for papers at large-scale scientific meetings. If a student can master the 10-minute talk, he should have little trouble—except, perhaps, that of providing variety of pace and pitch—with longer talks, for the difficulty most people experience consists not in finding enough to say but in condensing what they have to say into the time allowed.

Organization

Should one write out the talk? Yes, but never read it (the reasons will be discussed later). Once the talk is organized through writing, the text can be reduced to an outline. But it should be written out first, rather than simply outlined, so that one can (a) check the logical development, (b) ensure proper transitions, (c) check sentence length and thereby develop the habit of forming short conversational sentences, (d) search for synonyms for frequently recurring words that would otherwise lead to dullness, (e) discard attractive but inessential items, (f) develop colorful imagery, and (g) ensure that only familiar terms are used.

The shorter the time for an oral presentation, the more difficult is the task of organization. From the beginning, train your students to proportion their time correctly: 10 percent for the introduction, 80 percent for the body of the talk (procedure, results, and conclusions), and 10 percent for the summary.

The Introduction

A speaker often has many things to contend with at the outset. Rooms get overheated and smoky, and the audience may be restive after listening to previous speakers. People may be moving about in the rear of the room, greeting incoming or outgoing friends, rustling the pages of their programs, coughing, and so forth. The opening words of a speech must, therefore, be simple, easily understood, and carefully slanted toward the interests of the audience. One secret of speaking successfully to a large audience is to gain attention with the opening sentences; otherwise it may never be secured at all.

The part of the introduction that precedes the statement of purpose is called the approach to the audience because its aim is to arouse interest, to create a friendly and receptive mood, and to prepare the audience to listen and pay attention to the statement of purpose.

Many devices can be employed to capture audience attention, and students should be encouraged to invent examples. Opening with a narrative arouses interest because people like to hear stories. ("There is a story of two protein chemists who, encountering each other at the Biochemical Congress in Tokyo, got into an argument about . . . ;" or, "One of the most appealing stories in the history of organic chemistry is the one in which Kekulé, jolting along on top of a London bus, suddenly envisioned the benzene molecule in the form of a snake with its tail in its mouth. Unfortunately, the story is inaccurate.")

Opening with a quotation is effective if one is chosen that is relevant to the speech and points toward a direct statement of the speaker's purpose. ("Shortly after argon had been discovered, Lord Rayleigh said 'I have seen some indications that the anomalous properties of argon are brought as a kind of accusation against us. But we had the very best intentions in the matter. The facts were too much for us, and all that we can do now is to apologize for ourselves and for the gas. . . .' A somewhat similar situation has arisen with respect to the X-protein, the anomalous properties of which have formed the basis of several unjust accusations. Would it not be preferable to recognize the anomalies, and try to explain them?")

A rhetorical question centers attention on the purpose of the study and makes the audience think about the main issue. ("How much do we really know of the mechanism whereby DNA directs the synthesis of RNA?")

Sometimes a startling statement will jolt the audience into paying attention. ("Reading our most distinguished scientific journals corrupts the minds of young scientists," or, "Cell membranes seem to be wide open to penetration by all sorts of noxious substances—that is, if you consider them merely as physicochemical barriers.")

A negative statement will heighten the "suspense." ("Lowering blood cholesterol levels will not prevent atherosclerosis. At least, there has been no good evidence for this so far.")
A comparison or contrast makes a neat opening, particularly if the contrast is a striking one. ("In former times, delicate ladies were carried through the doors of opera houses in sedan chairs to avoid being jostled by the crowd. We are concerned here today with the concept of carrier molecules that will transport particular substances safely through the burly burly of the cell membrane," or, "Few phenomena are so well understood thermodynamically, or so ill understood kinetically, as the osmotic flow of a solvent through a semipermeable membrane.")

If the speaker knows the dominant interest of his audience, he can use it to establish an understanding with them. ("We are all familiar with the thesis that bats use some form of radar to navigate in the darkness. I would like today to offer a novel and unrelated explanation of their skill in avoiding objects under these conditions.")

The attention of a group can usually be caught by listing specific instances that relate to a general topic. ("Molecules can pass through a membrane by passive diffusion, or by dissolving in the membrane lipids, or by active transport. Which of these applies to the absorption of bile salts in man?")

Other introductory devices include the practice of starting with a broad statement and gradually narrowing it to lead into the purpose of the study being reported; the descriptive opening (best suited to papers dealing with new equipment, new techniques, etc.); and the historical approach.

Speakers on nontechnical subjects customarily open their talks with a funny story. The pseudohumor of the stock joke ("a funny thing happened to me on the way to the convention hall") is likely to fall flat on its face before an audience of scientists. However, the more subtle humor of asides interpolated throughout the speech is to be encouraged. Still other introductory possibilities include the asking of a question, which the speaker then proceeds to answer immediately; the listing of a series of particulars or a set of vivid details to provide transition to the main thesis; and the use of analogy, where the unknown is paralleled with the known. Examples of several types of openings for a single talk are given in the appendix (pages 165 and 166) to this chapter.

The most obvious device, of course, is to open with a statement of the speaker’s purpose. This is certainly one of the most useful when the audience is known to have a direct interest in the topic. However, there are dangers in this straightforward and commonsense approach, which rests on three assumptions: that the listeners have a consuming interest in the topic; that they have actually heard and understood the title of the talk and studied a previously published abstract; and that they have a thorough knowledge of work on the topic to date. These assumptions may be far from true.

Having (it is to be hoped) captured the interest of the audience, the speaker must state clearly the underlying objectives of the work—why it is of interest—and then give the exact purpose of the experiments to be described. The purpose may be quite a small part of the over-all objectives. There is no shame in this; indeed, the shorter the talk, the more circumscribed the purpose should be. Nothing is more foolish and arrogant than the sickly "Of course I can’t really compress four years of work into 15 minutes, but I’ll try." The speaker has not been asked to do so, and he has no right to insult his audience by attempting it.

Body of the Talk

Make it clear to your students that the body of a talk requires much the same logical organization of material as an article prepared for publication. The principles of style given in Chapter 6 apply with equal or greater force here. Ideas must be conveyed in short, clear statements (Rule 1). Words must be chosen and used appropriately and precisely (Rule 2) if the listeners are not to be distracted or misled. Vivid language can transform a prosaic talk into a memorable one and speakers should strive to avoid abstract nouns (Rule 3) and to use active rather than passive verbs. The terms used must be readily comprehensible (Rule 4). If the speaker feels that definition of a term is necessary, he must give the definition when the term is first mentioned, taking care not to sound patronizing as he does so.

The purpose of each experiment should be stated and related to the over-all purpose given in the Introduction. This takes time, but the time is well spent because the audience is really in touch with the thread of the argument. Because the time for presentation is limited and the audience is mostly interested in concepts, experimental details must be kept to an absolute minimum. They can always be elicited later during the question-and-answer period when the audience takes the initiative, and, of course, they can be provided in a printed text.

In stating the conclusions from each experiment, the speaker should keep the main purpose of the study in mind and ensure that every point he makes is related to that purpose.
VISUAL AIDS

Visual aids can be effective in maintaining interest, but only if they are used with judgment. They range from a simple tool like the blackboard to complex methods of slide or movie projection. Your students will welcome some discussion of their usefulness and disadvantages.

The use of the blackboard should be confined to small rooms, for people in the back must be able to decipher the message. Blackboard explanations should be planned in advance so that the first part of algebraic symbols or equations or lists will not have to be erased to make room for the last parts. Bits of information should not be jotted down in corners of the board, with sweeping lines to indicate where they should have been written in the first place. If circumstances permit, blackboard demonstrations should be executed in advance as well, otherwise much valuable time may be lost while the speaker is writing.

Illustrative slides are the most popular form of visual aids, but they, too, pose problems (see Table 1). Remember that slides take time; the audience must be able to understand them fully. At the very least, 1 minute must be allowed for showing and describing a slide, unless it is an extremely simple one shown for a single effect. Demonstrate by example why a graph is preferable to a table and why a simple graph is preferable to one cluttered with more detail than the audience can easily absorb. Let students practice writing captions that are both descriptive and concise and insist that axes be labeled in letters that can be read easily.

Audiences should not be left in the dark throughout the talk, but having the lights constantly flipped on and off can also be distracting. The best compromise is to show well-defined groups of slides, with the lights on between groups. When the speaker wants to provide many data, he will be well advised to show only a small group of slides and supplement them with handouts distributed after the talk (not before, or they, too, will distract the audience’s attention!).

The disadvantage of most projection techniques is that while the slide is being projected it replaces the speaker. A notable exception is overhead projection; it complements the speaker because he controls the machine while facing the audience in normal lighting. He can use separate components of a transparency (“vugraphs”) to build up a composite image or to disclose information progressively. The versatility of vugraphs in simulating

### Table 1 Use of Slides

<table>
<thead>
<tr>
<th>Design</th>
<th>Don’t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allow at least 1 min per slide</td>
<td>Make too many points per slide</td>
</tr>
<tr>
<td>Allow time for getting slide on and off</td>
<td>Plan too many slides for time allotted</td>
</tr>
<tr>
<td>Allow for accidents to happen</td>
<td>Use tables when graphs are more vivid</td>
</tr>
<tr>
<td>Provide titles for slides</td>
<td>Put too many lines on a graph</td>
</tr>
<tr>
<td>Plan exactly what to say about each slide</td>
<td>Use unlabeled axes</td>
</tr>
</tbody>
</table>

**Technique of making the slide**

<table>
<thead>
<tr>
<th>Design</th>
<th>Don’t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select standard size (2 x 2 or 3⅓ x 4 inches)</td>
<td>Use illegibly small numbers</td>
</tr>
<tr>
<td>Make material fit a rectangle with long side horizontal</td>
<td>Use square or tall slides unless unavoidable</td>
</tr>
<tr>
<td>Use colors if helpful, but not for doubtful esthetic effect</td>
<td>Use white letters on blue or black ground*</td>
</tr>
<tr>
<td>Label micrographs to direct audience to point of interest</td>
<td>Use poor-quality prints accompanied by an apology</td>
</tr>
</tbody>
</table>

**Presentation**

<table>
<thead>
<tr>
<th>Design</th>
<th>Don’t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure slides are in correct order and all the same way up</td>
<td>Keep audience continuously in dark</td>
</tr>
<tr>
<td>Locate the pointer before talk</td>
<td>Keep flicking lights off and on</td>
</tr>
<tr>
<td>Switch off a flashlight arrow-pointer after each use</td>
<td>Continue to show slide after it is needed</td>
</tr>
<tr>
<td>Show slide long enough for comprehension</td>
<td>Read aloud every word on the slide</td>
</tr>
</tbody>
</table>

* Some practitioners maintain stoutly that these “negative” slides are more legible than those with black letters on a white ground. In order not to be dogmatic about it, have your students use the experimental approach and judge for themselves between examples of the same slide made both ways and shown under good and bad conditions in a completely darkened or partly illuminated hall.

† Typewritten slides can be legible if all the material that is to be photographed on a 3⅓ x 4 inch slide is kept within a rectangle 56 spaces (4.8 inches) wide by 22 spaces (3.7 inches) high, and if a reversed carbon paper is placed behind the paper during the typing. Hand lettering is almost always preferable, however, because the ratio of black to white “blank space” can be increased and because many different sizes of letters can be used.
motion makes them ideal for describing various biological processes.

The professionals in the field of visual aids are the technical illustrators employed by most large institutions. Even if a scientist has mastered the art of graphic presentation in a written article, there is no guarantee that he is also a master at selecting the lettering that will project best. Encourage your students to consult professional illustrators and heed their advice. Too often these artists complain, and with justification, that "every author is an Art Director—he thinks!"

SUMMARY OF THE TALK

The talk should end with a summary of the ideas presented and leave the audience with the central theme firmly in their minds. Devices for ending the talk include restressing the main points, restating the thesis, concluding with an anecdote, concluding with a question, and concluding by stating a future program.

OUTLINING THE TALK

Once you have impressed upon your students the need for careful preparation and writing of a scientific talk, disabuse their minds of the notion that the talk should be read exactly as written. A speaker cannot hope to hold an audience if he buries his head in a text, raising it only occasionally to reassure himself that he is not alone in the room. Technical material is difficult enough for listeners to absorb without the additional burden of boredom. Train your students, then, to speak either entirely without notes or from a simple outline.

The three most common types are the topic outline, the key-phrase outline, and the sentence outline. The inexperienced speaker is well advised to construct all three in order to fix the organization of the talk in his mind in three different ways. The extent to which a speaker can free himself from the prepared text is usually in direct ratio to his experience as a public speaker. The experienced speaker writes and revises his speech, fixes the main points of the organization in his mind along with some of the key sentences, and uses only a few cards to refresh his memory. On these cards (5 x 7 inches, not smaller) may be written topic headings, key sentences, or transitional sentences; speakers differ on which they find most useful. Suggest to your students that they try all three types. The cards are merely a device to keep

ORAL PRESENTATION

the talk in sequence and to avoid the hazards of suddenly going blank. They are the visible end-product of much careful planning, the most important product of which is invisible—a mental image of the intention, structure, and conclusions of the projected talk.

Delivery

Nothing destroys a well-organized talk faster than its delivery in a mumbled monotone by a speaker who obviously wishes he were anywhere except on the platform. Deadly delivery, unintentional punctuation with ah's and er's, and nervous mannerisms evoke an audience reaction ranging from boredom to acute sympathetic embarrassment. All are obstacles that keep the audience from getting the message. Practice and more practice is the solution (more on this in the next section of the chapter).

Speaking Rate, Force, and Pitch

Justly or not, an audience is prone to judge a speaker in great part by the way he sounds. Granting that there is a tremendous range in natural ability, each speaker can, with a little training, make better use of his voice mechanism.

Because good speaking implies that the listeners should be able to think along with the speaker as he talks, a proper speaking rate is essential. It takes practice to avoid talking so quickly that the words are slurred. On the other hand, phrases should not be so dragged out that the audience yearns to supply the words.

The force used in delivery is as important as the rate. In a room that has no provision for mechanical amplification, the best rule is to talk to the people in the back row. Both force and pitch should be varied in a way that emphasizes the main ideas and important parts of the talk, and the longer the talk is to be the more planning should go into this variation. A deadly monotone should be avoided at all costs; the room is probably stuffy enough without giving the audience an additional reason for drifting off to sleep.

Microphone Technique

The increasing availability of mechanical aids permits a speaker to use a more natural voice and still be heard in the back row. However, the mere
presence of a microphone does not guarantee that his words will be understood, and amplification emphasizes the speaker's faults as well as any pleasing qualities his voice may have.

Coach your students to stand at least six inches from the microphone; the optimum distance will depend on the strength and quality of a particular voice and on the type of microphone. Have them speak in a natural voice and move away from the instrument slightly when they reach points they wish to emphasize by raising their voices. This will avoid undue amplification. Stress that they must never cough or clear their throats directly into the microphone unless they want to sound like the mating call of a bull elephant.

Practice will prevent "Mike fright" and ensure that the instrument is a help rather than a hindrance. Once the microphone technique has been acquired, the instrument can be ignored. Be sure your students don't talk directly to it; once they have lost eye contact, they have lost the audience.

Eye Contact
The inexperienced speaker is greatly tempted to look at the floor, the ceiling, out of the window—anywhere, in fact, except at his audience. But eye contact is absolutely essential to effective speaking. One helpful piece of advice is to tell the speaker to pick out several individuals in the audience and speak directly to them in turn—a man near the back row, a lady who looks as though her feet hurt, a man who seems in danger of falling asleep. If he can hold their interest, he has made it!

Posture
Posture is a comparatively minor part of delivery, but good posture can contribute much to the impression of relaxation, and the more relaxed the speaker appears to be, the more the audience will be at ease. Warn your students, however, against being excessively informal (hands in pockets, tucked into the belt, etc.), for this can be offensive to a distinguished audience. There is no standardized recommended posture, but there are certain awkward positions that you can help your students avoid. Standing with heels together and toes pointed out at a 45-degree angle tends to make the speaker's legs look tied together. Standing with feet wide apart, as though weathering a gale, will cause a rocking motion that is highly distracting to the audience. A natural stance results when the feet are placed 8 to 10 inches apart, one foot slightly forward of the other. This permits the weight to rest on the foot in back and allows a natural, easy movement when the speaker wants to walk toward the audience or move to right or left. Walking should always be planned and purposeful; aimless wandering about may relax the speaker, but not his listeners.

Gestures
An untrained speaker is extremely self-conscious about gestures and regards them as theatrical. Assure him that the complete absence of gesture is still more unnatural, because it suggests that he is made of stone, incapable of moving arms or legs and even of changing facial expression. Train him to let his arms hang naturally, not stiffly, and to move fluently from this position into the most frequently used gesture—pointing to a slide. The ability to locate and point to a portion of a slide while continuing to face the audience and to speak smoothly and coherently is fundamental to good oral presentation.

Ask your students to observe their colleagues in an informal conference. A man smoking a pipe or holding a pencil will gesture with it from time to time to emphasize a point; such gestures are spontaneous and come as a result of his concentration on what he is saying. Some gestures gracefully underline the speaker's words; others, even though unrelated to the subject matter, are somehow reassuring. Gestures in an informal talk should give an equally natural impression, although in point of fact they must be on a larger scale in a lecture theatre if they are not to appear puny or perfunctory.

Nervous Tension
It is natural for any speaker to feel some nervous tension when he faces an audience. A certain amount may actually be beneficial by acting as a mental spur. However, nervous gestures and visibly quaking knees disturb the audience. A rostrum is a handy gadget for concealing nervousness and awkward posture, but it should not be clung to as though in desperation. Absolute mastery of one's feelings seldom comes even with much practice in public speaking. However, there are ways to reduce nervousness. The most important one, of course, is to know the subject thoroughly, to be
completely sure of the outline, and to have prepared and rehearsed so thoroughly that absolutely nothing major can go wrong.

Advise a student not to start speaking as soon as he reaches the platform; instead, tell him to relax by taking several deep breaths. Then have him concentrate on his outline, pause slightly between paragraphs, and speak deliberately but in a normal tone of voice. Remind him that the listeners are sympathetic and want him to do his best. At worst, they are neutral toward him personally, having come in the hope of gleaning useful information. A single warm, friendly smile at the beginning does wonders to relax both the speaker and the audience.

**Timing**

As timing is so important, timing marks should be inserted into the organizational plan of the talk; changed, if necessary, during each rehearsal by a colleague listening with stop-watch in hand; and finally marked in red on the file cards used for the performance. If nervousness has made the speaker go faster or slower during the actual talk than during the rehearsal sessions, the timing marks will bring this to his attention early enough to make the appropriate correction.

A speaker who is neither hurrying nor dallying requires about one minute for 120 words. The equivalent of a double-spaced typewritten page will take roughly 2½ minutes to present. This allows time for brief pauses after important points.

A technique used by news commentators and other professional speakers will stand all speakers in good stead: rather than using a simple period at the end of each sentence, they place a series of periods at the end of principal thoughts. These are reminders to pause and allow time for audience comprehension.

**Getting off the Platform**

When inexperienced speakers realize they are nearing the end of a talk, they are likely to speed up the rate of delivery as though they cannot wait to finish and rush off—which, indeed, may well be the case!

Because the end of a speech should be its strongest point, the conclusion should be rounded out and the final sentence delivered in a firm voice. Train a student to avoid asking for questions when he finishes. In the first place, this is the chairman's responsibility; second, it precludes applause; and third, it takes the listeners' thoughts away from the speaker's final sentence.

Taking one step back after the final words and looking at the chairman is a good plan. This enables the speaker to pick up his outline during the applause and saves him from the final indignity of having to retrieve cards or papers that can be scattered far and wide by a hasty retreat.

**Rehearsal**

An instructor can render a lasting service to his students not only by convincing them of the importance of thorough preparation for oral communication, but also by providing opportunities for practice in giving talks. A first step in developing effective speaking techniques is to organize working sessions in which one student gives a 10-minute talk, with the rest of the class at the back of a lecture room to serve as audience. Familiarity with the subject is the best way to avoid nervousness, so topics should be carefully selected—one that ties in with part of a student's major assignment from the writing course, or a description of some other research he has conducted, or a "journal club" presentation summarizing one or more papers in which the speaker is particularly interested. You can gain the confidence of your class and create an atmosphere of constructive criticism by leading off with a 10-minute talk yourself and inviting criticism. If you don't want your self-image to be too badly bruised, insert some deliberate errors in both speech and slides to permit the criticism to have a starting point and a focus.

When tape recorders are available, they should be recommended for solo rehearsal sessions. Their usefulness is, however, limited, because the delivery may sound slow to the practicing student when actually it is the proper speed for audience absorption.

Classroom practice sessions serve a function that no amount of solitary practice can. They provide the "live" audience essential for rehearsing eye contact, gestures, and other aspects of platform ease. The question-and-answer period following his presentation can pinpoint the weaknesses in a student's talk, particularly by showing him the points he failed to make clear and those he should have emphasized more.
There will be times when questions directed to the speaker strike him as stupid or even malicious. Tell him to make sure he has heard the question correctly. Asking that it be repeated also gives him additional time to marshal his thoughts and phrase his response. If a courteous and informative reply is not accepted, the speaker can suggest meeting his questioner later so they can go into more detail without bogging down the session or running over the allotted time.

The question period can also prepare him for the shock of an unresponsive audience. It is most disheartening to conclude what one feels was an effective presentation and have total silence in response to the chairman's request for questions. One question is usually all it takes to get an audience started. The student will do well to furnish one or two of his close friends with questions he would like to be asked. Their questions not only get things moving but also give him an opportunity to provide more detail on a point than time limitations allowed in his formal presentation. This device, incidentally, is often employed at large-scale congresses by scientists who have gained recognition as effective speakers.

Criticism of a student's initial efforts should come mainly from the instructor and they should be constructive. Greater frankness can come later! Class seminars make a useful forum in which the fledgling speaker can gain confidence before venturing farther afield, and they prepare him for the unexpected hazards of oral presentation—the disappearing chalk, the unadjustable microphone, slides that persist in being out of order or upside down, and fainting or other disturbances in the audience.

Something that students find most surprising is that success in presenting serious, scholarly work depends to a considerable extent on techniques borrowed from the theatre. Coach the shyest and most introspective of your students to give his short talk in an overemphatic, theatrical way, with a degree of projection that he considers inappropriate, and ask for the class's reactions. If the lecture room is any bigger than a classroom, the chances are that the class will think it a refreshingly clear performance, not in the least exaggerated. Even the tape recording will reveal to the distrustful performer that he is by no means a candidate for an Oscar, but has merely given—perhaps for the first time in his life—a talk with the firm, strong delivery that it deserves.

APPENDIX TO CHAPTER 13
Examples of possible openings for the topic The Epidemiology of Frostbite, suitable for many different types of audience.

THE NARRATIVE
“The typical sergeant in Korea during the winter of 1951–52 was a mother hen. He coaxed, pleaded, cajoled, and ordered his men to change their socks often, to cleanse their feet as often as possible, to keep moving their toes and fingers as much as possible when pinned down by enemy fire. A man so eager to have his men do such things is not likely to forget to do them himself. Small wonder, then, that the rate of frostbite among sergeants at identical risks was 4.2 per 1,000 compared to 13.0 for privates.”

RHETORICAL QUESTION
“Why did so many American fighting men suffer frostbite in Korea during the winter of 1950? Was it because Uncle Sam was unprepared? Was it that Uncle Sam just didn’t care?”

STARTLING STATEMENT
“Alcohol is the most successful protection against frostbite—alcohol taken internally and in large quantities. Or so we might be led to believe from newspaper stories of drunks who peacefully survived a night in an alley under winter temperatures that could be expected to kill an average person.”

NEGATIVE STATEMENT
“Improved standards of clothing developed on the basis of World War II did not prevent cold injury during the Korean conflict. Improved equipment designed for better operation in freezing temperatures did not prevent cold injury during the Korean conflict. And training techniques in effect from the lessons of World War II failed to prevent cold injury during the Korean conflict.”

COMPARISON OR CONTRAST
“The United States Army often awards the Purple Heart to soldiers who have incurred frostbite. The British Army is more apt to slap their men with a charge of malingering.”
REFERENCE TO AUDIENCE'S DOMINANT INTEREST

"All of you here this morning have a special interest in cold injury. Some of you have made important contributions to that general area, either by categorizing degrees of severity of injury or by delineating treatment regimes. But I wonder how many of you have given thought to such subtle modifying factors as fatigue and morale."

LISTING OF SPECIFIC INSTANCES

"A frontline rifleman is more apt to suffer frostbite than a cook at Division headquarters. An inadequately clad soldier is much more susceptible to frostbite than one who is warmly clad. But how do we explain the fact that one soldier suffers frostbite while another, wearing the same type of combat clothing and in the same immediate locale, does not? What, in insurance language, is it that makes one a better risk than another?"

GRADUAL NARROWING OF BROAD STATEMENT

"Weather conditions during the 1950 police action in Korea were probably the most severe ever faced by the American fighting man. Winter temperatures were lower than those in Europe during World War I or in either Europe or the Aleutians during World War II."

DESCRIPTIVE OPENING

"For the first time in field research into cold injury under combat conditions, finite temperatures and wind speeds were measured along the front lines. The separation of data according to intensity of combat permitted formulas to be devised that were reasonably reliable in predicting the incidence of frostbite under other conditions."

HISTORICAL APPROACH

"Historical reference to cold injury in war goes back many centuries. The armies of Alexander the Great experienced it, as did Napoleon's forces in Russia. Indeed, cold continued to be an effective ally of the Russians in World War II, as can be attested by any German soldier who survived a Russian winter."