NOAA Technical Memorandum NMFS-NE-185

Revised and Updated Edition of F. Bruce Sanford's 1957 "Planning Your Scientific Research Paper"

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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181. In press.

182. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2003.** By Gordon T. Waring, Richard M. Pace, Janeen M. Quintal, Carol P. Fairfield, and Katherine Maze-Foley, eds., Nicole Cabana, Phillip J. Clapham, Timothy V.N. Cole, Gregory L. Fulling, Lance P. Garrison, Aleta A. Hohn, Blair G. Maise, Wayne E. McFee, Keith D. Mullin, Debra L. Palka, Patricia E. Rosel, Marjorie C. Rossman, Frederick W. Wenzel, and Amy L. Whitingham, contribs. May 2004. vii + 287 p., 47 figs., 58 tables, 4 app., index. NTIS Access. No. PB2004-106431.

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Revised and Updated Edition of F. Bruce Sanford's 1957 "Planning Your Scientific Research Paper"

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Editorial Notes

Internet Availability

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Preface to the Revised Edition

In my 28 years as a technical writer-editor for the Northeast Fisheries Science Center (NEFSC), I have been asked on several occasions by different Center Directors and division chiefs to go beyond editing research papers, to training specific individuals in order for them to write better papers. In general, those individuals were young scientists who had been identified as having strong research potential, but weak writing skills. In each case, I worked one-on-one with the young scientist, evaluating his/her previous papers, pointing out the relative strengths and weaknesses of the writing, suggesting methods for correcting the weaknesses, and providing reference materials for further self-training. The results for the young scientists were mixed: some individuals showed improved writing, adopting the lessons from the training; others showed little or no improvement, reverting more or less to their pre-training weaknesses. Because I am trained and experienced in technical writing and editing, but not as an instructor *per se* of those activities, it is unclear to what extent the mixed results were a consequence of the failures of the instructor or of several of the instructees.

The results for me personally, though, were not mixed. Every individualized training exercise took a lot of time and effort. From an efficiency standpoint, I found it more and more difficult to justify that time and effort with each new exercise. Consequently, I began to look around for an existing training tool -- a manual, a videotape, a course, anything -- which would let me effectively train individual scientists without taking a lot of time, or, let me effectively train many scientists concurrently regardless of the time taken. Dozens of training tools, from a Society for Technical Communication training manual to a U.S. Air Force training videotape to a U.S. Department of Agriculture Graduate School training course, were evaluated, but nothing seemed to address adequately the typical weaknesses in the writings of these young scientists. I was resigned to having to design and deliver my own training course.

Then I accidentally came across an old, faded report on "Planning Your Scientific Research Paper," authored by F. Bruce Sanford, a chemist with the U.S. Fish and Wildlife Service's (USFWS's) Branch of Commercial Fisheries in Seattle, Washington. The report was issued as *U.S. Fish and Wildlife Service Commercial Fishery Leaflet* 10 (February 1957, 95 pages). The title caught my attention, so I scanned the report. Although some of the information in the report is outdated, and some of the information I personally would not follow nor recommend that others follow, it nonetheless -- *as a whole and at the conceptual level* -- comes the closest to an effective and efficient training tool to address the predominant weaknesses in the writings of the NEFSC's young scientists.

Soon after I came across the Sanford report, I attended a November 2002 meeting for scientific and technical editors of the National Marine Fisheries Service (NMFS) in Seattle, Washington. A major thrust of that meeting was to identify the needs of NMFS for improving its scientific publishing program. Identified as a key need was the training of our young scientists to write better research papers. I mentioned the Sanford report; several at the meeting felt that it might be a useful training tool, so I committed the NEFSC and myself to updating and revising the report and re-issuing it in the *NOAA Technical Memorandum NMFS-NE* series for use throughout NMFS as my counterparts might see fit.

This report is an updated and revised edition of Sanford's 1957 report. Much of the new information which is conceptually different from the original information has been kept separate from the original information. In the paper version of this report, this new information is contained in an "Endnotes" section; in the online version, this new information is accessed through internal links. This separation of new and original information has been done to achieve two objectives: 1) to recognize properly the contributions of Sanford in his original work, and 2) to identify the contributions of myself should there be any disagreements by readers over the recommendations inherent in the new information. Very limited editing of Sanford's original work has been performed where there were some obvious errors, outdatedness, and awkwardness -- after all, Sanford was a chemist, not an editor.

The original report had 23 figures: 18 which used cartoon-like caricatures and provided humorous emphasis of the points made in the text, and 5 which provided substantive examples of the points made in the text. The five substantive figures have been redrafted and appear in this updated and revised edition of the report.

The separation of the original and new information also means that the core of the report reflects the views of society and the manner of language of almost a half-century ago. In one of Sanford's examples, he describes how to cut up a whale for market. Throughout the report, only masculine pronouns are used. There are other examples as well. If anyone finds Sanford's original report to be politically incorrect and thus offensive, then there is an antidote: grow older by about -- oh, let's say -- 50 years, then look back; many of the views that are politically correct today will not necessarily be politically correct then.

For NEFSC researchers, this report should not be read alone, but also in combination with the NEFSC's official position on such matters: "Manuscript/Abstract/Webpage Preparation, Review, and Dissemination: NEFSC Author's Guide to Policy, Process, and Procedure," which is available on the NEFSC Intranet. The NEFSC author's guide contains important information which complements and supplements the information in this updated and revised edition of Sanford's 1957 report.

Finally, I take this opportunity to thank Laura Garner, an editor with the NEFSC's Research Communications Branch in Woods Hole, Massachusetts. In my 24 years before Laura joined the NEFSC, I handled a host of time-consuming technical and administrative tasks associated with the NEFSC's scientific publishing program. In the five years since, Laura has handled a number of those tasks, freeing me to undertake several special projects such as this updating and revising of Sanford's 1957 report. She also retyped the original report in order to have it available in an electronic format.

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JUNE 14, 2004

"Your paper is both good and original.
Unfortunately, the good part is not original,
and the original part is not good."

Ben Johnson (1702-1784)

Abstract

This manual presents numerous suggestions on how to plan your scientific research paper. The first part deals with preliminary steps in planning such as outlining, choosing headings, and making up tables. The last part deals with the following: title, abstract, introduction, methods, results and discussion, conclusions, summary, and literature cited or bibliography. Much stress is laid on the importance of keeping your paper in mind from the moment your research is conceived, of making adequate use of tables and making them clear, of using outlines, and of using headings. Particular attention is focused on the introduction and on the need for stating your specific problem and for orienting your readers to it. Suggestions are given on how to deal with problems in the writing of the methods, results and discussion, and the conclusion. The differences between the conclusions and the summary are made clear. Relationships between the title and the abstract and between the title and the specific objectives stated in the introduction are pointed out. Finally a reminder is given of the importance of following the format of your journal when you are citing the literature.

Preface to the Original Edition

(*Note: This manual is not a scientific research paper; hence it does not follow the style of such papers, particularly in the use of personal pronouns.*)

Definition

For the purposes of this manual, a scientific research paper is considered to be a report in which you: 1) state what specific problem (or set of closely related specific problems) you were trying to solve; 2) explain the significance of your problem (if you think that your intended audience may need this explanation for a full understanding of your work); 3) tell what method you used to solve the problem; 4) give the results you obtained; and 5) list the conclusions or the recommendations you arrived at after considering these results. **[*See Endnote #1.*]**

Importance of Planning

Giving careful thought to the plan of your paper is important to you in three ways: 1) your research will be aided; 2) your papers will be less difficult to write; and 3) your papers will be easier to understand.

Aid to Research

Carefully considering the organization of your research paper will aid you in planning the research itself and will catalyze your flow of ideas on the research. Furthermore, it will help to insure that your research will be carried out soundly and that your findings will be published.

Aid to Writing

If your paper is written poorly, it may be subject to major revision -- which means, in addition to spending time in writing the original paper, you must spend significantly further time in revising it.

The time spent in the revision of your work can be longer than the time spent in the original writing; and if your paper is reviewed by several critics, the number of pages of criticism can be more than the number of pages of writing in your original paper. You then wearily must read, evaluate, and act upon all of this tiresome criticism. If your paper has been criticized and revised greatly, you hardly will be able to recognize the final publication as being your own, and it still may not be good. After a few experiences of this kind, you are likely to lose much of your enthusiasm for research.

Experience has shown that a principal cause of poor writing in scientific papers is poor planning. Experience has also shown that the poorly planned papers require the greatest amount of revision. Your errors in grammar, for example, can be corrected with relatively little difficulty; whereas those in planning often require you to rewrite your entire paper. A knowledge of planning therefore will make your paper much easier to write.

Aid to Comprehension

The number of research papers now being published is so large you are faced with the bitter choice of trying to keep abreast with the advancements in your field or of doing research of your own. Your fellow scientists have the same problem. They therefore read your published research papers in the same way you read theirs -- hastily. Thus, if one of your papers is poorly written, it is not likely to be given sufficient attention for full appreciation and comprehension of your work. To the extent then to which you fail to write your papers clearly, the time spent on your research is likely to have been ineffectual; and the funds spent, to have been wasted.

The seriousness of this problem seems not generally to be realized; at least there does not seem to be a general awareness that anything much can be done about it. Somehow, the impression prevalent among laymen that scientific papers are hard to comprehend is believed by scientists themselves. Thus if you publish a paper that is unclear, no one censures you particularly, since the majority of your fellow scientists apparently themselves believe that scientific papers are inherently difficult to understand. Can you visualize, however, what the effect on science would be if all papers were clear and

easy to read -- if all you had to do was to read rapidly through a paper once and you would comprehend it completely?

You can see that such an improvement in the clarity of scientific papers would effect almost a revolution in scientific progress.

Can all scientific papers be written in this manner? Experience in writing, in abstracting, and in editing has led me to believe that they can be. Without underestimating the great importance of the other elements of composition, I also have been led by this experience to believe that poor planning is one of the basic causes of unclarity in scientific papers. My purpose therefore in presenting this manual to you is to enliven your interest in planning and to offer you some suggestions that have proved helpful to others.

Plan of the Manual

The plan of this manual is simple, for it might be considered as having only two main parts. In the first of these, you are given general suggestions on the planning of your paper; and in the second, some rather specific suggestions related to the title, the abstract, the introduction, the methods, the results and discussion, the conclusions, the summary, and the literature cited or bibliography.

PRELIMINARY CONSIDERATIONS

GIVE THOUGHT TO IMPORTANCE

The quality of your research paper will depend in no small part upon your attitude toward the writing. If you are not convinced that the paper is an important part of your research and that the time taken to make the paper easily readable and clear is well spent, you obviously will not give the writing of the paper the attention that it requires.

During your period of university training, you probably spent only 5 percent of your time in learning how to write and some 95 percent in learning how to do research. **[*See Endnote #2.*]** You therefore unconsciously may feel that the writing is only about one nineteenth as important as is the research work itself.

Yet, depending upon the use to which your research findings are to be put, the effectiveness of your research may depend entirely upon your paper. If, for example, the users of your results will not be able to query you directly, your entire research effort may be wasted if you write any of the essential parts of the paper in an ambiguous manner or if you leave any important questions unanswered. Furthermore, if the paper is too hard to read, the potential users of the results of your research may never find the time to decipher what you have written. **[*See Endnote #3.*]** Therefore, if you are not content to pass your time in a scientific squirrel cage and really want to have your work count for something, take the care in planning and in writing that is required to make your paper unambiguous, complete, and easy to read.

PLAN FROM INCEPTION OF RESEARCH

Writing your paper can be made much easier if you will start to plan it from the moment that your research is conceived. Think back to whatever papers you already have published and you undoubtedly will remember some that would have been far less difficult to write if you had carried out the research in a better manner.

You cannot write a logical paper if the research itself was not logically organized, for your paper can never be any better than the research it reports. By keeping your paper in mind while you still are able to modify the direction of the research, you can make whatever changes are necessary to enable you not only to do your research in the best way but also to report it in a logically developed paper.

Keeping your paper constantly in mind is particularly helpful to you in the following five ways:

1. You save yourself from doing useless work by deciding, before you start the research, whether the finding will be publishable. Incidentally, in starting your research and in carrying it through to completion, keep in mind that you eventually will have to write an introduction to your paper in which you must show, directly or indirectly, the need for the data you have obtained. Unless you carefully have determined prior to undertaking the work and while completing it that your problem is one that definitely needed solving by your particular organization, you will find that the introduction will be exceedingly difficult to write.

2. You prevent yourself from wandering aimlessly. In each of your research papers, you should make a concrete and specific statement of the problems you were trying to solve. Obviously, if your research had no clearly defined objectives, you cannot state them in the paper. By keeping your paper in mind, you recognize the need for defining the objectives of your research as soon as is possible, and you thus avoid wandering.

3. You protect yourself from being sidetracked. One of the pleasures of research is that of making an unexpected discovery. After such a finding, you naturally are tempted to learn more about it unless you clearly realize that the data you obtain in this new investigation will not fit into the paper on the original problem. The correct procedure is to keep on with your original objectives and to set up the new discovery as a project for later investigation.

   Often the only immediately tangible result of your research is your research paper. After you have spent a reasonable time on your investigation, you therefore are expected to write a paper reporting your results. If you have followed the will-o'-the-wisp of new discoveries and have not held to your original problem, you may be hard pressed to find enough data on a single subject. You then may decide to throw into one paper all of the data you have obtained on your series of more-or-less unrelated experiments. Since the subject matter of the resulting paper has no obvious unity, you are now faced with the tortuous experience of trying to supply verbally the unity that was not inherent in the investigation. After a paper of this kind has gone through the mill of criticism, you well may have spent as much time on the work of writing and of revising as you did in carrying out the original research. All of this effort then may terminate in nothing worthwhile accomplished because often such papers finally are rejected for publication.

   Thus, it is not sufficient to have clearly defined goals; you must stick to them.

4. You help to insure yourself against overlooking or neglecting some factor on which data must be given when you publish. Ordinarily, if you fail to make some of the required observations, you will not discover this fact until you start to write your paper -- which may not be until after your project has been termi-

nated and the data are impossible to obtain. On the other hand, by keeping your paper constantly in mind, you are not apt to overlook anything that you will require when the paper is being written.

5. You help to insure yourself against carrying out the work in an unscientific manner: that is, the more thought that is given to the research, the more likely it is to be sound. Also, by keeping your paper in mind, you are more likely to watch for those points on which you might be criticized when you submit your paper for publication.

From the discussion of the preceding five points, it is clear that by giving thought to your paper while you are planning and carrying out the research work, not only will you write a better paper, but you also will do a better job of research.

MAKE EARLY DECISION AS TO WHO WILL WRITE

Since most research projects are cooperative ventures involving several workers, there may be a problem as to who will write the paper; that is, the senior author is not necessary the one who does the actual writing of it. Hence, a decision should be made as to which one of the research workers is to have the primary responsibility for writing the paper and for seeing it through to publication. This decision should be made early so that the paper can be kept in mind from the very start of the research. (Other aspects of authorship have been discussed by Young and Crowell (1956).)

ALLOW SUFFICIENT TIME FOR WRITING AND PUBLISHING

A common error in scientific writing is the failure of research workers, in planning their project, to allow sufficient time for writing and publishing the paper. This process of writing and publishing is complex and time-consuming, particularly if several workers are involved. As a result, estimates of the time needed are almost invariably too short. The writing and related tasks required in the publishing of the paper then must be sandwiched in between other projects or must be done outside of working hours.

Any delay in the publication of the paper can add greatly to the other complications. Other rush projects may take every moment of available time, or key workers may become ill or transfer to other jobs. Thus your paper may never be published if sufficient time is not assigned for the work that will be required in the writing and publishing of it.

ALLOW SUFFICIENT TIME FOR SEARCH OF LITERATURE

As has been pointed out by Piskur (1956), the scientific literature represents a tremendous amount of man-years of work that is available to research, development, and production. Thus, in a search of the literature, you obtain "experimental results, history of experiences, and data at a cost in effort and supplies comparable to as little as a p.p.m. or even a millimicroγ of the supplies and labors expended to produce this information." Obviously, the failure to make a proper search of the literature is a colossal blunder. Furthermore, when you write the introduction to your paper, you will look foolish if you have not searched the literature well.

In many lines of research, the old idea of changing one variable at a time is inefficient. You therefore should consider your statistical requirements or possibly consult a statistician when planning your research. At the termination of your project, however, you cannot expect the statistician to wave his magic wand of mathematics over a hatful of unreliable data and pull out a sound research rabbit for you. That is, statistics is not a substitute for careful planning, sound experimental techniques, and old-fashioned common sense.

TAILOR PAPER TO AUDIENCE

Write your paper in such a way that your intended audience will understand it completely after rapidly reading it through once. **[*See Endnote #4.*]**

To accomplish this, you will have to visualize your audience. In particular, you will have to visualize the least informed individual who you wish your paper to be read by, because you will have to write the paper at a level he will understand. Otherwise, in effect, you will have eliminated him from your audience and will have narrowed your readers accordingly.

The more specifically you can visualize this least informed individual, the more successful you are likely to be in reaching the entire audience you have in mind. By writing for a well characterized individual, you will be able to determine better: 1) what he already knows, and 2) what he needs to be told.

Remember that the better informed you assume this individual to be, the narrower will be your circle of understanding readers. If you lose sight of this fact, you unwittingly may exclude from this circle, by your method of presentation, the very people you most would like to have read and act upon your paper.

Unless you have a good reason for doing otherwise, I would suggest that you visualize as your least informed reader, a recent graduate with a bachelor of science or engineering degree in the field in which you are writing. This

practice will give you about the widest audience possible without making your paper into a popular one or involving you in vast amounts of explanation.

Whatever audience you choose, you should keep your presentation consistent, for any shift in your point of view will alienate some of your readers. If you start your discussion after introducing it on a more difficult level, you will give your better informed readers the impression that you are starting to talk down to them. By keeping one fairly well characterized individual in mind while you are planning and writing your paper, you are less likely to fall into these errors.

LIMIT SCOPE

Complexity of Ideas

To express an idea, you must use a certain minimum number of words. Unless you use this required number, you are obviously doomed to failure. **[*See Endnote #5.*]**

The number of words required depends upon two factors: 1) the complexity of the idea, and 2) the background of knowledge of the least-informed member of your audience. Owing to the limitation in space in the scientific journals, you are restricted as to the type of subjects you can present to certain audiences. If you do not keep this fact in mind, you may attempt to present too complex an idea for the audience in the particular journal in which you intend to publish. For this reason, you should carefully consider whether the limitations in space in your contemplated journal will preclude a successful presentation of the idea that you had in mind.

Number of Subjects

The more different subjects you present to your readers at one time, the greater the difficulty they will have in understanding you, and the harder you will find the paper to write. In planning your paper, make certain you are dealing with only one problem or with only one set of closely related problems. You are not justified in reporting two or more separate research projects in the same paper -- even though you may have studied all of them at the same time. Unity is just as important in scientific papers as in any other type of publication. **[*See Endnote #6.*]**

If you limit your paper to reporting only one problem or one set of closely related problems, you may find that some of your papers are relatively short. If you are not reporting upon a fragment of your research, do not let this fact disturb you because there is nothing less "scientific" about a short paper than about a long one. (This topic is treated by Young and Crowell (1956).) The value of your paper lies not in its length but in its contents.

CONSIDER THE TABLES [*See Endnote #7*]

It does not appear generally to be realized that many subjects can be presented better in tables than in words alone. Almost any subject that is difficult to write because of its repetitive nature can be given better in tabular form; that is, the use of tables is not limited necessarily to the presentation of numerical data, as can be seen from Table 1. (Note: This illustration shows you the value of using a table for repetitive material. If you are skeptical, try presenting the contents of this table in writing. Also, to conserve space, I have abridged the table, as I have most of the others in this manual. The longer tables would have illustrated the various points more impressively.) In fact, almost every subject that can be presented in a table will take less writing time, will require less space in a journal, and will be much easier for your readers to comprehend if it is given in a table rather than in a written discussion.

The names of the various parts of the formal table are shown in Table 2 (Jenkinson 1949). Table 3 gives a specific example corresponding to Table 2. Compare these two tables. **[*See Endnote #8.*]**

The following are suggestions on the preparation of tables:

1. Present all of your tabular material in formal tables. There are two reasons for this suggestion: a) the formal table, being able to stand independently of the text, is the clearest of all tables; and b) since the formal table does stand independently, the printer can place it on the pages wherever it will fit best.

2. Type each table on a separate sheet of paper. If you follow this practice, you will not have to retype your table every time you revise the text -- or vice versa. **[*See Endnote #9.*]**

3. Give special thought to the title. Keep it short, if you can, but make it adequate, and make it logical. The title preferably should give the intent of the table rather than merely catalogue its contents, which the reader readily can determine for himself by reading the various headings. The title of Table 4, for example, might have been given as: "Composition of press cake and of the corresponding meal produced in different types of dryers." Such a title, however, would not show exactly the relationships that the author had in mind. The title "Effect of the type of dryer upon the vitamin content of the meal as compared with that in the press cake" reveals more the intent of the author because the information wanted was the following: a) is there a loss of vitamins when the press cake is dried to meal?; and b) if the vitamins are decomposed, which type of dryer contributes to the greater loss? You can see that the title I suggested as a possibility does no more than hint at

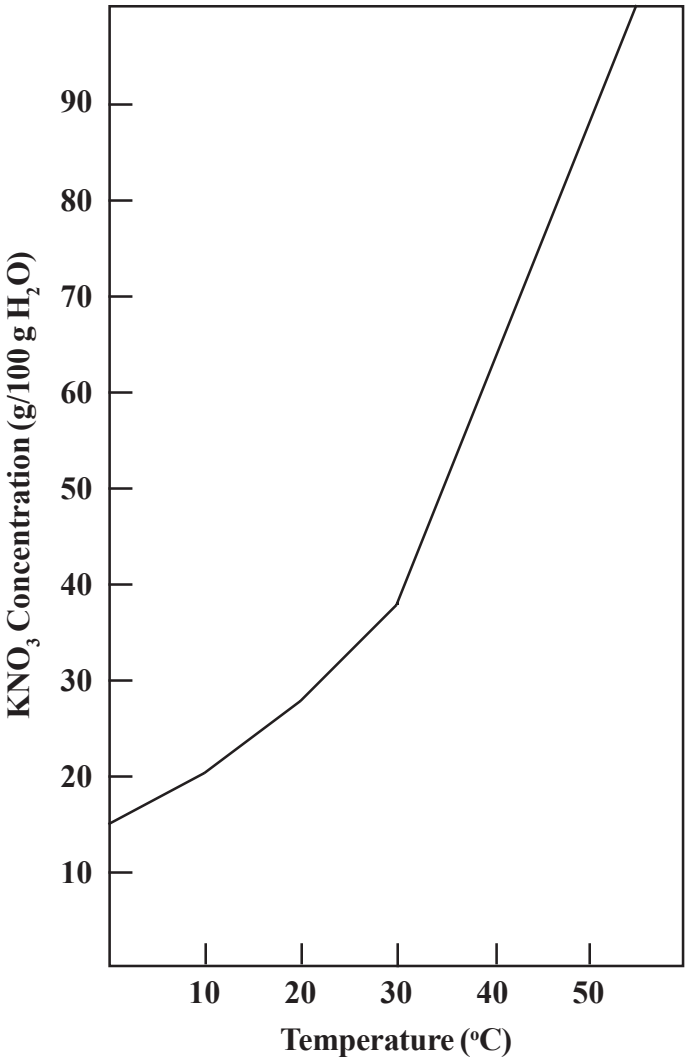


Figure 1. Influence of temperature on the solubility of potassium nitrate in water.

these relationships and therefore is not nearly as good as was the one chosen by the author.

4. Try to place the units at the head of columns (Table 4), if at all possible, rather than bury them in line captions (Table 5). (If your head is nodding at this point, wake up because this suggestion is tremendously important to you. Placing the units at the head of columns not only greatly aids clarity but also makes your tables far easier to design.)

5. Draw vertical guidelines between all columns. (Here is another simple but highly important suggestion. Compare Table 6 with Table 7.)

6. Draw the appropriate horizontal guidelines (Table 4 and Table 7).

7. If room permits, space each line of data (Table 8 and Table 9). To learn whether horizontal guidelines and spacings between lines of data in tables contribute to the clarity of the tables, I polled 53 readers and asked them to compare Table 7 with Table 8, Table 8 with Table 9, and Table 9 with Table 10. The results of this poll, which are given in Table 11, indicate the following: a) most of the readers preferred the use of horizontal guidelines; b) most of the readers preferred relatively wide spacing between the lines of data; and c) when the spacing between the lines of data was decreased, more of the readers felt the need for horizontal guidelines than when the spacing was wider. On the basis of this limited poll, I recommend that you take Table 4 and Table 8 as your standard format, without forgetting suggestion No. 9 below.

8. Make your tables stand independently of the text.

9. Regardless of any of the preceding suggestions, follow the format of the journal to which you intend to submit your paper.

10. Test your table by asking someone who is not familiar with it to explain it to you.

Your tables should be devised, of course, prior to the time that you first start to gather your data. These data then can be entered in the appropriate table as they are obtained. This practice will enable you to follow the trend of your research more closely than if you wait until you start to write your paper before devising your tables and entering your data. By following this practice, you are not likely to miss taking any of the essential observations.

CONSIDER THE GRAPHS [*See Endnote #10*]

If the same information can be given in either a table or a graph, the graphical presentation is likely to be comprehended more readily by your readers. Tables, however, have certain advantages that should not be overlooked. Exact values, for example, can be taken directly from the table, whereas they are somewhat more difficult to determine from a graph. If the policy of your journal permits, you therefore may wish to present both the table and graph.

In constructing your graph, keep in mind that it probably will be photographically reduced in size for publication. Therefore, make all of the lettering and the figures large enough to be read easily in the published paper. **[*See Endnote #11*.]** Do not forget to label your ordinate and abscissa and to state the units, if any (Figure 1). **[*See Endnote #12*.]**

The title of the graph should reflect your intent rather than merely repeat the variables that can be read from your labeled ordinate and abscissa. Figure 1, for example, might have been given the title: "Concentrations of Potassium Nitrate Versus Temperature." This title lists the variables but does not reveal much of the intent of the author. Note how much more informative is the title: "Influence of Tem-

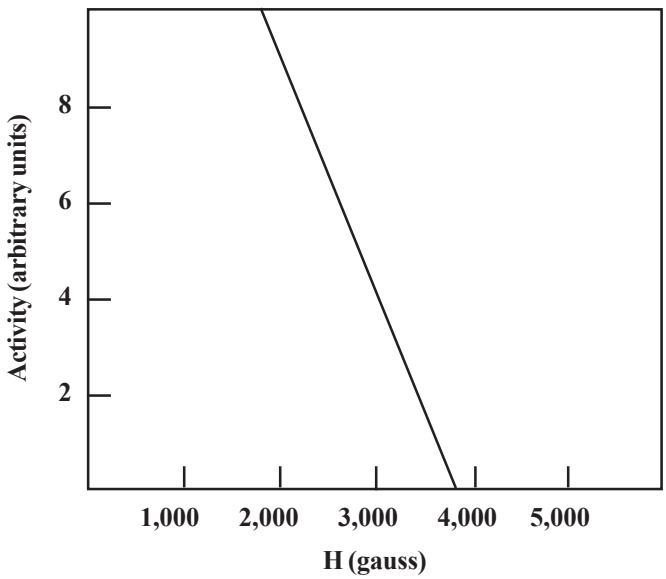


Figure 2. Variation of ionization current with increasing magnetic field.

perature on the Solubility of Potassium Nitrate in Water." This second title supplies information that otherwise might not be apparent to the reader.

The value of an informative title is illustrated further by Figure 2. Could you have guessed the intent of this table from a mere listing of the ordinate and the abscissa?

Follow, of course, the format of the journal in which you intend to publish. You will save yourself much effort if you will check on the format before you make the graphs.

CONSIDER THE PHOTOGRAPHS AND OTHER ILLUSTRATIONS

Many subjects are impossible to present adequately by words alone, and almost all others can be made clearer and more interesting if they are illustrated. If your journal permits the use of illustrations, you show a lack of perception if you do not make adequate use of them. **[*See Endnote #13*.]**

Including illustrations in your paper often requires forethought. If photographs are to be used, you may not be able to take them after your project is completed. Try to schedule your photographs ahead of time or at least to keep the need for them in mind while you are doing the research.

MAKE OUTLINE

One of the really great labor-saving devices in the writing of scientific papers is the use of an outline. Unfortunately, many beginning writers in science are not convinced of this fact. The result is much unnecessary work not only for the authors, but also for typists, critics, and editors. It therefore follows that the least expensive way to write a scientific paper is first to make an outline. The mere fact that you may have published papers without an outline proves only that: 1) some of the published scientific papers are vastly in need of improvement, and 2) many workers who may be expert at research do not know how to plan and to write scientific papers properly.

A word of warning: the use of an outline is not foolproof. The outline simply enables you to organize your thoughts, but it does not guarantee that you will do so. In short, the perfunctory use of an outline will get you nowhere. Only by careful thinking can you be sure that your outline will enable you to present your material to the best advantage.

Many writers have trouble getting started on their outline. If you have this difficulty, you might try first to divide your subject into its principal divisions:

I. _____
II. _____
III. _____, etc.

Next, divide each of these divisions into its principal subdivisions:

I. _____
  A. _____
  B. _____
  C. _____, etc.
II. _____
  A. _____
  B. _____
  C. _____, etc.
III. _____
  A. _____
  B. _____
  C. _____, etc.

Continue this approach until you have completed your outline down to the paragraph level. If you follow this process, you will find that you have made several short outlines, with each succeeding one increasing in complexity. You thus will have to reconsider your paper in its entirety several times, but this is a small price to pay for a logically organized paper.

In practice, you probably will find that it will be easier to develop an outline for certain divisions of the paper than for others. Once your ideas start to flow readily on a given division, go ahead and finish it without worrying about the other ones. The point is not how you make the outline but that you make a good one.

While you are reflecting on how best to write the paper, you may think of a good idea concerning some subsection of it before you have thought the paper through completely. As has been pointed out by Prince (1955), a practice that you may find useful is to write down your ideas on the subject, taking care to use a separate sheet of paper every time your thoughts take a new direction. When you come

to writing your final article, you then can shuffle these papers until the various subjects discussed fit into your outline. As long as you do not write on more than one subject to a single piece of paper, you will have no trouble in fitting these subjects into whatever logical outline you finally devise.

In developing your outline, do not be satisfied too easily. Check it and recheck it, and then discuss it with your colleagues. If you have a supervisor, you should give it to him for a final check. Remember that only if your outline is logical and complete, will your problem of writing be relatively easy.

Often times you can think of several different ways to write the paper. If so, make an outline to correspond to each of them before arriving at your final decision as to which way to write the paper. Making the additional outlines will be far less work for you than will be the work of revising the paper if you decide later that your first way was not the best. Furthermore, the additional time spent in considering the various outlines will clarify and help to firm up your ideas and will greatly facilitate the later process of getting them down on paper. **[*See Endnote #14*.]**

USE HEADINGS

A monumental discovery in the history of writing was the invention of headings, for they serve two very important functions: 1) they act as sign posts pointing out to the reader changes in your direction of thought; and 2) they serve as filing guides showing where certain information is given in the paper.

By the aid of headings, the reader is able to follow -- without confusion -- intricate changes in your line of thinking, since the headings serve as sign posts to guide him. The headings also enable the reader to: 1) skip large sections of the paper, if he is so inclined, and to read only those parts in which he has a particular interest; or 2) go back to these parts, time and time again if need be, for data and other information.

Important though headings are as filing guides, the use of them as indicators of changes in your direction of thought is vastly the more important function. The mind of the reader has a certain amount of inertia. It therefore will continue to follow along the same line of thoughts, unless you supply a force sufficient to start it to think in whatever new direction you desire. Headings are forceful enough to enable you to accomplish these shifts in the thinking of the reader.

Theoretically, you could omit headings by substituting transitional sentences and paragraphs. But why weary your readers unnecessarily by forcing them to read a paragraph for which a short heading will suffice? This question is not meant to imply that transitional sentences and paragraphs are not useful in scientific writing, for they are. Rather, it is intended to impress you with the fact that headings help greatly to reduce reader fatigue. Furthermore, a short heading often will arrest the attention of the reader far better than will a tiresome transitional paragraph. Your readers therefore are less likely to get lost in your discussion if you employ an adequate number of headings. In fact, unless you do make adequate use of headings, your readers will seldom be able to understand your paper completely on one rapid reading of it.

The editor of your paper, recognizing the great importance of headings, often will supply them for you if you have omitted them. As you already may have discovered, the headings supplied by the editor are not always worded logically nor are they always placed at logical divisions. The explanation for this apparent mental aberration on the part of your editor is simple. Not having the benefit of proper headings when he reads your paper, he may misinterpret what you mean, particularly if you also have failed otherwise to write the paper well; and without the aid of an outline, he often can only guess at the direction your thinking has taken. Do not depend therefore upon the editor to supply your paper with headings. Ordinarily, you can devise them better than he can.

As already has been indicated, the use of headings makes the writing of your paper easier, since often they spare you the need for composing transitional sentences and paragraphs, which can be hard to write. Headings are also an indirect aid to you, in that they help to insure that your paper will be logically organized; that is, it usually is difficult to find suitable headings for an illogically planned paper, and you yourself will become convinced that your paper needs reorganization. Furthermore, the use of headings makes your paper much easier to comprehend. Critics and editors therefore are more likely to find errors if any are in it. In this use, headings admittedly do not save you any work, but they may help to save your reputation.

Relationship between Outline and Headings

Your outline and the headings of your paper are closely related in two ways: 1) the headings in your written paper reveal the various divisions in your outline; and 2) if you employ care in the wording of the outline, the wording of the headings can be taken directly from the outline. In a paper by Brown, Venolia, Tappel, Olcott, and Stansby (Submitted), for example, the outline of the paper was as follows:

OXIDATIVE DETERIORATION IN
FISH AND FISHERY PRODUCTS.
II. PROGRESS ON STUDIES CONCERNING
MECHANISM OF OXIDATION OF OIL IN FISH TISSUE

I. Introduction
II. Hematin catalysis
    A. Hematin-compound content of fish
    B. Catalytic effect of hematin compounds
    C. Catalytic effect of proteins
    D. Hematin-compound changes during oxidation
    E. Rate of oxidation in fish flesh

III. Role of antioxidants
  A. Naturally occurring antioxidants
  B. Commercial antioxidants
IV. Oxidation of oil in fish meals
  A. Rate of oxidation in meals
  B. Effect of commercial antioxidants
V. Summary

The corresponding headings in the paper were:

OXIDATIVE DETERIORATION IN FISH AND FISHERY PRODUCTS.
II. PROGRESS ON STUDIES CONCERNING MECHANISM OF OXIDATION OF OIL IN FISH TISSUE

INTRODUCTION
HEMATIN CATALYSIS
Hematin-Compound Content of Fish
Catalytic Effect of Hematin Compounds
Catalytic Effect of Proteins
Hematin-Compound Changes During Oxidation
Rate of Oxidation in Fish Flesh
ROLE OF ANTIOXIDANTS
Naturally Occurring Antioxidants
Commercial Antioxidants
OXIDATION OF OIL IN FISH MEALS
Rate of Oxidation in Meals
Effect of Commercial Antioxidants
SUMMARY

You thus can see that the headings in the paper by Brown and his coworkers were the same as those in their outline.

Types of Headings Available

In the paper just cited, the degree of subdivision of the outline was revealed by the types of headings used in the paper. There were, for example, only two degrees of subdivision (Table 12). The first degree of subdivision was shown by capitalizing all of the words in the heading and by putting it in the center of the page:

HEMATIN CATALYSIS

The second degree of subdivision was shown by capitalizing only the principal words in the heading, by putting it at the left-hand side of the page, and by underlining it:

Hematin-Compound Content of Fish

With only two degrees of subdivision, you have no difficulty in devising suitable types of headings -- even with the limited facilities of a typewriter -- but you may require as many as six different types of headings with an outline of the following degree of subdivision:

I. _____
  A. _____
    1. _____
      a. _____
        (1) _____
          (a) _____

After you have given this problem some thought, you may wish to adopt the system of headings widely used by those writing in publications of the federal government. **[See Endnote #15.]** In this system, for convenience of reference, each type of heading is given a number as follows:

THIS IS AN EXAMPLE OF A TYPE-ONE HEADING

This Is an Example of a Type-Two Heading

This is an example of a type-three heading

This Is an Example of a Type-Four Heading

This is an example of a type-five heading. -- The type-five heading is indented and made part of a paragraph as shown here.

1. This is an example of a type-six heading: The type-six heading is similar to the type-five heading in that it is indented and made a part of the paragraph, but it differs in: a) being numbered, b) not being underlined, and c) having a colon rather than a period and a dash following the last word.

Perhaps you have not thought of the title of the paper as requiring a separate type of heading. Nevertheless it does, and this type has been designated by the number zero, as follows:

THIS IS AN EXAMPLE OF A TYPE-ZERO HEADING:
TYPE-ZERO HEADINGS ARE USED ONLY
IN THE TITLE OF THE PAPER

In the paper by Brown and co-workers, the title was a type-zero heading, the principal subdivisions of the paper were type-one headings, and the other subdivisions were type-four headings. (The reason why the last was not a type-two heading, as would seem more logical, is discussed in a later section of the manual.)

Capitalization of Type-Two and Type-Four Headings

In the type-two and type-four headings, the articles *a*, *an*, and *the*; the prepositions *at*, *by*, *for*, *in*, *of*, *on*, *to*, and *up*; the conjunctions *and*, *but*, *if*, *or*, and *nor*; and the second element of a compound numeral are not capitalized as is shown by the following examples, which are taken from the

United States Government Printing Office Style Manual (Anonymous 1953).

Built-up Stockpiles Are Necessary
Men Hit with 2-Inch Pipe
No-Par-Value Stock for Sale
Price-Cutting War
Yankees May Be Winners
No Ex-Senator Admitted
Notice of Filing and Order on Exemption from Requirements

but

Building on Twenty-first Street (if spelled)
One Hundred and Twenty-three Years (if spelled)
Only One-tenth of Shipping Was Idle
Many 35-mm. Films in Production

Recommended Headings

If you will compare the preceding seven types of headings (types 0, 1, 2, 3, 4, 5, and 6), one with another, you will see that unfortunately many of them are very similar in appearance, and that for that reason, your readers may have difficulty in distinguishing one type from another one. Remember that the only way your readers can keep your outline readily in mind is by the type of heading you use. Thus if he fails to distinguish one type from another, he will become confused (Figure 3).

The ideal arrangement would be to use only those types of headings that are as dissimilar in appearance as is possible. If, however, your outline is as complex as the one illustrated in Figure 3, you would have no choice as to the types you could use because you would require a type-zero heading for the title to your paper and you would need to use all of the remaining six types to distinguish between your various subdivisions. Fortunately, it so happens that most scientific research papers do not require such a high degree of subdivision. You therefore ordinarily have a choice among the types of headings you can use.

The problem now becomes, which types are the most dissimilar and how should they be chosen? The following method of choosing the best types of headings to use has been tested and has been found to work well. In this method, you first classify your paper into one of six categories, which are determined by the complexity of the outline of your paper as follows:

Outline of category-A papers (one subheading):

I. _____
II. _____
III. Etc.

Outline of category-B papers (two subheadings):

I. _____
  A. _____
  B. _____
  C. Etc.

Outline of category-C papers (three subheadings):

I. _____
  A. _____
    1. _____
    2. _____
    3. Etc.

Outline of category-D papers (four subheadings):

I. _____
  A. _____
    1. _____
      a. _____
      b. _____
      c. Etc.

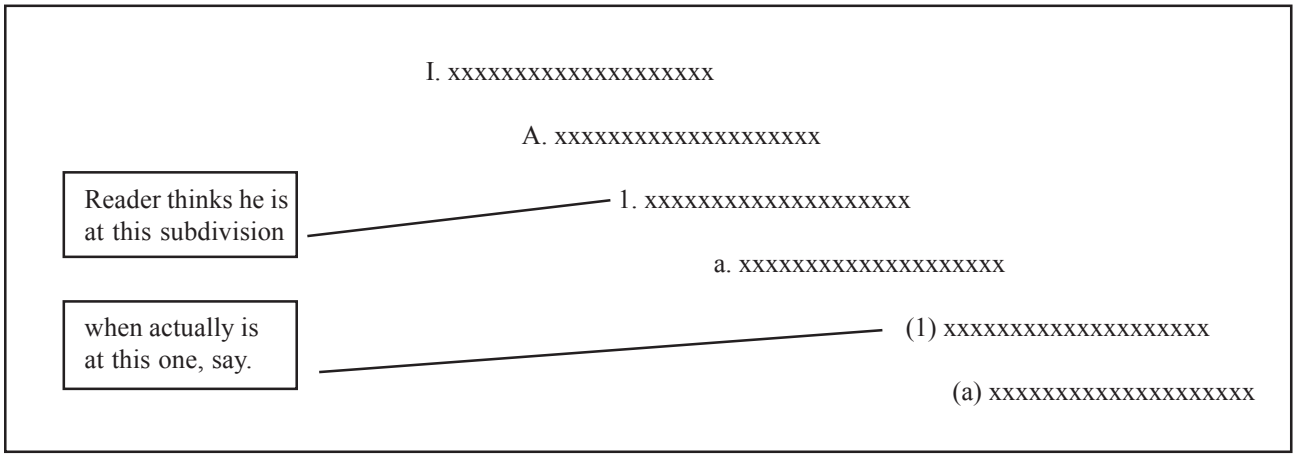


Figure 3. Illustration of how the reader becomes confused as to where he is in your outline if he fails to distinguish between your types of headings.

Outline of category-E papers (five subheadings):

I. _____
  A. _____
    1. _____
      a. _____
        (1) _____
        (2) _____
        (3) Etc.

Outline of category-F papers (six subheadings):

II. _____
  A. _____
    1. _____
      a. _____
        (1) _____
          (a) _____
          (b) _____
          (c) Etc.

After deciding which category your paper falls into, you then choose the proper headings as follows:

Headings for category-A papers (those with one subheading):

I. Type-1 heading
II. Type-1 heading
III. Etc.

Headings for category-B papers (those with two subheadings):

I. Type-1 heading
  A. Type-4 heading
  B. Type-4 heading
  C. Etc.

Headings for category-C papers (those with three subheadings):

I. Type-1 headings
  A. Type-4 heading
    1. Type-5 heading
    2. Type-5 heading
    3. Etc.

Headings for category-D papers (those with four subheadings):

I. Type-1 heading
  A. Type-2 heading
    1. Type-4 heading
      a. Type-5 heading
      b. Type-5 heading
      c. Etc.

Headings for category-E papers (those with five subheadings):

I. Type-1 heading
  A. Type-2 heading
    1. Type-3 heading
      a. Type-4 heading
        (1) Type-5 heading
        (2) Type-5 heading
        (3) Etc.

Headings for category-F papers (those with six subheadings):

I. Type-1 heading
  A. Type-2 heading
    1. Type-3 heading
      a. Type-4 heading
        (1) Type-5 heading
          (a) Type-6 heading
          (b) Type-6 heading
          (c) Etc.

You will note from the foregoing that the type-three and type-six headings, being the least distinctive ones, are used only in those papers that require so many different types that all the others need also be used. If you examine the scientific literature, you will find that most papers fall into categories B, C, or D.

The paper by Brown and co-workers, for example, falls into category B, and this is the reason why the type-four heading was used in that paper instead of the type-two heading, as might have seemed logical. (The present manual falls into category C.)

Use of Headings with Individual Paragraphs

Ordinarily, you will not set off each individual paragraph by a heading. The factor determining whether you should use a heading for an individual paragraph depends upon how abruptly you shift your line of thought. Remember that one of the principal purposes of headings is to indicate to your readers that your direction of thought has changed. Therefore where the subject matter of your paper varies markedly from one paragraph to another, do not hesitate to use headings to signal this fact to your readers. In this manual, for example, you will find numerous places, in addition to the present paragraph, where I have set off individual paragraphs by headings.

Logical Use of Headings

One error often made by scientific authors is to use headings illogically. Suppose that the following is the outline of a paper:

I. _____
  A. _____
  B. _____
II. _____

This is a category-B paper, and the correct headings therefore are:

I. Type-1
  A. Type-4
  B. Type-4
II. Type-1

Quite often, however, an author chooses the correct types of headings, but mixes them up illogically as follows:

I. Type-1
  A. Type-4
  B. Type-1
II. Type-4

If you will make an outline and follow it, you easily can avoid this kind of error.

As has been pointed out earlier, you also will find that if in devising your outline you use care in the wording of it, you can take the titles for the headings directly from the outline. This practice has the great advantage of helping to insure that your headings will be logical and parallel in form.

Importance of Headings

Of all the devices that you can use to make your paper easy to read and to comprehend, headings must be ranked among the most important. Unless you make adequate use of them, you never can achieve your maximum potential as a writer of clear scientific papers. In concluding this section, I therefore strongly urge that you always give careful thought to the headings when you write your future papers.

GIVE THOUGHT TO THE PARAGRAPHING

The use of paragraphs has much the same function as the use of headings; that is, the paragraph alerts the reader to the fact that you have finished discussing one topic and now are ready to discuss another. There also is a further parallel between headings and paragraphs in that the heading signals to the reader that the group of paragraphs being considered is related, and the paragraph signals that the group of sentences is related.

In the same way also that you should not have long sections in your paper without organizing them into shorter subsections, you should not have long paragraphs without trying to break them into shorter groupings; that is, long paragraphs, like long sections, are mentally tiring for the reader. If it is at all logically possible, the long paragraphs therefore should be broken into shorter ones. View with suspicion any paragraph that is longer than a typewritten page because it usually can be separated logically into smaller divisions.

Pay particular attention to the opening paragraph. A long opening one looks formidable, promises much dull reading, and tends to repel prospective readers.

It is very important that your paragraphs be logical units of thought. An example of a type of paragraphing that gives scientific authors much difficulty in this respect is the following:

> The analysis was carried out in two steps.
>
> In the first step, so and so, and so and so, and so and so was done…
>
> In the second step, such and such, such and such, and such and such was done…

As you can see, this is logical paragraphing, and it is clear. You know how many steps there are, and you know where the description of each one starts. You may feel, however, that you are breaking some rule of composition by using a one-sentence paragraph such as:

> The analysis was carried out in two steps.

There is no objecting to the use of the one-sentence paragraph -- if such use aids reader comprehension. Naturally it should not be overdone because it would defeat its purpose of arresting the attention of the reader. If all of the above paragraphs are short, for example, all three should be combined into one paragraph:

> The analysis was carried out in two steps. In the first step, so and so, and so and so, and so and so was done… In the second step, such and such, such and such, and such and such was done…

The introductory sentence, in this example, belongs just as much to the second step as it does to the first one. I grant that combining the introductory sentence with the paragraph explaining the first step is only slightly illogical, but this practice is far more serious than you might think because in scientific writing, you need be only slightly confusing to cause your readers much mental fatigue.

You complicate matters further if you forget about parallel construction and start your description of the second step with different wording from that used with the first step:

> The analysis was carried out in two steps. In the first step, so and so, so and so, and so and so was done…
>
> The second step consisted in such and such, such and such, and such and such…

Your attention has been focused on these slight changes, and you know what they are, but you will be surprised at how fast you can lose an inattentive reader by this confused method of breaking up your paragraphs and of presenting your thoughts. This confusion will be greatly compounded if you use several paragraphs to describe the first step and several to describe the second.

Let me hasten to add that these faults are minor in comparison to leaving out the introductory statement:

> In the first step, so and so, so and so, and so and so was done…

> The second step consisted in doing such and such, such and such, and such and such…

Now visualize the confusion if you also neglect to mention that you are describing the first step:

> So and so, so and so, and so and so was done…
> The second step consisted in doing such and such, such and such, and such and such…

If your reader has been half asleep, the statement about the second step may wake him up, and he will go back to discover what your first step was. If your discussion is short, he may have no difficulty in finding the first step, but if your discussion is long, he may waste much time before he discovers where in your paper your discussion of the first step begins.

The last example is not the worst. You also might omit mentioning that you are describing the second step:

> So and so, so and so, and so and so was done…
> Such and such, such and such, and such and such…

In addition, you might run the paragraphs together:

> So and so, so and so, and so and so was done…Such and such, such and such, and such and such was done…

Do all these things, and you leave your readers with a nice little puzzle to solve -- if they ever get around to it.

THE TITLE

In searching the literature, have you ever been misled by the titles of certain papers into believing these papers would furnish you with the information you needed? On the other hand, because of poorly worded titles, have you ever rejected certain other papers only to discover later, through different sources, that these particular ones really were important? If so, you already are aware of the need for carefully wording your title.

TOO GENERAL

One of the pitfalls to avoid in wording the title is to make it too general. Although such a title may inform the reader that your paper treats subjects in his field of interest, it will not tell him whether your paper contains the particular information he needs. After a worker fruitlessly has looked up a large number of papers because of titles that are overly general, he tends to become highly critical and to reject all those general titles. Unless your title is specific, your paper may be among those eliminated -- possibly incorrectly.

INCOMPLETE OR MISLEADING

Another common error in titles is that of incompleteness. Thus, your paper may treat certain subjects, but your title may give no clue to this fact. Still another difficulty is that your title may be misleading in that it indicates your paper is about one subject, whereas it actually is about another.

SHORT VERSUS SPECIFIC TITLES

In planning and writing your paper, you may fall into errors such as making your title too general, incomplete, or misleading, owing to your desire to keep the title from becoming overly long. Now, although it is important to have a short title, it is even more important to have one that correctly reveals the main contents of your paper.

You have only to go through the tiresome act, however, of writing out the titles to half a dozen papers to discover the great virtue of brevity. It therefore is unfortunate that brevity and specificity usually are not compatible. With many of your papers, the title will be a compromise between what you think should be mentioned and what space you think can be spared for it. The following examples illustrate how the length of the title increases as the title becomes more specific:

Measurements

Fish Measurements

Determining Fish Measurements

Accurately Determining Fish Measurements

Device for Accurately Determining Fish Measurements

Photographic Device for Accurately Determining Fish Measurements

Automatic Photographic Device for Accurately Determining Fish Measurements

Fully Automatic Photographic Device for Accurately Determining Measurements of King Salmon

Fully Automatic Photographic Device for Accurately Determining Measurements of King Salmon (*Oncorhynchus tsawystcha*)

Fully Automatic Photographic Device for Accurately Determining Measurements of Live King Salmon (*Oncorhynchus tsawystcha*)

Fully Automatic Photographic Device for Accurately Determining, Aboard Ship, Axial Measurements of Live King Salmon (*Oncorhynchus tsawystcha*)

Fully Automatic Photographic Device for Accurately Determining, Aboard Ship at Near-Freezing Temperatures, Axial Measurements of Live King Salmon (*Oncorhynchus tsawystcha*)

Fully Automatic Photographic Device for Accurately Determining, Aboard Ship at Near-Freezing Temperatures Under All Conditions of Lighting, Axial Measurements of Live King Salmon (*Oncorhynchus tsawystcha*)

To arrive at the proper balance between specificity and brevity, you will have to give much thought to the subject. A good plan is to assign a temporary title when you first start to consider your paper and then to improve upon the title as time goes by. The first one you think of usually is not the best.

IMPRACTICAL SOUNDING

Another unfortunate aspect of scientific titles is that some of them sound impractical. In fact, often the better and more specific the title -- from the scientific point of view -- the less sensible it may sound, especially to the layman who might not be sufficiently acquainted with your project to see the need for it. Take for example, the title: "Fully Automatic Photographic Device for Accurately Determining, Aboard Ship at Near-Freezing Temperatures Under All Conditions of Lighting, Axial Measurements of Live King Salmon (*Oncorhynchus tsawystcha*)." You can see that this title sounds pedantic. To make it actually ridiculous, all you now need to add is something like: "Caught at the Mouth of Hunter Creek" or "Caught at the Mouth of Hunter Creek by Frogmen."

You should keep this aspect of titles in mind because often it is a layman who must approve of the bill for your investigation, and you cannot expect him to be enthusiastic about a project that does not seem to be of value. If your title is unavoidably pedantic sounding, make sure that you show the significance of your work when you write the introduction to your paper.

THE ABSTRACT

Your abstract has two principal functions: 1) to supplement your title, and 2) to give the reader an overall view of your paper.

In the function of supplementing the title, the abstract supplies further information on what the paper is about. As we have seen, owing to the need for brevity, the title does not always reveal completely the contents of your paper. The abstract, not being quite so limited in length, makes up for this deficiency. Thus a principal function of it is to supplement the title and thereby help the reader to decide whether your paper will be of sufficient value to him to warrant his time spent in reading it.

One of the main requirements of the abstract is that it be short and to the point. If it is wordy, the prospective reader may reject both your abstract and your paper.

In the function of giving the reader an overall view of the paper, the abstract helps him to keep from getting lost in the maze of details most scientific papers contain. After having read the abstract, he can see better where these details fit into the overall picture. For this reason, the small amount of space taken by your abstract more than pays for itself in aiding your readers to a quick comprehension of your paper.

A well-known technique in writing and in public speaking is the following: 1) tell your readers what you are going to tell them, 2) tell them, 3) tell them what you told them.

In the writing of scientific papers, the abstract is step 1 of this technique, the body of the paper is step 2, and the summary is step 3. The use of this technique helps to insure that your readers will understand your paper completely the first time they read it.

A problem arises if you have both an abstract and a summary in that you may repeat in the summary what you said in the abstract. You can solve this problem by making the abstract qualitative (descriptive) and the summary, where you are less restricted as to wordage, quantitative. (An example of how to do this is given later in the manual under the heading "Summary.") If you omit the summary, you should make the abstract as quantitative as your limitations of space will allow. **[*See Endnote #16*.]**

Omitting the summary, however, gives your readers a feeling of incompleteness and an impression that you have left your paper to dangle. If you think that you must omit either the abstract or the summary, your paper will be stronger if you retain the summary instead of the abstract.

I strongly recommend that you retain both.

THE PRINCIPAL DIVISIONS

The principal divisions of the scientific paper that have become more-or-less traditional are: 1) introduction, 2) methods, 3) results and discussion, and 4) conclusions. These divisions have resulted from the desire of the readers to obtain answers to the following five questions: 1) what were you, the author, trying to accomplish?; 2) why were you trying to do this?; 3) how did you carry out the work?; 4) what did you find out?; and 5) what did you conclude from your findings? Questions 1 and 2 are answered in the introduction; question 3 is answered in the methods; question 4, in the results and discussion, and question 5, in the conclusions. **[*Also, see the embedded table in Endnote #2*.]**

The subsections of this manual immediately following will discuss these principal divisions.

THE INTRODUCTION

As was just stated, the primary function of the introduction is to answer two questions: 1) what were you trying to do?, and 2) why were you trying to do it?

Your failure to answer adequately these questions may very greatly reduce the effectiveness of your research. If you fail to answer the first of them, you force your readers to turn detective in that they must infer your objectives from the data and from the discussion in the latter part of your paper. The odds are that they will be unsuccessful, and as a result, badly confused. The omission, therefore, of a specific statement of objectives in the introduction is one of the most serious errors in scientific writing, and in my opinion, is the principal cause of unclearness in many scientific papers. If you fail to answer the second question, your paper may join the myriad of others that have lain long in disuse because their authors did not make clear the significance and usefulness of their findings. A thought you might keep in mind in this regard is that numerous examples exist of worthwhile research projects that have been terminated because those who have had to pay the bills for the research were not shown it was worth the cost.

In answering these two questions, you may find it helpful to consider the general nature of research, which is illustrated in Figure 4 and Figure 5. These figures are intended to show two points:

1. Your paper ordinarily reports on the solution to some closely related set of problems of relatively very narrow scope, which for convenience, can be grouped together and called the specific problem.

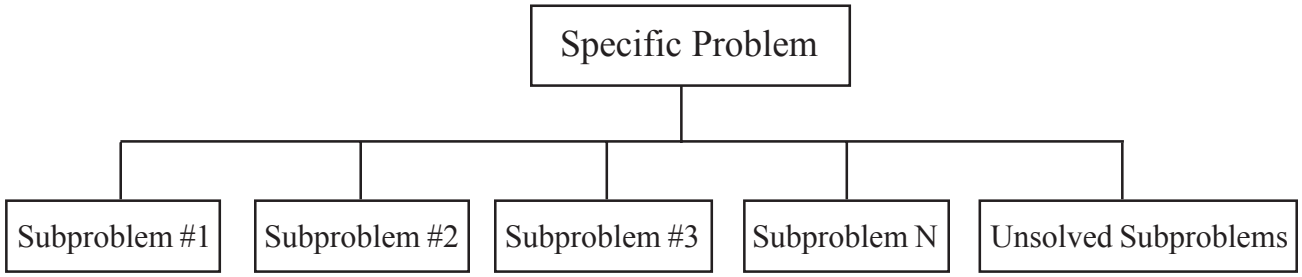


Figure 4. Illustration showing that your paper ordinarily reports on the solution to a number of closely related subproblems.

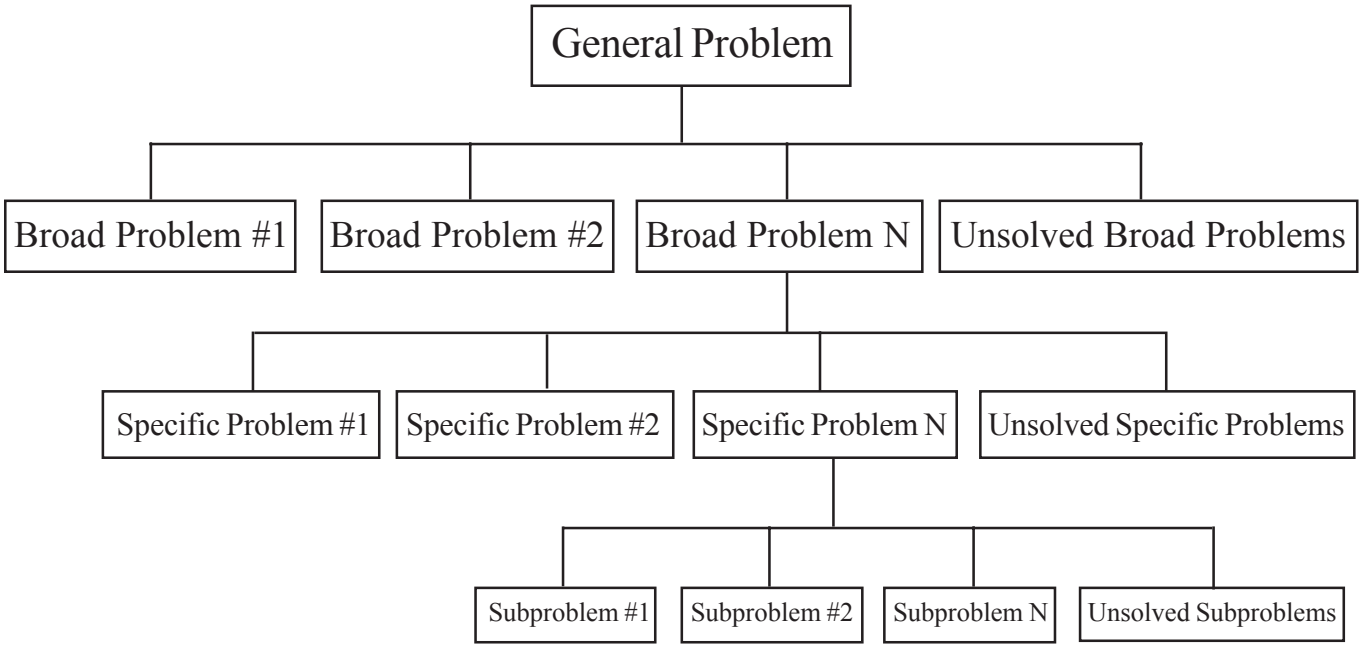


Figure 5. The general problem is made up of a number of broad problems, these broad problems are made up of a number of specific problems, and the specific problems, in turn, usually are made up of a number of closely related subproblems. The solution of a problem at one level contributes to the solution of the problem at the next higher level. The general problem, the broad problem, and the specific problem seldom are completely solved; that is, there usually is room for more research in every field. Ordinarily, many different groups of authors contribute to the solution of the broad and general problems; whereas prior to the publication of your paper, your group will be the only one working on your specific problem, unless some group elsewhere independently has got the same idea.

2. Your specific problem is never an isolated one, for your findings always contribute to the solution to some problem of greater scope, which can be called the broad problem. The solution to the broad problem, in turn, contributes to the solution to a problem of even greater scope, which can be called the general problem. This process can be continued to the widest field of knowledge. It however seldom is profitable to consider relationships beyond the general problem -- or one of a scope that is even wider, since there are not many limitations to the extent of the inquiries of science and since few problems ever are solved completely.

The subjects treated in scientific papers are so widely different that no one outline will suffice for all introductions. The following is offered, however, as being suggestive of the general approach:

I. Introduction
  A. Orientation of your readers to your specific problem
    1. Transitional sentence or paragraph to relate the title of your paper to your general problem.
    2. General problem
      a. What it is
      b. Why it needs solution
      c. What has been done on it
    3. Broad problem
      a. What it is
      b. Why it needs solution
      c. What has been done about it
    4. Specific problem
      a. What it is
      b. Why it needs solution
  B. Statement of objectives of specific problem
    1. Objective of subproblem 1
    2. Objective of subproblem 2
    3. Etc.

Orienting Your Readers to Your Specific Problem

We now see from the outline that orienting your readers to your specific problem (answering question 2 given in the first paragraph of this section, "The Introduction") may be somewhat involved -- depending upon their background of knowledge. With a poorly informed audience, you may have to tell them something of the general problem -- what it is, why it needs solution, and what has been done about it -- and then go on to discuss the broad and the specific problems. With a better informed audience, no mention need be made of the general problem. Only with the most specialized audiences, however, can you omit mention of the broad problem -- and even then you are taking a chance that some of your readers may not see the significance of your work. In planning and writing your paper, keep in mind that you cannot possibly visualize all the many uses for your findings. You therefore should be careful not to restrict the size of your audience unnecessarily by your failure properly to orient your readers to your specific problem.

Your title should reveal your specific problem. If therefore you start your paper directly with a discussion of your general problem, your readers may get the impression that you have already strayed from your subject. The opening transitional sentence or paragraph is to assure them that your discussion of the general problem is pertinent to the subject indicated in your title. Take, for example, the paper entitled: "Photographic Device for Accurately Determining Fish Measurements" (Long and Arzylowicz, In preparation). The opening paragraph begins as follows: "The photographic measuring device described in this paper was developed to aid the work of the International North Pacific Fisheries Commission. As a result of a treaty between Canada, Japan, and the United States, this Commission was formed…" You can see that if the paper had not included the opening transitional sentence, the readers would have wondered what the statements about the Commission had to do with a photographic device.

Some papers do not require this transitional statement, whereas others, such as the one just cited, definitely do. You therefore always should give thought to whether a transitional statement will be helpful to your paper.

You may feel that you can eliminate any need for this transitional statement by starting with the specific problem and then discussing the broad and general problems, in that order. This technique leaves your readers thinking about your general problem. You then will need a transitional statement to bring them back to the problem at hand. Ordinarily, you will find the better technique is to start with the general problem and end up with the specific problem rather than the reverse.

In telling what has been done on the broad and general problems, you will be citing the literature. Keep in mind that often a citation of only one or two papers that have good bibliographies will give references to all the important papers that have been written in your particular field. Because of this fact, you may wish to call special attention to these papers in your citation.

Another point you should keep in mind is that your readers should always be able to distinguish between your work and that of others. Owing to the custom in scientific writing of omitting personal pronouns, the readers often are left in doubt as to whether the author or someone else did the work being cited. This is not to suggest that you start to use personal pronouns but simply that you make clear, in your discussion, what you and your coworkers did and what the other authors did.

You will note in the outline immediately preceding this subsection, "Orienting Your Readers to Your Specific Problem," that under 4, "Specific problem," no mention is made of what has been done on it. The reason for this omission is that ordinarily, unless you simply are repeating the work of others, you will be the only one who ever has studied your specific problem. Thus there will be no work to report

other than your own. The reporting of the work that you have done on the specific problem is what forms the body of your paper.

You can see from the outline that most of the introduction is devoted to orienting your readers to your specific problem. In summary, the basic technique for doing this is first to point out the importance of your general problem and then to show that: 1) your broad problem is necessary to the solution of the general problem; and 2) your specific problem, in turn, is necessary to the solution of the broad problem. How detailed you make these explanations will depend upon the background of information of your intended audience.

Stating the Objectives of Your Specific Problem

As is indicated in Figure 4, your specific problem ordinarily is composed of a number of closely related subproblems. The objectives of your specific problem are to solve these subproblems. In stating your specific problem, you should list these objectives by number and state them explicitly so that your readers will know exactly what you were trying to do. Let me strongly emphasize that from the standpoint of clarity, numbering your objectives and stating them explicitly are two of the most important things you can do in planning and writing your paper.

The more objectives you have, the more important it becomes that you state them explicitly. If you have only one objective, a careful reader may be able to infer what it is even if you do not state it. If, however, you have several objectives and do not state them, you can see that it will be almost impossible not to confuse your readers. Why chance puzzling them when the simple technique of listing your objectives will make your paper so much easier to understand?

If you have done an adequate job of showing the need for your research, you ordinarily can include the word "therefore" in your statement of objectives, as in the following example:

The objectives of the research reported in this paper therefore were as follows:

1. _____
2. _____
3. _____

You will find that usually the listing of your objectives will determine the logical structure of the rest of the paper. This fact seems not to be well known, for many authors use only the following outline 1 for all of their papers:

OUTLINE 1

I. Introduction
II. Methods
III. Results and discussion
IV. Conclusions

The following outline 2, however, generally will be more appropriate.

OUTLINE 2

I. Introduction
   A. Orientation of readers to specific problem
   B. Statement of objectives of specific problem
      1. Objective of subproblem 1
      2. Objective of subproblem 2
      3. Etc.
II. Subproblem 1
   A. Introduction
   B. Methods
   C. Results and discussion
   D. Conclusions
III. Subproblem 2
   A. Introduction
   B. Methods
   C. Results and discussion
   D. Conclusions
IV. Subproblem 3, etc.
V. Overall discussion
VI. Overall conclusions

From an examination of outline 2, you can see that outline 1 normally will be suitable only if your specific problem has but one objective. You thus can see one reason why so many scientific papers are hard to understand: the authors of them use only one outline, regardless of how unsuitable it may be.

Let me state that outline 2 is not the ultimate for all papers. It is presented simply to stimulate your thinking. Each of your papers should be considered individually, and you should develop whatever logical outline will enable you to present your paper to best advantage. My point in this discussion is not to recommend that you use any one particular outline. Rather it is to impress you with two facts: 1) the statement of the objective of your specific problem ordinarily determines the structure of your paper, and 2) neglecting to state your objectives usually will make your paper hard to organize and even harder to understand.

You probably have noticed that in discussing the subproblems of your specific problem, I always have been careful to point out that they must be closely related. If this relationship is not close, you will have two or more papers instead of one, as otherwise unity will be violated. With each of your papers, you therefore should determine whether your specific subproblems are closely enough related to justify reporting of them in one paper.

An Example of an Introduction

To see how these suggestions work in practice, let us consider a paper by Thurston (Submitted). The following is a slightly altered and abridged version of the introduction to it:

DYE-BINDING CHARACTERISTICS OF FISH-MEAL PROTEIN, PART I -- SOME PRELIMINARY FINDINGS AS TO SUITABLE DYES

By Claude Thurston

INTRODUCTION

Statement of general problem and why it needs solution

Owing to the time required in animal tests for determining the quality of proteins in foods, chemists long have been interested in developing quicker methods. One promising approach has been to correlate the quality of the protein with its dye-binding properties. Such a method has many practical advantages because of the simplicity with which the concentration of dyes can be measure by spectrophotometric techniques.

What has been done on general problem

Several of the investigations reported in the scientific literature indicate that the quality of a vegetable protein can be determined by its dye-binding characteristics. Chapman, Greenberg, and Schmidt (1927) showed by reactions of several acid dyes with various protein solutions, that the amount of dye bound was proportional to the number of basic groups in the protein. Fraenkel-Conrat and Cooper (1944) found that dyes could be used to determine the number of acidic and basic groups present. Udy (1954) -- working with vegetable proteins, chiefly wheat -- found that the quality of the protein could be determined from its dye-binding characteristics.

Statement of broad problem and why it needs solution

If a similar relationship exists between dyes and the proteins in fish meal, the nutritive value of these proteins might be determined by a chemical index, in hours, rather than in 1-3 wk as is now required when a feeding test is used.

Statement of specific problem and why it needs solution

An investigation of the dye-binding characteristics of the protein in fish meal accordingly has been started at the Seattle Technological Laboratory in order to learn if there is any correlation between the nutritive value of the meal, as determined by chick-feeding tests, and the extent of binding of the dye. Since no previous research has been reported on the use of dyes with fish meals, one of the preliminary steps necessary in undertaking this investigation was to determine what dyes are suitable and how they best can be employed.

Statement of objectives of specific problem

The specific objectives of the study reported in the present paper there fore were to determine: 1) what dyes will bind the proteins of fish meal, and 2) what are the optimum conditions in the use of these dyes.

If you analyze this introduction, you see that the general, broad, and specific problems are as follows:

General problem:	To determine the quality of proteins by the use of dyes.
Broad problem:	To determine the quality of proteins in fish meals by the use of dyes.
Specific problem:	To determine what dyes will be bound by the proteins in fish meals and what are the optimum conditions in the use of these dyes.

Note that: 1) the first part of the title, "Dye-Binding Characteristics of Fish-Meal Protein," points to the broad problem, since this part of the title refers to the series of papers that yet are to be written; and 2) the second part, "Some Preliminary Findings as to Suitable Dyes," points to the specific problem, since it is the part of the title referring to Dr. Thurston's paper itself. Note also there is no transitional statement to relate the title of the paper to the general problem, since the discussion of the general problem seems to be related closely enough to the title.

The opening paragraph of Dr. Thurston's paper gives an indirect statement of the general problem and tells why it needs solution. The second paragraph tells what has been done on the general problem. The opening part of the third paragraph gives an indirect statement of the broad problem and tells why it needs solution. No other information is given on the broad problem because no work has been reported on it in the literature. The last part of the third paragraph states the specific problem and tells why it needs solution. Since the statement of the specific objectives is so very important, it is set apart in the fourth paragraph, for emphasis, and the specific objectives are listed by number.

As was pointed out earlier, the statement of the specific objectives of the research determines the structure of the paper. Dr. Thurston's paper, for example, falls into two main divisions: 1) the determination of suitable dyes, and 2) the determination of optimum conditions in the use of them.

You thus can see the tremendous importance of clearly stating your specific problem. If, however, you have not thought your research through, and do not have a clear idea of what your specific problem is, you hardly can state it when you come to reporting your data. This is one of the principal reasons why you were advised earlier in the manual to give very careful thought to the planning of your research and to the writing of your paper at the time you start your research project.

THE METHODS [*See Endnote #17*]

Statement of Strategy and Motives

If you study the scientific literature, you find that many customs have developed that do not contribute to the clarity of the writing. It is the custom, for example, to give a step-by-step statement of the methods without telling the readers where these steps are leading or why this particular approach to solving the problem was used. The readers are then forced to infer what the methods are supposed to accomplish and why they were the best available ones.

In presenting your methods, you therefore should give thought to whether they need an introductory statement as to their overall scope. Ordinarily, you will find that only a short paragraph or two will be all that is needed to make a vast difference of the ease of comprehension of your work by your readers. Incidentally, the more difficulty you have in composing this paragraph, the greater will be the need for it.

This short introductory statement will be helpful particularly to those of your readers who want to find out what you did in a general way but who do no have the time to read the details or who actually lack the ability to synthesize them into a meaningful picture. These readers deserve more consideration than most scientific papers give them. You might keep in mind that this group often includes abstracters and that the niche in scientific history your paper will occupy actually may depend on how well some abstracter understands it. You will not be exhibiting wisdom if you lose him and your other readers in a maze of details.

Description by Reference to Authors

If your methods already have been published, you should not describe them in detail in your own paper. You, however, should include a brief general statement of them for the benefit of those of your readers who are not familiar with the methods and who may not have the time to look up the reference to them. A key word that often aids the general description of the methods, in this case, is the word "essentially."

Description of Methods Involving a Number of Consecutive Steps

A problem frequently encountered is how to describe methods involving a number of consecutive steps. In such a description, you have two difficulties: 1) the structure of your sentences becomes monotonously the same as does also your choice of words; and 2) your readers find it difficult to follow you, especially if you intersperse explanations with directives, as often you should.

This problem of describing a number of consecutive steps can be solved by the use of the following technique: 1) number each step, and 2) give the directions in imperative sentences and the explanations in declarative ones.

An example of this technique is given in the earlier section "Consider the Tables." A second example is shown in the following directions on how to cut up a whale:

1. Strip off the blubber from both sides of the whale with the aid of a winch.
2. Remove the jawbone.
3. Remove, from one side, the long loin that runs from the shoulder to the tail.
4. Etc.

If you number each step, your readers will have no difficulty in determining where you finish one step and start the next one. If your directives are given in imperative sentences and your explanations in declarative ones, your readers also will have no difficulty in distinguishing between a directive and an explanation. Enclosing the explanatory material in parentheses also may be helpful.

The use of the imperative sentence for stating the directive ordinarily will enable you to start each sentence with a different verb instead of monotonously starting it with the article "the" as usually will be the case if declarative sentences are used, as for example:

1. The blubber is stripped off from both sides of the whale with the aid of a winch.
2. The jawbone is removed.
3. The long loin that runs from the shoulder to the tail is removed from one side.
4. The etc.

You may find, however, that even with imperative sentences, you will need to start many sentences with the same verb, since that particular verb may be the best one to use. If so, repeat it as many times as necessary, as for example:

1. Strip etc.
2. Remove etc.
3. Remove etc.

Scientific writing, like any other kind, is more pleasing if it is euphonious; but logic, clarity, and faithful reporting of the facts should never be sacrificed to euphony.

Description of a Series of Similar Experiments

If your work involved a series of experiments all of which were quite similar to one another, you may find it difficult to describe the methods. The following technique provides a good solution to this problem: 1) tell the readers how many experiments there were in the series, 2) describe the first experiment in detail, and 3) tell

how each of the remaining experiments differed from the first one. If you will give thought to the numbering of the experiments, you may find that you can simplify your description of them. In short, unless the chronological sequence is significant, the experiments should be numbered in whatever order will best aid in the logical description of them.

In the use of the foregoing technique, you will find that the following practice will be helpful to your readers: 1) set off, in separate paragraphs, the introductory statement and the description of each experiment; and 2) use parallel construction so that the reader easily can see any similarities and differences. The practice of setting off the introduction to the series and the description of each experiment in a separate paragraph may result in a number of paragraphs that contain only one sentence. Although longer paragraphs usually are to be preferred, the function of paragraphing, as was explained earlier in the manual, is to help the reader to a quick comprehension of the article. Thus, when clarity is aided, the use of one-sentence paragraphs not only is permitted but is recommended.

The following description of methods, adapted from a report by Osterhaug and Andrews (1955), gives an example of these various points:

Statement of number of series	Two experiments were made: series I, experimentally handled oysters, and series II, commercially handled oysters.
Detailed description of series I	In series I, shucked Pacific oysters, which had been purchased in 0.5-gal cans in Seattle and transported to the laboratory, were sorted into damaged and undamaged groups. The undamaged oysters were repacked in 0.5-lb cans, hermetically sealed, frozen at -20°F, and stored for 3 days at 0°F. The frozen oysters were divided into five groups of six cans each, and each group was thawed under one of the following conditions: 1) in still air at 34°F, 2) in still air at 48-52°F, 3) in front of a fan at 65-70°F, 4) in water at 45-47°F, and 5) in water at 110°F.
Description of series II, showing how it differed from series I	In series II, 10-oz cans of commercially frozen oysters that had been in storage at 10°F for approximately 9 mo were used. These oysters were divided into similar groups and thawed under the same conditions as were those in series I.

Description of Complex Methods

The general technique for describing complex methods is the following: 1) analyze the methods into their fundamental components for your own information; 2) tell your readers how many components there are and what they are; 3) describe each component, one at a time; and 4) show your reader how the components fit together.

Illustrations

In describing the methods, do not forget the limitations of words; that is, always keep in mind the vast importance of illustrations.

There are two possible approaches toward illustrations: 1) that the illustrations are used simply to support the text, and 2) that the text is used to support the illustrations. You will find that the second approach greatly simplifies your problems of description. Thus if you have something hard to describe, first make whatever pictures and other illustrations are possible and then build your write-up around these illustrations. This technique often will save you pages of difficult writing. Furthermore, it will enable your readers to obtain an almost instantaneous comprehension of your subject; whereas a written description, in addition to being tiresome, may leave them with only a foggy notion of what you are trying to convey. Thus, whenever illustrations are applicable, use them.

Pitfalls in the Methods

In writing your methods, keep in mind the need for warning your readers of any pitfalls; that is, tell them where the methods may go wrong if they do not take certain precautions. Otherwise they uselessly will have to rediscover for themselves all your hard-won knowledge of how to avoid these various difficulties. Those who try to follow your methods are not likely to revere you for leaving out any of these warnings. In fact if they have trouble in making your methods work, they may regard you as being something of a faker instead of being merely an inept author.

Adequacy of the Sample

In describing the materials employed in your experiments, give a full description of any samples that you may have used. Keep in mind that no work is ever more reliable than is the sample. This fact, unfortunately, is not always recognized clearly. Much of the early analytical work in fishery technology, for example, was almost useless because in experiment after experiment, the samples were not adequate.

A striking example of the great care needed in sampling has been pointed out by Karrick, Clegg, and Stansby (1956) in their work with sheepshead, a common species of freshwater fish:

"If only 16 sheepshead (a much larger sample than that for most values reported in the literature) from Clearwater Lake, Minnesota, had been used as representative of all sheepshead, the oil content would have been reported as ranging from 0.72 to 1.67 percent and as averaging 1.04 percent. Sheepshead then would have been considered a non-oily fish. If only sheepshead had been used from another small lake, Lake Kegonsa in Wisconsin, the oil would have been reported as ranging from 2.00 to 8.84 percent and as averaging 4.89 percent. Sheepshead would then have been considered as intermediate in oil content. If, however, 16 samples of sheepshead from the Mississippi River had been taken in June 1954, values from 3.57 to 14.20 percent and averaging 8.78 percent would have been found. Sheepshead then would have been classified as an oily fish. This is an example of the danger of analyzing one fish, or even one large lot of fish from the same source, and reporting that the values obtained are representative for the species."

THE RESULTS AND DISCUSSION

As was pointed out earlier, if at all possible, present your results in tables and graphs, for this is the most efficient and satisfactory way to do so.

Important though your tables and graphs are, however, you should make your discussion stand independently of them so that any of your readers who do not have the time to study the details of your report can still follow the main trends of your findings. This technique of making your discussion stand independently helps to insure that both your tables and graphs and your discussion will be clear.

In your discussion, take care not merely to recapitulate the details of your data; that is, do not make the mistake of repeating in words the detailed contents of your tables and graphs. This repetition does not constitute a discussion but merely a waste of time, for the tables and graphs, as was pointed out earlier, will present the data more clearly than you can verbally. Furthermore, you will alienate your readers because after laboriously going through all your verbiage, they will find that you have told them nothing that was not already more clearly seen from the tables and graphs themselves. What a reader wants to learn from your discussion are the trends, correlations, and conclusions that he otherwise would have to extract from your data himself -- presuming that he would bring to the task a sufficient background of knowledge to enable him to do so.

Be sure to point out any apparent or real inconsistencies in your data, and if you can, explain them. Leaving your readers to wonder about them will weaken your paper more than if you point them out yourself. Also, if your conclusions are not obvious, explain the reasoning process by which you arrived at them. Otherwise, your readers, lacking your insight into the work, may disagree with you.

If your readers might mistakenly think that certain trends or correlations exist in your data where none actually do, be sure to make the situation clear. Also, in your discussion, clearly distinguish between fact and theory.

THE CONCLUSIONS

The most important part of the scientific paper ordinarily is the conclusions. The rest of the paper usually is for the primary purpose of showing the reader: 1) the significance, and 2) the reliability of them. Thus most scientific papers would need only to present the conclusions were it not for the readers' lack of information regarding the need for the research and for the healthy skepticism as to the correctness of the results and of the conclusions drawn from these results. On the other hand, the willingness of readers tentatively to accept conclusions that are known to be supported by a formal publication accounts in no small part for the tremendous usefulness of such journals as *Biological Abstracts* and *Chemical Abstracts*.

Occasionally you see a paper in which the author has neglected to draw conclusions from his data. This practice is very poor; for the author, being the one who is best acquainted with the work, obviously should be the one who is best able to draw the conclusions. Furthermore, many of the readers who themselves might not be sufficiently informed on the subject to draw the correct conclusions, might very well be able to use these conclusions once they have been drawn.

Because the conclusions are so very important, they rate a subsection of the paper entirely to themselves. In writing your conclusions, list each one by number so that each will stand out separately and distinctly and be easy to read. Do not include any discussions or explanation. If you find yourself tempted to add an explanation, you have not done a good job of writing your "Results and Discussion."

After presenting your conclusions, you should check back to your statement of objectives in the introduction to make sure that your conclusions are in line with what you started out to do. Experiments have a way of straying from the intended path. Make certain that yours have not done this.

THE SUMMARY

Many scientists appear to be confused as to the difference between the "Summary" and the "Conclusions." The difference, however, is distinct. Your conclusions give only the inferences that you have drawn from your data, whereas your summary recapitulates the paper and gives it to the readers in miniature. Thus in writing the summary, you ordinarily make some mention of each of the various other sections (introduction, methods, results and discussion,

and conclusions) of the paper. In the summary, you mentally digest the paper for the readers and present it to them in its barest essentials. In restricting the summary to the essentials, however, remember to be informative -- by giving quantitative data -- and not merely descriptive.

Your summary should stand independently. On the other hand, you should not mention any topic that was not mentioned in the body of the paper. The summary is not for the purpose of tucking in facts that you forgot to mention earlier.

Inasmuch as the summary helps the reader to separate the essentials from the details and to give him a final comprehensive mental grasp of the article, one should be included with every scientific paper -- even those that are quite short.

Since your summary and your abstract deal with the same material, the one will simply be a repetition of the other unless you make the abstract qualitative (descriptive) and the summary quantitative. **[*See Endnote #18*.]** An example of how to do this is shown in a paper by Cocca (Submitted):

SOME FACTORS AFFECTING "SAWDUST" LOSSES DURING THE CUTTING OF FISH STICKS

By F.J. Cocca

ABSTRACT

Much fish is lost as "sawdust" in the cutting of fish sticks (a three-step operation). As the result of a study to reduce this loss by making the bandsaw blade more efficient, an "ideal" blade was designed. The loss of sawdust with this blade was significantly less than that with the blades that are regularly used. The data obtained in this study show the great importance of using a slicing operation rather than a sawing operation in the third step.

SUMMARY

Fish sticks are cut from frozen blocks of fillets in a three-step operation that results in the loss of 7 to 12 percent of the weight of the block as "sawdust". To help minimize this loss, the Fishery Technological Laboratory at East Boston carried out a series of tests to determine the effect of the type of bandsaw blade on the loss of sawdust in the bandsaw cutting operations.

Increases in width, in thickness, and in degree of set of the bandsaw blades caused the amount of fish that was lost as sawdust to increase. An increase in the number of teeth per inch of blade caused the amount of fish that was lost to decrease. The type of set -- regular set or every-tooth set -- had no effect on the amount of fish that was lost.

From these observations, an "ideal" bandsaw blade was designed to reduce the loss of sawdust to a minimum. The loss incurred by this blade was 7.21 percent less than that with the regularly used blade producing the least loss of sawdust and was 35.4 percent less than that with the regularly used blade producing the most loss of sawdust.

In the study of the regularly used bandsaw blades, about 0.6 percent sawdust was lost in the first step in the cutting operation; about 2 percent, in the second step, and about 6 percent, in the third step. These data show the great importance of using a slicing or nonsawdust-forming cutting operation in the third step.

THE LITERATURE CITED OR BIBLIOGRAPHY

In citing references, follow the format of the journal to which you intend to submit your paper. Checking the format may seem like an inconsequential detail, but it will save much labor for you, for your typist, and for all others involved. Thus if you do not follow the proper format, the editor of your journal will think unkindly of you. Furthermore, he will tend to distrust your work, for carelessness in regard to the format indicates carelessness in regard to other matters, including the technical content of your paper.

The following examples show you the format used in most of the publications of the federal government in citing authors **[*See Endnote #19*]**:

Many investigators have studied various methods of preserving fish and have made recommendations involving: 1) the use of proper icing techniques (Kuake 1946; Carter and MacCallum 1953; and Castell, MacCallum, and Power 1956); 2) the freezing of fish at sea (Hartshorne and Puncochar 1952); and 3) the addition of certain substances to the crushed ice in which the fish is stored, in order to inhibit the growth of bacteria and thereby reduce fish spoilage (Tarr 1956).

Antibiotics, particularly chlortetracycline and oxytetracycline added to the ice in which the fish is stored, have been shown to be effective in reducing the growth of bacteria in fish (Tarr, Southcott, and Bissett 1952; Farber 1954; and Gillespie, Boyd, Bissett, and Tarr 1955). Tarr (1956) has found chlortetracycline to be the more effective of these two compounds.

Certain areas were explored previously by use of the U.S. Fish and Wildlife Service fishing vessel, the *John E. Cobb* (Powell, Alverson, and Livingstone 1952).

Nitrogen was determined by use of the standard techniques of the Association of Official Agricultural Chemists (1950).

Vitamin B_{12} was determined by a modification of the method of Hoffman, Stokstad, Hutchins, Dornbush, and Jukes (1949).

If you give only the references that actually have been cited in the paper, they are listed at the end of the paper in a section called "Literature Cited." **[*See Endnote #20*.]** If, however, you list references that you did not cite, the heading "Bibliography" is used. The following examples, which are presented for your convenience, show the format used in listing the references **[*See Endnote #21*]**:

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS

1950. Official methods of analysis. Seventh edition, pp. 296-297, Association of Official Agricultural Chemists, P.O. Box 540, Benjamin Franklin Station, Washington 4, D.C.

DASSOW, J.A., and CRAVEN, H.J.
1955. Reduction of curd in canned salmon prepared from frozen fish. Part I -- Use of acid and brine dips. U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C. (In preparation).

HART, J.L.
1949. The lengths of albacore in commercial catch. Circular No. 17, Fisheries Research Board of Canada, Pacific Biological Station, Nanaimo, B.C. May.

JARVIS, NORMAN D.
1943. Principles and methods in the canning of fishery products. Research Report No. 7, U.S. Fish and Wildlife Service, Department of the Interior, 366 pp. (Available from Government Printing Office, Washington 25, D.C., $1.25.)

ODAN, RICHARD
1952. Effect of temperature and rate of thawing on drip formation in true cod (*Gadus macrocephalus*). Manuscript report, University of Washington, Seattle, Washington, 9 pp.

SLAVIN, J.W.
1955. Technical Note No. 32 -- Freezing rates and energy requirements for freezing package fish fillets and fish sticks in a multiplate-compression freezer. Commercial Fisheries Review, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C., vol. 17, No. 7, July, pp. 21-26.

STREET, GUY
1955. New approaches in labeling. Modern Packaging Encyclopedia, pp. 568-576, Packaging Catalog Corp., Bristol, Conn.

TARR, H.L.A.; LANTZ, A.W.; and CARTER, NEAL M.
1950. The preparation and application of brines and dipping solutions for processing certain fish products. Progress Reports of the Pacific Coast Stations, Fisheries Research Board of Canada, 898 Richards Street, Vancouver, B.C., No. 84, October, pp. 51-57.

WIGUTOFF, NORMAN B., and CARLSON, CARL B.
1950. S.S. *Pacific Explorer*. Part V -- 1948 operations in the North Pacific and Bering Sea. Fishery Leaflet 361, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C., January, 161 pp.

SUMMARY

1. This manual is based upon the premises that: a) poor planning is one of the basic causes of unclarity in scientific papers, b) properly planned and written scientific papers can be understood completely after a single rapid reading by the intended audience, and c) a significant increase in the clarity of scientific papers would effect almost a revolution in the progress of science.

2. Assuming that your research is sound, the quality of your paper will depend largely upon whether you are willing to take the time and give the thought required in planning and writing your paper properly.

3. Writing your paper can be made easier if you will start to plan it from the moment that your research is conceived.

4. Make an early decision as to which one of the coworkers in your research team is to have the primary responsibility for writing the paper and seeing it through to publication.

5. Budget sufficient time for the planning, writing, and publishing.

6. Allow sufficient time for searching the literature.

7. Consider your statistical requirements when planning your research.

8. Tailor your paper to your audience. To do this effectively, visualize the least-informed member in it.

9. Limit the scope of your paper. Keep in mind that: a) to express an idea, you will require a certain minimum number of words and that you therefore should not attempt too much for the available space in your journal; and b) unity is just as important in scientific papers as in any other type of publication.

10. Keep in mind that: a) almost every subject that can be presented in a table will take less writing time, will require less space in the journal, and will be much easier for your readers to comprehend if it is presented in a table rather than in a written discussion; and b) two of the secrets to making clear tables are to: 1) place the units at the head of columns rather than in line captions, and 2) draw vertical guidelines between all columns.

11. Where suitable, present your data graphically.

12. If possible, use illustrations, for there are many subjects that cannot be presented adequately by words alone, and almost all others can be made clearer and more interesting if they are illustrated.

13. Use an outline.

14. Use headings, for they serve two exceedingly important functions: a) they act as signposts pointing out to the reader changes in the direction of your thought, and b) they serve as filing guides showing where certain information is given in the paper.

15. Your outline and the headings of your paper are closely related in two ways: a) the headings reveal the various divisions in your outline; and b) if you employ care in the wording of the outline, the wording of the headings can be taken directly from the outline.

16. There are about seven types of headings that can be made easily on a typewriter.

17. Choose the most dissimilar types of headings that the complexity of your outline will allow.

18. The factor determining whether you should use headings for an individual paragraph depends upon how abruptly your line of thought has changed from the preceding paragraph; the more abrupt the change, the greater the need for the heading.

19. In choosing your headings, follow your outline so that you will not mix up the types of headings illogically.

20. Unless you make adequate use of headings, you cannot achieve your maximum potential as a writer of clear scientific papers.

21. Paragraphing has much the same function as has the use of headings; that is, the paragraph alerts the reader to the fact that you have finished discussing one topic and now are ready to discuss another.

22. Your title should correctly reveal the main contents of your paper.

23. If your title tends to sound impractical, make sure that you show the significance of your work in the introduction to your paper.

24. Include an abstract; make it short and to the point.

25. Every scientific paper should answer the following five questions: a) what were you trying to do?; b) why were you trying to do it?; c) how did you do it?; d) what did you discover?; and e) what did you conclude from your findings?

26. Your introduction, as a minimum, should answer the two questions: a) what were you trying to do?; and b) why were you trying to do it?

27. Your paper ordinarily reports on the solutions to some closely related set of problems of relatively very narrow scope, which for convenience can be grouped together and called the specific problem.

28. Your specific problem is never an isolated one, for your findings always contribute to the solution of some problem of greater scope, which can be called the broad problem.

29. The solution to the broad problem, in turn, contributes to a problem of even greater scope, which can be called the general problem.

30. Your title should reveal your specific problem.

31. The basic technique for orienting your readers to your specific problem is first to point out the importance of your general problem and then to show that: a) your broad problem is necessary to the solution of the general problem, and b) your specific problem is necessary to the solution of the broad problem.

32. In stating the objectives of your specific problem, list each one by number and state it explicitly. From the standpoint of clarity, numbering your objectives and stating them explicitly are two of the most important things you can do in planning and writing your paper.

33. The statement of the objectives of your specific problem ordinarily determines the structure of your paper.

34. In presenting your methods, give thought to whether they need an introductory statement as to their overall scope.

35. If your methods already have been described in the literature, omit the details of them in your paper, but include a brief general statement of them.

36. If your methods involved a number of consecutive steps, then: a) number each step, and b) give the directions in imperative sentences and the explanations in declarative ones.

37. If your work involved a series of experiments, then: a) tell your readers how many experiments there were in the series, b) describe the first experiment in detail, and c) tell how each of the remaining experiments differed from the first one.

38. To describe complex methods, analyze them into their fundamental components; tell your readers how many components there are and what they are; describe each component, one at a time; and finally show your readers how the components fit together.

39. If your methods are hard to describe, first make whatever pictures and other illustrations are possible and then build your write-up around these illustrations.

40. In writing your methods, be sure to warn your readers of any pitfalls in them.

41. Give a full description of any samples you may have used so that your readers can judge as to the adequacy of these samples.

42. Make your discussion stand independently of your tables and graphs in order that any readers who do not have the time to study the details of your report can still follow the main trends of your findings.

43. In your discussion, take particular care not merely to recapitulate the data in your tables and graphs; instead, point out: a) the trends and correlations, and b) the conclusions to be drawn from them.

44. In writing your conclusions, list each by number so that each one will stand out separate and distinct and be easy to read.

45. Make sure that your conclusions are in line with the objectives given in your introduction.

46. In your summary, recapitulate your paper and give it to your readers in miniature.

47. Make your summary quantitative, not merely descriptive.

48. In citing references, be sure that you follow the format of the journal to which you intend to submit your paper.

BIBLIOGRAPHY

Anonymous. 1953. United States Government Printing Office style manual. Rev. ed. Washington, DC: Government Printing Office.

Brown, W.D.; Venolia, A.W.; Tappel, A.L.; Olcott, H.S.; Stansby, M.E. (Submitted.) Oxidative deterioration in fish and fishery products. II. Progress on studies concerning mechanism of oxidation of oil in fish tissue. *Commer. Fish. Rev.*

CBE [Council of Biology Editors, Committee on Form and Style]. 1972. CBE style manual. Third ed. Washington, DC: American Institute of Biological Sciences; 297 p.

Cocca, F.J. (Submitted.) Some factors affecting "sawdust" losses during the cutting of fish sticks. *Commer. Fish. Rev.*

Jenkinson, B.L. 1949. Bureau of the Census manual of tabular presentation. Washington, DC: U.S. Department of Commerce, Bureau of the Census; 266 p. Available *from*: Government Printing Office, Washington, DC.

Karrick, N.; Clegg, W.; Stansby, M.E. 1956. Composition of fresh-water fish -- No. 1. *Commer. Fish. Rev.* 18(2):13-16.

Long, C.W.; Arzylowicz, R.A. (In preparation.) Photographic device for accurately determining fish measurements.

Osterhaug, K.L.; Andrews, M. 1955. Cold storage of frozen Pacific oysters (*Crassostrea gigas*) -- No. 1. *Commer. Fish. Rev.* 17(12):11-14.

Piskur, M.M. 1956. The importance of a good technical library for research, development, and production. *J. Am. Oil Chem. Soc.* 33(10): 4,18.

Prince, M.V.H. 1955. News item. *Chem. Eng. News* 33(34):3513.

Thurston, C. (Submitted.) Dye-binding characteristics of fishmeal protein. Part I. Some preliminary findings as to suitable dyes. *Commer. Fish. Rev.*

Weil, B.H., editor. 1954. The technical report: its preparation, processing, and use in industry and government. New York, NY: Reinhold; 485 p. [Note: This book contains a number of excellent bibliographies covering all aspects of technical writing.]

Young, F.N.; Crowell, S. 1956. The application of gamesmanship in science. Washington, DC: American Institute of Biological Sciences; p. 13-14.

ENDNOTES TO THE REVISED EDITION

ENDNOTE #1

Many papers authored by NMFS employees aren't "scientific research papers" as defined by Sanford. Those other types of papers cover a wide spectrum of written products, ranging from descriptive biology articles to stock assessment reports. Nonetheless, Sanford's report is variously useful in preparing any type of paper authored by NMFS employees.

ENDNOTE #2

Different experts recognize different types of writing, but most experts recognize at least five major types: expressive, creative, persuasive, expository, and technical. Some experts lump one or more of these five types together into a more general type (*e.g.*, lumping expository and technical writing together as just expository writing); more experts, though, split one or more of these five types into several specialized types (*e.g.*, splitting technical writing into business, high-tech, engineering, and scientific writing).

Regardless of how many and what types of writing there are, none of them were designed from the start; rather, each evolved slowly to meet a different communication need. This evolutionary process has yielded a unique combination of communication strategy, format, and style for each type of writing. Our ability to understand the strategy and to master the format and style of a given type of writing is directly related to our success in communicating via that type of writing.

It's likely that your high school and college instruction in writing was in a type, or types, other than technical/scientific. Accordingly, it's probably worthwhile to introduce or review — depending on your background — the basic communication strategy, format, and style of scientific writing.

Communication Strategy in Scientific Writing

We seek to address two fundamental needs in writing papers about our research for other researchers. First, if the reader of our paper has little or no background on the subject of our research (*e.g.*, the first-year graduate student), then we need to create a structure within the brain of that

reader not only for the storage and recall of information on our research, but also for the subsequent storage of additional information from others' research on the same subject, and for the effective and efficient comparison by the reader of all such information. Second, if the reader of our paper has a background on the subject of our research (*e.g.*, the seasoned scientist), and thus has already created within his/her brain the necessary structure for information storage, recall, and comparison on that subject, then we need to present our information so that the reader can effectively and efficiently disassemble it, store it at the appropriate sites in his/her brain, easily compare it with existing similar information, and reassemble it so that our research is now part of his/her knowledge.

Both of the aforementioned needs in communicating about our research, especially the latter one, operate more — but not exclusively — through the linear-oriented, logical-thinking left side of the brain than through the spatially-oriented, abstract-thinking right side of the brain. To deal with such left-brain-dominated needs, a type of writing known as technical writing, with its unique combination of format and style, has evolved. Those of us in the sciences use the subset of technical writing known appropriately as scientific writing.

Format in Scientific Writing

The basic format of scientific writing follows the progression of the scientific method. Note the following table:

Scientific Method Component	Scientific Writing Component
Observation	First part of "Introduction"
Hypothesis	Second part of "Introduction"
Experiment	"Study Area" (if appropriate), "Sampling Gear" (if appropriate), "Experimental Apparatus" (if appropriate), "Test Specimens" (if appropriate), "Methods," and "Results"
Theory	"Conclusions," "Recommendations,"and "Summary" (if appropriate)
Law or principle	Not applicable

Within each component of scientific writing, the basic format follows one or more logical orders: chronological, serial, etc.

Style in Scientific Writing

To facilitate comparisons among the concepts of a research paper, scientific writing stresses four style principles: 1) definition of technical terms or phrases, either implicitly in context or explicitly in the text or in a table of definitions, but always prior to the use of such technical terms in dealing with concepts; 2) repetition of chosen terms and phrases (*i.e.*, limited varying of expressions); 3) parallel construction of clauses, sentences, paragraphs, and sections when dealing with components of one concept or with a series of related concepts; and 4) example or analogy for explaining a complex concept.

For researchers, the principle of scientific writing style which they are typically most reluctant to adopt is the repetition of terms and phrases. Often, a researcher will say to a technical editor, "I have a long list of related information, and repeating the same term or phrase to describe that information would be monotonous." Just about as often, the technical editor will respond to the researcher, "You have just argued for taking the information out of the text and placing it in a narrative table." The principle of scientific writing style which these researchers are typically next-most reluctant to adopt is the parallel construction of clauses and sentences.

Conclusion

The above comments do not apply to all of our written communications about our research. Occasionally, we find ourselves in the position of communicating in writing about our research to legislators, news reporters, K-12 students, etc. Depending on whom we are communicating with, we may need to rely more on expository writing, persuasive writing, etc. For the bulk of our communications with other researchers, though, technical/scientific writing is the best choice.

ENDNOTE #3

We often don't recognize those passages in our own writing which are difficult for others to comprehend. We typically first learn of those difficulties when our paper is read by a colleague or a clearing official.

So, what do we do to improve the comprehensibility of difficult passages in our writing? While there may be several ways to improve our writing, the one which has overwhelmingly worked the best for me in advising authors over four decades follows this course: 1) have a face-to-face meeting with the author; 2) take all paper copies of the writing away from the author; 3) read out loud the difficult passage to the author; 4) turn on a tape recorder, and 5) ask the author "What were you trying to say?". In almost all cases, when we're separated from our original written material and have to explain our meaning verbally, then our spoken words are more organized and understandable than our written words. With only minor editing, the transcribed passage on the tape recorder can usually be substituted for the previously difficult-to-comprehend written passage.

If you have imagination, then you don't need an editor to engage in this process — just a tape recorder. If you have a good imagination and a good memory, then you don't need the tape recorder either.

ENDNOTE #4

Readers of our papers are increasingly foreign, often with only rudimentary skills in English comprehension. Three aspects of English writing that especially can cause problems for foreign readers are hackneyed phrases (*e.g.*, "designed from scratch"), acronyms (*e.g.*, "ANOVA"), and abbreviations (*e.g.*, "vs."). In general, avoid using hackneyed phrases and abbreviations (except as components of bibliographies and as units of measure where there are international standards for such abbreviations), and define all acronyms upon first mention. It's increasingly common in scientific and technical monographs to have either a listing of "Acronyms"at the end of the "Table of Contents," or even a separate "Glossary of Technical Terms, Acronyms, and Units of Measure" among the report's preliminary pages.

ENDNOTE #5

Just as it's important to consider the number of words used to describe your research, it's also important to consider the size and familiarity of the words used to describe your research. There is nothing wrong in using a long word or an unusual word if that word effectively and efficiently conveys your meaning. Far too often, however, the young researcher will use a long and/or unusual word to impress his/her colleagues, when that word is neither the most effective nor efficient at conveying meaning, and when it's even misleading. By the way, in your most recent study, did you employ certain "methods" or certain "methodologies"?

ENDNOTE #6

There is, nevertheless, a role for papers which synthesize results of several studies in different disciplines, particularly when those studies collectively bear on resource and/or habitat management issues. If NMFS's resource and habitat *researchers* do not perform the synthesizing, then NMFS's resource and habitat *managers* must perform that task. Unfortunately, such synthesizing by managers often doesn't seem to take place, or if it does, it seems quickly to become a casualty of the political process (*e.g.*, resource economic concerns taking precedence over resource status concerns).

Fortunately, there are now several journals which specifically carry synthesis papers (*e.g.*, *Reviews in Fisheries Science* and *Conservation Biology*).

ENDNOTE #7

The increasingly common practices by scientists of reading the works of their colleagues directly from a computer monitor screen, and of sharing the components (*e.g.*, an individual table) of their own works online with their colleagues, have a major effect on how we should prepare our tables from now on.

Screen Reading Concerns

Virtually all computer monitor screens — just as virtually all television viewing screens — have an "aspect ratio" (*i.e.*, the ratio of width to height) of 4:3. To the extent practical, you should construct your tables so that their overall dimensions also have a 4:3 aspect ratio. If a table has an aspect ratio >4:3 (*i.e.*, *a wide and shallow table*), then the horizontal "scrunching" of the table to get it to fit on the screen can make the size of the table's letters and numerals so small that they are difficult or impossible to read. If a table has an aspect ratio <4:3 (*i.e.*, *a narrow and deep table*), then the horizontal "stretching" of the table to get it to fill out the screen can make the bottom of the table disappear, with the reader needing to scroll down to see the bottom matter, and then needing to scroll back up again to see the column headings. Aspect ratios which significantly depart from 4:3 particularly affect readers using small monitors (*e.g.*, 13-inch monitors, where the 13-inch measure refers to a single diagonal measure since the aspect ratio is fixed).

Sometimes it's nonetheless impractical to have our tables conform to the 4:3 aspect ratio. There are two circumstances which typically lead to such impracticality:

1) There may be so much data in the table (*i.e.*, so many columns and rows both), that even if the table perfectly fills out the screen both horizontally and vertically, then the size of the table's letters and numerals may be so small that they are difficult or impossible to read. As a general rule, the size of the letters and numbers in your typed table should be no smaller than 9 points, when the "type area" has been set up as 9.5 x 7.0 inches (i.e., the correct dimensions for a 4:3 aspect ratio on a landscape page). Any smaller point size appearing on a small, low-resolution screen is difficult to read. If you feel that you need to reduce the point size in a table below 9 points in order for the table to conform to a 4:3 aspect ratio, then jettison the attempt to make the table conform to the 4:3 aspect ratio, and try to reconstruct the table to reduce the number of columns (*i.e.*, it's easier to comprehend a table via up-and-down scrolling than via side-to-side scrolling). There are three common editorial "maneuvers" to reduce the number of columns in a table:
   a) "Field Spanners" — In most tables, the left-most column (*i.e.*, stub) and sometimes even the second-left-most column contain "collectivizing" terms. A collectivizing term applies equally to two or more rows.

As an example, refer to original Table 4; note the two collectivizing terms under the "Type of Dryer" stub (*i.e.*, "Direct flame dryer" and "Indirect flame dryer"). Because this stub is composed of only collectivizing terms, the whole column can be eliminated and the collectivizing terms can be converted into "field spanners." Refer to the following modification of original Table 4 to see how such a conversion appears. The use of field spanners is probably the most useful technique that an author has for reducing the number of columns in a table.

b) "Subtables" — Any large table can be broken up into two or more smaller subtables. Have no hesitation in breaking up larger tables, but take two steps to avoid any confusion on the part of the reader: 1) number the subtables in such a manner as to indicate the relationship among them (*e.g.*, Table 1 becoming Tables 1a and 1b); and 2) reword the subtable titles to reflect the interconnections among them (*e.g.*, "Table 1. Total weight of haddock captured in each of 24 trawl tows in the special sampling area," becoming "Table 1a. Total weight of haddock captured in each of the initial 12 (of 24 total) trawl tows in the special sampling area" and "Table 1b. Total weight of haddock captured in each of the final 12 (of 24 total) trawl tows in the special sampling area.")

c) "Rotated Text" — Often, the part of a table which drives its overall width is the collective width of its column headings (*e.g.*, see the following modified Table 4). Data entries in the field normally take up less width than their respective column headings. By rotating the text of column headings by 90 degrees counterclockwise, the width of column headings often can be dramatically reduced. However, don't underestimate the difficulty of trying to read rotated text on a computer monitor screen. In the old days — when everything was printed on paper — it was easy enough to just rotate the page back and forth quickly by hand on the surface of your desk. These days, however, it's not that easy nor that quick to do so with the "rotate tool" provided by your computer's software. In almost all cases, the use of rotated text should be the third option behind either field spanners or subtables.

2) The nature of the data may be such that there is no recourse to having either an extremely wide-and-shallow or an extremely narrow-and-deep table. In the fisheries science arena, I've seen two kinds of situations which typically force such tables. First, there can be the need to sample a large number of stations/specimens for just one or two measurements per station/specimen (such as quickly determining the concentrations of oil in the

Table 4. Effect of the type of dryer upon the vitamin content of the meal as compared with that in the press cake

Material	Composition of Sample				
			Vitamins (moisture- and oil-free basis)		
	Moisture (%)	Oil (%)	Riboflavin (mg/g)	Nicotinic Acid (mg/g)	Vitamin B_{12} (mg/g)
	Direct Flame Dryer				
Press cake A	56.5	5.55	4.7	90	0.33
Meal A	8.4	8.57	4.5	66	0.29
	Indirect Flame Dryer				
Press cake B	53.6	4.80	3.8	82	0.23
Meal B	7.5	7.85	3.8	80	0.24

Note: This table illustrates the correct format for many governmental publications and can be considered as being the standard table.

water following a widespread oil spill). Second, the economic or biological cost of obtaining a sample may be so high that it makes sense to measure as many aspects of each sample as possible (such as determining the complete contaminant and bacteriological profile of just a couple of captured specimens of an endangered species). In such situations, be prepared to use all three of the aforementioned editorial maneuvers, but especially subtables.

Online Sharing Concerns

Again, in the old days — when everything was printed on paper — it was acceptable for a monograph of several chapters or sections to have the tables (and figures) of *each* chapter or section be numbered from "1" onward. There was no chance for confusing Table 1 of Chapter 1 with Table 1 of Chapter 8; each table was physically bound within the correct chapter. Not so today. With the ability to select a given table (or figure) within a work, and then share just that table (or figure) with colleagues online, and with the ability to refer colleagues to a numbered table (or figure) within an online work, the chances for sharing or referring to the wrong table (or figure) have greatly increased. Consequently, within any given monograph, you should adopt one of two conventions: 1) number every table (and figure) consecutively over the whole work, including all appendices (*e.g.*, Table 1 through Table 37); or 2) use "English notation," where each table (and figure) number is composed of a unique alphanumeric string (*e.g.*, the first table of Chapter 8 becomes Table 8.1, the twelfth table of Appendix A becomes Table A.12).

To minimize any distortion of your tables as they are converted from word processing software to a digital markup language, you should use the "table formatting" function (*i.e.*, row-and-cell architecture) of your word processing software. To reduce the amount of "cleaning up" of your tables when they are received by an editor, webmaster, or publisher, you should place the table title and any table footnotes within cells which are *integral* to that single table.

Further, to avoid even momentary confusion by your readers, you should use letters — not numbers — for all superscripts in the table which are both appended to numerical data and referenced to footnotes.

ENDNOTE #8

Tables 2 and 3 do not show field spanners. Refer to "Endnote #7/Screen Reading Concerns/1/a" for a brief discussion of field spanners.

ENDNOTE #9

To use the global-search-and-replace tool of your word processing software for treating all of your tables (and figures) at one time, you may want to have all of your tables (and figures) in just one large file. However, when the time comes to forward the manuscript to an editor, webmaster, or publisher, place a copy of every table (and figure) in a separate small file, and forward both the one large file of all tables (and figures), as well as the collection of small files for each table (and figure).

ENDNOTE #10

Refer to "Endnote #7/Online Sharing Concerns" for a brief discussion of numbering — a consideration which applies to figures just as much as tables.

ENDNOTE #11

Refer to "Endnote #7/Screen Reading Concerns/1/" for a brief discussion of aspect ratios and point sizes — two considerations which apply to figures as well as tables.

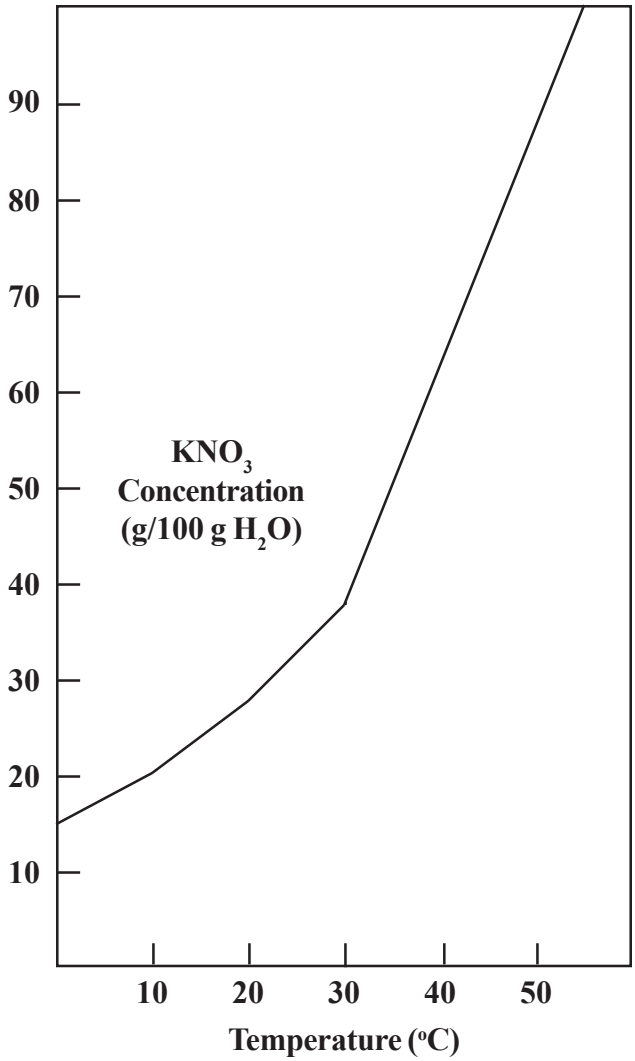
ENDNOTE #12

Refer to "Endnote #7/Screen Reading Concerns/1/c" for discussion of rotated text — something seen more often in figures than tables, especially in the labels of vertical axes of coordinate-based graphs. Although unconventional, you should consider "stacking" instead of rotating the labels of vertical axes. Refer to the modification of original Figure 1 to see how such a stacked vertical axis label appears. Depending on circumstances, a stacked label can also be placed inside the axis (as intentionally shown in modified Figure 1) to save space.

ENDNOTE #13

If an illustration does not occupy the whole page, then you may have the option — within some limitations — of where you place the illustration on the page. Two aspects of brain functioning guide us in choosing this placement on the page.

First, the right side of the brain processes images, and the left side of the brain processes language. Since the eye-brain nerve pathways criss-cross (*i.e.*, the left eye is connected to the right side of the brain, and the right eye is connected to the left side of the brain), there is reason to believe that the brain more easily processes information



Modified Figure 1: See Endnote #12 for description.

when the illustrations are on the left side of the page, and the text is on the right side of the page.) Research in both the neurological and communication sciences isn't definitive, but is supportive, of this idea. (Next time you look at a "high-end" magazine with some concordant "high-end" advertisers, take a close look at the relative left-right placement of the text and images in the advertisements.)

Second, if the illustration occupies the full width of the page, but not the full depth of the page, then you may have the option of placing the illustration either towards the top or the bottom of the page. This is where that aspect of brain functioning known as "geographic center of attention" comes into play: our attention is initially drawn to the upper righthand quadrant of any page. (That's why you always see the lead story on the front page of every daily newspaper occupying the upper righthand quadrant.) If you want to draw attention to the illustration, then place the image towards the top, and the text towards the bottom, of the page. (Next time you look at an advertisement for a "high-end" automobile, take a close look at the relative top-bottom placement of the text and image in the advertisement.)

ENDNOTE #14

There is an apparent irony in the use of word processing software, instead of paper and pencil, to compose our writing — whether that composition be at the outline stage or the manuscript stage. While it's easier to create, insert, delete, and move text around with word processing software, we seem less likely to perform the latter three operations with such software than with paper and pencil.

Among professional editors, there is consensus on the ubiquitousness of this behavior, but there is no consensus on the cause of this behavior. The leading candidate as the cause, though, seems to be what has been called "showroom syndrome." Text created with word processing software often looks so relatively finished and polished — even though it's not — that the author is hesitant to change the original creation.

If you're having a hard time bringing yourself to rewrite your work when using word processing software, even if you know the work needs to be rewritten, then experiment by printing out a double-spaced paper copy of the work, grabbing a colored pencil with a big eraser, and having at it. In not all cases, but in many cases, this technique has worked for authors whom I've advised on their writing approach.

ENDNOTE #15

Sanford worked with a manual typewriter, and his recommendations on headings are based on the limitations of such. We work with word processing software, and the following comments are based on the opportunities that such software offers.

Headings can either be "stand-alones" or "in-lines." Stand-alone headings are separated from surrounding text typically by two preceding blank lines and one following blank line. Nested stand-alones (*e.g.*, see "Preliminary Considerations/Give Thought to Importance" at the beginning of this document) are separated from each other typically by one blank line.

There are three factors that convey the level of importance ("Level") of a stand-alone heading; in order of importance, they are: 1) location (*i.e.*, centered on the page, centered on the column, flush left on the column, and increasingly indented from the left); 2) the combination of type size (*i.e.*, measured in "points," where each point equals 1/72 of an inch) and emphasis (*e.g.*, bold, underline, and italic); and 3) case (*i.e.*, all letters of each word upper case, or only the initial letter of each word upper case). Following is a heading level "recipe" — but certainly not the only one — which

agrees with the ranking factors for assigning levels of importance to headings. Also, shown after the recipe is an example which corresponds with this recipe.

In-line headings appear on the same line as the first line of the text with which they are associated. Refer to "Endnote #7/Screen Reading Concerns/1/a" to note the use of "Field Spanners" as an in-line heading. In-line headings typically: 1) are flush left on the block of text with which they are associated; 2) are the same type size as the associated block of text; and 3) use initial capitals only. Consequently, in-lines are distinguished from the text by their emphasis (*e.g.*, bold, underline, italic, quotation marks) and by their suffixial punctuation (*e.g.*, colon, em-dash).

ENDNOTE #16

The contemporary preference of almost all journals in the natural sciences is for the quantitative, or "informative," abstract. The contemporary preference of many journals in the social sciences is for the qualitative, or "indicative," abstract. Following is text, excerpted from CBE (1972), discussing these two types of abstracts:

Most journals specializing in primary publication of research results prefer, or even insist on, an informative abstract, a condensed version of the purpose, methods, results, and conclusions of that research. Most journals specializing

Level of Heading	Location	Type Size & Emphasis	Case
I	Centered on page	Large & bold	All capitals
II	Centered on column	Large & bold	All capitals
III	Flush left on column	Large & bold	Initial capitals
IV	Flush left on column	Regular & bold	Initial capitals
V	Flush left on column	Regular & italic	Initial capitals
VI	Single left indent	Regular & italic	Initial capitals
VII	Double left indent	Regular & italic	Initial capitals

LEVEL I HEADING

LEVEL II HEADING

xxxx

in review articles prefer an indicative abstract, a kind of expanded table of contents that contains generalized statements and directs the reader to the full article for any quantitative or qualitative data.

If you are reporting original research, and you are writing an informative abstract, identify in the abstract — as you did in the title — the main topic of your paper. Also, state the basic reason for doing the research being reported, indicate the methods used, list materials studied, and briefly summarize the results and conclusions. Do not merely describe or recite the contents of your article, e.g., "Activity of largemouth bass at various times of the day is discussed." Instead, tell what you did and what you found: "Largemouth bass were most active between the hours of 0900 and 1100."

ENDNOTE #17

Throughout his report, Sanford used the term "procedure" as the heading of the section of a paper which describes what a researcher did, and how he/she did it. Contemporary scientific writing almost universally uses the term "methods" instead of "procedure." That change has been made throughout the revised and updated report.

ENDNOTE #18

Since Sanford's time, the practice of placing a summary at the end of a research paper has largely been abandoned. Contemporary practice is to place a robust informative abstract at the beginning of the paper, and dispense with the summary. There is one specialized exception to this contemporary approach: the technical report with its "executive summary." Executive summaries largely serve the same purpose as a summary (*i.e.*, restating in simple language the key results, conclusions, and recommendations of the report, without introducing any new material), but are placed either as the last section of the preliminary pages (*i.e.*, those using lower case Roman numerals) or as the first section of the text (*i.e.*, beginning on page "1").

The format of an executive summary differs slightly from the format of a summary. Often, the summary will include nothing more than numbered or "bulleted" brief statements on the key results, conclusions, and recommendations. The executive summary always begins with a narrative section which is a synoptic version of the report's introduction; then appear the numbered or "bulleted" brief statements on the key results, conclusions, and recommendations.

ENDNOTE #19

The record for the number of authors of a single paper is over 900! (It was a clinical study in the medical sciences; clinics all over world were involved; and there were numerous people at each clinic who qualified for authorship.) Clearly, there has to be a rule on how many authors of a multi-authored paper can be listed in the in-text citation of the paper. The rule varies from journal to journal, and you need to conform to rule of your target journal. In the absence of any journal rule, though, it's recommended that you use the traditional, conservative rule of listing both authors for a two-author paper, but list only the first author — followed by "*et al*." — for papers authored by three or more authors.

ENDNOTE #20

The contemporary practice is to split the category "literature cited" into two categories: 1) if *all* of the works in the listing are in the primary literature (*i.e.*, anonymously peer reviewed), then the category label remains "literature cited"; and 2) if *some or all* of the works in the listing are in the secondary literature (*i.e.*, transparently peer reviewed) and/or tertiary literature (*i.e.*, not reviewed), then the category label becomes "references cited."

ENDNOTE #21

In the absence of any guidelines on bibliographic style by your target journal, it's recommended that you follow the guidance of the Council of Science Editors (CSE, the former Council of Biology Editors). The "Bibliography" of this report has been restyled to follow closely, although not exactly, the CSE guidelines.

Table 1. Scale of organoleptic ratings

Description of Flavor and/or Odor of Fish Sticks		Organoleptic Rating
Whole Fish Stick	**Component Parts[a]**	
Normal, characteristic of fresh product; no off-flavor or off-odor.	Normal, characteristic of fresh product; none to trace off-flavor or off-odor; barely noticeable.	Good (Grade A)
Lacking normal flavor or odor of fresh product; none to slight off-flavor or off-odor; barely noticeable.	Lacking normal flavor or odor; slight to moderate off-flavor or off-odor; definitely noticeable but not objectionable.	Reasonably good (Grade B)

[a] Breading, dark meat (including the layer of skin fat), and light meat.

Table 2. The formal table and its major parts. [The text immediately following the table number is the "heading." Any text at the end of the heading which is enclosed by parentheses is a "headnote." The text in boldface type immediately below the heading is the "boxhead." Any horizontal line separating the heading from the boxhead is the "top rule." All text below the stubhead, plus the stubhead itself, constitute the "stub." Each repetition of two or more rows of text in the stub is a "block" (*i.e.*, in this table, there are two blocks, each beginning with "CENTER HEAD, followed by "Total line caption" and seven lines of "Line caption"). All text and data below the spanner head, plus the spanner head itself, constitute a "panel." All text and/or data below the boxhead and to the right of the stub constitute the "field."]

Stubhead	Spanner head			Spanner head[a]		
	Column head	**Column head**	**Column head**	**Column head**	**Column head**	**Column head**
CENTER HEAD						
Total line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
CENTER HEAD						
Total line caption	Cell	Cell	Cell	Cell	Cell	Cell
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		
Line caption				Cell		

[a] Footnote.

Table 3. Age of all persons and of citizens by sex, for the United States, urban and rural: 1940 (Age classification based on completed years.)

Area and Age	All Persons			Citizens[a]		
	Total	Male	Female	Total	Male	Female
UNITED STATES						
All ages				769		
<5 yr				26		
5-14 yr				115		
15-24 yr				139		
25-34 yr				178		
35-44 yr				205		
≥45 yr				106		
≥21 yr				567		
URBAN						
All ages	988	475	513	453	302	265
<5 yr				15		
5-14 yr				73		
15-24 yr				86		
25-34 yr				104		
35-44 yr				116		
≥45 yr				59		
≥21 yr				328		

[a] Includes both native and naturalized.

Table 4. Effect of the type of dryer upon the vitamin content of the meal as compared with that of the press cake

Type of Dryer	Material	Composition of Sample				
				Vitamins (moisture- and oil-free basis)		
		Moisture (%)	Oil (%)	Riboflavin (mg/g)	Nicotinic Acid (mg/g)	Vitamin B_{12} (mg/g)
Direct flame dryer	Press cake A	56.5	5.55	4.7	90	0.33
	Meal A	8.4	8.57	4.5	66	0.29
Indirect flame dryer	Press cake B	53.6	4.80	3.8	82	0.23
	Meal B	7.5	7.85	3.8	80	0.24

Note: This table illustrates the correct format for many governmental publications and can be considered as being the standard table.

Table 5. An example of how not to present the data in Table 4

Composition of Samples	Type of Dryer[a]			
	Direct Flame Dryer		Indirect Flame Dryer	
	Press Cake A	Meal A	Press Cake B	Meal B
Moisture (%)[b]	56.5	8.4	53.6	7.5
Oil (%)	5.55	8.57	4.80	7.85
Vitamins (moisture- and oil-free basis):				
Riboflavin (mg/g)	4.7	4.5	3.8	3.8
Nicotinic acid (mg/g)	90	66	82	80
Vitamin B_{12} (mg/g)	0.33	0.29	0.23	0.24

[a] Note that this heading does not tell you what the figures in the field are about, whereas the corresponding heading in Table 4 does give this information.
[b] Note that the units are wrongly in the line captions rather than at the head of the columns.

Table 6. Treatment of samples

Sample	Frozen Immediately (no. of cans)	Held at 56-66°F for 48 hr (no. of cans)	Held at 56-66°F for 72 hr (no. of cans)	Held at 56-66°F for 168 hr (no. of cans)
Raw skin	½	-	-	-
Raw caecae	2	2	2	-
Raw livers	2	2	2	-
Raw hearts	2	2	2	-
Raw loins	2	2	2	-
Cooked loins	2	-	2	2
Cooked heads	2	-	2	2

Note: Compare this table with Table 7 as to clarity.

Table 7. Treatment of samples

Sample	Frozen Immediately (no. of cans)	Held at 56-66°F for 48 hr (no. of cans)	Held at 56-66°F for 72 hr (no. of cans)	Held at 56-66°F for 168 hr (no. of cans)
Raw skin	½	-	-	-
Raw caecae	2	2	2	-
Raw livers	2	2	2	-
Raw hearts	2	2	2	-
Raw loins	2	2	2	-
Cooked loins	2	-	2	2
Cooked heads	2	-	2	2

Note: This table has the minimum number of vertical and horizontal lines required for clarity. Compare this table with Table 8.

Table 8. Treatment of samples

Sample	Frozen Immediately (no. of cans)	Held at 56-66°F for 48 hr (no. of cans)	Held at 56-66°F for 72 hr (no. of cans)	Held at 56-66°F for 168 hr (no. of cans)
Raw skin	½	-	-	-
Raw caecae	2	2	2	-
Raw livers	2	2	2	-
Raw hearts	2	2	2	-
Raw loins	2	2	2	-
Cooked loins	2	-	2	2
Cooked heads	2	-	2	2

Note 1: Compare this table with Tables 7 and 9.

Note 2: This table has the format preferred by most readers.

Table 9. Treatment of samples

Sample	Frozen Immediately (no. of cans)	Held at 56-66°F for 48 hr (no. of cans)	Held at 56-66°F for 72 hr (no. of cans)	Held at 56-66°F for 168 hr (no. of cans)
Raw skin	½	-	-	-
Raw caecae	2	2	2	-
Raw livers	2	2	2	-
Raw hearts	2	2	2	-
Raw loins	2	2	2	-
Cooked loins	2	-	2	2
Cooked heads	2	-	2	2

Note: Compare this table with Tables 8 and 10.

Table 10. Treatment of samples

Sample	Frozen Immediately (no. of cans)	Held at 56-66°F for 48 hr (no. of cans)	Held at 56-66°F for 72 hr (no. of cans)	Held at 56-66°F for 168 hr (no. of cans)
Raw skin	½	-	-	-
Raw caecae	2	2	2	-
Raw livers	2	2	2	-
Raw hearts	2	2	2	-
Raw loins	2	2	2	-
Cooked loins	2	-	2	2
Cooked heads	2	-	2	2

Note: Compare this table with Table 9.

Table 11. Preference of readers regarding lining and spacing in tables as determined by a poll of 53 readers

Tables Being Compared	Readers Preferring:			
	Table 7 (N)	Table 8 (N)	Table 9 (N)	Table 10 (N)
Table 7 vs. Table 8	20	33		
Table 8 vs. Table 9		44	9	
Table 9 vs. Table 10			42	11

Table 12. Degree of subdivision used in the outline of the paper by Brown and coworkers

Degree of Subdivision	Outline
First	I. _____
First	II. _____
Second	A. _____
Second	B. _____
Second	C. _____
Second	D. _____
Second	E. _____
First	III. _____
Second	A. _____
Second	B. _____
First	IV. _____
Second	A. _____
Second	B. _____
First	V. _____

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