need for talk about science is on the increase. Scientists can expect to be subjected to increasing pressure to do some of the talking themselves. A great many of them are using public money, and it is not unreasonable to expect them to make an occasional "report to management."

It pains me to say so, but relatively few scientists are yet aware of the enormous importance of reasonable competence in their use of English. If they examine the five steps of the generalized scientific method, they will see that only one of these steps—making the actual measurements—does not involve the use of symbols. And this is the only step that they can leave to a technician; the *scientists* must frame the question and draw the theoretical conclusions. Language is their business.

Aside from their need of reasonably adequate English as an essential part of their written and spoken reports to one another, they will need English for communicating with laymen at various levels —for example, in the trade journal article, the "popular" speech, and the interview with the press. Some of them do these things very well indeed; but far too many of them do these things rather badly.

The ones who do it badly err on two counts: a bumbling, fumbling use of the language itself and a thoroughly mistaken idea of how much detail is required. There is no substitute for adequate training in writing and speaking, but it may be possible to give a quick insight into the amount of detail needed. The graph in Fig. 3, adapted from an original by J. Ansel Anderson, chief chemist of the Grain Research Laboratory in Winnipeg, may be helpful.

At the time this graph was prepared, neither Anderson nor I had heard of Gaston Bachelard. Nevertheless, we agreed that science for laymen was in the area of 0,0: zero technical knowledge and zero detail. Scientists please note.

Conclusions concerning attitudes. Some common attitudes of our scientists bother me, such as their persistent refusal to learn the techniques of communication —resulting, on the one hand, in some of the worst-written documents in the world and, on the other, in a firm belief that the press is out to misquote them deliberately.

Certain other attitudes of our scientists seem to me to be worth pondering: the desire to find out what is really going on, instead of being content with what other people say is going on; the determination to take no man's word, not even your own, for a material fact unless you can put it to the test and observe for yourself; the confident expectation that whatever you do will soon become outmoded and surpassed, and that this does not matter in the least; the expectation that other people will be markedly different from you, and that this is an excellent arrangement; the convictions that doing your best to think straight is a worthy occupation for a full-grown man, that this is a strange and wonderful universe whose ultimate secrets we will never quite plumb, that it is nevertheless the best sport in the world to try to plumb them, that you *never* get something for nothing, that you *always* get less than you expect—and that *never* and *always* are very dangerous words.

One way to spread these notions is for the scientists themselves to do a bit more talking; the attitudes will soon become apparent, no matter what the scientist is actually saying.

In conclusion, I might point out that we have some very old precedents for breaking through the barriers and talking to ordinary folk about extraordinary things. Jesus had such a problem. His technique was to put what he had to say into a perfect little short story, dealing only with familiar things that you can touch and see. He would begin with, "A certain man had two sons," or "Behold, a sower went forth to sow." To this day, the only device I know that will actually work for an audience of fishermen, taxgatherers, publicans, housewives, or other groups of laymen is this same technique of analogy, comparison, metaphor, simile, and parable.

Making Popular Science More Popular

Tested techniques of communication can help make the leading ideas of science clear to the layman.

John Pfeiffer

It is a pleasure to comment on M. W. Thistle's thoughtful and stimulating article, which comes as an important contribution to the continuing problem of bringing science to nonscientists. Two attitudes may stand in the way of those most actively concerned with communication in this area. There are still scientists who feel that the problem cannot be solved, that the layman does not have the mental equipment required to appreciate basic aspects of science, and that any attempt to communicate is an utter waste of time. They regard their colleagues' ventures into popularization as a mild form of corruption.

At the other extreme are the few scientists and science journalists who believe that they have solved the essential problem of popularizing science. Their monolithic complacency may annoy us, but it nevertheless deserves some sympathy. It is not always easy to live with the knowledge that one's writing and editing frequently leave much to be desired. On the other hand, insight and a fair share of humility may be helpful when it comes to setting higher standards and making a serious effort to meet them. I think it is reasonably evident by this time that higher standards are called for.

Thistle, chief public relations officer of the National Research Council of Canada, is neither frustrated nor complacent. Critical in a positive way, he indicates major limitations and then suggests that the situation is not as hopeless as it has been pictured. Indeed things could be a great deal worse, especially if we consider some of the things that are happening outside the laboratory.

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One of the most awe-inspiring symptoms of the times is the prospect of publicity gone wild. We are being subjected to a mounting and almost incessant barrage of messages from experts in the fine art of pleading causes, lost and otherwise. A legion of organizations and institutions compete for our undivided attention. Like a crowd milling past the sideshows of a great amusement park, we are exposed to the shouts of many barkers.

Only a near-miracle—or a succession of sputniks and other overseas achievements—can account for the fact that the earnest and unexcited voice of the scientist, or the somewhat more compelling voice of the science writer, is heard increasingly in such a hubbub. To be sure, science may not be getting its full message across. But something important is beginning to come through, and the techniques for communicating a great deal more have long been in existence. I have no serious argument with Thistle's estimate that only about one hundredth of one percent of what scientists know finally reaches the layman, but, as he is quick to point out, that may not be a completely suitable measure of the problem.

Lopsided View

Most people who visit art galleries know very little about art by comparison with professional painters, yet they may appreciate what they see and be ready for deeper understanding. The problem is not how much the layman knows but the quality of his knowledge. If the right things are communicated, it is quite possible that one hundredth of one percent may be ample. The trouble, of course, is that we have not succeeded in conveying all the "right things." The image of the scientist in the eyes of recently surveyed high-school students, the popularity of pseudoscience and antiscience, the attitudes of many businessmen as indicated in off-the-culff statements and in the advertisements they approve—these and other phenomena suggest that the public has an exquisitely lopsided view of science.

Science means "applied studies" to the vast majority of nonscientists, and to an appreciable proportion of scientists. The layman reads too little about basic research. What he does read may fail to get across, as I. I. Rabi of Columbia University indicated at a meeting of the American Institute of Physics: "There is hardly anybody in this room who has not had the frustrating experience of trying to explain what science is about to laymen, whether in government, in the universities, or to the ordinary educated layman, professional or businessman. Such is the spirit of the time that it is difficult, if not impossible, to communicate the feeling of dedication and reverence which all physicists have for our discipline."

Something is wrong here. We have unsuccessful communication where, on the face of it, one has every reason to expect success. In many ways it is far less difficult to convey feelings than facts. The layman has more experience with dedication and reverence than with most scientific concepts—and the odds are that the failure is ours rather than his. One reason for the failure, of course, is the scientists' "persistent refusal to learn the techniques of communication." The techniques are as familiar to professional writers and public-relations specialists like Thistle as standard laboratory methods are to professional investigators. Yet I know of no publication which consistently uses these techniques to present interesting and literate articles on basic research to the layman.

Concentration of Emphasis

Concentration of emphasis is perhaps the most important single technique, or principle, of effective writing. It is also the most widely and flagrantly neglected. Suppose a scientist wants to write an article on basic research, a common enough subject in times like these. Many ideas crowd into his mind. Basic research needs more adequate support. Basic research cannot flourish without an educational system capable of producing more scientists interested in the fundamental aspects of natural phenomena. Sooner or later, most basic research "pays off" in terms of practical results and technology. Basic research is a creative activity like music or painting. And so on.

These and a host of other ideas are well worth emphasizing. *But,* and the point is crucial, it is impossible to emphasize more than a single one of them and still communicate. An article must have a theme as well as a subject. This does not imply that the article must be devoted to one idea only (although such a practice frequently has much to recommend it.) Nevertheless, the job is to select as few ideas as possible—an absolute minimum—and then focus on one of them as the main theme of the article. This is what I mean by concentration of emphasis. It is essentially a problem of organizing, a problem which should be solved once and for all before the writing itself starts.

When a purportedly popular article is crammed with ideas, it tells us a great deal more about the author than it does about the subject. We see that the author writes for a very small audience consisting of himself, his colleagues, and a few others whom he would like to impress. We see that in pursuing his private objectives, in satisfying his ego, he has forgotten the general reader. It is far better to discuss one point—and get it across—than to discuss many points and lose them all. The scientist often feels he must cover a subject comprehensively—and swamps the reader with a mass of unweighted information. Limiting one's scope calls for a certain amount of self-discipline, but that is the essence of communication.

Courtesy to the Reader

As far as the writing process itself is concerned, in the last analysis every device and every technique boils down to plain everyday courtesy to the reader. Taking special steps to attract and hold his interest is simply a form of good manners. We come to him with our problems or with information we want to share. We ask him, in effect, to drop his own concerns for a time and listen to ours. He is often ready to listen, perhaps more often than we realize.

With the best of intentions we may nevertheless bore him somewhat because, in a fundamental sense, we are all amateurs in popularizing science. But it is sheer rudeness not to try to make ourselves interesting and convey our enthusiasms. If we take the trouble to try, he will know it and will sympathize with our spirit and our message. If we do not try he will know that, too.

A warning is appropriate at this point. Techniques used at present in most classroom lectures do not necessarily apply to the writing of popular articles. In facing up to the "courtesy" problems, scientists are beginning to appreciate the fact that there are major differences between addressing a group of undergraduates and addressing general readers. Students represent a captive audience. Taking extra pains to interest them is not widely accepted as a vital and continuing part of educational practice, although the validity of this attitude could be argued. After all, the student must pay attention or suffer the consequences.

The uninterested layman passes quickly and happily to another article, or another magazine.

There are many ways of writing colorfully, warmly, and with dignity. One rule is never to let a generality stand by itself. It should be followed by examples and anecdotes chosen so as to make a broad point as clear and definite as possible. For instance, take the statement, "After considerable technical difficulties, a suitable experimental procedure was devised." Such statements cry for expansion. A serious attempt should be made to indicate in simple, straightforward terms the nature of the difficulties and the effort required to overcome them. The reader may be interested in this sort of information. It not only involves anecdotes, but also provides some concrete idea of what working in a laboratory means.

Another rule—Thistle calls it "the old rule of writing"—concerns the use of comparisons to help bring the reader closer to concepts which might otherwise seem remote and abstract. A comparison, whether brief or extended, is not something to brush off—to hurry past on the way to an important point. It should be a leisurely and stimulating excursion for readers. An article conceals little about the attitudes and feelings of its author. He can take his job seriously enough to put his imagination to work and present unusually appropriate analogies. His article will sparkle as a result.

But if he is not really interested in the job, his article will not really be interesting. Good comparisons can make all the difference between a first-rate and a mediocre style, between effective and futile communication. A trite metaphor or simile, for example, is unfortunate, for it is an infallible sign of laziness—and, again, lack of courtesy. Yet atoms are still "miniature solar systems" (even though the concept no longer holds in modern physics), amino acids are still "building blocks," spiral galaxies are still "fourth-of-July pinwheels." The list of well-worn analogies which were once original could be extended indefinitely. We need fresh analogies and the sort of thinking that produces them.

"Shorthand" Vocabulary

Finally, we turn to the much-discussed matter of vocabulary. It is difficult for the scientist, or the scientifically trained writer, to appreciate the full extent of the gap between himself and nonscientists when it comes to technical terminology. Certain words have become so familiar to him that he uses them without thinking, and consequently much of what passes for popular science is semitechnical writing at best. Thorough and most enlightening studies of this problem have recently been completed by W. E. Flood at the Institute of Education of the University of Birmingham in England. Space does not permit a detailed account of his methods and results, but a few examples may help indicate how far we have to go.

One study dealt with the British popular-science magazine *Discovery,* which is a notch or two less technical than the *Scientific American.* In an advertisement, *Discovery* makes the following statement: "Its articles are written by eminent scientists and technologists, but in language that nonspecialists can easily understand." The University of Birmingham study does not confirm this claim. It shows that articles in the magazine are liberally sprinkled with terms like *phosphatic, sedimentary rock, electrostatic, metamorphosed,* and *thermal ratio* —terms which, however evident their meaning to scientists, mean little or nothing to laymen.

Flood concludes: "This magazine . . . is certainly not wholly written in nontechnical language and a nonscientific reader would not understand it. It may well be that it is really intended for a different type of reader. . . . But the study shows the extent to which scientific terms are liable to creep into reading matter which is meant to be popular rather than academic." A similar conclusion holds for articles in the Penguin publications *Science News* and *New Biology.*

Attention may also be drawn to a related and equally serious problem. The following quotation from the British magazine *The Listener* illustrates a common kind of failure in communication: "I suppose every naturalist and biologist who has contemplated the extraordinary adaptive variety of the world of animals and plants, or has investigated the amazing perfection of a highly developed sense-organ, such as the eye or ear, must have been brought up short by a doubt —is it conceivable that a fortuitous concourse of variations can have been responsible for the adaptive perfection we see?" This sentence is so bad in so many ways that I wish it were less typical. It should have been written as at least three sentences. It includes a number of charming, antique, and totally uncalled-for words and turns of phrase. But these faults are relatively minor. The main point is that the sentence says something quite definite and significant to some scientists and, at the same time, says little to the scientifically unsophisticated reader. From the layman's point of view it is dense and condensed beyond intelligibility. Words like *adaptive* and *variations,* as they apply to evolutionary theory, are shorthand. They mean a great deal to biologists, somewhat less to physical and social scientists, and considerably less to the general public. Science is full of such words. In popular-science writing every one of them must be amplified and clarified, with the aid of examples and comparisons and all other available devices.

Fresh Efforts Needed

I have mentioned a few of the many well-tested and recognized techniques which, if more widely applied, would make popular science more popular. Thistle has discussed these and others. Still other problems require the development of entirely new techniques. To cite only one example, there is the problem of magnitudes—the distance of the Andromeda galaxy, the size of a virus, the brief existence of a meson, the time that has elapsed since the earth's formation or the coming of man. How can we convey a real feeling for the enormously large or the infinitesimally small? An article could be written on past efforts to deal with magnitudes, and on the increasing need for fresh efforts in the future.

It is encouraging to note that more scientists are approaching popular science seriously enough to consider using established methods of communication. But, to look ahead, established methods are not sufficient. We still do not know precisely how effective any single method is in practice, nor do we know enough about the comparative effectiveness of different methods. We do not know what problems most urgently require the use of new methods. In other words, popular science is itself an area that demands further research. As I have already indicated, we are all amateurs in this field.