	Review journals, "Progress" series, etc.	Articles in other books and journals
Solid-state physics sample	0.100	0.034
Chemistry	0.081	0.047

Figure 5. Ratio of citations per year to pages of review material

column headings, and the denominator is the number of pages of review material of the type specified. As you will notice, a page of review material in review journals or "Progress" series is significantly more popular with its users, as measured by citations, than a page of review material in other books or other types of journals. I have tried to get similar statistics for a random sample of articles selected from the 1960 *Bibliography of Chemical Reviews*, and additionally from several review journals and "Progress" series in chemistry. The results, shown on the second line, are rather unreliable because of small-number statistics, but tend to support a similar conclusion.

Now then, what about the future? In over-all perspective, our total national investment in review literature in the sciences is foolishly low in comparison with our investment in new research. In my own field, for a typical example, the total value of all the man-hours and other expenditures for book and review-article preparation in solid-state physics is only a small fraction of a per cent of what we spend on new research. If we're ever to create a healthy scientific community, government agencies, university administrations, and scientists themselves are going to have to recognize that those who sponsor research have a responsibility also to sponsor synthesis.

As for the immediate future, my feeling is that what is most needed is improvement in the quality, the accessibility, and the convenience for use of the review literature. Secondarily, an increase in quantity is needed. Both the improvement in quality and the increase in quantity will require a greater total investment of time by authors of review material. Studies of time actually spent in review writing, however, suggest that such time should be easily available, if proper motivation of authors and of their employers can be secured.

As for accessibility, there are a variety of steps that could be taken by scientific societies. These include coverage of books in abstract and current-awareness publications and the maintenance of a cumulative and annotated bibliography of existing reviews. Authors can also play an important role, and based on the statistics I showed earlier, I would like to make a special plea to authors to avoid wasting their time writing small reviews for publication in out of the way places.

Most of the responsibility for quality improvements lies with the authors, although guidance or even pressure from editors of review journals or collections of review articles may play a role. I would like to make another special plea to authors, especially those of books and longer reviews, to write their material in a way that will encourage piecemeal use; in other words, to make it as convenient as possible for a user to find something in the middle of the article and make effective use of it after he has found it, without reading all the preceding material. Another point which should be mentioned is the importance of proper education of users of review material, specifically, education to locate such material and to use it properly when it is found. The graduate schools might help here.

Finally, besides all these rather unspectacular measures, I hope people can be encouraged to try, on a small scale at first, imaginative experiments in new techniques of book and review writing, and in particular of tapping the expertise of large numbers of scientists in the preparation of a review written by one or two.

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Critical Reviews: The Sponsor's Point of View*

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The major items which the sponsor of critical reviews must consider include: (1) the audience for whom the review is produced, (2) the selection of the subject and the scope of the review, (3) the method of production of a review, and (4) distribution of the completed product. The audience any given sponsor serves will, to some degree, determine the subject and scope of the reviews he might sponsor. The general methods of production are the single individual, special workshop, or large symposium. The distribution can be done by one of several methods, but will probably be dictated by the audience and the resources available.

The "Critical Review" is defined for this paper as a synthesis of existing knowledge relevant to some defined problem. It examines all of the hypotheses or theories germane to the question in hand, the evidence which gave rise to the theories; it assimilates new research results and other pertinent data into these theories, and identifies assumptions used to support the theories. Such a review may just restate what is common knowledge, but point out the areas supported by assumptions and the areas where there is solid knowledge. On the other hand, if there has been much recent research, the critical review may require synthesis of the research results into a new statement of knowledge which confirms or discredits old

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ideas and develops new theories or hypotheses. The "critical review" is to be distinguished from the annotated bibliography which all too often is passed off on an unsuspecting public as "the" critical review.

The sponsor of such critical reviews faces five interrelated questions: (1) What is the sponsor's relationship to the field of the critical review? (2) Who is the audience for whom the review is intended? (3) What is the subject of the review and what are the reasons for its choice? (4) Who is to do the review and how is it to be prepared? and (5) What is the method of distribution, once the review is finished?

The sponsor and his relation to the field of the review have a profound impact on the other four questions raised. At one extreme, the sponsor can be a benevolent patron with no substantive interest in the review; at the other end of the scale, such a review could mean intellectual (if not commercial) life or death to the sponsor. The interests and attitudes of an industrial organization are different from those of a public or philanthropic institute whose interests are different from those of a mission-oriented government agency or a university department. The attitudes of this paper, in discussing the other questions, will generally reflect the problems of a large disease-oriented research institute, but the position of other types of sponsors will also be considered.

The major concern here is the sponsor who will continually generate or support critical reviews. The sponsor of a single review is a special case of the general problem and of no interest except that, after deciding to sponsor only one review for his own special reasons, he must face the other questions.

The benevolent patron with no interest in the subject, but who wants to provide support for various things, makes decisions on the basis of advice. His problem is the selection of advisers, and it is the advisers who face the questions relative to the reviews. The reasons for allocation of funds by the patron depend on policy, logic, whimsy, or some combination of these. The actions and decisions of mission-oriented, industrial, and philanthropic organizations are more interesting to examine.

An industrial organization which sponsors critical reviews as a method of improving its operation to create more profit might be the simplest case, although it is not necessarily so. Here, the organization has well-defined problems; the audience is the management, the employees or some segment of them, the stockholders, or all of these groups. Whatever the subject of the review, the review will be directed to the structure of the company and its functions. Distribution will probably be through some established company system, but additional distribution through trade journals or other publications may be used.

The management of a large research institute has a different problem in decision-making for the support of critical reviews. Such a research institute with many complex interrelated problems to solve, has the possibility of sponsoring many different reviews. How to choose?

Like that from the industrial organization, the critical review sponsored by the research institute probably will reflect its problems and goals, but the research institute usually has a wider choice of possible audiences which will affect both the choice of subject and its manner of preparation. The audiences are:

a) Those in the institute responsible for allocation of resources.
b) The scientists doing the definitive work at the forefront of the field.
c) Scientists working on related subjects tangent to or intersecting a particular field.
d) Educators working in this field.
e) The general scientific community.
f) Financial contributors to the institute and other interested lay groups.
g) The general public.

This list indicates a decreasing need for intricate technical knowledge and an increasing need for knowledge of interrelated fields.

The question here is: Does a specific audience need or request a review or is the review subject identified first and then the audience selected because of their interactions with the sponsor?

Usually, the need and subject for the critical review is identified by the needs of the audience. An example is a discovery of some kind that leads to a new general hypothesis so important that it defines a new field. If this new field is quite radical, embracing phenomena which had previously been considered quite remote and uninteresting, and if it also happens to generate considerable enthusiasm among the scientific community, attracting many new workers, then there will be a need to assemble all information, common and remote, so that new workers may easily and intelligently enter the field.

It is also possible that a lot of new knowledge is produced essentially substantially by many widely scattered people, all at the assumed forefront of the field, but unable to know, much less really absorb, all that is going on. Here a critical review is needed. Another example is when the sponsor decides to enter, or considers whether he should enter a new research enterprise. The scientists need to know all there is about this new field so that they can plan their attack intelligently.

Here, the problem is to become aware of the on-going research, synthesize it in relation to the new ideas, see which things have been put on a solid foundation, what new assumptions have to be evoked, and what areas can be considered solid. This is a difficult effort using data and concepts in a way which requires an expert in the field, with a solid scientific background, who is able to evaluate the on-going research and able to synthesize it into concepts and theories. This illustrates the distinction between the annotated bibliography and the truly synthetic review.

In fields that have been moving very slowly for a number of years, information lies in widely scattered locations, and ideas which were originally assumptions have taken on the mantle of fact. A new worker in the field is plagued by old concepts supported by these transformed assumptions, and often his progress is blocked because of them. Here, the critical review pulls together existing knowledge and synthesizes it into solid concepts, bringing thinking up to date, but most important, it identifies these supposed facts which are really only assumptions. If the field is slow-moving, the urgency for distribution is not quite so great as in the rapidly expanding new fields, but it might be urgent if it were needed for the sponsor's planning or allocation of resources.

An institute should know its own problems. What are the most important problems for the institute to solve? What problems seem to be lacking in progress? What specific areas of a problem do not seem to be making any progress? Here, if the institute can find an area which seems to be stagnant in terms of progress toward a solution, it may decide to have a critical review done to find the bottleneck. This is an analysis of what is known, what is being done in other fields which may apply to it, but the emphasis is where the problem should be attacked. Here, the audience may be two; the institute management, and the scientific community at large for the purpose of stimulating interest. This is the kind of document which, if well done, can be a foundation for the planning of a great deal of research.

One generality about the people who do critical reviews seems to prevail. The scientific quality and merit of a review is directly proportional to the scientific ability of the writer. An important aspect which must be emphasized is the skill of the author in synthesis. This skill is a very hard thing to find.

If a document is to be used for the lay public, the stockholders, or for financial support, then a high-grade scientific writer with a fair amount of knowledge can take a lot of information and put it together meaningfully. But it is doubtful, probably impossible and not to be expected, that this same person will be able to synthesize scientific data into a new hypothesis or write a document for those at the forefront. It follows then that the critical review must be done by a scientist in the field.

The next question is whether this is something for a beginning scientist—a Ph.D. student or an early post-doctoral scientist—a practicing scientist, or an emeritus scientist to do.

Unquestionably, scientific innovation and discovery have resulted from the questioning and syntheses of younger scientists. They are the ones who are quite likely to challenge something based on assumptions that for years have been accepted as fact. They are not afraid to propose new ideas and, by so doing, quite often pull together facts into very solid new hypotheses. This is not to say that the older scientists are not capable of doing likewise; they are. The question is whether they have time to do so. Usually, the minds of younger scientists are uncluttered; furthermore, they have more time to do this sort of thing. A scientist working in the field is quite capable of reviewing it, and probably would do a creditable job, if he could be recruited. The difficult thing is to get him to do it. Recruiting is a special problem, and will not be considered here.

The method of preparing the review also relates to who is going to do it. Traditionally, this has been a slow, steady, long-time work of scientists reading in the library, thinking, and finally writing, taking a period of many months and even years. This has been effective and worthwhile. If there is urgency in terms of time in the production of a review, however, this method won't do. Anything that takes two years to produce will almost certainly be partly out-of-date by the time it reaches its audience. A method which is being utilized today is the "workshop." Here a group of scientists, after a certain amount of preparation, come together and discuss the subject, including their own work and the work of others, try to agree on points of solidity, and identify questions. One of the group, using this material, writes a critical review of the problem. The realities of this method usually are that the person assigned to the writing takes a long time, partly because of his own activities and partly because of the exchange of information, review of manuscripts, and correspondence with the other members of the panel.

This kind of delay has been avoided through the use of a technical writer to work with the scientists. The discussions of the workshop are transcribed, and the technical writer edits this, and puts it into a highly readable form. The responsible scientists then review this draft for omissions and misstatements. This kind of manuscript can be produced very rapidly for dissemination and, depending on the rapport between the writer and the responsible scientist, can be at any level of sophistication.

Once the manuscript has been produced, how is it disseminated? This, again, is an important consideration for the sponsor. What are the normal channels to get to the intended audience?

There are the journals, supplements to journals, and monographs for special distribution. A good way to make sure that people will read it is to put it into the channels they normally use; that is, through regular journals. To speed this up, very often special arrangements must be made with journal editors.

Sending out free copies of a review to everyone is another way; this method is expensive and often it is very difficult to identify the audience. On the other hand, a special journal is usually seen by most workers in a given field and it automatically goes to subscribers. An additional group of people might be sent copies, if they can be identified. Special announcements can be sent out.

There are a variety of ways to reach people, but, before devising or planning any new method of distribution, the sponsor should examine available methods to find those which are most likely to take the critical review to the audience with whom he is concerned. If, on inspection, these routes are inadequate, then new ones must be considered. The energy with which a sponsor does this, again, relates to his position relative to the review. If it is something that he is trying to push, great efforts will be expended. If it is just a review of a part or portion of his program, with no specific significance, his efforts are likely to be considerably less. The sponsor must be cognizant of all possible methods of distribution and their impact on various audiences to which the sponsor relates and in which he is interested.