Critical Reviews: The User's Point of View*

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Scientists are worried about the "information explosion" and the amount of published literature that could have a significant impact on their work. One thing that can help is a condensation and evaluation of the published material. This is the task of reviews, and without them, the other tools for dealing with the information explosion will be inadequate. Suggestions are made on ways for authors and editors to make their reviews more accessible and more useful and on the need for better education of users.

The contents of this paper may seem to be more the remarks of an observer of the whole picture than those specifically of a user. My interest in problems of science information, and especially in review literature, however, is a direct outgrowth of the frustrations I have suffered, as a research worker, in my work. I shall start by detailing some of the reasons why a healthy review literature is, in my opinion, an important, in fact even indispensable, part of the information apparatus of science.

Many people nowadays take a rather complacent attitude toward the information explosion. They say, and this is of course true, that scientists have *never* been able to keep up with all of the intellectual developments they would like to, and that for centuries scholars have found it necessary to narrow the range of fields in which they keep currently informed. I would like to counter this by pointing out that there is more difference between the relation of a scientist to his literature today and that of 30 years ago, than a mere scale change. Figure 1 shows some purely schematic graphs on which the density of certain kinds of information is plotted vertically as a function of a horizontal distance measuring the remoteness of the field of this information, as it might be judged by an impartial observer, from the field of specialization of a particular scientist. Thirty years ago, the information in the literature that the scientist might have been able to keep abreast of would have had a distribution something like the full curve in the top diagram. Today, because of the information explosion, he can keep up only with a much narrower range of fields, as shown by the full curve in the lower diagram. But these curves are not to be considered by themselves: they have to be compared with the curves representing the distribution of information weighted by its relevance to the scientist's research work. In the 1930's, such a curve might have been like the dashed curve in the upper diagram, which has a width comparable with that of the full curve, although not necessarily referring to the same items of information. Today the corresponding curve of relevance, in many fields at least, is wider as well as higher, because different fields are becoming more interrelated. Thus the dashed curves provide a natural scale of width against which the full curves are to be measured. It is obvious that there is a serious discrepancy now between the width of the curve of what the scientist can keep up with and the curve of what is relevant for his work. Of course there is a great variation from field to field in these curves, and there are still a few fields in which one can pursue a narrow specialty without much need of drawing on data or concepts from nearby fields. For most of us, however, the trend shown is already quite painful.

The second point to make, pertaining to the importance of reviews, has to do with the quality of the primary literature: How much of this is of real value and how long does it remain of value? Figure 2 shows some curves of the frequency distribution of journal literature over a value scale. The horizontal scale has a center at zero

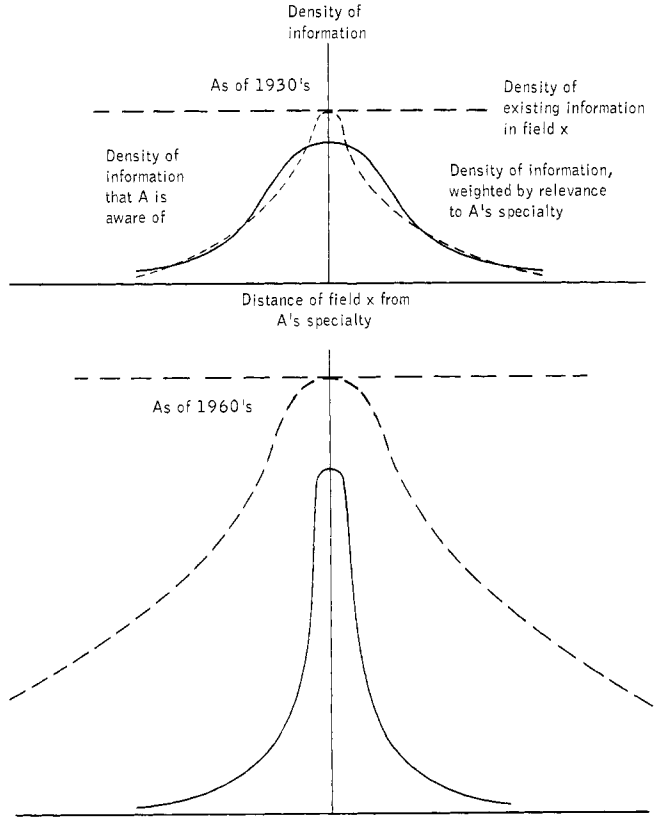

Figure 1. Awareness vs. relevance, for fields neighboring the specialty of a typical scientist "A"

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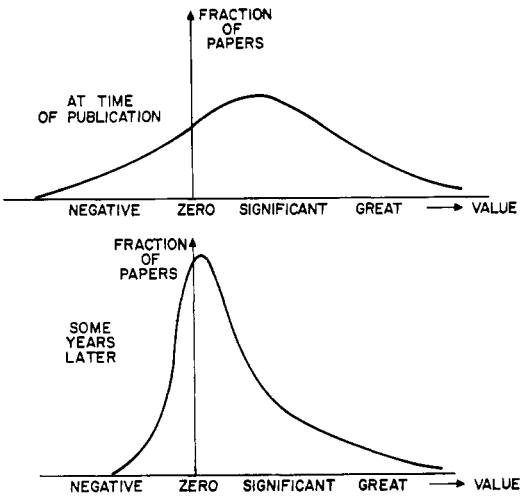

Figure 2. Frequency distribution of journal literature over a value scale

value, with negative value to the left and positive value increasing to the right as shown. The curves are schematic, but I have tried to compare them in a roughly quantitative way with some data that I have taken on articles randomly selected from the literature in certain areas of solid-state physics. If one evaluates papers at the time of their publication, one finds a distribution like that shown in the top diagram, with a small proportion of papers wrong or otherwise of clearly negative value, a somewhat larger number of essentially zero value, and most of the papers making some identifiable positive contribution to the advancement of science. As the years go on, nearly all papers regress in their value toward zero, the papers of negative value becoming less harmful as their fallacies become more and more apparent, and the papers of positive value becoming less valuable as they become more and more out of date. Thus the frequency distribution of a given set of papers alters with time in the direction shown by the lower diagram, which has of course the same area as the upper and in fact the same area for its positive and negative halves as the upper, but a different shape.

However, a small-scale study I have made recently suggests strongly that, at least in solid-state physics, nearly half of all papers published in the larger journals remain of appreciable value—in particular, are not out of date or superseded—after four or five years have passed. This study used two samples. For one, a couple of dozen papers of this age were selected at random from the world's literature (though probably with some bias toward the larger journals) in about a dozen different sub-fields of solid-state physics. Each of these was then evaluated by an expert, not associated with the author, whom I considered trustworthy. Any error in this method of evaluation is likely to be in the direction of giving too low a rating. Yet nearly half turned out to be rated "still of significant value, not superseded." For the other sample, I myself evaluated about three dozen papers of greater than five years' age from an exhaustive bibliography in a single field of special interest to me. Over half of this sample fell in the category "still of significant value, not superseded."

Many chemists seem to think that the yield and performance of significant results in the chemical literature are much poorer than this. But on the statistically rather meager basis of a similar study of a slightly smaller sample of papers in physical and inorganic chemistry, I am inclined to feel that these areas, at least, fall only slightly below solid-state physics in their yield of significant and long-lived material.

This fact is important, because it means that an optimum use of the literature requires some sort of access to a very large amount of material. Although it is fashionable to deplore the amount of "garbage" in the literature, the hard fact is that most papers in the literature are of some value and use. How, then, can these data and concepts become readily available to the people who need them?

One institution that has been, and is continuing to be, remarkably effective at making information available is the grapevine—i.e., the whole complex of informal communication whereby scientists tell one another about the interesting things, exchange preprints, and so on. But although this is remarkably effective, and is coming to be relied on more and more as people get more and more discouraged with the flood of published literature, I know of a number of studies[1] which indicate that it falls far short of optimal effectiveness, especially for certain individuals and in certain fields.

Let me take an example from my own personal history. Usually, I try to browse the published literature systematically, but for a period of about a year, I was unable to do this. Later I tried to catch up by systematically looking over the literature that had been published in the year that I had missed, and I found that most items that I considered to be of major and urgent interest to me during this year were those that I had not heard of through any of my informal channels. Of course, the efficiency of the grapevine is very different for different individuals and depends on the breadth of their interests, the extent of their contacts with colleagues of like interests, and many other factors. But I have been forced to conclude that in most fields of physics, and doubtless in many fields of chemistry, even well-known men in large institutions would miss a good deal of information of great value to their work if they relied entirely on the grapevine.

Another class of mechanisms, about which there is currently a great deal of talk, is that of information retrieval schemes, that is, abstracting and indexing services, current-awareness publications, selective dissemination of information, files of references that can be searched on a computer, and so on. Some of these tools are important and if properly developed can contribute a great deal to the effective use of information in the literature. But I want to stress that, by themselves, these techniques are not enough. Even if they are ideally efficient—and it is quite hard to make them so—such devices can only provide the user with a list of papers that pertain to a topic he is interested in, or to a question he has put to the system. Although this can often be quite helpful, it can also often be quite frustrating.

Let me again take an example from my own experience, from the field of the theory of transport phenomena in semiconductors and metals in the presence of magnetic

fields so large that one must use quantum transport theory rather than the Boltzmann equation. There are at least 130 or 140 papers in this field now, and the typical paper is a rather opaque mish-mash of commutators, Green's functions, Laplace transforms, and what have you, so that it often takes hours (or even days!) to understand what the author is saying. Some of these papers are wrong and contradictory; others duplicate each other but with a different language and terminology. Yet most of the papers contain some contribution of value, and it is impossible to select any small group of the papers that will contain all the valuable contributions that the whole set contains. In spite of this condition, an orderly presentation of the subject could provide all this material in no more than a tenth the total space of these papers.

While this example may be extreme, it illustrates the sort of thing that is going to be encountered more and more often in the future. No set of information tools is going to supply what we need of them unless they include some means of digesting, evaluating, and, above all, condensing the scattered bits of information in the literature into coherent and comprehensible packages. This is the function that treatises and critical reviews should serve, and they can do this adequately only if their authors invest a great deal of highly creative thought in their preparation. For, to condense information, one must create order and simplicity.

If we are to think intelligently about how to improve our present review literature, we have to know something about what it is now like. Let's start with the simplest question: How much review literature is there? Figure 3 gives a few rather incomplete figures for several fields of science, as of 1966. The lengths of the bars represent pages per year in the various categories, according to the scale at the bottom. The crosshatched regions correspond to hard-cover books as obtained from listings in *Nature*, which require a slight but probably not very serious augmentation to take account of the incomplete listing of non-English language books. Open bars correspond to review articles in journals and, just for comparison, the lengths of the black bars represent 10% of the number of pages published annually in the primary, that is, nonreview literature. I have not allowed the fields to overlap—e.g., I have included under "Chemistry" only material that belongs more properly to chemistry than to biology or physics or engineering. In physics, which is probably not too dissimilar from chemistry, I have subdivided the books roughly into texbooks, collections of papers (such as conference reports, compilations, etc.), and other types of books. As one might suspect from the size of this section, there is considerably more material of review-article form in these collections than in journals; I'm sure the same holds for chemistry, too.

It is interesting to note that the average factor by which the primary literature is condensed varies quite a bit both from field to field and, within a given field, between review articles and longer treatises. Thus, review articles in biology average 5 or more references per page, those in chemistry 4, and those in physics 2 to 2½. As for longer treatises, in physics these seem to have only about one-third as many references per page as review articles.

A much more difficult but very important question concerns the adequacy of the coverage of contemporary

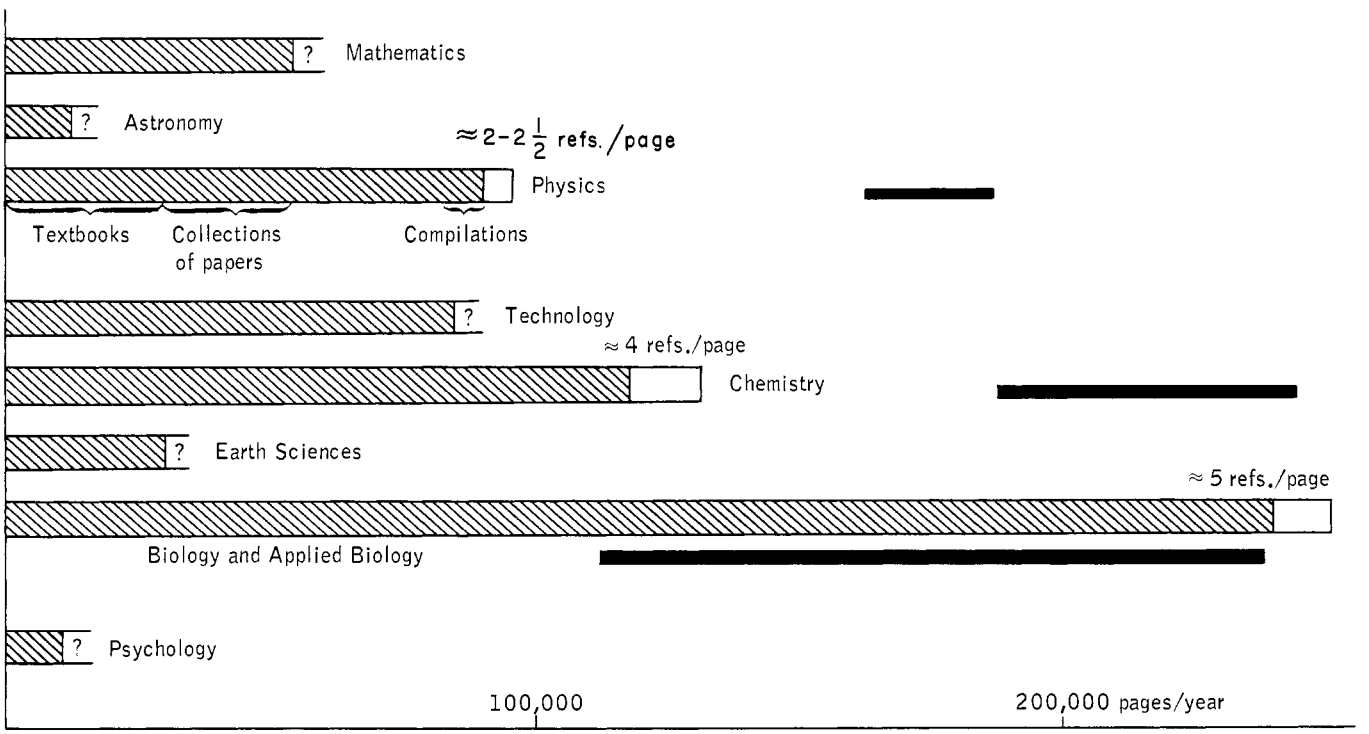

Figure 3. Page bulk of the annual production of review literature in several fields, as of 1966, data adjusted to eliminate overlap between fields

Open bars are review articles in journals, cross-hatched bars material in books, solid bars estimates of 10% of the primary literature. A few figures are given on the average ratio of bibliography entries to pages

research by the review literature. To discuss this quantitatively, we have to ask: Coverage of what material and in what depth? Thus one could ask: How well does the review literature or any portion of it cover, firstly, material of any value at all, or secondly, material that meets some specified criterion of significant value. Again, for material of any specified type, we could ask firstly, whether it was mentioned at all, or secondly, whether something useful was said about the material in question, or finally, whether that material has been discussed at a sufficient depth so that the average user need not refer to the original literature at all.

I have made some studies recently on the coverage, in books and reviews, of the material in a sample of solid-state physics papers representative of something like the upper 20% or so of the value distribution in Figure 2. For this sample, it appears that treatises and review articles contribute comparably to the total coverage of the review literature, and that the probability for one of these rather significant papers to be at least mentioned somewhere in the total review literature within five years of its date of publication is close to unity. As mere mention may not help the user very much, it's of more interest to know the probability that somewhere in the review literature there will be a statement at least of the principal results of the paper in question. For the sample I mentioned, the probability for this to happen within five years also seems to be fairly high, of the order of 9/10. But the probability for a discussion sufficiently detailed to relieve the majority of users from the necessity of consulting the original paper is much lower, only of the order of 5/10.

From these solid-state physics figures one can conclude that the present review literature is far more than just a drop in the bucket as compared with what is needed, but that it is still quite a bit short of what is needed if physicists are to make effective use of existing information. For, in an ideal review literature, it would hardly suffice if there were only one book or review article that yielded a reasonable amount of information about a given item of importance within five years of its publication. Different users of this information will often have different levels of sophistication and require different levels of presentation; moreover the user should not have to rely on the evaluation of a single reviewer.

So much, then, for coverage: What about use of review material? This is also difficult to measure: one can study citations of review literature or one can ask people what they use, but neither of these numbers takes adequate account of the long range effect of review literature which is read by one person and then influences others via the grapevine. If we recognize these limitations, however, we can learn at least a few things of value from citation and preference studies.

Figure 4 gives the distribution of a sample of references to review literature in the solid-state field which appeared in the papers of the solid-state sections of a sample of the *Physical Review*. I show this because I believe, on the basis of somewhat sketchier data, that this general picture is valid both for other areas of physics and for many areas of chemistry. The total number of references to the review literature in this sample was about 2 per paper as compared with 15 references per paper altogether.

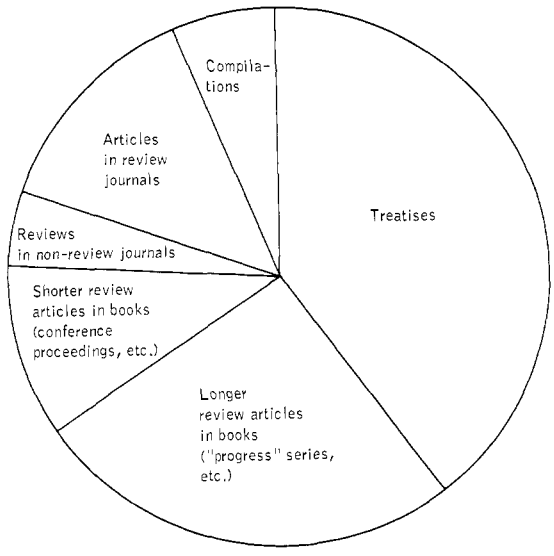

Figure 4. Distribution of citations to the review literature of solid-state physics, in a typical sample of research papers in this field

The distribution over the various types of review literature is indicated by the areas of the different sectors. As one might expect, the most frequently cited category is that of treatises, that is, books on a single subject. One might, however, have expected treatises to constitute an even larger fraction of the citations, for they constitute about $^2/_3$ of the total number of review pages published in solid-state physics. A feature of special interest is the fact that the citations to review articles in review journals are much more frequent than to those in non-review journals, in spite of the fact that there are more pages of the latter published than of the former. There seems to be an analogous effect among the review articles in books. Thus review articles in books that go by the name "Progress in...," or in books that undertake to cover systematically a fairly broad field, seem to be cited considerably more often than review articles in other books such as conference proceedings, even though the page bulk of the latter exceeds that of the former. Both in books and in journals, there seems to be a preference for the more comprehensive type of review article, or perhaps for the more accessible type of review article.

The data I have on citations in the *Journal of the American Chemical Society* suggest that the picture is very similar to the solid-state physics data in Figure 4, except that the preference for treatises is even more marked.

I'd like to stress this matter of the greater utility of reviews that appear in standard review publications. Figure 5 shows some figures from studies made with the *Science Citation Index* on the number of citations of samples of review material of various types. The first row refers to citations of a sample of review papers obtained from a random selection of Fellows of the American Physical Society in solid-state physics, who were asked what review articles they had written since World War II. The decimal entries are ratios in which the numerator is the number of citations in the 1965 and 1966 *Science Citation Index* to review material of the author in question, of the type corresponding to one or the other of the

	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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