people who subscribed to it and that we had to select material and handle things on that basis." By and large, this view prevailed.

For *Science*, the postwar decade was a period of muddling through. Under Cattell, *Science* had gained a prominent place in American science, but had suffered a decline in both quality and influence in the later years of the editor's life. When AAAS took control of the magazine after the war things were at low ebb. *Science* was fortunate when it was weak that it was not seriously challenged by competitors. That it weathered the period as well as it did is a tribute to a staff that was loyal and long-suffering under adverse conditions and to the voluntary efforts of countless scientists who acted as editors, contributors, and referees, and to the good will of the scientific community toward the AAAS and *Science*. The turning point came with the Wolfle initiatives in the middle 1950's. That AAAS was willing to give *Science* its head was confirmed when it appointed Abelson as editor and showed its confidence in him by granting him a virtually free hand with the magazine. By the early 1960's, therefore, *Science* was ready to participate in the second phase of the postwar expansion of American science that began after Sputnik.

Science: A Memoir of the 1960's and 1970's

Dael Wolfle

Some future historian may describe *Science* since 1962, the end of the period reviewed by John Walsh, but this article is not such a history. The period is too recent, and I was too closely involved. Instead, this will be a personal account of how the editorial staff works, and some of the problems and satisfactions of securing, selecting, writing, and editing 4000 to 5000 pages of text a year that will go to essentially every major research institute and university in the world.

A New Editor

The period starts in 1962 when Graham DuShane, who had been editor since the first of 1956, accepted appointment at Vanderbilt University as chairman of the Department of Biology and Dean of Graduate Sciences. The *Journal of Geophysical Research* was then prospering under the editorship of Philip Abelson, director of the Geophysical Laboratory, and subsequently president, of the Carnegie Institution of Washington. I had several talks with Abelson; liked the way he thought about editorial problems; and recommended to the board of directors that we invite him to become editor of *Science*. They agreed; he accepted; and in August started what has become the longest editorship in the history of *Science* except for the never to be repeated half-century of James McKeen Cattell.

Abelson stepped into a going enterprise. Ellen Murphy, production editor, and Robert Ormes, managing editor, had come in 1954 during Duane Roller's brief period as editor; and John Ringle, assistant managing editor, had come during the DuShane period. They had the help of experienced manuscript editors, proofreaders, and other aides. Circulation was increasing steadily. And Earl Scherago, the advertising representative, and his staff were expanding advertising sales. With an experienced and able staff in place, the new editor could concentrate on broadening the content of the magazine and on the never completed task of improving the quality of the material published.

To help choose the topics and authors who should be in *Science*, editors have long had the help of an editorial board. In addition, Abelson considered it his personal responsibility to keep broadly informed about new ideas and major developments across the forefront of science. He uses the telephone extensively; seeks the advice of a wide range of scientific acquaintances; and makes frequent exploratory visits to universities, industrial laboratories, and research institutes. The result has been a broadening of the content with less of the concentration on biology that had developed for quite understandable reasons but that was nevertheless worrisome to the AAAS officers and staff. The most notable broadening of content was in geophysics and space and planetary science. Unmanned space probes, the Apollo Program, plate tectonics, and new instruments for geophysical research have led to new findings of wide interest. *Science* has given much attention to these developments.

Selection and Quality Control

When there are only enough pages to print 20 to 25 percent of the papers that authors would like to have published in the magazine, selecting those of highest quality and widest interest is always a responsibility that calls for the most careful attention. To help make the selection a panel of willing, well-informed, and critical referees is essential. A quarter of a century ago, when manuscripts were fewer, they were parceled out to members of the editorial board who read and decided, or sought the advice of knowledgeable colleagues. As the volume of work increased, a card file of referees became necessary. When John Ringle joined the staff in 1961 the improvement and use of an expanding panel of referees became his primary responsibility. The number has now grown to 10,000 and the old card file has been replaced by magnetic tape.

When Abelson came, he quickly introduced the practice of telephoning prospective referees instead of writing them. The telephone bill jumped, but the average lag between receipt and publication of accepted articles was cut by a month, for no longer were manuscripts sent to referees who were off to Europe for a conference or for some other reason were unable to respond promptly.

In the past few years the continuing effort to improve the reviewing process

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has involved participation of some of the associate and assistant editors who have much experience in substantive editing and some of whom hold doctors degrees in science. Their help in selecting just the right referees, evaluating their comments, and discussing those comments with referees and authors has raised the level of the reviewing system.

Yet no matter how carefully the manuscripts are reviewed authors of rejected papers are often disappointed, and sometimes irate. On a trial basis, authors who objected to editorial decisions were sometimes invited to name several experts in the field (not from the author's institution) whom they thought best qualified to referee their rejected papers. They almost always named well-qualified scientists. Sending the manuscript to a couple of referees from these author-proposed lists usually brought confirmation of the original decision. On the basis of this experience authors are now frequently invited to nominate referees. In 1973, the editor reported to the editorial board: "We have studied the outcomes of reviews by author-suggested reviewers compared with reviewers selected by the staff. There is no difference in the ranking of papers. Neither does there seem to be a difference in author complaints about rejected papers. Authors complain equally about prejudice or incompetence of referees, whether the referees are their choice or ours or a mix." Nevertheless, writing rejection letters is one of the unhappy but inescapable duties, for space limitations require rejection of many papers that unquestionably merit publication, and in retrospect any editor can find decisions that probably should have gone the other way.

Staff Writers

Soliciting some of the articles is one method of achieving broad and balanced content. Having some of the material written by members of the staff is another. As a scientific magazine, rather than a pure journal, *Science* has always published news items and editorial comment on scientific affairs. Late in the 1950's we decided to supplement the personal news then being published by adding a reporter who could write interpretive accounts of the President's budget for research and development, of congressional actions, of trends in executive agencies, and of other matters affecting the course of scientific research and education. This was a new kind of journalism, not science writing and not the usual type of political reporting. The first two writers did not work out satisfactorily. But on the third try we found Howard Margolis, the first News and Comment writer to succeed. In 1961, the appointment of Daniel Greenberg added strength and spice to the section. Both wrote clear, sharp prose. Both knew how to track down a story and how to get behind its surface aspects. And both got us into trouble. Trouble was probably inevitable. Adding a news section written by journalists to a magazine edited for and by scientists was a mixed pleasure for the management. Some readers complained that *Science* had no business discussing politics; it was unscientific and undignified. When a News and Comment story described shortcomings or lapses in the way scientists managed their affairs we were accused of washing dirty linen in public. But criticisms were outnumbered by compliments. Many letters and comments told us that readers found the new section lively, interesting, and a source of information they wanted to know but could not find elsewhere.

In 1962, Secretary McNamara persuaded Margolis to join his staff as a speech writer, and we engaged John Walsh. Greenberg and Walsh set a pattern for the kind of writer needed. Greenberg had tried law school and decided he really did not want to become a lawyer. After 3 years as a reporter on the Wilmington *Journal* and 2 years on the Washington *Post*, he had received a fellowship from the American Political Science Association to work in Congress. Walsh had had 5 years of experience on the Louisville *Times*, the first three as a general reporter and the last two as education editor. He had then become legislative assistant to Congressman John Brademas. These were the kind of people we looked for. A few years later, when the News and Comment staff had grown to five, every one had a background in economics, history, or political science; all but one had done graduate work, two as Rhodes Scholars; every one had experience on a newspaper; and all but one had worked on Capitol Hill.

They have done well for *Science* and *Science* has been a good platform for them. They have been invited speakers and seminar leaders at major universities; several have received fellowships for a few months or a year for special study; and several have written books. Several former members of the staff have gone on to senior posts on major dailies or to other editorial responsibilities. They have also been teachers; an internship under the News and Comment staff has provided part of the training of several reporters now on major newspapers.

By the late 1960's it seemed desirable to start a new section called Research News. For that purpose, a quite different type of writer was needed. Young scientists, usually trained to the doctoral level, who also had a flair for writing were chosen. Robert Holcomb came first, in 1969; then Allen Hammond, now editor of *Science 80*; then others until the larger present staff was built up. Recently, members of the News and Comment and the Research News staffs have been experimenting with the technique of joint reporting in order to give readers integrated accounts of the scientific and political aspects of an important development. Recent articles on efforts to control toxic substances provide an example.

News and Comment and Research News staff members are professional writers. They do a good deal of checking of facts and interpretations. But like other contributors to *Science* they need quality control. They write under the stern discipline of knowing that some readers will know more than they do about almost any topic they choose to discuss, and when time permits some of their stories are reviewed and criticized by external critics.

Surveys of Readers

Referees are helpful; authors and staff members are essential; but readers are the magazine's rulers. *Science* readers are a highly educated and literate group. Well over half hold doctoral degrees. Some 80 percent write for publication. The weekly Letters section and many unpublished letters bring continuing evidence of their critically discriminating judgment of the content and policies of the magazine. To supplement their advice, short questionnaires are periodically sent to random samples of subscribers. The questions are varied, but the purpose is always to find out what readers like, or dislike; which sections they find most interesting and most valuable; what they would like to see expanded, or contracted. Results have been quite consistent. The articles always come out on top. Reports and News and Comment follow, more or less together, and the other sections get fewer favorite rankings. But when asked about balance, the present distribution of space among the several sections is generally endorsed. It should be; previous surveys have helped determine the present balance.

Because advertisers are skeptical of

surveys conducted and interpreted by a publisher, periodic surveys are also made by an independent firm that surveys many magazines to assess their value to advertisers. These surveys have in general confirmed the findings of those conducted by the staff, and have sometimes added some interesting tidbits. For example, more than three-fourths of the readers who work in hospitals or medical centers read their copies at home, while more than half of those who work for government read their copies at work.

Special Issues and Books

The special issue that will probably be longest remembered by the staff members who worked on it was the Moon Issue of 30 January 1970. Apollo 11 had brought back 22 kilograms of moon rocks and dust that were being analyzed by many laboratories in the United States and abroad. A conference was planned for early January 1970 in Houston for presentation and discussion of the findings of those analyses. To prevent hasty and uncoordinated publication of the findings, the National Aeronautics and Space Administration contracted with AAAS for a special issue of *Science* that would include all of the papers from the Houston conference.

With an augmented staff, partly in Houston and partly in Washington, D.C., in 27 days time all of the manuscripts were received from their authors and reviewed by critics; the authors responded to their critics' comments; the manuscripts were edited for style and, in lieu of later distribution of galley proofs, were submitted to authors for their review; the manuscripts were marked for the printer and set in type; illustrations were redrawn and relettered for uniformity; engravings were prepared; galley proofs were corrected and paged; page proofs were proofread and corrected; revised pages were proofread and corrected; and the magazine was printed, bound, and mailed. The Moon Issue included four times as much material as usually appeared in an issue, and work on it had to proceed on its own tight schedule without interrupting the flow of work on the other issues that appeared shortly before and after it. The publication of 325 pages of refereed scientific material in less than 4 weeks from first receipt of manuscripts to mailing of the magazine must have set some kind of record in scientific publishing. The issue was eagerly received by readers wanting to know what those moon rocks showed, and for the staff, the proud feeling of "Look what we've done" was a fine tonic.

For many years *Science* had published two special issues a year, one on books and one on scientific instruments. The success of the Moon Issue led to numerous occasions on which all or most of an issue was devoted to a single subject: energy, electronics, health care, materials, cancer, or another timely topic. As a recent example, the year 1979 was a high peak in planetary exploration, and *Science* gave much space to the information sent back by planetary probes to Venus, Jupiter, and Saturn. In January 1980, the *National Geographic*, *Scientific American*, and the *Smithsonian* magazine all appeared with covers showing a Voyager I picture of volcanic activity on the Jovian moon Io. Members of the *Science* staff were not at all displeased to remember that 6 months earlier their 1 June 1979 issue had included that same picture and several others from the Voyager mission to Jupiter.

Sometimes special attention has resulted in a series of related articles rather than a concentration in one issue. Some of the series and special issues have also been published as books. For example, a series of 18 Research News articles became the book *Energy and the Future* (*1*), which was later republished in German, Japanese, Portuguese, Hebrew, and Arabic editions.

Business Management

Science is printed on a tight production schedule that requires close collaboration between the editorial staff and the printer. More than a few news stories have been completed on a Monday, set in type that night, corrected and paged on Tuesday, and printed and mailed Tuesday night and Wednesday morning. Following President Kennedy's assassination on Friday, 22 November 1963, Jerome Wiesner, Kennedy's special assistant for science and technology, spent part of the weekend writing a memorial account of Kennedy's interests in scientific affairs. The account appeared in the issue that began to be mailed about midnight the following Tuesday.

To operate on such a fast schedule requires printing on a rotary press, similar to those used by newsmagazines and newspapers. Robert Ormes, managing editor, works closely with the printer to coordinate work in the editorial office with that at the printing plant, to contain costs, and to take advantage of new printing techniques. Along the way there has been a good bit of experimentation and early use of innovations in printing. Beginning in the 1960's, some of the content was set by computers. Now much is and it appears likely that soon all will be.

In 1979, the budget for the magazine came to over $7 million, more than $48 per paid subscription. That kind of cost requires looking for all possible savings. A current example results from the increasingly high cost of energy. Rolls of freshly inked paper coming off a rotary press must be dried quickly to prevent smearing. Gas or fuel oil has usually been used to fire the driers. The amount of heat needed to dry the ink depends on the type of paper used, and the type of ink. With proper selection of paper and ink many dollars can be saved. But paper must also be sufficiently opaque to minimize show-through of printing on the other side and must have good lasting quality, for files of *Science* are expected to last a long time. Balancing these several and sometimes conflicting characteristics is one of the cooperative undertakings of printer and managing editor.

It costs more to edit, print, and mail a year's issues of the magazine than most readers pay for a subscription or in annual dues as a member of the AAAS. Part of the difference is made up from ancillary activities such as the sale of reprints, but most of it comes from the sale of advertising space. When Earl Scherago became advertising representative agreement was easily reached that advertising was an integral part of the magazine, and that advertisements were appropriate and acceptable only if they appealed to scientists as scientists. Thus the advertisements have been of instruments, books, scientific and technological services, and scientific meetings or positions. Occasionally, however, problems have arisen. Some advertisements have been refused because the companies involved had a poor record of performance. One light-hearted conference was required to decide that *Science* would accept an ad for a line of neckties displaying different scientific symbols.

Measures of Success

One measure of the success of a magazine is its circulation. For a magazine such as *Science*, which has its own niche and specialized audience, it is of little value to make comparisons with the circulation of other magazines, but it can be compared with itself, over time. In 1962, average paid circulation was 77,000. The figure increased every year to early 1971 when it reached a peak of 163,000. Then circulation figures were battered by eco-

nomic recession, reduction in funds for research and development, some unemployment among scientists and engineers, and increasing inflation. By 1975 and 1976 paid circulation had fallen to 137,000, but by 1979 was back up to 152,000.

The circulation is worldwide. In 1979, more than 14,000 subscriptions were regularly mailed to 141 countries other than the United States.

Other indicators of success can be found in various measures of usage. Requests for permission to reprint tables, figures, excerpts, or whole papers have increased steadily over the years and in 1979 over 7000 requests were granted. Also in 1979, 5000 libraries purchased microfilm copies of single issues up to runs of several volumes from University Microfilms. These sales ranked *Science* ninth among the 12,200 periodicals in the University Microfilm catalogue, following *Time*, *Newsweek*, *U.S. News and World Report*, and several other magazines. In a 1974 analysis, the British Library Lending Division reported receiving more requests for photocopies of articles from *Science* than from any other of the 15,000 periodicals from which photocopies were wanted (*2*).

In 1978, 59,000 citations to articles previously published in *Science* gave it seventh rank in total citations among 3463 science, social science, and clinical periodicals covered by *Journal Citation Reports* (*3*). In 1976, the Ladd-Lipset Survey found *Science* ranking fourth among periodicals read by American faculty members, and third (behind *New York Times* and *Time*) among faculty members at major universities (*4*).

Science writers and the public media also find *Science* useful. In a 12-month period of 1978–1979, stories credited to *Science* appeared in 70 magazines and newsletters and in more than 400 U.S. newspapers.

More than 30 indexing and abstracting services include material from *Science*, and it is the only technical journal indexed in the *Readers Guide to Periodical Literature*. In 1977, *Readers Guide* announced it was dropping *Science*, but received so many protests, especially from smaller libraries, that the decision was rescinded.

Like most journals, *Science* makes reprints available to authors and to others who wish to use them for classroom or other purposes. Reprint orders running into the thousands have occasionally been needed to satisfy requests for copies. Still the most popular reprint, almost a dozen years after its publication on 13 December 1968, is Garrett Hardin's "The tragedy of the commons."

That article also illustrates the fruitful collaboration that can occur between author and editorial staff. "The tragedy of the commons" was originally given as Hardin's presidential address to the Pacific Division of the AAAS. I did not attend that meeting, but after reading the printed version I sent him a complimentary note regretting that I had not heard his address. He wrote back saying I should have no regrets; thanks to the good advice of the editorial staff the printed version was better than the original.

Reprints, circulation figures, citation counts, and other numerical measures are all useful indicators of how effectively a periodical is meeting its objectives. But the real answer must be one of judgment. How best to try to meet those objectives depends on the judgment of the editorial staff. How well they have succeeded is for the readers to decide.

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Scientific Communication

Philip H. Abelson

Those engaged in the pursuit and preservation of scientific knowledge are part of a great and lasting enterprise. Through the devoted efforts of a relatively tiny fraction of the earth's population, a marvelous edifice of knowledge has been created. Each day additions to the structure are made. Occasionally modifications or partial renovations are necessary, but the major features of the structure have stood and will continue to stand the tests of time, not for just a century but for the millennia.

It is unfortunate that the uninitiated cannot fully perceive the beauty of the structure, the intricacy and subtlety with which it is tied together, or the solidity of the foundations on which it is built. However, billions of people already have enjoyed some kinds of benefits from applications of science, as will countless billions in the years to come.

The key element in the building and preservation of this marvelous edifice is communication. Without communication there would be no science. Without archival preservation many values would be lost. Thus, on this centennial of *Science*, it is appropriate to consider trends in scientific communication.

Many of the qualitative patterns of verbal and written communication of present-day science were already established by the year 1880. For example, the scientific journals, though few in number, were similar in form to those of today. But quantitative aspects have changed greatly and new patterns, such as electronic storage of data, are beginning to emerge.

When the first issue of *Science* was printed, several scientific journals were being published in Europe but only one respectable publication, the *American Journal of Science*, was being published in the United States. There were few scientists and few were being educated here. The American Association for the Advancement of Science was a small but vital organization that held annual meetings and maintained a sense of community among scientists.

From 1880 on, the number of scientists being trained increased, as did the number of scientific societies and their publications. In 1900 about 100 doctorates were awarded in the natural sciences, and this grew to 11,000 in 1970. The number of scientific publications grew to be in the thousands, with a content of millions of pages. In 1880 it would have

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