derstand research methods. Today there are few men so qualified. There is an impressive number of competent plant ecologists scattered throughout related professions who are oriented toward management, but there are relatively few who have had experience in a detailed assessment of the environmental complex, and even fewer who have had experience in manipulative techniques.

The vegetation-preservation specialist will not replace the research ecologist and to a large extent will be dependent upon him. He must be competent to understand research, to evaluate research findings in terms of his management function, and to translate research into manipulative techniques particularly suited to the specific vegetation he must manage. These manipulative techniques must be based on an understanding of the ecology of the vegetation in question; if such information is not available and ecologists are not employed to develop it, the preservation specialist will be forced to forego his primary responsibility and to spend his time collecting basic ecological data.

Because success in the field of vegetation preservation requires several—usually many—years to evaluate, the vegetation-preservation specialist often will operate in an atmosphere in which unsubstantiated opinions are forcefully urged. Many fire enthusiasts, for example, are convinced that fire protection should be curtailed, and do not recognize that merely because fire control has led to some undesired effects it does not necessarily follow that fire control should be abandoned or prescribed burning introduced. Involved is the whole process of recognizing the management objective, evaluating the ecological forces in play, identifying the conditions which must be achieved to develop the desired vegetation response, and, finally, evaluating all the possible ways of moving toward those conditions economically and with a minimum of unwanted side effects. In all of this the vegetation-preservation specialist will need a fine sense of perspective.

Little can be accomplished in the field of vegetation-preservation management until a source of competently trained specialists has been developed—and perhaps not until considerable numbers of these specialists have infiltrated the various responsible administrative bodies. How can we develop such a source? At the moment I can see only one solution: Ask those universities that have strong programs both in ecology and in land management, for example, those with forestry and range-management curricula, to take on the job. It should be possible to train these specialists by means of a 2-year graduate program, provided it is preceded by an undergraduate degree with a proper emphasis on basic biology and is followed by an appropriate period of apprenticeship. Several universities could readily meet this challenge, provided financial support were assured. The question that remains to be answered is: How soon will the universities that have staffs capable of carrying out this graduate program be asked to join in creating this new profession?

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NEWS AND COMMENT

Chemistry: A "Little Science" Would Like a Little More Money

There is a saying among lawyers, If you have a strong case, pound on the facts, otherwise pound on the table. In recent years, as various scientific disciplines have turned out studies to justify their designs on the federal treasury, there has been a good deal of table pounding.

Last week the chemists produced their study, *Chemistry: Opportunities and Needs*,* a 222-page document, nearly 2 years in the works, which, in the science-study genre, sets a mark for careful data collection and humble advocacy. Inevitably the chemists arrive at the conclusion that needs are unfulfilled and opportunities are wasting. But chemistry is a relatively inexpensive brand of research, and, as wish lists go in this business, they are talking about "little science."

Chemistry, the report acknowledges, has overflown disciplinary boundaries, and it is not easy to identify all the places where chemistry is practiced. But, working with the definition that, in universities, chemistry is what takes place in chemistry and joint chemistry-biochemistry departments, the report concludes that last year the federal government provided less than $60 million of the $90 million spent, outside of construction costs, in the direct support of these departments. Over the past decade the federal contribution has annually grown by 15 percent. The chemists would like to see the federal growth rate stepped up to 25 percent for 3 or 4 years, principally to buy new instruments and computer time, so that by 1968 the direct federal contribution would be $120 million. (In 1964, the report calculates, university chemistry

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departments received an additional $24 million in "hidden" support, mainly in the form of fellowships, training grants, and "non-reimbursed" faculty research time.) Meanwhile, the chemists would like to see the other sources of funds—foundations, industry, and the universities—also increase their support. The study, however, focuses principally on the federal government and its relations with university chemistry.

While the high-energy physicists, for example, have to lean heavily on speculation to explain what society might receive for investing in their work, the chemists comfortably rely on history. They persuasively point to the U.S. chemical industry, which in 1962 had 850,000 employees and $32 billion worth of production, and by tracing the footnotes in the announcements of 38 major industrial and pharmaceutical developments, they demonstrate that basic research in chemistry has frequently had a swift economic payoff. For their colleagues in adjoining disciplines, they also argue that chemistry has had an extremely beneficial influence on other basic sciences.

Then they go on to argue, on the basis of questionnaires returned by 80 percent of the 125 universities that granted at least one chemistry Ph.D. in the period 1960–63, that a lot of promising research is being bypassed by the federal granting agencies. And they say that a systematic study shows that chemistry, which is not the assigned business of any one federal agency (in the way that atomic energy research is specifically the business of the AEC, for example, or that research in the life sciences is the concern of NIH), has been poorly treated when it comes to passing out federal grant funds. They report that, among all federal agencies, grant applications from chemists have, on the whole, consistently fared worse than grant applications from scientists in other disciplines. "Only 17 percent of the dollars requested for new projects in 1964 from the National Science Foundation by chemists were allocated, as compared to 28 percent in other sciences." For the Air Force Office of Scientific Research, the corresponding figures were 14 and 21 percent; in the Army Research Office, at Durham, they were 11 and 14 percent; and for the AEC, they were 5 and 37 percent. Furthermore, the study found that, a year after being rejected, "most of the senior investigators in chemistry whose 'A-rated' proposals had been turned down had been unable to initiate the project."

The chemists also disposed of the widespread impression that the chemical industry takes care of university chemistry. Differing definitions and bookkeeping practices complicate any assessment of the figures, but the universities report receipts from industry of $3.7 million for research grants and support for training; 133 major industrial firms report that they gave universities $3.4 million for these purposes. Whatever the precise sum, there is no evidence that industry is bearing a large portion of the load, though the chemists acknowledge that they fare better than any other discipline in obtaining industrial support for basic research.

The chemistry study is another product of the National Academy of Sciences' Committee on Science and Public Policy (COSPUP), which, among other goals, has set for itself the task of helping to promote rationality as the various disciplines tend to compete for shares of the increasingly tight federal science budget. (The chemists note, for example, that their explicit annual support from the federal government "is equivalent to five weeks of federal expenditures for basic research in the earth sciences, or to four days of the National Aeronautics and Space Administration budget." The dilemma of the federal budget makers perhaps becomes clearer when it is recalled that the earth sciences and NASA can match any group for distress over the alleged

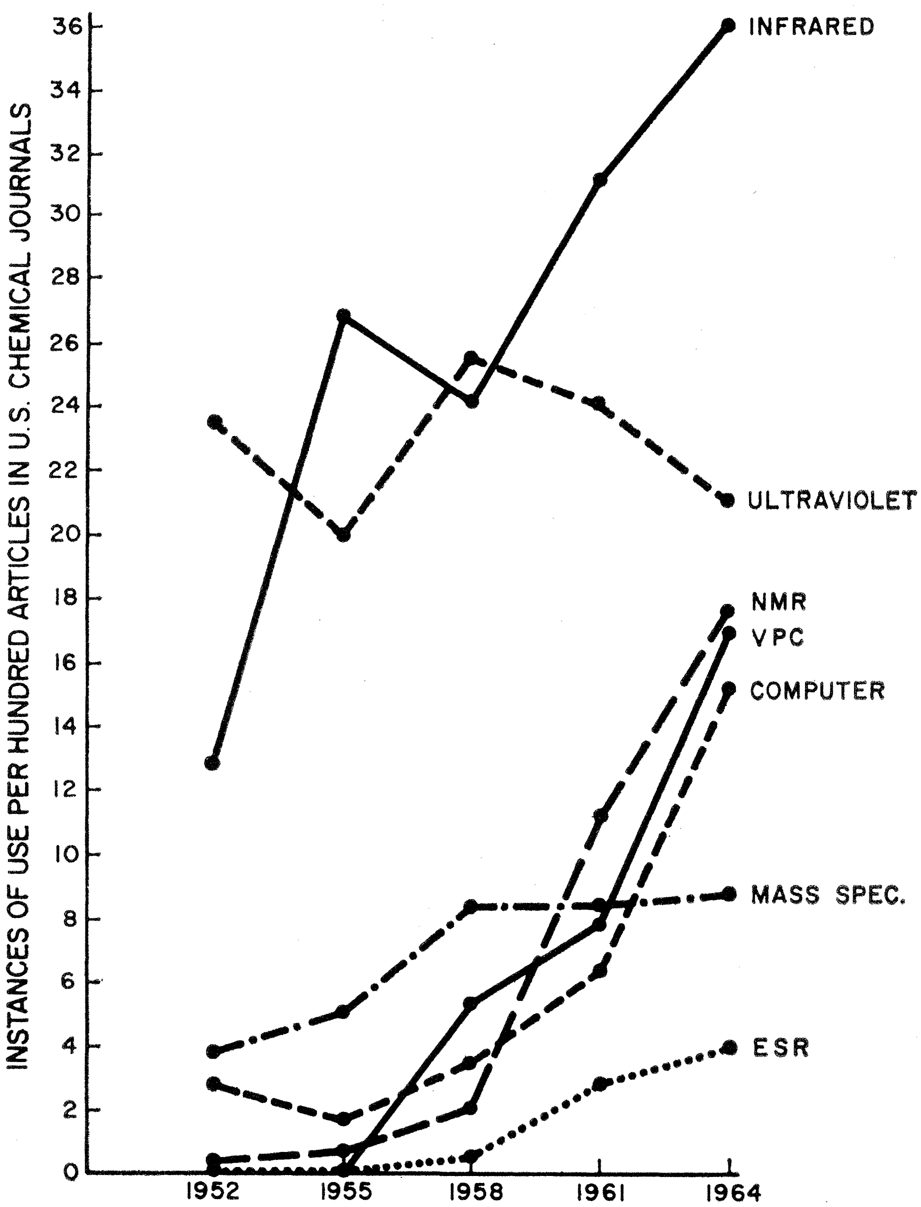

Fig. 1. The use-rate in chemical research in the United States for seven of the most commonly used types of instrumentation, obtained by reviewing about 300 papers for each year in representative journals, at 3-year intervals from 1952 to 1964. The use-rate is defined as the instances of use cited per 100 papers.

Table 1. Country of origin of publications abstracted by *Chemical Abstracts* (percentages for each of 4 years). [*Chem. Eng. News*, 17 July 1961, p. 78]

Country	1909	1929	1951	1960
United States	20.1	25.8	36.6	27.1
U.S.S.R.	1.2	3.4	6.3	19.1
British Commonwealth	13.4	13.5	17.4	13.8
Japan	0.3	3.7	9.1	7.8
Germany	45.0	26.9	7.9	7.8
France	13.2	7.0	6.2	5.0
All other	6.8	19.9	16.5	19.4
Total number of papers and patents (1000's)	14	47	61	127

inadequacy of their respective budgets.)

COSPUP's object has been to obtain a sage assessment of where the disciplines now think they stand in scientific attainment and what they think they need in order to exploit the foreseeable possibilities. In such an assessment there is obviously an opportunity for fervent belief in one's discipline to lapse into salesmanship, and salesmanship has occurred in the past. But the chemistry study, chaired by Frank H. Westheimer* of the Harvard chemistry department, probably comes as close to disinterested analysis as could ever be expected when representatives of the ultimate recipients of money are asked to assess how much they need.

What is unique about the chemistry study is its scrupulous effort to determine the facts of financial life in basic chemical research through lengthy questionnaires to universities, industry, and government agencies. In the course of this effort the study develops some fascinating information about the economic significance of basic chemical research, the international position of American chemical research, and the incredibly rapid growth in the use of expensive instruments.

As for economic impact, the study starts with an admittedly "somewhat arbitrary" list of 38 economically important industrial and pharmaceutical products, including synthetic rubber, oral contraceptives, antibiotics, Teflon, and Pyroceram, and traces the citations that were included in the announcements of their discovery. For the industrial products, 65 percent of the citations referred to basic research performed in universities, and of these citations, 67 percent appeared in "fundamental journals and books." For the pharmaceuticals, 56 percent of the research was university-conducted and 87 percent of the citations were in fundamental publications. The relationship between science and technology is complex and poorly understood, and possibly the chemists have left something out, but their line of reasoning and their data make a powerful case for the utility of basic research in chemistry; or, as they put it, "in chemistry, nothing is so powerful as basic research."

The international position of American basic research in chemistry is also evaluated through an assessment of publications as reported in *Chemical Abstracts*, which in 1962 abstracted 166,749 articles and patents from 100 countries (Table 1).

There is no indication as to whether the national standings bear a close relationship to the level of expenditure, but in any case the United States is spending more than any other country and is producing more papers. The question of quality and scientific significance is difficult to determine, but the chemistry committee made an interesting attempt by counting the frequency with which researchers in four foreign nations that are strong in chemistry research cited work performed in other nations (Table 2). Except for the British Commonwealth and Japan, work done at home came out first in the citations, but the U.S. was first in citations by Commonwealth and Japanese scientists and a strong second everywhere else.

Table 2. Citations of research papers in foreign publications.

Source of publication	Numbers of citations in sample surveyed		
	Domestic	U. S.	All other "foreign"
British Commonwealth	1048	1175	955
U.S.S.R.	583	234	344
West Germany	521	271	368
Japan	160	162	187

The study of the rise in the use of expensive instrumentation (defined as equipment costing at least $2000; see Figs. 1 and 2) was based on an examination of 3000 papers selected from a total of 25 major chemistry journals published in the United States, Great Britain, Germany, Japan, and the U.S.S.R. from 1952 to 1964. From these papers it was found that seven classes of instruments were involved in nearly 80 percent of the citations: infrared, ultraviolet, and nuclear-magnetic-resonance spectrometers; vapor-phase chromatographs; high-speed electronic digital computers; mass spectrometers; and electron-spin-resonance

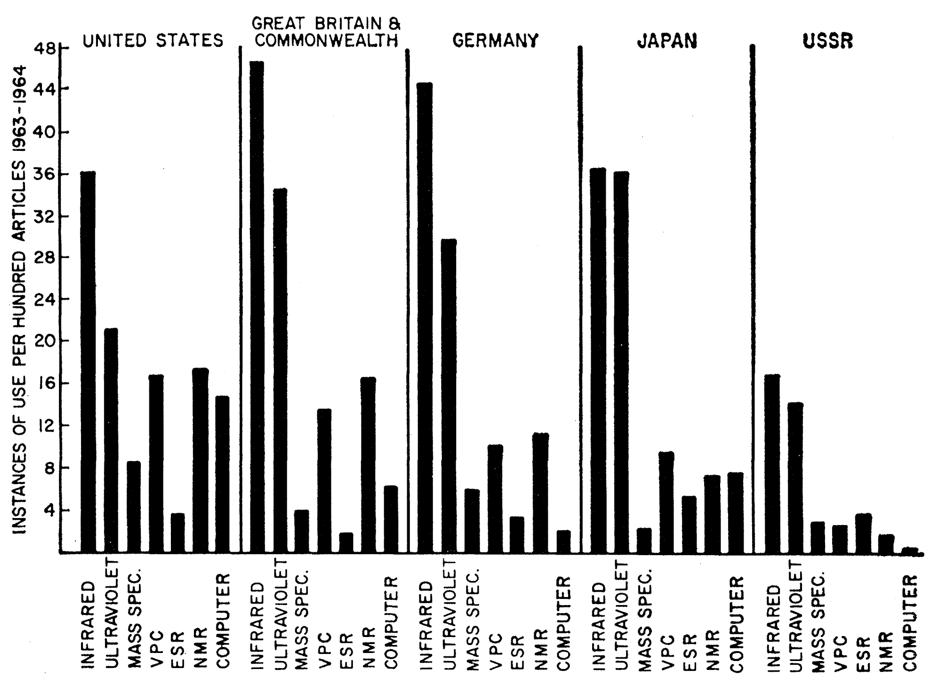

Fig. 2. The 1964 use-rate in chemical research in five countries for seven of the most commonly used types of instrumentation, obtained by reviewing about 300 papers for each country in representative journals. The use-rate is defined as the instances of use cited per 100 papers.

* Other members are William O. Baker, Bell Telephone Laboratories; Theodore L. Cairns, Du Pont; Melvin Calvin, University of California, Berkeley; Bryce L. Crawford, Jr., University of Minnesota; Herbert S. Gutowsky, University of Illinois; Franklin A. Long, Cornell; Robert W. Parry, University of Michigan; Kenneth S. Pitzer, Rice; Charles C. Price, University of Pennsylvania; John D. Roberts, California Institute of Technology; Harrison Shull, Indiana University; Walter H. Stockmayer, Dartmouth; Gilbert Stork, Columbia; Henry Taube, Stanford; and Martin A. Paul, Harpur College.

Frank H. Westheimer

spectrometers. From the number of use-citations per 100 papers, the committee found that the total use-rate of the seven rose from 44 in 1952 to 119 in 1964; it also noted that the older instruments, such as the ultraviolet spectrometer, which was available commercially even before World War II, held at a constant use-rate of 22 for the 12 years reviewed. And it concluded, "The use-rate of 119 shows that, on the average, more than one piece of expensive chemical equipment was needed for each of the research problems reported. Besides the threefold increase in the use-rate of instrumentation, there has been a more than twofold increase in the number of papers published per year in the 12-year period. Therefore, the total reported frequency of instrument use in chemistry research has increased more than sixfold in 12 years."

Comparing the national patterns of uses of these instruments, the committee found that the relative use-rates are similar, and that the infrared and ultraviolet spectrometers are the most commonly used instruments. In total use rate, however, it found that the Soviet Union lags far behind the other major nations, and that the United States runs far ahead of all others in the use of computers. (The chemistry study, like many of its counterparts in the science study field, also extracts some mileage from the Soviet scene, noting that "the Soviet Union has announced a 7-year program for a $46 billion expansion of Soviet chemical industry. Presumably such a massive effort in industry will require added emphasis on basic research as well." Presumably, too, when the Soviet chemists make their pitch, they will cite *Chemistry: Opportunities and Needs.*)

How well equipped are the university chemistry laboratories? To get an answer, the chemistry committee made what is probably an unprecedented inventory of instruments throughout the institutions under study, and they came to the conclusion that the accumulated investment in major equipment, homemade or purchased between 1954 and 1964, totals about $55 million; or, as the report notes in another interdisciplinary comparison, the total, covering 4100 instruments acquired by 125 departments over 10 years, "is an amount intermediate between the estimated cost of a single high-resolution radio telescope and the amount budgeted for oceanographic ships in 1962 and 1963; it is less than half the amount allocated for the Stanford linear accelerator. Yet the latter is a single instrument for research in high energy physics." As demands grow and the overall budget for research fails to keep pace, the sounds of strife grow in the once-sedate scientific community.

How much do the chemists say they need for new instruments? Again, the sums are relatively small. In a survey conducted 2 years ago by NSF, 121 departments said they needed a total of $20 million to make up the "deficit" beyond their regular spending, which now totals about $11 million a year. The chemistry committee estimated, on the basis of replies to its questionnaires, that the deficit now totals about $300,000 per department, and suggested that the total needed to cover this deficit may be as high as $35 million.

If the committee has, in fact, developed an accurate assessment of chemistry's financial plight, it is useful to ask why, in an era of affluent science, this relatively inexpensive and highly important basic field has fallen so far behind. The answer offered by the report is that no one agency in the U.S. government is charged with looking after chemistry, and that therefore it has been neglected principally because of oversight. The committee does not propose establishment of a new agency to correct this, but suggests rather that the Office of Science and Technology use its influence to correct the matter.

If oversight is the cause, it is interesting to determine why it has occurred. Chemists, it should be noted, have ranked high in the government science advisory apparatus that is charged with looking after the health of science. George B. Kistiakowsky and Donald F. Hornig, two of the four men to serve as White House science advisers, are chemists; Glenn T. Seaborg, chairman of the AEC, is a chemist; and chemists are well represented on the President's Science Advisory Board and the National Science Board of the NSF.

Even if cool analysis were the prevailing force, it would be difficult to determine how much should be allocated for research and how this amount should then be allocated among the various disciplines. But in searching for the sources of chemistry's plight, it is worth considering whether fascination with the new and esoteric has something to do with the current financial situation of this valuable, but old, brand of science.

—D. S. GREENBERG

NDEA Fellowships: Expansion Doubles and Redoubles Number

The Office of Education is scheduled to award more new National Defense Education Act graduate fellowships for the next 2 academic years than the total awarded since the NDEA was passed in 1958. This big increase is one result of congressional action to extend and expand the act late in the preelection session of 1964.

Until then, new NDEA fellowships were being awarded at the rate of 1500 a year. Under the amended law the number jumped to 3000 in the current school year. This 3000 brings to some 11,500 the total number of awards made under the program since its inception.

The Office of Education recently an-