Industrial–Academic Interfacing

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Industrial-Academic Interfacing

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Marion Laboratories, Inc.

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M. Joan Comstock, *Series Editor*

FOREWORD

The ACS SYMPOSIUM SERIES was founded in 1974 to provide a medium for publishing symposia quickly in book form. The format of the Series parallels that of the continuing ADVANCES IN CHEMISTRY SERIES except that in order to save time the papers are not typeset but are reproduced as they are submitted by the authors in camera-ready form. Papers are reviewed under the supervision of the Editors with the assistance of the Series Advisory Board and are selected to maintain the integrity of the symposia; however, verbatim reproductions of previously published papers are not accepted. Both reviews and reports of research are acceptable since symposia may embrace both types of presentation.

PREFACE

THE GROWING IMPORTANCE of the relationship between industry and academia has become apparent over the last few years. The relationship is no longer simply platonic; rather it is fast becoming one of mutual need and satisfaction. Reports and editorials on corporate–university ties, not only in the scientific press but in the public media as well (see, for example, the *Wall Street Journal* for March 31, 1983); textbooks and primers on the topic; and increasing numbers of symposia on the subject are evidence of the growing attachment.

The importance of the industrial–academic interaction has been catalyzed by many factors. The attention recently focused on our national and worldwide research postures, the evolution of highly visible industry–university contracts, the decrease in Federal funds for university research, and industry's growing need for fundamental research in the face of increasing costs of research resources—all have contributed to the courtship.

However, critics have voiced concern over what they see as an underlying adulteration of the pure academic atmosphere by the invasion of industry-capitalized research efforts. In this view the academic pursuit of basic research is diverted by questions of application from its true purpose. Furthermore, academics see industry's need to maintain confidentiality and to protect patent rights in order to make investments pay off as conflicting with their own mandate to publish in order to serve the public good.

If we hope as a nation to compete in the world economy, we must nurture and strengthen the efforts we direct toward research and scholarship. The growing attention the industrial–academic nexus has been receiving sparked the ideas for the initial symposium on which this book is based, and brought together active leaders and spokesmen on the topic from industry, academia, and the public sector.

The coordination of a symposium and the subsequent compilation of a book take the generous cooperation of others. I am particularly appreciative of the dedicated assistance of my secretary, Ann Welch, who was invaluable in helping to complete this work. I also wish to acknowledge the assistance of David Stickel and Albert Saad, whose generous support helped this program to run smoothly. Sincere thanks go to all the authors, without whom neither the program nor the book would have been possible. I have sincerely enjoyed the opportunity to work with each of these dedicated

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individuals. Finally, I wish to thank the American Chemical Society's Division of Professional Relations and Marion Laboratories, Inc., for their foresight in supporting this timely project.

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July 1983

In Industrial-Academic Interfacing; Runser, D.;
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1

Mutually Beneficial Academic Consultantships for Industry

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Consultant arrangements between academia and industry are frequently used and, I believe, valued by nearly all parties concerned. The reasons are clear. On the industry side, few if any companies could hope to have on hand at all times the diverse talents and instrumentation that they need to pursue their complex research projects. On the university side, knowledge is of little value until it is shared. Yet for being so often used and highly valued, it appears the consulting relationship has been the subject of relatively little analytical thought.

The other authors of this monograph will present many aspects of the industrial-academic relationship with analysis which will help understand and utilize this interaction. In this brief overview I will offer the benefit of my experiences in managing consulting arrangements and give some insights into how consultants have helped our particular situation in an Industrial Laboratory.

Two Major Tasks

Before engaging a consultant in any area, two major tasks are undertaken. The first is the more difficult: finding the individual with the type of knowledge needed. This assumes you do not have someone targeted. One of the university's major "products" is knowledge and much of it is of immediate benefit to society through industry or some other channel. What is needed to bring this potential to reality from an industrial viewpoint is the further development of this knowledge, by industry, to a useable stage. We really cannot achieve this unless, of course, we do isolate the need, then identify the faculty member, a department, or even a product already developed to a certain point in time. The initial burden for solving this problem falls upon the university or with the individual faculty member so that the new skills for a potential product or for any particular skills can be brought to our attention in industry.

The second problem is more subtle but nevertheless common. It is the "N.I.H." syndrome, the Not Invented Here attitude which

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says that anything coming from outside our laboratory cannot be good. This is an attitude that is really from the industrial laboratory side and not, naturally, of the consultant. This is the toughest one we face in working out a mutually beneficial consultant arrangement. If you are going to have a consultant, the arrangement must result in a working environment that is mutually beneficial to all concerned. If the head of the industrial laboratory feels the need for a consultant but his managers and technicians feel threatened by the arrangement, this is obviously a lose-lose situation and nobody can win. Information will not be shared, the ideas of the consultant will be ignored, and the "cross-fertilization" will not occur. All you end up doing is wasting money, wasting a consultant's time and talent, and, probably, embittering the consultant to the point where he or she will never want to step into an industrial laboratory again.

Preventing vs Solving

There are no practical guidelines for solving the "N.I.H." problem once it occurs, for the solution depends on the personalities involved and the particular circumstances. Rather than solve the problem, I prefer to prevent it. This is relatively easy if the people in the industrial laboratory know what is expected of the consultant and of them. The industrial liason and the consultant need to make the laboratory personnel see the relationship as a symbiotic one, one that does not imply failure or inadequacies on the part of the laboratory people. If industry people see the situation as one which will result in greater accomplishments for all concerned, they will cooperate.

Three Areas of Consultant Use

There are basically three areas where consultants are used --one I have already mentioned, new product ideas. The outcome here can be extremely successful if the consultant is kept closely involved in the project from start to finish. This is only logical, for the new product idea was the consultant's in the first place. Why take him half way through the development of the product and then drop him? Why think you can do it better? Keep him in the project as long as he can contribute. Again, watch out for the "N.I.H." syndrome. If the product makes it to market, everybody wins--the university, the company, and most important, society. However, we all know that not all products/ideas end up as successful ventures. Therefore, if you are using a consultant to assist in the area of product development, they should be properly positioned again at the front end.

The second basic area of consultant use is guidance in developing or maintaining research programs. This is where most consultants from academia seem to be used. And, I might add, seem to be misused. If you are going to have consultants, use them and use them appropriately. Do not waste their time and do not waste your time. If you simply have this individual on board because of their name, this is an inappropriate use and it is not fair to them nor is it fair to the organization. Take advantage of their knowledge to supplement yours and that of your laboratory. There is no doubt that this cross-fertilization will improve the knowledge base and allow the particular corporate goals to be reached more expeditiously with the greatest benefit for all concerned.

In clinical research, we use the approach of having a panel of consultants for each research program. Separate groups of outside medical experts are called together, for example, on coronary artery spasm, burns, hypertension, and any other areas in which we have active programs. Biostatisticians and an appropriate preclinical specialist are usually also involved. All are outside consultants who assist our staff in the development of protocols and clinical programs. They later assist in the interpretation of results and in our interaction with government agencies. They can also assist us in the training of our personnel.

The third area of consultant use is in providing the hardware and instrumentation and subsequent interpretation of results. It would not make economic sense for all industrial laboratories to be equipped to handle all test or procedures, if it were even possible. In this day of proliferating technology, one cannot possibly afford the equipment and technicians just to have the appearance of "keeping up." Universities and private consulting laboratories have the equipment and the people who know how to use it. Why duplicate these resources for the sporadic short-time or even one-time use? By relying on outside help, industry assists universities in the purchase of equipment that helps them in their main endeavor, education.

University Resources Not Well Recognized

My comments have focused on consultants from academia, as if all should come from a university. Valuable consultants do come from other sources. However, I feel that universities are to a great extent unrecognized resources. This is particularly true with regard to new product ideas. For this to be recognized by industry, universities must make their faculties' abilities and talents known. Unless industry knows what is available, it cannot help to uncover the many possibilities that exist in the universities. A campaign to let industry know about resources would serve universities well, and ultimately, industry and society.

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2

Industry and Academe: Conflict or Reinforcement?

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The relationship between the chemical industry and university chemistry departments in the United States has changed considerably in the last 50 years. A decade and a half ago an alienation occurred, spawned by ignorance of each others' responsibilities and operations, which was in turn the result of years of increasing isolation. This has been damaging to both industry and academe. Industry has found itself concerned about reduced exchange of ideas and its own declining level of innovation, while universities' chemistry programs have found their B.S. graduates become less competitive in the job market partially because curricula have been isolated from the major concerns of the principal employer of B.S. chemists - the chemical industry. In recent years, the declining real level of support for basic chemical research in universities, coupled with decreasing enrollment in graduate school from 1970 to 1982, has helped make chemists in all employment sectors and positions sensitive to the mutually reinforcing capabilities of chemists and their employers. The most dramatic step towards improved relationships has been the initiative taken by the chemical industry through the establishment of the Council for Chemical Research (CCR) following the first Meeting on Advances in Chemical Science and Technology sponsored by Dow in Midland in 1979. This consortium now includes 40 corporations and over 130 universities, and seems destined to become a major vehicle for development of the interface between universities and the chemical industry. Some of the activities of CCR will be described within the broader framework of the advantages to all parties of closer industry-academe cooperation.

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HISTORICAL OVERVIEW

The evolution of the relationship between academic and industrial chemistry can be divided roughly into five epochs. To be sure, these are not clearly divided but overlapped over decades; the division illustrated here is somewhat arbitrary but provides a useful framework for discussion.

In the first epoch smelting, gunpowder manufacture, soap making, and similar operations proceeded empirically while "academic" chemistry (and for that matter, physics) were pursued with the purpose of achieving something of practical utility; examples are the conversion of lead to gold (Alchemy) and the use of chemicals in medicine (iatrochemistry).

The second epoch began perhaps in the 18th century and sought to understand nature. In the 19th century much of this work took place at universities. Towards the end of that period practical outcomes of such research became obvious and had a substantial effect on the development of the chemical industry. A close relationship between industry and universities was required to transform the ideas of the laboratory to practicality and onto a commercial scale. At the same time, the increasing cost of academic research was partly borne by industry through support both of a general nature, such as fellowships, and through direct subsidy of specific projects. This period ended with World War II.

As the complexity of academic research increased and research diversified more and more, further growth of chemical research was made possible, in the third epoch, first by enlightened policies of mission oriented federal agencies such as the Navy and the Atomic Energy Commission, which supported basic academic research of potential interest to new but perhaps of somewhat uncertain cultural practical usefulness. Some of these relationships evolved as a result of the Manhattan Project. In the late 1950's the National Science Foundation and the National Institutes of Health became major factors, enabling an increasing diversity of research and allowing for the unavoidable increase in the cost of each project as reasearch problems and methodologies became more sophisticated and dependent on expensive equipment. The level at which industry supported academic research remained about constant; since the increased need was met by the federal government, the fraction of academic research supported by industry declined substantially. This led naturally to a reduction of the influence of the chemical industry on universities. This was hastened by reorientation of corporate research towards shorter range objectives. The disillusionment with and deemphasis of basic research in industry further reduced university-industry contacts. One might argue that the increasing neglect of each other lead to a mutually condescending relationship and eventually to considerable stress.

Real tension may have surfaced in the late 1960's. In this

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fourth epoch, campus unrest caused by the draft and the war in Vietnam was often directed against industry, particularly the chemical industry, and recruiters of some companies were ill received on many campuses. Students, soon to become young faculty, thought that companies supported and profited from what they felt was an immoral or at best objectionable war, while industrial managers were embarrassed and could not understand that in a university it is not possible and not even desirable to control or suppress the free expression of ideas. An almost hostile relationship resulted, and was exacerbated by the economic difficulties of the early seventies when young chemists had difficulties finding jobs. Thus industry and the campus became isolated from and even hostile towards each other.

Within less than a decade, the real loss caused to industrial concerns, the academic enterprise, and to the economic welfare of the country were recognized. Industry took the initiative, and much of the credit for doing so must go to "Mac" Pruitt, of the Dow Chemical Company, who through his persuasiveness and the sheer force of his personality initiated, organized, funded, and made a success out of the first Conference on Advances in Chemical Science and Technology, held at Midland, Michigan in the fall of 1979, followed by conferences in Bethlehem, PA (1980), Rochester, NY (1981), and Houston, TX (1982). The Council for Chemical Research was incorporated in 1980 and its first Board of Directors elected in 1981. In my judgment, with these events we have entered a fifth epoch, a period of rebuilding the relationship between industrial and academic chemistry and chemists with a mature and still developing appreciation for the special priorities, opportunities, and constraints on both sides. It is an effort requiring sensitivity, cooperation, mutual understanding, and patience if it is to succeed.

SOME NEEDS OF INDUSTRY

Industry requires principally three things from universities: an adequate supply of trained and educated graduates, new ideas to stimulate innovation, and special expertise and know-how.

The first of these is by far the most important because in a technological enterprise the recognition and development of new ideas depend heavily on the intellectual capabilities of personnel. It is very easy to lose the long-range outlook when one is dealing with daily problems: yet the future health of any industry depends on the corporate ability not only to stay solvent and make a profit for the current year, but to look ahead five and ten years and to analyze how the company will be able to compete and prosper under different conditions. The U.S. steel and automobile industries are dramatic examples of what happens when the status quo is protected and the horizon is only a year or two away.

It is a general complaint that new graduates are "green" and naive. It would seem that this is merely an outcome of the general isolation between academia and industry. In universities, faculty rarely ask the question how much something costs, whether the value of the new knowledge to be gained is commensurate with the investment of time and money it requires, and what it takes to convert a laboratory result to a useful, profitable process. An overview of cost/benefit analyses is something from which graduates could really benefit. Attempts to introduce courses for seniors and graduate students which would cover the more applied aspects generally are not very successful. They tend to fail because of lack of faculty expertise and student interest. It would probably be best to weave such considerations into existing upper-division courses but there is still much apathy concerning this aspect of chemical education. The proposed Institute for Chemical Education might make available support material for such course modifications.

It is worthy of note that training is not enough. Training becomes obsolete very rapidly as new instruments and methods are developed. Moreover, to work effectively an individual must want to grow continually and be able to communicate and work with others. Only educated people are likely to be looking toward the more distant future. They are the ones who will ask questions concerning values and ethics and help avoid the few instances of injudicious actions which have occurred in the past and have led to such poor publicity and substantial increases in the cost of doing business for the chemical industry. Education requires more than knowledge of chemistry or engineering: it requires a broad background and a set of values which are traditionally developed in the liberal arts part of the college curriculum.

New ideas and concepts are, of course, the backbone of advancing technology. Most often such innovation results from long-range research at least initially conducted by chemists since engineers are more likely to reduce new ideas to practice rather than to create them. The increasing difficulty, complexity, and cost of developing new knowledge, particularly since the applicability and utility are usually not clear, which results in great uncertainty about the return on the investment, demand that much of this research be performed at universities.

Universities, the federal government through its support, and industry have the opportunity to form a partnership, but it is not often recognized or exploited. Two major barriers exist towards optimization of this relationship. The first is the difficulty of information or technology transfer which has been talked about a great deal. It is not always readily possible for industrial chemists or managers to identify which faculty member is performing research in areas which might be interesting to the company; CCR is attempting to solve this problem through development of a computer searchable file of faculty research students, while ACS is developing a concordance project based on the biannual Graduate Directory. Second is the isolation of the academic investigator from the practical environment of industry. The prestige fields in academic chemistry are not necessarily those which might be of interest to industry. CCR is developing mechanisms for transmitting information about industry to the academic community.

Finally, faculty who dedicate their lives to pursuit of knowledge in a given area are bound to become highly expert in at least some areas to a degree which normally cannot be expected from industrial chemists. The expertise they develop can often be useful to industry, and thus university faculty can be an excellent source of information and know-how which can be tapped by industry. In establishing such relationships, consulting is of course the traditional approach, but provision of modest research support, particularly for younger faculty, is possible also and other means have been discussed at times as well.

SOME NEEDS OF ACADEMIA

University researchers require support for their individual research, very little of which is provided by universities these days, access to common facilities including shops and expensive general instrumentation (such as NMR, X-ray crystallography and mass spectrometry), summer support, and a "market" for graduates at all degree levels.

In addition, salary equity is becoming an increasing problem. In many universities pay scales are established relatively uniformly regardless of the discipline; many university administrators are reluctant to introduce salary differentials for selected disciplines for fear of negative reaction from faculty in other fields. At some universities special programs to take cognizance of the need for salary level differentiation between disciplines exist but the resources to implement them are almost always inadequate, particularly at a time when universities are facing increasing budgetary difficulties; chemistry is rarely included in such efforts. An even more serious problem in this area exists in high schools, which tend to be unionized more often. Their pay scales are usually be tied to experience, and are generally at a level so low that the much better salaries in the chemical industry and more generally the private employment sector preclude the entry into the school system and retention of a substantial number of teachers expert in the sciences. This is a large part of the problem of high schools discussed below. Recent industrial programs to provide special appointments for young faculty in chemical engineering are a limited but excellent step in the right direction.

The federal government provides most of the support for individual research on a highly competitive basis. Judgment is based on scientific merit with some priority placed on areas which are thought to be particularly ripe for advancement.

Mission oriented agencies, which provide over half of all research funding to academic chemistry departments, must give preference to research falling within their interest range. Federal funds do not address well the problems associated with starting up young faculty, which can easily run to over $100,000 such as for someone who wishes to start a program in catalysis or molecular beams, with operational and maintenance costs of large, shared equipment, or with keeping undergraduate laboratories up-to-date, particularly with the decrease in NSF funds dedicated to science education. NSF also provides major research equipment resources through the chemical instrumentation program, but funds are really not sufficient to keep current even the top 50 to 60 departments in the country. The program recently announced by the Department of Defense may provide substantial help in this area.

Summer salary support is available to research active, externally funded faculty through their research grants, and to a more limited extent from summer teaching of lower division undergraduate courses. The second mechanism detracts from research. Summer salary is a particularly severe problem for young faculty in their first few years of academic life at a time when they must establish themselves. This is an area where industry could help and build long-term good will.

Academic Institutions need a steady "market" for their graduates to permit reasonable planning. Industry is of course affected by normal business cycles; these often lead to cycles in hiring patterns as well. Educational institutions cannot readily respond to these because of the long lead-times: a minimum of two years for B.S. graduates and perhaps three or four for those holding the Ph.D. A modest "buffer" for the latter is available through postdoctoral positions, but it depends also on non-University, primarily federal, funding and can not expand quickly. A second, perhaps even more important problem is the poor publicity which reaches into high schools; these are already troubled by inadequate teaching staffs in the sciences. This limits the number of high school graduates interested in the sciences and, to a lesser degree, in engineering. It is not clear what can be done to isolate hiring from normal business fluctuations.

Universities appropriately emphasize chemistry in their graduate programs, with little regard for the broader needs of those who will be entering industry. However, even the undergraduate curriculum provides little perspective of the "real world" of chemistry in industry and tends to prepare students for entry into graduate school, even though it is well known that ca. three fourths of those who earn the B.S. in chemistry and stay in the field will eventually be employed in industry. Even elementary familiarity with cost/benefit analyses mentioned earlier, with elements of engineering processes, accounting, and economics would make the transition from universities to industry easier, and young graduates effective more quickly, whether or not they obtain an advanced degree.

The health and vitality of academic chemistry depend to a large extent on the possible practical consequences of research. If chemistry were purely an intellectual discipline, it would have no more right to substantive funding than history or philosophy. Increased industry-university interaction can be helpful by making the academic value system, which appropriately places high priority on the development of insight and understanding, more responsive to practical considerations.

THE COUNCIL FOR CHEMICAL RESEARCH (CCR)

CCR was already mentioned above as an important initiative identified as the beginning of the fifth epoch. As of January 1983, 40 companies have joined CCR, and about 135 universities have become members. Most of the major companies and leading universities are part of this consortium. Member companies may, optionally, also join the Chemical Research Fund, with a commitment to increase support of academic chemistry using a formula based on the number of B.S. and Ph.D. graduates in the chemical sciences they employ. A portion of this commitment may be distributed through CCR to departments on the basis of the number of Ph.D.'s produced in the chemical sources during the preceding year.

CCR was incorporated about three years ago. Its board is elected and substructured into a series of committees, of which that dealing with the university-industry interface is perhaps the most significant for this presentation. It is currently developing industry information stations in academic chemistry departments, a directory of industrial research laboratories and general topics of investigation, and a computer searchable file of research interests of faculty in their first three years of academic life as a pilot project for possible later expansion to all faculty.

CONCLUSIONS

The future of the interface between industry and universities looks positive: recognition of the special needs and constraints within which each type of institution must operate is beginning to evolve, and with this mutual understanding is bound to come the development of ever stronger ties and the recognition that industry and academe can live together in harmony, that their welfare is interdependent, and that their progress is perhaps even symbiotic.

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3

Industrial Research and Development: An Academic's Experience

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The majority of visiting professor programs arranged between academia and industry give the visiting professor only a few weeks in company surrondings and do not require direct involvement in the work being done. Although much can be gained from such programs, both by academia and industry, they also leave much to be desired. Solutions to industry challenges barely have time to be proposed, let alone tested, and the visiting professor may well see only the particular challenges facing his host-managers in that brief period. Ideally, visiting professor programs would encompass larger and therefore more representative portions of industry's work. Such a program was designed by the authors when they had already completed more than a year in a client-consultant relationship.

The client, Dr. Dennis Runser of Marion Laboratories, Kansas City, Missouri, and consultant, Dr. Robert Lanman, Professor of Pharmacology and Medicine, became acquainted during the course of a study concerned with the kinetics of diltiazem (CARDIZEM) which was conducted at the University of Missouri-Kansas City (UMKC). During one of their many discussions, the idea of a visiting professorship was conceived. It quickly became apparent that there was a mutual interest in improved, stronger, university-industrial relationships. For Dr. Lanman's part, a passive, visitor type of experience was not acceptable. Dr. Runser agreed that if his staff were to benefit from this experience, and if the visiting professor were really to gain an understanding of what is required of future graduates entering the job market, a more concentrated and in-depth program would be needed. Thus, plans were formulated to propose an in-house consultant role for the visiting professorship. Once the proposed experience had been formulated, University approval of a sabbatical leave was sought and obtained. Dr. Runser submitted the proposal to upper management, which was also subsequently approved.

A contract was drawn up which detailed the commitments of each party. The contract was relatively simple. First, it physically provided for an office with a telephone and secretarial

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assistance in the Chemical Affairs Department at Marion Laboratories. Chemical Affairs is organized into three departments: Analytical Research and Chemical Stability, Chemical Development and Scientific Resources, and Biopharmaceutics. Second, it covered the financial terms agreed upon, which included reimbursement for travel expenses incurred in the performance of consulting duties. Third, the contract provided that periodic reports be written as necessary, and that strict confidentiality be maintained as well as adherence to Company policies. It is important to recognize that this visiting professorship had the status of an independent consultant or contractor, not a part-time employee of the Company. This provision simplified the arrangement and eliminated the administrative burden and cost associated with an employee status. Finally, statements were included which allowed either party to terminate the program with a 30 day notice. This provision was made to cover all contingencies; however, it was never intended to be used.

The process of developing the program and contractual arrangements took nearly a year, which included obtaining approval through the respective University and Company administrations. The program began in January, 1982.

From the academic point of view there were specific objectives to pursue through this research and development experience. The first related to administration of the graduate program in the Pharmaceutical Sciences at the School of Pharmacy. This program offers either the MS or PhD degree in Pharmaceutical Sciences with research emphasis in pharmaceutics, pharmaceutical chemistry, pharmacy administration and pharmacology/toxicology. The program is designed around a core of pharmaceutical science coursework intended to assure that all graduates have a broad base of pharmaceutical knowledge in addition to the expertise developed in their chosen areas of research. Since these graduates often accept positions in the pharmaceutical industry, as well as with government agencies and in academia, it was desirable to explore first-hand the specific needs of the pharmaceutical industry, as represented by Marion Laboratories, with respect to the training of pharmaceutical scientists.

A second objective also related to graduate education. Often students about to receive their graduate degrees are somewhat undecided as to the next step. They frequently ask questions such as:

1. Should I take a postdoctoral position?
2. Should I accept a teaching position?
3. Should I seek a position in industry?

Frequently, some actual experience can help when such choices must be made. Thus, it was decided to explore the feasibility of establishing a residency program in research and development (R&D) at Marion Laboratories for UMKC pharmaceutical science graduate students. Under this program, graduate students about to embark upon their careers would have the opportunity to compete for residency positions in Marion's R&D Departments and through this mechanism obtain first-hand experience in the pharmaceutical industry. Such a program can be viewed as being mutually beneficial to Marion Laboratories and UMKC, particularly with respect to future recruitment potential for research and development related positions.

In these days of tight state budgets and ever shrinking extramural research funds, universities must seek additional sources of support for their programs. The graduate program in the pharmaceutical sciences at UMKC has experienced a continuing increase in applications, and as the program has grown, so has the need for research support. Thus, the third objective was to explore the feasibility of a cooperative research program between Marion Laboratories and the UMKC School of Pharmacy. Such a program would consist of School of Pharmacy faculty and their graduate students investigating specific research projects, mutually agreed upon and supported on a project basis by Marion Laboratories.

The last objective was to personally become involved in the day-to-day activities of research and development at Marion and gain industrial experience.

On the part of Marion, several objectives were also laid out. These included:

1. Assisting their Medical, Biological, Product Development, and Biopharmaceutics departments in the planning of projects and data analysis.
2. Helping to develop and implement in-house pharmacokinetic computer modeling and statistical analysis programs within the Biopharmaceutics Department of Chemical Affairs.
3. Providing in-house staff training in the form of classes, seminars, and/or workshops.
4. Assisting with ongoing research and development projects as needed.
5. Evaluating the needs of R&D in terms of how it operates and what skills its staff needs to better help train students, which could increase the company's opportunity to hire more graduates locally.

This latter objective was entirely consistent with the academic objectives regarding the training of pharmaceutical scientists.

One means of accomplishing these objectives was to spend time with research and development directors and other Marion management team members to gain insight into the needs, activities, and requirements of the different operating functions of Marion's R&D departments. This was accomplished in a series of informal conferences with Directors of Pharmacology, Toxicology, Chemistry, Pharmaceutical Technology, Clinical Research, Regulatory, Product Development, Medical Devices, and Marketing. Information was obtained as to the skills sought in potential employees, desirable attributes, most common backgrounds, approximate number of positions occupied by MS and PhD persons relative to the total staff in an area, and the necessity of a graduate degree over the BS degree. Such requirements varied with the R&D area concerned. It was reassuring to find that UMKC's program in the pharmaceutical sciences is currently addressing most of the specific educational requirements and skills that were considered necessary.

The perception of an R&D residency program for graduate students was found to vary among the scientific departments at Marion. In the area of pharmaceutical technology, a residency program was looked upon as a valid concept. In fact, there already is precedence for such a program at the undergraduate level through the Summer BS Pharmacy internship program conducted at Marion. The Pharmacology area regarded the residency program as desirable, but felt the minimum time necessary to achieve any benefit was one year. Since Toxicology felt the residency period would be difficult to correlate with ongoing toxicologic testing, combining pharmacology and toxicology into a one-year residency was considered a possibility. In general, the feasibility of establishing residencies of this type at Marion Laboratories was considered to be directly related to the growth rate of the research and development effort of the company and the ability to provide enough time so a student could become familiar enough with an area to actually make a contribution.

To examine the feasibility of a cooperative research program between Marion and UMKC, certain key questions were discussed.

1. Does your department currently have any research projects contracted with universities?
2. Would such an arrangement be feasible in your area?
3. What problems do you envision in such an arrangement, if any?
4. What manner of implementation of a research arrangement would you suggest?

In pharmaceutical technology, most research has immediate deadlines and as a result not many opportunities for cooperative research projects exist. So-called "back burner" research projects are few and far between. Cooperative outside research efforts in the area of toxicology would have to be on an "as needed" basis. Much of toxicologic research on pharmaceuticals is highly regulated and, thus, is not conveniently accomplished outside the industrial setting. Pharmacology offers more possibilities for cooperative research projects, particularly continuing research on drugs already approved for human use, but for which additional information is desired. A personal preference in the establishment of such a cooperative research effort is to begin discussions on a project basis through interactions at the level of the research scientist. Research projects that arise from discussions between academic and industrial scientists rather than university and company adminstrators are much more likely to be successful. With such an approach, once a mutually attractive problem has been identified, a protocol and budget can be developed, approval sought from management and work begun. A similar approach in funding academic research was taken by the Upjohn Company. As reported in

"The Pink Sheet" (July 19, 1982, T&G-9), at a recent seminar, Jacob Stucki, Vice President of Pharmaceutical Research for Upjohn, explained, "We feel that the best collaborations are those that involve mutual intellectual attraction between our (Upjohn) scientists and academic scientists." Instead of building an affiliation with a university via a large scale project, Upjohn plans to build a relationship from individual projects.

First-hand experiences in research and development at Marion Laboratories were both varied and interesting. They included the opportunity to participate with Marion's R&D Team in both written and verbal dialog with the Food and Drug Administration concerning the approval and release process for new drugs. The frustrations of preparing written submissions which seemed to address all likely concerns, only to be rewarded by requests for additional information or the application of a different statistical test, were not totally expected. The means of adjusting to these necessary expenditures of time and effort was learned early. Opportunities were also provided to personally conduct some in-house research projects. This involved both bench work and the opportunity to direct the laboratory work of some R&D team member. For example, as part of a larger kinetic study in humans, the partitioning of a new drug between red blood cells and plasma was investigated in vitro. Another study involved the use of a new radioisotope facility at Marion in which total carbon-14 recovery was determined by liquid scintillation counting of biological matrices such as whole blood, plasma, urine, and feces following administration of a carbon-14 labeled new drug entity that acts locally in the alimentary tract. This provided the opportunity to gain hands-on experience with a new microprocessor-controlled liquid scintillation spectrometer. Having had considerable experience with liquid scintillation counting, this opportunity was used to offer training in radioisotope methods to the bioanalytical staff. Specific requests for specialized data treatment were sometimes recieved. For example, on one occasion a request was made to prepare projections of maximum and minimum plasma levels that one could expect from a specified intravenous dosing schedule of a particular drug. On another occasion, information was requested as to the application of criteria suitable for identifying analytical standards which are outliers and thus should not be included in a standard curve.

As for Marion Laboratories' objectives, assistance was provided in the planning of at least two new research and development projects for the Biopharmaceutics Department. In working with kinetic data for Food and Drug Administration submissions, the computer facilities at Marion were made available through provision of a terminal and disk storage. By working with data processing and statistical personnel, access to specific pharmacokinetic subroutines, Fortran programs such as NONLIN, and statistical packages such as SAS were streamlined. In connection with this activity, a weekly series of lecture/workshops were conducted on handling data, which included curve fitting techniques and statistical analysis of pharmacokinetic parameters. Sessions were conducted over an eight week period according to a schedule that encompassed contributions of time from both Marion and the staff. Manual procedures, as well as the use of computer programs, were covered in this applied, rather than theoretical, series of presentations. Work was performed on certain key projects for Marion, particularly in the area of data analysis for regulatory submissions, and help was provided in the initial screening of applicants for a new position in the biopharmaceutics department.

The seven month sabbatical which was spent as an in-house consultant was an interesting and rewarding work experience. Marion Laboratories was true to their word. They allowed involvement in staff meetings, protocol writing, data analysis, problem solving, preparation of government submissions, and dialog with the Food and Drug Administration. Freedom was given to pursue the specific objectives of the sabbatical. These were a stimulating variety of experiences which included the on-and-off pressure situations one often associates with industry. However, the pressures were not uncomfortable, but rather were tolerable to the point of being exciting. Most of the objectives were at least partially satisfied, and return to the academic community occurred with a much more secure attitude with respect to the needs of industry for pharmaceutical scientists. Thus, the feeling was reinforced that a researcher with a broad base of knowledge in the pharmaceutical science areas of pharmaceutical chemistry, pharmaceutics, pharmacy administration, pharmacology, and toxicology, in addition to in-depth research expertise in one of these areas, can be a very important addition to the R&D efforts of a pharmaceutical company. True, these impressions were largely based on experiences at Marion Laboratories, and particularly on activities in the Biopharmaceutics Department. However, the pharmaceutical industry has traditionally employed BS degreed pharmacists in production and marketing areas and the use of pharmaceutical scientists in research and development is a logical extension of this practice.

Marion Laboratories also achieved their objectives from the program. Successful assistance and contribution was obtained on several projects from planning through data analysis. Several in-house computer modeling programs were implemented which helped the firm reduce its outside expenditures and improve its turnaround time for these data handling procedures. In-house training was carried out on a one-for-one tutorial basis as well as in a classroom setting covering topics from how to operate specific instrumentation to basic introductory lectures in pharmaceutical chemistry. From the consultantship, the opportunity was made available to assist the firm in this capacity internally and externally as an expert witness at key government hearings. The program was considered a success.

Comment

The approach favored for involving graduate students in cooperative research projects would depend upon contacts between facutly members and members of the industrial R&D staff. For example, by means of initial discussions, the R&D group can be made aware of the capabilities and expertise of various interested faculty members, and some insight as to the potential R&D needs can be attained. During discussions with R&D Directors at Marion Laboratories, such information was freely exchanged. At the request of R&D, or upon the person's own initiative, a faculty member would develop a protocol for a requested project or a project perceived to be worthwhile. Further interaction between the faculty person and an R&D scientist ideally will lead to a mutually agreed upon research project with subsequent generation of a budget. The graduate student should be involved in all discussions during the project evaluation period and take part in the protocol and budget preparation. The approach favored involves research support on an individual project basis as opposed to providing a block grant to the academic research unit. In the authors' opinoins, industrial-academic cooperative research programs should begin in this manner and expand as the situation requires.

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4

University–Industry Cooperative Research: Expectations, Rewards, and Problems

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The title of this presentation covers a range of interrelated subjects: expectations, rewards, and problems associated with cooperative research between industry and the academic institution. These are critical attributes to the understanding of this interface. I will refer to these points and also present an industry-university program to improve the effectiveness of research in our universities.

First, in a historical context, "the founders of the American political system clearly believed that the secrets of nature must be better known so that they might be used to advance the welfare of all our people...From the very outset of our Republic, the government of the United States has sought to encourage science and learning." These statements were made by President Eisenhower (1) at a time when the government support of science was at an all time high and science administrators were vitally concerned with types of support which would best increase basic research in our universities. One-half of all basic research of this nation is conducted in the universities (2), and "no one would think of defining a university leaving out basic research as one of its foundation stones" (3). Glen T. Seaborg (4) clearly presented the relationship of the university to basic research. He stated "that beyond question the university graduate school is the most effective device we have for the cultivation of the intellectual powers of a potential scientific investigator." All components are there: teachers, students, atmosphere, drive, interrelated disciplines, libraries, etc. He also indicated "there is a need to attract and identify increasing numbers of people capable of creative thinking.

Now we are again facing a growing concern that the usual forms of financial support of research should be supplemented by different approaches and there are strong indications that our efforts in science education are inadequate. Since "ideas and the development of ideas are weapons," (5) our survival as a nation depends upon the contributions of our scientists (6).

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The accelerated tempo of change in many spheres of knowledge and the problems associated with these changes have place heavy responsibilities on the personnel, research, and educational facilities of our institutions of higher learning. I believe that new thrusts to aid research as a part of science education are needed if this nation expects to go forward in basic research and graduate education. Teaching through research is a most important part in the education of future scientists. Whether the quantity and quality of basic research and graduate education in the United States in the 1980's will be adequate or inadequate depends to a considerable extent upon new and innovative programs of support from sources other than the government, such as the National Science Foundation and National Institutes of Health.

Some Considerations for Industry and Academe:

In my experience with university-industry cooperative research, I have seen programs that have been very successful, as well as programs that were unsuccessful. It seems that the successful programs all have some general features in common that are directly concerned with the expectations of, and rewards for, the respective participants. In this light the following areas will be discussed.

The "Expectations". A. What does the academic scientists expect when cooperating with industry? B. What can industry expect from the academic scientist, and the academic institution?

The "Rewards". A. What are the rewards for the academic institution? B. What are the rewards for private industry? C. What are the rewards for the academic scientist?

The "Problems". A. What are the problems for the academic scientist? B. What are the problems for the academic institution?

A Library of Instruments Plan. A. Responsibility of Colleges and Universities.

A Research Council Plan for Industry-University Research. A. Approaches and recommendations.

The "Expectations"

A. First, expectations of the scientist in academia. What are the usual expectations, or assumptions, of the academic scientist regarding cooperative research with his counterparts in industry?

Rightly or wrongly, the academic scientist usually assumes the goal(s) of the research project will be well-defined and achievable in the relatively short term, especially if the research program or project is being proposed by industry, and the industry is seeking cooperation from a scientist(s) in an academic institution.

The academic scientist also expects that substantial progress or successful completion of the project will result in economic benefit to the industry, and therefore tends to view industrial research in general as perhaps more short-term goal-oriented than his/her own research program at the university which is considered more long range. To oversimplify, the academic scientist regards the primary product of successful academic research as knowledge, while the products of successful industrial research are multiple and varied; eg. new or improved products, new services, and increased corporate earnings and growth of the company.

B. What can, and should, industry expect from the academic scientist, and the academic institution? First, the academic scientist can provide a perspective of the research problem that will tend to be somewhat different from that of his colleagues in industry. The academic scientist generally conducts his own research fairly independently, and therefore can provide a point of view to industry that could be of considerable value in approach and solution of the problem. Secondly, the academic scientist should not be expected in any way to use the institutions' resources to subsidize a particular industrial firm for financial gain. This is especially true for the academic scientists employed at public academic institutions. Industrial firms need to be aware of the academic scientist's concerns in this area. That is, the direction and type of proposed university-industry cooperative research must not be seen to hinder, or be in conflict with, the mission or responsibilities of the public institution. The research programs should be mutually acceptable to both and also to advance the research programs of the academic scientist. Thus, industry can expect the full cooperation of the public academic institution in programs that can be seen to benefit the institution, the professionalism of the scientist, and the public institutions' constituents: the public.

At the private university, however, industry-private university cooperative research may be subject to somewhat less scrutiny, as the funding of such institutions may be mainly from non-public sources.

The "Rewards"

A. The potential rewards for the academic institution are: 1. Financial; 2. Improvement of public image--the university could be seen to be involved in solving "real world" problems, and contributing to the welfare of the community, state, and nation; and 3. Prestige and status are also involved. For example, in instances in which universities receive very substantial funding, the institution is recognized among peer institutions as a leader in a particular research area.

B. Rewards and Advantages for Industry. These are: 1. Industry can achieve immediate access to scientific expertise and facilities at a relative low cost; 2. Access to a "network" of experts usually is also possible, as academic scientists exchange information among themselves more freely than scientists in the private sector (eg. experimental results are published in journal articles, and are not usually held as "trade secrets.") 3. Exposure to additional and new points of view regarding solution of a research program. 4. The public image of the company can also be enhanced when the public is aware that the corporation is cooperating in programs with an academic institution.

C. Rewards for the Academic Scientist. These are: 1. Direct contact with the latest developments and directions of industry provides a background that will increase his effectiveness in teaching and research. The scientist can then better advise his students (and graduate students) of the needs and directions of industrial research and development, and have an understanding of the problems the industry scientist must solve in the private sector. 2. Personal satisfaction is a reward also in successfully applying his "academic" skills to practical problems--also the professional development that takes place in closely associating with his counterparts in the private sector. 3. The academic scientist's recognition among his colleagues can also be enhanced by successfully contributing to a joint research program with industry. 4. Financial--As any professional, the academic scientist expects tangible benefits for his research program from investing his time, expertise, and efforts in advancing the research project. In addition, other benefits are available as trips, meetings, and new acquaintances.

The "Problems"

A. For the Academic Scientist. In some cases, it appears to the academic scientist that industry may have a misconception of the work, effort, money, and level of technical expertise required to solve a particular research problem, or to answer certain questions.

For example, the academic scientist may be contacted as a means of "last resort" to solve a problem. The industrial firm may have tried for a solution, and being unable to achieve it within constraints of time and financial outlay, then contacted the academic scientist hopefully to provide an answer. Usually there are no quick answers, and this is not a realistic expectation. Also, on an industrial research project, the scientist has costs for everything from chemicals to dishwashers, and he must be accountable and able to document that these costs are totally covered by non-public funding.

Further, institutional demands on the academic scientist's time for teaching, committees, seminars and other duties prevent him from obtaining short-term solutions to the problem. As a generalization he needs to work in a time frame of not less than 6 months. We must keep in mind the industry-university project goals must be mutual in benefit, somewhat long range, and fit into the ongoing research program of the academic scientist.

B. "Problems for the Academic Institution." The public institution must maintain its reputation as an objective, non-biased entity dedicated to the highest of ideals. Therefore, the institution is extremely sensitive on issues dealing with controversial areas of research, especially if it views itself as susceptible to public criticism. In cooperating with a public institution, if the private firm is cognizant of the institution's sensitivity to reputation, cooperation will be achieved more easily.

A Library of Instruments Plan

One of the most frustrating factors which dims the dreams of a research-minded faculty member is inadequate facilities. Although most administrators would count basic research as an important function of a university, the universities themselves have not generally accepted the full responsibility of an "employer" to provide the tools needed by the "employee." Where else in our society must the employee furnish major tools? Except for token amounts and the inheritance left by predecessors, the university researcher is expected to provide his own equipment through the usual channels, whether or not he is adept at this. Thus, seeking of funding becomes added to teaching, student conferences, committees, and some administration all to be done prior to research. On the national level, the chemical and biological instrumentation programs of NSF and NIH are strongly biased in favor of the excessively self-confident person and the "big operator". These programs are not well-designed to favor the quietly creative scholar.

In the average university there are a few scientists with well-recognized research and/or fund-raising abilities; they have vigorous and rewarding graduate student programs. These fortunate few represent a small fraction of the research potential on many campuses. Most scientists in most universities are the Ordinary Common Man of Science. He is the one who will do the bulk of the teaching--good, bad, or indifferent--and he is the one who will identify and develop the teacher-researcher potential in students. Since it has been successfully argued that the ordinary university scientist is the key to the realization of a great present and future research potential, the question is--by what means can this be accomplished?

A. Responsibilities of Colleges and Universities. The universities and colleges should accept the principle that they, as employers, are obligated to provide the research-teachers with a substantial percentage of the fundamental tools of his trade--in this way a real burden would be lifted from the individual scientists with obvious advantages. The universities should make a systematic effort to help to provide the accepted instruments of those sciences represented by their faculties. Each scientist should expect to have available somewhere on campus the needed equipment for his/her work in a "library of instruments." The instruments would be available to students and faculty for teaching and research. It is of paramount importance that the ideas and research objectives must first come from the individual investigators across the science areas. Instruments, as we know, are only tools for testing ideas and theories. The major purpose for providing this "specialized facilities," simply stated, is to support the personal research activities of the individual investigator, and to strengthen the stated missions of the university in science research, teaching, and public service.

In 1981, at the University of Missouri-Columbia, our administration in matching NSF Grants has significantly supported our research programs by providing in excess of $500,000 for state-of-the-art high resolution chromatographic and mass spectrometric instrumentation, and two nuclear magnetic resonance spectrometers. The total facility package cost about $1 million. More importantly, financial support has been provided by the University for the expertise salary for 2 high level scientists and 2 technical staff to operate the facilities, and to provide research-support on a university-wide basis. This is one of the most important additions to science at our university in the past 30 years, and sets the stage for the 1980s to experiment and test the ideas of our researchers.

A Research Council Plan (RCP) for University-Industry Research

A. Approaches and Recommendations - Viewpoints. Industry and the academic institution should view each other as resources --the academic institution as a resource of expertise and information in short time frame to industry at relatively low cost. Industry should make greater efforts to find what expertise is available so that they can use this expertise, or have it available for the future to address their problems. The academic scientist is generally very receptive to inquiries from industry, and after all, his "business" is knowledge. As is well known, the universities are considered as the technical center of gravity in advancing the leading edge of technology.

On the other hand, the academic institution should consider the industrial firm as a potential resource; a resource of current information on general industrial directions, needs and problems to be solved in the private sector.

The U.S. House of Representatives has recently passed a bill that sets aside a share of federal research and development funds to advance innovation by small firms. Called the Small Business Innovation Research Program, the intended result is that small firms will be spared, to an extent, the burdensome, uncertain process of competing for R & D funds. Perhaps this program could develop into a synergistic relationship with academe.

In the Research Council Plan, industrial firms would make funds available as unrestricted gifts to individual scientists, or departments, or to the Research Council for faculty competition. These funds would be in the range of $10,000 to $100,000 each. In particular cases they could be considerably greater. Top and middle industry management would make contact with scientists who have the needed expertise to meet the goals of the problem to be solved. The university and industry would jointly sponsor efforts for close communication between industry and academic scientists on a local and regional basis through forums, symposia, or a specific industry(ies) day or week at the university. Industry should accept the leadership and initiate contacts that will prove useful and mutually beneficial to both.

Advantages of the "Research Council Plan" (7). The Research Council Plan (RCP) provides the following advantages in this area: Creative research would be stimulated. 2. Support for research projects would be immediately available without drawing up formal detailed plans. 3. Faculty with newly acquired Ph.D. degrees could begin basic research immediately with a minimum of effort, red tape, and administrative channels. 4. Many small projects and ideas would be probed which otherwise might be passed over due to a lack of personnel, facilities, and support. 5. Industry would provide a single grant to the college or university, while the research council would be responsible for reviewing research proposals on the local scene. 6. Research Councils at the university level are in a good position to help and encourage the researcher with new projects. 7. Small colleges and universities would participate more effectively in research. 8. RCP would improve education of graduate students by providing access to modern science tools and technical supporting services. 9. Expenses of handling research grants would be reduced. RCP would provide a workable small grants program so obviously needed in the framework of college and university research support. 10. RCP would sustain and strengthen present centers of excellence. 11. RCP activities would result in an increased identification of creative talent.

Basic research is a major element of survival in the new world of biotechnology, automation, and other science technologies that has emerged and which will be ever more evident in the decade of the 1980s.

What our universities now need at all of its levels of science is other sources of funds to help in identification and development of more creative minds; a constant flow of ideas, conventional, traditional, unorthodox and unique; and a closer tie between academe and industry to tap the expertise of both groups to solve both fundamental and applied problems.

In most cases, small to medium-sized industries, unless they have a broad base, cannot and do not have expertise in many areas of science, nor the funds, to set up and operate expensive "Library of Instruments" centers such as: electron microscopy, NMR, chromatography-mass spectrometry, automated chemical systems, plasma spectroscopy, bioengineering technology, complex animal centers, and engineering systems. Many specialists are at universities. In a university-industry cooperative research venture, the goals of the research problem can be mutual, even though the missions of the institutions are different.

The Research Council Plan could play a dominant role in this process to benefit not only industry and the academic institution, but the general public as well.

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5

Interfacing with Academia: Some Corporate Approaches

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In recent years considerable attention has been focused on methods for increasing academic-industrial interactions in the chemical sciences. Crucial to bringing about the necessary and desired cooperation is action on a variety of the better programs that individuals or organizations have proposed. Some of the mechanisms that The Dow Chemical Company is currently employing in its overall effort will be reviewed, with emphasis being given to a program for cooperative research that appears to be meeting with considerable success.

Over the past few years there has been a considerable increase in interest in improved interactions between academia and industry in the sciences. One can easily see many reasons for such trends and there often appears to be a genuine desire, as well as a need, for this interaction to take place. One can hear proponents at just about any recent technical conference. Many of these meetings even have a special symposium dedicated to the topic, as does this National ACS meeting in Kansas City. Indeed, entire meetings of substantial size have been called to address the topic. Some of the various discussions, symposia, meetings, etc., have been reasonably productive. However, a number of these have resulted in a fair amount of talk, but a rather limited amount of action. Talk is very important to get the various views aired, but follow-up action is even more important if any significant progress is going to be made

Over the years, some new mechanisms for increasing this very important interaction have been proposed. Occasionally, some of the aspects of these mechanisms have been controversial, but it is important that we resolve any major differences and go about the business of making the necessary interactions work -- and work well. As scientists, we in academia and industry have a lot more in common than is often admitted, and if we draw upon these common

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interests they can often be the catalysts to make good things happen!

Some Dow Approaches.

Most of us realize that no one program for interacting is going to meet the needs of all (or maybe not even a majority) of the needs of the parties involved. This is why we at Dow have developed a multi-faceted approach to increasing interactions with our academic partners in science. Although this program has numerous components and each individual interaction can be varied to meet individual needs, there are primarily five basic methods (or major programs) that we are using at present. These are listed in Figure I. The method of operation in each of these programs is more or less defined, although most are quite flexible and are continuing to evolve as we see the needs of the colleges and universities and our own needs evolve.

A brief overview of Dow's involvement in each of these programs will be given below with emphasis on the last program, Cooperative Research, as that is the program with which I personally am most involved.

Dow's University Relations Program

Figure 2 shows the majority of the basic components in our University Relations Program. Our procedure in interacting with any given university through this program has been "to find out what the needs are and follow up". Typically, the university will give Dow a description of its needs with suggestions for Dow's participation in helping to meet those needs.

We subsequently respond with what we feel we can do to help. We respond not only to the university's suggestions, but may well suggest some new and different mechanisms ourselves. We fully realize, however, that we cannot be everything to everybody, but we make an honest attempt to help in as positive a way as we can.

When a support decision is made, we also attempt to identify Dow people with that support, such that the university has a prime contact for continued professional relationship with Dow. The net result has been that the typical response from the universities has been extremely favorable to our overall approach.

The Dow Chemical Company Foundation

This Foundation was established in December 1979 "to support basic research in physical and natural sciences at U.S. colleges and universities." Research proposals for possible project support were first received in the fall of 1980, and subsequently about 20 projects received support beginning in 1981. While continuing to fund existing projects and reviewing additional proposals already received, the Foundation has placed a hold on receiving new proposals at this time. In addition, some financial assistance is now being given for undergraduate scholarships in the chemical sciences and a program of faculty support in chemical engineering departments at various colleges and universities.

Figure 1: MAJOR DOW MECHANISMS FOR INTERACTION WITH ACADEMIA

I. University Relations Program

II. The Dow Chemical Company Foundation

III. Participation in the Council for Chemical Research (CCR)

IV. Grants from Individual Dow Laboratories

V. Cooperative Research Program

FIGURE 2: BASIC COMPONENTS OF DOW'S UNIVERSITY RELATION PROGRAM

Contributions

Research Programs

Advisory Panels

Visits

Scholarships

Loaned Professors

Seminars

Speakers

Matching Grants

Alternate Term Co-Ops and Summer Interns

Career Days

Recruiting

Special Programs

The Council for Chemical Research

Dow Chemical was instrumental in getting the newly established Council for Chemical Research (CCR) off the ground. The first University-Industry Research Conference that eventually led to the founding of CCR was held in Midland, Michigan, in the fall of 1979. Subsequent meetings have been held in Bethlehem, PA (1980), Rochester, NY (1981), and Houston, TX (1982) with each being co-hosted by at least one major university and a corporation within the chemical industry. A fifth meeting is scheduled for Boston, MA (October '83). The Council was incorporated in December 80, and the organizational structure put into place in 1981. It is a non-profit organization with representatives from industrial research laboratories and departments of chemistry and chemical engineering in universities. Its major goals are shown in Figure 3.

In addition to seeking improved methods for interaction, the Council has established the Chemical Science and Engineering Fund (CSEF) to encourage increased financial support of university research.

Although CCR is still in its infancy, it appears to have the potential for becoming a significant catalyst for increased academic-industrial interaction.

Support from Individual Dow Laboratories

Since any given laboratory within the Dow research organization may find it very desirable to have a direct interaction with a specific department or professor at a particular university, such a laboratory may decide to direct a portion of its own budget towards support of that department or professor. This could take the form of an unrestricted grant, a fellowship grant, or perhaps even a specific "contract research grant" to conduct studies of importance to that laboratory, studies which for various reasons could best be done at the university rather than at Dow. Most of such support evolves directly from the professional relationships between university scientists and Dow scientists.

The total amount of support activity in this category not surprisingly can vary somewhat from time to time, depending upon the specific needs of these laboratories. Nonetheless, a significant amount is always in progress at any given time, and the professional ties established have proven to be extremely valuable to both parties involved.

Dow's Cooperative Research Program

A primary goal of the Cooperative Research Program at Dow is to identify and develop cooperative exploratory research between Dow scientists and academic scientists with the objective of establishing technical bases for new Dow businesses. An additional goal is to strengthen the professional ties of Dow scientists with their academic colleagues and thus broaden their overall research perspectives.

The first step in this program is the identification of specific academic research programs or ideas that are of strong interest to Dow scientists. Some of the mechanisms for achieving the necessary information flow to assist in this identification are shown in Figure 4. Any of these mechanisms can be the primary one used to identify a specific research program of interest, and the academic scientist involved. Using visits by Dow's Cooperarive Research function as an example, Figure 5 shows some of the specific steps that may be involved leading up to project support.

FIGURE 3: MAJOR GOALS OF THE COUNCIL FOR CHEMICAL RESEARCH

To promote valuable cooperative activities between the chemical industries and research universities.

To work for continued health and vitality of chemical science, engineering and technology in the United States.

To support new, significant, and continuing sources of funding for research universities.

To ensure advanced education of the highest quality in the chemical sciences and engineering.

FIGURE 4: LEADS FOR IDENTIFICATION OF COOPERATIVE RESEARCH PROGRAMS

The Technical Literature

Technical Conferences/Meetings

Professional Contacts of Individual Dow Scientists

Cooperative Research Contacts/Visits

Unsolicited Inquires

Technology Search Firms

Others

FIGURE 5: COOPERATIVE RESEARCH TECHNOLOGY SEARCH MECHANISM (ACADEMIC)

1. Arrange a visit (usually 1-3 days) at the university through research administration and/or department heads.

2. Make a group presentation on the goals of the Cooperative Research program and its mechanism of operation.

3. Interview selected individual faculty members regarding research projects/ideas. Request a brief, written non-confidential description.

4. Communicate results of the visit within the Dow technical community (global basis).

5. If the research project/idea is of sufficient interest, invite the professor to Dow for a seminar and individual discussions.

6. If still of strong interest, request a brief research proposal, including a budget.

7. If the decision is to support the project, submit a research agreement to the university for review and execution.

8. Assign a Dow technical monitor to follow the project in detail.

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

FIGURE 6: HIGHLIGHTS OF DOW FELLOWSHIPS FROM COOPERATIVE RESEARCH

1. Established to support specific research with specific professors.

2. Provides financial support for a graduate student or post doc, plus expendables.

3. Generally the support is on a one-year basis, with potential for renewal.

4. The college/university makes periodic reports to Dow of the research results.

5. The college/university has freedom to publish.

6. Dow is given the opportunity to review any manuscripts in case patent recommendations needed.

7. Dow encourages the university to pursue patents on potentially patentable inventions.

8. Dow obtains first right of refusal to license the patented technology. The college/university has the opportunity to gain substantially from royalties.

9. Close monitoring of the project in progress give the Dow technical community first-hand knowledge of the field "as it is being developed".

10. Visits by the professor and/or fellow to Dow, and the visits by the Dow monitor to the college/university, strengthen the professional ties that can last well beyond the term of project support.

If indeed project support does result, such support usually takes the form of a fellowship for a graduate student or post-doc working with that specific professor. The highlights of these Dow Fellowships are shown in Figure 6.

Currently, Dow is supporting about fifty research projects with various colleges and universities through the Cooperative Research Program. In addition, we are constantly on the lookout for new potential projects. This program has been in operation for about four years now, and we are quite pleased with the initial results we are starting to see from it. Some of the more valuable projects have been those in which the technology area is also being researched actively at Dow and truly cooperative interactions with exchange of technical data results.

In addition to establishing some very strong ties with our academic colleagues, a significant number of these supported projects have resulted in preliminary patent activity on some very interesting technologies. As yet, it remains to be seen whether or not any of this activity will result in patents that are subsequently licensed and commercialized by Dow, but we certainly anticipate that it eventually will. Nonetheless, the professional ties that have developed between a number of Dow scientists and their academic colleagues alone have been extremely rewarding from the standpoint of broadening research perspectives.

Summary

In this brief overview I have attempted to outline some of the approaches that one company, The Dow Chemical Company, is utilizing to improve its overall interactions with the academic community. In addition to the programs described above, Dow also works closely with various scientific organizations, for example, the ACS and AIChE, both at the local and national levels to facilitate these academic-industrial interactions. For it is only with this type of cooperation in a program of action that we can expect our nation to maintain its technological leadership in today's competitive environment.

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6

Recent National Science Board Studies in University–Industry Research Relationships

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National Science Board Committee on 14th Annual Report, Washington, DC 20550

These remarks will provide a brief preview of some results from a major national field study commissioned as background material for the National Science Board 14th Annual Report, University-Industry Research Relationships: Myths, Realities and Potentials. The Board Report will contain some historical considerations, a fairly comprehensive data analysis of trends over the past 20 years, a discussion of the federal role, and a hypothesis about the future of university/industry relations.

The report from the field study will be published separately together with five other specially commissioned studies. The limited time available during this symposium permits presentation of only a few of the interesting statistics generated in the course of the field study, and it should be understood that they remain provisional until final publication of the study.

During the field study interviews were conducted at a sample of forty universities and seventy companies. Over 400 instances of research relationships were identified and analysed. They included over a dozen types of relationships, and covered a wide range of scientific and engineering disciplines as well as many industrial sectors. For each case the participants on both sides were queried concerning how the relationship came about, their expectations about it, the administrative and legal arrangements, the stumbling blocks, successes, failures, etc.

One of the most interesting issues was the existence and nature of any prior connections between the academic and industrial partners in a relationship. In about one-third of the 340 cases analyzed for this purpose a prior relationship between the parties had existed, and in one quarter of the instances a prior consulting relationship was extant. Universities should thus take note that consulting connections may well generate significant research support from industrial sources.

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Who initiates university/industry relationships? It was quite unexpected that in two-thirds of the cases the participants agreed that the impetus for the connection came from the university. Companies were seen as taking the lead in only about one-fifth of the cases. The remainder of the cases were seen as mutually initiated. It is worth noting that one type of relationship did not exhibit this pattern of initiation. Cases of "general research support" -- primarily industrial philanthropic gifts of funds or research equipment to individual faculty members or to departments -- were slightly more likely to be seen as initiated by companies than by the academics. Also, prior relationships were less in evidence in the case of philanthropic gifts.

Corporate and academic participants expressed rather different patterns of motivations for entering into relationships. In over three-quarters of the corporate interviews, the number one motive offered for entering into academic research relationships was personnel acquisition or recruitment. Companies are creating opportunities to make early connections with bright graduate students and faculty scientists. This is especially important in areas where there is currently fierce recruitment competition between companies for the best new scientists and engineers. Two examples: one fresh Ph.D. in computer science started a job with a new company at $90,000 a year - in California, of course. Further, new Ph.D.'s with recombinant DNA expertise in the plant sciences are said to currently have their pick of 30 job offers each.

Personnel acquisition has been historically important for corporations and more research is needed into the patterns of hiring relationships between particular corporations and particular university departments.

The university's principal motivation is easier to predict -- a need for new sources of funds for research, student support, equipment, supplies,and the like.

The second most important aim expressed by those people interviewed was, a window on new science and technology. This was mentioned as a significant motivation in about half of the cases.

While the preferred mode of relationship for this purpose remains by far the "one-on-one" grant or contract connection, we are seeing an interesting increase in the use of collective research arrangements between one university unit and several corporations. Examples are the new microelectronics research centers and the somewhat older cooperative research centers in a variety of fields of science and engineering (many of these latter received initial "seed money" support from Federal research agencies). Further, fledgling industry-wide arrangements with many university units, such as the Council for Chemical Research and the Semiconductor Research Cooperative are an important new feature of the research landscape. These initiatives have been encouraged by recent changes in federal regulations. A 1980 Department of Justice publication on the subject helped to clarify the application of antitrust laws to such research cooperation. The Department of Commerce is currently working on further facilitating measures.

Two additional motives raised in about two-fifths of the corporate interviews were, general support of technical excellence and gaining access to university facilities, including opportunities for education and training, adjunct professorships and personal exchange, and so on. It is interesting that only about one tenth of the companies mentioned that they became involved in research interactions with universities in order to solve a problem or to obtain specific information unavailable elsewhere.

The second and third most frequently mentioned academic motivations, mentioned in about a third of the cases, focussed on the educational implications of the interactions, i.e., that industry sponsored research provides students with exposure to real world research problems, thereby providing better training for the increasing numbers of graduates opting for industrial career.

There were very interesting differences in the corporate and academic perceptions of problem areas in the interaction process. It should be said that the academics were a lot more outspoken about problems and barriers than their corporate opposite numbers who tended to be more circumspect. In all of the interviews at universities, patents, licensing, proprietary rights and prepublication review were perceived as problems or barriers in their relations with industry. In about four-fifths of the cases the academics mentioned as problems institutional differences in objectives and goals, administrative structures and time frames. About one-third of the academics mentioned personal attitudes as a barrier.

From the corporate perspective the biggest problems lay in institutional differences -- mentioned in about half of the cases. About two-fifths of the corporate managers saw proprietary rights and prepublication review as generating problems in relationships. Surprisingly enough, difficulties in arriving at patent and licensing arrangements were mentioned in only one-fifth of the corporate interviews. This was about on par with the one-fifth that mentioned geographical distance as posing problems.

The field study report will contain data on patent and prepublication review policies and practises at about 40 campuses as of mid-1981. This is, of course, a rapidly changing scene as universities pay more attention to these matters. The report will also display some data on patent income for a subset of 20 universities which suggests that such income, while relatively small, may be increasing.

In conclusion, a strong message emerges from these materials that university-industry connections involve webs of relationships of different kinds. They are rarely one-shot in nature. These relationships are also historical and sequential. Certain campuses and companies have over the years developed especially close relations in the recruitment of graduates. Thus the upper ranks of management in these companies contain high proportions of alumni from particular campuses. Further, the companies are likely to be well represented on the university board of trustees. As mentioned above, these patterns deserve much closer study.

It can be hypothesized that the formal relationship flows from the informal contact: that one type of interaction generates another relationship. For example, the following characterizes a frequently occurring scenario.

> A company wants technical or scientific advice, perhaps concerning its own research program, and seeks out a professor as a credible consultant. While providing the expertise the professor observes opportunities for research, and he or she negotiates a research grant or contract. In this phase of the relationship the initiative is seen as coming from the professor. The professor's research proceeds apace and the company tracks it and possibly utilizes it. But the company will be sure to be tracking the bright young graduate students working on the project. It may offer them summer jobs in the company, or even support for postdoctoral work. It may recruit some of them for permanent jobs. With the former students now in the company, the web of contacts thus becomes denser, and the cycle may be repeated in future years.

It is worth noting that corporations are becoming increasingly aware of these webs of relationships. They are beginning to develop comprehensive tracking systems in order better to understand and integrate their philanthropic and their research grant and contract relationships with universities.

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7

Academic and Corporate Values and Goals: Are They Really in Conflict?

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The academic and corporate communities have depended upon one another for many years.

The fact that there is a symposium of this title on the American Chemical Society Meeting's agenda implies that something important is changing in the symbiotic relationship between academia and industry. To be sure, there has been a new focus of attention towards the important relationship between universities and corporations as a result of the recent "commercialization" of the findings of the biological sciences. The rise of biotechnology corporations, such as Cetus Corporation, has signaled the commercialization of research findings in an area which not long ago was regarded as purely scholarly. But this is not the same thing as the commercialization of the university.

The pharmaceutical industry, once a rather specialized hybrid between the chemical industry and the clinical research laboratory, has also taken on a new dimension - also exploiting the remarkable advances in both molecular genetics and cell biology. It is not the case that the rise of biotechnology has brought about an unprecedented clash between corporate and scholarly values. First, while there is clearly a conceptual distinction between the profit motive and the search for the truth, these values are not, in any significant way, in conflict. Second, the academic-corporate connection has existed for many years in many areas. It is novel only to certain areas of biological research.

A conference held in the spring at Pajaro Dunes, California, in which university presidents and corporate leaders met, presumably to discuss their mutual problems, indicated to the public once again that there were, indeed, major problems to be solved. This was followed by a workshop in May sponsored by the Industrial Biotechnology Association, this ACS forum today, and a major conference held in December at the University of Pennsylvania. Does it follow from this continuing dialogue that there are, in fact, major problems to be solved? If corporations and universities have been cooperating for many years in both basic and applied research, why are corporate-university relations apparently a new issue? Are there aspects of corporate-sponsored research in the biological sciences which are

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unlike those attending research in polymer chemistry, for example? Is the interest of corporations seriously compromising, as some have suggested, academic freedom and the nature of basic research in universities? We know that university professors are carrying out "commercial" research in their university laboratories. But then, to whom do the results and the patents belong? The answers are not as simple as some might think, but these are the easier questions.

More difficult to deal with are the more subtle questions like the following: Is the creative process inhibited because people are afraid to discuss their ideas with each other for fear of betraying proprietary information? Are graduate students deprived of one of the most important parts of their training by being muzzled and told not to talk to their colleagues for fear of giving somebody else a competitive edge in the world of commercial biotechnology? Do university consultants, in fact, spend more of their time with their commercial ties than the university rules would allow? Do they "raid" their publicly supported colleagues' laboratories, offering much more lucrative commercial jobs to the best research technicians? And are their commercial ties breeding division and resentment in their university laboratories and among their university colleagues?

These questions reflect the charges that have been raised concerning the new academic-corporate ties in the area of molecular and cell biology. It is in the interests of everyone, including corporations, that problems are kept to a minimum, and that our relationships with universities are not only harmonious, but are perceived to be so by all those concerned.

How at least some of these points of possible contention can be avoided will be briefly discussed below. On the basis of Cetus' experience in negotiating contracts for the support of research in universities, I know it is rather easy to eliminate misunderstanding at the outset, and to see that the interests of both institutions are protected. There are some, of course, who have argued that there is an intrinsic conflict of interest in any relationship between academia and a profit-making institution. I suppose it is possible for one to subcribe to a set of values where that would be true. Further examination, however, reveals that at least in the United States the goals for society espoused both by academicians and corporate leaders are more or less the same. What may at first glance appear to be a conflict of interest turns out to be in the final analysis, not a conflict at all, but, in fact, an expression of what was intended in the first place. While there is certainly a cultural value in knowledge, per se, the principal mechanism by which the practical benefits of research are achieved in the United States is through commercial development. That means, by companies.

First let me distinguish between two rather different types of arrangements which currently exist between corporations and universities. The most common, and the type in which Cetus engages, includes individual contracts for research awarded to universities by corporate institutions, generally in the support of a particular project in the laboratory of a particular scientist. These contracts are generally for relatively modest sums of money, perhaps ranging from $25,000 a year to rarely more than

$150,000 or $200,000 a year, and are, therefore, in the same monetary range as the federal research grant or contract.

The other type of corporate-academic arrangement includes the granting of massive sums of money from a particular company to an entire academic department or to establish a new institute within an academic institution. This is a fundamentally different relationship than exists with support to an individual scientist. Here the strings attached may look more like chains. Examples of this type of arrangement would include the Hoechst $50 million endowment of the Department of Molecular Biology at Harvard's Massachusetts General Hospital. This is what I would describe as the "commercialization" of the university. It would also include the funding of research at Harvard and at Washington University in St. Louis by Monsanto, and possibly the establishment of the Whitehead Foundation at MIT, although that is, perhaps, an exception to the rule.

At present, universities differ a great deal in the terms they wish to specify in their research contracts. It is critically important that the terms of all such contracts be carefully examined by both university and corporate lawyers, in anticipation of any difficulties which could arise. Some of the trouble that has given rise to the rancor that some of us have heard about undoubtedly stems from a failure to consider these potential problems in advance and to write the research contract accordingly. In the first place, it must be understood that such a contract is not an act of charity from the corporation's point of view. The terms must be sufficiently attractive to both parties to give birth to the relationship. It has been our experience that by sitting down with university counsel, it is rather easy to arrive at a mutually agreeable set of conditions designed to protect the academic freedom of both the faculty and students, to protect proprietary rights of the inventor, and to ensure that the sponsoring corporation will be permitted to commercialize inventions which ensue from the contract in a way which is both fair and reasonable.

The question of patent rights, while sometimes raising a red flag to the uninformed or the doctrinaire opposed, is one of the easier questions to deal with. The Patent Law passed by the 96th Congress, Public Law 96-517, clearly gives the patent rights of federally supported research to the institution. The institution may then negotiate a royalty agreement with the original inventor. In general, passage of this law has resulted in higher royalties to the individual scientists. In the case of research sponsored by a corporation, the federal model is generally followed. That is, the institution in which the research is carried out has the right to patent any invention ensuing from such sponsored research. It at least has the right of first refusal in the event it chooses not to patent the finding. In some instances, public as well as private universities permit the sponsored professor to retain the title to any inventions.

Most university contracts permit the corporate sponsor to review any research results, particularly those prepared for publication, for a fixed period of time to determine whether patents should be sought for any inventions. The period of time is generally thirty days. If the corporate sponsor decides something is patentable, this period may usually be extended for perhaps another sixty days while the university attorneys file for patents. After that period, the results may be freely published in the open literature.

The 30-day review period is generally not considered an inordinate delay of communication of the results. Most often, even before a manuscript is prepared, there will be communication between the scientist, the corporate sponsor and university patent counsel so that patents may be filed at the same time a manuscript is ready for submission for publication, in which case there is no delay. This protects the professional competitive position of the scientist and allows inventions to be protected, too. Of course, in order for this arrangement to provide a benefit to the corporate sponsor, the one provision that is usually insisted upon, is exclusive licensing rights. Otherwise, why sponsor the research? After a patent is filed, the corporation has a fixed period of time in which to decide whether it wishes to obtain a license. The university generally limits the period for which a license may be held. Typically, this limitation may be five years from the date of first sale of a commercial product, or eight years from the issuance of the patent, but this could change if the "useful" life of a patent is extended for pharmaceuticals by proposed patent legislation. For these rights the university is paid a royalty, the terms of which are worked out to be mutually agreeable between the institution and the corporation. Thus, not only is the academic scientist supported in research, but the university benefits as well, particularly if a product is commercially successful.

The protection of proprietary rights is an issue that certainly concerns the corporations. It is also a matter of importance to the institution, where it can be rather difficult for a faculty member to remember, in the course of talking to students or colleagues, whether a certain bit of information is somebody else's property. This is clearly something which has to be spelled out in detail before research is undertaken. First of all, in order to protect the patentability of an invention outside the United States, it is legally important that patentable results not be communicated publicly before a patent is filed (a one-year period of grace exists under U. S. patent law). And, of course, there is always the concern that somebody might steal your invention.

The Stanford Patent of Herbert Boyer and Stanley Cohen now seems to be running aground for at least some of these reasons. The second part dealing with products of recombinant DNA technology has been delayed indefinitely by the Patent Office. The first part, granted earlier, concerned with the basic recombinant DNA processes and for which most of us pay Stanford $10,000 a year in non-exclusive license fees, is also being re-examined. The timing of public announcements, the contributions of others not named in the patent application, and the extent of "prior art" are all being questioned anew.

Universities tend to be rather sensitive on the issue of access to proprietary information. Most prefer that the project be set up in such a way that graduate students and postdoctoral fellows not have access to, or work on what is considered confidential research data. They feel, and I agree with them, that this would greatly inhibit an important part of the learning process where the free exchange of ideas and the critique of each other's work is not only a way of learning, but a way of learning how to be creative. Principal investigators and a specific number of paid research assistants may have access to such data, but it is the primary responsibility of the principal investigator to protect proprietary information. This responsibility must be clearly understood and assumed by the principal investigator before he accepts research funds under these conditions. Certainly, not every scientist wishes to be in this position, and that, of course, is his or her choice. For those who do, however, it is important that the project involving proprietary data be in no way confusable with any of the other projects being conducted in that person's laboratory.

These, then, are the principal stumbling blocks which appear to be the source of much of the criticism of corporate ties to academia. It may simply be the inexperience of those in the biological sciences, for one certainly hears relatively little about such problems in the area of chemistry or solid state physics. It may simply be that this is a process which is in its infancy in biological sciences, and that after a period of maturation these problems, or the perception of such problems, will disappear.

There are, of course, certain facts accompanying the rise of commercial biotechnology which have attracted a great deal of attention. Following recent press coverage, investors seemed more than eager to pour millions of dollars into the new biotechnology companies. Genentech made history when its highly coveted stock rose from $35 to $89 a share in twenty minutes of trading. The phenomena of instant paper millionaires and the awarding of a Nobel Prize to a Harvard scientist (Wally Gilbert) who had just "gone commercial" were unprecedented in other areas of science, and were certainly big news. There seems to be a somewhat tarnished aura surrounding those who have foresaken the robes of academic purity for the lure of money. Somehow, it is worse than if one were in business from the start. But the "fallen angel" image is purely one of perception rather than fact. The university is no more the bastion of morality any more than the corporation is fount of immorality.

I would now like to briefly touch upon the larger institutional arrangements, such as the Hoechst/Massachusetts General arrangement, whereby an entire department may be subject to an exclusive contractual arrangement with a corporation. The difficulty I see in such an arrangement is that it can have the effect of isolating perhaps an entire research unit from the rest of the academic institution. It is possible that all investigators supported by a particular company in a particular department - which may include the entire department - may be privy to the same confidential information. Certainly, the institutional type of arrangement relieves the difficulty of scientists talking among themselves in the corridors of a given department. But it could have a greatly inhibiting effect on discussing their work outside the department. This may not be in the best interests of a university, particularly, where one of the chief responsibilities of an academic institution is to educate students. Having read the contract establishing the Hoechst support of the Department of Molecular Biology at Massachusetts General, it is clear that anyone who wishes to be a part of that department would have to accept the exclusive terms demanded by Hoechst. That is, individual scientists no longer have the freedom to determine how to run their own laboratory or how to support their own research. To some, it may be a blessing that they no longer have to go through the time-consuming hassle of applying for federal grants and then not being sure that they will receive one. However, they may also pay a price, which may be too dear for those who cherish the freedom to make their own choices.

It's quite easy for me to talk about this arrangement. Cetus cannot afford to buy an entire academic department. For some, commercial affiliations and commercial research contracts may be satisfactory; for others, it is not. And it is, perhaps, this diversity which can contribute strength to university departments.

The final area to focus on deals with some of the larger issues generated by the so-called academic-industrial complex. One of the questions raised is the matter of free communication among scientists as being an important element in the creative process. The open exchange of ideas is, to be sure, essential to good research. Not only is this true of the communication of scientific findings in legitimate professional journals and scientific meetings, but of the kind of informal give-and-take that takes place among colleagues and their students.

If proprietary information is being discussed, however, then clearly it cannot be freely communicated. In order to protect patent rights abroad, only after a patent is filed can the information be freely discussed even in a legitimate scientific forum. One certainly might expect this type of reticence on the part of a corporate employee. It is a little disturbing, however, even from the corporate point of view, if university scientists feel reluctant to talk to the extent where this creative give-and-take is truly inhibited. Of course, the patent laws are designed to get inventions into the public domain as soon as possible. In the United States, one may file a patent up to a year after disclosure. But because patent rights abroad are forfeited if there is any prior disclosure, this well-intentioned provision of U. S. law is, for all practical purposes, irrelevant. This patent situation, then, does entail a certain delay. Just as scientists at one time would not talk about something that was still in progress in their laboratory purely because they were afraid their intellectual property or their ideas might be stolen, we find the same principle taking place when there is money at stake. The behavior of scientists in either case is not so different.

At present, I have not seen this phenomenon as a serious problem. To be sure, however, it has inhibited a discussion in certain aspects of molecular biology. It is, perhaps, for this reason that the commercial component of university research should never be allowed to increase past a relatively small fraction of the total - say, ten percent. Most science certainly should be open for free discussion, particularly, basic science. As long as the corporate extent of academic funding remains small, I do not believe that one is likely to see any serious degree of inhibition of the open exchange of ideas.

Secondly, some have argued that now that basic science is being commercialized, the corporations indeed have an obligation to support basic research, not simply research leading directly to a product and a proprietary position for the company, but basic research in general. In principle, I would agree that this is appropriate to some degree. However, again I must say that responsibility for supporting basic research should not be considered solely that of private industry. In fact, I would consider it to remain the province of national governments. The knowledge flowing from research should be considered a national asset. In fact, it's our only strong suit, vis-a-vis Japan. Where appropriate, of course, this should be translated into useful products and services to the benefit of the population. In many instances it will simply remain the building blocks for future achievements. I expect that federal support for basic science will continue to remain by far the largest single funding entity - and that is as it should be.

An additional issue which has been suggested as a serious problem is that of the brain drain. The companies generally offer higher salaries than universities. To what extent are the best minds, who would normally seek professorships and careers in academic research and teaching, being lured away by the greater financial rewards of the biotechnology companies? Well, perhaps that criticism could have been raised with respect to chemistry two or three decades ago. Obviously, many able people chose to go the industrial route. Nevertheless, there seems to have been no paucity of brilliant chemistry professors. There is no doubt that many highly able people are being drawn to what is in some ways a more attractive research environment in some of the corporations. Particularly since Wally's Nobel Prize, there no longer seems to be a stigma attached to those who leave universities to take jobs with corporations, suggesting that they just weren't good enough for a professorship and had to settle for less. Particularly for the young postdoc who faces stiff competition for a position and a research grant, this might be the best way to advance one's career and make some money besides. After all, there aren't that many university openings. The academic positions don't seem to be hurting for capable people. The field still remains highly competitive.

There are clearly those who don't care to compromise their freedom to pursue any problem they wish, and certainly anyone joining a corporation has to do that to some degree. It is fortunate if the area of your interest just happens to also be an area of corporate interest. Still, one is dependent upon the markets and the shifts of the commercial winds. There is not absolute security in corporate science any more than there is in academic science. Some would prefer the freedom of academia, and, fortunately, some genuinely love teaching. As long as there is federal support for research and there are universities, I would be very surprised to see a lowering of quality of academic faculties due to the drain into corporations. These are clearly two kinds of institutions for which our scientific resources are adequate to fill the needs of both.

Some scholars continue to raise the matter of fairness and justice. They point out that the findings upon which the biotechnology industry has based its products have come largely from federally supported research. Should not, they argue, the public then have the right to use any developments that ensue from this research? To that I respond, "Of course, that is what commercialization in our society is all about." As a matter of fact, in order that these findings would become available to enhance the quality of human life depends absolutely on a strong industry and its ability to develop and produce the products of medicine, chemistry, and agriculture enabled by the new biology.

The federal government has traditionally supported the bulk of basic research in academic institutions. The argument, however, that publicly supported research should not be commercialized - that is, that the results should not be developed into useful products or services which are then "sold" for profit - is certainly counter to the intent of Congress in supporting research. The government funds science in order that the benefits of research will accrue to society. Certain activist-critics of the commercialization of research results obtained with public support have espoused the "rip-off" hypothesis. In its simplistic presentation, it suggests that the taxpayers are being exploited and robbed to make a few people rich. To that, they scream, "Hey, that's not fair." But such an oversimplified conclusion quickly crumbles within the context of a so-called free enterprise economy, where the ingenious entrepreneur is rewarded for the innovative application of general knowledge. As a philosophical tenet, this is reflected in the constitutional provision (Article I, Section 8) allowing Congress to protect inventions with patent laws. The values underlying the "rip-off" hypothesis may be consistent with a political and economic philosophy where the government is the sole instrument of providing benefits to the public, and where the profit motive is illegal. In most of the world, however, this is not the case. It is clearly the intention of the federal government that the findings of federally supported basic research not only be commercialized, but be commercialized with as few obstacles as happen to be necessary.

The fairness and justice issue would only be legitimate if the products were ultimately made available only to the rich and not to all taxpayers. At present, while I do not contend that there is universal equity in our society or any other, the fruits of scientific research, as expressed by the biotechnology industry, are certainly going to be as available to the public as are those of the pharmaceutical industry, or the automobile industry, or of any other industry or technology. The question of justice then reduces not simply to commercialization and an unfair advantage being taken of taxpayers' funds, but rather the entire economic philosophy of a country. That is, biotechnology is no different in its economic structure than any other aspect of the American economy. If miracle drugs made by biotechnology are costly, then it is our political policies, such as providing the elderly and the poor with those drugs free of charge, that will determine equity. Modern medicine, practicing a state of knowledge enabled largely through federally supported research, is in exactly the same situation. Such policies clearly vary with the party in power. Justice, then, is an essentially political problem, and dependent upon political, social and economic values. As such, it is irrelevant both to any particular industry and certainly to academic-industrial relations.

To conclude, let me just say that the survival of a nascent exciting industry, such as biotechnology, is intimately dependent upon a continuum of scientific creativity. It is only as a result of strong universities that this creativity can continue. We are absolutely dependent upon our relations with universities - more so, probably, than are universities dependent upon our survival. Yet it is clearly in both of our interests to see that science is translated where possible into benefits for mankind. Close cooperation with academia is the key to insuring that there will be a fresh supply of new science, and that any benefits resulting from such research will be made available as quickly as possible. Universities are also the source of trained people which ultimately staff and become scientists in our biotechnical companies. Just as the universities provide chemists for the chemical industry, and chemical engineers, so must they provide cell biologists, molecular biologists and microbiologists. It is, therefore, clearly in our interests to see that universities remain strong. Only the best, most creative minds can make an innovative technology, such as ours, succeed.

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Industrial-Academic Cooperation in Education

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Certain problems of education and research in the university are examined in terms of their importance to industry, the preparation of the student-then-employee, and academic and industrial requirements and customs with regard to the generation and dissemination of knowledge.

Industry-university relationships are a very popular subject these days, with attention from several corners of the national administration and in the forums of virtually every technical society and industry group. In fact, the subject has been continuously popular for at least 20 years and probably for 60! Because this Symposium is taking place at a national meeting of the American Chemical Society, my comments will be derived primarily from reports of ACS scrutiny of the manifold relationships between the academic and industrial communities of chemists.

There is a long history of ACS concern over conditions at the Industrial-Academic Interface - a concern probably no less enduring than the communities whose juxtaposition creates and maintains that boundary surface. In recent years, for example, the ACS's OPERATION INTERFACE generated over 60 local conferences on the subject; the 1979, 1980 and 1981 ACS Presidential Conferences were either devoted to it or addressed it to some significant degree; several ACS task forces on industrial-academic cooperation were formed and most are still active.

Between 1979 and 1981 such bodies were created by the Board of Directors, the Science Commission, and the Society Committee on Education, among others. Many of these efforts have been reported in detail and the documents contain a large number of findings and recommendations. It is not surprising that these reports have much in common, and they are essentially unanimous when dealing with the delivery of educational services and the orientation and experience of educators. These documents reflect a good deal of creative discussion when they report findings and recommendations concerning the research function of universities and how present and likely future conditions point to desirable change.

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Educational Services

The reports of all ACS conferences and task forces published in the period 1980-1983 have observed that B.S. chemical engineers are more immediately useful to industry than are B.S. chemists; all have recommended that industry do a better job of informing colleges and universities of the kind of training they need entry-level scientists to have, and have urged that the academic community do something about these expressions of need - perhaps even to the point of accepting the stimulus of modified curriculum guidelines from the (ACS) Committee on Professional Training; and all have advised closer and continuing interaction between academic and industrial scientists, through devices such as:

- continuing education activities;
- faculty internships and sabbatical leaves to industrial laboratories;
- workshops (at industrial sites) for both students and faculty members;
- expansion of cooperative education;
- appointment of industrial chemists as adjunct professors; and
- establishment of advisory committees to chemistry departments with industrial as well as faculty members.

These mechanisms cover a broad spectrum, from the mounting of targeted educational efforts in response to specific industrial needs, through programs designed to improve student and faculty understanding of the industrial scene, to arrangements designed to increase industry influence on the way educational institutions do their work. None is novel in concept; all have been tried at colleges and universities from time to time and place to place; and the success achieved has usually reflected the similarity of the objectives as defined by provider and client and the availability of the required psychic energies and personal and fiscal resources.

Over time, industry has exhorted colleges and universities to employ these devices and sometimes has provided support for them. The picture is somewhat different in the areas of the curriculum and related student advising; there industry complains. The industrial complaint, which can be quite specific, is set forth in some of these same reports. There have been recommendations or findings, for example, that BS chemists should have at least some knowledge of <u>industrial chemistry</u>, <u>polymer chemistry</u>, <u>the patent system</u>, <u>economics</u>, and <u>the elements of chemical engineering</u>; and that colleges and universities should do a better job of guiding and counseling their students about the "exciting career possibilities in industry," and should "train and educate them properly" for industrial careers. (Since persons who earn doctorates in chemistry take B.S. degrees first, success in efforts like these would automatically increase the utility to industry of the entry-level research chemist as well.)

An academic surveying all these reports and noticing their agreement and the consistencies among their final pages might be pardoned for feeling a bit depressed. The same complaints are heard over and over again; people on both sides of the interface are sincerely worried and often give eloquent voice to their concerns; the parties don't seem to be listening to each other; incidents of progress and accommodation seem few and far between and thus the problems seem intractable.

The repair of the curriculum "deficiencies" noted above might shorten the period of in-house training that some companies offer-certainly some real understanding of polymer chemistry would be of immediate and direct benefit to a young person going to work for a company whose products included polymers and things made from them. But there are some other deficiencies that are no less real even if they are not so specific.

I lament the disappearance from the curriculum of almost every vestige of nontechnical content. We expect chemists to get along with their co-workers, but deny them contact with the social sciences; we expect them to have serviceable communications skills, but fail to provide them time for effective study of <u>any</u> language and literature - even their own; we hope for flexibility that will permit them to serve industry outside of the laboratory, but teach them nothing of economics, organizational behavior, or the world of commerce. Others feel that "the University environment (in itself) ought to expose students adequately to many aspects of the liberal arts without the need for spending valuable classroom hours on such subjects."

Industrial opinion, however, does not appear to be monolithic about maintaining such a concentration on chemistry, physics, and mathematics. A recent communication to the ACS Education Division from the ACS Committee on Corporation Associates remarked on the diversity of industrial career pathways actually followed by B.S. and Ph.D. chemists from the usual starting points of laboratory and research work and suggested that "Chemical educators would benefit their B.S. students more by helping [them] identify [a] related field of most interest [e.g. sales, safety, patents, business management] and best fitting their talents than by seeking how to adjust the B.S.-level chemical training to fit industry."

The reality of industrial preference for the skills of the B.S. chemical engineer over those of the average B.S. chemist is claimed to be reflected in salary trends in these related professions over the last decade and a half. It is well known that engineers and scientists have different personality profiles, and the divergence in their economic success is often attributed to the greater flexibility and more appropriate orientation of the former group. On the other hand, might it not be possible that industrial utilization of the increased production of Ph.D. chemists in the past 20 years (both relative to B.S. chemists and in absolute terms) has simply squeezed the B.S. chemist out of his former niche but not into another of similar effectiveness? Perhaps industry's needs at the baccalaureate level are for chemical engineering skills, the Ph.D. in chemistry having supplanted the B.S. (or even the M.S.) chemist. That would explain also the failure of industrial salaries for Ph.D. chemists to rise as rapidly as the overall science-engineering doctorate average.

Academics certainly should guide their students realistically from positions of knowledge and understanding of industrial opportunities and preferences, while giving heed to the chance that our problem is less the adequacy of training and more the insufficiency of education. But it ought to be the responsibility of others to provide counsel about the "exciting career possibilities in industry."

Research Relationships

Historically, universities have looked more often to industry for financial support of faculty research than for either information or cooperation in aid of scholarly investigations. As recently as 1980, one of the ACS task forces recorded the following no-nonsense remark on conditions at the interface: "The atmosphere for cooperative efforts may be improved if there is simply a demonstration of financial support from industry to academia on a continuing basis." That strikes a direct and practical note which, one hopes, was referring to mechanisms such as the recently established Chemical Research Fund and the widely known and utilized ACS Petroleum Research Fund.

The focus of that comment is cooperative efforts and most recent reports of task forces or study groups on relations between the industrial and academic communities have concentrated their attention on cooperative research activities; the more bold have recommended joint/collaborative research ventures and several spectacular examples of such new arrangements might be cited.

Industry may bewail some of the imperfections of the human product of academe, but it has always been interested in the parallel informational product, and never more so than right now. In fact, industry and business clearly have taken the initiative in proposing, perfecting, and, in some cases, implementing new kinds of partnerships with universities and their science faculties. The impetus for these developments comes in part from the long decline in Federal funding for basic investigations, and in substantial measure from industrial interest in the economic potential of discoveries in several rapidly surging areas of academic research.

As other contributors to this Symposium have detailed, the parties to each of these fledgling agreements has had to come to grips with the differences between academic and industrial practice in the design and conduct of research projects and in the disposition of the resulting information. Sometimes symmetry and mutuality are little reflected in the terms of the alliance.

Scientists regard the search for knowledge as an undertaking not simply meritorious but essential to the advancement and well-being of mankind. Like all of us, scientists draw much of their energy and direction from the approbation of others. Sometimes that approbation takes fiscal form. It is clear that the post-World War II expansion of Federal support for basic research in universities weakened the institutional loyalties of science faculties. This, in turn, led to an enormous increase in the strength of discipline driving of research and scholarship: faculty members look to their disciplinary fellows for the signals of recognition and acceptance that portend reward. Faculty are less concerned with service to university missions than they are about institutional service to disciplinary standards and objectives; the university is a place to create new knowledge as much or perhaps even more than it is a place to impart knowledge already gained. It is no wonder that concern for - or even awareness of - the needs of scientists in training for other-than-academic careers have received insufficient attention.

Curricula in colleges and universities reflect not only the state of knowledge in the discipline but the interests of the faculty. In turn, those interests, because of the nature of the academic value and reward systems, are influenced powerfully by disciplinary fashions. If industrial research needs happened to coincide with disciplinary fashions, this Symposium would likely never have been organized nor would there have been such repetitious scrutiny of the boundary between industrial and academic science or of the education of the practitioners. Indeed, some of the resurgence of attention to serious research collaboration between the two communities arises in today's coincidence of certain disciplinary fashions and industrial interests.

Academic and disciplinary value and reward systems depend heavily on free, open and rapid exchange and publication of ideas and research results. Whether we like it or not, exchange and publication are a principal nourishment of scientific progress and therefore of technical progress.

Although this fact is almost universally recognized, it is sometimes not easily honored. Academics have a difficult time accepting the notion that Nature Revealed ought to be kept under wraps, or made a trade secret, or otherwise treated in proprietary fashion. Industrial sponsors have a difficult time accepting the notion that findings of sponsored research ought to be broadcast, at least not until the good has been wrung out of them. After all, aren't such research findings the result of a procurement process -- bought and paid for?

This problem is a deterrent to the effectiveness of most personnel exchange relationships designed to improve university understanding of the needs of industry. It is also handled with great asymmetry: one is constantly reminded of the desirability of technology transfer from the academic world to the industrial, but nobody ever mentions technology transfer at the research level from industry to academe. Industrial visitors to campuses just don't talk about their recent work the way their faculty contacts talk about theirs.

This difference in approaches to the disposition of research results is usually resolved, in individual industry-university agreements, by faculty scientists accepting a "holding" or "cooling-off" period during which the industrial sponsor alone may examine the new findings and benefit from them. The length of this period is the subject of intense negotiation - one party anxious that it be as short as possible, the other needing it to be of sufficient length to permit action and to justify investment. Periods ranging from two months to two years characterize recently executed cooperative research pacts. Even if one allows for considerable duple individuality in the parties to such agreements, this wide range does not suggest that there is a common understanding of a serviceable balance between faculty and industry preferences in the disposition of new knowledge.

Perhaps we need to change the quality of communication between us about research in progress; perhaps we need to concentrate on kinds of research and ways of doing it that have some symmetry, some equality about them. If university and industry scientists could work together in ways that yielded benefits even-handedly, the present interface might no longer be a potential barrier.

A widely applicable and broadly successful resolution of our present difficulties is not likely to result from expansion of traditional exchanges of personnel - they tend to go in only one direction. And it probably will not be achieved through intensification of the usual applicant-sponsor type of cooperative research activity, for both of these modes of interaction lack the quality of <u>mutuality</u>.

A higher probability of success ought to attend arrangements characterized by high degrees of reciprocity and participation, possibly through academic and industrial scientists working together on the same research, in the same places, as the same times. This might involve the creation of laboratories devoted to investigations of mutual interest over a substantial period and from which each of the parties takes what he needs at appropriate times and with sensitive regard for the needs of his partner.

Industry sometimes treats academic research as the product of invention - something created in a moment of inspiration. I suspect that everyone really knows that research wherever it is done is a pretty slogging, drawn-out affair: lots of time is devoted to the careful exploration of blind alleys and the even more cautious checking and re-checking of data in hand. No one wants to publish work that is incomplete or unpolished; <u>but preliminary</u>

or partial results are often capable ot speedy and fruitful application. Let the professor partner complete and polish while the industrial scientist partner initiates application. Put another way, if academic and industrial project interests interpenetrate, so can the pursuit of investigations, and so can the two ultimate processes for dealing with results.

Such an approach would involve a lot of trust and mutual respect, and it might require some unusual flexibility on both sides of the house to avoid decay into the procurement mode; but, it is worth a try and the trial is being considered in many places and undertaken in a few. The implications for graduate education of this mode of cooperative research are straightforward and obvious. After all, the education of graduate students in science involves apprenticeship and those engaged in truly mutual university-industrial research could not fail to acquire both better understanding and greater skills for their future careers in industrial research.

In time, such collaborative endeavors would have the desired effects on undergraduate instruction as well - most professors teach at all levels during any period of a few years' length. It may not be possible to add that course in polymer chemistry to the curriculum, but the whole undergraduate experience could be infused with industrial example and other consciousness-raising elements. The resulting improvement in attitudes might be more important than the frequently urged repair of perceived deficiencies in the list of required courses.

Some universities and industrial laboratories are so close to each other geographically that there might develop in them at least a few individuals who were personally divalent. Geographic propinquity ought to make it possible for individuals who are able to work easily and simultaneously in industry and academe to develop in themselves the qualities achievable in the kind of research partnerships I have described earlier. If double agents are successful in espionage, why shouldn't the double scientist be a valuable bridge and channel of communication across the Industrial-Academic Interface?

Comments

Among the better publicized of recent industry-university collaboration models have been some in which a substantial fraction of a major department or of a school (i.e. a collection of departments) is set apart, becoming an operation staffed jointly by faculty members (who remain firmly in control of the program) and industrial scientists on assignment. These are interesting experiments, but I am not the only one who is wary of problems such as: conflicts of interest, maintenance of the free flow of information on which scientific progress depends, etc. To some degree, the conflict of interest problem may be self-correcting. If an academic scientist cannot keep separate his discipline-related and industry-related communications and values, his informal science communications networks will fall apart and his currency and effectiveness in the field will suffer rapid decline.

A useful alternative to this campus-plus-corporation pairing might be a variant of the arrangement developed over many years by Battelle and Mellon Institutes, where industry-established fellowships were held by Institute scientists who worked closely with industrial researchers on assignment or on leave. The variation would be that the "institute" scientists would be university faculty members. I admit that many universities would find it difficult to handle this kind of one-foot-in-each-camp status for a significant fraction of their faculty. But the arrangement should be viable if, over the early part of his/her academic career, the faculty member developed both a strong interest in research of significance to industry and parallel industrial familiarity and contacts. If this mode were well tended, a research group would have associated with it both the academic and industrial colleagues of the faculty members (i.e. both graduate students and corporate scientists).

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Perspectives for the 80s on Academic-Industrial Relationships

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In considering academic-industrial interaction, it is easy to vacillate between broad generalities and very specific details and proposals. A little of each is valuable. It is important to look at the broad question "what are we talking about?" One answer is "We are talking about organizations". After all, academic institutions are organizations, industrial firms are organizations. So there is a need to consider what purposes these organizations exist for and what their constraints and opportunities are.

Colleges and universities have developed over many, many years, clear back into the middle ages. They originally developed from a group of scholars coming together and both developing knowledge and passing that knowledge on to other people. Those basic purposes of the whole college-university-academic organization should be kept in mind. As time went on, particularly in the United States, considerable pragmatism came into the pattern. Originally most colleges were started to train ministers --- Princeton, for example --- because that was a very practical need at that time. Then another practical American frame of mind came more and more into the picture. This is typified by the fact that the University of Illinois was founded under the name of The Illinois Industrial University. It has risen to the top ranks of outstanding intellectual institutions, but it started with a practical flavor. So the whole concept of practical results coming out of the academic institution is not out of place. In fact, the opening statement in the University of Illinois catalog refers to its "...threefold mission of teaching, research, and public service."

It is often said that business organizations exist to make money. That is erroneous, or at least, misleading. Industrial organizations exist to make and sell products or services. From those activities they do intend to earn a profit, but the organization is structured for the make-and-sell role.

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Keeping clearly in mind these organizational structures and objectives is crucial in considering ways in which the organizations can interact.

In a 1982 speech to the N.Y. City Bar Association, E. E. Davis, President, Exxon Research & Engineering Co. former Presidential Science Advisor, discussed academic roles. "We cannot consider industry objectives in funding university research in isolation from industry objectives towards higher education in general. In order of importance, industry looks to higher education for: a steady supply of well-educated graduates; relevant basic science and scientists able to offer fresh insights; and, sometimes, technological ideas and leads. Graduates are by far the most important. Of the professionals that Exxon hires in a typical year, more than 70% are likely to hold degrees in engineering or science. Many hold advanced degrees. It is our acute awareness of the importance of these educated people to Exxon's future, that most animates our desire to be certain that higher education remains healthy. In 1982 Exxon will contribute nearly $30 million to higher education. In addition, we will spend over $4 million supporting research in universities. Even in supporting this research, our motives are strongly influenced by our interest in education, both on the undergraduate and graduate levels. Indeed, Exxon is probably not unlike the rest of industry in being at least as interested in promoting academic research as part of the educational process as in the results of that research."

Most industrial firms, if they carefully assess their objectives for the 80's, would agree that the first purpose of the higher educational institutions, from industry's viewpoint, is to turn out graduates which meet industrial needs. That leads us into the question of the extent to which the educational process should be geared to industry's needs, which may be viewed as somewhat limited, and perhaps, selfish. That legitimate question can be dealt with by consideration of institutional purposes; each school should define its objectives and come to its own answer as a consequence.

A quotation from TECHNOLOGY AS A COMPETITIVE WEAPON (Harvard Business Review, January-February, 1982) by Alan L. Frohman, a management consultant with a particular interest in how industry uses technology and brings new technology to the marketplace is germane. "No one doubts anymore that to be competitive with foreign companies, United States manufacturers need to increase their investment in R&D. Indeed, technology can be a powerful weapon on the battlefield of economic enterprise. But increasing R&D investments alone will not ensure that companies will successfully exploit technology as a competitive weapon .... What accounts for the difference between companies' experience? If it is not the amount of R&D investment alone, other factors must either inhibit or encourage the successful exploitation of technology .... Many aspects of an organization --- from technical talent to the reward system; from climate to equipment --- affect the payoff a company will receive from its investments in technology. In my experience, however, a company who can exploit technology well will have three conditions in common:

1. Top management orientation. The majority of the top managers responsible for running the company or business have technical education and work experience in their companies. They are comfortable with and fluent in technical topics.
2. Project selection criteria. Managers allocate funds among projects that will support and maintain their technological leadership in specified areas.
3. Systems and structures. The decision-making systems and structures of the company reinforce the priority given to technological matters in two ways:
   a. The company's systems provide a close connection between business and technological decision making, and
   b. The systems and structure for decision-making on technological matters are consistent with the company's other systems."

Using nine companies in evaluating how different companies handle application and development of new technology, he says, "Technology gives company number one the greatest competitive advantage over its competition and company nine the least." The tendency is to jump to a conclusion at that stage,--- company one is much more successful. But is it? In fact, he says "both one and nine are very respected on Wall Street, having shown strong sales and profit growth for a long time. While their strategies may be very different with respect to technology, each is effective in its particular markets and products. But, if company nine should decide to place more reliance on technology as a competitive weapon, in addition to examining the amount of resources directed toward technology, it would have to satisfy the three conditions that I have set. If it failed to meet those conditions, I predict that even with increased R&D investment, that company would reap a disappointing return."

The point here is two-fold and strongly related to the nature of academic-industrial interaction. Those companies which have decided to make technological innovation the basis of their competitive position are heavily dependent on a very broad supply of technically trained people. For example, eighty percent of all the college graduates that work for the DuPont Company have degrees in science or engineering. Even the top management people are almost entirely technically trained. Of the top 250 people in DuPont, 81% received technical college degrees. So, a technically innovative company is highly dependent on the educational function of those universities and colleges which choose to educate students in technical disciplines with at least some orientation towards industrial employment. The words "choose to" are used deliberately because each academic institution has every right, in fact every responsibility, to choose its role.

Another quotation is appropriate here. This is from a report by the chairman of the chemical engineering department of a major university to his advisory committee. "A large majority of our students, at all levels, will find their careers in industry, chiefly in the process industries, and that preparation for an industrial career will remain the major objective of our chemical engineering teaching program." The decision has been made, in that particular department, that the educational role will be primarily to prepare people for industry. Not every academic department should decide that, but, every academic institution should enunciate its educational objectives, departmentally and institutionally. This would greatly facilitate the definition of many useful academic-industrial interactions. For example, if a department expects a large proportion of its graduates to go into industry, industrial help in guiding the preparation of the educational plan should be useful. If that is not a significant objective, it is certainly completely valid for the educational institution to conclude that industrial recommendations are not particularly important. Interaction based on a clear understanding of institutional objectives is very important.

Now, some specifics fitting very clearly into the type of academic-industrial interaction appropriate where the academic institution has as one goal, maybe of several, the preparation of people for industrial careers. Co-op education is one of the very best forms of academic-industrial interaction at a level meaningful to students. Many interactions may be meaningful to the president or tc professors but do not get directly down to the students.

The American Chemical Society is playing a very effective role in promoting co-op education through its Office of Co-operative Education. Partly through the efforts of that office, there has been a substantial increase in the number of chemistry students doing co-op periods in industry. This kind of educational arrangement has long been common in the engineering world but has not been common in chemistry. It is one form of interaction which deserves to grow very markedly over the next few years.

Another specific mechanism for interaction could be the proposed Institute of Chemical Education at the University of Wisconsin. The staff there, led by Professor Shakashiri, are actively developing plans for such an institute. The ACS Division of Chemical Education, the Society Committee on Education, and the Board of Directors have endorsed the plan; seemingly its time has come. Industry should also support the concept of this institute; this is a logical focus for academic-industrial interaction. This kind of institute, common in the research area, would be a very real plus in developing new approaches in chemical education.

An example of a useful project for this institute comes out of an ACS workshop on "Cross-fertilization of Chemistry and Chemical Engineering Curricula." One of the conclusions was that some revisions in physical chemistry teaching could help chemistry and chemical engineering students better understand how thermodynamics, kinetics, and other fundamental topics of physical chemistry are used in industrial applications. A task force has been formed to initiate development of source materials for that purpose; an institute of chemical education could facilitate that activity greatly.

Another activity providing experience in the other world is the industrial sabbatical for chemistry professors. Numerous examples have demonstrated its effectiveness. It's not a new concept, but perhaps the time is ripe to markedly increase the number of professors and industries involved. And the reverse --- the industrial researcher spending a semester or year teaching --- can be equally useful.

Extension of the concept of temporary industrial employment to university placement people can likewise be valuable. Du Pont experience with summer jobs for placement directors involved with technical graduates has proven it mutually beneficial.

Industrial funding of academic activities is obviously a very important part of this discussion. Such funding can and should be aimed at both the teaching and research functions, though many different patterns can be used. One approach which Du Pont has found very successful is to direct its support to those fields of education which are directly related to our activities --- chemistry, physics, engineering, and now life sciences --- but otherwise, give the grant with essentially no strings attached. It goes to the head of the department in the chosen discipline within the academic institution to use in whatever way he or she feels will best support the departmental programs. This program includes gifts and grants to liberal arts colleges as well as departments in large universities. This relatively unrestricted pattern of giving has been much appreciated by the recipient institutions.

Another technique used by many companies, which certainly has some related characteristics, is the concept of matching employee contributions. That channels the funds to those schools that provide the people the industry has chosen to hire. So it does, again, get the funds back to those academic institutions which have met company needs, though it is less effective in steering the funds to a specific part of the school.

Support of the research end of the academic spectrum, as well as the teaching segment, is also extremely important. But, here, even more than in teaching, that need to emphasize very clearly the objectives of each organization becomes crucial.

As the Frohman study indicated, the industrial organization must have a clear picture of the use of new technology; blindly increasing money to research and development is no guarantee of industrial success. Therefore industry, interacting with the academic institutions, must give a clear picture of what is sought by involvement in university research activities. Conversely, it is equally important for the university to separate clearly the concept of fundamental research by a community of scholars from the concept of public service. Arguments about conflict of interest and possible exploitation come most frequently where clear-cut distinctions are not made between research aimed broadly at the increase of knowledge and providing an external service.

It is perfectly legitimate for a university to offer a service --- a service, in essence, of providing useful technical knowledge. The long and commendable history of university agricultural and engineering experiment stations exemplifies this. To the extent that a university enters into an agreement with another organization (whether industrial or governmental) which involves withholding publication, granting patent rights or sharing the directing of the research with the donor, it is providing an R&D service. There is nothing wrong with that if the university realistically relates that to the objectives of the institution. (An interesting comparison, not totally irrelevant, is the relationship of athletics to institutional goals.)

The same reasoning applies to other examples on a slightly smaller scale. A number of universities have established industrial associateships, which, quite frankly, are a nice way to raise a little money. A firm pays a fee and becomes an industrial associate; it then gets prior access to unpublished information and is invited to special seminars for the associates. Within limits, this is a legitimate service for the university to offer, but should be recognized as having at least some aspects of a service that is being sold.

Thus, on this question of funding research, there is a crucial need to be straightforward, realistic and very careful in evaluating the impact, short-term and long-term, of agreements involved. There is a great need for industry to provide funding directly, and to encourage government to provide funding, which does not involve the service element, but, instead, encourages the historic university function of development of new knowledge which will be generally disseminated. This basic research is vital to industry in particular, and society in general, if this country is to maintain its traditional place of world leadership. This kind of research cannot be planned and bought; instead it must be recognized and given non-restrictive support.

The proper roles of industry and academia are complementary --- with some overlap. Interactions which recognize this can be mutually very beneficial. Significant subversion of this natural relationship is doomed to being counter-productive to our nation's future well-being.

RECEIVED July 28, 1983

Appendix I. Council for Chemical Research

The Council for Chemical Research (CCR) is a nonprofit organization whose objectives are to (1) promote valuable cooperative activities between chemical industries and research universities, (2) work for continued health and vitality of chemical science, engineering, and technology in the United States, (3) support new, significant, and continuing sources of funding for research universities, and (4) ensure advanced education of the highest quality in the chemical sciences and engineering. The organization is represented by directors of industrial research laboratories and heads of departments of chemistry and chemical engineering in universities. The council is managed by a governing board of 18 members elected equally from industries and universities for three-year terms (one-third elected each year). Funding comes from membership dues and from a special Chemical Science and Engineering Fund (CSEF). Funds raised through CSEF are used to support university research in chemical science and engineering. To assist the implementation of CCR's programs the following committees have been established: (1) Scientific Advisory Board, (2) University-Industry Interaction Committee, (3) Scientific Manpower Committee, and (4) Government Relations Committee.

The following pages list the industry and university members of CCR. For additional information, write to the Executive Director, Council for Chemical Research, Post Office Box AJ, Allentown, Pennsylvania 18106.

NOTE: Information taken with permission from a pamphlet provided by the Council for Chemical Research, Post Office Box AJ, Allentown, PA 18106.

UNIVERSITIES

University of Akron
University of Alabama
American University
Arizona State University
University of Arizona
University of Arkansas
Atlanta University
Auburn University
Boston University
Brandeis University
Brown University
California Institute of Technology
University of California, Berkeley
University of California, Irvine
University of California, Los Angeles
University of California, Riverside
University of California, San Diego
Carnegie-Mellon University
Case Western Reserve University
Catholic University of America
University of Central Florida
Central Michigan University
University of Chicago
University of Cincinnati
City University of New York
Clark University
Clarkson College of Technology
Clemson University
Colorado State University
University of Colorado
Columbia University
University of Connecticut
Cornell University
Dartmouth College
University of Delaware
Drexel University
Duke University
Emory University
Florida State University
University of Florida
Georgetown University
Georgia Institute of Technology
University of Georgia
Harvard University
University of Houston
Howard University

University of Idaho
Illinois Institute of Technology
University of Illinois at Chicago Circle
University of Illinois at Urbana, Champaign
Iowa State University
University of Iowa
Johns Hopkins University
Kansas State University
University of Kansas
University of Kentucky
Lehigh University
Louisiana State University
University of Louisville
Loyola University of Chicago
University of Maine at Orono
Marquette University
University of Maryland
Massachusetts Institute of Technology
University of Massachusetts, Amherst
Memphis State University
University of Miami
Michigan State University
Michigan Technological University
University of Michigan
University of Minnesota
Mississippi State University
University of Mississippi
University of Missouri-Columbia
University of Missouri-Rolla
University of Missouri-St. Louis
Montana State University
University of Nebraska-Lincoln
University of Nevada
University of New Hampshire
New Mexico State University
University of New Mexico
University of New Orleans
New York University
North Carolina State University, Raleigh
North Carolina State University, School of Textile
University of North Carolina
North Dakota State University
University of North Dakota
Northeastern University
Northwestern University
University of Notre Dame
Ohio State University
Ohio University
Oklahoma State University

University of Oklahoma
Oregon State University
University of Oregon
Pennsylvania State University
University of Pennsylvania
University of Pittsburgh
Polytechnic Institute of New York
Princeton University
Purdue University
Queens College - CUNY
Rensselaer Polytechnic Institute
University of Rhode Island
Rice University
University of Rochester
Rockefeller University
Rutgers University
Seton Hall University
University of Southern California
University of Southern Mississippi
Stanford University
State University of New York at Buffalo
College of Staten Island
Syracuse University
University of Tennessee
Texas A&M University
Texas Tech University
University of Texas at Austin
University of Texas at Dallas
University of Toledo
Tufts University
Utah State University
University of Utah
Vanderbilt University
Villanova University
Virginia Commonwealth University
Virginia Polytechnic Inst. & State Univ.
University of Virginia
Washington State University
Washington University
University of Washington
Wayne State University
Wesleyan University
West Virginia University
University of Wisconsin-Madison
University of Wisconsin-Milwaukee
Worcester Polytechnic Institute
University of Wyoming
Yale University

COMPANIES

Air Products and Chemicals, Inc.
Allied Corporation
American Cyanamid Company
Amoco Chemicals Corporation
ARCO Chemical Company
Ashland Chemical Company
Borg-Warner Chemicals, Inc.
Celanese Research Company
Colgate-Palmolive Company
Diamond Shamrock Corporation
Dow Chemical Company
Dow Corning Corporation
E. I. du Pont de Nemours & Co., Inc.
Eastman Kodak Company
Exxon Corporation
FMC Corporation
General Electric Company
B. F. Goodrich Company
GTE Laboratories, Inc.
Gulf Oil Chemicals Company
Inmont Corporation
Johnson & Johnson
Liquid Air Corporation
Lubrizol Corporation
Mobay Chemical Corporation
Mobil Oil Corporation
Monsanto Company
Nalco Chemical Company
Pennzoil Products Company
Pfizer, Inc.
PPG Industries, Inc.
Procter & Gamble Company
Rohm & Haas Company
Shell Development Company
Smith Kline Beckman Company
Standard Oil Company of Ohio
Stauffer Chemical Company
Suntech, Inc.
3M Central Research Laboratories
Travenol Laboratories, Inc.
UOP, Inc.
Westinghouse Research & Development Center
Xerox Corporation

RECEIVED November 7, 1983

Appendix II. Inventory of University-Industry Research Support Agreements in Biomedical Science and Technology

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Procedures. The following is an inventory of large and longer-term research support agreements between universities and industry in the area of biomedical science and technology. It was compiled from publicly available secondary sources and, as such, may be subject to certain inaccuracies inherent in this type of source material. It is intended to provide an overview of the wide diversity of such relationships. The richness of the available material is extremely variable; thus, not all such instances are described here in equal detail. Further search, through direct telephone contacts and through a scan of the new biotechnology newsletters issued by 1982, indicates that this inventory is in fact a comprehensive one at this writing. The search also indicated that many further agreements are being contemplated and are in varying stages of discussion; for instance the University of Michigan is reportedly planning a new molecular biology institute, and many other universities, such as Johns Hopkins Medical School, are reportedly considering a variety of cooperative research arrangements.

Some Issues Frequently Raised (1). Much of the available literature about these university-industry arrangements deals with the controversies and conflicts which have been raised by the issues involved. Although a discussion of these issues is beyond the scope of the inventory presented here, it would seem useful at least to touch on a few of these points. For instance, with regard to the many new biotechnology companies which have recently been formed, it was pointed out that quite a few have principals who also serve on another company's board or whose primary employment is with a university. Concerns have been expressed regarding conflicts of interest, complications on safety fronts, patent and royalty areas, and communications. Some scientists fear that biologists will become reluctant to publish their findings once the profit motive is at work. Further, it was noted that the majority

UNIVERSITY AND INDUSTRY NAMED	TIME FRAME AND DOLLAR AMOUNTS	TYPE OF AGREEMENT	RESEARCH FOCUS	PROJECT SELECTION
Harvard University--Monsanto Medical School	12 years--$23 million	Endowment and research support Research materials	"Biology and Biochemistry of Organ Development" TAF	N/A
Mass. General Hospital--Hoechst, A.G. (Harvard Medical School)	10 years--$50 million (accompanied by private gift of $15 million for construction of molecular biology lab facility)	Grant (creation of Genetic Engineering Department)	Genetic Engineering Molecular Biology--insulin, growth hormone, Interferon.	"Goodman has right to reject plans and pursue other funding of suggested proposals for Hoechst's approval"
Harvard Medical School--Dupont	5 years--$6 million	Grant	Molecular Genetic Research--Dupont is interested in Interferon.	Du Pont states it is "not setting research goals" for Dr. Leder.
MIT--Whitehead Foundation	$7.5 million initially--Biology Dept. funding and admin. costs $20 million to build Whitehead Inst. for Biomedical Research $60 million trust, will supply $5 million annually for operating expenses	Creation of Biomedical Research Complex	Developmental/Molecular Biology	N/A (possibly determined by governing board of institute)
MIT--Flow Laboratories	$400,000 per year	Royalty payments (for use of MIT patent (half of amount will go to MIT Dept. of Nutrition and Food Science)	Cell Culture Technique Micro-carriers--for production of Interferon	N/A
Washington University--Mallinckrodt, Inc.	3 years--$3.9 million	N/A	Genetic Research focusing on "Hybridoms" technology Monoclonal antibodies	N/A
Stanford--UC-Berkeley-6 corporations Bendix Corp. General Foods Elf Technologies (Elf Aquitaine) Koppers Corp. Maclaren Power & Paper Co. (Moranda) Head Corp.	4 years--$20 million ($2 million of this to be split between the universities over 4 years, to support basic research). Capital appreciation or stock dividends generated by Engenics will be plowed back into Stanford's Dept. of Medical Microbiology and the Chemical Engineering Depts. of both schools.	Creation of nonprofit foundation to support academic research in genetic engineering (Center for Biotechnology Research). Creation of Engenics, a for-profit arm of that foundation that will concentrate on development of commercial biotechnology processes. Stanford has a "Sponsored Research Contract" with Center for Biotechnology Research.	Genetic Engineering--"Development of continuous fermentation processes and equipment designed to boost production and lower costs of systems employing genetically engineered organisms."	N/A
University of California-Davis--Allied Chemical Corp.	5 years--$2.5 million	Grant	Using recombinant DNA techniques to attempt to confer nitrogen fixation capabilities on plants that do not naturally possess that ability.	N/A
Stanford--UC/San Francisco-multiple corporations (e.g., Eli Lilly & Co., Schering Plough, Smith Kline Corp., Du Pont Co.)	Initial fee of $10,000; annual fee of $10,000; royalty rate: 1% on net sales of products up to $5 million; 0.5% on sales above $10 million annually	Patents Licensing Agreement (on patent granted to Stanford and UCSF in Dec. 1980, for techniques invented by Stanley Cohen of Stanford & Herbert Boyer of UCSF).	Basic gene splicing and cloning.	N/A (all commercial signers must agree to abide by all current NIH rules for recombinant DNA technology).
Salk Institute--Phillips Petroleum	$10 million	Purchase of 37% equity interest in for-profit, previously wholly owned subsidiary of Salk Institute, now called Salk Institute Biotechnology/Industrial Assoc., Inc.	Genetic Engineering; attempt to commercialize applications of recombinant DNA and other genetic engineering methods.	N/A
Scripps Clinic & Research Foundation--Johnson & Johnson	Undisclosed sum (estimated to be $30 million)	N/A ("joint venture"); ("additional funding source") Will include funds for a new research building.	Production of synthetic vaccines.	N/A
Scripps Clinic & Research Foundation--Eli Lilly & Co.	N/A	N/A	N/A	N/A
Batelle Memorial Institute, Weizmann Institute, Baxter Laboratories--multiple investors & corporations (e.g., Allied Chemical, Johnson & Johnson)	$40 million (project abandoned)	Creation of DNA science "Would function like a holding company"--small subsidiary companies established near major universities. "Scientist would have an equity interest in company and be a consultant to it, but would remain on campus."	Producing and testing genetically engineered interferon monoclonal antibodies; production and testing of hormonal proteins, including human growth hormone.	N/A

PATENTS	PUBLICATIONS	LEVEL OF FACULTY/STUDENT/ COMPANY SCIENTIST INVOLVEMENT	CONTACT PERSON OR PROJECT DIRECTOR
Harvard owns one patent Monsanto has exclusive rights to products or research processes	No restrictions	N/A	Monte C. Thordahl, president, Monsanto Henry C. Meadow, assoc. dean, Harvard
Harvard retains patent, Hoechst has exclusive licenses for their use	Researchers can publish freely after a 30-day review by Hoechst	Hoechst can send up to 4 scientists per year to work and train at Mass. General	Martin Bander, spokesman, Mass. General Howard Goodman, project director
University owns patents; Du Pont will have exclusive use through licensing arrangement.	"No provisions in the grant that will in any way control, inhibit, or restrict the conduct of the research or publication of the results" (Du Pont).	N/A	Philip Leder, project director William G. Simeral, senior v. p., Du Pont
Institute retains control of any patents; will split with MIT any revenues derived from patents it is issued.	N/A	Institute will hire about 20 new scientists, who will also be professors with full academic status at MIT. The two institutions share power to appoint professors and their students, although MIT has only minority representation on board that appoints researchers.	David Baltimore, Institute director
MIT will keep all patent rights to any finding made as a result of such funding.	N/A	N/A	N/A
University will hold title to any resulting patents; Mallinckrodt will have option for exclusive use of University patents.	No restrictions.	Agreement involves scientists from the Departments of Pathology and Internal Medicine.	N/A
N/A	N/A	N/A (2 faculty members from Stanford and one from Berkeley are associated with Engenics).	Franklin A. Lindsay president, Engenics Gerald A. Lieberman, dean of graduate studies and research, Stanford
N/A	N/A	Dean of College of Agriculture and Environment prevented Valentine from receiving funds from grant because Allied Corp. had purchased a 20% interest in Valentine's biotechnology firm, Calgene.	Raymond Valentine, plant geneticist Charles Hess, dean, College of Agriculture and Environment, UC-Davis
Nonexclusive license available to any commercial user of the process.	N/A	N/A	Andrew Barnes, Stanford Univ. Office of Technology
N/A	N/A	N/A	William C. Douce, president and CEO of Phillips Fredric De Hoffman, president, Salk Institute
N/A	N/A	N/A	Robert J. Erra, Scripps v. p., finance
N/A	N/A	N/A	N/A
Allied was promised certain rights to industrial applications of DNA science's products or processes; Johnson & Johnson was granted similar rights to the company's pharmaceutical work.	N/A	N/A	Nelson E. Schneider, analyst, E. F. Hutton

of these agreements were formulated quite recently--i.e., within the past few years and months--and that the speed with which many of the new ventures were enacted precluded any systematic appraisal of their overall worth. University administrators and faculty members are attempting to settle difficult issues that are seriously dividing members of the academic community. Some argue that many of the most important freedoms and fundamental values of the academic life are at risk; others feel that the trend is natural and is valuable to the universities and to society as well as to those who will profit directly. In December 1980, Harvard discarded its plans for directly investing in a biotechnology enterprise that was to involve a Harvard faculty member, after the issue had provoked a heated controversy. However, this criticism has tended to obscure the fact that dozens of other slightly less bold plans are already being implemented in academia, including at Harvard. Many new companies have been formed at universities such as Stanford, whose administrators were among the most vocal critics of Harvard. Critics of these activities are afraid that the integrity of the universities may be compromised or ruined by the blurring of traditional boundaries between universities and industry. There is concern that the increased movement of faculty members into commercial ventures will stifle the free flow of information and will lead to neglect and abuse of graduate students and postdoctoral fellows, possibly even changing the direction and quality of university research. There are fears that industrial firms may gain decision-making power over what goes on at universities, and that the public may lose out if university scientists become too tightly embroiled with their private sector interests, and no longer can play the vital role of being neutral consultants on important scientific policy issues.

Corporate Grants to Universities

Harvard University-Monsanto Company (2). In 1974, Harvard University and the Monsanto Chemical Company of St. Louis entered into an agreement which states that over a period of 12 years, Monsanto will give Harvard Medical School $23 million in research support and endowment money. In return, Harvard gave Monsanto patent rights to any findings of research on a controversial biological substance called TAF (tumor angiogenesis factor), which is reputed to regulate the growth of blood vessels and consequently the development of cancers that need a supply of fresh blood in order to grow. Neither party revealed the terms of the agreement in full.

In January 1977, Monsanto issued a press release announcing the formation of a five-man advisory committee "concerned with the public interest," which is charged with seeing that both sides honor their contractual promises to protect academic freedom--i.e., the right to publish--and to develop any products that may emerge in a manner consistent with the public good. The latter means that, for example, if TAF research leads to a cure for something, the company will not sell it at an unduly inflated price. The press release describes the research only as a project which "deals with the biology and biochemistry of organ development."

Spokesmen for the joint undertaking are Monte C. Throdahl, president of Monsanto, and associate dean Heary C. Meadow of Harvard Medical School. The principal researchers are M. Judah Folkman, surgeon-in-chief of Harvard's Children's Hospital Medical Center, and Bert L. Vallee of Harvard's Peter Bent Bingham Hospital, an enzyme biochemist.

Monsanto agreed to permit the researchers to publish whatever they wish as soon as they wish. As a result of a change in Harvard's patent policy, Monsanto secured patent rights to products or research processes which might emerge. Harvard's new patent policy places a real obligation on the scientist to let the university know if the research is leading to a patentable product. Further, in keeping with its commitment to the "public good," Harvard sought and was granted assurances from Monsanto that if there was anything to develop, the company would do so quickly and economically.

The agreement provides that Folkman and Vallee each get a research sum of about $200,000 a year, guaranteed for the years remaining in the contract; that amount is likely to rise to accommodate inflation as well as anticipated progress. Further, Harvard received an undisclosed sum, estimated to be at least $12 million in endowment money, to be used initially to support persons affiliated with the Folkman-Vallee research but ultimately to be used as general funds with no stipulations. Monsanto is also equipping one floor of Harvard laboratories at a cost of $1.4 million; much of the rest can be accounted for by the materials which Monsanto is supplying for the research.

In establishing a joint program, Monsanto made it clear that it wanted two things: first it is seeking patentable inventions, such as "a piece of the action on TAF" (the agreement includes a provision that, in the event that either Folkman or Vallee leave or die, Harvard must provide some investigator, acceptable to Monsanto, to take over); and second, Monsanto was motivated by a desire to gain access to Harvard's capabilities in biological research, an area in which Monsanto sought to increase its inhouse capabilities.

Massachusetts General Hospital-Hoechst Chemical (3). In May 1981, the Hoechst Chemical Company of West Germany announced that it would give Massachusetts General Hospital, a teaching affiliate of Harvard University, a ten-year, $50 million grant to establish a department of genetic engineering. The research program will be housed in a new molecular biology laboratory facility to be built through a separate $15 million gift from an American donor, Arthur and Gullan Wellman of Florida. The laboratory, which will be run jointly by Mass General and Harvard Medical School will be affiliated with the medical school's Department of Genetics and is expected to employ about 100 people.

The research effort will be headed by Howard Goodman, a molecular biologist from the University of California, San Francisco. He has worked on the genetic mechanisms which produce insulin, a human growth hormone; at Mass General, he will continue that work and will also apply the new genetics to plant research. Hoechst is presently researching Xanthan gum and single cell protein food; the Mass General research is expected to accelerate that work and improve any insulin or growth hormone projects under way using recombinant DNA technology as well as working on interferon.

Under the agreement, the corporation will not control or keep confidential the research in the new department. Mass General (Harvard) will retain any patents generated by the research, but will grant Hoechst exclusive licenses for their use. Hoechst can send up to four scientists per year to participate in the work and to train at the hospital.

Goodman has the right to reject project plans and pursue other funding for his work or suggest proposals for Hoechst's approval; the hospital will have full control over all research done under the Hoechst grant. The contract also allows researchers to publish their Hoechst-funded research freely after a thirty-day review by the company. Hospital authorities believe that the terms of the agreement ensure full academic freedom for their researchers and are quoted as saying that "our investigators will choose their own research projects, are open to collaboration with others, will write their own scientific articles, select the journals for publication and the meetings for presentation, and decide when to submit articles to journals."

Harvard University-DuPont Company (4). In September 1981, DuPont Chemical Company announced that it will give Harvard Medical School a $6 million grant to support molecular genetic research. The research will be done by the medical school's new Genetics Department, which is headed by Dr. Philip Leder.

The grant will cover a period of five years with an initial $2 million payment followed by annual $1 million payments through 1985. There are no provisions in the grant that will in any way control, inhibit, or restrict the conduct of the research or the publication of the results, according to DuPont.

Patents resulting from the research will be owned by the university; however, DuPont will receive exclusive rights to their use through licensing arrangements.

Research supported by the grant will "provide access to new basic information and will supplement genetics research already under way at DuPont." The company has been interested in the application of molecular genetics to the production of human interferon. DuPont states that it is not setting research goals for Leder, but instead is interested in contributing to basic research in the molecular genetics field, with the opportunity to draw on the results.

MIT-Whitehead Foundation (5). In December 1981, the Massachusetts Institute of Technology announced plans to accept an offer from the Whitehead Foundation of New York to build and staff a multimillion dollar biomedical research complex focused on developmental/molecular biology.

An initial $7.5 million will be used for biology department funding and to help defray administration costs; another $20 million will be provided to build the Whitehead Institute of Biomedical Research near Cambridge, Massachusetts. The institute will function under a $60 million trust that will supply $5 million annually for operating expenses; at or before Whitehead's death, the institute will receive $100 million, less funds already laid out from the trust.

The institute will retain control of any patents growing out of its research and will split with MIT any revenues derived from patents it is issued.

MIT microbiology professor David Baltimore will serve as the institute's director while continuing as a professor at MIT.

The institute would hire about 20 scientists, who would also be professors with full academic status at MIT. The professors would be under fully equal jurisdiction of MIT and Whitehead, and the two institutions would share the power to screen and appoint about 20 new professors, who will have the dual status, and their students. There is some concern among faculty that MIT would be losing control over faculty appointments, graduate students, and the direction of some research and that the institute's governing board might exercise undue control over the choice of scientists to become MIT faculty members. MIT will have only minority representation on the board that appoints researchers for the institute.

Harvard Medical School-Joseph Seagram and Sons (6). In April 1981, Joseph Seagram and Sons, through the Samuel Bronfman Foundation, made one of the largest single basic research grants ever made by private industry. The grant, nearly $6 million, was awarded to the Harvard Medical School primarily because of the work of Bert Vallie concerning an enzyme called ADH. This enzyme breaks down ethanol, or beverage alcohol. The grant was designated for "fundamental biological, genetic, and chemical studies of alcohol metabolism, alcoholism, and other alcohol-related human problems."

University of Maryland-DuPont Company (7). In April 1981, it was reported that DuPont Chemical Chemical Company had made a $500,000 grant to the University of Maryland (Baltimore County) for a joint effort to produce interferon. This two-year collaborative research project will be headed by Dr. Paul S. Lovett, and the agreement provides for continuing the project beyond the initial two-year period if the results of Lovett's work are promising.

Cal Tech-DuPont Company (8). In July 1981, it was reported that DuPont had made a grant of $150,000 to Cal Tech to study the sequencing of interferon.

Cornell University-Proctor and Gamble (9). In July 1981, an award of $119,946 was reportedly made by Proctor and Gamble to Cornell University. The grant was made to biochemist John T. Lis for study in the determination of how genes in animal cells are regulated.

Other Agreements Involving Universities

Washington University-Mallinckrodt, Inc. (10). In September 1981, Washington University in St. Louis and Mallinckrodt, Inc., a chemical manufacturer and medical supply company, announced the signing of a three-year, $3.9 million agreement for genetic research, focusing on "hybridoma" technology. The agreement involves scientists from the departments of pathology and internal medicine at Washington University, who will work to develop monoclonal antibodies that will be useful in such areas as immunology, malignancies, blood clotting, heart disease, and infectious diseases.

The agreement provides for the university to hold title to any resulting patents, and for Mallinckrodt, Inc. to have an option for exclusive use of the university's patents.

Washington University scientists will be free to publish their findings in scientific publications and to exchange new call lines and antibodies with their peers.

MIT-Flow Laboratories/Flow General, Inc. (11). In May 1981, the Massachusetts Institute of Technology entered an exclusive agreement with a Virginia biotechnology company, Flow General, Inc., to develop and market a pattented method of mass producing human and other animal cells. The method, which may provide a less expensive way of producing large amounts of human interferon, involves the use of microcarriers.

The patented cell culture technique utilizing microcarriers was developed at MIT's Cell Culture Center and has been licensed provisionally to Flow General, Inc. since 1977. Under the new agreement, Flow General will pay $400,000 a year to MIT in royalties. Half of this amount will go to the Department of Nutrition and Food Science at MIT.

MIT will keep all patent rights to any finding made as a result of such funding.

Stanford University-University of California at Berkeley-Engenics (12). In September 1981, six diverse firms announced that they are channeling $10 million over four years into a nonprofit foundation to support academic research in genetic engineering and into the creation of Engenics, Inc., a for-profit arm of that foundation, which will concentrate on development of commercial biotechnology processes.

The six corporations contributed the start-up funding in exchange for equal portions of a 35% equity stake in Engenics. The firms are: Bendix Corporation, General Foods, Elf Technologies, Koppers Corporation, Maclaren Power and Paper Company (Noranda), and Mead Corporation.

Engenics received $7.5 million from the corporations and a pledge of mutual cooperation with two universities, Stanford and the University of California at Berkeley, which will share in any of Engenics financial successes. Two faculty members from Stanford and one from Berkeley are associated with Engenics.

Stanford's relationship with the center is described as a sponsored research contract.

Neither of the universities will be a direct participant in the nonprofit Center for Biotechnology Research or in Engenics. Of the $10 million, $2 million will be split between the two universities over four years to support basic research.

The Center for Biotechnology Research holds a 30% interest in Engenics and will use profits from that interest to support university research, although not necessarily at Berkeley or at Stanford. Any capital appreciation or stock dividends generated by Engenics will be plowed back into Stanford's Department of Medical Microbiology and the chemical engineering departments of both schools.

Engenics will be engaged principally in development of continuous fermentation processes and equipment designed to boost production and lower costs of systems employing genetically engineered organisms.

The company will be headed by Franklin A. Lindsay, former chairman of Itek Corporation.

University of California at Davis-Allied Chemical Corporation (13). In September 1981, it was reported that Charles Hess, Dean of the College of Agriculture and Environment at the University of California at Davis, had blocked plant geneticist Dr. Raymond Valentine from receiving funds from a five-year, $2.5 million grant from Allied Corporation. Valentine is a professor at UC-Davis who works in the plant growth laboratory. He is involved in researching using recombinant DNA techniques to attempt to confer nitrogen fixation capabilities on plants which do not naturally possess that ability. Valentine is also a founder and a vice president of Calgene, Inc., which is a company founded in 1980 to capitalize on biotechnology.

According to a UC-Davis spokesman, Valentine attracted the grant from Allied in Summer 1981. The grant is being used to fund a number of researchers including Valentine. The dean's action in preventing Valentine from using part of the grant was apparently precipitated by Allied's recent purchase of a 20% interest in Valentine's firm. This was evidently more than the university officials could accept, and the dean called on Valentine to choose between the university and his firm.

Stanford University-University of California at San Francisco-Patents Licensing Agreement (14). In August 1981, it was announced that Stanford University and the University of California at San Francisco were offering an unusually broad arrangement for licensing a patent that covers basic gene splicing and cloning. The patent was granted to the two universities in December 1980 for techniques invented by Stanley N. Cohen of Stanford and Herbert W. Boyer of the University of California at San Francisco.

The nonexclusive license is available to any commercial user of the process for an initial fee of $10,000 plus an annual fee of $10,000. The royalty rate will be one percent on net sales of products up to $5 million and 0.50 percent on sales above $10 million annually. Annual revenues which Stanford estimates could reach $1 million in four or five years "will help to fund the basic research enterprise."

Fifteen percent will go to Stanford for the cost of administering the license through its office of technology; the rest will be divided between Stanford and UCSF. Then one third of Stanford's share will go to its medical school for basic research, a third will be shared by that school's departments of medicine and genetics, and the final third (ordinarily Cohen's by Stanford's policy) has been assigned by him for further research and support of his postdoctoral fellows.

To attract licensees, the universities have used tactics "uncommonly aggressive for the academic world." They have sent information packets and made telephone calls to U.S. companies, dispatched representatives to Europe and Japan, and advertised in business and scientific publications such as the Wall Street Journal, Science, Nature, and Genetic Engineering News.

More than a dozen companies had signed up as of December 1981. They include: Eli Lilly and Company, Schering-Plough, Smith-Kline Corporation, DuPont Company, International Minerals and Chemical, Advanced Genetic Sciences, and Japan's Green Cross. Several dozen more companies are expected to sign up in the near future.

According to Stanford, all commercial signers must agree to abide by all current NIH safety rules for recombinant DNA technology.

Ohio University-Genetic Engineering, Inc. (15). The first successful transfer of a gene from one animal species to another--from rabbits to mice and then to their offspring--was announced by biologists in September 1981. The technique could be used either to transfer a gene from a different species to create genetically unique animals, or to transfer some desired trait within the same species. The effort was headed by biologist Thomas E. Wagner of Ohio University. He and his co-workers performed their experiments in part at the university in Athens, Ohio, and partly in collaboration with the Jackson Laboratory in Bar Harbor, Maine. Ohio University has reportedly signed an exclusive licensing agreement with Genetic Engineering, Inc. to work toward uses in animal breeding.

University Genetics (Ugen) (16). A new type of biotechnology company emerged in 1980. The firm, University Genetics of Connecticut, is a unique company that seeks to make a profit while solving the dilemma of university researchers who are reluctant to forsake the laboratory for the board room.

University Genetics, known as Ugen, is a private company owned by University Patents. This parent company has an established business in patenting technologies or inventions which have been developed by researchers at universities and then licensing commercial exploitation by third parties. The idea of a technology transfer company specializing in genetic engineering emerged as more academics disclosed genetic engineering technologies or products that they thought were worth commercializing. Ugen began in October 1980, and as of mid-1981 it had raised $30 million in capital.

A university researcher may offer a proposal to Ugen; Ugen's team of scientists would then assess the proposal. If it looks promising, Ugen acquires the patent rights and licenses a third party to market it. According to Alan Walton, president and co-founder of the firm, Ugen would take "maybe 60%" of the profits, and the researcher would split the rest with his university. Walton states that Ugen's uniqueness lies with its readiness to provide a scientist with working funds for genetic engineering or related research or even an advance on royalties at the stage when backing is usually hardest to obtain, i.e., before his technology "rises to the surface."

Ugen has already brokered a one-to-one "prelicensing" deal in which the West German pharmaceutical company Hoechst, A.G., has forwarded several hundred thousand dollars to a university researcher working on the synthesis of a lymphoblastoid interferon gene. Further, Ugen has acquired the first rights to license the so-called "gene machine" developed by Dr. Marvin Caruthers of the University of Colorado. The machine can synthesize the genetic codes to produce any one of several desired substances. Other proposals include technologies for producing animal and human vaccines, and monoclonal antibodies for synthesizing alpha-beta amylase.

The government paved the way for Ugen with a new law standardizing the transfer of new technology developed at taxpayers' expense. In the past, each federal funding agency ran its own patent and licensing shop; for example, at NIH the policy has been that if any federal dollars helped pay for research, the patent rights remained with the institutes. The new Dole-Bayh bill, passed in 1980, however, gives universities the first crack at acquiring the rights to technology developed at their laboratories, thus opening the door for such organizations as Ugen by giving them a freer hand in making deals. According to its backers, part of Ugen's appeal also comes from its ability to provide a buffer between laboratory researchers and the world of business. Rather than taking the senior scientist away from the university, as some ordinary biotechnology companies would, Ugen theoretically leaves the scientist to his laboratory and the marketplace to the businessman.

Agreements Between Nonprofit Institutions and Industry

The Salk Institute-Phillips Petroleum (17). The Salk Institute, a prestigious nonprofit medical research organization in La Jolla, California, recently formed a for-profit, wholly owned subsidiary company, the Salk Institute Biotechnology Corporation. In June 1981, it was announced that Phillips Petroleum had bought a $10 million, 37% equity interest in the company; the name will be changed to Salk Institute Biotechnology/Industrial Associates, Inc. The company will begin operations in La Jolla, at a location separate from the Salk Institute.

According to a Phillips spokesman, the joint venture will attempt to commercialize applications of recombinant DNA and other genetic engineering methods to enhance oil recovery and other processes used in oil and gas production, agriculture, manufacture of chemicals, and the company's other businesses.

Phillips stated that Salk Institute would retain "majority ownership in the concern and that the new company is "engaged in discussions" with other U.S. and international companies to "broaden its industrial base." Other corporations are also expected to acquire interests in the Salk venture.

Salk Institute Biotechnology/Industrial Associates will have its own staff and be a fully taxable corporation. Fredric de Hoffman, president and chief executive officer of the Salk Institute will also be chairman and chief executive for the new corporation. Charles Cook, vice president for research and development at Phillips, will be vice chairman of the new concern.

A joint team of researchers from the Salk Institute and the University of California at San Diego published findings last fall about a potentially lucrative new method for producing synthetic vaccines. They are engaged in a dispute with another team from the Scripps Clinic and Research Foundation, also of La Jolla, which also published an article describing the new method and was the first to file a patent application.

For years, the Salk Institute survived on federal funds and

March of Dimes contributions; about 60% of its annual budget of $20 million comes from the federal government. But the advent of federal budget cuts has forced nonprofit institutes like Salk to search for alternative financing. Further, the independent non-profit groups are concerned that universities will get a greater share of scarce research dollars, since besides doing research, universities train the next generation of scientists, a factor that could sway federal agencies looking for the maximum benefit from research spending. Salk officials hope that profits from the biotechnology subsidiary will endow its pure research and ensure the institute's future.

Scripps Clinic and Research Foundation-Johnson and Johnson (18). In August 1981, it became known that the medical supply company Johnson and Johnson would enter into a joint venture with the Scripps Clinic and Research Foundation in La Jolla, California to produce synthetic vaccines. The company will pay Scripps an undisclosed sum, said to be $20 million, which will include funds for a new research building.

Scripps would seem particularly vulnerable to cutbacks because 90% of its money comes from the federal government. Robert T. Erra, Scripps vice president for finance, states that "federal expenditures for basic research are leveling off and (apparently) will decrease somewhat. (Scripps is) going to have to continue to develop alternative sources (of funding)."

Scripps is engaged in a dispute with a team of researchers from the University of California at San Diego and the Salk Institute, who have also applied for a patent for a new research method. The controversy centers around the development of the synthetic vaccine method as a research tool. The method is in essence a way of identifying proteins immunologically by chemically synthesizing their antigenic sites; the synthetic antigen can then be used to stimulate antibodies against the protein or virus from which it comes.

DNA Science-E. F. Hutton-Weizman Institute-Battelle Memorial Institute-Baxter Laboratories (19). In February 1981, E. F. Hutton announced the founding of a $40 million biotechnology company, DNA Science, with branches in Israel, Ohio, and California. Hutton planned to raise money from established investment institutions to finance a range of university-based research projects through the new company. The complex financial arrangement was dismantled--some corporate investors wanted proprietary rights to DNA Science's products and later E. F. Hutton withdrew its support--and the money was returned to the company's investors in August 1981. E. F. Hutton is reportedly restructuring DNA Science, turning it into a vehicle for channeling tax sheltered investments into biotechnology.

The basic idea of DNA Science was that it would function like a holding company; its business would be conducted mainly by small subsidiary companies established near major universities to accommodate specific scientists. These subsidiary companies would commercialize products which stemmed from a scientist's basic research; the scientist would have an equity interest in the company and would be a consultant to it, but would remain on campus.

The company which was to have been linked to the Weizman Institute, named Taglit, was to work on producing and testing genetically engineered interferon, as well as monoclonal antibodies. A joint venture with the Battelle Memorial Institute in Ohio was planned, as well as an arrangement under which DNA Science would set up a facility called Baxter Laboratories with endocrinologist John Baxter of the University of California at San Francisco. The initial focus of Baxter Laboratories would have been the production and testing of hormonal proteins, including human growth hormone.

Initially, DNA Science had hoped to raise the $40 million which it needed by July 28 from sources such as investment banks and pension plans, rather than from corporations that might want to exploit the company's products themselves. In the end, however, DNA Science was forced to turn to these sources.

Hutton itself was prepared to invest $8 million; between $20 and $30 million were raised from investors outside the chemical and pharmaceutical industries and corporations such as Allied Chemical and Johnson and Johnson would have accounted for the remainder. Allied was promised certain rights to industrial applications of DNA Science's products or processes; Johnson and Johnson was granted similar rights to the company's pharmaceutical work. Such an arrangement would have meant that the corporate investors stood to gain more than their stake in the company than other investors.

For a variety of reasons, the board of directors of DNA Science (which is dominated by Hutton executives) failed to agree on the financial arrangements by the closing date. Whatever the problems encountered in raising capital for the original company, Hutton believes that the new tax law should make it easier to raise cash for a different kind of operation. Hutton's tax specialists have found a way to structure the company to take advantage of the 25% tax credit for incremental investment in research and development. Officials of DNA Science state that the revamped company will essentially be financed by a collection of limited partnerships, and would work with individual scientists in much the same way as the original company was supposed to function. Funds raised by each partnership would support specific projects, analagous to existing tax shelter plans for oil and gas well drilling.

Faculty-Industry Relationships

An important aspect of the university-industry relationship is faculty participation in the management of commercial ventures. While not within the mandate of this inventory, a few cases are briefly described here to convey a sense of the issues involved. Included are several cases which could be described as "spinoff" companies.

Kansas University-Merck Corporation (20). In August 1980, a merger was announced between INTER-X, a drug research company, and Merck and Company, a multinational pharmaceutical corporation. INTER-X was founded by Takeru Higuchi, a professor of pharmaceutical chemistry at Kansas University. Merck is a New Jersey based corporation with 1979 sales of $2.4 billion; INTER-X is a multimillion dollar corporation located on Kansas University Endowment Association land in Lawrence.

INTER-X is expected to become a subsidiary of Merck's $189 million research and development division, but it is to remain in Lawrence, keep its name, and continue operation under Higuchi's supervision. Higuchi will keep his Kansas University faculty appointment and is expected to become a vice president in Merck's research division. INTER-X's operating budget will be increased by 50 to 100 percent in the first year. The arrangement will probably be settled through a stock transfer; the Endowment Association will recede from owning 37% of INTER-X stock to owning "just an infinitesimal amount" (e.g., 35,000 of 75 million shares).

University of Wisconsin-Cetus-Agrigenetics (21). At the University of Wisconsin at Madison, two scientists with interests in agriculture are encountering very different departmental attitudes in an institution which has had a long tradition of encouraging private enterprise. Recently Winston J. Brill of the bacteriology department joined a San Francisco based firm named Cetus. The department reviewed and accepted his proposals for handling his new role.

However, in the horticulture department, Timothy Hall has not yet reached a satisfactory agreement with his departmental colleagues concerning his involvement with Agrigenetics. According to Robert M. Bock, the dean of the graduate school, Hall plans to take a total leave of absence until remaining questions are worked out.

At Wisconsin, each department has first say as to what is proper and acceptable. A university wide study committee is preparing a report, probably ready in January 1982, reviewing policies and rules for faculty involvement in commercial and consulting activities.

Tufts University Medical School-Micromole (22). Members of the department of molecular biology and microbiology at Tufts University Medical School recently formed a "research partnership," separate from the university but consisting solely of faculty members from that department. The initial purpose of the partnership, which is known as Micromole, is to consult for other companies. Outside projects will be selected only if they do not overlap too closely with research underway at Tufts. The members of the Tufts department who formed the partnership hope that by working in an open way with one another, they can avoid the divisive forces which can affect individuals within a single department who go off in different directions.

Genetics Institute (23). In December 1980, a company called Genetics Institute was founded in Cambridge, Massachusetts. Two scientists from Harvard, Mark Ptashne and Tom Maniatis, will serve as principal scientific advisers to the company and will also serve on its board of directors. The company has more than $5 million in capital; other members of its board of directors include William Paley of CBS and Benno Schmidt of J. H. Whitney.

Genetic Systems Company (Geneco) (24). A company named Genetic Systems Company, or Geneco, was recently incorporated by professors Marvin Caruthers of the University of Colorado and Leroy Hood of the California Institute of Technology. Caruthers had developed a chemistry for fast nucleotide systehsis last year, but was unsuccessful in interesting chemical companies in helping him to manufacture a machine. Hood had developed a "microsequinator," a machine for analyzing the type and order of amino acids in any given protein, and the two scientists decided to form their own company specifically to make the machines.

Geneco's first synthesizers and sequinators are not expected to be available until mid-1982, but other instruments, reagents, and supplies will soon follow.

Both Caruthers and Hood serve on the science advisory panel of another firm, Applied Molecular Genetics, known as Am Gen, of Newbury Park, California.

Genentech (25). Genentech is a company founded in 1976 by Robert Swanson and Herbert Boyer for the purpose of exploring the commercial possibilities of gene splicing. As of August 1980, Genetech had grown to be a company of 112 people, 40 of whom have Ph.D.s. On October 14, 1980, the company made the first public offering of its stock, and it was one of the hottest issues that many brokers had ever seen; at the end of the first day, Genentech had a market valuation of $529 million.

The company's long-term strategy is to produce and market its own products, although for the moment it has contracts with established pharmaceutical firms such as Eli Lilly and Roche for production of insulin, interferon, and growth hormone.

Boyer is a biologist at the University of California at San Francisco and invented the recombinant DNA technique with Stanley Cohen of Stanford in 1973.

Acknowledgment

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Appendix III. Directory of Chemical Co-op

The 1982 Directory of Chemical Co-op[1] is the first edition of a publication intended to summarize the state of chemical cooperative education in the United States and Canada. It lists colleges and universities reporting such programs, gives contact information, and describes the characteristics of each program.

The objective of the directory is fourfold: it (1) provides a useful compilation of statistics and information, (2) gives employers a ready means for finding sources of chemical co-op students, (3) serves as a source of ideas and models for those wishing to develop or evaluate academic co-op programs, and (4) aids high school students and their advisors in locating academic institutions where co-op is available in the chemical sciences. This edition of the directory showed 243 schools reporting co-op programs enrolling 1700 chemistry students and 84 chemical engineering programs enrolling 3600 B.S. students each year. These programs also included students at the M.S. and Ph.D. levels.

The following information was taken from the 1982 directory and lists in alphabetical order and by state those institutions reporting co-op programs. The schools are categorized to indicate which of the following cooperative education programs are active at each institution listed:

- Baccalaureate level
  - Chemistry
  - Chemical Engineering
- Graduate level
- Associate level

For more information on the directory and this program, write to the American Chemical Society, Office of Cooperative Education, 1155 Sixteenth Street, N.W., Washington, D.C. 20036.

[1]The 1982 Directory of Chemical Co-op, Office of Cooperative Education, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036.

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CHEMICAL CO-OP PROGRAMS
Alphabetical Listing

School	Chem.	Ch.E.	Grad.	Assoc.
Adrian College	X			
University of Akron	X	X		
Alabama A&M University	X			
University of Alabama	X	X		
University of Alabama, Huntsville		X		
Albany State College	X			
The American University	X			
Andrews University	X			
Antioch College	X			
University of Arizona	X	X		
University of Arkansas		X		
University of Arkansas, Pine Bluff	X			
Atlanta University			X	
Auburn University	X	X		
Auburn University, Montgomery		X		
Baldwin-Wallace College	X			
Bay de Noc Community College				X
Beaver College	X			
Bergen Community College			X	
Berry College	X			
Black Hills State College	X			
Boston State College	X			
Bowling Green State University	X			
Bradley University	X			
University of Bridgeport	X			
Brigham Young University	X	X		
Butler University	X			
California Lutheran College	X			
California Polytechnic State University	X			X
California State College, Bakersfield	X			
California State Polytechnic University	X			
California State University, Chico	X			
California State University, Fresno	X			
California State University, Fullerton	X			
California State University, Hayward	X			
California State University, Long Beach	X			
California State University, Sacramento	X			
University of California, Berkeley	X			
University of California, Riverside	X			
University of California, Santa Cruz	X			
Calumet College	X			
Case Western Reserve University	X		X	
Castleton State College	X			
University of Central Florida	X			
Central Michigan University	X			

School	Chem.	Ch.E.	Grad.	Assoc.
Central Washington University	X			
University of Charleston	X			
Chestnut Hill College	X			
University of Cincinnati		X		
Univ. of Cincinnati, College of Applied Science				X
City Univ. of New York, Herbert H. Lehman College	X			
City University of New York, Queens College				X
City University of New York, York College	X			
Clarion State College	X			
Clemson University	X	X		
Cleveland State University	X	X		
Clinch Valley College	X			
Colorado School of Mines	X	X		
University of Colorado, Denver	X			
Columbia Union College		X		
Concordia College	X			
Concordia University	X			
University of Connecticut	X		X	
Cornell University		X		
University of Dayton	X	X		
Delaware Valley College of Science and Agric.	X			
University of Detroit	X	X		
University of the District of Columbia	X			
Doane College	X	X		
Drake University	X			
Drew University	X			
Drexel University	X	X	X	
University of Dubuque	X	X		
Duquesne University	X			
East Carolina University	X		X	
Eastern Illinois University	X	X		
Eastern Kentucky University	X			
Eastern Michigan University	X			
Eastern Oregon State College	X			
Edward Waters College	X			
Elmira College	X			
Emporia State University	X			
Fairleigh Dickinson University	X			
Fisk University	X	X		
Florida Atlantic University	X			
Florida Institute of Technology	X	X		
Florida International University	X	X		
Florida State University	X			
University of Florida	X	X		
Fort Lewis College	X			
Freed-Hardeman College	X			
Gallaudet College	X			

School	Chem.	Ch.E.	Grad.	Assoc.
George Washington University	X			
Georgia College	X			
Georgia Institute of Technology	X	X		
University of Georgia	X			
Glassboro State College	X			
Gordon College	X			
Governors State University	X		X	
College of Great Falls	X			
Greenville College	X			
Gustavus Adolphus College	X			
Hampton Institute	X			
Harding University	X			
University of Hartford	X			
University of Hawaii	X			
High Point College	X			
Hiram College	X			
University of Houston	X	X		
Howard University		X		
University of Idaho	X	X		
Illinois Institute of Technology	X	X		
Illinois State University	X			
University of Illinois, Chicago Circle		X		
University of Illinois, Urbana	X	X		
Indiana Central University	X			
Indiana State University	X			
Indiana University	X			
Indiana Univ.-Purdue University, Indianapolis	X		X	
Iowa State University		X		
University of Iowa		X		
Jersey City State College	X			
John Carroll University	X			
Kansas State University		X		
Kent State University	X			
University of Kentucky	X	X		
Lander College	X			
Lawrence Institute of Technology	X			
Lehigh University	X	X		
Lincoln University (MO)	X			
Lincoln University (PA)	X	X		
Long Island University, Brooklyn Center	X			
Long Island University, Southampton College	X			
University of Louisville		X	X	
Madonna College	X			
University of Maine at Orono	X	X		
Manhattan College	X			
Marshall University	X			
University of Maryland, Baltimore Campus	X			
University of Maryland, College Park Campus	X			

School	Chem.	Ch.E.	Grad.	Assoc.
Marymount College	X			
Maryville College, St. Louis	X			
Massachusetts Institute of Technology			X	
McNeese State University	X			
Meredith College	X			
Metropolitan State College	X			
Michigan State University	X	X		
Michigan Technological University	X			
University of Michigan		X		
University of Michigan, Dearborn	X			
University of Michigan, Flint	X			
Millersville State College	X			
Mississippi College	X			
Mississippi State University	X	X		
University of Mississippi		X		
University of Missouri-Rolla	X	X		
University of Missouri-St. Louis	X			
Montana College of Mineral Science & Technology	X			
University of Montana	X			
Montclair State College	X			
Morgan State University	X			
College of Mount St. Joseph	X			
Mount Saint Mary's College	X			
Mount Union College	X			
Mundelein College	X			
Murray State University	X			
National Tech. Institute for the Deaf, R.I.T.	X			
University of New England	X			
University of New Hampshire	X	X		
New Jersey Institute of Technology		X		
New Mexico Highlands University	X			
New Mexico Institute of Mining and Technology	X			
New Mexico State University	X	X		
University of New Mexico	X	X		
Norfolk State University	X			
North Adams State College	X			
University of North Alabama	X			
North Carolina Central University	X			
North Carolina State University	X	X		
University of North Carolina, Greensboro	X			
North Dakota State University	X			
University of North Florida	X			
North Park College	X			
North Texas State University	X			
Northeastern University	X	X	X	
University of Northern Iowa	X			
Northern Kentucky University	X	X		
Northland Pioneer College	X			

School	Chem.	Ch.E.	Grad.	Assoc.
Northwestern University	X	X		
Oakland University	X			
Occidental College	X			
Ohio State University	X			
Oklahoma State University		X		
University of Oklahoma		X		
Old Dominion University	X			
Otterbein College	X			
Pace University	X			
Pacific Lutheran University	X			
Pan American University	X			
Polytechnic Institute of New York	X	X		
Purdue University	X	X		
Ramapo College of New Jersey	X			
Regis College	X			
Rensselaer Polytechnic Institute	X	X		
Rhode Island College	X			
Richland College	X			
Rochester Institute of Technology	X			X
Rockhurst College	X			
Roger Williams College	X			
Rutgers University, Cook College	X			
Sacred Heart University	X			
Saginaw Valley State College	X			
St. Mary-of-the-Woods College	X			
Saint Peter's College	X			
College of St. Scholastica	X			
College of St. Thomas	X			
St. Vincent College	X			
Salem State College	X			
Samford University	X			
San Jose State University	X	X		
Savannah State College	X			
Seton Hall University	X			
Universite de Sherbrooke	X	X		
Simmons College	X			
University of South Alabama	X			
South Dakota State University	X			
University of South Florida	X	X		
University of Southern California	X	X		
Southern Illinois University	X			
University of Southern Maine	X			
University of Southern Mississippi	X			
Southwest Missouri State University	X	X		
State University College of Arts & Sciences	X	X		
State Univ. of New York, College at Cortland	X			
State Univ. of New York, College at Oswego	X			
Stevens Institute of Technology		X	X	

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

School	Chem.	Ch.E.	Grad.	Assoc.
Tennessee Technological University	X	X		
University of Tennessee, Knoxville	X	X		
University of Tennessee at Martin	X	X		
Texas A&M University	X	X	X	
Texas Southern University	X			
Texas Women's University	X		X	
University of Texas, Austin		X		
Thomas More College	X			
Tougaloo College	X			
Towson State University	X			
Trenton State College	X			
Tri-State University	X	X		
University of Victoria	X			
Virginia Polytechnic Institute and State Univ.	X	X		
Viterbo College	X			
Washington State University		X		
Washington University	X	X		
University of Waterloo	X	X		
Wayne State University	X	X		
University of West Florida	X			
West Georgia College	X	X		
West Virginia Institute of Technology	X	X		
Western Carolina University	X	X		
Western Connecticut State College	X			
Western Kentucky University	X		X	
Westminster College	X			
Wheaton College	X			
Wichita State University	X			
University of Wisconsin, Eau Claire	X			
University of Wisconsin, LaCrosse	X			
University of Wisconsin, Madison		X		
University of Wisconsin, Platteville	X			
Worcester Polytechnic Institute	X	X		
Wright State University	X			

CHEMICAL CO-OP PROGRAMS LISTING BY STATE

School	Chem.	Ch.E.	Grad.	Assoc.
ALABAMA				
Alabama A&M University	X			
University of Alabama	X	X		
University of Alabama, Huntsville		X		
Auburn University	X	X		

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

School	Chem.	Ch.E.	Grad.	Assoc.
Auburn University, Montgomery		X		
University of North Alabama	X			
Samford University	X			
University of South Alabama	X			
ARKANSAS				
University of Arkansas		X		
University of Arkansas, Pine Bluff	X			
Harding University	X			
ARIZONA				
University of Arizona	X	X		
Northland Pioneer College	X			
CALIFORNIA				
California Lutheran College	X			
California Polytechnic State University	X		X	
California State College, Bakersfield	X			
California State Polytechnic University	X	X		
California State University, Chico	X			
California State University, Fresno	X			
California State University, Fullerton	X			
California State University, Hayward	X			
California State University, Long Beach	X	X		
California State University, Sacramento	X			
University of California, Berkeley	X	X		
University of California, Riverside	X			
University of California, Santa Cruz	X			
Occidental College	X			
San Jose State University	X	X		
University of Southern California	X	X		
COLORADO				
Colorado School of Mines	X	X		
University of Colorado, Denver	X			
Fort Lewis College	X			
Metropolitan State College	X			
Regis College	X			
CONNECTICUT				
University of Bridgeport	X			
University of Connecticut	X		X	
University of Hartford	X			
Sacred Heart University	X			
Western Connecticut State College	X			

School	Chem.	Ch.E.	Grad.	Assoc.
DISTRICT OF COLUMBIA				
The American University	X			
University of the District of Columbia	X			
Gallaudet College	X			
George Washington University	X			
Howard University		X		
FLORIDA				
University of Central Florida	X			
Edward Waters College	X			
Florida Atlantic University	X			
Florida Institute of Technology	X	X		
Florida International University	X	X		
Florida State University	X			
University of Florida	X	X		
University of North Florida	X			
University of South Florida	X	X		
University of West Florida	X			
GEORGIA				
Albany State College	X			
Atlanta University			X	
Berry College	X			
Georgia College	X			
Georgia Institute of Technology	X	X		
University of Georgia	X			
Savannah State College	X			
West Georgia College	X	X		
HAWAII				
University of Hawaii	X			
IDAHO				
University of Idaho	X	X		
ILLINOIS				
Bradley University	X			
Eastern Illinois University	X	X		
Governors State University	X		X	
Greenville College	X			
Illinois Institute of Technology	X	X		
Illinois State University	X			
University of Illinois	X	X		
University of Illinois, Chicago Circle		X		
Mundelein College	X			
North Park College	X			

School	Chem.	Ch.E.	Grad.	Assoc.
Northwestern University	X	X		
Southern Illinois University	X			
Wheaton College	X			
INDIANA				
Butler University	X			
Calumet College	X			
Indiana Central University	X			
Indiana State University	X			
Indiana University	X			
Indiana Univ.-Purdue Univ., Indianapolis	X		X	
Purdue University	X	X		
St. Mary-of-the-Woods College	X			
Tri-State University	X	X		
IOWA				
Drake University	X			
University of Dubuque	X	X		
Iowa State University		X		
University of Iowa		X		
University of Northern Iowa	X			
KANSAS				
Emporia State University	X			
Kansas State University		X		
Wichita State University	X			
KENTUCKY				
Eastern Kentucky University	X			
University of Kentucky	X	X		
University of Louisville		X	X	
Murray State University	X			
Northern Kentucky University	X	X		
Thomas More College	X			
Western Kentucky University	X		X	
LOUISIANA				
McNeese State University	X			
MASSACHUSETTS				
Boston State College	X			
Gordon College	X			
Massachusetts Institute of Technology			X	
North Adams State College	X			
Northeastern University	X	X	X	
Salem State College	X			

School	Chem.	Ch.E.	Grad.	Assoc.
Simmons College	X			
Worcester Polytechnic Institute	X	X		
MARYLAND				
Columbia Union College		X		
University of Maryland, Baltimore Campus	X			
University of Maryland, College Park Campus	X			
Morgan State University	X			
Mount Saint Mary's College	X			
Towson State University	X			
MAINE				
University of Maine at Orono	X	X		
University of New England	X			
University of Southern Maine	X			
MICHIGAN				
Adrian College	X			
Andrews University	X			
Bay de Noc Community College				X
Central Michigan University	X			
University of Detroit	X	X		
Eastern Michigan University	X			
Lawrence Institute of Technology	X			
Madonna College	X			
Michigan State University	X	X		
Michigan Technological University	X			
University of Michigan, Ann Arbor		X		
University of Michigan, Dearborn	X			
University of Michigan, Flint	X			
Oakland University	X			
Saginaw Valley State College	X			
Wayne State University	X	X		
MINNESOTA				
Concordia College	X			
Gustavus Adolphus College	X			
College of St. Scholastica	X			
College of St. Thomas	X			
MISSOURI				
Lincoln University	X			
Maryville College, St. Louis	X			
University of Missouri-Rolla	X	X		
University of Missouri-St. Louis	X			

School	Chem.	Ch.E.	Grad.	Assoc.
Rockhurst College	X			
Southwest Missouri State University	X	X		
Washington University	X	X		
MISSISSIPPI				
Mississippi College	X			
Mississippi State University	X	X		
University of Mississippi		X		
University of Southern Mississippi	X			
Tougaloo College	X			
MONTANA				
College of Great Falls	X			
Montana College of Mineral Science & Technology	X			
University of Montana	X			
NEBRASKA				
Doane College	X	X		
NEW HAMPSHIRE				
University of New Hampshire	X	X		
NEW JERSEY				
Drew University	X			
Fairleigh Dickinson University	X			
Glassboro State College	X			
Jersey City State College	X			
Montclair State College	X			
New Jersey Institute of Technology		X		
Ramapo College of New Jersey	X			
Rutgers University, Cook College	X			
Saint Peter's College	X			
Seton Hall University	X			
Stevens Institute of Technology		X	X	
Trenton State College	X			
NEW MEXICO				
New Mexico Highlands Univ.	X			
New Mexico Institute of Mining & Technology	X			
New Mexico State University	X	X		
University of New Mexico	X	X		
NEW YORK				
CUNY, Herbert H. Lehman College	X			
City University of New York, Queens College			X	
City University of New York, York College	X			

School	Chem.	Ch.E	Grad.	Assoc.
Cornell University		X		
Elmira College	X			
Long Island University, Brooklyn Center	X			
Long Island University, Southampton College	X			
Manhattan College	X			
Marymount College	X			
National Technical Institute for the Deaf, R.I.T.	X			
Pace University	X			
Polytechnic Institute of New York	X	X		
Rensselaer Polytechnic Institute	X	X		
Rochester Institute of Technology	X			X
State University College of Arts & Sciences	X	X		
State Univ. of New York, College at Cortland	X			
State Univ. of New York, College at Oswego	X			
NORTH CAROLINA				
East Carolina University	X		X	
High Point College	X			
Meredith College	X			
North Carolina Central University	X			
North Carolina State University	X	X		
University of North Carolina, Greensboro	X			
Western Carolina University	X	X		
NORTH DAKOTA				
North Dakota State University	X			
OHIO				
University of Akron	X	X		
Antioch College	X			
Baldwin-Wallace College	X			
Bowling Green State University	X			
Case Western Reserve University	X	X		
University of Cincinnati		X		
Univ. of Cincinnati, School of Applied Science				X
Cleveland State University	X	X		
University of Dayton	X	X		
Hiram College	X			
John Carroll University	X			
Kent State University	X			
College of Mount St. Joseph	X			
Ohio State University	X			
Otterbein College	X			
Wright State University	X			

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

School	Chem.	Ch.E.	Grad.	Assoc.
OKLAHOMA				
Oklahoma State University		X		
University of Oklahoma		X		
OREGON				
Eastern Oregon State College	X			
PENNSYLVANIA				
Beaver College	X			
Chestnut Hill College	X			
Clarion State College	X			
Delaware Valley College of Science & Agriculture	X			
Drexel University	X	X	X	
Duquesne University	X			
Lehigh University	X	X		
Lincoln University	X	X		
Millersville State College	X			
St. Vincent College	X			
RHODE ISLAND				
Rhode Island College	X			
Roger Williams College	X			
SOUTH CAROLINA				
Clemson University	X	X		
Lander College	X			
SOUTH DAKOTA				
Black Hills State College	X			
South Dakota State University	X			
TENNESSEE				
Fisk University	X	X		
Freed-Hardeman College	X			
Tennessee Technological University	X	X		
University of Tennessee, Knoxville	X	X		
University of Tennessee, Martin	X	X		
TEXAS				
Universitv of Houston	X	X		
North Texas State University	X			
Pan American University	X			
Richland College	X			
Texas A&M University	X	X	X	
Texas Southern University	X			

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

School	Chem.	Ch.E.	Grad.	Assoc.
Texas Women's University	X		X	
University of Texas, Austin		X		
UTAH				
Brigham Young University	X	X		
Westminster College	X			
VIRGINIA				
Clinch Valley College	X	X		
Hampton Institute	X			
Norfolk State University	X			
Old Dominion University	X			
Virginia Polytechnic Institute & State University	X	X		
VERMONT				
Castleton State College	X			
WASHINGTON				
Central Washington University	X			
Pacific Lutheran University	X			
Washington State University		X		
WISCONSIN				
Viterbo College	X			
University of Wisconsin, Eau Claire	X			
University of Wisconsin, LaCrosse	X			
University of Wisconsin, Madison		X		
University of Wisconsin, Platteville	X			
WEST VIRGINIA				
University of Charleston	X			
Marshall University	X			
West Virginia Institute of Technology	X	X		
CANADA				
Concordia University	X			
Universite de Sherbrooke	X	X		
University of Victoria	X			
University of Waterloo	X	X		

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Appendix IV. University–Industry Research Relationships: Annotated Bibliography and Subject Index

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NOTE: This information has been published in *NSB University–Industry Research Relationships: Selected Studies* (U.S. Government Printing Office: Washington, D.C., 1983).

Atkinson, Richard C. "Planning for Science in the 1980s." Speech at the Public Affairs Symposium, Annual Meeting of the Federation of American Societies for Experimental Biology, Anaheim, California, April 14, 1980. 11 pp.

Discusses areas of future emphasis in planning for the biosciences. Nearly two pages are devoted to discussion of the university-industry connection and the associated changing patterns of research performance and scientific careers.

Baer, Walter S. Strengthening University-Industry Interactions. Santa Monica, California: RAND Corporation, January 1980. 28 pp.

Analyzes policy objectives of attempts to increase flow of university-industry interactions, and examines current state of knowledge regarding effects of three broad types of university-industry relationships upon industrial innovation. Sets forth eight policy options. Bibliography.

Battenburg, Joseph R. "Forging Links Between Industry and the Academic World." Journal of the Society of Research Administrators, Vol. XII, Winter 1981.

Battenburg is with the Corporate Research Department of the Eaton Corporation of Michigan. The paper examines the problems associated with university-industry interactions. "Gap size" factors are listed, i.e., those tending to widen or reduce the gap between the sectors. Ten types of mechanisms to promote closer relationships are listed and briefly discussed. Specific first steps for initiating contracts--both for universities and companies--are suggested.

Bearn, Alexander A. "The Pharmacuetical Industry and Academe: Partners in Progress." American Journal of Medicine, 71, pp. 81-88, July 1981.

A useful review of the state of university-industry relationships in pharmaceuticals by an official at Merck Sharp and Dohme International.

Bement, A. L. "DARPA's Experience with University-Industrial Interactions in Materials Research." Notes and slides for a presentation at DOE/IRI Conference on Mechanisms of University-Industry Interactions, Reston, Virginia, December 7-8, 1978.

The Director of the DARPA Materials Science Office lists DARPA's various "institutionalized" programs, and examines the "coupling" programs (1966-1973) in some detail. Proposes a number of "lessons learned" from the experience. Appended is NSF's 1973 "MRL Program Policy Statement" which governed the takeover of these interdisciplinary laboratories for materials research from DARPA.

Bindon, G. "Output Measures of Cooperative Research: The Case of the Pulp and Paper Research Institute of Canada." Scientometrics, 3, pp. 85-106, 1981.

This paper describes and analyzes the scientific output of a cooperative industrial research institute, Pulp and Paper Research Institute of Canada (PAPRICAN). It compares the employment patterns of McGill graduate students who have done their thesis research under the auspices of the industrial laboratory with graduate students from the same departments who have not worked at PAPRICAN. A comparison is also made of the publication practices of three groups: PAPRICAN staff not associated with the university (McGill), the PAPRICAN staff who also hold academic appointments at McGill, and the faculty of the Chemistry Department at McGill who do not hold staff positions at PAPRICAN.

It is found that the academic association with PAPRICAN during graduate research has a significant impact on the number of students who go on to careers in industry.

The publication record is compared to various standards so as to judge various qualities of the scientific output of the different groups. The PAPRICAN staff performs as would be expected of industrial researchers, and the McGill faculty show normal characteristics for an academic group. However, those who hold positions in both the industrial institute and the academic sector reveal the special role they play in linking the "science" of the second with the "technology" of the first.

Bok, Derek. "President's Report: Business and the Academy." Harvard Magazine, pp. 23-35, May/June 1981.

Can the universities enter the marketplace without subverting their commitment to learning and discovery? This in-depth review covers most of the issues, starting from the position that better industrial/commercial utiliaztion of academic research (technology transfer) is an important and desirable goal.

Bok posits six conditions necessary to maintain the highest quality of fundamental research in science, and examines the state of academic science with reference to each one. He further posits four dangers to the quality of academic science from increased emphasis upon technology transfer.

"...the prospect of reaping financial rewards may subtly influence professors in choosing which problems they wish to investigate."

"...professors may be diverted from any form of research (and teaching) in order to perform other tasks involved in the process of technological development."

"...the risk of introducing secrecy into the process of scientific research."

"...a threat to the quality of leadership...the state of morale...[and] the reputation for disinterested inquiry [that] helps to preserve the confidence and respect of the public--a state of mind that is ever more essential to the progress of academic science as its dependence on external support continues to rise."

Borstein, Morris, et al. The Planning and Management of Industrial Research and Development in the USSR. Joint US-USSR Science and Technology Exchange Program, Final Report, Technical Note SSC-TN-7557-7, under NSF Grant INT78-18699, Task 1, June 1980. 63 pp.

Report of a December 1979 visit by a US delegation of specialists to study the Soviet experience in planning and management of research and development, and the introduction of the results of R&D in "Science-Production Associations" (N.P.O.s).

Describes case studies of two N.P.O.s in which research-oriented institutes for scientific research are associated with experimental and full-scale production plants. Instructive financial comparisons are drawn with the US corporation Union Carbide.

Branscomb, Lewis M. "Opportunities for Cooperation Between Government, Industry, and the University." Annals of the New York Academy of Sciences, 334, pp. 211-227, December 14, 1979.

The author of this article is Vice President and Chief Scientist of IBM, a former Director of the National Bureau of Standards, and since 1980, Chairman of the National Science Board.

The article focuses attention on the inadequacy of "technology demonstration projects' as a government means to stimulate commercial technology. It discusses two possible alternatives for government-industry-university cooperation in technology development: "Exploratory Generic Technology," and more speculatively, "Cooperative Development of Product Prototypes."

The typical federal concern with commercial technology development has involved massive demonstration projects, e.g., in synfuels, solar energy, and personal rapid transit. The shortcoming of this approach is that it leaves out the costly investments in engineering and production tooling and processes that make the product commercially manufacturable. The author uses the example of the proposed Cooperative Automotive Research Program to illustrate the lack of connection with product and process design and manufacturing engineering.

Branscomb, Lewis M. "Strengthening Industry's University Connection." The Bridge (National Academy of Engineering), 2, pp. 35-38, Fall 1981.

Article by the Vice President and Chief Scientist of IBM and Chairman of the National Science Board argues for the need for increased flexible funding of university research and training in science and engineering through corporate philanthropy. The IBM Program of Departmental Grants is discussed--the program makes grants of $25,000 to selected departments in fields of science and engineering relevant to IBM.

The British Council. Academic/Industrial Collaboration in Britain and Germany: Proceedings of the British-German Seminar on Academic Research and Industry. The British Council, Cologne, February 1977. 31 pp.

A report of two days of discussion of academic research and industry by six German and six British senior researchers, administrators, and managers from industry and the universities.

The objectives of the seminar were to examine and compare experience in the two countries and to make recommendations on the ways in which academic institutions can usefully increase or more effectively select the industrially

oriented aspects of their scientific research, but without essentially impairing their freedom of study. The discussions focused principally on engineering and those technologies and related sciences which support the manufacturing industries.

Brodsky, N., Kaufman, H. G., and Tooker, J. D. University Industry Cooperation: A Preliminary Analysis of Existing Mechanisms and Their Relationship to the Innovation Process. New York: NYU Center for Science and Technology Policy, July 1979. 108 pp. (Under National Bureau of Standards Order No. NB79NAA/A8898.)

A catalogue of existing university-industry relationships with short descriptions of case examples. Assessment of contribution of each type to four phases of the innovation process: (1) additions to knowledge/experience pool; (2) development of new concepts; (3) development of new products and processes; and (4) market development.

Brown, Alfred E. "The Industry/University Interface in America Today." Paper presented at the American Society for Metals, Materials, and Processes Congress, Cleveland, Ohio, October 28-30, 1980. 18 pp.

A manager from the Celanese Corporation discusses: (1) current mechanisms of industry/university cooperation; (2) barriers to cooperation; (3) suggestions for improvement of the interface. Leans heavily on the 1978 NYU study of industry/university connections. His suggestions include: more effective communication to professors by companies of their research interests; greater personnel movement--including permanent career changes--between the sectors; university establishment of interdisciplinary research centers; experimentation with novel joint arrangements.

Brown, George E., Jr. "University-Industry Links: Government as Blacksmith." Paper presented at AAAS Symposium on "Government/Industry/University Relations," San Francisco, California, January 5, 1980. 16 pp.

Congressman Brown assesses some effects of the changing environment for innovation upon existing and potential university-industry linkages. Describes six current federal efforts to foster linkages, and six additional areas of linkage which "should be considered."

Bugliarello, George. "Focusing on the Function of the University." Proceedings from the First Midland Conference, sponsored by Dow Chemical Company, October 1979, pp. 153-170.

Useful brief compilation of statistics on the sources of support for and performers of R&D, focusing on the university-industry relationship. Presents more detailed information on chemistry and chemical engineering.

Valuable listings of eight major obstacles to a more fruitful university-industry relationship, and six strategies for dealing with these problems.

Business Week. "The Second Green Revolution: Harnessing Biotechnology to Produce More Food with Less Energy." August 25, 1980. 4 pp.

Discusses university, industrial, and government activities in plant bioengineering and focuses upon the "rapid buildup in corporate bioengineering research." Notes the competition between academic and corporate laboratories for competent scientists.

Cannon, Peter. "A Model for Industry-University Minority Doctoral Engineering Programs." Research Management, July 1980, pp. 21-23.

Dr. Cannon, Vice President for Research, Rockwell International, describes a program begun three and a half years ago by Rockwell International Science Center (Rockwell's corporate research laboratory) aimed at increasing the number of minority engineers with Ph.D.s in solid state electronics.

The principal mechanism utilized was to subcontract company funded research on gallium arsenide to two historically black universities--Howard and North Carolina A&T. NASA has also participated in this project.

Cantwell, Katherine M. "University-Industry Research Relationships at the Stanford Synchrotron Radiation Laboratory." A report submitted to the National Science Board, July 1980. 6 pp. and appendix.

The Assistant to the Director of the SSRL describes joint industrial-university cooperation at the laboratory.

All of the advisory panels have industrial members. Of the 88 institutions experimenting at SSRL, 26 are private corporations; and of the 309 proposals for research at SSRL active in March 1980, 55 involved joint university-industrial research.

Three types of cooperation are identified: (1) cooperation on specific research proposals; (2) industrial contributions to facility beam line development and instrumentation; (3) implementation of new scientific techniques by industrial groups, which then become available to the general user community. A list of industry-university proposals is appended.

Chemical Week. "Weighing University Research Proposals." February 3, 1982, pp. 55-56.

Describes Monsanto's new Office of External Research and Development--a central corporate clearinghouse to weigh all university grant proposals--whether internally or externally generated. Brief discussions of mechanisms employed at Dow Chemical and DuPont for initiating research contact with universities.

Committee on Economic Development. Stimulating Technology Progress. New York and Washington, D.C.: Committee on Economic Development, January 1980. 96 pp.

Discusses the nature of technological progress and its relationships to economic growth. Focuses primarily on the hindrances to technological progress required by tax policies, government constraints upon innovation, and patent policies. The role of universities in basic research is briefly discussed. Recommends provision of a tax credit for support of nonproprietary university research.

Council for Financial Aid to Education. Voluntary Support of Education, 1979-80. New York: CFAE, May 1981.

An annual survey of educational philanthropy dating from 1954-55. The survey for 1979-80 reports actual returns from each of the participating 914 four-year colleges and universities and 105 two-year colleges. These data are extrapolated to arrive at estimates of total national voluntary support of colleges or universities--the total for 1979-80 being $3.8 billion. It is estimated that 15.2% of the total, or $577 million, were gifts earmarked for research purposes. "Business corporations contributed a record 18.3% of total voluntary support as a result of a 25.2% increase in their grants."

Council of Graduate Schools/National Science Foundation (CGS/NSF). Industry/University Cooperative Programs: Proceedings of a Workshop Held in Conjunction with the 20th Annual Meeting of the Council of Graduate Schools in the United States, December 2, 1980. 123 pp.

Useful compilation of cases of a variety of academic/industrial programs both from industrial and university perspectives. University programs discussed include: MIT Industrial Liaison Program, University of Delaware Composites Center, Case Western Reserve Polymer Science and Engineer-

ing, Materials Research at Pennsylvania State University, Animal Science Programs at Iowa State University, and a cooperative computer science degree program at New Mexico State University. Companies expressing their perspectives included: Shell Development, Johnson and Johnson, Pfizer, IBM, and Rockwell International. Also described is the unique Philadelphia Association for Clinical Trials--a consortium of six area academic medical institutions which aims to coordinate the resources available to provide an attractive opportunity for the placement and performance of clinical trials of new drugs and devices.

Culliton, Barbara. "Biomedical Research Enters the Marketplace." New England Journal of Medicine, 304, pp. 1195-1201, May 14, 1981.

Reviews recent steps in the progress of biotechnology--in particular recombinant DNA and monoclonal antibody techniques--toward front stage. The role of the press in publicizing the phenomenon is examined. A brief history of Harvard's patent policy is presented, followed by a description of Harvard's proposed biotechnology company and a discussion of the various arguments and points of view that led to its rejection.

The suit and countersuit between Hoffmann-LaRoche and the University of California over the proper utilization of the KAI cell line which produces interferon are described and discussed as an example of the difficulties of establishing substantial collaboration between academic institutions and industrial corporations.

Concludes that there is room for collaborative arrangements that suit both sides.

Culliton, Barbara. "Harvard and Monsanto: The $23-Million Alliance." Science, pp. 759-763, February 25, 1977.

An intensive case study of this highly visible agreement. Discusses the antecedents of the agreement; the "readiness" and motivations of the parties to cooperate (one of the principal investigators had been a long-time Monsanto consultant, and Monsanto wanted a "window" on the new biology as well as rights to a long-shot possible cancer cure); the tortuous process of negotiation; the patent and publication issues and their resolution (Harvard changed its patent policy); the appointment of a prestigious national advisory committee to oversee the public interest aspects of the agreement; three kinds of monetary support which are estimated to total $23 million over twelve years: (1) $200,000 a year for each of the co-investigators; (2) $1.4 million to equip laboratories; (3) a $12 million endowment--

current income from which would support the project research, but which would ultimately be used as general, string-free funds.

David, E. E., Jr. "Science Futures: The Industrial Connection." Science, pp. 837-840, March 2, 1979.

The president of Exxon Research and Engineering Company explores the idea that the traditional diversity of mechanisms for the transfer of knowledge and ideas to industry, as well as the communication of realistic problems to academic researchers, may not be adequate for the future.

A rich and detialed discussion of trends and characteristics of industrial research laboratories is compared with a cursory treatment of academic orientations. The paper concludes with an optimistic review of "strands for the industrial connection."

Davis, Bernard D. "Sounding Board: Profit Sharing Between Professors and the University?" New England Journal of Medicine, 304, pp. 1232-1235, May 14, 1981.

Weighs the pros and cons of two mechanisms by which university inventions enter the commercial market: (1) patents; (2) formation of private corporations by faculty members.

Presents arguments for a third kind of arrangement--institutional profit sharing--which is seen as both providing a fair share of profits to the university and the scientist inventor, while avoiding some of the dangers to science posed by the existing arrangements. Davis argues that the rejected Harvard proposal for profit sharing did not receive a fair hearing due to high emotions, press ballyhoo, and the Genentech stock offering episode.

Davis, Lance E. and Kevles, Daniel K. "The National Research Fund: A Case Study in the Industrial Support of Academic Science." Minerva, 12, pp. 207-220, 1974.

The story focuses on the period 1915-1932 and the attempts of a number of individuals to generate industrial support for "pure" scientific research. The eventual failure of the effort provides an instructive case study in the behavior of business enterprises in the financing of academic research.

George E. Hale, of the Mt. Wilson Observatory, was instrumental in the creation of the National Research Council (NRC) in 1916 which was designed to bring together government, industry, and the universities to mobilize science and engineering for the national defense. In 1918 the NRC was made a permanent agency, and Hale had it create an Industrial Advisory Commission, which he encouraged to

promote a campaign for business support for university science.

In 1925 a plan and organization emerged when the National Academy of Sciences (NAS) authorized the creation of a National Research Endowment--which was to raise $20 million in capital from industry, to be disbursed by the NAS as grants in aid of research. The word "Endowment" was soon changed to "Fund" because corporations were not permitted to engage in philanthropy--they had to demonstrate that donations worked to the corporation's profit-making advantage. Herbert Hoover was chairman of the Fund. But in three years the Fund had raised less than half of its goal and that from a few large corporations. The goal was reduced to $10 million, and this amount was pledged by 1930, but when the Fund tried to call in the pledges in the first year of the Depression, the National Electric Light Association, a trade association of electrical generating and equipment manufacturing firms which had pledged $3 million, found that its members could not pay. By 1932 the promoters agreed that the National Research Fund was dead.

The economic-theoretical concept of "externalities" is used to explain the failure of the National Research Fund (NRF). "The campaign for the NRF was an attempt to finance academic science in which those who paid the costs could not avoid having much of the resulting benefits flow to others"--the "free rider" problem. Eventual government funding of basic research provided a solution to the problem that gained the support of industrial corporations.

Declercq, Guido V. "A Third Look at the Two Cultures: The New Economic Responsibility of the University." International Journal of Institutional Management in Higher Education, July 1981.

The Administrator of the Catholic University of Leuven in Belgium explores the idea that the relations between the economy and the world of learning and research are changing under the pressure of the scientific revolution, as the economy of the developed world is increasingly based on high technology and applied science.

"Universities are being drawn to the centre of high technology based national economies from their former position at the outer fringe of economic society. As a result of this new development, universities are being forced into new roles for which many are not prepared and that raise a number of new and urgent questions. This may lead, in Eric Ashby's words, to a 'thorough revision of the inner logic of universities.' (Eric Ashby, Adapting Universities to a Technological Society, Jossey-Bass, p. 114, 1974) We are fast moving away from the monastic conception of Newman's university with its pursuit of knowledge irrespective of its utility."

"The new economic responsibility demands that the university in the innovation process, develop a broker's function, either by the university itself or by means of professional outside help, to bring the two parts of the innovative process together." Several such brokerage mechanisms are discussed.

Declercq, Guido V. "Technology Transfer from Campus to Industry." International Journal of Institutional Management in Higher Education, 3, pp. 237-252, October 1979.

Since World War II universities have been considered as elements in industrial development of countries, and more recently in terms of their functions as sources of innovative ideas for economic regeneration. This article examines the question of how universities should fulfill this role.

A discussion of three general questions is followed by examination of examples of mechanisms to improve university-industry interfaces in several European countries, Canada, and the United States. The three questions discussed are: (1) Do universities have something to offer to industry? (2) Does industry, or society, expect a return, in the form of inventions, from the large financial inputs that go into our higher educational system? (3) Why are universities as such apparently weak in transferring technology to the marketplace?

"Existing professional transfer formulas" discussed include: (1) industrial liaison centers--possibly in cooperation with local or central governments; (2) profit-making or nonprofit "campus companies"; and (3) research parks.

Dickson, David. "'Summit' Set on Academe-Industry Big Links." Science and Government Report, 12, pp. 1-4, March 15, 1982.

Report on a scheduled meeting between the presidents of five major research universities and the presidents of about ten biotechnology companies to explore guidelines for future relationships. This activity is taking place as the State of California's Fair Political Practices Commission (FPPC) gave formal approval to a rule which will require university faculty members to disclose whether they have any financial interest in companies that provide them with research grants.

The case of Raymond Valentine, Professor of Plant Biology at the University of California's Davis campus is discussed at length. Professor Valentine was closely involved in setting up a private genetic engineering company in Davis--Calgene. He also had a $2.3 million research contract from Allied Chemical to investigate the nitrogen-fixing properties of plants. When it was revealed that Allied Chemical had purchased a large block of Calgene shares, conflict of interest concerns were raised which resulted in an ultimatum to Valentine from the UC-Davis administration that he must either withdraw from the research project or from Calgene--he chose to withdraw from the project.

The debate, however, continues on the difference between occasional consulting on the one hand, and long-term commitments involving substantial financial interest on the other. It was argued that the latter was "already stifling free exchange of information and ideas on the Davis campus."

Dietrich, J. J. and Sen, Rajat. "Government-University-Industry Interaction in Research and Development: A Case Study." Research Management, pp. 23-25, September 1981.

Two managers of the Diamond-Shamrock Company, a major force in electrochemical technology and in the chloralkali industry, describe the development of a cooperative agreement between the company, the U.S. Department of Energy, and Case Western University (Dr. Ernest B. Yeager, international leader in electrochemical research) for research in oxygen electrocatalysis.

The proximate goal of the research is to invent an oxygen depolarized air cathode which, if fitted to a membrane cell for the production of pure caustic, could save the U.S. chloralkali industry billions of kilowatt hours of electricity annually.

The article describes the organizational and legal arrangements which permit all parties to maximize their divergent interests.

Conclusions are drawn concerning the conditions for successful interactions of this kind.

Doan, Herbert D. "New Arrangements for Industry-Academic Research." Research Management, pp. 33-35, March 1978.

Two proposals are offered for interlocking university and industry research more closely, and thereby raising the effectiveness of the U.S. research effort.

Engles, E. F. "A New Initiative in Stimulating Industry/University Cooperation: The First Midland Conference on Advances in Chemical Science and Technology." Paper presented at the Congress of the American Society of Metals, Materials, and Processes, Cleveland, Ohio, October 30, 1980. 14 pp.

A research manager for Dow Chemical provides a useful account of the genesis and development of the 1979 Midland Conference and its 1980 sequel at Allentown, Pennsylvania.

European Industrial Research Management Association (EIRMA). Industry/University Relations, Working Group Report No. 7. Paris: EIRMA, 1972. 58 pp.

A useful discussion of the following topics: (1) mental attitudes; (2) joint and sponsored research; (3) exchange schemes; (4) the role of government; (5) the special situation of the small firm. Discussion of each topic is followed by conclusions and recommendations.

Fakstorp, Jorgen and Idorn, G. M. "University-Industry Relations in Europe." Research Management, pp. 34-37, July 1978.

Two technical executives of Danish firms argue that because the political and social unrest of the sixties disrupted what ties there were between industry and academia, a dialogue should be initiated to explore cooperative R&D activities. Differences between the U.S. and European traditions relating to university-industry relationships are described (these are less developed in Europe). In addition, much of the post-war expansion of public funding for research resulted in the creation of a number of national research institutes which neither possessed a graduate program nor cooperated with industrial sectors.

Farris, H. W. "The Campus and Industry." Industrial Research, pp. 76-81, April 1964.

The article by the associate director of the University of Michigan Institute of Science and Technology expresses an "aid to industry posture." Discusses four mechanisms for matching university capabilities with industry needs. Attempts to define appropriate kinds of industrially supported work in the university.

Fernelius, W. Conrad and Waldo, Willis H. "Role of Basic Research in Industrial Innovation." Research Management, pp. 36-40, July 1980.

An analysis (supported in part by the NSF) of 78 case histories of successful commercial developments since 1965 was conducted to determine what role was played by basic research information (since 1945) in the process, and to evaluate the resultant economic benefits as quantitatively as possible.

The principal conclusion reached was that, "There are difficulties in gathering information about the process of industrial innovation."

Fox, Jeffrey. "Can Academia Adapt to Biotechnology's Lure?" Chemical and Engineering News, pp. 39-44, October 12, 1981.

Excellent review of the problems of conflict of interest, intellectual property, and the openness of scientific research created by the commercial vitality of the new biotechnology.

"As an idea, this technology has already touched off an epidemic of entrepreneurial activity that is running rampant on university campuses. Cool-headed scientists have turned into feverish schemers caught up in a heady delirium of corporate planning, real estate speculation for lab expansions, and market watching."

"Neither political leanings nor social standing is a guarantee of immunity from this new 'bug.' As one still resistant university scientist puts it, 'It's like the original version of the movie, The Body Snatchers. You look into the eyes of someone and realize it's too late."

Report contains interviews with ten faculty members involved in commercial activities and a valuable summary of conversations with postdocs in the field.

Fox, Jeffrey. "Plant Molecular Biology Begins to Flourish." Chemical and Engineering News, pp. 33-44, June 22, 1981.

Informative survey of U.S. and international academic industrial and joint activities in adapting genetic engineering techniques to plant molecular biology. The R&D thrusts of the various groups are discussed.

Fusfeld, H. I. "New Approaches to Support and Working Relationships." Special "Industry/University R&D" issue of Research Management, 19, May 1976.

More effective links in R&D activities must be forged between industry, academia, and government. To accomplish this the author suggests some new mechanisms.

Fusfeld, H. I. "The Recent Science and Engineering Doctorate from an Industry View." Paper presented at the AAAS Annual Meeting, San Francisco, California, January 8, 1980. 15 pp.

Argues that stimulation of the growth of cooperative research between universities, government, and industry, on the basis of current mechanisms, "could amount to $500 million in five to ten years. This would support close to 10,000 Ph.D. scientists and engineers, about 40% of those not on faculty today, or about 25% of the research effort not accounted for by tenured faculty....This expansion would not be in new funds, but would represent a restructuring and a shift in commitments from government and industry."

Gallagher, Colin. "Time for an Industrial Research Council." Times Higher Education Supplement, September 26, 1980. 1 p.

The head of the Industrial Management Department at the University of Newcastle in Great Britain presents arguments for a national body to look after the university-based research needs of industry. A close analogue is made to the proposed U.S. National Technology Foundation.

Gilpin, Robert. Technology, Economic Growth, and International Competitiveness. A report prepared for the use of the Subcommittee on Economic Growth of the Joint Economic Committee, Congress of the United States, July 9, 1975. Washington, D.C.: U.S. Government Printing Office, 1975. 87 pp.

This report is excellent background reading for a broad understanding of the role of technology and research and development in the economy. It contains a thorough examination and assessment of the scholarly literature on the role of technology in economic growth, an examination of the performance of the U.S. economy in the light of thid knowledge, and an assessment of the role of government in facilitating several strategies for growth.

In a section on Government Support and University Research, Gilpin advocates, "...the need for a new alliance between government, university, and private industry in newer areas of concern to replace the declining efficiency of the anachronistic alliance forged at the end of the Second World War. On the university side the situation is ripe for cooperative efforts which would invigorate scientific and technical research relevant to our emergent set of national priorities."

He also maintained that, "The government side of this potential alliance has yet to develop its full potential," due to inadequate leadership structure which at that time centered upon the Director of the NSF, and a lack of appreciation in the mission agencies of the importance of exploratory development and basic research.

A very useful section summarizes "what we know (and don't know) about industrial innovation," including a discussion of the role of basic research. Another section discusses what the government should and should not do.

Hamilton, W. B. "The Research Triangle of North Carolina: A Study in Leadership for the Common Weal." South Atlantic Quarterly, 65, pp. 254-278, Spring 1966.

"The tale of the Triangle is one of local and state leadership for the common weal and of the interrelationship of ideas and action, of cooperation among businessmen, university professors, and political leaders. The concept evolved by that leadership was unique at the time; its eventual realization was a product of such good old fundamentals as hard work, brains, persistence in the face of difficulties, and philanthropy; of the presence of universities growing in grace; of the exertion of political influence; and of an expanding national economy. A priceless ingredient was a decent state atmosphere for human relations."

The detials of the story of the development of the Triangle from 1952 to 1965 are well told by this professor of history at Duke University.

Healey, Frank H. "Industry Needs for Basic Research." Research Management, pp. 12-16, November 1978.

The vice president for research and engineering of the Lever Brothers Company reviews data from NSB Science Indicators--1976 bearing on the decline in industrial support for basic research.

Applauds the initiation of the NSF University Industry Cooperative Research Program and argues that "it is unlikely that industry will spend any more of its own money on basic research unless some positive incentive is provided."

Hencke, W. R., Greene, J. H., Rosner, D. E., and Nordine, P. C. "A Program for Student Involvement in Industrial R&D." Special "Industry/University R&D" issue of Research Management, 19, May 1976.

This article describes a novel industrial research training approach in which students perform as consultants to industry on real-life problems.

Heylin, Michael. "Confusion Over Innovation Highlighted Again." Chemical and Engineering News, March 3, 1980.

Report on a February 1980 conference at Massachusetts Institute of Technology (MIT) on the role of cooperative R&D among industry, the universities, and government in stimulating technological innovation. The conference was cosponsored by the MIT Laboratory for Manufacturing and Productivity, and the NSF.

The article described the conference as "a love-in for cooperative research," but said that few new policy recommendations emerged.

Several individuals expressed reservations about university-industry cooperative programs--they were worried about unanticipated effects upon universities ("a potential threat to academic freedom") and the poorly understood linkage between growth in science and technology and growth in innovation.

Hill, Lamar. "Negotiating with the Community: UCI Industrial Associates." In Institutional Mechanisms of Interaction Between Higher Education and the Community: Illustrative Examples. Paris:OECD, 1980.

This case study, written by a historian, examines the means employed by the University of California at Irvine to negotiate with the surrounding community through a specifically created entity: UCI Industrial Associates. The case study begins with a background statement regarding the origins of UCI, a description of its environment, and a description of the circumstances surrounding the organization of the negotiating entity. There follows a description of the development and current status of the Industrial Associates. In conclusion there is an analysis of the results of the negotiating entity's activities, of its relationship with the university, of the continuing problems which derive from the discordant mentalities in the university and the surrounding community, and of the integration of Industrial Associates with specific academic and research programs in order to reduce the mutual isolation which this discordance occasions.

Honan, James P. "Corporate Education: Threat or Opportunity?" AAHE Bulletin, pp. 7-9, March 1982.

A useful review of the literature on corporate-based education programs which have grown in both scope and magnitude during the past decade. Several large corporations including IBM, AT&T, Wang, and Xerox are assuming a major role in educating and training their employees in fields heretofore primarily the responsibility of colleges and universities. Some of the corporate programs are even granting degrees.

Concludes that the corporate programs should be seen as an opportunity for higher education to become more sensitive to the needs of industry and to expand cooperative efforts. Bibliography.

Industrial Research Institute, Incorporated. Industrial Innovation: The Impact of Federal Policies on Industry/University Relations. A Position Statement by the Industrial Research Institute. New York: Industrial Research Institute, September 26, 1980. 1 p.

The IRI strongly supports increased interaction between industry and university research, and urges that federal policies be developed to promote closer collaboration between universities and industrial organizations.

The recommended policies include: (1) tax incentives to stimulate industrial support of university research and graduate education; (2) federal funding agency programs to enhance coupling; (3) uniform patent policies which permit universities to retain title to inventions made using government funds; (4) improve forecasting of scientific and technical manpower requirements.

The NSF's University/Industry Cooperative Research Program is "especially commended." But "the IRI views with great caution proposals to establish new 'Generic Technology Centers,' since there is significant risk that such laboratories may become a self-perpetuating drain on national resources and lack the necessary inputs on market needs and opportunities to be an effective force in the innovation process."

Industrial Research Institute/Research Corporation. Contribution of Basic Research to Recent Successful Industrial Innovations (Final Report to NSF under Grant No. PRA 77-17908, September 1979). 18 pp. plus 271 pp. of attachments.

Query of 529 companies to accumulate 54 usable case histories of industrial innovations.

Johnson, Elmima C. and Tornatsky, Louis G. "Academia and Industrial Innovation." In New Directions for Experiential Learning: Business and Higher Education--Toward New Alliances, Gerard G. Gold, Ed. San Francisco: Jossey-Bass, 1981, pp. 47-63.

A useful analytical approach to university-industry linkages, geared toward their role in industrial innovation. An "array of operational options" is presented. Several integrating concepts from the literature on organization theory dealing with interorganizational behavior are discussed: goal congruity and compatibility, boundary-spanning structures, and organizational incentives and awards.

These concepts are utilized in examining several cases described in the literature: MIT Polymer Processing Program, Harvard-Monsanto Research Project, Rockwell International-Black Colleges, NSF Innovation Centers, Harvard University-Genetic Engineering Company.

Keane, Peter and Place, Geoffrey. The Government Role in the Development and Commercialization of Technology. Proctor and Gamble Company draft, August 31, 1979. 20 pp.

Discusses three factors upon which the effectiveness of the process of the development and commercialization of new tech-

nology depends. The third factor is, "The effectiveness of coupling among the various sectors of the national R&D resource." Cites several authorities to argue that the current level of university-industry coupling is far below optimum.

Explores possible federal roles in stimulating these partnerships: "jawboning," matching industrial grants to universities with federal awards, and tax incentives for industry support of university research.

Kenyon, Sir George. "The Public View of the Universities: Direct Services to Industry." Speech to the Twelfth Commonwealth Universities Conference, Vancouver, British Columbia, Canada, August 1978. 14 pp. Summarized as "No Egg, No Chicken" in Manchester Guardian, March 6, 1979.

The Chairman of Manchester University's Council discusses university-industry relationships, both in training and research. Describes a range of efforts currently underway by the 44 British universities to "sell themselves to industry."

"Teaching companies" and "sandwich courses" are two instructional innovations bridging the gap between the sectors. Several universities have formed separate companies for the purpose of acquiring industrial research contracts.

Kiefer, David M. "Forging New and Stronger Links Between University and Industrial Scientists." Chemical and Engineering News, pp. 38-51, December 8, 1980.

Substantive overview of current developments in the area. Includes discussion of: (1) the available statistics; (2) existing NSF programs; (3) the Carter Administration initiatives for Department of Commerce support of "generic technology centers" and the Cooperative Automotive Research Program; (4) the Exxon-MIT combustion research agreement; (5) the Harvard-Monsanto arrangement for research in biology and biochemistry of organ development; (6) the University of Delaware Center for Catalytic Science and Technology with 20 industrial sponsors; (7) an extensive treatment of the movement toward establishment of a Chemical Research Council.

Langrish, J. "The Changing Relationship Between Science and Technology." Nature, 250, pp. 614-616, August 1974.

"The author examines the premise that technological innovation stems from scientific research, and suggests that relative to the early decades of the twentieth century, the relationship between science and technology has changed drastically. To test this premise, abstracts in five volumes of the Journal of the Society of Chemical Industry between 1884 and 1952 were classified by institutional locus, the main geographic divisions between Britain, the United States, and Europe. A marked decline in university-based contributions is paralleled by a concomitant increase in industrial-based research over time. When citations from 1957, 1961, and 1967 Industrial Reviews are examined by institutional locus, again a notable decrease in the relative contribution of the university to industrial chemistry emerges."

Lepkowski, Wil. "Academic Values Tested by MIT's New Center." Chemical and Engineering News, pp. 7-12, March 15, 1982.

An in-depth description and critique of the $125 million Whitehead Biomedical Research Institute at MIT. The story is constructed from interviews with David Baltimore, the head of the institute, and both proponents and opponents among the MIT faculty and administration. Extensive discussion of the issue of potential conflict of interest centering on Baltimore's $3.5 million equity stake in the biotechnology firm of Collaborative Research, Inc. The president of the company is also interviewed.

Libsch, J. F. "The Role of the Small, High Technology University." Special "Industry/University R&D" issue of Research Management, 19, May 1976.

The need in smaller universities is a means to achieve a "critical mass" effort of people and capabilities in selected research areas without destroying opportunities for individual research efforts.

Linvill, John G. "University Role in the Computer Age." Science, 215, pp. 802-806, February 12, 1982.

The Director of Industrial Programs at Stanford University's Center for Integrated Systems discusses the role of the university in the development of manpower resources in computer technology, and opportunities in university-industry linkages.

Little, Arthur D., Ltd. New Technology-Based Firms in the United Kingdom and the Federal Republic of Germany. London: A. D. Little, Ltd. for the Anglo-German Foundation for the Study of Industrial Society, 1977.

This comparative assessment of the environment for new technology-based firms (NTBFs) was undertaken to provide a detailed analysis of the environmental factors within each country which influence the developemnt of NTBFs and to make recommendations on how the creation and growth of such firms might be encouraged.

In contrast to the situation within the U.S. where there are several thousand NTBFs with sales of billions of dollars, there are only about 200 NTBFs in the U.K. and slightly less in Germany.

Among the factors cited as more favorable in the U.S. for the generation of NTBFs are: (1) greater mobility of individuals between academic institutions and private industry; and (2) the behavioral and attitudinal character of American scientists, many of whom are willing to set up their own businesses in order to exploit their technical knowledge.

A section on the role of universities in "spinning off" NTBFs (pp. 105-109) reports on two British studies in 1969 and 1970 which documented the reluctance of university scientists to become involved in industry.

Lohr, Steve. "Campuses Cementing Business Alliances." New York Times, November 16, 1980.

Prompted by Harvard's disclosure that it was considering establishment of a commercial genetic-engineering company, this article reports on a range of issues and activities in the university-industry area. In addition to the standard examples of Exxon-MIT and Harvard-Monsanto, mention is made of : a Purdue-Control Data project on computer design and production, and establishment by Estee Lauder of an Institute of Dermatology at Johns Hopkins University.

Lucchesi, Peter J. "Exxon's University-Industry Program." Proceedings of the First Midland Conference on Advances in Chemical Science and Technology, pp. 178-179, September 1979.

Describes the following Exxon programs: (1) Scientific Grant Program--about $500,000 a year in grants to professors selected by Exxon's basic research staff; (2) Exxon Fellowship Program (under development) to assist promising non-tenured faculty; (3) Visiting University Scientists Program--currently supporting eight university scientists working summers at Exxon labs; (4) Exxon Faculty Fellow Program--five year support to a prominent academic scientist who must spend 20% of his time at Exxon labs doing work of his own choice. One Fellow currently has support, and a second is soon to be named; (5) Exxon-MIT ten year agreement on combustion research--support at about $600,000 a year. Participating faculty devote 50% of their research time to working the agreement.

Lyon, R. E. Jr. "A Bridge Reconnecting Academia and Industry through Basic Research." Paper presented to the George

Washington University, Graduate Program in Science, Technology, and Public Policy, seminar series on "The Research System for the 1980s: Public Policy Issues," March 26, 1982. 5 pp.

The paper explores the following five main points: (1) the "connection" should be at the basic research level; (2) the "connection" must be at the cooperative, working level; (3) government should assist the process, but not attempt to "steer the science and technology"; (4) a tax incentive for industry is the first step; and (5) "industry funding should supplement and complement, not totally replace" government funding of academic research.

MacCordy, E. L. "Prospects for Government/University/Industry Research Cooperation." Paper presented before the Division of Science Resource Studies, National Science Foundation, Washington, D.C., September 22, 1980.

Explores the emerging role of the federal government in stimulating greater collaboration between universities and the industrial sector in research and development, and discusses the potential such linkages have for matching the technological development interests of industry with the research interests of university scientists. Government participation is described as including: the continued financing of fundamental research through university laboratories; the development of a climate of understanding and support for this collaborative process; the identification and evaluation of impediments in the innovation process; and the collection, analysis, and publication of statistics to monitor the progress of this triparty arrangement. Suggestions for ways in which universities and the industrial sector might contribute to the development of a research partnership are also provided.

Mansfield, Edwin. "Basic Research and Productivity Increase in Manufacturing." American Economic Review, 70, pp. 863-873, December 1980.

The results of Mansfield's study indicate that there is a statistically significant and direct relationship between the amount of basic research carried out by an industry, or by a firm, and its rate of increase of total factor productivity, when its expenditures on applied R&D are held constant.

Mansfield also collected new and original data on basic and applied R&D expenditures of 119 companies, concerning the changes in the mix of R&D between 1967 and 1977, and the changes they expect between 1977 and 1980. The findings

indicated that "practically all industries have cut the proportion of their R&D expenditures going for basic research. Most industries have cut the proportion going for relatively risky projects."

Mansfield cautions that correlation is not causation and that basic research expenditures could be a function of high productivity growth rather than vice versa.

Mansfield, Edwin et al. Research and Innovation in the Modern Corporation. New York: W. W. Norton, 1971.

This classic textbook treats the several phases of R&D in several R&D intensive industries. In Chapter 8 on major pharmaceutical innovations (originally the dissertation of co-author Jerome Schnee) data are presented on the sources of innovations for 68 of the most widely used drugs in the U.S.

Three major findings are advanced: (1) "External sources--sources other than the innovating firm--have played a major role in the technological progress of the ethical pharmaceutical industry in the U.S. These external sources provided 54% of the discoveries which produced pharmaceutical innovations during 1935-1962....in particular the innovations contributed by universities, hospitals, and research institutes (23% of the...total) had substantial... importance." (2) "...the grouping of the innovations into two time periods indicates that external sources have declined in importance over time." During 1935-1949 external sources provided 62% of the discoveries, which declined to 43% during the 1950-1962 period. (3) There was considerable variation among product categories in the sources of discoveries. A major factor accounting for these differences is the existing state of the art within the categories. The biological test and screening systems used by pharmaceutical firms have greater potential for uncovering new and useful chemical structures in those areas where there is reasonably high correlation between animal tests and clinical trials--e.g., digestive and genitourinary drugs, and respiratory system drugs. But in product categories not amenable to biological tests system approaches, such as drugs for neoplasms and the endocrine systems, the nonscreening approaches of external sources have been relatively more fruitful.

Mansfield, Edwin. "Tax Policy and Innovation." Science, pp. 1365-1371, March 12, 1982.

A comprehensive, scholarly review of what is known about the quantitative impact of particular tax measures upon the rate of innovation and R&D investments. Includes a detailed examination of the provisions of the Economic Recovery Tax Act of 1981 relating to R&D investments.

Concludes, "Without question, our nation's tax policies have a major impact on the rate of innovation. But because practically no studies have been conducted to estimate the effects of past or proposed tax changes, we have little or no dependable information concerning the quantitative impact of particular changes of this sort on the rate of innovation."

Marcy, Willard. "Patent Policies at Educational and Nonprofit Scientific Institutions." Paper presented at the 175th Meeting of the American Chemical Society (ACS Symposium Series 81), March 13-14, 1978. 12 pp.

Provides a brief history of the development of administrative mechanisms for handling the transfer of useful technology from the university laboratory to the marketplace, beginning with the pioneer efforts of Dr. Frederick Gardner Cottrell who founded the Research Corporation in 1912. Reviews the purpose, objectives, and administration of university patent policies, including procedures for reporting inventions and for distributing income realized from patents. Considers factors influencing university patent policies such as government policies and foreign patenting opportunities. Concludes with several examples of basic problems "which suitable drafted patent policy guidelines can help resolve."

Massachusetts Institute of Technology, Office of Sponsored Programs. "Research Agreements with Industrial Sponsors: Review Draft." MIT, Cambridge, Massachusetts, November 5, 1981. 31 pp.

This comprehensive guide summarizes the broad principles and specific contract provisions applicable to research agreements between MIT and industrial and commercial organizations. George Dummer, Director of the Office of Sponsored Programs, states in a separate letter, "This is still a review draft....consequently it should not be cited as representing an official statement of MIT policy, although it accurately reflects current practice."

McConnell, J. Douglas. "Productivity Improvement in Research and Development and Engineering in the United States." Society of Research Administrators' Journal, Vol. XII, pp. 5-14, Fall, 1980.

This article focuses primarily on internal management and personnel factors in productivity. However, a useful listing is presented of four nationwide factors that accounted

for decreasing R&D productivity in the U.S. from 1960 through 1975: (1) changes in capital gains tax codes in the late 1960s; (2) an obsession in the 1960s among many companies with the idea of rapid growth while minimizing risk to short-term earnings; (3) low investment in process engineering and manufacturing technology R&D compared to Japanese and German industry; (4) overenchantment by many companies with the glamor of high technology. "One mining [company] supported research in solid state physics and semiconductors for some 15 years without a payoff because top management felt it enhanced the image of the company."

Mogee, Mary Ellen. "The Relationship of Federal Support of Basic Research in Universities to Industrial Innovation and Productivity." In U.S. Congress, Joint Economic Committee, Special Study on Economic Change, Volume 3, Research & Innovation: Developing a Dynamic Nation. Washington, D.C.: U.S. Government Printing Office, December 29, 1980, pp. 257-279.

Section II examines "The Relationship of Basic Research to Industrial Innovation," and concludes that the contribution is usually delayed and indirect, but that science "seems to act as an 'engine' of technology."

Section III examines "The Relationship of Industrial Innovation to Productivity," and concludes that there is consensus of scholars that "the contribution of R&D to economic growth is high." Section IV on "The Relationships Between Universities and Industry" notes the "natural barriers" between university and industry that may obstruct the transfer of academic basic research to industrial utilization. These include differences with regard to patents, publications, and freedom of research directions. Concludes "the transfer of knowledge between academic science and industrial application requires active effort on both sides."

Miller, Julie Ann. "Spliced Genes Get Down to Business." Science News, 117, pp. 202-205, March 29, 1980.

Examines the founding and growth of Genentech, Cetus, Biogen, and Genex.

Murray, Thomas J. "Industry's New College Connection." Dun's Review, 59, pp. 52-54, May 1981.

A useful overview of developments in the university-industry area. The optimistic tone of the piece is reflected in the following: "Both academic and corporate leaders seem confident that they can meet their mutual goal to increase industry's share of total college research to 15% or $600 million

during the 1980s. To help the cuase along, they are currently lobbying hard to get tax incentives for corporate funding of projects."

Mullins, R. T. "A Technical Enrichment Program for Minority Students." Special "Industry/University R&D" issue of Research Management, 19, May 1976.

A preparatory and support program at Stevens Institute of Technology helps engineering students overcome the deficiencies of high school education and lowers attrition rate.

Nason, Howard K. and Steger, Joseph A. Support of Basic Research by Industry (prepared for NSF/STIA/SRS under Grant NSF C-76-21517). Washington, D.C.: National Science Foundation, 1978. 55 pp.

Presents results of a 1975 survey of company expenditures for R&D. Concludes that there had been a "real" decrease in industrial basic research expenditures. Advances five principal explanations for the decline.

National Academy of Engineering. Academe/Industry/Government: Interaction in Engineering Education. A Symposium at the Sixteenth Annual Meeting, October 30, 1980. Washington, D.C.: National Academy Press, 1981. 74 pp.

Panels of distinguished speakers addressed three broad topics: (1) In-house Industry Engineering Education Activities. Representatives from GM, IBM, Bell Laboratories, Hughes Aircraft, and GE described their programs. (2) Academe-Industry Joint Programs. Programs are described at Digital Equipment Corporation for equipment grants to universities; the Purdue-Control Data Corporation effort in the CAD/CAM area; another CAD/CAM course at UCLA assisted by several corporations. (3) The Support Role of Government. Federal programs are described including NSF's Industry/University Cooperative Research Program, NSF's University/Industry Cooperative Research Centers, Innovation Centers, and its graduate fellowships. DOE's programs to help support university-industry interaction in research are described, as well as its $3 million institutional awards program which requires the universities to develop mechanisms to ensure that there is long-term industrial participation. The role of the DOE supported National Laboratories is also mentioned.

National Association of College and University Business Officers. "Survey of Institutional Patent Policies and Patent Administration." Administrative Service Supplement, March 1978.

Examines the findings from a survey of university patent policies and practices conducted by the Society of University Patent Administrators in 1977. Data are tabulated for the 48 major research institutions responding to the survey, and the implications of the results are discussed. More than 70% of the responding institutions have established "patent committees" whose functions include making decisions on patenting inventions, formulating patent policy, and determining royalty distributions for the institution. Well over 80% of the institutions use patent management firms such as the Research Corporation. The majority of institutions invest their share of royalties from patenting activities in further research. Among the other issues analyzed are: the number of patents applied for and issued during the last ten years; the use of arbitration in the event of disagreement about the institution's rights in an invention; methods to obtain invention disclosures; institution patent agreements with federal agencies.

National Commission on Research. Industry and the Universities: Developing Cooperative Research Relationships in the National Interest. August 1980. 38 pp.

Reviews the post-war funding history of basic research in universities and industry. Concludes that with appropriate safeguards, increased research relationships between universities and industry "currently have an opportunity for growth, and out of that growth will come increased innovation."

Report contains an excellent systematic statement of the benefits and hazards of cooperative research relationships to universities, industries, and government. Also, there is a good statement of the roles and responsibilities of the partners. A one-page bibliography is appended.

National Research Council. "Research in Europe and the United States." In Outlook for Science and Technology: The Next Five Years, Chapter 13. San Francisco: W. H. Freeman, 1982.

This chapter describes the R&D systems of the United Kingdom, France, and Germany. The materials were primarily collected and written up by Dr. Charles V. Kidd of George Washington University and Dr. Bruce Smith, co-author of The State of Academic Science. Each country report contains a number of references to university-industry research and training linkages, seen in the perspective of the total research system of the country.

Noble, David F. and Pfund, Nancy E. "The Plastic Tower: Business Goes Back to College." The Nation, pp. 233, 246-252, September 20, 1980.

Noble teaches the history of technology at MIT, and Pfund is a research associate at the Health Services Research Division of Stanford Medical School.

The authors view the emergent phenomenology of university-industry relationships from a socialist perspective. The universities and their faculties are seen as being induced through a variety of incentives into structuring their research along lines dictated by corporate profit motives.

The universities are seen as "an inherited resource that rightfully belong to us all, a substantial social investment" with a large degree of public accountability for their work. "This fact is recognized explicitly in the case of government support. Funds are given in the name of the citizenry by government to foster social ends that are shaped and defined in the political process--a multiplicity and diversity of ends which oftentimes conflict."

The authors argue that in the case of the $23 million Harvard-Monsanto agreement, "the firm has in essence transformed part of the public sector social resource into a private sector preserve, with little public scrutiny or accountability over its use of the facility."

The authors further argue that in the eager campus quest for industrial support, a social climate has been created in which dissenters and critics of industrial perspectives will be elbowed aside and their voices suppressed.

Noble's book American by Design: Science, Technology and the Rise of Corporate Capitalism (New York: Oxford University Press) provides a full historical analysis from this general perspective.

Norman, Colin. "MIT Agonizes Over Links with Research Unit." Science, pp. 416-417, October 23, 1981.

Reports on the debate in the MIT community about the proposed establishment of the Whitehead Institute for Biomedical Research with a unique affiliation between the institute and MIT. Mr. Edwin C. Whitehead, a self-made millionaire, proposed to spend $20 million to build and equip the institute, provide $5 million a year in operating funds, and leave an endowment of $100 million when he dies. He characterized the proposed institute as "a purely philanthropic enterprise."

Faculty concern revolves around three issues: the administrative structure, appointment of faculty, and selection of research projects.

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

Omenn, Gilbert S. "University/Industry Research Linkages: Arrangements Between Faculty Members and Their Universities." Paper presented at AAAS Symposium on Impacts of Commercial Genetic Engineering on Universities and Nonprofit Institutions, Washington, D.C., January 6, 1982.

Substantive review of cases of faculty who have sought opportunities to combine academic and commercial roles. Materials are included on: (1) the history and functioning of the Wisconsin Alumni Research Foundation (WARF); (2) Indiana University and Crest Toothpaste; (3) MIT's Industrial Liaison Program; (4) two cases in econometric forecasting--Otto Eckstein's Data Resources Incorporated and Laurence Klein's Wharton Econometric Forecasting Association; (5) medical school clinical practice plans, including income sharing plans for basic science faculty.

Omenn prescribes a pluralistic approach but says, "We should encourage coherent institutional responses and explicit, openly negotiated arrangements with their most precious resource--their faculty--for their mutual benefit and for the public interest.

Pake, George E. "Some Industrial Perspectives on the University-Industry Relationship." Council of Graduate Schools Communicator, 12, pp. 1-2, 8-10, April 1980. Revised version published in Physics Today, pp. 44-47, January 1981.

The Vice President for Corporate Research at the Xerox Corporation presents a good typology of mechanisms for university-industry interaction. They include:
-Participation of business and industrial leaders in university governance: (1) boards of trustees, (2) visiting committees;
-Direct support by industry of programs in universities: (1) direct funding of academic research programs, (2) joint research ventures, (3) company funded fellowships and scholarships, (4) industrial philanthropic grants;
-University services provided to or for industry: (1) continuing education programs, (2) extension services, (3) specially tailored short courses, (4) industrial associate or affiliate programs;
-Enhancement of personal development of individuals: (1) faculty sabbaticals in industry, (2) industrial leaves to university faculties, (3) faculty consulting to industry, (4) placement of graduates in industry.

The role of government is also discussed, especially in relation to tax arrangements for R&D investments.

Prager, D. J. and Omenn, G. S. "Research, Innovation, and University-Industry Linkages." Science, 207, pp. 379-384, January 25, 1980.

At the time of writing, Prager and Omenn were with the Office of the President's Science Adviser.

Carter Administration actions to enhance basic research and stimulate industrial innovation have focused attention on the importance of formal university-industry cooperative relationships in science and engineering. This paper examines the status of and potential for university-industry research consortia and research partnerships and the current and prospective roles of the federal government in stimulating such relationships. A useful typology of university-industry relationships is presented.

Rabkin, Y. M. and Lafitte-Houssat, J. J. "Cooperative Research in the Petroleum Industry." Scientometrics, 1, pp. 327-338, 1979.

Paper describes an unusual historical case of cooperation in petroleum research between industry, government, and the universities.

"After years of debate, the American Petroleum Institute (API), a trade association representing America's oil companies, decided in 1926 to sponsor nearly thirty research projects connected with various aspects of the science of petroleum. One of the projects, known as API Research Project 6, was conducted at the National Bureau of Standards (NBS) in Washington and from 1950 until its termination a decade later at the Carnegie Institute of Technology in Pittsburgh. The project was remarkable in many respects. For one, while it was financially sponsored by the API, i.e., by the entire petroleum industry, its operation took place outside industry, and its results were openly published."

"The project's organization was of a novel cooperative nature. The cooperation among the oil companies embodied by the API, and the cooperation between the API, on the one hand, and the Federal Government and several universities, on the other, affected the goals and the modes of operation of Project 6. Both kinds of cooperation involved contradictions. One basic contradiction could be noticed in the initial formulation of the research program. It had to generate knowledge relevant to the interests of the petroleum industry. At the same time that knowledge had to be fundamental, i.e., not 'too relevant,' because the practical application and commercialization of the results had to be left to individual companies. The maintenance of a balance between relevance and fundamentality was a major concern for those involved in the research planning at the API."

Rae, John. "The Application of Science to Industry." In The Organization of Knowledge in Modern America, 1860-1920, Alexandra Oleson and John Voss, Eds. Baltimore: Johns Hopkins University Press, 1979, pp. 249-268.

The author, Professor Emeritus of the History of Technology at Harvey Mudd College, provides a compact summary and interpretation of the uses of science by industry in the period covered.

"Since America was a new country...there was normally more work to be done than there were hands available to do it. There was therefore a premium on devising techniques and gadgets that supplemented labor. It was important to be able to make devices that worked, but it was not important to know why they worked."

The absence in America of well established universities or any considerable body of "gentlemen scientists" led to an American tradition that "minimized the pursuit of science for its own sake and magnified...the untutored but ingenious gadgeteer." Further, the absence of sufficient trained craftsmen in America strengthened the role of the "cut-and-try" tinkerer. "The ingenious tinker enjoyed an astonishing longevity as an American folk-hero, reaching an apex in fact in the 20th century with Thomas A. Edison and Henry Ford." The creation of institutional structures for the application of science to industry took the form of development of professional societies during the late 19th and early 20th centuries, and the growth after the turn of the century of in-house industrial research laboratories. Many of these were initially geared towards analysis and testing."

The First World War created a situation where "for the first time in American experience, scientists and engineers from industry, government, and the academic world came together to work cooperatively in group research....There was a lesson to be learned, and it was." When the country returned to peacetime activity it was ready for a new stage in the utilization of science by industry--the substitution for "cut-and-try" methods of the application of science through organized and systematic research.

Research Corporation. Science, Invention and Society: The Story of a Unique American Institution. New York: Research Corporation, 1972.

Describes the formulation (in 1912), growth and functioning of the Research Corporation. In 1979 competitive peer reviewed awards for basic research totaled $2.3 million. An additional $500,000 was pledged in 1979 by a variety of corporations and foundations to support basic research through Research Corporation programs.

The Research Invention Administration Program provides institutional visiting and evaluation (including legal) services to identify inventions with potential for technology development, and to assist in the patenting process. The amount of $1.6 million was expended in 1979 in support of activities to evaluate nearly 400 inventions from 114 institutions. Royalties and license fees from successful patents in this program are shared by RC, the inventors and their institutions. In 1979 a gross income of $4 million from these activities was allocated as follows: $1 million to institutions; $0.8 million to inventors; and $1.4 million for support to RC programs.

Ridgeway, James. The Closed Corporation. New York: Random House, 1968. 273 pp.

The best selling Vietnam era radical critique of the "military-industrial-academic complex."

Numerous cases are presented of cozy relationships between professors and presidents and corporate enterprise. These are taken as evidence for the "corruption" of academia. Many of these same cases today are seen as the harbingers of new roles for academia in society--increasing technology transfer to raise industrial productivity. A case in point is the WARF--Wisconsin Alumni Research Fund--which was castigated by Ridgeway for engaging in price fixing, but which today is hailed as a model for obtaining university benefits from university research.

The book is a goldmine of briefly discussed cases of professor-entrepreneurs running businesses while retaining their university positions, corporate board activities of academic administrators (including a lengthy list of names), university owned business deals, the varieties of consulting, and the related conflicts of interest and the strategies for investment of academic endowment funds. Interesting accounts are made of the role of professors with consulting or research relationships with industry or trade associations giving Congressional testimony for or against bills in the interest of their patrons--cases in the pharmaceutical, automobile, and tobacco industries are treated in detail.

A whole chapter is devoted to several University of California enterprises ("Multiversity Inc."). Examined are UC's relationships with the AEC, the Pacific Gas and Electric Company, agribusiness on the braceros issues, and the Irvine Company. The private industry connections of the university administrators are catalogued in detail.

Roberts, Edward B. and Peters, Donald H. "Commercial Innovations from University Faculty." Research Policy, 10, pp. 108-126, 1981.

Study of a sample of faculty of the Massachusetts Institute of Technology (MIT) has determined that many academic scientists and engineers have commercially oriented ideas, but that few take strong steps to exploit their ideas. "Idea-havers" scored high on creativity measurement instruments and participated in more diverse work environments. Academic "idea-exploiters" are marked by personal background characteristics of family, religion, and parental occupation that have been identified in earlier research as characteristics of new technical company entrepreneurs. Other indicators reflecting high need for achievement were also observed in the idea-exploiting group. Finally, professors reporting commercial ideas were much more likely to be involved in consulting with business or government than were those who did not report ideas. Policy implications for universities and countries interested in technology-oriented development are discussed.

Robinson, Arthur L. "National Synchrotron Light Source Readied." Science, 214, October 16, 1981.

Reviews the evolution of policies for expansion, equipping and industrial utilization of national facilities for synchrotron radiation sources.

The innovative concept of "participating research teams" (PRTs) was developed at the new Brookhaven National Laboratory National Synchrotron Light source.

"A group (industrial, university, or government laboratory) accepted as a PRT would build and finance one or more experimental stations in exchange for unrestricted use of the facilities for 75 percent of the running time. The PRT would also have to give outside users access to its instrumentation for the remaining 25 percent of the time. Included in PRTs selected so far are IBM, Bell Laboratories, Exxon, and Xerox, who together account for about 40 percent of the PRT-supplied experimental stations."

The financial contributions of the industrial members of the PRTs provide a way to get the light source instrumented at a much faster pace than would otherwise be possible given the available government funding.

Rogers, Everett M., Eveland, J. D., and Bean, Alden S. "Extending the Agricultural Extension Model" (U.S. Department of Commerce, NTIS # PB-285119). Stanford University Institute for Communication Research, September 1976.

This report is responsive to concerns among government and industrial officials that the U.S. lacks adequate mechanisms for linking the performer and users of research together for purposes of enhancing technological innovation. It is often asserted that "the agricultural extension model" should be the basis for improving upon existing technology transfer and research utilization mechanisms. This report describes the historical development and current operating structure of the Cooperative Extension Service (CES) of the U.S. Department of Agriculture, in order to accurately portray the major features of what is commonly called the "Agricultural Extension System." Comparisons are made between the CES and seven other government programs designed to enhance innovation and ostensibly modeled after the CES. Conclusions are drawn about the degree of correspondence between the CES and its imitators and their relative effectiveness. Recommendations for future research are noted.

Science Council of Canada. "University-Industry Interaction, Statement of the Chairman, Dr. Claude Fortier." In Annual Review 1981 (Cat. No. SS1-2/1981), pp. 21-44.

Explores at length the issues of the government role in the provision of university trained science and engineering "operational manpower" and "research-trained manpower."

Section on university-industry cooperation discusses three model relationships: the Pulp and Paper Research Institute of Canada and McGill University, the Center for Cold Ocean Resources Engineering and Memorial University in St. John's, and the research brokering functions of the Industrial Research Institutes, and the Centres for Advanced Technology--both created by the Federal Department of Industry, Trade, and Commerce. Additional programs discussed: (1) L'Institut National de la Recherche Scientifique, a constituent branch of the University of Quebec, INRS-Telecommunications--a center for graduate studies and research situated within the laboratories of an industrial organization (Bell Northern Research); (2) PRAI grants--Project Research Applicable in Industry; (3) the "Relevant Research" Approach; (4) Industrial Innovation Centeres in Quebec and Ontario; (5) Initiatives by industry.

Servos, John W. "The Industrial Relations of Science: Chemical Engineering at M.I.T., 1900-1939." Isis, 71, pp. 531-549, 1980.

This study examines the questions: "How did industrial patronage [for scientific research and training at universities] affect the evolution of academic science, basic and applied, and how did it influence the goals and values of scientists themselves?"

Using primary materials from MIT archives the study documents two major transformations of the institution. The first, around the turn of the century, saw the shift from a

local, vocational/technical school to a nationally recognized institution with both basic (A. Noyes) and applied (William H. Walker and A. D. Little) research and training capabilities.

During the decades of the 1910s and 1920s, the applied research orientation came to dominate MIT, with strong ties to and support from industrial organizations.

The second transformation, during the 1930s, saw a realignment of the balance between basic research and basic science training, applied research and training in current industrial technique. The study is an instructive case on the limits of industrial support of an academic institution.

During the 1910s and 1920s "[W.] Walker and [A. D.] Little has been willing to allow industry to determine the priorities of the Research Laboratory for Applied Chemistry and indeed to subordinate the program in chemical engineering to the immediate interests of business. They were willing to do so because they perceived an identity of interests between businessmen and applied scientists. Their successors were, to a much greater degree, sensitive to the need for disciplinary independence and eager to follow their own judgements regarding the best opportunities for research. In part this attitude arose from their experience with the restrictions imposed by sponsors; in part it resulted from the increasingly abstract character of chemical engineering itself."

Shapero, Albert. University-Industry Interactions: Recurring Expectations, Unwarranted Assumptions and Feasible Policies (prepared for NSF/STIA/PRA under PO-SP-79-0991). Columbus, Ohio: Ohio State University, July 31, 1979.

Explores implications of several aspects of university social and organizational structure for possible expansion of university-industry relationships. Five "exemplar options" are recommended. Bibliography.

Sinnott, Maurice. "University-Industry Programs: An Analysis of a Series of Joint University-Industry Research Programs Sponsored by the Defence Advanced Research Projects Agency." Paper presented at a Conference on University Research Management, June 6-7, 1977. 7 pp.

Written by an associate dean of engineering at the University of Michigan, these remarks track and interpret DARPS's experiments in "coupling" companies and universities in R&D during the 1960s.

The author believes that the principal lesson learned from these experiments was the development of a better appreciation by both industry and the universities of each other's strengths and limitations in R&D.

Small, Henry and Greenlee, Edwin. A Citation and Publication Analysis of U.S. Industrial Organizations (Final Report for NSF Contract PRM 77-10048). Philadelphia: Institute for Scientific Information, January 1980. 95 pp.

This is an exploratory study using Science Citation Index data for 1973 and 1976 to see how these data and techniques can be used to examine industrial research.

The study determines the extent to which industrial organizations cited research performed in the university, government, and other sectors, and the extent to which industrial organizations were cited by the various sectors.

Several kinds of evidence were noted of a gradual decline in publication productivity of industrial organizations from 1973-1976--especially in basic research.

Interesting citation measures of association between specific industrial firms are presented to map the relationships between these organizations. A structure which reflected research field and product orientation was formed.

Smith, Lee. "The Unsentimental Corporate Giver." Fortune, pp. 121-124, 129, 132, 137, 140, September 21, 1981.

Useful examination of the patterns and motivations of corporate philanthropy. Contrasts two philosophies of corporate philanthropy: that espoused by Milton Friedman, "supposedly the headmaster of the give-nothing school," and the view that "the purpose of business is to serve society," sponsored by Lawrence A. Wien and Kenneth N. Dayton.

Some relevant facts cited are: (1) In the late 1970s corporations (and corporate sponsored foundations) surpassed the independent foundations in total gifts for the first time since the mid-1950s. (2) Average gifts have oscillated around 1% of pre-tax earnings since the 1950s. (3) Five of the ten top recipients of corporate largesse were universities. (4) The proportion of total corporate gifts going to education (about 40%) declined slightly between 1965 and 1979.

Swalin, R. A. "Improving Interaction Between the University and the Technical Community." Special "Industry/University R&D" issue of Research Management, 19, May 1976.

A number of steps taken at the University of Minnesota have substantially increased cooperative efforts between the university and the surrounding technical community.

Sweden. Utbildnings Departementet. Adjungerade Professorer: Utvardering av forsoksverksamheten aren 1973-1979. Stockholm: LiberForlag, 1979. (Ds U 1979:13) In Swedish.

An evaluative study, based on interviews, of seven years of experience with an "adjunct professor" program between industries and universities in Sweden. Descriptive information on the 60 participants--their education, employment, work activities and field of competence. Description of the administrative arrangements--including percent of time and salary adjustment. Recruitment to the program and motivations are explored, as are effects upon the incumbents.

Thomas, Lewis. "Business and Basic Science." Bulletin of the New York Academy of Medicine, 57, pp. 493-502, July-August 1981.

"The recent examples of marketable products from hybridoma antibodies and recombinant DNA genomes ought to be raising new anxieties....[Corporations] are or should be uniquely concerned, out of pure self interest, for what will be available in, say, the year 1995 or 2000, waiting then for application to new products. If long-term investments in basic science are not continued, they will find themselves out of business or at least out of competition with their counterparts."

Tokyo Chamber of Commerce and Industry. The Current Condition and Future Prospects of Industry-University Cooperation in Research and Development and in Manpower Development. May 1973.

Report is in Japanese, but a ten-page English summary was prepared for NSF.

In 1972-1973 about 700 Japanese companies returned questionnaires dealing with their modes and levels of interaction with universities. Past, current, and desired future cooperation were described. The study analyzes present and expected future involvement in 13 types of interaction, including "joint research," "offering scholarships," "sending employees as lecturers to universities," and "utilizing facilities of universities," by size of company and type of industry. Thus, for example, 29% (52%) of all the manufacturing companies reported current involvement in "doing joint research and commissioned research"--32% (58%) for the "machine and tool" industry, 48% (60%) for concerns in the "chemical, rubber, ceramics, and earth and rocks" industry, and 21% (46%) of the companies in "steel, metal, and nonferrous metal." The percentages in parentheses are the companies expectations for future cooperation--thus, in 1973 Japanese companies held very optimistic expectations of expansion of their research connections with universities.

United Nations Association of the USA, Economic Policy Council, Technology Transfer Panel. The Growth of the U.S. and World Economies Through Technological Innovation and Transfer. New York: UNA-USA, Inc., 1980. 76 pp.

This report examines the development of industrial technology and its international transfer. It claims that it "is in the main a consensus veiw among the business, labor, and academic groups represented on the Panel."

Amongst the recommendations aimed at the generation of new technologies in the U.S. were:

-"Business, labor, universities, and financial institutions should work together more closely at all levels--plant, community, industry, trade association, and national organization--to develop new technologies at home and to acquire new technologies from abroad."

-"The U.S. Government should play an important but largely indirect role. It should support technologies with industry-wide or inter-industry applications...."

-Business is encouraged "to invest greater resources in joint industry-university research...."

United States, Department of Commerce, Office of Productivity, Technology, and Innovation, Office of Cooperative Generic Technology. Cooperative R&D Programs to Stimulate Industrial Innovation in Selected Countries. Washington, D.C.: various dates in 1979 and 1980.

Appendix 17 - "A Summary" by Elaine Bunten-Mines, Julie Menke, and Carl W. Shepherd, June 1980. 75 pp.
Appendix 16 - "Sweden" by Carl W. Shepherd, June 1980. 55 pp.
Appendix 14 - "Japan" (no author listed), November 1979. 73 pp.
Appendix 11 - "Federal Republic of Germany" by Carl W. Shepherd, May 1980. 124 pp.

These studies were carried out in response to an OMB directive to "review past Federal and State cooperative technology programs...and those of other countries" in order to determine the viability of the Department of Commerce's proposed Cooperative Generic Technology Program. All of the reports are considered working papers for discussion only and do not represent official policy or conclusions of the Department of Commerce.

United States, Department of Energy/Industrial Research Institute. "Mechanisms of University-Industry Interaction." IRI/DOE Conference, Reston, Virginia, December 7-8, 1978. 117 pp.

Packet of materials for attendees containing: four short statements of problems and issues by participants; short descriptions of nine actual workshop, fellowship, intern, equipment and liaison programs; short descriptions of seven joint research programs.

United States, Department of Justice. Antitrust Guide Concerning Research Joint Ventures. Washington, D.C.: U.S. Government Printing Office, 1980.

An outgrowth of the Carter Administration Domestic Policy Review of Industrial Innovation, this document seeks to clarify Department of Justice policy on collaboration among firms in research to make certain that the antitrust laws are not "mistakenly understood to prevent cooperative activity...."

The Guide includes a general introduction explaining the Antitrust Division's analytical approach to research joint ventures, followed by a number of hypothetical cases designed to exemplify the most important or difficult situations, and the Division's approach to them. In addition, the Guide contains summaries of previous business review clearances and advisory letters of the Antitrust Division relating to joint research.

United States, House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology. Hearings on Government and Innovation: University-Industry Relations, July 31, August 1-2, 1979. Washington, D.C.: U.S. Government Printing Office, 1979. 522 pp.

Contains testimony, letters and articles by a variety of persons prominent in R&D relating to proposed legislation entitled "National Science and Technology Innovation Act of 1979."

United States, National Science Foundation. 1980 Industrial Program Grantee Conference Proceedings, David D. Douglas, Ed., Industrial Research and Extension Center, University of Arkansas, Little Rock, Arkansas. 172 pp.

These proceedings document the substance of a conference held in Hot Springs, Arkansas, May 12-14, 1980, on the theme of innovation and productivity in America. Seven sections containing 4-6 papers each were on the following topics: (1) thematic presentations on innovation and productivity; (2) current programs--university/industry coupling; (3) current programs--innovation center/technology innovation projects; (4) current programs--small business innovation research; (5) current programs--planning experiments; (6) government views--university/industry cooperative research; (7) lessons learned/new opportunities.

United States, National Science Foundation. Proceedings of a Conference on Academic & Industrial Basic Research, Princeton University, November 1960. NSF 61-39.

Participants from 43 major R&D companies, universities, and government examine the conditions for advance in basic science. The roles of the several sectors in basic research were discussed, and four papers examined the industrial experience in basic research (GE, Bell Telephone, Merck, Celanese). The interdependence of academic and industrial basic research was discussed in three papers on: polymers, semiconductors, and aerodynamics.

United States, National Science Foundation. Research in Industry: Roles of the Government and the National Science Foundation. Washington, D.C.: NSF, December 1976. 21 pp. plus 160 pp. attachments.

Reviews role of scientific research in nonacademic institutions with special attention to NSF programs and policies relating to private industry. Contains much data and bibliography.

Useem, Elizabeth. "Education and High Technology Industry: The Case of Silicon Valley. Summary of Research Findings." Boston, Massachusetts, August 1981. 32 pp.

Dr. Useem, sociology professor at Boston State College, has produced a richly documented report on the varieties of relationships between the over 500 high technology firms in the Santa Clara valley (Silicon Valley) and all levels of the educational system--secondary schools, two-year community colleges, and four-year colleges and universities. The study explores the degree and manner in which educational institutions are changing to meet the demands of a rapidly transforming technology.

The general conclusion is that the relationships are positive, strong, and evolving in appropriate directions at the university level. At the community college level relationships are bedeviled with misunderstandings, mistrust, and discontinuities, with no real improvements perceived. At the secondary level, science and technical education is in complete disarray still sinking fast, and with few exceptions the high technology business community is paying little attention. During 1981-1982, Dr. Useem will carry out a comparative study of education-industry relationships in the Boston/Route 126 area.

Useem, Michael. "Business Segments and Corporate Relations with U.S. Universities." Social Problems, 29, pp. 129-141, December 1981.

It is generally assumed that business derives important benefits from higher education and provides financial support in return. This presumes that business is relatively undifferentiated, and that corporate relations with universities are largely uniform. Using data on the governing boards and characteristics of 341 colleges and universities selected through a national sample, this paper shows that what is called the "dominant stratum" of business, rather than business as a whole, has formed an enduring relationship with universities that are oriented toward education of the elite; the governing boards of these universities are disproportionately composed of members of the dominant stratum; universities with high proportions of dominant stratum trustees are more successful than others in raising financial support from corporations; and members of the dominant stratum take a direct role in obtaining corporate contributions. The findings imply that relations between business and higher education are structured less around business as a whole and more around a distinct segment of business. Extensive bibliography on corporate and university ownership and control.

Watson, Kenneth M. "Technologists in Top Management, Part One: The Business SUCCESS Factor," and "Part Two: Management, Technologists, Coordination, and Communication." Chemical Engineering Progress, 55, pp. 37-44, 37-41, February and May 1959.

The papers examine the factors determining business success and the relationship of technology to it. "In the study reported herein, a business success factor was developed by evaluating and combining annual profit on invested capital with rates of income growth and capital expansion. A technology factor was then developed by combining level of research and development activity with percentage participation of technologists in management."

"The business and technological performances during the ten years 1948-58 are compared for 20 large oil companies and 20 large chemical companies on the basis of readily available published data. Companies having higher technological factors are found to show significantly greater success indexes. No significant relationship is found between business success index and either research level, or technological participation in management alone. There are indications, however, that a high level of research activity may be a liability unless combined with a technologically perceptive management. Such results are believed to provide standards of comparison which will be generally useful to management, technologists, and investors."

Weber, David. "A New Industry Springs to Life." Venture, pp. 88-93, May 1981.

This article catalogues the mushrooming of entrepreneurial biotechnology companies--at least 40 since 1978. The new companies include those aiming to produce products in fields ranging from medicine to plant and animal breeding, and from energy production to industrial chemistry. Other companies focus on support activities, making biological materials, such as already modified DNA, machinery with which to conduct research, and even a new crop of newsletters and journals.

A significant proportion of these companies have direct academic connections.

Weiner, Charles. "Relations of Science, Government, and Industry: The Case of Recombinant DNA." In Policy Outlook: Science, Technology, and the Issues of the Eighties. Washington, D.C.: American Association for the Advancement of Science, 1981, pp. 109-156.

Excellent short history of the problems posed by the rapid development of recombinant DNA techniques. Topics treated include the concerns about risks in the 1970s, the current status of DNA technology and its regulation, and policy problems and prospects for applied molecular genetics in the 1980s. The perceived damages to the health of basic scientific research posed by its close association with highly profitable commercial ventures are discussed in detail. Bibliography.

Weiss, Malcolm A. and White, David C. "The MIT Energy Laboratory and the Role of Industry/University Interaction." Paper presented at the 1980 ASM Materials and Processes Show and Congress, Cleveland, Ohio, October 30, 1980. 12 pp.

The Director of the MIT Energy Laboratory describes four methods by which industry sponsors research at his laboratory. The lab has a $12 million budget, roughly two thirds from government and one third from industry. He states, "although it doesn't come easy...Government money comes easier...industry sponsored research is worth going after." The benefits for MIT and for the sponsoring companies are listed and four models of support--in addition to the traditional one-shot support of a single faculty member's research--are listed:
-Center for Energy Policy Research--basically an "associates" program with three year rolling commitments according to no fixed formula (24 companies, 9 other organizations). No restrictions on MIT's choice of topics. Many associates have their senior staff participate in projects. 1980 budget about $500,000.

-Electric Utility Workshop--seminar-workshop program in which electric utility companies identify problems and then sponsor research projects. Sponsors have prepublication review rights, and nonexclusive royalty free patent rights. Up to 15 sponsors spend about $500,000-$700,000 annually.
-Exxon Research and Engineering Combustion Research--a ten year bilateral agreement for annual project support of about $600,000 predominantly for specific basic research projects mutually agreeable to Exxon and MIT in the combustion of fuels containing carbon. Some portion of the support will be spent at the sole discretion of MIT researchers. Exxon has the right to review proposed publications for patent applications and to ensure that no proprietary information disclosed by Exxon to MIT is included. MIT owns the patents and Exxon has a nonexclusive royalty free right to use the patents. Termination of the agreement requires two year's notice. The MIT researchers agree to make at least half their research time available to the program.
-ASPEN Project--a large computer program developed with DOE support as a tool to simulate proposed or existing industrial processes. Firms (48 so far) commit $15,000-$25,000 at MIT over two years, for which MIT trains their personnel in the use of ASPEN and make available the MIT computer to work real problems of the firm, and to assist in installing ASPEN on an in-house computer if desired.

Concluding bon mot: "How does a university negotiate with a firm to a mutually satisfactory agreement? The same way any negotiation is carried out--by knowing the location of both pressure points and erogenous zones and when to touch which."

Wolff, Michael. "The President's Initiatives for Industrial Innovation." Research Management, pp. 172, January 1980.

Useful report on the substance and political background of President Carter's initiatives relating to his domestic policy review of industrial innovation. While some of the measures received fairly universal approval, e.g., in the patent area, considerable disappointment was expressed in industrial circles that no tax measures were proposed to "address the disincentives to capital formation."

Wolff, Michael. "The Why, When, and How of Directed Basic Re-Search." Research Management, pp. 29-31, May 1981.

"The enthusiastic growth in basic research that occurred in industry during the booming 1950s and 1960s was throttled by the financial turbulence of the 1970s. For the decade of the 1980s, however, concern with U.S. productivity and technological competitiveness spells a potential resurgence in industrial basic research--but with one difference: this time it will be directed research."

"At a recent IRI Special Interest Session a group of research managers addressed four key questions related to directed basic research (DBR). The answers provide useful guidelines for the successful conduct of this often misunderstood type of research."

One manager included the following criterion for deciding what DBR to undertake: "Leverage your research dollar whenever possible with working university relationships and competitively won Federal study contracts in areas of basic research relevant to your company's technologies."

Subject-to-Author Cross Reference for Appendix IV

Agricultural Extension-Model for Technology Transfer

Rogers

Biotechnology and Genetic Engineering Industry

Business Week, Culliton 1981, B. Davis, Fox 6/22/81, Fox 10/12/81, Lepkowski, Miller, Norman, Thomas, Weber, Weiner.

Cases of University-Industry Interactions

American Petroleum Institute (API) - Rabkin
Case Western Reserve University, Macromolecular Science - Council of Graduate Schools
Case Western Reserve University and Diamond-Shamrock Company - Dietrich
Defense Advanced Research Project Agency (DARPA) - Bement, Sinnott
Econometric Forecasting Cases - Omenn
Exxon, University/Industry Programs - Lucchesi
Harvard-Monsanto - Culliton 1977
Indiana University and Crest Toothpaste - Omenn
MIT, Industrial Liaison - Council of Graduate Schools, Omenn
MIT, Chemical Engineering in 1920s - Servos
MIT, Energy Laboratory - Weiss
MIT, Whitehead Institute - Norman, Lepkowski
Monsanto Central Research Grant Clearinghouse - Chemical Week
NSF University-Industry Programs - US/NSF 1980
Pulp and Paper Research Institute of Canada (PAPRICAN) - Bindon, Science Council of Canada
Research Triangle Institute (RTI) - Hamilton
Rockwell International Incorporated Programs with Minority Universities - Cannon, Council of Graduate Schools
Silicon Valley - Useem
University of California at Davis-Calgene and Allied Chemical - Dickson

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

University of California at Irvine, Industrial Associates - Hill
University of Delaware, Composites Center - Council of Graduate Schools
University of Minnesota - Swalin

Commercial Innovations by University Faculty

Roberts

Corporate Philanthropy

Branscomb 1981, Chemical Week, Council for Financial Aid to Education, Research Corporation, L. Smith, M. Useem

Industrial Research Organization

Chemical Week, David, Fernelius, Healey, Industrial Research Institute/Research Corporation, Mansfield 1971, Watson, Wolff 1981.

Industrial Research-Science Citation Analysis

Small

Intellectual Property-Patents, Licensing, Proprietary Rights

Fox 10/12/81, Marcy, Massachusetts Institute of Technology, National Association of College and University Business Officers, Omenn, Research Corporation, US Department of Justice.

Science, Technology, Innovation and Productivity-Relationships Among

Gilpin, Keane, Langrish, Mansfield 1980, McConnell, Mogee, Rae, Watson

Tax Policy

Mansfield 1982

University-Industry Relationships-Conferences

US Department of Energy/Industrial Research Institute, Dickson, Engles, Heylin, US/NSF 1980

University-Industry Relationships-Dangers for Academic Research

Bok, Dickson, Lepkowski, Servos

University-Industry Relationships-Education

Hencke et al., Honan, Mullins, National Academy of Engineering.

University-Industry Relationships-Foreign Countries

Sweden
- Sweden/United States Department of Commerce, Office of Productivity, Technology, and Innovation.

France
- National Research Council (NRC)

Japan
- Tokyo Chamber of Commerce/United States Department of Commerce, Office of Productivity, Technology, and Innovation.

USSR
- Borstein

United Kingdom
- British Council, Gallagher, Kenyon, NRC, A. D. Little

Germany
- British Council, NRC, United States Department of Commerce, Office of Productivity, Technology, and Innovation, A. D. Little

Europe
- Fakstorp, European Industrial Research Management Association, Declerq 1979.

Canada
- Science Council of Canada

University-Industry Relationships-General Overviews

Baer, Battenburg, Bok, Brodsky, A. Brown, G. Brown, Bugliarello, Declerq 1979, Declerq 1981, Doan 1978, Europena Industrial Research Management Association, Farris, Fusfeld 1976, Fusfeld 1980, Kiefer, Linvill, Lohr, Lyon, MacCordy, Murray, National Commission on Research, Noble, Pake, Prager, Ridgeway, Shapero, M. Useem

University-Industry Relationships-Government Role

Branscomb 1979, G. Brown, IRI, Keane, MacCordy, Mogee, Prager, US Congress/Subcommittee on Science, Research, and Technology, US/NSF 1976, US/NSF 1980.

University-Industry Relationships-Minorities

Cannon, Council of Graduate Schools, Mullins

University-Industry Relationships-National Research Facilities

Cantwell (Stanford Synchrotron Radiation Laboratory), Robinson

(Brookhaven National Laboratory, National Synchrotron Light Source).

University-Industry Relationships-Policy Statements

Atkinson, Brown, Industrial Research Institute, National Commission on Research, Wolff 1980.

University-Industry Relationships-Statistics

Brodsky, Bugliarello, Council for Financial Aid to Education, Mansfield, Mason.

Venture Capital

Fox, A. D. Little, Weber.

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Author Index

Subject Index

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

Author Index

Subject Index

In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

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RONALD E. CAPE is cofounder and chairman of Cetus Corporation, a biotechnology firm. He earned an A.B. in chemistry at Princeton, an M.B.A. at Harvard Business School, and a Ph.D. in biochemistry at McGill. Dr. Cape did postdoctoral research at the Molecular Biology and Virus Laboratory at the University of California, Berkeley. He is 1978-79 Foundation for Microbiology lecturer of the American Society for Microbiology; a member of the Advisory Council to the Department of Biochemical Sciences, Princeton University; and a member of the Rockefeller University Council. Dr. Cape is also adjunct professor of business administration at the University of Pittsburgh and a member of the board of directors of Scientific American, Inc., and of Neutrogena Corporation.

CHARLES W. GEHRKE is professor of biochemistry and manager of the Experiment Station Chemical Laboratories at the University of Missouri in Columbia. In addition to teaching and research, he is state chemist for the State of Missouri. He received his B.A. degree from Ohio State University, a B.S. degree in education, and an M.S. degree. From 1941 to 1945 he was professor and chairman of the department of chemistry at Missouri Valley College, returning to Ohio State University as an instructor in biochemistry and receiving a Ph.D. degree. Dr. Gehrke was president-elect of the American Chemical Society and is on its Board of Directors; he also is active in the Association of Official Analytical Chemists. His research interests include the development of quantitative gas, high resolution liquid chromatographic, and automated spectrophotometric methods. He received the annual AOAC Harvey W. Wiley award in analytical chemistry and the ACS Kenneth A. Spencer award for achievement in agricultural and food chemistry.

CARLOS E. KRUYTBOSCH is a staff associate in the National Science Foundation Office of Planning and Policy Analysis and is executive secretary of the National Science Board (NSB) Committees on the 12th and 14th NSB Reports. He has also served as executive secretary of the NSB Committee on Minorities and Women in Science. Dr. Kruytbosch is a sociologist, a holder of the Ph.D. from the University of California at Berkeley, an has done undergraduate work and the University of British Columbia in Canada and the University of Amsterdam in the Netherlands. His principal fields of interest are in organization theory; science policy; the sociology of science, of occupations, and of professions; and research administration. He edited a book on "The State of the University." Dr. Kruytbosch has taught at the Berkeley and Davis campuses of the University of California, at the University of Idaho, and at the State University of New York in Buffalo.

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In Industrial-Academic Interfacing; Runser, D.;
ACS Symposium Series; American Chemical Society: Washington, DC, 1984.

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