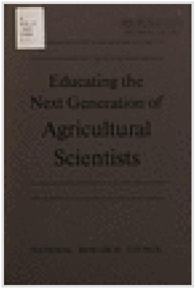

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Educating the Next Generation of Agricultural Scientists

Committee on Evaluation of Trends in
Agricultural Research at the
Doctoral and Postdoctoral Level

Board on Agriculture

National Research Council (U.S.).

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Preface

The agricultural community has raised questions regarding the future availability of an adequate supply of doctoral scientists trained to work on problems in agriculture. To help answer these questions, the U.S. Department of Agriculture asked the National Research Council's Board on Agriculture to study the present and projected adequacy of doctoral scientists working in support of U.S. food and fiber industries. The board established the Committee on Evaluation of Trends in Agricultural Research at the Doctoral and Postdoctoral Level to analyze issues relating to the next generation of agricultural scientists. The committee was specifically asked to review present sources of information and seek additional information from the public and private sectors; prepare a profile of food and agricultural scientists; assess future demand for agricultural research scientists; and recommend ways to initiate changes in the public and private sectors to meet the future needs of the agricultural system and its scientists.

In many instances, the committee could not identify reliable data or past analyses central to its charge. Hence, many of the principal conclusions and recommendations in this report depend on the committee's judgments.

Regardless of the field or time period, it is difficult to project the supply and demand for doctoral scientists and engineers, particularly when qualitative factors must be taken into account. In the case of agricultural scientists and engineers over the next two decades, these difficulties are compounded by several factors. They are lack of data describing characteristics of doctoral scientists; rapid change in several sciences critical to agriculture, human nutrition, forestry, and food- and fiber-processing industries; uncertain future public- and private-sector investments in the agricultural sciences and technology development; and economic adjustments, social and demographic changes, and institutional reforms that are expected to affect priorities in agricultural R&D and education programs. The committee chose to limit its analysis to a simple examination of employment trends over the last decade as the basis for discussion.

Drawing on data available from the National Research Council's Office of Scientific and Engineering Personnel, the committee constructed profiles of the employment, demographic, and educational backgrounds of doctoral agricultural scientists and engineers. (The reader should note that numbers based on the survey of doctorate recipients are estimated.) Subsequently, it developed a set of simple projections, based on three scenarios, of the changes in employment opportunities through the mid-1990s and beyond.

The committee convened several ad hoc meetings. At these meetings, the committee and agricultural science leaders, educators, and research administrators discussed future needs for agricultural scientists with certain skills and abilities. The committee also discussed with these specialists the adequacy of current skills and what should be done to try to cultivate added skills. Questions were also raised regarding how educational institutions would respond to upgrade curricula and research programs.

This report contains the committee's findings, conclusions, and recommendations regarding the current status and future needs of doctoral scientists working in agriculture. Chapter 1 is a summary of the report's findings and conclusions and offers recommendations. Chapter 2 presents an overview of challenges in food, fiber, and agricultural industries that the committee believes will lead to new employment opportunities. The number of jobs that might result in specific fields is not quantified, however. Chapter 3 contains a profile of agricultural scientists, including trends in employment patterns among the industrial, government, and academic sectors. The profile also reflects age distribution, salary patterns, and the quantity of new doctoral degree recipients in agriculturally related fields. Chapter 4 reports the committee's simple projections of the future demand for agricultural research scientists.

Advances in U.S. agricultural science and technology will affect people around the world. It is essential for our nation to educate and support skilled individuals to fulfill this responsibility.

ROGER L. MITCHELL
Chairman

1
Executive Summary and Recommendations

Sustaining our nation's internationally competitive food production, processing, agricultural input, forestry, and fiber industries is essential. The challenge is to sustain these industries in an increasingly competitive world in which government trade, technology, and subsidy policies affect agricultural competitiveness in many complex ways. This report focuses on only one factor that will help to determine future competitiveness—the number and quality of doctoral scientists working in agricultural science and on technology problems.

Measuring and projecting the competence and adequacy of scientists and engineers within a major sector of the economy are difficult analytic tasks. A basic purpose of this study was to make such assessments of doctoral scientists working in the agricultural, food, and related sciences.

Nations need individuals skilled in science and technology to acquire and maintain agricultural industry competitiveness. The lack of such skill is a barrier that countries must overcome to be profitably active in international markets for food and fiber products or agricultural industry inputs and services.

Countries that possess and use scientific and technical skills in any industrial sector will lower trade and policy-related costs associated with remaining competitive in world markets.

For this reason, the number and quality of the agricultural and food sciences doctoral scientists is a concern for the United States. The committee makes recommendations that should be implemented to build a firm basis for future agricultural competitiveness.

THE COMMITTEE'S CHARGE

The U.S. Department of Agriculture (USDA) charged the committee to analyze future competency needs of doctoral scientists. The task was challenging for several reasons, not the least of which were the difficulties encountered in defining and measuring competency needs. The committee defines competency "as having the necessary skills and abilities to perform a given task or tasks successfully, according to an established set of standards or records."

Qualitative characteristics of the scientific and technologic labor force are hard to measure. They can be difficult to project into the future. In agriculture, projecting competency needs is made more complex by five additional factors:

1. Rapid rates of scientific and technologic advance in agricultural science and engineering;
2. Changing domestic and international opportunities in major agricultural commodity markets;
3. Interactions between unpredictable social, economic, technologic, and demographic trends;
4. A lack of previously compiled data or projections of the characteristics of doctoral scientists in agricultural sciences, either in terms of supply and demand trends or needs; and
5. Limited information on how current educational policy and programs affect the qualitative dimensions of doctoral scientists.

For these reasons, the committee relied on its collective experience and judgment in reaching conclusions about future competency needs and trends in the supply and quality of doctoral scientists. Moreover, the committee depended mainly on judgment in offering recommendations for education and training initiatives.

PRINCIPAL FINDINGS

About 20,600 agricultural, food, engineering, and environmental scientists who have earned Ph.D. degrees focus their skills in five broad areas:

1. Basic science essential to plant and animal production, such as genetics, biochemistry, physiology, animal nutrition and health, plant pathology, entomology, agricultural engineering, and food sciences;
2. Applied research on agricultural technologies, resource protection, and the functioning and performance of agricultural systems;
3. Postharvest use and marketing of agricultural and forest products;
4. Agricultural economics and policy in domestic and international contexts; and
5. Monitoring and regulating the performance and effects of agricultural activities and food products on human health, food safety, the environment, and the productivity of the resource base.

Characteristics of the Doctoral Labor Force

Of the estimated 20,600 scientists and engineers now employed in applied agriculture, 15 percent are involved primarily with teaching, 41 percent in research and development (R&D), 21 percent as managers, and 21 percent in other work, such as marketing or regulatory activities (see Table 3-4). Academia employs about half of the Ph.D.s working in the agricultural sciences, industry a third, and government—primarily the Agricultural and Economic Research Services within the USDA—the rest (see Table 3-3).

In the last decade, the distribution of Ph.D.s who hold agricultural science degrees among employment sectors shifted toward industry, from 22 percent in 1975 to 29 percent in 1985 (see Figure 3-2). Academia's share declined from 60 to 55 percent and government's from 19 to 16 percent during the same time.

About 16,700 active scientists and engineers have received their Ph.D. degrees within applied agricultural science disciplines (see Figure 3-2). Of these, 12,600 (about 75 percent) are currently employed in applied agricultural science positions (see Table 3-3). Applied agricultural science disciplines included agronomy;

soil science; horticulture; plant breeding; animal husbandry, science, nutrition, and breeding; food science; hydrology; environmental sciences; agricultural engineering; general agriculture; and forestry. The balance of active agricultural scientists and engineers, which is 8,200, or 40 percent of the total of 20,600, earned Ph.D. degrees outside applied agricultural disciplines. These fields included biochemistry, bacteriology, genetics, molecular biology, plant and animal physiology, zoology, botany, economics, ecology, sociology, plant pathology, entomology, and other sciences.

In recent years, the distinction between applied and basic scientific research has become less distinct. For example, scientists trained and working within fields traditionally classified as applied are contributing to the development of biotechnology research methods. Applied scientists often pioneer new research methods and contribute to basic scientific knowledge. Collaboration between basic and applied scientists in multidisciplinary research terms decreases the distinction between basic and applied science. (See Chapter 3 for a more detailed discussion of the field and subfield definitions used in this report.)

Most of the tables and trends discussed in this report refer to doctoral scientists employed in agriculture *by field of employment* (20,600); a few tables report data for those agricultural scientists and engineers trained in an applied agricultural discipline or program, or *by field of degree* (16,700).

The large number of currently employed agricultural scientists and engineers trained outside traditional applied agricultural science disciplines has important implications. Many doctoral scientists who have earned degrees in nonagricultural sciences are being hired in agriculture-related positions; and educational initiatives and reforms within traditional applied agricultural science fields only are unlikely to adequately meet future needs.

Quality

Many educators think the quality of undergraduate and graduate students intending to enroll in agricultural science programs is low (Christensen and Heinrichs, 1985). According to the National Association of State Universities and Land-Grant Colleges: "A major issue confronting our society is the declining quality of students who are preparing for scientific and professional careers in food, agricultural, and natural resource disciplines. The availability of food, agricultural, and natural resources expertise is in serious jeopardy" (NASULGC, 1986b). The committee reviewed evidence supporting this statement (see Table 3-6).

The verbal and quantitative scores of students intending to study agriculture as undergraduates were among the lowest on the Scholastic Aptitude Test (SAT). Among all students taking this test, only those intending to major in home economics had lower average scores. Results from a comparison of Graduate Record Examination (GRE) scores are similar. These tests were designed to predict performance in educational programs, not intelligence. Nonetheless, the low average scores of students intending to pursue agricultural studies lend evidence to the concerns regarding quality and the ability to attract students that agricultural research and technology development administrators, recruiters, and practitioners voiced to the committee.

In the committee's judgment, agricultural institutions and industries should be able to offer challenging careers that will increasingly attract talented scientists. But in meeting this need, the emphasis should not be on numbers alone; it should also be on excellence. Agriculture is not attracting enough of the brightest undergraduate and graduate students. Moreover, agriculture's ability to attract such students will probably not improve without incentives and initiatives backed by sufficient funds.

Foreign Students

A significant number of U.S. doctoral candidates are foreign students. In 1985, foreign students with temporary visas accounted for 392 of the 1,192 new Ph.D.s in applied agriculture and 391 of 3,093 new Ph.D.s in agriculture-related basic sciences (see Table 3-6). This is clear evidence of the attraction of U.S. educational programs in these fields. The task of training scientists from other countries, especially developing countries, will continue to require special commitments by U.S. colleges and universities.

The presence of foreign students can benefit domestic teaching programs, students, and institutions. Foreign students can be an important source of knowledge about their respective countries. They can help U.S. scientists gain a better understanding of conditions and scientific challenges outside the United States. Agriculture is a global endeavor; the marketplace is the world.

Educating foreign students can be a way to help them—and all students—develop an international view of agriculture and a sense of the global challenges that must be overcome to feed all people. But we should not become too dependent on foreign students to fill classrooms.

Institutions and individuals in the United States have been assisting developing countries in three principal agricultural science areas: (1) education and training, (2) agricultural development, and (3) establishment of scientific and agricultural institutions. To improve these efforts, U.S. agricultural science programs should be developed to better fit the needs of students from developing countries. These students usually need help with language, computer, and cultural skills to complete a program.

They also often need to learn basic science skills and gain knowledge about technologic options. Those who intend to return to their countries would benefit most during their academic programs from some focus on those technologies that might be practical outside the United States.

Foreign students must also acquire an understanding of socioeconomic influences on agriculture, particularly the effects of domestic and international food and agricultural policies on the development, transfer, and profitable use of agricultural technologies.

Projections of Supply and Demand

The committee assessed existing projections of future labor market conditions and demand. In the committee's judgment:

- Currently available Ph.D. labor market projections are inadequate in assessing possible future imbalances in the supply of and demand for agricultural doctoral scientists and engineers. None of these projections address qualitative factors.

Available analyses and projections are outdated, too aggregated, or do not extend sufficiently into the future. Projections are even less relevant in assessing necessary skills and abilities, because they deal exclusively with the number of scientists entering the labor pool relative to employment opportunities. There is a need for improved projections of supply of and demand for Ph.D. agricultural scientists and engineers.

Data that the committee reviewed coupled with its collective judgment regarding likely future employment in the next decade produced several conclusions, however:

- Little overall change is expected in the supply-demand balance for basic or applied agricultural Ph.D. scientists, although fluctuations will be different in various specialty fields. A lasting shortage in any field is unlikely.
- In the next decade, there will be a continuing increase in industrial employment.
- Among all sectors, work other than research and teaching—marketing, management, and regulatory activities and underlying abilities, such as communication skills—are becoming more important.

In 1985, 27 percent of the Ph.D.s in applied agricultural disciplines employed in industry report research as their primary work activity (see Chapter 4). Slightly more than one-half of academic scientists in applied agricultural disciplines report research or teaching as their primary activity. In industry and government, doctoral scientists are focusing more on marketing, management, and regulatory activities as areas of responsibility. In addition to research, students need more opportunities to gain experience in the areas of problem solving, practical research collaboration, and writing and speaking.

PRINCIPAL CONCLUSIONS

Two conclusions of the committee helped to identify the steps toward greater proficiency in agricultural science and technology:

- Although there may be an adequate supply of candidates, the key will be to attract into agricultural and food industry careers more of the brightest, best-trained young scientists and use their skills to advantage in single-discipline and multidisciplinary teams.
- The overall quality—skills, knowledge, and intelligence—of doctoral scientists must be continuously improved. To improve quality, a series of research and education system reforms will be needed, with adequate funding and professional opportunities, such as fellowships and continuing education.

The committee notes that employers are already drawing upon scientists and engineers from disciplines other than those included in traditional basic and applied agricultural sciences. If recent trends continue, nearly one-half of newly hired Ph.D.s in the next decade will be trained outside applied agricultural science fields. New initiatives are needed, however, to better use the skills, often in a multidisciplinary research environment, of all Ph.D.s; periodically retrain and upgrade skills of active scientists; and attract the most gifted individuals to careers in the agricultural and food sciences.

RECOMMENDATIONS

The committee believes that agricultural science and technology educators, administrators, recruiters, and practitioners must focus attention on the quality of doctoral scientists, basic skills, broadening and redirecting, and multidisciplinary interactions. Improvements in these areas would benefit all active and prospective agricultural scientists and engineers. Moreover, these areas need attention throughout an individual's career.

To respond to these needs, the committee offers four recommendations involving (1) up-to-date projections of supply and demand of agricultural scientists and engineers, (2) core curriculum and re-education in the basic sciences, (3) multidisciplinary interactions, and (4) fellowships.

The impetus to act upon most of these recommendations must come from individuals in leadership positions. To be successfully adopted, the recommendations will require commitment of funds as well as professional rewards. The USDA, Congress, public and private foundations, academic leaders, and associations should seek out and support ways to implement the committee's recommendations.

Projecting Supply and Demand

An institution or organization with appropriate technical expertise working under the guidance of public sector agencies, particularly the USDA and National Science Foundation (NSF), should develop projections of supply and demand of agricultural scientists at least every three to five years.

Projections should take into account rapid change in the agricultural sector, demographics, and scientific and technologic opportunities.

Congress should commit funds to support compilation, analysis, and distribution of such data. Analysis results will help executive branch agencies and Congress to plan and monitor educational programs, policies, and investments to enhance the competence of doctoral scientists working within agriculture.

Core Curriculum and Re-education in the Basic Sciences

To meet the need for basic science training, academic institutions should require agricultural science students to take core curriculum courses taught within basic science departments, such as chemistry and biology.

At each stage of a scientist's career, the ability to carry out basic science studies at the frontiers of knowledge and the experiences gained from them are valuable in preparing him or her for research, teaching, extension, and management activities in the public and private sectors.

To provide future scientists with appropriate skills, emphasis should be increased on educational, research, and work experiences during graduate training and professional careers. The USDA and NSF should offer guidance and support to academic institutions pursuing student and faculty development initiatives responsive to this need.

The skills that agricultural scientists need in the future will change at a rate even faster than in the past decade. As in all other disciplines, scientists in agriculture will have to continuously update their abilities and knowledge throughout a 30- to 40-year professional career to remain at the forefront of science. A scientist's progression must begin with basic science training and research experiences that increasingly develop his or her problem recognition, experimental design, and related analytic skills.

Multidisciplinary Interactions

More financial and administrative support should be provided for multidisciplinary team research. University leaders and the USDA should implement a strategy for professional renewal by multidisciplinary research throughout the careers of agricultural scientists *from academia, industry, and government. All sectors need to remain current with advances in science and instrumentation. Therefore, sectors should help to develop, implement, and pay for new educational strategies and opportunities.*

Multidisciplinary interaction is a way to identify research opportunities, develop new technologies, and pursue creative solutions to problems that require knowledge in combined sciences such as biochemistry, cell biology, immunology, physiology, and genetics. Such interaction should include frequent contact with colleagues working in other sectors, fields, states, and countries. This collaboration can advance science and benefit the individuals involved.

A strategy to support multidisciplinary collaboration among scientists at different career stages can contribute to the scientists' renewal and retraining. Frequent interactions with colleagues are often the best way for scientists to remain current with new instruments, methodologies, and knowledge. To increase interaction, more incentives should be directed toward research teams in the form of grants, laboratory space and equipment, and professional recognition.

In academia, such interaction is an essential part of teaching and learning the scientific method and strategies for conducting research programs. Opportunities to work with graduate and postdoctoral students who have learned new skills can partially meet the faculty's continuing education needs. Such interaction can be particularly valuable when a student from a newly established basic science subdiscipline brings new insights to a research team. Multidisciplinary research can be supported within the university by establishing graduate programs that cut across departmental lines; recognizing and rewarding faculty contributions to cooperative research programs; promoting collaborative projects and exchanges between scientists in land-grant universities, non-land-grant universities, industry, and government laboratories; and recruiting new faculty to create multidisciplinary research programs that can attract competitive funding.

Academia is not alone in its need for change. Private and public research laboratories and institutions, respectively, also need strategies to support multidisciplinary interaction and retraining and attract higher-quality individuals.

If the skills and abilities of agricultural scientists and engineers are to be broadened, individuals at progressive career stages should have the opportunity to:

- Expand technical skills—through multidisciplinary interactions and sabbaticals, for example—to promote interaction with U.S. and foreign scientists in other basic and applied fields and with the general public;
- Increase knowledge of agriculture at home and abroad—including policy and socioeconomic concerns—in pursuing science and technology goals.

Fellowships

Expanded national graduate and postgraduate fellowship programs are needed to support advanced scholarship and research within food and agricultural sciences and related engineering fields, with particular emphasis on multidisciplinary research opportunities. The fellowships should assure keen competition, drawing individuals who have demonstrated excellence into agricultural science careers. Funds to support new fellowships should be awarded to a variety of educational institutions, including private colleges and collaborative ventures among schools on a single campus. Successful but currently underfunded USDA and NSF programs should be expanded. These programs must receive sufficient support to meet their obligations to individuals and institutions.

The fellowship programs should be periodically assessed to ensure that they are responsive to needs. The committee also believes that new fellowship opportunities will be most valuable if they aim toward excellence in agriculture-related basic sciences, support multidisciplinary research activities, and foster communication among disciplinary and national boundaries.

In 1984 Congress appropriated $5 million to establish the USDA National Needs Graduate Fellowship Program. This appropriation and the competitively awarded grants it provided enabled 60 universities to enroll 302 students in graduate degree programs in biotechnology, food science and nutrition, agricultural engineering, and agricultural marketing. Funding for the program ceased in its third year (1986), leaving some departments with a financial burden in providing continuing support to fellowship recipients pursuing doctoral degrees. In 1987, the USDA provided $2.8 million for new fellowships. Considerably fewer fellowships will be awarded, however, because the USDA now provides recipients the full three years of support out of each year's appropriation.

The number of federally supported fellowships should be increased. Support is also needed for new centers of excellence, curriculum reform, and faculty retraining opportunities (NRC, 1985a, 1987). A relatively modest investment would support the recommended increase in fellowship program opportunities. Combined federal and state support of the traditional agricultural research system accounts for $1.9 billion, which includes the $2.8 million that the USDA spends annually on graduate fellowships (USDA, 1986). Federal, state, and private institutions spend slightly more than $4 billion annually for agricultural research in the United States (NRC, 1987).

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Challenges in Food, Fiber, and Agricultural Industries

Agriculture is interwoven with many segments of American life and the U.S. economy. Apart from sustaining human health and nutrition, agriculture in many ways supports commerce and trade, transportation, R&D, education, public service, private enterprise, community and family development, and outdoor recreation. For these reasons, agricultural sector prosperity will remain an important goal for national economic policy. All levels of government will still give attention to agriculture despite continued abundant production of high-quality, affordable food and fiber.

U.S. industries that serve agriculture by producing, processing, marketing, and preparing food and fiber products for consumers account for about $450 billion in economic activity each year, which is about 20 percent of the gross national product. These industries provide food for 235 million Americans and export about 20 percent of the food on the international market. They also meet a variety of other needs. Agricultural industries supply materials for clothes, paper, medicines, oils, and thousands of other manufactured products. The labor force underlying this remarkable economic activity includes only 2.7 million farm workers, about 3 percent of the nation's labor force. But agribusinesses employ another 7 million workers, which is more than two for every full-time farmer. Retail and service industries that sell agriculturally related products employ 12 million more workers, mostly in restaurants and other commercial eating facilities.

An estimated 20,600 doctoral-level scientists and engineers employed in agricultural sciences and engineering positions address the scientific and technical challenges associated with the activities of these 21.7 million workers. One of the committee's tasks was to assess how the nature and scope of future agricultural science career opportunities might change. The committee surveyed many reports and assessments and consulted numerous experts in the public and private sectors. By these means and by interacting with one another, using their knowledge and experiences as a guide, the committee identified future areas of need. The committee judged that science and technology and R&D have the most important needs. Although many other fields are important, they appear able to meet foreseeable needs.

Careers within agricultural and food industries are as diverse as their products and services. Ph.D. agricultural scientists and engineers focus their talents in five broad areas. First, the majority of active doctoral-level scientists, including agricultural engineers, soil scientists, plant breeders, animal scientists, entomologists, plant pathologists, veterinary scientists, and individuals trained in other applied and basic agriculture science fields, work on plant and animal production at the farm level. Problems in production agriculture include sustaining soil fertility, controlling pests, efficiently harvesting crops, breeding profitable new varieties of plants and species of animals, protecting animal health, and studying farm management.

A second group of agricultural scientists works on sustaining scientific progress and vitality. They spend most of their careers in research and teaching at academic institutions. Their products—new knowledge, improved R&D tools, and trained individuals—are the raw materials of scientific and technologic advance.

A third area, which is growing in importance, involves the postharvest use and marketing of agricultural and forest products. In this area, doctoral, master's, and bachelor's degree level engineers, systems experts, food scientists, chemists, microbiologists, and a variety of other skilled individuals work on the efficient processing of raw agricultural commodities into foods and other useful products. The capacity of U.S. agriculture to efficiently manufacture new, high-quality products from traditional agricultural commodities may prove increasingly significant to agricultural economic growth and resiliency.

A fourth group of doctoral-level scientists, including agronomists, economists, and other individuals who have economics, legal, and business training, works with domestic and international agricultural markets, financial institutions, and policy. The challenge for these individuals is to design more effective safeguards into production and marketing systems. These safeguards will subsequently help to assure that social needs are reliably satisfied while industries earn profits and generate stable employment opportunities.

A fifth area is the monitoring of human health, environmental quality, and social needs, particularly as affected by the products and activities of farmers and food and fiber industries. Scientists active in these areas study human nutrition, nutrient composition, bioavailability, toxicology, and other fields related to monitoring and evaluating food safety and quality.

ISSUES IN AGRICULTURE

Current and future issues in agriculture, which are often based on national and international commercial activity in food and fiber industries, affect career opportunities in agriculture in complex ways. Issues of growing prominence for science and technology include making economic adjustments, implementing public policy, sustaining internationally competitive industries, protecting resources and environmental quality, expanding commercial opportunities in new crops and value-added products, and understanding consumer behavior here and abroad.

U.S. agricultural scientists and engineers trained in a variety of fields find solutions to problems that in turn open up commercial opportunities. The income and capital generated by this activity is essential to sustain the cycle of investment and innovation that has kept U.S. agriculture at the forefront of global food and fiber industries, despite periodic turbulence in domestic and international commodity markets over the last several decades.

Economic Stress and Adjustments

Today many agricultural producers and industries are in the midst of an income and equity crisis. The most severely affected regions are those that produce surplus field crops, such as corn, soybeans, wheat, cotton, rice, and other grains. These are the crops that attracted unprecedented capital investment, drawing new land and yield-enhancing inputs into agricultural production during the export boom of the 1970s. The subsequent decline in foreign demand for agricultural goods relative to available supplies in the early 1980s overextended many producers. Crop prices declined 30 percent or more below peak levels in 1980 to 1981; agricultural land values dropped an average of 30 to 50 percent. Surpluses grew quickly. The situation created the need for longstanding federal agricultural policies and programs to expand to support farm income and reduce production, while moving commodities into global markets at competitive prices.

The first step in dealing with production adjustment and income problems is to understand how past programs have often worked at cross-purposes. One example is paying farmers to idle land while providing strong economic incentives for higher yields and bringing new lands into cultivation. Another is sacrificing international markets by artificially supporting commodity prices above world market levels.

A consensus is developing among U.S. citizens regarding the need for agricultural policies that allow this country to compete while protecting soil and water resources and encouraging cost-saving management practices. Because of the economy and environmental concerns, policy changes may also be needed to help some farmers diversify their operations (see also OTA, 1986).

Problems stemming from low crop prices and surplus production capacity are not restricted to the farm. Other institutions affected by reduced business volume or underutilized capital investments are rural, regional, and agricultural banks; small businesses in rural towns; local government services, such as schools and clinics; and agricultural input, transport, processing, and marketing industries.

Public Policy

Government support of agricultural income and rural economic development will be augmented by greater attention to food safety and quality and resource conservation needs. Decisions about changing research and agricultural program priorities will necessitate some redirection of public funds, which raises difficult institutional and analytic challenges.

Agricultural economists and policy specialists will be called upon to explain the impact of programs and technologies on competitiveness, resources, and farm income. They will have to identify efficient ways to achieve public policy objectives. While adjustments are frequently resisted and entail some costs, they often create new opportunities. Benefits for individuals and communities will follow as agriculture moves toward a profitable production and technology base.

Economic policies will also change in other countries. The ability of most countries to produce some surplus foodstuffs surprised many analysts. Global trends toward self-sufficiency in food production, particularly the two major human food grains, rice and wheat, will have to be reckoned with as more and more countries compete for shrinking export markets. Research designed to solve these problems will benefit the global agricultural community.

International Competition

To regain profitability for U.S. agriculture and use productive capacity more fully, economic and geopolitical factors shaping international trade flows must be understood.

Tight commodity markets and growing international competition have raised the issue of whether the United States should allow or encourage the transfer of its technology overseas, where it can be used to produce crops that compete with American exports. It is doubtful that agricultural technology transfer could be prevented, even it if were desirable to do so. There are many channels of communication between individuals and groups in the United States and other countries. Moreover, restrictions on the international exchange of technology would impede the exchange of genetic resources and capacity of U.S. farmers to use advanced biotechnologies. Some technologies are difficult to transfer, however, particularly those that require management skill and understanding in biological needs and interactions.

Technology transfer has often been important to rural economic development within less-developed countries (LDCs). Such development often helps to open up markets for U.S. agricultural exports as per capita incomes rise.

Natural Resource Protection

The natural resources of the United States—land, water, and forests—have contributed greatly to the success of American agriculture. But there is continuing concern about agriculture's impact on the environment and the extent to which agricultural resources in a highly productive state are protected.

On the positive side, however, technologic advances provide solutions to problems concerning farming practices and land-use patterns. For example, scientists have learned a great deal about how to sustain soil fertility while controlling soil erosion. In the last few years, scientists have also studied the flow of water off farm fields and into lakes, streams, and aquifers. Progress is being made in understanding the relationships between land use and tillage practices and water quality. Researchers are discovering more ways to use the tools of biotechnology to exploit genetic potential to overcome persistent plant and animal pest and disease problems. Scientists have used biotechnology to develop a vaccine for foot-and-mouth disease in cattle; treatment of calf scours, an enteric disease; and plants resistant to herbicides, which could increase the number of crops that can be protected against competing weeds. Resource-conserving crops and marketable products may soon be developed, expanding the range of profitable opportunities. (For further discussion, see OTA, 1986; NRC, 1987.)

Farmers also protect natural resources, although sometimes indirectly. For example, some farmers are using fewer chemical pesticides and fertilizers, primarily to cut cash production costs, which is helpful in reducing agricultural sources of water pollution. (See NRC, 1986a.) Farmers that improve livestock waste management by diverting feedlot runoff, for example, help to protect nearby water sources and meet plant nutrient needs. Land retirement programs can be put into effect in regions of the country that have surpluses and soil erosion or water pollution.

In spite of progress in the last decade, there is a need to better understand how farm programs and policies and the economy influence farm management and resource conservation decision-making. A stronger commitment of public programs and policies to agricultural resource management systems and practices would affect employment opportunities. These systems require more information to be developed, monitored, and transferred on farms than traditional farming methods. Management plans that meet conservation goals must be developed according to the needs of individual farmers and fields. To develop plans, technology and farm management specialists will require an understanding of a variety of biological sciences and the characteristics of hydrogeological cycles, for example.

Job opportunities for scientists and engineers include careers in soil science, hydrology, land-use planning, park and range management, ecology, and molecular biology. Social scientists with expertise in management, technology transfer, and policy analysis will also be in demand.

Commercial Opportunities

The profitability of agriculture will be improved as scientists discover new, economical uses for established crops. Other R&D targets are commercial markets for new crops. For example, the plants guayule and jojoba may become staple crops in the Southwest by creating industries to process rubber and oil products, respectively. New products for use in manufacturing, medicine, and the chemical industry may become practical as biotechnology discovers new production processes. Animal production, including commercial aquaculture, offers many opportunities in research, management, training, and profitability.

To support research on new crops and products, corporations will need individuals to research, develop, test, and market pharmaceuticals and biologicals, feed formulations, raw and processed foods, forest by-products, and genetically engineered products.

Commercial employment opportunities will not only be available to basic or applied researchers, but also to individuals with skills in management, finance, economics, international affairs, policymaking, and public affairs, among other disciplines and specialties. Opportunities for consultants and information management experts are also growing. As production processes involving biotechnology are discovered, positions for chemical and other bioengineering specialists will increase. New industries may have to be created from the ground up—a task dependent on individuals working in multidisciplinary teams.

Consumer Behavior

Consumers demand high-quality, reasonably priced food. Nutritional qualities, safety, appearance, selection, convenience, and ease of preparation are important to consumers.

Market opportunities must be monitored and pursued in different ways around the world because consumer tastes and preferences change at different rates and in a variety of ways, depending on culture, eating habits, and standards of living. The results of future studies of demographics, local markets, lifestyles, diet and health, the distribution of income and consumer spending behavior, and the effects of public policies will help the agricultural sector anticipate change in consumer behavior.

3 Profile of Food and Agricultural Scientists

To assess current and future personnel needs, the committee reviewed the demographic, training, and employment characteristics of doctoral scientists employed in food and agricultural science. Changes in employment and activity patterns sometimes result in the need for new skills and educational experiences. Many doctoral scientists have been educated at land-grant colleges and universities. The education and research training provided have been regarded as successful but in need of reform given current demands (Rossiter, 1986).

Doctoral agricultural scientists can be defined as individuals having Ph.D. degrees in agricultural subfields (regardless of current employment field) or working in agricultural employment specialties (regardless of fields within which doctoral degrees were earned). The second definition best indicates the demand for scientists in agricultural work, even though it includes many scientists originally trained outside traditional agricultural disciplines. The first definition includes some individuals who no longer work or never worked in agriculture despite earning doctorates in applied agricultural disciplines. The field of employment classification is generally used, although some data are presented on agricultural scientists classified by field of doctorate.

The doctorate subfields and employment specialties, which are aggregated to provide "agricultural" totals in this analysis, do not correspond precisely to those used in other National Research Council (NRC) publications (see Appendix C). They were selected by the committee to encompass applied agriculture and include the fields in Table 3-1.

Agricultural economics appears in the tables as a separate category (NRC specialty code 000). Totals are also presented for the biological sciences category (codes 100–199).

The reader should exercise caution when comparing data in this report with those in other publications, which may use different categories and definitions of basic and applied agricultural disciplines. Moreover, the features that differentiate applied from basic sciences have become difficult to define in the context of many agricultural science disciplines. Recent graduates earning Ph.D. degrees in traditional applied science fields, such as plant breeding or animal nutrition, might spend their careers engaged in research essentially comparable to work undertaken by colleagues with basic science degrees in plant genetics or animal physiology. Likewise, many scientists with basic science degrees are identifying and pursuing new approaches in the conduct of research on subjects traditionally considered within the domain of applied science.

Based on the fields selected by the committee as encompassing applied agricultural employment, there were an estimated 20,600 scientists and engineers with Ph.D.s who classified themselves as working within applied agricultural science fields in 1985 (NRC, 1986b). Table 3-2 shows the numbers of agricultural scientists and engineers employed in basic and applied agricultural sciences, agricultural economics, and biological sciences.

It is important to note that many individuals employed in applied agricultural specialties do not hold doctoral degrees in applied agricultural fields. An estimated 39 percent received degrees in basic, natural, or other science fields, such as biology, genetics, biochemistry, or zoology, and are using their training in applied agricultural jobs as shown in Table 3-3. The group educated in academic departments outside traditional applied agricultural disciplines is large in industry and government (50 percent for each sector) and least pronounced in academia (27 percent).

The total number of doctoral degrees awarded annually in basic science fields related to agriculture is much larger than the number of degrees in applied agricultural fields. Basic science fields

TABLE 3-1 Employment Specialties

Specialty	Code
I. Applied agricultural sciences	
Animal sciences	
Animal breeding and genetics	005
Animal husbandry, science, and nutrition	010, 019
Veterinary medicine	250
Plant and soil	
Agronomy and soil	020
Plant breeding and genetics	025
Soil sciences	045
Other plant sciences	039
Horticulture and hydrobiology	050
Food science and technology	040
Natural resources and environment	
Fish and wildlife	055, 060
Forestry	065
Environmental sciences	580
Hydrology	585
Other fields	
General and other agriculture	098
Agricultural engineering	303
II. Agriculture-related basic sciences	
Biochemistry	100
Biophysics and biometrics	105, 133
Ecology	139
Cytology and embryology	142
Entomology	148
Molecular biology	154
Genetics	170
Plant-related	
Bacteriology and microbiology	110, 157
Plant genetics	115
Plant pathology	120
Plant physiology	125
Botany	125
Animal-related	
Immunology	151
Nutrition and dietetics	163
Animal physiology	185
Zoology	189

SOURCE: Adapted from NRC (1986b).

TABLE 3-2 Employed Ph.D.s by Field and Employment Sector

Field of Employment	Year	Academia[a]	Industry[b]	Government	Total[c]
Applied agriculture	1975	7,900	4,100	2,800	14,800
	1985	9,900	7,000	3,800	20,600
Animal	1975	1,900	600	200	2,600
	1985	2,500	1,100	300	3,900
Plant and soil	1975	2,600	600	700	3,800
	1985	3,200	1,300	800	5,300
Food	1975	700	1,300	200	2,200
	1985	700	1,800	200	2,700
Natural resources	1975	1,800	1,100	1,500	4,400
and environment	1985	2,000	2,000	2,100	6,100
Other	1975	1,000	600	300	1,800
	1985	1,500	900	300	2,700
Agricultural	1975	1,200	300	400	1,900
economics	1985	1,900	300	400	2,700
Agriculture-related	1975	24,800	5,200	4,500	34,500
basic sciences	1985	31,300	9,600	5,000	45,900
Biological sciences	1975	24,900	4,900	4,100	34,000
	1985	34,600	10,700	5,300	50,600

[a]This sector does not include postdoctoral students.
[b]This sector includes self-employed Ph.D.s.
[c]Totals are not exact because a small number of Ph.D.s (less than 0.1 percent) did not report their employment sectors and because of rounding.

SOURCE: NRC (1986b).

can partially satisfy future demand for agricultural scientists. For many agricultural jobs, however, a degree in one of the applied fields, complemented by a thorough background of basic training, may be preferable.

RECENT TRENDS

The committee examined information on employment trends, degrees granted, and sectoral and activity distributions. It analyzed employment in government, academia, and industry sectors. Primary work activities were categorized as teaching, R&D, management, and all other activities. The committee believes that these data provide insights into the hiring preferences of employers of agricultural scientists, labor market conditions, and, at least

TABLE 3-3 Distribution of Applied Agricultural Scientists by Employment Sector and Doctorate Field in 1985

	Applied Agriculture Employment Sector (percentage)			
Field of Doctorate	All Sectors	Academia	Industry	Government
Applied agricultural sciences	61	73[a]	50	50
Agriculture-related basic sciences	20	16	22	24
Other natural sciences[b]	13	6	20	16
Other fields[c]	6	5	8	10
Total				
Number[d]	20,000	9,900	7,000	3,800
Percentage	100	100	100	100

[a]For example, 73 percent of academic doctoral scientists working in applied agriculture had their degrees in that field.
[b]This field includes the specialties listed under the agriculture, biological sciences, health sciences, computer and information sciences, mathematics, and physical sciences headings from Summary Report: 1985 Doctorate Recipients from United States Universities (NRC, 1986b) except those specialties that are included under applied agricultural sciences and agriculture-related basic sciences. See Table 3-1 and Appendix C.
[c]These fields include the specialties listed under the engineering, psychology, social sciences, humanities, education, and professional fields headings from Summary Report 1985: Doctorate Recipients from United States Universities (NRC, 1986b). See Table 3-1 and Appendix C.
[d]Totals may not be exact because of rounding.

SOURCE: NRC (1986b).

indirectly, the skills required to meet the challenges of new and more traditional agricultural jobs.

Figure 3-1 shows that the rate of growth in the total number of doctoral degree recipients working in applied agricultural sciences and engineering had slightly slowed between 1979 and 1983. Preliminary 1985 data seem to indicate that the growth rate has increased to a level comparable to that in the mid-1970s.

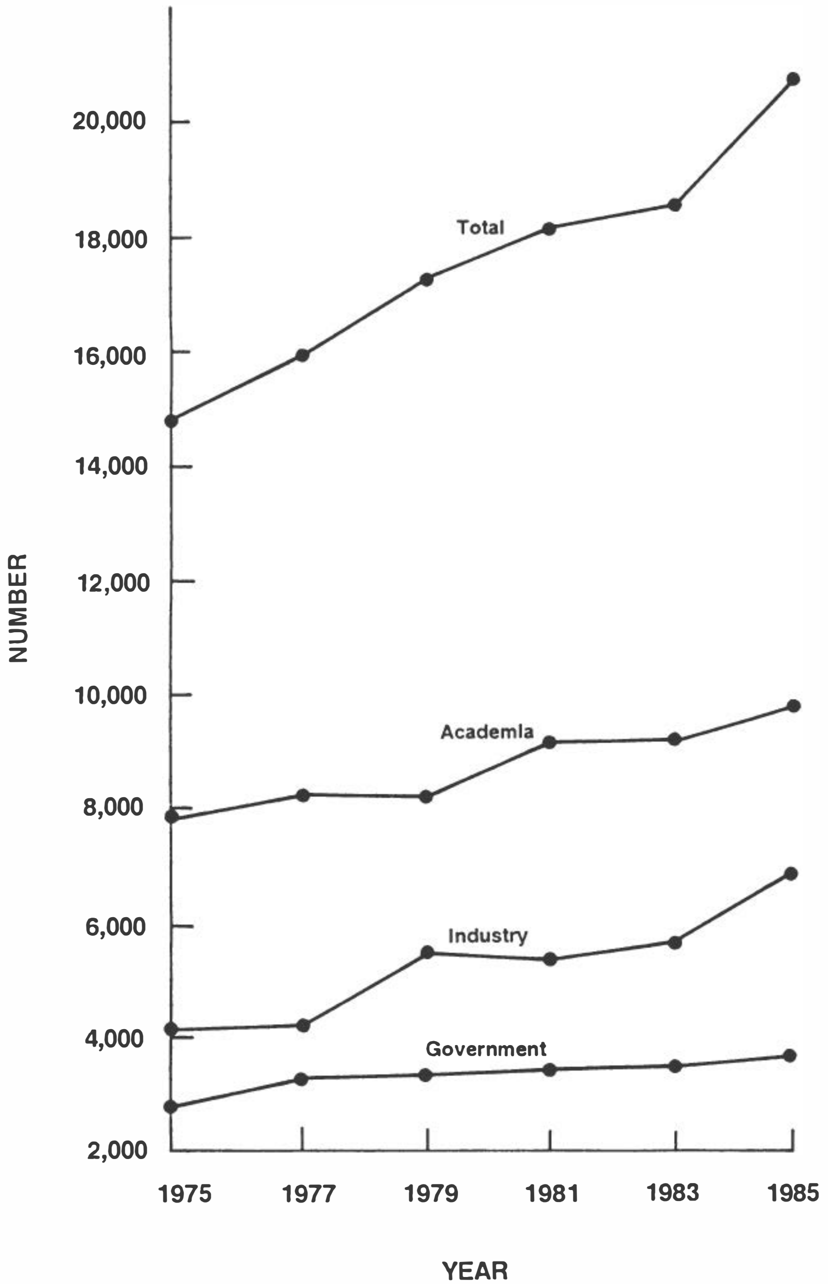

FIGURE 3-1 Employment of Ph.D.s in applied agricultural sciences classified by field of employment. Source: NRC (1986b).

TABLE 3-4 Primary Activity Distribution of Applied Agricultural Science and Engineering Ph.D.s (percentage)

Year	Teaching	R&D	Management	Other
1973	20	37	31	11
1975	20	38	28	12
1977	20	34	30	15
1979	17	33	31	18
1981	18	39	25	17
1983	18	38	22	21
1985	15	41	21	21

NOTE: Applied agricultural science and engineering Ph.D.s are classified by field of employment. Percentages do not total 100 because of a 2 to 3 percent nonresponse rate.

SOURCE: NRC (1985c).

Activity Distributions

Table 3-4 shows the distribution of primary work activity as reported by Ph.D.s employed in agriculture. In 1975, 5 percent fewer scientists reported teaching and 3 percent more reported R&D as their primary work activities than in 1985. From 1977 to 1985, fewer jobs were reported as management. Jobs in the other category reflected the move of Ph.D.s into product development and stewardship, marketing, regulation, and private consulting businesses. But the distribution of work activity remained essentially stable from 1975 to 1985 if teaching and R&D categories are combined and contrasted to management combined with the other category. This observation holds when the data are examined according to either field of doctoral degree (see Appendix A, Table 3) or field of employment.

Moreover, activity distributions within the academia, business and industry, and government sectors were comparably stable. The most notable changes occurred within the management and other categories in the industrial sector. The proportion of those primarily involved in management declined; the proportion of those involved in other activities such as sales, quality control, and compliance with government regulations consequently increased.

Table 3-4 reflects another significant feature of the work performed by agricultural scientists. The doctorate signifies mastery of an appropriate body of scientific knowledge and research skills. But only 41 percent of all Ph.D.s employed in applied agricultural activities in 1985 reported R&D as their primary work activity. Teaching was the primary activity of another 15 percent. Significantly, 42 percent of the respondents reported management, administration, or related activities as their primary work activity.

Employment Sectors

Figure 3-1 shows academia employs almost half of Ph.D.s working in the agricultural sciences, and industry employs about one-third. Government and nonprofit institutions employ the rest. The largest employers in this sector are USDA's Agricultural Research Service (ARS) and the Economic Research Service (ERS). The 1983–1985 data indicate future employment growth in industry and academia.

Figure 3-2, which is based on field of degree, presents a similar picture. Trends and sectoral distribution were similar. But a smaller total number of Ph.D.s was employed (16,700 instead of 20,600) because this figure excluded Ph.D.s working in agriculture who earned degrees outside agriculture. The size of this difference is not surprising because of the basic science fields that have become critical to progress in applied agricultural science programs.

In Figures 3-1 and 3-2, industrial employment has shown the most rapid growth from 1975 to 1985. Industry's share of employed Ph.D.s with agricultural science degrees increased from 22 to 29 percent from 1975 to 1985, academia's share decreased from 60 to 55 percent, and government's share decreased from 19 to 16 percent.

Age Distribution

Age distribution of doctoral scientists within a laboratory, department, or discipline can be an important factor, particularly in areas with rapidly developing new research methodologies. The

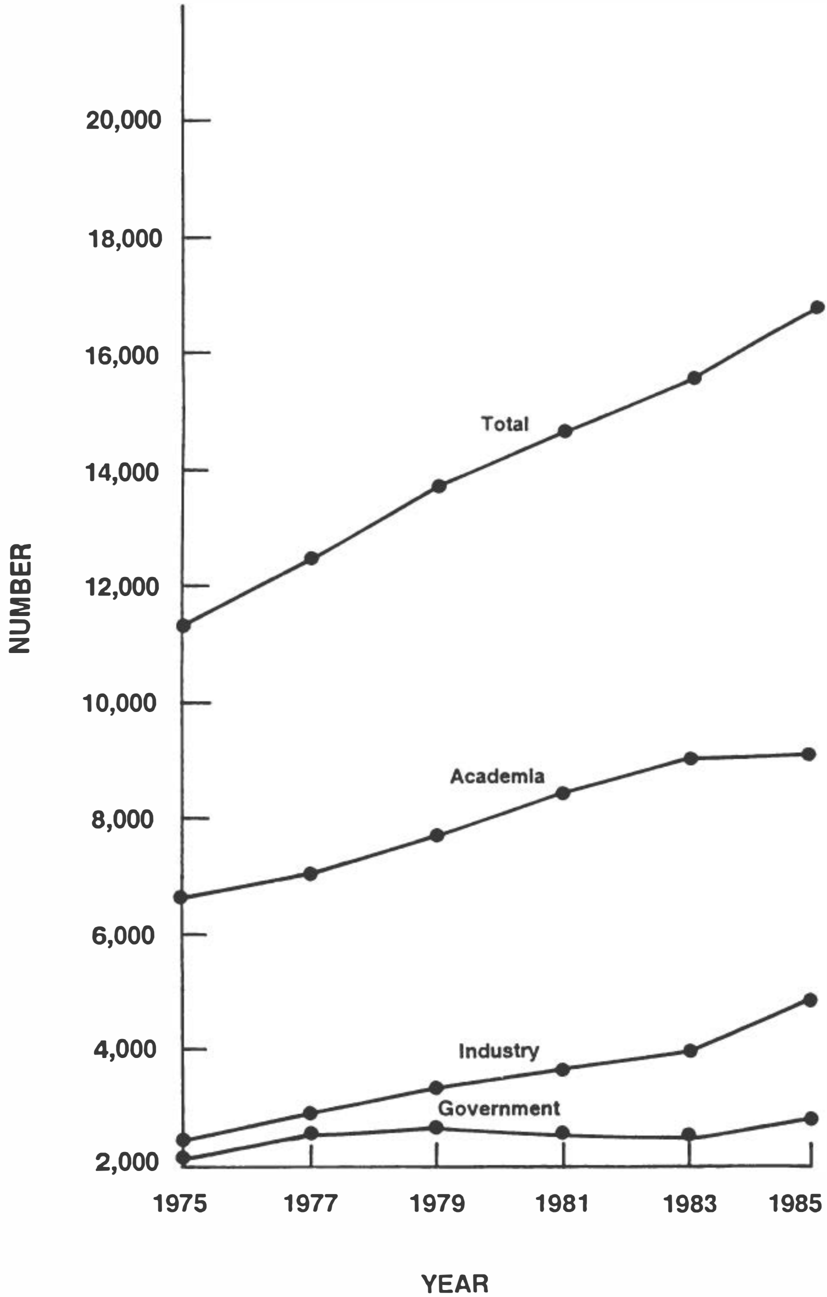

FIGURE 3-2 Employment of Ph.D.s in applied agricultural sciences classified by field of degree. Source: NRC (1986b).

distribution of ages within the labor force, especially the proportion more than 55, determines how many new Ph.D.s are likely to be hired into existing positions.

Of the doctoral scientists in applied agriculture in 1985, 18 percent were more than 55 years old, and 28 percent were under 40 (see Appendix A, Table 8). This situation is similar to age distribution in the biological and natural sciences; the over-55 groups constituted about 17 percent of the total. The situation varied considerably by field and sector, however. Figure 3-3 shows that a larger percentage of applied agricultural scientists more than 55 years old were employed in academia and government compared to natural scientists. In the industrial sector, the situation was reversed. About 28 percent of applied agricultural Ph.D.s were under 39; of these, the government employed 22 percent.

Retirements and newly established positions are opportunities to bring new ideas and skills to the agricultural sciences. If those now more than 55 years old retire by age 65, and all positions are filled, there will be openings throughout the next decade for as many as 2,300 new Ph.D.s in universities and colleges and 700 in government. Recruitment for new Ph.D.s combined with opportunities for their collaboration with senior scientists will help to ensure that the latest advances in science and technology are incorporated into R&D programs.

Underrepresented Groups

Demographic studies indicate a modest decline in the college student population over the next 10 years (OTA, 1985). In addition, there are indications of increasing percentages of women in the undergraduate student body. Agricultural administrators and educators should initiate efforts to reach women and other underrepresented groups in agriculture.

The data in Table 3-5 show cause for concern. Women who had doctoral degrees represented 14.6 percent of all Ph.D. scientists and engineers in the United States in 1983, but only 5.5 percent of agricultural scientists (NSF, 1985b). As a point of reference, women comprised 34 percent of the U.S. full-time working population.

Asians who held doctoral degrees represented 8.6 percent of all Ph.D. scientists and engineers and 5.8 percent of Ph.D.s in agricultural sciences. Because Asians comprise only 1.6 percent of

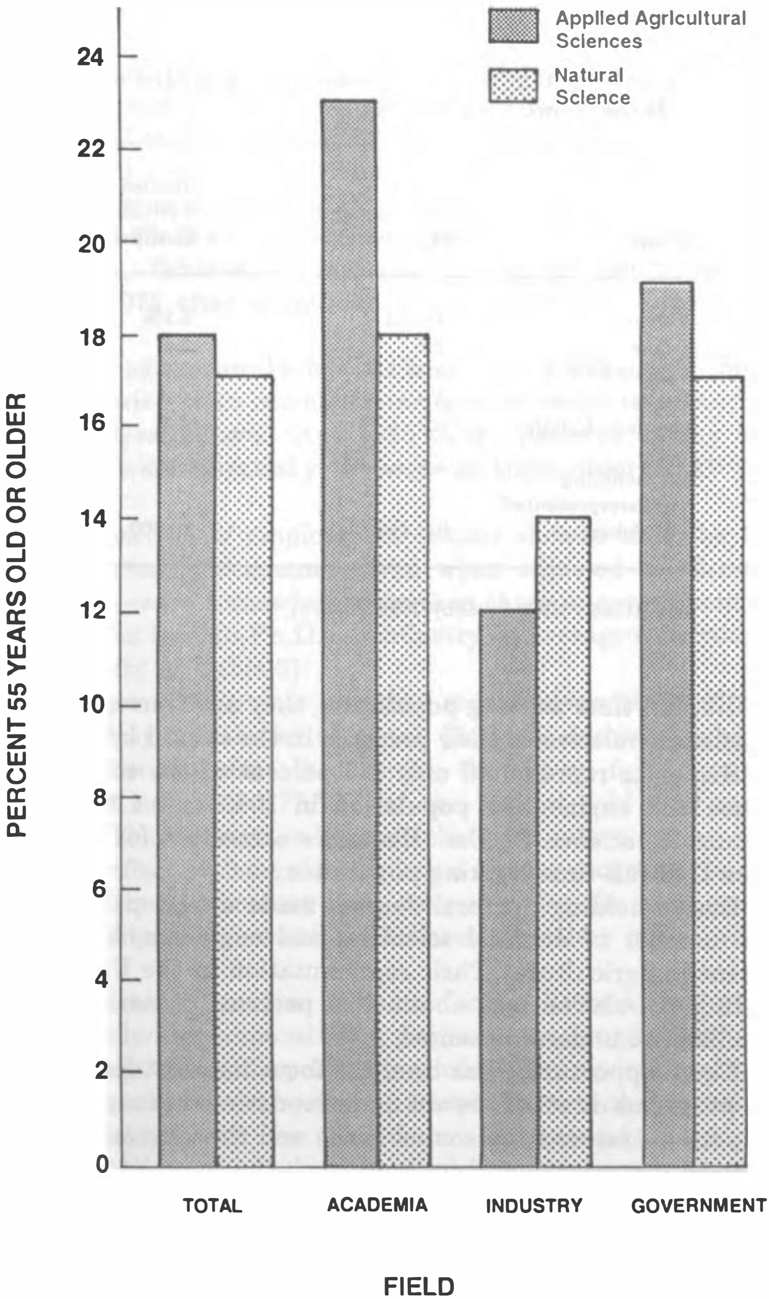

FIGURE 3-3 Ph.D.s 55 years old or older by selected fields and sectors of employment in 1985. Source: NRC (1986b).

TABLE 3-5 U.S. Doctoral Scientists and Engineers from Underrepresented Groups in 1983

Group	Scientists and Engineers	Applied Agricultural Scientists
Women	14.6%	5.5%
Asians	8.6	5.8
Hispanics	1.5	1.2
Blacks	1.4	0.8
American Indian	0.1	0.2
All, including underrepresented (number)	400,400	20,600

SOURCES: NRC (1985b); NSF (1985b).

the U.S. full-time working population, they are overrepresented in the sciences relative to their presence in the overall labor force.

Hispanics represented only 1.5 percent of the total doctoral science and engineering population in 1983 and 1.2 percent of agricultural science Ph.D.s. Hispanics accounted for 5.5 percent of the U.S. full-time working population.

Blacks holding doctoral degrees made up 1.4 percent of the total number of doctoral scientists and engineers, but only 0.8 percent in agriculture. Their representation in the U.S. full-time working population was about 10.4 percent. American Indians were likewise underrepresented.

Equal opportunity has been the focus for most federal education programs directed toward underrepresented groups. In examining future research personnel needs and the increasing need for scientific expertise at the doctoral level, the committee concluded underrepresented minority groups should be reached more effectively in undergraduate and graduate fellowship programs and recruitment efforts. Recruitment efforts need to recognize and overcome sometimes negative cultural impressions about agriculture among women and other underrepresented groups.

Salary Patterns

The committee examined salary patterns among sectors of employment and disciplines to assess labor market conditions that might suggest excessive supply or demand (see Appendix A, Tables 4 through 7). The median annual salary of Ph.D.s in applied agricultural science was $43,100 in 1985—about 7 percent higher than that of Ph.D.s in the agriculture-related basic sciences (see Appendix A, Table 4). Salaries in 1985 were often lower than salaries in 1975 after adjustment for inflation (see Appendix A, Table 5).

Applied agricultural scientists frequently make slightly higher average salaries than scientists in agriculture-related basic sciences. Analyses showed that 1985 salary patterns among fields and sectors were essentially the same as those observed 10 years earlier.

A comparison of employment sectors showed that the 1985 median salaries in academia—even when adjusted to 12-month equivalence—were somewhat lower than those in government and industry, even though Ph.D.s in industry on average were younger (see Appendix A, Table 6).

The committee points out that some universities and companies are paying salaries of about $100,000 annually, which is a positive development. In contrast, the cap on federal salaries is currently less than $77,500 for the highest-paid civil service positions. The committee believes that this salary ceiling has a deleterious effect on federal agricultural science programs, because it prevents the government from competing for the most sought-after scientists. The committee believes the salary ceiling should be lifted.

Salaries are a function of many factors beyond employment demand, including responsibility, performance, length of appointment, and age. The salary advantage of applied agricultural scientists noted earlier could be due, at least in part, to their age distribution, which shows a bias toward the older group (see Appendix A, Table 8). Another factor may stem from the low participation rates of applied agricultural scientists in postdoctoral fellowships. Most agricultural scientists move directly into professional positions upon graduation. Therefore, they tend to have more years of professional experience than scientists of comparable ages in related fields that commonly offer postdoctoral fellowships.

In 1985 the average salary of 30- to 34-year-old agricultural science Ph.D.s was slightly higher than that of agriculture-related basic science Ph.D.s (see Appendix A, Table 6). In general, the demand for Ph.D.s in applied agriculture—measured by relative salaries—appears similar to agriculture-related basic science Ph.D.s and has not changed significantly during the last decade. The only exception to this salary pattern occurs in industry where the 30- to 34-year-old applied agricultural science degree recipients lag in average salary behind agriculture-related basic science degree recipients.

Overall, the salary data suggest there are no current supply and demand problems for Ph.D.s in agricultural science, although there may be a relatively small pool of recent graduates within specific subspecialties in some regions of the country. The prospect of future supply and demand imbalances are assessed in the next chapter.

Employment Mobility

The committee reviewed data indicating considerable employment mobility between sectors and fields. Movement between related fields occurs at all stages of a scientist's career. As demonstrated by Table 3-3, 39 percent of doctoral scientists employed in 1985 in applied agricultural science fields held degrees in fields other than applied agricultural science (20 percent were in agriculture-related basic sciences, 13 percent in other natural sciences, and 6 percent in other fields). Individuals from fields other than applied agriculture will continue to be important resources for agriculture. On the other hand, movement out of the field of degree is limited at the time the individual enters the job market, for example, just after receiving a doctoral degree. This is not surprising; a new graduate generally seeks jobs in the field of his or her degree.

PRODUCTION OF PH.D.S IN AGRICULTURE

Table 3-6 summarizes the number of Ph.D.s awarded in 1985 to U.S. and non-U.S. citizens by subfield in the basic and applied agricultural science fields. The new doctoral recipients in the basic science fields outnumber the applied agricultural sciences degree recipients by almost three to one. This ratio is not unexpected, because Ph.D.s in the basic sciences work in many areas other than agriculture.

Figure 3-4 shows the number of Ph.D.s granted in applied agriculture from 1975 to 1985. The number of Ph.D. recipients has increased significantly since 1977. In 1985 the number of recipients in these fields was an estimated 40 percent larger than in 1977. However, only two-thirds of the 1985 graduates were U.S. citizens or foreigners with permanent residence visas. The 1977–1985 increase in doctoral degrees granted in agricultural sciences occurred primarily in animal and plant/soil-related fields; the food and natural resources/environmental sciences fields showed essentially no growth at all. The number of Ph.D.s granted in agriculture-related basic sciences peaked in 1980 and declined to a 9 percent lower level in 1985.

It is important to note that during this period of increasing numbers of doctoral degree recipients in applied agricultural sciences, undergraduate enrollment patterns differed markedly. Between 1978 and 1985, undergraduate majors in agriculture in the member institutions of the National Association of State Universities and Land-Grant Colleges (NASULGC) dropped about 28.5 percent.

In sum, it is not clear whether a continuation of the trend toward decreasing undergraduate enrollments will produce corresponding decreases in the numbers of Ph.D.s in agricultural science. Many factors could increase the number of doctoral candidates despite declining undergraduate enrollments. The most important include recruitment efforts and the availability of attractive fellowship and research assistant opportunities.

Foreign Students

About one-third of new Ph.D.s in applied agriculture were non-U.S. citizens holding temporary visas; the figure was about 13 percent in the basic sciences for agriculture (Table 3-6). These data show evidence of the attractiveness of U.S. applied agricultural education to foreign students. For U.S. educators and researchers, foreign students are a source of knowledge about agriculture methods, problems, and goals in other countries. The chance to carry out or supervise doctoral thesis research in a foreign country can be a rewarding experience.

Foreign students who received doctorates in 1985 showed the

TABLE 3-6 Doctorates Granted in Selected Basic and Applied Sciences in 1985

Specialties[a]	Number[b] Total	Non-U.S. Citizens with Temporary Visas
I. Applied agricultural sciences		
Animal	252	79
Animal breeding and genetics	28	9
Animal husbandry, science, and nutrition	173	53
Veterinary medicine	51	17
Plant and soil	440	159
Agronomy and soils and soil sciences	255	99
Plant breeding and genetics	88	25
Other plant sciences	21	8
Horticulture and hydrobiology	76	27
Food science and technology	136	53
Natural resources and environment	238	36
Fish and wildlife	74	6
Forestry	105	19
General and other environmental sciences	42	6
Hydrology and water	17	5
Other	126	65
General and other agriculture	66	31
Agricultural engineering	60	34
Subtotal	1,192	392
II. Agriculture-related basic sciences		
General	1,833	205
Biochemistry	579	69
Biophysics	69	9
Biometrics	40	6
Cytology	100	7
Ecology	200	17
Embryology	15	-
Entomology	173	32
Molecular biology	277	30
Genetics	105	11
Other general biological sciences	275	24
Plant-related	640	120
Botany	120	17
Bacteriology and microbiology	304	40
Plant genetics	31	16
Plant pathology	127	35
Plant physiology	58	12
Animal-related	620	66
Immunology	121	10
Nutrition and dietetics	113	24

TABLE 3-6 (Continued)

Specialties[a]	Number[b] Total	Non-U.S. Citizens with Temporary Visas
Animal physiology	239	23
Zoology	147	9
Subtotal	3,093	381
III. Agricultural economics	147	48

[a]See Appendix C.
[b]For 3 percent of individuals with Ph.D.s, citizenship was unknown.

SOURCE: NRC (1985c).

greatest representation in agricultural engineering (57 percent) and lowest in natural resources and environment (15 percent). The committee believes the following issues associated with the education of foreign students deserve further study:

- The degree of dependence of some institutions and departments on foreign students to fill classrooms;
- The interest and capability of faculty in meeting the education and training needs of foreign students, including supervision of field research outside the United States;
- The ways interests and needs of foreign students should be reflected in the curricula and related class activities; and
- Strategies to foster understanding of agricultural problems and systems in other countries through interaction with foreign and domestic students and foreign faculty.

The committee believes that the task of educating scientists from other countries, especially developing countries, is an important mission of the U.S. university system. Education of foreign students warrants support from university administrators and faculty. Many foreign students need help in understanding a new culture and language and and gaining familiarity with scientific procedures and equipment. These problems must be overcome so that foreign students can benefit from the educational resources available to them. Additionally, institutions and faculty often

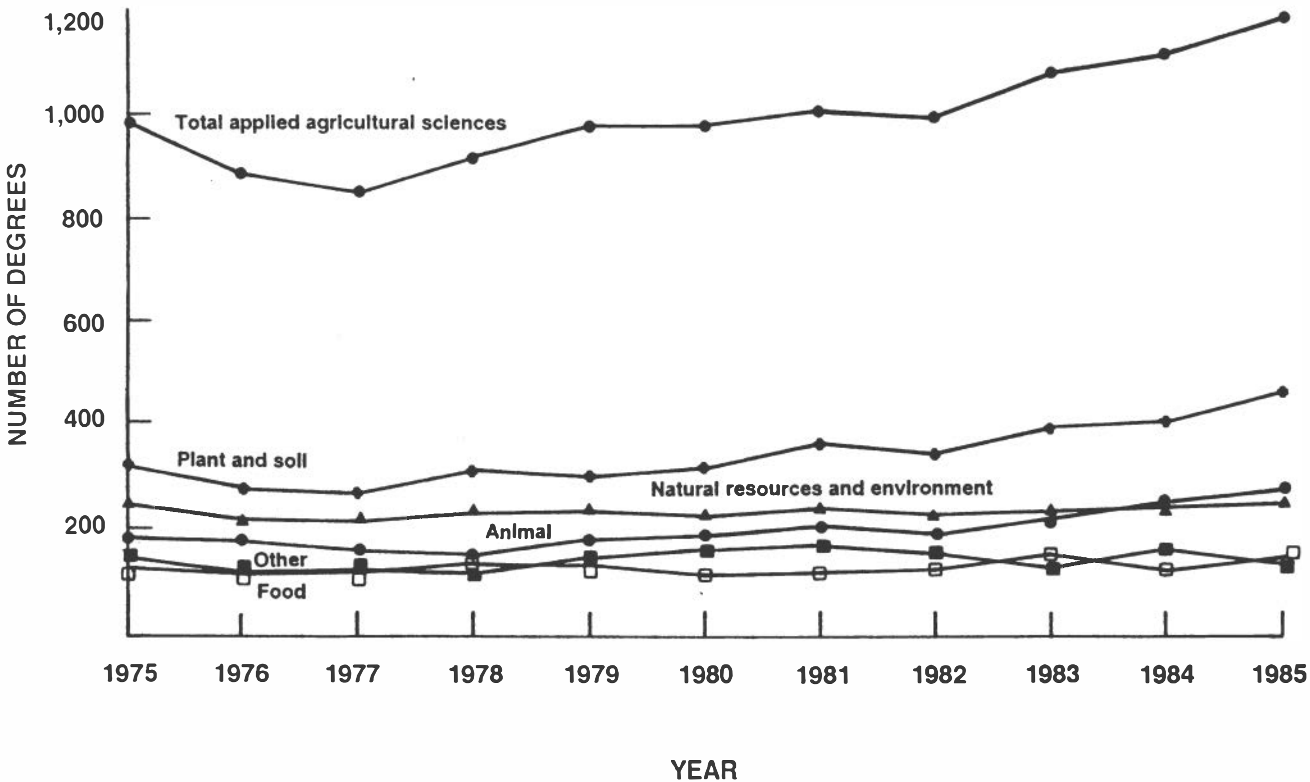

FIGURE 3-4 Ph.D.s granted in applied agricultural sciences. Source: NRC (1986b).

need to make sure foreign students are able to apply their new knowledge to situations within their countries.

The presence of foreign students can benefit teaching programs, students, and institutions. Foreign students can be an important source of knowledge about their respective countries. They can help U.S. scientists gain a better understanding of conditions and scientific challenges outside the United States. Agriculture is a global endeavor; the marketplace is the world. Educating foreign students can be a way to help them—and all students—develop an international view of agriculture and a sense of the global challenges that must be overcome to feed all people.

Basic Skills of Students

In recent years, many educators have noticed the quality of students—undergraduate and graduate—intending to enroll in agricultural science programs is relatively low (NASULGC, 1986b). Test scores support this perception.

Most college-bound high school seniors take the SAT. As seen in Table 3-7, the verbal and quantitative scores of students intending to study agriculture as undergraduates were among the lowest on the SAT. Among all students taking this test, only those intending to major in home economics had lower average scores. Students planning to major in physical sciences and English had combined verbal and mathematics average scores 19 percent or more above those of the prospective agricultural majors.

A similar picture emerges from GRE average scores. College seniors who plan to attend graduate school take the GRE, which is intended to predict performance. Students intending to go to graduate school in biosciences, computer sciences, mathematics, and physical sciences had higher verbal and quantitative scores than students intending to go to graduate school in agriculture.

The implications of these data are disturbing. Agriculture has an impact on the well-being and health of all citizens, and plays a role in assuring a prosperous national economy. Agricultural doctoral scientists face many technical and scientific challenges.

Employers in the private sector and agricultural educators and institutions must overcome misunderstandings among gifted students in high school and at the undergraduate level that agricultural science careers are either uninteresting or unrewarding. This effort will take time and require some changes in educational

TABLE 3-7 Basic Skills of Students as Reflected in Test Scores

Intended Area of Study	1985 SAT Scores (average)		1981-1984 GRE Scores (percentage with scores above mean of 500)	
	Verbal	Math	Verbal	Quantitative
Agriculture	400	433	33.7	65.2
Biosciences	480	516	54.6	77.6
Business and commerce	407	456	35.8	64.7
Computer science	413	488	48.3	91.0
Education	404	432	30.6	42.3
English	526	499	76.9	57.4
Home economics	385	408	20.6	33.8
Mathematics	459	578	56.4	93.0
Physical sciences	506	569	56.6	89.4

SOURCES: Educational Testing Service (1985b); The College Board (1985).

programs. The students and previously trained Ph.D.s that agriculture needs to reach have many options. They tend to carefully analyze their career choices. As a group, they are attracted to careers that provide interaction with colleagues, scientific challenges, professional recognition, and competitive salaries. Some agricultural science positions meet these requirements and attract top-notch candidates. Most positions do not meet these requirements to the extent necessary to improve the quality of doctoral scientists.

4
Future Demand for Agricultural Scientists

To predict the skills and abilities that agricultural scientists will require, the committee assessed future supply and demand trends for these scientists and developed simple projections of possible changes in the distribution of employment opportunities among employment sectors, work activities, and disciplines.

The committee's analysis produced no evidence projected changes in market demand will require changes in competency needs. On the supply side, the committee concluded it is unlikely a serious shortage will arise for scientists trained to carry out agricultural and food system research. Underlying this judgment is the assumption agricultural science positions will provide competitive salaries, professional opportunities, and interactions with colleagues.

The committee's supply-side conclusions rested on the finding that about 40 percent of doctoral scientists who worked in applied agriculture held degrees in other disciplines, usually basic science. This mobility has potential benefits to agricultural science and research. The committee expects this mobility could grow if basic scientists are persuaded agricultural career opportunities exist in businesses, research institutions, and academia.

PROJECTIONS

A number of projections of U.S. science and engineering labor markets have been made, including some disaggregated according to field of employment. Only a few projections examine doctoral scientists, however. The NSF (NSF, 1979) and the Bureau of Labor Statistics (BLS) (U.S. Department of Labor, 1975) produced projections of doctoral scientists. The most recent NSF publication about this subject was issued in 1979, extends only to 1987, and does not disaggregate the relevant fields more finely than "life sciences." It provides little information directly pertinent to agricultural scientists. The most recent Bureau of Labor Statistics doctoral projections were issued in 1975 and extended into 1985. They too did not disaggregate fields below the life sciences level. No new BLS or NSF doctoral projections are currently anticipated.

Other projections that have covered agricultural scientists and engineers combine those individuals with bachelor's, master's, and doctoral degrees. The USDA issued projections in 1986 that extend to 1990 (Coulter et al., 1986); the BLS, projections that extend to 1995 (U.S. Department of Labor, 1984); and the NSF, projections that extend to 1987 (NSF, 1984b).

In responding to its charge, the committee found these pooled projections of limited use. The committee determined it is inappropriate to assume that the job placement outlook for doctoral agricultural scientists is similar to that for all agricultural scientists with bachelor's, master's, and Ph.D. degrees. Moreover, there are differences in degree distribution among types of employers and activities. For example, 58 percent of doctoral agricultural scientists and engineers (by field of degree) worked in academia in 1983 (see Figure 3-2); 25 percent of all agricultural scientists and engineers worked in this sector. Only 26 percent of these doctoral scientists and engineers worked in industry; 46 percent of all agricultural scientists and engineers worked in industry. In terms of major work activities of scientists and engineers among all sectors, 38 percent of those at the doctoral level were primarily engaged in R&D (see Table 3-4); only 30 percent of all agricultural scientists and engineers were similarly engaged (NSF, 1985b,e).

Another difference in job opportunities for doctoral, master's, and bachelor's degree recipients who studied agriculture can be noted by the percentage of those who actually worked in agriculture. About two-thirds of the 1980 graduates who received bachelor's and master's degrees in agricultural disciplines and were employed in science and engineering jobs in 1982 worked in agriculture (NSF, 1984a). In 1981 slightly more than 80 percent of 1979–1980 agricultural doctoral graduates had jobs in agriculture (NRC, 1985b).

Available projections on Ph.D.s working in agricultural science are also inadequate. They are outdated, too aggregated, or do not extend sufficiently into the future. The committee recommends an institution or organization with appropriate technical expertise working under the guidance of public sector agencies, particularly the USDA and NSF, should develop projections of supply and demand of scientists at least every three to five years. Congress should commit funds to support compilation, analysis, and distribution of such data.

The committee used a variety of data sources to project conditions of the labor market for Ph.D. scientists in agriculture (by employment field). Among these sources were several U.S. government agencies; trade and educational associations; and agricultural science leaders, educators, and research administrators.

The data in the source publications were difficult to compare because they are represented by different categories and definitions. Additionally, qualitative characteristics of Ph.D.s are hard to measure and, consequently, to project into the future. For these reasons, the committee took the perceptions of agricultural science leaders, educators, and research administrators into account in making its projections and drawing conclusions.

Future Scenarios

There are problems in assessing how future employment demand might influence the skills and abilities required of agricultural scientists. It is difficult to predict future needs because of rapid scientific advancements, which are causing needs for economic adjustments. There is no verified model, which means that assumptions about international developments, public and private support for research, and academic demographics are necessary.

The committee interviewed public- and private-sector research leaders and administrators to assess future needs. Other research leaders and educators directed attention to changes in the skills that future Ph.D.s will need when beginning their careers. The perceptions of research leaders helped the committee structure analytical assessments and projections. Sector and activity scenarios for the next decade were examined.

Three scenarios for employment demand are projected—minimum growth, extension of current (1975–1985) growth, and maximum growth. (Because only economic indicator of demand is employment, the term *agricultural scientist* in the ensuing section is defined in terms of field of employment.)

To make appropriate curricular changes, it is necessary to assess the time period during which new graduates will receive their training. Individuals who received Ph.D.s in agricultural science in 1984 required an average of 5.9 years of registered time to obtain their degrees, and 8.4 years of total time (NRC, 1985c). Many Ph.D. recipients in the 1990s are in graduate school.

The 1985–1995 Period

Because of variable growth rates in academia, industry, and government, the distribution of agricultural science Ph.D.s among employment sectors would change by 1995, with a continuing shift toward industry (see Table 4-1). Academia would decrease its share slightly but would still be employing nearly half of the agricultural science and engineering Ph.D.s; industry would increase its share from 34 to 38 percent; and the government would decrease its share from 18 to 15 percent.

A more sophisticated projection requires consideration of factors that are likely to affect future growth rates among sectors. The committee examined factors expected to affect academia, industry, and government.

Academia In academia, R&D expenditures and enrollments are the two dominant factors determining employment demand. During the 1975–1985 period, these two parameters followed distinctly different patterns. R&D expenditures increased steadily between 1975 and 1982, but leveled off in 1984. This increase reflected support from state government for research at land-grant colleges and universities and at agricultural experiment stations. Currently, about 30 percent of academia's agricultural R&D expenditures come from the federal government, about 60 percent from state government, and the balance from industry and grower organizations (NSF, 1985d).

TABLE 4-1 Sectoral Employment Distributions, 1985-1995 (percentage)

	1985 Share of Agricultural Ph.D. Employment	1995 Share of Agricultural Ph.D. Employment[a]		
		Current Trends[b]	Minimum	Maximum
Academia	48	47 (1.4)	43 (0.0)	35 (1.4)
Industry	34	38 (2.8)	40 (2.8)	50 (9.0)
Government	18	15 (0.5)	17 (0.0)	15 (2.9)
Total	100	100 (1.8)	100 (1.1)	100 (5.4)

[a]Figures in parentheses show projected yearly 1985-1995 growth rates based on alternative assumptions.
[b]Trends are for 1975-1985.

SOURCE: NRC (1986b).

Data on the number of degrees conferred (bachelor's, master's, and doctoral) are widely viewed as the best available data to use as a surrogate for enrollment. (Data on enrollments for academic institutions are not consistently collected or compiled.)

Enrollments declined steadily from the mid-1970s until the mid-1980s (U.S. Department of Education, 1983). Yet, academic employment of agricultural science doctorates increased steadily. These and data cited in Chapter 3 (see Table 3-4) suggest that a growing portion of faculty time was devoted to research and extension activities instead of teaching. If these trends in enrollments and R&D funding continue, employment demand for academic department and experiment station staff with Ph.D.s may become more dependent on state and federal appropriations for agricultural research.

There is little evidence that recent downward enrollment trends in the agricultural sciences at the undergraduate level are changing. Available demographic data point to an approximate 15 percent decline in the college-age population (18- to 22-year-olds) between 1985 and 1995 (U.S. Department of Commerce, 1984). Economic prospects throughout the agricultural, food, and fiber industries appear to be reinforcing declining enrollments.

As shown in Table 4-1, the committee believes a minimum rate of change in academic employment over the 1985–1995 period would be 0.0 percent per year; the maximum rate would be a continuation of the trend of 1.4 percent per year experienced during 1975–1985. While these growth rates in the total number of Ph.D.s working in academia are low, additional opportunities will arise for new hires, because there are significant numbers of individuals in the existing labor pool who will be retiring. About one-quarter of academically employed applied agricultural science Ph.D.s will reach 65 by 1995 (NRC, 1985c).

Industry In addition to factors such as regulatory policy and international trade, the degree to which commercially significant biotechnologic advances occur in plant breeding; pesticide development; animal health, growth, and reproduction; and related areas will determine the near-term employment demand in the industrial sector.

Multibillion-dollar worldwide markets for new products stemming from biotechnology are considered realistic within 20 years. U.S. agricultural industries are attempting to capitalize on biotechnologic advances by structuring R&D activities toward short- and long-term commercial opportunities. Commercial success will have an effect on the demand for agricultural and food scientists because most industrial firms devote a percentage of gross sales to R&D programs. In the agrochemical industry, for example, R&D expenditures rose in proportion to sales through the 1970s. The annual increase of R&D expenditures in 1985, adjusted for inflation, was close to 10 percent (NACA, 1986).

It is difficult to predict how applications of biotechnology will improve agricultural competitiveness in less-developed countries (LDCs). Some individuals believe that biotechnology will upgrade agricultural productive capacity in areas of the world where food is grown at or near subsistence levels, with little or no yield-enhancing inputs, such as fertilizer (Hardy, 1985). Adjustments will occur in international commodity markets and the structure and location of agribusinesses if biotechnology can be applied in LDCs. This outcome may affect the kinds of skills that U.S. agricultural scientists need.

The committee does not foresee enough biotechnology-generated profits to finance additional R&D activity for up to a decade. But the committee does foresee growing emphasis in industrial research programs on ways to use biotechnology to develop products, production processes, and diagnostic and monitoring capabilities.

A minimum growth rate in the industrial sector from 1985 to 1995 period would be a continuation of the 1975–1985 growth rate of 2.8 percent per year. If economic conditions improve, a maximum annual growth rate of 9 percent in industrial employment could occur.

Government Current fiscal pressures at the federal level are unlikely to lessen during the next several years. But costs in equipment, facilities, and other support are increasing, which means that more funds are needed to sustain the current number of active scientists.

From 1985 to 1995, the committee assumes that 0.0 is the minimum annual growth rate in government sector employment. The assumed maximum growth rate would be 2.9 percent per year, which is equal to the actual 1975–1985 average annual growth rate.

Summary and Implications of 1985–1995 Scenarios

Shifts Among Sectors

Table 4-1 shows the growth rates assumed under each scenario and the estimated proportions of employment by sector. Several shifts occur in moving from current trends to the minimum and maximum scenarios. A progressively larger decline in academia's share of total employed agricultural Ph.D.s—from 47 to 35 percent—would be accompanied by corresponding increases in industry's share—from 38 to 50 percent. The number employed by the government would remain relatively stable at about 15 to 17 percent regardless of scenario.

The most likely projection foresees a smaller share of total agricultural doctoral employment for academia and a correspondingly larger share for industry. Each of these sectors would account for a roughly equal portion of total agricultural scientist employment.

Required Skills

The committee drew tentative conclusions from the data it analyzed regarding changes in skills required by future agricultural scientists. From 1975 to 1985 the industrial and academic shares of employed doctoral degree recipients in agricultural sciences moved in opposite directions. Industry's share increased and academia's decreased. The committee believes that this pattern will continue until 1995.

It is unclear what this shift means for educational programs and priorities, however. Many individuals expressed the view that doctoral-level scientists in industry, many of whom follow career paths that soon leave the laboratory, can best learn the skills they need on the job. Industrial research leaders stressed their interest in scientists with strong basic skills and the ability to work in multidisciplinary, mission-oriented environments.

In contrast to academia, work patterns in industry are skewed toward non-R&D activities. Only 25 percent of industrial scientists with doctorates in applied agricultural disciplines were primarily involved in R&D in 1975. Ten years later, the figure had marginally increased to 27 percent. The time devoted to management and marketing represented another change in industrial work activity distribution. Management accounted for 46 percent of the primary activities in 1975, but decreased to 28 percent in 1985. Other activities, which included marketing and responding to regulatory requirements, rose from 25 percent in 1973 to 41 percent in 1985.

The difficulties involved in applying technologies, gaining licenses, distributing and marketing commodities, and advising farmers in the use of new technologies probably accounted for much of this shift toward non-R&D activity in the industrial sector. While thorough training in basic science skills should be the principal educational goal, providing graduates with skills to carry out these non-R&D activities should be explored. Specific objectives should include skills in applied problem-solving, communications, and management of the application of biotechnological advances. Graduates should also understand economic market forces and opportunities, including those related to the changes in the international marketplace, trade rules, export controls, international patent and licensing laws, and agricultural policies.

The shift in the skills needed as a consequence of the expansion of industrial activities may lead to changes in the skills needed in government and academia. Academic research administrators and leaders in state legislatures and Congress may need to direct additional research support to public policy issues including the economic, environmental, and social implications of agricultural technologies. Government regulatory agencies may have to increase their doctoral staffs to evaluate scientific issues that arise in regulatory decision making.

In spite of the prevalence of non-R&D work activities in industry, the committee observed that industrial leaders prefer scientists trained in the basic sciences. In 1985, nearly 40 percent of Ph.D.s in industry working in applied science positions came from nonapplied agricultural science fields, a percentage which the committee expects to grow among newly hired Ph.D.s. (see Table 3-3).

There are two possible reasons for the large number of individuals in industry who have Ph.D.s in basic science disciplines. Several industrial research leaders who met with the committee believe that many scientific and technologic advances depend on knowledge about molecules and cells. Another possible explanation is that most Ph.D. scientists and engineers in industry begin their careers in research. After the scientists spend some years in research, higher-paying career opportunities open up in product development and management, marketing, and other corporate divisions. (This shift in work activities implies that a broader range of abilities, in addition to research skills, would benefit Ph.D. scientists employed in industry.)

Beyond the Mid-1990s

The committee examined only general trends within the agricultural science and engineering doctoral labor market to assess likely outcomes through the late 1990s and beyond.

Academia It is easier to predict Ph.D. employment in academia than in the other sectors. This is because academic employment depends to a major extent on student enrollments, which in turn are influenced by demographic factors. The size of the cohort of 18- to 22-year-olds, the source of undergraduate enrollments, can be estimated with some precision. Individuals born in 1984 will be candidates for undergraduate academic enrollment in 2002—more than midway into the 1995–2005 decade. Demographic factors are not the only ones influencing enrollments, however.

Enrollments in colleges and universities and in agricultural science programs will depend on student preferences and labor market conditions. Negative perceptions about agriculture and food system issues are likely to discourage students, at least in the near term, from pursuing careers in agriculture. If national leaders stress the importance of the United States remaining at the forefront of technology and efficiency in all agricultural industries, the image of agriculture as a career choice will improve. Public confidence in agricultural industries may also build over the next decade as agricultural commodity market conditions improve.

In addition, faculty retirements will increase between 1995 and 2005. In 1985, 32 percent of the Ph.D.s working in applied agricultural science fields in universities were between the ages of 45 and 55. All who survive will reach age 65 between 1995 and 2005, and most will probably retire near that age.

Another factor that may help to change enrollments is the extent to which the United States attracts foreign students to educational programs. If land-grant colleges and universities make efforts to improve educational curricula and opportunities in this country for foreign students, enrollments of foreign students might grow in the future. Increased enrollment would, in turn, affect the kinds of skills needed by certain faculty members. Language skills, knowledge of agricultural conditions and field research opportunities abroad, familiarity with and access to international scientific literature, and opportunities to work outside the United States would become more important.

Industry Agricultural scientists in industry are expected to continue to move from predominantly research jobs into other facets of business during the course of their careers. A growing percentage of the agricultural scientists in industry would benefit from more technical, analytic, and communication skills as well as basic science education. Because most U.S. agribusinesses have become internationally active, knowledge about regions of the world will also become more valuable. While formal educational programs are important for the development of scientists' skills, continuing education and learning on the job will also be important.

Government Among all the scenarios, committee projections show the least change in the percentage of government-employed agricultural scientists.

Research administrators interviewed by the committee suggested that there would be some change in the skills required of government-employed scientists, at least in fields such as molecular biology and animal genetics. These fields are among those in which biotechnology is changing research techniques and opening up new lines of inquiry (NRC, 1987). The federal government is emphasizing basic science in its laboratories. This is partially because of the expectation that the private sector will pursue applied research and technology development for commercial uses.

Regulatory agencies, patent offices, and the judicial system will probably offer some new opportunities for Ph.D. scientists. These public sector scientists will research or analyze regulation and licensing, environmental protection, food safety and quality, ecology, wildlife and forest management, and related policy areas. The committee expects these opportunities to occur because of the complexity of agricultural issues and the growing proportion of Ph.D.s working in other sectors that provide data to the government.

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Appendix A: Tables

TABLE 1 Employed Scientists by Doctorate Field and Employment Sector

Field of Doctorate	Year	Employment Sector: Academia[a]	Industry[b]	Government	Total[c]
Applied agriculture	1975	6,700	2,400	2,100	11,300
	1985	9,200	4,800	2,700	16,700
Animal	1975	1,700	600	300	2,600
	1985	2,300	1,100	400	3,800
Plant and soil	1975	2,700	700	900	4,300
	1985	3,300	1,400	700	5,500
Food	1975	500	700	100	1,300
	1985	600	1,100	100	1,800
Natural resources and environment	1975	1,100	200	700	2,000
	1985	1,800	800	1,300	3,900
Other	1975	700	200	200	1,100
	1985	1,100	400	200	1,800
Agricultural economics	1975	1,000	300	300	1,600
	1985	1,900	600	400	3,000
Agriculture-related basic sciences	1975	27,400	8,300	5,300	41,000
	1985	37,100	17,200	6,700	61,100
Biological sciences	1975	27,200	7,900	4,800	39,900
	1985	37,200	16,500	6,200	60,000

[a]This sector does not include postdoctoral students.
[b]This sector includes self-employed Ph.D.s.
[c]Totals are not exact. Numbers were rounded and a small number of Ph.D.s (less than 0.3 percent) did not report their employment sectors.

SOURCE: NRC (1986b).

TABLE 2 Primary Work Activities of Employed Ph.D.s by Field of Employment

		Primary Work Activity					
		R&D	Teaching	Management	Other	Total[a]	
Field of Employment	Year	(%)	(%)	(%)	(%)	(%)	(Number)
Applied agriculture	1975	38	20	28	12	100	14,800
	1985	41	15	21	21	100	20,600
Animal	1975	30	30	22	16	100	2,600
	1985	34	22	16	27	100	3,900
Plant and soil	1975	53	20	15	9	100	3,800
	1985	60	13	13	12	100	5,300
Food	1975	41	9	39	9	100	2,200
	1985	41	8	33	16	100	2,700
Natural resources	1975	30	22	33	13	100	4,400
and environment	1985	32	14	23	29	100	6,100
Other	1975	32	14	36	15	100	1,800
	1985	31	18	28	19	100	2,700
Agricultural	1975	40	26	19	11	100	1,900
economics	1985	41	30	10	17	100	2,700
Agriculture-related	1975	42	40	12	4	100	34,500
basic sciences	1985	49	30	11	8	100	45,900
Biological sciences	1975	40	43	12	3	100	34,000
	1985	50	30	12	8	100	50,600

[a]Totals are not exact. Numbers were rounded, and a small number of Ph.D.s (less than 4 percent) did not report their work activities.

SOURCE: NRC (1986b).

TABLE 3 Primary Work Activities of Employed Scientists by Field of Doctorate

Field of Doctorate	Year	Primary Work Activity: R&D (%)	Teaching (%)	Management (%)	Other (%)	Total[a] (%)	Total[a] (Number)
Applied agriculture	1975	40	22	22	13	100	11,300
	1985	42	19	18	18	100	16,700
Animal	1975	33	24	24	16	100	2,600
	1985	35	20	20	23	100	3,800
Plant and soil	1975	47	19	18	12	100	4,300
	1985	51	16	17	15	100	5,500
Food	1975	38	14	32	12	100	1,300
	1985	36	13	28	19	100	1,800
Natural resources	1975	33	35	19	11	100	2,000
and environment	1985	36	24	17	21	100	3,900
Other	1975	48	19	23	10	100	1,100
	1985	51	22	12	11	100	1,800
Agricultural	1975	35	25	27	8	100	1,600
economics	1985	34	26	20	17	100	3,000
Agriculture-related	1975	38	36	16	7	100	41,000
basic sciences	1985	43	25	16	14	100	61,100
Biological sciences	1975	36	38	16	7	100	39,900
	1985	43	27	15	14	100	60,000

[a]Totals are not exact. Numbers were rounded, and a small number of Ph.D.s (less than 4 percent) did not report their work activities.

SOURCE: NRC (1986b).

TABLE 4 Median Annual Salaries of Full-time Employed Ph.D.s

Field of Employment	Year	Academia[a]	Industry[b]	Government	Median
Applied agriculture	1975	41,800	49,400	49,000	45,800
	1985	40,500	46,900	45,700	43,100
Animal	1975	44,400	45,200	49,400	44,800
	1985	40,700	46,000	45,900	43,600
Plant and soil	1975	40,600	42,600	40,200	42,200
	1985	38,800	42,000	49,600	40,300
Food	1975	40,200	51,000	49,800	48,400
	1985	42,000	50,600	45,600	49,300
Natural resources	1975	39,600	50,800	48,600	45,400
and environment	1985	40,600	46,700	43,400	42,900
Other	1975	45,200	49,200	56,600	47,000
	1985	44,500	48,600	48,200	46,300
Agricultural	1975	43,600	65,000	56,800	47,400
economics	1985	41,400	68,500	41,400	42,100
Agriculture-related	1975	40,600	46,000	49,000	43,600
basic sciences	1985	38,300	44,200	44,400	40,300
Biological sciences	1975	40,600	40,800	49,200	42,400
	1985	38,400	45,000	44,700	40,400

NOTE: Applied agricultural scientists have a higher average age than biological or natural scientists and, on average, more years of professional experience at each age.

[a]Academic salaries are adjusted for a 12-month equivalent. Salaries are in constant 1985 dollars.

SOURCE: NRC (1986b).

TABLE 5 Normalized Median Annual Salaries of Full-time Employed Ph.D.s

Field of Employment	Year	Academia[a]	Industry[b]	Government	Median
Applied agriculture[b]	1975	1.00	1.00	1.00	1.00
	1985	1.00	1.00	1.00	1.00
Animal	1975	1.06	0.91	1.01	0.98
	1985	1.00	0.98	1.00	1.01
Plant and soil	1975	0.97	0.86	0.98	0.92
	1985	0.96	0.90	1.09	0.94
Food	1975	0.96	1.03	1.02	1.06
	1985	1.04	1.08	1.00	1.14
Natural resources	1975	0.95	1.03	0.99	0.99
and environment	1985	1.00	1.00	0.95	1.00
Other	1975	1.08	1.00	1.16	1.03
	1985	1.10	1.04	1.05	1.07
Agricultural	1975	1.04	1.32	1.16	1.03
economics	1985	1.02	1.46	0.91	0.98
Agriculture-related	1975	0.97	0.93	1.00	0.93
basic sciences	1985	0.95	0.94	0.97	0.94
Biological sciences	1975	0.97	0.95	1.00	0.93
	1985	0.95	0.96	0.98	0.94

NOTE: Applied agricultural scientists have a higher average age than biological or natural scientists and, on average, more years of professional experience at each age.

[a]Academic salaries are adjusted for a 12-month equivalent.
[b]Applied agricultural scientists' salaries equal 1.00.

SOURCE: NRC (1986b).

TABLE 6 Median Annual Salaries in Dollars of 30- to 34-year-old Full-time Employed Ph.D.s

Field of Employment	Academia[a]	Industry	Government	Median
Applied agriculture	30,800	34,600	33,300	32,400
Animal	30,700			32,600
Plant and Soil	30,900	34,600		30,900
Food		45,500		45,100
Natural resources and environment	26,600	24,900	41,400	27,600
Other				33,800
Agricultural economics		33,000		32,900
Agriculture-related basic sciences	28,500	38,100	31,000	30,500
Biological sciences	28,700	37,900	32,000	30,700

NOTE: Applied agricultural scientists have a higher average age than biological or natural scientists and, on average, more years of professional experience at each age. In several of the fields of employment and employment sector columns, the number of respondents was too small for meaningful estimates of salaries.

[a]Academic salaries are adjusted for a 12-month equivalent.

SOURCE: NRC (1986b).

TABLE 7 Normalized Median Annual Salaries of 30- to 34-year-old Full-time Employed Ph.D.s

Field of Employment	Academia[a]	Industry	Government	Median
Applied agriculture[a]	1.00	1.00	1.00	1.00
Animal	1.00			1.01
Plant and soil	1.00	1.00		0.95
Food		1.32		1.39
Natural resources and environment	0.86	0.72	1.24	0.85
Other				1.04
Agricultural economics	1.07		1.02	
Agriculture-related basic sciences	0.93	1.10	0.93	0.94
Biological sciences	0.93	1.10	0.96	0.95

NOTE: Applied agricultural scientists have a higher average age than biological or natural scientists and, on average, more years of professional experience at each age. In several of the fields of employment and employment sector columns, the number of respondents was too small for meaningful estimates of salaries.

[a]Applied agricultural scientists' salaries equal 1.00.
[b]Academic salaries are adjusted for a 12-month equivalent.

SOURCE: NRC (1986b).

TABLE 8 Age Distribution of Employed Ph.D.s in 1985 (percentage)

Field of Employment	Under 35	35-39	40-45	46-49	50-55	Over 55	Total[a]
Applied agriculture	10	18	22	16	16	18	100
Academia	11	19	16	15	17	23	100
Industry	11	17	28	17	15	12	100
Government	6	16	26	17	17	19	100
Agricultural economics	12	17	21	20	10	20	100
Academia	13	15	20	23	9	21	100
Industry	6	17	26	16	0	35	100
Government	15	27	20	10	21	6	100
Agriculture-related basic sciences	11	20	23	15	12	18	100
Academia	10	18	24	16	13	18	100
Industry	19	26	21	11	10	14	100
Government	6	20	22	19	13	20	100
Biological sciences	12	21	23	15	12	17	100
Academia	10	20	24	15	13	18	100
Industry	19	25	22	12	9	13	100
Government	7	20	22	20	12	19	100

[a]Totals are not exact because of rounding.

SOURCE: NRC (1986b).

TABLE 9 Field Mobility of Employed Ph.D.s in 1985 (percentage)

Field of Employment	Field of Doctorate: Applied Agriculture	Agricultural Economics	Agriculture-Related Basic Sciences	Other Natural Sciences[a]	Other Fields[b]
Applied agriculture	75[c]	7	7	2	0
Agricultural economics	1	65	0	0	0
Agriculture-related basic sciences	9	0	66	3	0
Other natural sciences	8	2	21	80	6
Other fields	7	27	7	15	93
Total[d]	100	100	100	100	100

[a]This field includes the specialties listed under the agriculture, biological sciences, health sciences, computer and information sciences, mathematics, and physical sciences headings from Summary Report 1985: Doctorate Recipients from United States Universities (NRC, 1986b) except agricultural economics and those specialties that are included under applied agricultural sciences and agriculture-related basic sciences. See Table 3-1 and Appendix C.
[b]These fields include the specialties listed under the engineering, psychology, social sciences, humanities, education, and professional fields headings from Summary Report 1985: Doctorate Recipients from United States Universities (NRC, 1986b). See Table 3-1 and Appendix C.
[c]For example, 76 percent of individuals with Ph.D. degrees in applied agriculture worked in applied agriculture.
[d]Totals are not exact because of rounding.

SOURCE: NRC (1986b).

TABLE 10 Field of Doctorate Distribution of Employed Ph.D.s in 1985 (percentage)

	Field of Employment				
Field of Doctorate	Applied Agriculture	Agricultural Economics	Agriculture-Related Basic Sciences	Other Natural Sciences[a]	Other Fields[b]
Applied agriculture	61[c]	3	3	1	1
Agricultural economics	1	72	0	0	
Agriculture-related basic sciences	20	0	87	10	2
Other natural sciences	13	0	9	78	7
Other fields	6	25	1	12	90
Total[d]	100	100	100	100	100

[a]This field includes the specialties listed under the agriculture, biological sciences, health sciences, computer and information sciences, mathematics, and physical sciences headings from Summary Report 1985: Doctorate Recipients from United States Universities (NRC, 1986b) except agricultural economics and those specialties that are included under applied agricultural sciences and agriculture-related basic sciences. See Table 3-1 and Appendix C.
[b]These fields include the specialties listed under the engineering, psychology, social sciences, humanities, education, and professional fields headings from Summary Report 1985: Doctorate Recipients from United States Universities (NRC, 1986b). See Table 3-1 and Appendix C.
[c]For example, of the Ph.D.s who worked in applied agriculture, 61 percent received Ph.D.s in that field.
[d]Totals are not exact because of rounding.

SOURCE: NRC (1986b).

TABLE 11 Work Mobility of Agricultural Ph.D.s (percentage)

Sector Status in 1979	Sector Status in 1985		
	Academia	Industry	Government
Academia	93	12	6
Industry	4[a]	81	2
Government	3	6	92
Total[b]	100	100	100

[a]For example, 4 percent of those employed by industry in 1979 were employed by academia in 1985.
[b]Totals are not exact because of rounding.

SOURCE: NRC (1986b).

TABLE 12 Ph.D. Degrees Granted by U.S. Colleges and Universities

Field	1975	1977	1979	1981	1983	1985
Applied agriculture						
Total	997	854	968	1,063	1,096	1,192
Domestic	716	574	643	662	723	765
Animal						
Total	176	150	179	209	218	252
Domestic	128	109	118	129	147	167
Plant and soil						
Total	316	269	288	352	393	440
Domestic	208	157	172	210	246	268
Food						
Total	119	113	118	104	141	136
Domestic	78	64	79	53	89	79
Natural resources and environment						
Total	244	209	226	236	227	238
Domestic	208	177	192	189	172	193
Other						
Total	142	113	157	162	117	126
Domestic	94	67	82	81	69	58
Agricultural economics						
Total	162	143	154	168	157	147
Domestic	103	87	79	103	88	87
Agriculture-related basic sciences						
Total	3,219	3,124	3,247	3,343	3,178	3,093
Domestic	2,831	2,731	2,885	2,986	2,804	2,618
Biological sciences						
Total	1,758	1,631	1,555	1,414	1,468	1,516
Domestic	1,421	1,316	1,318	1,104	1,093	1,077

NOTE: "Domestic" included U.S. citizens and individuals with permanent visas. "Total" included the domestic number and the number of foreign students who received Ph.D. degrees from U.S. colleges and universities. For 3 percent of individuals with Ph.D.s, citizenship was unknown.

SOURCE: NRC (1985c).

TABLE 13 Bachelors' and Masters' Degrees Granted by U.S. Colleges and Universities

Field of Degree	1975	1977	1979	1981	1983
Agriculture and natural resources[a]					
Bachelor's	17,500	21,500	23,100	21,000	21,000
Master's	3,070	3,700	3,990	4,160	4,270
Biological sciences					
Bachelor's	51,700	53,600	48,800	47,600	40,900
Master's	6,550	7,110	6,830	5,870	5,740
Physical sciences					
Bachelor's	20,700	22,900	23,200	24,100	23,500
Master's	5,810	5,330	5,450	5,510	5,290

[a]This category includes agronomy; soil science; animal science; dairy science; poultry science; fish, game, and wildlife management; horticulture; ornamental horticulture; agriculture and farm management; agricultural economics; agricultural business; food science and technology; forestry; natural resource management; agriculture and forestry technologies; and range management.

SOURCES: U.S. Department of Health, Education, and Welfare (1975, 1977, 1979); U.S. Department of Education (1981, 1983).

TABLE 14 Total 22-year-olds in the U.S. Population (in thousands)

Year	Men	Women	Total
	Actual		
1970	1,757	1,737	3,494
1971	1,759	1,750	3,509
1972	1,762	1,749	3,511
1973	1,839	1,817	3,656
1974	1,892	1,865	3,757
1975	1,944	1,919	3,863
1976	1,996	1,975	3,971
1977	2,041	2,015	4,056
1978	2,072	2,047	4,119
1979	2,158	2,127	4,285
1980	2,177	2,138	4,315
1981	2,173	2,139	4,312
1982	2,169	2,131	4,300
1983	2,204	2,165	4,369
1984	2,160	2,112	4,272
1985	2,126	2,086	4,212
	Projected		
1986	2,144	2,068	4,212
1987	2,051	1,988	4,039
1988	1,932	1,868	3,800
1989	1,869	1,815	3,684
1990	1,830	1,771	3,601
1991	1,877	1,816	3,693
1992	1,934	1,864	3,798
1993	1,936	1,867	3,803
1994	1,760	1,699	3,459
1995	1,701	1,644	3,345
1996	1,642	1,586	3,228
1997	1,682	1,622	3,304
1998	1,653	1,597	3,250
1999	1,710	1,650	3,360
2000	1,704	1,646	3,350

SOURCE: U.S. Department of Commerce (1984, 1986).

Appendix B: Data Sources

SURVEY OF DOCTORATE RECIPIENTS

National Research Council

This survey has been carried out since 1973 on a biennial basis. It is a longitudinal study. The same sample group of individuals with Ph.D.s in the sciences, engineering, and the humanities obtained in the United States are surveyed every two years. The survey produces employment, demographic, and educational characteristics of the U.S. population with Ph.D. degrees in the sciences, engineering, and the humanities.

The sampling frame is stratified to assure coverage of all significant subpopulations. While sampling rates in particular strata vary between 2 to 100 percent, the overall sampling rate for the latest survey was about 13 percent. It involved about 72,000 individuals. Overall response rates for the surveys have been about 70 percent (NRC, 1985).

SURVEY OF EARNED DOCTORATES

National Research Council

This survey has been conducted annually since 1958. Graduate school deans distribute questionnaires to all recipients of Ph.D. or equivalent degrees near graduation. Professional degrees such as the M.D., D.D.S., and D.V.M. are not covered by this survey. The survey provides information on educational and demographic characteristics as well as work plans of new Ph.D.s. Response rates have been near 95 percent (NSF, 1983).

SURVEY OF RECENT SCIENCE AND ENGINEERING GRADUATES

National Science Foundation

Information in this survey is collected on the demographic and employment characteristics of individuals who received a bachelor's or master's degree one or two years before the survey year.

The survey is carried out on a national sample basis and covers only those individuals who are permanent residents of the United States. Names and addresses of potential respondents are supplied by a national sampling of universities and colleges, drawn from a universe of 274 institutions that awarded science and engineering degrees. Sampling strata for the universities are selected for a number of parameters, including geography, public or private status, proportion of engineering graduates, existence of agricultural curricula, and minority representation. The sample of degree recipients constitutes about 3.5 percent of science and engineering graduates with bachelor's degrees and about 13 percent of science and engineering graduates with master's degrees. Response rates are about 60 percent (NSF, 1985a).

SURVEY OF SCIENTIFIC AND ENGINEERING EXPENDITURES AT UNIVERSITIES AND COLLEGES

National Science Foundation

This survey's universe in 1983 included 562 educational institutions in the United States and its territories. To qualify for inclusion in the universe, the institution had to have programs leading to a doctorate or master's degree in science or engineering, or separately budgeted research and development (R&D) expenditures of at least $50,000. Federally Funded Research and Development Centers (FFRDCs) administered by a university or a consortium of universities were also covered, but were reported separately from the institutions of higher education. In 1984 the survey methodology was changed to involve all doctorate-granting institutions, but only a sample of the master's and bachelor's degree-granting institutions.

The survey collects data on current expenditures for separately budgeted science and engineering R&D by field, the proportions of these expenditures used for basic research, and sources of these funds. Data are also collected on expenditures for research equipment by the source of funds, and capital expenditures for facilities and equipment (regardless of whether they are for research or instruction). Institutions are given the opportunity to correct data from the year before. When this happens, the NSF changes corresponding trend data. Research expenditures that are not separately budgeted are not covered in the survey. The response rate for the 1984 survey (which represents 1983 data) was 78 percent (NSF, 1985b).

HIGHER EDUCATION GENERAL INFORMATION SURVEY

National Center for Educational Statistics
U.S. Department of Education

This survey, which was started in 1966, is designed to acquire and maintain information on the characteristics and operations of all U.S. institutions of higher education. The survey solicits information concerning institutional characteristics, faculty salaries, finances, enrollment, and degrees (U.S. Department of Education, 1985).

GRADUATE RECORD EXAMINATION SCORES

The Graduate Record Examination Board/
Educational Testing Service

The Graduate Record Examination takes place five times per year at test centers throughout the world. Two types of tests are offered: (1) a general test, consisting of verbal, quantitative, and analytic parts, and (2) subject tests in 17 disciplines. For each year, aggregated data based on the performance of persons who have taken the tests during the respective past three years are presented.

General test scores range from 200 to 800, with 800 as the highest score; subject test scores range from 299 to 990, with 990 as the highest score. An individual's score on a test is not a perfect measure of his or her knowledge or ability. There is a hypothetical "true score," which represents the individual's average score if all the possible editions of the test had been taken with no change in the individual's knowledge or ability. The difference between the observed score in a single test and the true score is called the "error of measurement." For the general test scores quoted in this report, the standard errors of measurement are in the 34 to 40 percent range (Educational Testing Service, 1985a,b).

SCHOLASTIC APTITUDE TEST SCORES

The College Entrance Examinations Board

About one-third of all high school seniors participate in the College Board's admissions testing program. The College Board's publication summarizes aggregated data for all seniors who registered for the SAT or Achievement Tests by March of their graduating year. The records include a few foreign students seeking higher education in the United States, but their participation rate is so small that it does not significantly influence the results reported.

The survey produces aggregated data on the scholastic aptitude scores, scores for achievements in 13 academic subjects, demographic data on the test takers, plans for college study, and extracurricular activities. Data are presented in annual reports (The College Board, 1985).

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Appendix C
Specialties List

The following is an excerpt from survey material used by the National Research Council in its *Summary Report 1985: Doctorate Recipients from U.S. Universities.*

Instructions: The following field listing is to be used in responding to items 13, 14, 21b, and 22c. If a field marked with an asterisk (*) is chosen in item 13 or 14, please write in your field of specialization in the space provided.

Agriculture

000 Agricultural economics
005 Animal breeding and genetics
010 Animal nutrition
019 Animal sciences, other*
020 Agronomy
025 Plant breeding and genetics
030 Plant pathology (see also 120)
039 Plant sciences, other*
040 Food sciences
045 Soil sciences
050 Horticulture science
055 Fisheries sciences
060 Wildlife management
065 Forestry science
098 Agriculture, general
099 Agriculture, other*

Biological Sciences

100 Biochemistry
105 Biophysics
110 Bacteriology

115 Plant genetics
120 Plant pathology (see also 030)
125 Plant physiology
129 Botany, other*
130 Anatomy
133 Biometrics and biostatistics
136 Cell biology
139 Ecology
142 Embryology
145 Endocrinology
148 Entomology
151 Immunology
154 Molecular biology
157 Microbiology
160 Neurosciences
163 Nutritional sciences
166 Parasitology
169 Toxicology
170 Genetics, human and animal
175 Pathology, human and animal
180 Pharmacology, human and animal
185 Physiology, human and animal
189 Zoology, other*
198 Biological sciences, general
199 Biological sciences, other*

Health Sciences

200 Audiology and speech pathology
210 Environmental health
215 Public health
220 Epidemiology
230 Nursing
240 Pharmacy
250 Veterinary medicine
298 Health sciences, general
299 Health sciences, other*
200 Audiology and speech pathology
210 Environmental health
215 Public health
220 Epidemiology
230 Nursing
240 Pharmacy
250 Veterinary medicine
298 Health sciences, general
299 Health sciences, other*

Engineering

300 Aerospace, aeronautical and astronautical
303 Agricultural
306 Bioengineering and biomedical
309 Ceramic
312 Chemical
315 Civil
318 Communications
321 Computer
324 Electrical, electronics
327 Engineering mechanics
330 Engineering physics
333 Engineering science
336 Environmental health engineering
339 Industrial
342 Materials science
345 Mechanical
348 Metallurgical
351 Mining and mineral

354 Naval architecture and marine engineering
357 Nuclear
360 Ocean
363 Operations research (see also 465, 930)
366 Petroleum
369 Polymer
372 Systems
398 Engineering, general
399 Engineering, other*

Computer and Information Sciences

400 Computer sciences
410 Information sciences and systems*

Mathematics

420 Applied mathematics
425 Algebra
430 Analysis and functional analysis
435 Geometry
440 Logic (see also 785)
445 Number theory
450 Probability and mathematical statistics (see also 690)
455 Topology
460 Computing theory and practice
465 Operations research (see also 363, 930)
498 Mathematics, general
499 Mathematics, other*

Physical Sciences

Astronomy

500 Astronomy
505 Astrophysics

Atmospheric and Meteorological Sciences

510 Atmospheric physics and chemistry
512 Atmospheric dynamics
514 Meteorology
518 Atmospheric and meteorological sciences, general
519 Atmospheric and meteorological sciences, other*

Chemistry

520 Analytical
522 Inorganic
524 Nuclear
526 Organic
528 Pharmaceutical
530 Physical
532 Polymer
534 Theoretical
538 Chemistry, general
539 Chemistry, other*

Geological Sciences

540 Geology
542 Geochemistry
544 Geophysics and seismology
546 Paleontology
548 Mineralogy, petrology

550 Stratigraphy, sedimentation
552 Geomorphology and glacial geology
554 Applied geology
558 Geological sciences, general
559 Geological sciences, other*

Physics

560 Acoustics
561 Atomic and molecular
562 Electron
564 Elementary particle
566 Fluids
568 Nuclear
569 Optics
570 Plasma
572 Polymer
574 Solid state
578 Physics, general
579 Physics, other*

Other Physical Sciences

580 Environmental sciences
585 Hydrology and water resources
590 Oceanography
595 Marine sciences
599 Physical sciences, other*

Psychology

600 Clinical
603 Cognitive
606 Comparative
609 Counseling
612 Developmental
615 Experimental
618 Educational (see also 822)
621 Industrial and organizational (see also 935)
624 Personality
627 Physiological
630 Psychometrics
633 Quantitative
636 School (see also 825)
639 Social
648 Psychology, general
649 Psychology, other*

Social Sciences

650 Anthropology
652 Area studies
658 Criminology
662 Demography
666 Economics
668 Econometrics
670 Geography
674 International relations
678 Political science and government
682 Public policy studies
686 Sociology
690 Statistics (see also 450)
694 Urban studies
698 Social sciences, general
699 Social sciences, other*

Humanities

History

700 History, American
705 History, European
710 History of science

718 History, general
719 History, other*

Letters

720 Classics
723 Comparative literature
729 Linguistics
732 Literature, American
733 Literature, English
734 English language
736 Speech and debate
738 Letters, general
739 Letters, other*

Foreign Languages and Literature

740 French
743 German
746 Italian
749 Spanish
752 Russian
755 Slavic (other than Russian)
758 Chinese
762 Japanese
765 Hebrew
768 Arabic
769 Other languages*

Other Humanities

770 American studies
773 Archeology
776 Art history and criticism
780 Music
785 Philosophy (see also 440)
790 Religion (see also 984)
795 Theater
798 Humanities, general
799 Humanities, other*

Education

800 Curriculum and instruction
805 Education administration and supervision
810 Educational media
815 Education statistics and research
820 Education testing, evaluation, and measure
822 Educational psychology (see also 618)
825 School psychology (see also 636)
830 Social foundations
835 Special education
840 Student counseling and personnel services
845 Higher education

Teacher Education

850 Pre-elementary
852 Elementary
854 Junior high
856 Secondary
858 Adult and continuing

Teaching Fields

860 Agricultural education
861 Art education
862 Business education
864 English education
866 Foreign languages education
868 Health education
870 Home economics education
872 Industrial arts education
874 Mathematics education

876 Music education
878 Nursing education
880 Physical education
882 Reading education
884 Science education
885 Social science education
886 Speech education
888 Trade and industrial education
889 Teacher and education specific subject areas, other*
898 Education, general
899 Education, other*

Professional Fields

Business and Management

900 Accounting
905 Banking and finance
910 Business administration and management
915 Business economics
920 Marketing management and research
925 Business statistics
930 Operations research (see also 363, 465)
935 Organizational behavior (see also 621)
938 Business and management, general
939 Business and management, other*

Communications

940 Communications research
945 Journalism
950 Radio and television
958 Communications, general
959 Communications, other*

Other Professional Fields

960 Architecture and environmental design
964 Home economics
968 Law
972 Library and archival science
976 Public administration
980 Social work
984 Theology (see also 790)
988 Professional fields, general
989 Professional fields, other*
999 Other fields

Glossary

Agriculture-related basic sciences. Specialties include biochemistry, biophysics, biometrics, ecology, cytology, embryology, entomology, molecular biology, genetics, botany, bacteriology, microbiology, plant genetics, plant pathology, plant physiology, immunology, nutrition and dietetics, animal physiology, and zoology.

Animal sciences. Specialties include animal breeding and genetics; animal husbandry, science, and nutrition; and veterinary medicine.

Applied agricultural sciences. Specialties essentially include those from *Summary Report: 1985 Doctorate Recipients from United States Universities* (NRC, 1986a). (See Appendix C.) Additions to applied agricultural sciences are: 250—veterinary medicine; 303—agricultural engineering; 580—environmental sciences; and 585—hydrology. Deletions are: 000—agricultural economics and 030—plant pathology.

Biological sciences. Includes specialties listed by numbers 100 through 199 in *Summary Report: 1985 Doctorate Recipients from United States Universities* (NRC, 1986a). (See Appendix C.)

Field of doctorate. Field of doctorate degree.

Field of employment. Field of science selected by respondents as most closely related to their principal employment activity.

Natural resources and environment. Specialties include fish and wildlife, forestry, environmental sciences, and hydrology.

Natural sciences. Includes the specialties listed under the agriculture, biological sciences, health sciences, computer and information sciences, mathematics, and physical sciences headings from *Summary Report: 1985 Doctorate Recipients from United States Universities* (NRC, 1986a). (See Appendix C.)

Other applied agricultural sciences. Specialties include general and other agriculture and agricultural engineering.

Plant and soil sciences. Specialties include agronomy and soils, plant breeding and genetics, soil sciences, other plant sciences, and horticulture and hydrobiology.