Chapter 16

Institutional Change Within the Land-Grant System

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The U.S. agricultural research system is large and diverse, employing some 23,000 doctoral level agricultural scientists and economists in academia, industry, and government. For many years, funding of agricultural research was divided evenly between the public and private sectors, but recent studies indicate that today this is not the case—nearly 60 percent of the funding for agricultural research is in the private sector **(9).**

The public-sector agricultural research budget exceeded $2.2 billion for 1989; Federal funding for agricultural research, however, has been a shrinking proportion of total Federal research funding. In 1955, for example, the research budget for the U.S. Department of Agriculture (USDA) represented 13.4 percent of the total Federal nondefense research funding, but was only 4.6 percent of the funding in 1988 (7).

The public agricultural research system nonetheless plays a significant role in the American economy. Studies have estimated high rates of social returns to public agricultural research investments, indicating that these investments have been a wise social investment.

Different types of research are conducted by the public and private sectors and is determined by the extent of externalities. Externalities exist when the action of a single entity (or firm) affects the environment (or decision) of another. If they exist the private sector cannot capture the full returns of its investment, and will not invest in such research at socially optimal levels. The public sector must fill in the gap. The private sector, for example, conducts little agriculture-related social science research; primarily the role of the public sector. Research that creates easily transferable information is conducted by the public sector, while research that creates information embedded in a product is conducted by private sector. For example, the public sector develops pure lines and self-pollinated crop varieties that can be used by any seed company while the private sector develops hybrid varieties that must be purchased annually by farmers if they are to be productive.

The U.S. public sector agricultural research system, a dual Federal-State system, had its origins in the 1860s, but it was not until the late 19th century that the system truly began to acquire the capacity to provide the scientific knowledge needed to deal with the problems of agricultural development. Today the Federal agricultural research system includes the USDA's Agricultural Research Service (ARS), Economic Research Service (ERS), and Forest Service; and the State Agricultural Experiment Stations (SAES) located within the land-grant university system.

The Agricultural Research Service, established in 1953, conducts basic and applied research in six programs covering Natural Resources, Plant Science, Animal Science, Commodity Conversion and Delivery, Human Nutrition, and Integration of Systems. ARS employs approximately 2,670 scientists and engineers (of which about 2,500 have doctoral degrees) and had a fiscal year 1991 research budget of $624 million. Research is conducted at some 127 domestic and 7 foreign locations, including 5 major regional research centers located in Maryland, Pennsylvania, Illinois, Louisiana, and California. ARS has cooperative research agreements with other USDA agencies and many of the ARS facilities are located at or near academic institutions. Some ARS staff hold adjunct faculty appointments and participate in graduate teaching (7, 17, 18).

The Economic Research Service was established in 1961 to provide economic and other social science information and analysis for improving the performance of agriculture and rural America. ERS collects and maintains a number of historical data series on farm type, size, and number; production and input levels; trade; effects of farm policy; and socioeconomic characteristics of rural areas of the United States. The ERS also performs statistical and analytical research, and is organized into four divisions covering Commodity Analysis, Agricultural and Trade Analysis, Resources and Technology, and Agricultural and Rural Economy. ERS has limited funds to contract for research in the academic sector but is not authorized to administer a competitive grants program. The ERS budget for fiscal year 1990 was $51.3 million (7, 16).

The Forest Service is responsible for research on the Nation's forests and for technologies useful in the manufacture of pulp and wood-based products. Research topics cover a broad range, and the Forest Service also manages 182 million acres of forest. The research budget for fiscal year 1990 was $157.4 million.

The land-grant university system in the United States was established in 1862 with the passage of the Merrill Act. The impetus for establishing these land-grant schools arose from both a populist reaction to the elitism of uni-

Table 16-1-Current Formula for Allocating Hatch Funds to States

- 20 percent of the funds are allocated equally to each experiment station.
- At least 52 percent of the funds are allocated as follows: ½ in an amount proportionate to each State's share of the total rural population of all States, and ½ in an amount that is proportionate to each State's share of the total farm population of all States.
- Not more than 25-percent of the funds are allocated to States for cooperative research in which two or more SAES cooperate to solve agricultural problems that are of concern to more than one State.
- 3 percent of the funds are for the administration of the Hatch Act.

SOURCE: National Research Council, Board on Agriculture, "Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System, " National Academy Press, Washington, DC, 1989.

versities in the eastern United States, and a perceived need to provide higher education to the masses, with particular emphasis on the children of farmers and industrial workers. The Merrill Act made grants of land to States that were willing to create universities that would fulfill this mission. Originally, education focused on agriculture and the mechanical arts, but subsequently the educational focus has expanded to include all of the major disciplinary fields.

The partnership between the State and Federal Government was extended to research with the Hatch Act of 1887, which provided Federal funding for the support of agricultural experiment stations at land-grant universities. Before this, agricultural science was limited to the activities of innovative farmers and inventors and the industrial sector, and progress came primarily in the form of mechanical technology. Few States provided significant funding for agricultural research. Eventually, however, agricultural output did not keep up with demand and food prices began to rise. This set the stage for the passage of the Hatch Act. It was not until the 1920s that the land-grant system was fully functional. Today, there are 57 experiment stations located in each of the 50 States, the District of Columbia, the Pacific Territories (American Samoa, Guam, Micronesia, and the Northern Mariana Islands), the U.S. Virgin Islands, and Puerto Rico. Additionally, six historically black universities (the 1890 Universities) and the Tuskegee Institute also conduct publicly supported agricultural research (10).

The Hatch Act provides research funding to States based on a formula that considers the importance of the agricultural sector to the State's economy. The formula funding system (table 16-1) provides stable funding for research programs that may have long gestation periods. All formula funds must be matched by the State. The current formula for funding designates 1955 as the base year and the minimum amount to be allocated.

The structure of the current system was completed with the passage of the Smith-Lever Act in 1914, which created the Cooperative Extension Service-a mechanism to carry the results of the research system to the farmer. Funding is provided by a formula mechanism somewhat similar to that of the Hatch Act. Today there are extension offices in nearly every county in the United States, employing approximately 9,650 county agents and 4,650 scientific and technical specialists; the extension budget totals about $1.2 billion annually (31% Federal) (13).

THE MISSION OF LAND-GRANT UNIVERSITIES

Land-grant universities are distinguished from other universities by their legislatively mandated mission; the Federal-State partnership embodied in the formula funding mechanism; and their integration of research, teaching, and extension. Academic departments within the State Experiment Stations have three functional budgets, one each for teaching, research, and extension; individual professors tend to have joint appointments in one or more of these functional endeavors.

The legislated mission of the system is to provide higher level education to the masses; apply research knowledge to the solution of society's problems; and provide outreach or extension programs for nonresident instruction groups. Over time, the sense of institutional mission has declined as research has become more basic and more focused on increasing disciplinary knowledge than on solving the problems of society. Less emphasis has been given to the development and adaptive research needed to apply basic research to solving social problems. When the system was first established, disciplinary specialization had not yet progressed very far; it was easy to obtain multidisciplinary cooperation among scientists and to communicate the research results to lay people. This is no longer the case.

Rapid post-World War II advances in knowledge and increasing intellectual specialization has made interdisciplinary cooperation and extension increasingly difficult. Specialized language, compounded by the scientific illiteracy of the public, has increased the difficulties in communicating research results to the public. This situation will be even more problematic for research conducted with the tools of biotechnology. The lack of

understanding of these technologies has raised public concerns and in some cases a call for the end of this type of research. University researchers will need to improve their communication skills with the public if they wish to enjoy the academic freedom to conduct this research. The basic premise that the same faculty can efficiently fulfill the multiple missions of the modem land-grant university (research, teaching, and extension) still prevails, but tensions are growing in the system as it becomes more and more difficult to achieve these multiple ends.

The research system must have public support and funding to function. It also must have the flexibility to reallocate scarce resources to new priorities, and to attract highly qualified personnel that can keep abreast of changing technological opportunities. Despite high social returns to public sector agricultural investments, the system has been the subject of criticism from internal and external sources. External critics focus primarily on the heavy research emphasis on agricultural productivity and the lack of research devoted to nutrition, rural problems, and environmental concerns. Internal criticisms have focused on the perceived low quality of the research, on the inadequate interaction of agricultural researchers with the basic scientific disciplines that underlie agriculture, and on the limited role of peer evaluation in project formulation and review. In addition, public-sector budget constraints have frozen funding. Thus, the public sector agricultural research system is being challenged from many directions. Whether the system can be revitalized and renew its historical commitment to solve the problems of society, or whether it becomes isolated and loses its credibility with the public remains to be seen. The decade of the 1990s will be a period of significant change within the agricultural research system.

CHANGING ENVIRONMENT FOR AGRICULTURAL RESEARCH

The ability of the land-grant system to carry out its historic missions is becoming increasingly suspect. Internal as well as external pressures could significantly alter the structure and function of the system. Changing political support, resource base, and institutional frameworks combined with the development of revolutionary new technologies will put presure on the system to change dramatically.

The Political Environment

Historically, political support for the agricultural research system has come primarily from the farm and rural population; as a result, agricultural research has placed heavy emphasis on increasing the productivity of agriculture. However, agricultural's traditional base of support has been eroding steadily. Farm numbers and populations have been declining (table 16-2), and today more than 75 percent of the total U.S. population resides in metropolitan areas. Of the 435 members of the House of Representatives, approximately 100 represent rural districts and this proportion will decline with the new redistricting in 1992 (12).

Table 16-2—Number of Farms in the United States, Selected Years

Year	Number of Farms
1900	5,737,000
1950	5,382,000
1960	3,963,000
1970	2,949,000
1980	2,433,000
1984	2,328,000
1986	2,214,000
1989[a]	2,172,920

[a] *1989* **figures are preliminary.**

SOURCE: U.S. Department of Agriculture, *Agricultural Statistics,* **Washington, DC,** various **years,**

Public interest groups have become increasingly critical of the emphasis on productivity in agricultural research. *Silent Spring (1)* and *Hard Tomatoes, Hard Times (3)* criticized the system for its failure to consider the problems of rural communities, the environment, and consumer needs. Environmental, consumer, and animal welfare groups have become increasingly active in the debates of recent Farm Bills. Additionally, these groups have challenged the universities themselves by bringing forward law suits on the use of public funds for productivity increasing research. For example, a law suit was brought against the University of California system for the development of a mechanical tomato harvester.

The changing demographics of the United States combined with the increased activism of a wider range of constituents is indeed changing the climate in which the land-grant system conducts research. The 1985 Farm Bill contained several conservation measures, and many more such measures were added in the 1990 Farm Bill. Several environmentally oriented research initiatives, such as the groundwater initiative and the low input sustainable agricultural initiative were also passed. Congress increasingly has earmarked agricultural research funds to help the agricultural research system more quickly to adjust to these new priorities. (See table 16-3.)

The political climate is changing at the State level as well, as State agricultural income dwindles. In 1980,

Table 16-3-State Agricultural Experiment Station Funds From Special Grants, Selected Years
(in millions of dollars)

Year	Special grants
1982	12.9
1984	15.8
1986	19.9
1987	21.8
1988	23.2
1989	29.1
1990	39.6

SOURCE: Cooperative State Research Service, Inventory *of Agricultural Research,* **U.S. Department of Agriculture, Washington, DC, various years.**

nearly 29 percent of nonmetropolitan counties received at least one-fifth of their total income from farming-related industries. That number had dropped by 1986 to 21 percent and it continues to decline (2). During past recessions, State support for the land-grant system generally has remained strong, but during the last 2 years, as State budgets have become severely constrained, support for the land-grant system has wavered. Not only is funding not increasing, in many States it is actually declining. Thus, for the first time since World War 11, the University of Minnesota received a cut in its operational budget; faculty salaries were frozen for 2 years. Additionally, proposals were introduced in the State legislature to have students pay the full cost of their resident instruction (11). Other State universities are facing similar situations.

The Resource Base

Although total research funding for the State Agricultural Experiment Stations (SAES) has increased slightly over the last decade (table 16-4), in general agricultural research is underfunded. The States provide the majority of the funding for research at the SAES, and through the 1980s, State support increased by 58 percent. (See tables 16-4 and 16-5.) However, the recession of the early 1990s has constrained State budgets, resulting in few increases and in some cases declining State support for agricultural research.

The USDA is the second largest single contributor to SAES research funding. Historically, USDA funding has been in the form of a block grant formula funds. Decisions concerning allocation of these funds have been made at the local level. USDA funding has basically stagnated and barely keeps up with inflation. Increases in USDA funding primarily reflect congressional earmarking of special grants for such areas as water quality, nutrition, and integrated pest management and biological control research.

In response to widespread criticisms of the agricultural research system, a major new funding initiative was undertaken in 1977 to establish a USDA competitive grants program. Competition for funding is open to researchers from both the land-grant and non-land-grant universities and research laboratories. Today, grants are awarded in plant and animal systems; natural resources and the environment; human nutrition, food quality, and health; markets, trade, and policy; and development of new products. Funding for the program was $15 million in 1978, rising to $39.7 million in 1989. Partly as a result of a National Research Council proposal to strengthen agricultural research, allocations of the competitive grant program rose to $97 million for 1992. However, funding per grant is small relative to other Federal agency grant programs.

Researchers within the SAES also can compete for competitive grants from other Federal agencies such as the National Institutes of Health (NIH) and the National Science Foundation (NSF). Competitive grant funding from such agencies to the SAES researchers and projects increased by 83 percent between 1982 and 1989, and now represents about 10 percent of total SAES research funding.

Funding from the private sector has increased by 60 percent since 1982 (table 16-5). Private sector funding comes from industry or from the sale of products by the university. Currently these sources of income represent less than 9 percent of the total funding. Analysts speculate that industry-supported research is not likely to continue growing at such a high rate, as many research-intensive industries are reducing their own in-house research budgets. However, funding likely will be available for selected research programs that are expected to yield high payoffs. The product sales category also is a potentially lucrative source of funding for universities. Legal and institutional changes, which will be discussed later in this chapter, have made it easier for universities to capitalize on their research. Income from product sales rose only 6 percent between 1982 and 1986, but increased 33 percent between 1986 and 1989.

Research funds are not evenly distributed to all experiment stations (table 16-6). The experiment stations in 12 States (California, Florida, Iowa, Illinois, Indiana, Michigan, Minnesota, North Carolina, Nebraska, New York, Texas, Wisconsin) account for nearly 49 percent of the total research funding available to the SAES, nearly 69 percent of the USDA competitive

Table 16-4-Research Funds for State Agricultural Experiment Stations, Selected Years[a]
(in millions of dollars)

Year	USDA[b]	USDA competitive	Other Federal[d]	State[e]	Industry	Product sales	Other[f]	Total
1982	161.3	5.5	77.8	522.2	57.0	58.5	70.0	952.3
1984	174.9	6.1	81.7	591.4	64.1	61.3	79.8	1,059.3
1986	174.4	11.9	110.8	704.3	78.1	62.9	89.8	1,232,1
1987	175.6	16.8	114.9	732.5	87.4	68.4	104.2	1,299.8
1988	187.0	19.3	115.0	770.0	91.2	77.8	114.1	1,374.2
1989	194.0	21.9	130.4	827.6	101.2	82.4	132.1	1,489,6
1990	203.6	20.0	143,9	877.9	113.8	91.6	145.7	1,596.5

[a] Funds are for State Agricultural Experiment Stations only and do not include the 1890 universities, the Schools of Veterinary Medicine, or the Forestry Schools. Funding is in current dollars.

[b] USDA includes Hatch, Mclntyre-Stennis, Special Grants, Evans-Allen, Animal Health, and miscellaneous other funds administered by the Cooperative State Research Service.

[c] USDA competitive is the USDA competitive grants program.

‘Other Federal includes funding from Federal agencies excluding USDA and includes funding from NIH, NSF, AID, DOD, DOE, NASA, TVA, HHS, PHS, etc.

‘State is State appropriations.

'Other includes funding from nonprofit organizations, and contracts and cooperative agreements administered by USDA.

SOURCE: Cooperative State Research Service, Inventory of *Agricultural Research,* U.S. Department of Agriculture, Washington, DC, various years.

Table 16-5—Distribution of Research Funds by Source for State Agricultural Experiment Stations, Selected Years[a]
(in percent)

Year	USDA[b]	USDA competitive	Other Federal[d]	State[e]	Industry	Product sales	Other[f]	Total
1982	16.9	0.6	8.2	54.8	6.0	6.1	7.4	100
1984	16.5	0.6	7.7	55.8	6.1	5.8	7.5	100
1986	14.2	1.0	9.0	57.2	6.3	5.1	7.3	100
1987	13.5	1.3	8.8	56.4	6.7	5.3	8.0	100
1988	13.6	1.4	8.4	56.0	6.6	5.7	8.3	100
1989	13.0	1.5	8.8	55.6	6.7	5.6	8.8	100
1990	12.8	1.3	9.0	55.0	7.1	5.7	9.1	100

‘Due to rounding, the total figure may not add to 100 percent.

[b] USDA includes Hatch, Mclntyre-Stennis, Special Grants, Evans-Allen, Animal Health, and miscellaneous other funds administered by the Cooperative State Research Service.

[c] USDA competitive is the USDA competitive grants program,

‘other Federal includes funding from Federal agencies excluding USDA and includes funding from NIH, NSF, AID, DOD, DOE, NASA, TVA, HHS, PHS, etc.

[e] State is State appropriations,

'Other includes funding from nonprofit organizations, and contracts and cooperative agreements administered by USDA.

SOURCE: Cooperative State Research Service, *Inventory of Agricultural Research,* U.S. Department of Agriculture, Washington, DC, various years.

grants, 61 percent of all competitive funds obtained from Federal agencies other than the USDA, and nearly 59 percent of all funding from industry support and product sales. The State Agricultural Experiment Station system clearly contains ‘‘have and have not’ institutions. The ‘‘have not’ institutions rely primarily on the traditional sources of funding (State and USDA formula funds), while the “haves” have diversified their funding sources.

The agricultural research system employs at least 23,000 PhD-level agricultural scientists, of which nearly 10,000 are employed in academia (table 16-7). Another 65,000 doctoral scientists who work in academia, may be conducting research applicable to agricultural problems. Of those research scientists employed in academia in applied agricultural disciplines, approximately 27 percent received their PhDs in fields other than applied agriculture. Sixteen percent received their doctoral degree in an agriculturally related basic science such as molecular biology, plant pathology, genetics, microbiology, and biochemistry, and 6 percent received their doctoral degrees in some natural science field such as mathematics, computer science, chemistry, or physics (table 16-8). Approximately 5 percent of academic researchers working in applied agricultural fields received their doctoral degrees in the social sciences and engineering. The percentage of academic agricultural researchers receiving their doctorate degrees in an agriculturally related basic science is lower than for agricultural researchers employed by other sectors of the economy.

Table 16-6—Research Funds for 12 Largest State Agricultural Experiment Stations, 1989

	USDA[a]	USDA competitive	Other[c] Federal	State[d]	Private[e]	Other[f]	Total
Total funding for 12 **SAES**[g] **($ million)**	**69.4**	15.0	80.0	399.8	107.5	58.0	724.6
Percent of total funding by source	9.6	2.1	11.0	55.2	14.8	8.0	100.0[h]
Percent of total SAES funding captured by 12 SAES	35.8	68.5	61.3	48.3	58.5	43.9	48.6

[a] USDA includes Hatch, McIntyre-Stennis, Special Grants, Evans-Alien, Animal Health, and miscellaneous other funds administered by the Cooperative State Research Service.

[b] USDA competitive is the USDA competitive grants program.

[c] Other Federal includes funding from Federal agencies excluding USDA and includes funding from NIH, NSF, AID, DOD, DOE, NASA, TVA, HHS, PHS, etc.

[d] State is State appropriations.

[e] Private includes industry support and product sales.

[f] Other includes funding from nonprofit organizations, and contracts and cooperative agreements administered by USDA.

[g] States include California, Florida, Iowa, Michigan, Minnesota, New York, North Carolina, Texas, Wisconsin, Indiana, Illinois, Nebraska.

[h] Due to rounding, the total figure may not add to 100 percent exactly.

SOURCE: Cooperative State Research Service, *Inventory of* Agricultural Research, U.S. Department of Agriculture, Washington, DC, various years.

Table 16-7—Doctoral Level Scientists by Employment Sector, 1985

Employment sector	Academia[a]	Industry[b]	Government	Total
Applied agriculture	9,900	7,000	**3,800**	**20,600**
Animal	2,500	1,100	**300**	**3,900**
Plant and soil	3,200	1,300	**800**	**5,300**
Food	700	1,800	**200**	**2,700**
Natural resources and environment	2,000	2,000	2,100	6,100
Other	1,500	900	300	2,700
Agricultural economics	1,900	300	400	2,700
Agricultural related basic science	31,300	**9,600**	5,000	45,900
Biological science	34,600	**10,700**	5,300	50,600

[a] Employment in academia does not include post doctorates.

[b] Employment in industry includes those who are self-employed.

[c] The distinction between basic and applied is somewhat arbitrary in that scientists employed in applied agricultural fields may be conducting basic research while those employed in agriculturally related basic science may be conducting applied research.

SOURCE: National Research Council, *Educating the Next Generation of Agricultural Scientists,* Washington, DC, 1988.

Table 16-8—Distribution of Applied Agricultural Scientists by Employment Sector and Doctorate Field, 1985

(in percent)

Field of doctorate	All sectors	Academia	industry	Government
Applied agricultural science[a]	61	73	50	50
Agriculturally related basic science[b]	20	16	22	24
Other natural Science[c]	13	6	8	10
Other[d]	6	5	8	10

[a] Appliecf agricultural sciences include animal breeding and genetics; animal husbandry, science, and nutrition; veterinary science; agronomy and soil; plant breeding and genetics; soil sciences; other plant sciences; horticulture and hydrobiology; food science and technology; fish and wildlife; forestry; environmental sciences; hydrology; agricultural engineering; and general agriculture.

[b] Agriculturally related basic sciences include biochemistry; biophysics and biometrics; ecology; cytology and embryology; molecular biology; genetics; bacteriology and microbiology; plant genetics; plant pathology; plant physiology; botany; immunology; nutrition and dietetics; animal physiology; and zoology.

[c] Other natural sciences include fields such as biological sciences not listed above, health sciences, computer sciences, mathematics, chemistry, geology, physics, meteorology, etc.

[d] Other includes engineering; psychology, social scientists, humanities, and education.

SOURCE: National Research Council, *Educating The Next Generation of* Agricultural Scientists, Washington, DC, 1988.

Concerns have been raised that the physical plant of the universities has deteriorated. Many laboratories at land-grant universities are old. Equipment, in many instances is obsolete and the cost of procuring new equipment to conduct new types of research, such as biotechnology, is rising. This has been remedied to some degree by the development of research centers. In addition to providing an environment for multidisciplinary research, they allow for the sharing of expensive equipment and other laboratory needs for personnel conducting similar types of research. Such centers, however, are not the complete answer to this problem.

The Technology Base

To continue to perform high-level research, universities need to keep abreast of new information and technologies. New biotechnologies and information technologies in particular are yielding powerful research tools that can be applied to questions in a wide range of scientific disciplines. Effective use of these technologies will require new funding. or a reallocation of funding from traditional research projects. The scientists who use these new research tools will need a thorough grounding in the basic scientific disciplines that underlie biotechnology and information technology.

The allocation of resources (funding and research personnel) for research classified as biotechnology[1] at the SAES has been increasing (table 16-9). The primary funding sources for such research are USDA and other Federal agency competitive grants. and private industry (table 16- 10). It is likely that significant funds also arise from the licensing of technologies, royalties, and product sales.

The same 12 SAES that capture most agricultural research funds also are able to capture the majority of the resources devoted to biotechnology research (table 16-1 1). Indeed, the concentration of resources in only a few experiment stations is even more pronounced for biotechnology than for all agricultural research. Twelve experiment stations capture nearly 64 percent of all biotechnology funding available to the SAES and more than 65 percent of all competitive grant and private sector funding. These same stations also receive more than 72 percent of the "other" funds, which includes product sales. Additionally. the distribution of biotechnology funding by source differs for these 12 stations relative to the other SAES. They rely on competitive grants and private-sector funding for at least 40 percent of their biotechnology funding; only 17 percent of their total agricultural research funding comes from these sources.

Biotechnology research requires a thorough knowledge of agriculturally related biological and natural sciences. However, only about 16 percent of agricultural scientists working in academia received their PhDs in the basic disciplines underlying this new technology (i. e.. molecular biology. genetics, microbiology. etc.) (See table 16-8). Furthermore. most SAES do not include many of these more basic disciplines as part of the training of agricultural scientists. Thus, many agricultural researchers in academia lack formal training in the disciplines that underlie biotechnology. The same is true for advanced computer technology research.

Advanced computer applications have been used in agriculture for less than 10 years. Consequently, there is a shortage of scientists who understand and are capable of applying these technologies to agricultural problems. Existing personnel with these attributes are recently graduated PhD students and faculty who have taken a sabbatical leave to study this area, and they number less than 20 (4). Intensive training programs are needed to prepare researchers for the public and private sectors. Such training should consist of domain specific subject matter, computer science topics, and system design. Universities with identifiable agricultural programs in advanced computer applications include: Cornell University, Virginia Polytechnic Institute and State University. Purdue University, Texas A&M University, University of Illinois, University of Idaho, University of Kentucky, Pennsylvania State University, Mississippi State University, and North Carolina State University. However, each of these programs is narrowly focused.

The development of advanced computer technology relevant to agriculture is impeded by funding and a professional reward system in SAES that does not support the development of computer systems. Research in agriculture traditionally has been classical biological research whereby a researcher States a hypothesis and

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[1] Biotechnology is first and foremost a set of tools and techniques. It is sometimes argued that resources are being shifted from other discipliner} activities into biotechnology research to the detriment of these other fields. Indeed, increased funding and scientist years (full-time equivalents) for biotechnology could mean that those resources are being taken away from other research programs. However, that is not the only plausible explanation. Because biotechnology is a tool, rather than an end in itself, increased resources for biotechnology}' research could also mean that the tools of biotechnology rather than traditional tools are now being used to examine the same questions. Thus, this research would now be classified as biotechnology even though the research focus is the same. A much more extensive examination of how biotechnology is being used is needed to determine if resources are actually being shifted from other disciplines into biotechnology'.

Table 16-9-SAES Resources Devoted to Biotechnology Research, Selected Years

Year	Projects	FTE[a]	Share of total FTE (percent)	Funds (million$)	Share of total funds (percent)
1982	**571**	**273.5**	**4.5**	**40.8**	**4.7**
1986	**1,043**	487.5	8.0	89.6	8.2
1988	1,360	681.9	11,1	131.3	10.6

‘Full-time equivalent.
NOTES:Data is for 41 stationss responding to survey.
Stations not included are Alabama, Alaska, Connecticut, Delaware, District of Columbia, Idaho, Nevada, New Mexico, North Dakota, Pacific Territories, Virgin Islands, Vermont, Wyoming.
The 1984 survey was different from the other three and not completely compatible.

SOURCE: National Association of State Universities and Land Grant CollegesDivision of Agriculture, Committee on Biotechnology, “Emerging Biotechnologies in Agriculture: Issues and Policies,” Progress reports I thru Vlll, November, 1982–1989.

Table 16-10—SAES Biotechnology Research Funds, Selected Years

Year	USDA	USDA competitive	Other Federal	State	Private	Other	Total
				Funds by Source (in million dollars)			
1982	5.1	NC	14.6	16.2	4.9	NC	40.8
1986	0.6	7.1	20.9	38.0	9.5	3.5	89.6
1988	8.3	10.0	27.6	55.2	14.0	6.2	31.3
				Distribution of Funds by Source (as percent of total SAES biotechnology funds)			
Year	**USDA**	USDA competitive	Other **Federal**	**State**	**Private**	**Other**	**Total**
1982	12.5	NC	35.8	39.7	12.0	NC	100
1986	11.8	7.9	23.3	42.4	10.6	3.9	100
1988	13.9	7.6	21.0	42.0	10.7	4.7	100

NC = **Not collected**
NOTES: Data is for 41 States responding to the survey.
Stations not included are Alabama, Alaska, Connecticut, Delaware, District of Columbia, Idaho, Nevada, New Mexico, North Dakota, Pacific Territories, Virgin Islands, Vermont, Wyoming.
The 1984 survey was different from the other three and not completely compatible.

SOURCE: National Association of State Universities and Land Grant Colleges, Division of Agriculture, Committee on Biotechnology, “Emerging Biotechnologies in Agriculture: Issues and Policies, ” Progress reprots I thru Vlll, November, 1982-1989.

Table 16-11—Biotechnology Research Funds for 12 Largest State Agricultural Experiment Stations, 1966°

	USDA	USDA competitive	Other Federal	State	Private	Other	Total
Total funding (million $)	**9.96**	**6.48**	**18.58**	**34.70**	**9.47**	**4.50**	**83.69**
Distribution of biotech funds by source (percent)	**11.9**	**7.7**	**22.2**	**41.5**	11.3	**5.4**	100.0
Share of total biotech funds (percent)	**54.5**	**64.9**	**67.4**	**62.9**	**67.7**	**72.1**	**63.8**

‘12 SAES include California, Florida, Iowa, Indiana, Illinois, Michigan, Minnesota, Nebraska, New York, North Carolina, Texas, Wisconsin.
Data for total funding does not include the stations of Alabama, Alaska, Connecticut, Delaware, Districe of Columbia, Idaho, Nevada, New Mexico, North Dakota, Pacific Territories, Virgin Islands, Vermont, Wyoming.

SOURCE: National Association of State Universities and Land Grant Colleges, Division of Agriculture, Committee on Biotechnology, “Emerging Biotechnologies in Agriculture: Issues and Policies, ” Progress reports I thru Vlll, November, 1982-1989.

conducts an experiment to test it. Research in computer systems does not easily lend itself to this approach and traditional agricultural journals are reluctant to publish articles on computer application. Research in advanced computer applications require a multidisciplinary effort by domain experts and computer scientists and cannot, in general, be performed by a single scientist. Multidisciplinary development efforts currently cannot be adequately recognized solely through publications. In fact, the end result of most computer-related research projects is a marketable product not a manuscript. And, advanced computer applications are perishable. Once a system is developed, it will generally require regular maintenance to ensure that the information and knowledge are current. Consequently, there exists a perception, especially among conservative faculty, that advanced computer technology research does not represent an appropriate topic for academic professionals. This technology will challenge traditional institutional arrangements.

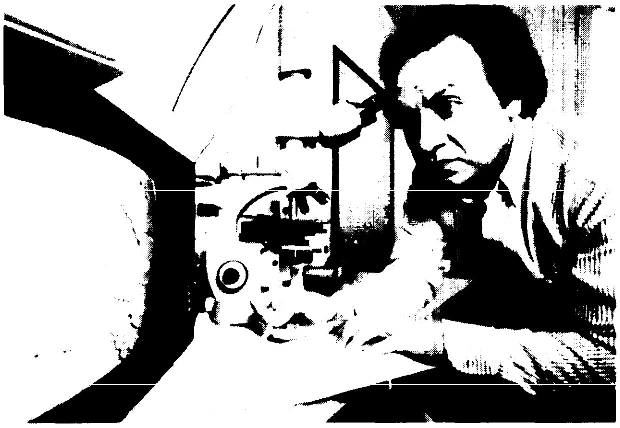

Photo credit: U.S. Department of Agriculture, Agricultural Research Service

Biotechnology research requires a thorough knowledge of agriculturally related biological and natural sciences. Only 16 percent of agricultural scientists working in academia received PhDs in basic disciplines underlying this new technology.

Photo credit: U.S. Department of Agriculture, Agricultural Research Service

Development of advanced computer technology relevant to agriculture is impeded by funding and a professional reward system in State Agricultural Experiment Stations that does not support the development of computer systems.

The Legal Environment

The legal environment in which the agricultural system operates is changing. As discussed in chapter 15, Congress has for the past 60 years expressly permitted intellectual property protection of new plants. Since 1980, the U.S. Patent and Trademarks Office has interpreted patent laws to cover not only plants but also microorganisms and animals as patentable subjects (14). The Patent and Trademark Amendments (Public Law 96-517, 1980 and amended in 1984) gave universities, other nonprofit organizations, and small businesses the option, with few exceptions, to retain the title rights to any federally funded inventions that they developed. The same rights were extended to large businesses by executive order (14). Legislation has also been enacted to facilitate technology transfer between Federal laboratories and industry. The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) provides Federal laboratories with a mandate to undertake technology transfer activities, while the Technology Transfer Act of 1986 (Public Law 99-502) created an organizational structure to meet this mandate.

The changing legal environment in which the agricultural system operates is changing the system itself. Universities are creating new structures to take advantage of these "legislated" opportunities. Until recently, only a few institutions (i. e., the Massachusetts Institute of Technology and Stanford University) aggressively marketed the research of their faculty, primarily by licensing their technology to the private sector. Now, however, other universities are establishing venture capital pools, technology development companies, and research companies with the goal of transferring technology and making money.

Universities have usually patented their inventions, so patenting per se does not represent a significant change. And not surprisingly, the universities receiving the most patents are generally larger, research intensive institutions (table 16-12), Among those universities receiving the most patents in 1989, six are land-grant universities.[2] As discussed previously, the sale of products by the SAES

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[2] The six land-grant universities are Massachusetts Institute of Technology, which does not have a SAES, and the University of California, the University of Florida, Iowa State University, the University of Minnesota, and the University of Wisconsin, which do have SAES. Patent figures are for the whole university, and not exclusively the SAES.

The patent awarded to Stanley Cohen and Herbert Boyer in 1980. This patent has since become Stanford University's top earning patent ($1.7 million annually).

United States Patent [191

Cohen et al.

[11] **4,237,224**

[45] **Dec. 2, 1980**

[54] **PROCESS FOR PRODUCING BIOLOGICALLY FUNCTIONAL MOLECULAR CHIMERAS**

[75] **Inventors:** Stanley N. Cohen, Portola Valley; **Herbert W. Boyer, Mill** Valley, **both of Calif.**

[73] Assignee: **Board of Trustees of the Leland Stanford** Jr. University, Stanford, **Calif.**

[21] Appl. No.: **1,021**

[22] Filed: **Jan. 4, 1979**

Related US Application Data

[63] Continuation-in-part of Ser. No. 959,288, Nov. 9, 1978, which is a continuation-in-part of ser. No. 687,430, May 17, 1976, abandoned, which is a continuation-in-part of ser. No. 520,691, Nov. 4, 1974.

[51] Int. Cl. C12P 21/00

[52] U.S. Cl. ....435/68; 435/172; 435/231; 435/183; 435/317; 435/849; 435/820; 435/91; 435/207; 260/1 12.5 S; 260/27R; 435/212

[58] Field of Search .... 195/1, 28 N, 28 R, 112, 195/78, 79; 435/68, 172, 231, 183

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*Primary **Examiner—*** Alvin E. Tanenholtz
Attorney, Agent, or Firm-Bertram 1. Rowland

[57] ABSTRACT

Method and compositions are provided for replication and expression of exogenous genes in microorganisms. Plasmids or virus DNA are cleaved to provide linear DNA having ligatable termini to which is inserted a gene having complementary **termini, to provide** a biologically functional replicon with a desired phenotypical property. The replicon is inserted into a microorganism cell by transformation. Isolation of the transformants provides cells for replication and expression of the DNA molecules present in the modified plasmid. The method provides **a** convenient and efficient way to introduce genetic capability into microorganisms for the production of nucleic acids and proteins, such as medically or commercially useful enzymes, which may have direct usefulness, or may find expression in the production of drugs, such as hormones, antibiotics, or the like, fixation of nitrogen, fermentation, utilization of specific feedstocks, or the like.

14 Claims, No Drawings

SOURCE: Office of Technology Liensing, Stanford Unversity

Table 16-12—Universities Receiving the Most Patents, 1989

Massachusetts Institute of Technology[a]	102
University of California[a]	81
California institute of Technology	59
University of Texas	57
Stanford University	43
University of Florida[a]	42
University of Minnesota[a]	41
Iowa State University[a]	28
University of Wisconsin[a]	28
Johns Hopkins University	27

*Land-grant universities.
SOURCE: Association of University Technology Managers, 1991

Table 16-13—USDA Agricultural Research Service Technology Transfer Activities, 1987-1990

	1987	1988	1989	1990
Number of patents awarded	34	28	47	42
Royalties from licenses (in thousand dollars)	85	97	418	567
Number of active CRADAS	9	48	86	104
Value of active CRADAS (in million dollars)	1.6	8.7	15.6	18.9

SOURCE: Data provided by staff of USDA Agricultural Research Service, Office of Cooperative Interactions, 1991.

increased from $58.5 million in 1982 to $83.4 million in 1989.

What is different is that universities now have title to the patent rights, even if the research was federally funded. Thus, universities now own pieces of or are otherwise involved with new ventures that invest in and commercialize the new technologies they developed. Universities, in some cases, seethe new ventures as a means of establishing closer cooperation with private companies, ultimately with the goal of inducing the private sector to contribute research funding to the university, of facilitating the transfer of the technology, and of helping faculty to see the relevance of their work to real world problems. In addition, the researchers who create the new technology are now often given a share of the returns. Some examples help to illustrate the new arrangements.

Iowa State University has a research budget of over $110 million annually and conducts over 2,500 research projects. The goal of the university is to create new businesses and generate new revenue and new jobs. Emphasis is being given to biotechnology. The university keeps track of all research and helps obtain patents when needed. It has even built a pilot manufacturing plant to test a new innovation and eventually hopes to entice a private company to provide capital for an expanded operation (11).

The Southwestern Medical Center at the University of Texas has established a for-profit company with $12.5 million in equity from a private venture capital firm and individual investors. The center retains a stake in the company and expects to share any profits (11). Other approaches include establishing joint projects with other institutions. The University of Chicago and the Argonne National Laboratory have created a not-for-profit corporation that will develop and market inventions produced by scientists at the two institutions. The Universities of Texas and Chicago are not land-grant universities, but the types of institutions described could serve as a model for the development of similar institutions at the land-grant schools.

Federal research laboratories also are responding to the new incentives, and to congressional wishes that they do a better job of transferring their research results to the private sector. The USDA Agricultural Research Service (ARS) has entered into 104 Cooperative Research and Development Agreements (CRADAS) with private industry valued at nearly $19 million. Additionally, ARS patents its research findings and in 1990, received $567,000 from royalties on licenses issued (table 16-13).

ISSUES RAISED BY THE NEW ENVIRONMENT

The changing environment in which the agricultural research system operates raises three main issues for the system:

1. What is the appropriate allocation of existing resources'?
2. Who decides what the appropriate allocation is?
3. How is the system to be structured to effectively achieve the desired allocation'?

As indicated by the high rates of social return to agricultural research investments, the system as a whole has not been funded at optimum levels, and there is a general need for more research funding. However, increased research funding is not sufficient to achieve desired results. Funds also need to be reallocated from current projects to research that reflects new needs. The appropriate allocation of resources will depend primarily on what society wants the system to accomplish. Resources cannot be allocated appropriately unless priorities are determined and goals established.

Land-grant universities differ from other universities in that they have a legislated mission to address research to the problems of society. Some argue that the land-grant system has, at least to some extent, already abandoned its mission, as researchers increasingly work for the laurels of their disciplinary peers rather than society's benefit. Others argue that the system defines society's problems too narrowly and places too much emphasis on increasing agricultural productivity and too little on nutrition, environmental, and rural problems. Some also argue that too much attention is given to production agriculture and not enough on postharvest technologies, value-added products, consumer preferences, and agribusiness problems.

There are no easy answers as to what types of research should be conducted with public funds. What is clear, however, is that as the traditional clientele (i.e., farmers) continues to shrink, greater demands will be placed on the system to address the needs of other groups. Difficult choices must be made concerning the mix and prioritization of research.

Historically, decisions on how research funds were allocated were made at the local institutional level. This approach was because most funds were awarded to institutions as block grant formula funds. The institution, with input from local clientele, determined how the funds should be administered. However, competitive grants, from USDA and other Federal agencies are an increasing component of total funding, and these grants are awarded to individual researchers or projects. Project proposals reflect the individual researchers personal interests and views of social needs. Decisions concerning which proposals are awarded grants are made by peer review at the national level.

The shift toward greater reliance on project funding (competitive grants) rather than institutional funding (formula funds) is an attempt to induce greater responsiveness of the State system to national priorities. Additionally, the wider competition increases the pressure to perform and be more productive. However, these goals must be balanced against the potential losses that come from not being part of a larger mission and attentive to local needs and from the potential lack of continuity that might come from a competitive grants program (11). Additionally, it is argued that competitive grants may shift the research focus from solving society's problems to short-term projects, the results of which are more readily publishable in peer reviewed journals.

An increase in research funds from the private sector has raised a great many concerns. The actual extent of private sector-public university collaboration is unknown, but university administrators suspect that it is not yet extensive. Industry funding of research at the SAES comprises about 6.5 percent of total funding, and that share has not dramatically increased over the past decade. Industry support of biotechnology research is higher than for agricultural research in general, but even in this area, funding from industry represents about 11 percent of total funding.

Industry support for university research is not expected to continue growing rapidly. Private firms are decreasing their own research budgets and may not have the money to spend on university research. The biotechnology industry appears to be undergoing the long expected shakeout, with many smaller, dedicated biotechnology firms consolidating, retrenching, or going out of business. The large firms that likely will remain major players in the area of biotechnology research have now developed their own in-house research capacity. Industry financing of university research will be directed toward specific fields that industry feels will be most beneficial to them, and may be leveling off.

The changes in the legal environment combined with constrained research budgets provide many incentives for universities to increase funding through product sales. This potential privatization of public sector research raises many issues. Product sales currently represent only 5.5 percent of total research funding, but whereas growth potential in other sources of funding seem limited, there is a possibility of high growth in revenue from the sale of university inventions.

Incentives to privatize the benefits of university innovations for the benefit of the university rather than society could conflict with the mandated mission of the university. Using public resources to reap private gains raises many ethical questions. The situation of allowing individual researchers to share in the profits of their work, even if it was publicly funded, and of encouraging universities to produce consumer products opens the door to potential abuses.

Certainly there is potential for conflicts of interest if universities and individual researchers are allowed to capture the returns of their innovations. To some extent, this same issue is raised when researchers use public funds to generate new knowledge that can be sold to the private sector in the form of consulting fees. But there is a distinction between providing expertise to potentially multiple clients and having a vested interest in the development of one or several products by companies. The credibility of a university may suffer if it is viewed as being too cozy with industry. An interesting dilemma may arise for a university if its researchers identify significant hazards with a product or technology that generates profits for the university, or for a company with which the university collaborates. If public universities prioritize their own private good above the public welfare, the public may not maintain its support for the university. On the other hand, given the underinvestment in agricultural research as a whole, the additional revenue from product sales could provide great benefits for the university and society. Whether or not the funds are used for desirable purposes will depend on how well university administrators provide leadership to maintain a sense of priority for the overall research and teaching mission, and whether they have the administrative skills to allocate resources to the proper ends.

Channeling more resources to innovative activities from which private return can be reaped may alter the focus of research. There could be a shift in the research mix from research that is a public good to that which will be attractive to industry. University research potentially could shift from long-term research to more short-term projects that are likely to have quick payoffs. There is also concern that changes in intellectual property rights will cause universities to change the focus of their research. Results of a preliminary analysis (5) suggest that intellectual property rights do influence the amount of resources devoted to specific commodity research in universities (i. e., universities do allocate more resources to research on commodities where they can get Plant Variety Protection Act certificates and capture some of the returns to their research). Results suggest, however, that universities do not direct more public sector funding to commodity research supported by industry funding. The agricultural research system often is criticized for focusing too much attention on basic research and little on development and adaptive research to solve social problems; a shift toward practical technologies and products may be perceived by some as a positive outcome.

One of the underlying principals of scientific research is the free exchange of research results. Concern has arisen that if research begins to generate income, it could become more proprietary. The free exchange of germ plasm between individual researchers and countries may be inhibited as germplasm owners seek to profit from that germplasm. Moreover, research results may be exchanged less freely, or exchanged only after the researcher, university, or industry supporting the research attempts to patent the results or seeks additional private-sector funding. The growing tendency of researchers to announce their results via press release rather than in peer-reviewed journals may also, at least to some extent, be an attempt to attract the attention of private industry and to enhance the opportunity of obtaining private funding for further work. One unfortunate fallout of these activities is to confuse a public that has little understanding of scientific issues, and thus to diminish the credibility of scientific research.

Concern also has been expressed that the potential for financial rewards will lead to the exploitation of graduate students by faculty advisers. If, for example, students are directed toward research designed to benefit a particular company or are not allowed freely to publish their research results, their future employment opportunities could suffer.

Finally, it is likely that only some universities will benefit from collaborations with the private sector. The same universities that receive the bulk of the public-sector funding also attract the most private-sector funding, patent the most innovations, and receive the largest revenue from the sale of products. As the costs of maintaining university programs continue to rise, then only schools that can attract private revenue may be able to continue to maintain a full research, teaching, and extension function. Smaller universities most likely will need to reorganize and cooperate on a regional basis to maintain research programs. Neither Federal formula funds nor competitive grants nor State funding mechanisms are designed to accommodate cooperative institutional arrangements.

RESEARCH TO EVALUATE IMPACTS OF THE NEW ENVIRONMENT

The above discussion has been based on possibilities and speculation. There is little information available on what changes actually are occurring at the SAES as a result of the changing research environment. No comprehensive data exist on the present extent of collaboration between the public and private sector; on the nature of existing arrangements; or on the amount and uses of revenue generated from such arrangements and how that revenue is being used. Data also do not exist on how additional revenue is being used to support socially desirable but underfunded research, or to support teaching activities. It is unknown to what extent existing university-private sector arrangements create additional economic activities. Any discussion of these issues is based on speculation and anecdotes—u more rigorous analysis is needed.

Likewise, little is known about how increasing reliance on competitive grants is impacting agricultural research. It is widely presumed that the research supported via a competitive grant mechanism is of higher quality than that funded by formula funds, and that greater reliance on competitive grants increases productivity. However, it is also possible that competitive grants distort the research mix favoring disciplinary research over problem-solving research.

Little research has been conducted to determine the productivity of the different funding mechanisms. However, recent research completed by OTA and the University of Minnesota suggest that the most appropriate policy is a mixture of formula and competitive grants, with different funding mechanisms potentially more appropriate for different functions and goals of land-grant universities (19).

The data set used to analyze the productivity of different funding mechanisms is a subset of agricultural research at SAES. This subset is for fiscal year 1986 research projects that are receiving at least some funding from USDA and at least some portion of the research project involves using the tools of biotechnology. The biotechnology data set was chosen because trends that seem to be occurring within land-grant universities appear to be magnified in the area of biotechnology research. Therefore, whatever is occurring in that subset of research may be indicative of future changes in other fields of agricultural research. The data set includes research funded by Hatch grants, USDA Competitive grants, and Other grants which include State grants, Evans-Allen grants, Animal Health grants, and McIntyre-Stennis grants (i.e., formula funds somewhat analogous to Hatch funds). Data was obtained from the Cooperative Research Information System (CRIS) and includes publications as reported by the principal investigators

Output is measured by publications including peer reviewed journal articles (published articles, abstracts, articles in press, and articles submitted), experiment station bulletins, and graduate student degrees. These types of publications were chosen because they can be used as measurable proxies to represent the research, teaching, and extension missions of the land-grant system. Quality of published peer reviewed journal articles was measured by the number of citations the article received. Citations are not a perfect measure of quality, but are widely used.[4]

Findings from this research suggest that different types of publications are more likely to be funded by different sources. (See table 16- 14.) The actual number of journal articles per grant did not differ significantly by funding source, however, articles published from research funded by competitive grants were cited much more frequently than research articles funded by other mechanisms. Also, competitive grants provide funding for fewer years and generally are for lower levels of funding than Hatch grants, suggesting that for cutting-edge research, competitive grants are more productive and of higher quality. However, Hatch funding supports more research students, and generally produces a higher number of experiment stations bulletins, which are geared to be more useful to farmers and others in the industry and may be more representative of adaptive research than are many journal articles.

The conclusion suggested by these results is that different funding mechanisms may be more appropriate for different goals of the university system. If the goal is to increase cutting-edge research, competitive grants might best be emphasized. If the primary goal is to enhance research applicable to problem solving (more development and adaptive research and technology transfer) or to train future researchers, the more stable and locally controlled Hatch funds may be the more appropriate mechanism. The appropriate allocation of the two types of grants depends on the priority given to the multiple missions of the experiment stations. However, developing mission priorities is not a simple task. Research

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[3] The total number of grants have been normalized to account for the fact that while all projects were being funded in FY 1986, some projects received their initial funding in that year while others had been funded for several years. For example, for Hatch grants and other grants, over 50 percent of the projects received initial funding prior to 1985. For competitive grants, only 25 percent of the grants had received initial funding prior to 1985. Previous research has shown that it generally takes about four years of funding before significant levels of output can be expected (8). However given the recent nature of biotechnology research, significant levels of funding did not exist prior to 1982. This is why 1986 and 1987 publications were chosen as the data set. However, for many of the projects funding had not occurred for four years. It is unreasonable to expect a research project which has been funded for one year to produce as many articles as one which has been funded for several years and the grants were normalized to account for this difference. (The actual normalization equation was as follows: (grants in 1982) + 4/5(grants in 1983) + 3/5(grants in 1984) + 2/5(grants in 1985) + 1/5(grants in 1986).)

[4] Citations indicate that other researchers have read and used the work. However, not all citations may be positive. Additionally, review articles are likely to be sighted more often than other types of articles. It is also possible that an article is of high quality, but is in a field that not many other researchers are working, and therefore the number of citations may not be a good measure of the quality of the article. It may also be the case that an article is cited only by the author of the article (self cites). One might argue that the research was useful in furthering the work of the author, but that may not represent input into other researcher's work. Citations were corrected by subtracting self-citations.

Table 16-14—Mean Values of Selected SAES Output by Grant Type

	Hatch	Competitive	Other
Citations per article[a]	1.70	3.98’	1.82
Articles per grant	2.47	2.14	2.24
Weighted articles per grant[b]	4.83	8.33[f]	4.74
Journal publications per grant[c]	4.70	4.52	3.68
Weighted publications per grant[d] . . . . ,	7.07	10.62[g]	6.58
Degrees per grant	**0.45’**	**0.18**	**0.25**
Bulletins per grant	0.35	0.09’	0.28

[a] Articles are articles published in peer reviewed journals

[b] Weighted articles are published articles weighted by citations

[c] Journal pubs are published articles, articles submitted, articles in press, and abstracts in peer reviewed journals.

[d] Weighted pubs are articles submitted, articles in press, and abstracts in peer reviewed journals, and published articles weighted by citations

[e] Significantly different from other two groups at 950/. confidence level

‘ Significantly different from other two groups at 94% confidence level

[g] Significantly different from other two groups at 920/. confidence level.

SOURCE: Mane Walsh, “Factors Affecting the Cost and Productivity of Biotechnology Research at the State Agricultural Experiment Stations”, PhD thesis, University of Minnesota, in progress.

is needed to analyze what sort of institutional structure can best involve all relevant clientele in priority and goal setting for SAES.

POLICY OPTIONS

ISSUE: The new partnership between the public- and private-sectors potentially can revitalize agricultural research, but could also bias the overall research endeavor and destroy the credibility of universities. Research and close monitoring will be needed to understand the changes occurring within the land-grant system and to ensure that they are not undermining the system as a whole.

Option: Congress could require the U.S. Department of Agriculture to monitor the increased private-sector funding of agricultural research and to prepare an annual report to Congress containing the data.

Currently, little is known about the extent of private-sector funding at land-grant universities and the nature of the relationship between the universities and the private sector. Congress could provide oversight of this situation by periodically conducting oversight hearings. Furthermore, Congress could request that USDA collect data from the land-grant universities on the extent of public-private collaboration, prepare an annual report to Congress containing the data, and provide guidelines on the appropriateness of various public- private-sector research collaborations.

Option: Congress could direct USDA to require land-grant universities to establish an explicit policy with regard to research sponsored by the private-sector and report that policy to Congress.

The USDA would require each university using private-sector research funds for agriculture to establish a policy as to how those funds are used. Establishing an advisory board that includes members of the public in setting spending priorities for the funding of research from the private sector might be an effective mechanism. This would help to increase the confidence of the public that the university is using these funds to solve problems that confront society.

Option: Public-sector support of social science research could be increased.

Understanding the complex institutional changes occurring in the public agricultural research system will require increased social science research. Currently, social science research is underfunded by the public sector, and it is highly unlikely that the private sector will support this kind of research. Lack of social science research may constrain the ability of the land-grant system effectively to understand and the control the changes that are occurring and to address the problems of society as its mission dictates.

ISSUE: **High rates of return to public-sector investments have been reported by numerous studies. This a clear indication that public-sector research funding is below socially optimum rates.**

Option: Congress could increase public-sector support of agricultural research.

Increasing public-sector support of agricultural research might help to lessen the pressure on land-grant universities to try and obtain funds from the private sector. Given the high rate of return on public-sector funding of agricultural research, increased funding is a good investment for the future.

Option: Congress could maintain or decrease public-sector funding for agricultural research.

Federal funding for agricultural research has been relatively flat for the last 30 years. As a consequence States have picked up the increased costs of conducting agricultural research. It is difficult for States any longer to take on an ever increasing share of public supported research. If the Federal Government continues to shrink from its partnership with the States in the funding of research, land-grant universities have no choice but to look for alternative sources of funding. Private-sector funding from specific industries or individual firms or product sales from technologies developed by the university are the most likely sources of additional research funds. The impact of this shift in support is unknown and needs further analysis.

ISSUE: Land-grant universities have been and are now rapidly developing into "have and have not" universities. In this situation it is difficult for the "have not" universities to individually fulfill their historic responsibilities.

Option: Congress could increase Federal funding for multiregional projects as opposed to institutional or individual funding.

There is nothing magic about State Boundaries, yet they have defined agricultural research problems since the inception of the research system. Most cultural problems and solutions, however, are more appropriately defined within and across geographic regions. Universities would be better able to collaborate on common agricultural problems or to specialize in certain areas for the region where they have a critical mass of expertise. The major disadvantage is State leaders accepting this concept after so many years of expecting their university to provide the research, teaching, and extension to solve their problems and provide education.

Option: Congress may wish to allow the States to find their own solutions to this growing problem.

The States would have the major responsibility for finding a solution. This could be in the form of increased funding to the university to provide at least minimal services in all traditional activities eliminating some activities and reallocating those funds to high priority activities or working with other States to jointly determine activities suitable for cooperation. However, if the decision is to work with other States the Federal Government could be an obstacle by placing a constraint on the proportion of Federal funds that can be used for regional projects.

ISSUE: Recent research indicates that public sector funding mechanisms should be goal oriented.

Option: Congress could appropriate funds for agricultural research through funding mechanisms based on well-defined goals.

The land-grant system provides teaching, extension, and research functions. Preliminary research indicates that Hatch formula are more conducive to teaching and extension activities and competitive grants more conducive to basic research. By appropriating funds via goals to be achieved, Congress could improve the effective use of public funds.

Option: Congress could maintain the current emphasis of increased funds for competitive grants and level or decreased funding of formula and intramural funds.

Implicitly, this would indicate that Congress places. greater emphasis on basic research than on adaptive research, extension, and teaching activities. Evidence does not exist that the lack of basic research is the primary constraint to the ability of land-grant universities to fulfill their historic mission of addressing research aimed at serving societal problems.

Option: Congress could extend competitive grants to extension and teaching curriculum development.

A strong case can be made for formula funding of agricultural research. However, if politically the only acceptable form of increased funds is competitive grants, then expanding these grants to also include adaptive research, extension, and teaching could be considered. Balanced funding of basic research, adaptive research, teaching, and extension would significantly strengthen the land-grant universities and help them meet their multiple missions more effectively.

Option: Congress could award some competitive grants to basic research that ties successfully into adaptive research.

This would be a clear signal that Congress considers the original mission of land-grant universities to be appropriate today. Currently, most grants for basic research are not tied directly to adaptive research. Thus, it is difficult to differentiate between funding provided by the National Science Foundation (the major funding agency for basic research) and the U.S. Department Agriculture (a major funding agency for mission-oriented adaptive research).

ISSUE: The public is increasingly losing confidence in land-grant universities. Credibility needs to be restored. Development of a more mission-oriented system with increased public input would help to restore confidence in the system.

The OTA report *Agricultural Research and Technology Transfer Policies for the 1990s (15)* addresses this issue in some detail and provides specific options that suggest changes in the system to make it more mission oriented. Those options are incorporated here by reference. Some of the options were incorporated into the 1990 Food, Agriculture, Conservation, and Trade Act of 1990 (1990 Farm Bill).

ISSUE: Few professional benefits exist for conducting adaptive and multidisciplinary research or to effectively communicate the purpose of university research to the public. Continuing focus on basic, disciplinary research that is communicated only to peers enhances the public's perception that research is irrelevant and undermines the public willingness to support such research.

Option: Land-grant universities could develop professional rewards for researchers conducting adaptive or multidisciplinary research.

A change at land-grant universities to reward researchers for adaptive or multidisciplinary research and those that communicate well the purpose and results of research to the public will be difficult to achieve. In many universities, determination of reward criteria goes beyond research administrators to include faculty committees, which in many cases have the last word on the university's reward criteria. And, faculty who comprise these committees are, for the most part, basic scientists. Until such time that these committees' composition is changed or their power diminished, it will be difficult for any change to occur. The only leverage available is through those that control research funding. Thus, more strings could be attached to Federal grants that provide incentives for adaptive research, multidisciplinary research, and communication of results. This is especially crucial for research in advanced computer technologies. This promising area will continue to languish unless changes are made to reward researchers in these other areas in addition to basic research.

Option: Land-grant universities could maintain the status quo by continuing to provide the highest professional awards for basic research.

In the short run this option will be the path of least resistance. But in many ways, it will be costly in the long run. Following this course leads to the fundamental question of the difference between a land-grant university and any other university. Why should the public uniquely support universities that provide a product no different from other universities? If there is no difference then it is difficult to provide a rationale for the special public funding provided to land-grant universities. Indeed, such funding is to be used by the university to provide a service to society that is unique.

ISSUE: **Advances in the application of advanced computer technologies require establishing this field of research as a priority. Currently, research in this area relies on ad hoc funding from numerous scientific disciplines and weak ties to basic computer science and the private sector. Research for advanced computer systems requires a nontraditional approach and multidisciplinary teams that include computer scientists, traditional production-oriented scientists, business, marketing, and policy specialists, and system designers.**

Option: Congress could establish nationally recognized centers of excellence for advanced computer technology research.

The Federal Government, States, and the private sector could jointly establish centers of excellence at various land-grant universities. These centers would involve the various university departments that comprise SAES, computer science, the business school, etc. The center concept has worked well in other major technological areas such as biotechnology. It provides a focus for research with continuity. A drawback is the lack of incentive for faculty, especially young, untenured faculty, to participate in multidisciplinary research.

Option: Congress could establish this area as a priority with increased funding to land-grant universities.

Funding would be available through various types of grants much like other scientific disciplines. To enhance the multidisciplinary effort, grant applications could be required to contain a strong adaptive component conducted by a multidisciplinary team. However, this is still an ad hoc approach. A project investigator (PI) must convince scientists in other disciplines that it is in their best interest to be a part of the project. Even if the PI is successful there is no guarantee of any continuity of interest. Once the project is completed, team members go back to their respective disciplines. Also, as mentioned above, it would be difficult to entice young, untenured faculty to participate. At best this approach is only a step above the current situation.

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