Biotechnology research and the public university: An assessment of the social and organizational impacts

William Joseph Kinney
Iowa State University

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Biotechnology research and the public university: An assessment of the social and organizational impacts

by

William Joseph Kinney

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

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Signatures have been redacted for privacy

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GENERAL INTRODUCTION

Ever since the means to manipulate DNA was discovered approximately 15 years ago, it has been clear that the invention and application of recombinant DNA (rDNA) technology would have a wide variety of impacts on society. Indeed, over the last ten years, an entire biotechnology industry has arisen to explore the full economic potential that this relatively recent technological innovation may offer.

With specific regard to the potential agricultural applications of rDNA biotechnology, many preliminary research efforts appear to hold considerable promise for the future (growth hormones, herbicide resistance, plant and animal disease resistance, reproduction enhancement, and many others). As a result, federal and state governments, in addition to a wide variety of private sector interests, have begun to invest heavily in research focussing upon genetic engineering and agricultural biotechnology.

In 1988 for example, the federal government was spending approximately $2.7 billion annually for basic research in biotechnology (Lacy et al., 1988). While only $150 million of that money was earmarked specifically for the development of agricultural biotechnology, the National Research Council's Board on Agriculture recommended in 1988 that this level of funding be dramatically increased over a very short period of
time, to approximately $500 million annually by 1990 (Moses et al., 1988).

State governments have also increased their funding of biotechnology research programs dramatically, and were spending a combined total of approximately $150 million annually on such projects by 1987 (U.S. Congress, 1986). And, in comparison to the funding expenditures of the federal government, state governments are spending a considerably greater portion of these funds on the development of agricultural biotechnologies. Primary examples of projects established with the assistance of these funds are New York State's Center for Biotechnology in Agriculture at Cornell University and Iowa's Biotechnology Council at Iowa State University (Lacy et al., 1988). The hoped-for result of such expenditures is most often the establishment of research and development centers linking industry to universities, with the anticipated result of such linkages being the enhancement of economic development in these areas.

In addition to these research expenditures by federal and state governments, biotechnology industries have also invested heavily in university research. In 1984 for example, biotechnology companies awarded about $120 million in contracts and grants to universities (Lacy et al., 1988). As a result of these private investments, a variety of contractual linkages have also developed between these
companies and individual faculty, departments, and institutes.

The transfer of biotechnological innovation from the laboratory to the marketplace has thus followed a clear and logical progression: technological breakthroughs have occurred as a result of basic research in universities; these technological innovations and breakthroughs spark business interest and investment; applied research and development occurs in order to create an investment payoff; products are created, marketed, and put to use.

The players in this process are also clear: government and business, seeking economic development and private profit, respectively; the universities, which serve as tools to assist in the economic development process; and consumers (i.e., farmers), to whom the products are marketed. While the impacts/benefits of economic development for governments, and profits for businesses, are fairly evident, the impact of this overall process is less clear in terms of the outcomes that may result for the universities involved in this research, and the farmers who will likely put these biotechnological products to use.

It is therefore my intent to more closely examine the relationship of these two entities--universities and agricultural producers--with the ever-expanding program of agri-biotechnological research and development.
The University

Over the last several decades, much attention has been focussed upon the changing nature of the modern university, particularly in terms of its purpose, role, and responsibilities in today's research-hungry, business-oriented social world. Some have argued for a 'pristine' model of university operation, wherein the creation of knowledge is a process which remains unpolluted by the influences of the external world. Proponents of such a model argue that these external influences may serve to alter the nature or character of new knowledge, and also impinge upon academic freedom. Others, however, view the university in a more utilitarian light, stressing that the knowledge created by universities must not only build in some way upon past knowledge or achievements to create a general advancement in the cumulative body of knowledge in a given field, but also be of substantial, practical use in the 'real world.'

Another debate regarding the operation of the nation's universities regards their financial ability to maintain adequate efforts at the creation (through research) and impartation (through instruction) of knowledge. With federal funding of many academic institutions severely restricted in the budget-tightenings of the 1980s and early 1990s, the procurement of research funding has become paramount to many
universities around the nation. As a result, with revenues declining and operating costs increasing, many universities have been forced to 'hire-out' their research abilities to private industries or governmental agencies in order to maintain operation at levels comparable to those achieved when federal funds were in ample supply.

Growing numbers of analysts are therefore coming to recognize some of the more negative aspects that may accompany the increasing influence of private funding for public universities. Leslie Roberts (1983) states;

In the face of declining federal support, universities need money for research and instruments. For industry, such agreements mean access to the scientific expertise that is still centered in the universities and rights to any patentable discoveries. And both sides espouse the societal good arising from rapid technology transfer. There is less agreement, however, on how serious a threat corporate funds pose to the integrity of the university. (p. 159).

Charles Caldart (1983) stresses four fundamental implications that the trend towards industry investment in university research may have: 1) such investments may have a negative impact on institutional autonomy, due to an over-reliance on private funds for institutional survival; 2) problems may arise in that the nature and direction of research may come to be based more upon corporate need than academic merit; 3) access to the results of university research may become restricted, due to competitive needs of private sector investors; and, 4) long-term university
policies may become altered in the effort to accommodate corporate or other economic interests, and thus institutionalize a heightening acquiescence to the needs of private investors.

Lacy et al. (1988) also express concerns regarding the impacts that may result from the heightened drive towards private research investments for universities, but addresses these concerns with a specific eye towards the impact of biotechnology investments. Several impacts are discussed:

1) industrial interests and research administrators may increase pressure for public sector scientists to abandon varietal breeding and applied research for molecular biology and biotechnology research;
2) in addition to traditional animal and plant breeding, other important disciplinary and methodological perspectives may be neglected due to an over-concentration on biotechnology and molecular biology;
3) due to the highly specialized nature of biotechnology research, research funds and scientific talent may become over-concentrated at the small number of colleges and universities capable of carrying out such research;
4) long-term research projects may be greatly reduced due to the short-term, profit-oriented emphasis of private investors;
5) communications may be restricted regarding research findings;
6) releases of technology may become much more exclusive, via patent rights or restricted licensing procedures;
7) the likelihood of conflicts of interest or scientific misconduct will increase, due to the growing clash between public and private occupational demands;
8) changes may arise in the general orientation of, and clientele benefitted by, public research (away from farmers and farm cooperatives to larger pharmaceutical, agrichemical, and food processing corporations), and;
9) the benefits of biotechnology may become increasingly concentrated in the agribusiness sector, resulting in a continuation of the 'industrialization' of agriculture (p. 10).

Another factor of specific relevance to the increase in biotechnology research is that this new industry is in a very tenuous state. Over three-quarters of biotechnology firms continue to lose money, and, in 1988, at least 24 biotechnology companies filed for bankruptcy- and five of these were publicly supported (Lacy et al., 1988). Reflecting this uncertainty was a 1989 poll (Kumar, 1989) showing that a majority of executives in biotechnology companies believe that within ten years, roughly half of the nearly 500 biotechnology companies in the United States will fail, merge, or form cost-sharing alliances. Over-reliance upon the funds of individual corporations may thus present serious financial
dangers to those departments reliant upon them.

It is also worth noting that the impacts of this increased level of research and investment in biotechnology have not been restricted to the research laboratories of the beneficiary universities. Curriculum offerings are being altered, both to accommodate the needs of the burgeoning biotechnology industries (by providing them with trained personnel), as well as to serve as a vent through which the expertise of the growing number of university biotechnologists may find curricular release. Each year, growing numbers of universities, colleges, and institutes have incorporated courses in biotechnology into their curricular offerings, and have established undergraduate majors in biotechnological fields (Amatniek, 1983).

In essence then, factors such as these have served to alter the makeup of the modern university by placing a heavier emphasis upon research-oriented activities than may have been present in the past. A fundamental question thus becomes, 'will this alteration in operational emphasis in turn alter the ability of the university to perform the functions it was originally intended to perform?' In order to answer this question, it is useful to examine a specific case in which such a research-oriented shift has taken place.
Biotechnology at Iowa State University

As has been previously discussed, universities around the nation have become increasingly involved in research efforts geared towards the development of biotechnological innovations and applications. As has also been discussed, the university system in the State of Iowa is no exception to this trend, and substantial amounts of money have been invested towards utilizing rDNA biotechnology to assist in the development and well-being of that state's agriculturally-oriented economy.

This course of action began in 1985, when the Iowa Development Commission, at the behest of the Seventy-first Iowa General Assembly, allocated the sum of $10 million to the State’s Board of Regents, public universities, and/or independent colleges (Laws of the Seventy-first General Assembly, 1986 session: 295-296). This money was to be used in an effort to explore the potential for biotechnological industries, and their products, to assist in the recovery of Iowa's ailing rural economy. After initial investments began to show promise, additional biotech monies were appropriated to the State’s universities to further develop their growing proficiency in the field. As a result, biotechnology has now become an area of research expertise in many academic departments at the State’s universities.

A primary participant in this effort has been Iowa State University, a land-grant institution with an enrollment of
approximately 25,000 students. In fiscal year 1985, the Iowa General Assembly allocated $500,000 to Iowa State University for the purpose of agricultural biotechnology research. Additional appropriations were to follow, with the allocation of $3.75 million in 1986, and $4.25 million each for fiscal years 1987, 1988, and 1989 (Laws of the Seventy-first General Assembly, 1986 session). Projects resulting from these appropriations have included the development of new biodegradable plastics, technologies for using cholesterol reductase to produce animal products with lower cholesterol content, and molecular and genetic techniques for the isolation of maize genes to control crop yields (Worthy, 1989).

As has been previously stated, the fundamental goal of many biotechnology research efforts—and many private and public research efforts in general—is economic development. Iowa State’s program is no exception to this trend, with the explicitly-stated purpose of the General Assembly’s allocation being the enhancement of economic development and research and development. This goal has remained intact throughout the implementation of the program, as evidenced by the remarks of the chairman of the oversight committee of the Iowa State Biotechnology Council, Walter Fehr:

With regard to the vision for biotechnology at Iowa State University, our ultimate goal is to use the new techniques of molecular biology to enhance the economic welfare of the state. We believe that this will occur
through research in three primary areas: (1) the development of new products from our traditional commodities through bioprocessing; (2) improving the efficiency and profitability of crop and livestock production; and (3) development of new products and processes through the genetic modification of plants, animals, and microorganisms. The vision of Iowa State University’s biotechnology program is strongly influenced by the desire to fully utilize the agricultural resources of the state for the welfare of its constituents. (Fehr, 1987).

In order to bolster the effectiveness of this research-centric approach to economic development, technology transfer networks have been put in place at I.S.U., in order to enhance the speed and accessibility with which innovations may be transferred from university laboratories to local industries desirous of the new biotechnological advancements (e.g., the Eastman Kodak fermentation plant in Cedar Rapids, the Cargill biotechnology facility in Eddyville, and the Ajinomoto Heartland Lysine feed-additive plant, also located in Eddyville--Worthy, 1989).

State policy makers appear content with the results-to-date of this biotechnology-grounded economic development plan (and Iowa State University’s role in it). Iowa’s General Assembly has extended appropriations for the operation of the Biotechnology Council, and for the entire program of biotechnology research, beyond the initial three-year implementation period (FY 1986/87-88/89). And, in assessing the general effectiveness of the project, Iowa’s governor, Terry E. Branstad, states:
Iowa is turning biotech breakthroughs into business success stories. Partnerships between private industry and Iowa's two world-class research universities are resulting in innovative products and economic progress. (Worthy, 1989).

The university system in Iowa thus appears to have been an effective tool for economic development in that state, and shall likely continue this function for the foreseeable future. Iowa's effort to stimulate economic development through the funding of university-based research thereby serves as a model by which other states may attempt to undertake their own research-oriented programs of economic development (biotech or otherwise) in the future. And, within this model, the utilization of Iowa State University serves as a case-study by which to examine the impact of such a program upon a participant university, or other institution, involved in the research and development process.

Farmers and the Rural Concern

Another set of questions arises regarding the impact biotechnology research will have on those for whom its products are targeted--farmers and others involved in the agricultural production industry. Concerns regarding the impact of rDNA technology on agricultural producers focus on several key issues.

One major concern involves the general potential of biotechnology to heighten the productivity and efficiency of
plant and animal production and utilization. Several varieties of production enhancement are possible through the application of rDNA technology:

1) the heightening of plants' and animals' capacity to create usable goods (e.g., the enhancement of milk production through Bovine Somatotropin, or bST--Hansel, 1986; OTA, 1986);

2) the heightening of producers' ability to produce more product per plant or animal (e.g., the enhancement of growth rates and capacities through the use of porcine Somatotropin, or pST--Kliebenstein, 1989);

3) the improvement of plant and animal health using rDNA-inspired advances in disease control and disease resistance (biotechnological techniques have produced promising vaccines related to the control of pseudorabies, hoof and mouth disease, Rift Valley fever, trichinosis, mastitis, and a variety of other viruses and disease-producing organisms--CAST, 1986);

4) the alteration of agricultural products themselves (e.g., decreased fat or cholesterol content, taste enhancement or alteration, etc.--Kuchler, et al., 1989);

5) the alteration of the reproductive capacities of plants/animals (Seidel, 1989), and;

6) the potential to decrease the cost of plant and animal production by obtaining higher rates of product output for lower levels of input (e.g., nitrogen fixing, improved feed
conversion efficiency, etc.--Kliebenstein, 1989; CAST, 1986; Riepe, 1989).

The most problematic of the impacts identified with these likely applications of agricultural biotechnology is the potential for overproduction. Alper (1987) states;

Bovine growth hormone, which is slated to come on the market in 1988, should increase milk production by about 30%. Yet dairy farmers are already plagued with surplus milk. So most farmers see little need for a product that will result in further surpluses. (p. 60).

Thus, to economic sectors in which supply is short and demand is strong, such production-enhancing technologies would be highly welcome and beneficial to producers as well as consumers. However, when supply is strong and demand is static, the productive enhancement may indeed be of a detrimental nature. The dangers of overproduction are also raised by Pimentel, 1989; Kvistgaard, 1986; Mix, 1987; Kalter, 1985; Kliebenstein, 1989; Hayenga, 1988; and CAST, 1986, among others.

More specific concerns have been raised with regard to the effect of biotechnological production practices on small farms and the rural way of life. Patrick Madden and Paul Thompson illustrate the manner by which farmers may be acting to their own economic detriment through the widespread adoption of biotechnological means of production enhancement;

...dislocation associated with new technology may be associated not with the scale or type of technology, but with the rapidity with which a farmer is able to adopt it. Early adopters reap profits, but as many adopt and
prices go down, adoption becomes a necessity in order to remain competitive, and many who cannot afford to adopt the technology are forced out of farming... If this picture is correct, farmers themselves may be the agents with greatest causal responsibility for changing farm structure. (p. 103-104).

DuPuis and Geisler (1988) further summarize that, as a result of such technologies,

...large farms would adopt the technique first, reaping innovators' benefits. And smaller farms would be left to make ends meet in an environment of lower milk prices and more expensive dairy technologies. Some of the small farms would be expected to go out of business. (p. 408).

Kalter (1985), similarly observes the potential for an eventual elimination of low-yield dairy farms from the productive environment, and discusses, "...the necessity to design policy to encourage the orderly exodus of resources, including farmers, from dairying."

Gary Comstock (1988) therefore concludes that,

To the extent that potentially displaced dairy farmers have done nothing for which they ought to be punished; to the extent that the research establishment has clearly favored large producers in its development of techniques and technologies; to the extent that fiscal, monetary and economic policies have disadvantaged small dairy producers; and to the extent that bGH will only exacerbate the unjust consequences of the past; to that extent we ought to oppose this particular biotechnology. (p. 49).

Considerable attention has also been devoted to this issue by Alper (1987); Pimentel et al. (1989); Fox (undated); Buttel (1988); and many others.

Kliebenstein (1989) also tends to examine the issue of affected subgroup populations in terms of the differential
impacts that biotechnology utilization may have on the various segments of the agricultural industry. For example, it is stressed that, through a combination of price reduction from increased production, and product improvement through the lowering of fat and cholesterol content, pork producers may come to recapture the health-conscious and price-wary consumers that currently purchase poultry or fish products (with the result being a negative impact on the poultry and fish producers). It is also pointed out that biotechnological products may result in uneven impacts upon feed producers, for example, through heightening the demand for high-protein feeds such as soybeans, and decreasing the demand for traditional feeds such as corn.

Alper (1987) therefore summarizes that:

Although pig farmers will benefit, grain farmers will be hurt, as PGH-treated pigs will consume less grain. And if consumers eat more pork, they will buy less beef, chicken and other meats, thereby hurting producers of these commodities. (p. 60).

Another subgroup of concern is nonfarm rural populations. Frederick Buttel (1988) devotes considerable attention to this issue, and states that:

A final neglected issue related to biotechnology and rural people concerns the virtual lack of attention to how biotechnologies will affect nonfarm rural people and rural regions... There seems... to be little likelihood that rural America will benefit directly from industrial bioprocessing in this 'hand-me-down' fashion. (p. 4).

Another area of concern is the impact that genetically altered products may have upon consumer health, and of
potential consumer reactions to products created through the utilization of recombinant DNA technologies. Buttel (1988) states,

...the matter of 'public reactions to biotechnology'—particularly concerning whether 'the public,' or the more articulate and influential segments thereof, will become mobilized to create a 'climate' unconducive to testing and commercializing new agricultural biotechnology products—has recently become a major preoccupation. (p. 4).

Halbrendt et al. (undated) examined consumer attitudes towards pork produced with pST, and found that, although there is a high degree of concern regarding the use of genetically engineered products, pST use is acceptable under certain conditions (such as reducing production costs, producing leaner or higher quality meat products, etc.). Approximately half of the respondents in his study indicated they would not change their consumption of pork due to the use of pST.

Others project that consumers might even come to prefer products made with the assistance of biotechnology. Alper (1987) states:

Growth hormones like PGH also provide an attractive replacement for the steroid hormones and subtherapeutic doses of antibiotics now used in animal feed. Those growth promoters are less effective and more costly than growth hormone, and they have generated consumer concern about trace amounts of the promoters in meat. (p. 60).

Another concern related to agricultural biotechnology is the potential for environmental or ecological harm that may result from the introduction of biologically altered organisms into the environment. For example, Fox (undated) states:
Farmers have been using dangerous pesticides for decades, many of which are so harmful that they have been banned for use in the countries of origin. Soon they will be using patented, genetically engineered bacteria, the so-called 'new generation of bacterial pesticides.' Agribusiness has been reticent to acknowledge that pesticides are a health hazard, devastate wildlife populations and threaten all terrestrial and aquatic ecosystems worldwide. We now have pesticide-laden rain and fog, drinking water, and mother's milk. The entire food-chain of life has been contaminated. There could be equivalent profound environmental consequences following the release of genetically-altered microorganisms. (Fox, undated, p. 4).

Buttel (1988) also raises the possibility of secondary or tertiary negative environmental impacts that may result from the application of biotechnology:

A case could be made... that the chief impacts of biotechnology on the agricultural environment may have little to do with the genetic engineering and ultimate 'release' of agriculturally-related organisms. Instead, the greatest environmental implications of biotechnology will likely relate to the potential of a massive shift from fossil hydrocarbons and oxychemicals to plant-derived feedstocks in the production of chemicals and other substances two to three decades from now... biotechnology production could place profound demands on rural ecosystems by dictating increased intensification of primary production and causing more marginal lands to be brought under cultivation to provide the necessary feedstocks. (p. 4).

Kvistgaard (1986), Hayenga (1989), Comstock (1988), and many others devote considerable attention to the environmental risks posed by the utilization of biotechnological methods of production enhancement and alteration.

Thus, it is clear that farmers, as well as participating research universities, face a myriad of questions as a result of the growing ag biotech industry. It is therefore my intent
to examine the impact of the growing biotechnology research enterprise both upon the universities involved in this research, as well as the farmers toward whom its products are targeted. I propose to undertake this examination in the manner described below.

An Explanation of the Dissertation Organization

In light of the diverse nature of the concerns provoked by the growing biotechnology research effort, this dissertation is organized into four separate analyses. The first paper, "Economic Development Funding and the Public University: The Changing Nature of University Personnel and Their Research," has both a quantitative and qualitative component. In quantitative terms, the impacts of the push towards biotechnology research are evidenced by the shifts that have occurred in 'full time equivalency' (FTE) job categorizations within the individual departments of the university. Comprehensive listings of these FTE categorizations were obtained for the period from fiscal year 1983/1984 to 1990/1991, and were obtained with the cooperation of Iowa State University's Office of Institutional Research, Affirmative Action Office, and Provost's Office.

The qualitative component of the paper consists of input received from Departmental Executive Officers (DEOs), as well as from interviews with the biotechnology faculty hired at
Iowa State University since 1986/87. These interviews took place between March and May of 1991, and questions covered a wide range of topics (the nature of their research, how biotechnology research has altered their departments, the effectiveness of the biotech program at I.S.U., possible environmental impacts of the products that result from their research, farm production, animal welfare, and the status of biotechnology in general). The quantitative shifts revealed by the statistical analyses are thus translated into qualitative terms, through the input of DEOs and the researchers themselves.

The second paper, "Economic Development Funding and the Public University: The Changing Fiscal Structure of Academia," deals with another important aspect of the biotechnology research program--the question of what differential impact-if any-the large infusions of biotechnology research monies have had upon the departments of the university. Data for this determination consists of comprehensive records of all research expenditures (grouped according to monies appropriated from General University Research, the Agricultural Experiment Station, and Contracts and Grants) for the period beginning fiscal year 1983/1984, and ending fiscal year 1989/1990. Thus, for purposes of comparison, the first two years (1983/1984-1984/1985) of this period reflect a time in which no biotechnology funding was received by the
university, and the last five (1985/1986-1989/1990) reflect a period of heavy biotechnology funding, as the research effort began its implementation. This information was gathered with the cooperation with Iowa State's Office of the Associate Provost for Research.

As was also the case with the first paper, some information from the interviews with DEOs and the biotech researchers is utilized to describe the qualitative impacts of the budget changes that have accompanied the implementation of the biotech program at I.S.U.

The third paper in the dissertation, "Economic Development Funding and the Public University: The Case of Biotechnology at Iowa State University," constitutes a summary review of both the budgetary and personnel data described above, and contains an overall assessment of the structural impact of the I.S.U. biotechnology research and development project. Methods, analyses, etc. are the same as those described in the first and second papers, but simply put into a combined format to examine the comprehensive impact of the biotech program.

While it is clear that the first through third papers examine the direct structural impacts of the biotechnology research program on Iowa State University, the fourth paper serves to expand upon this analysis, by examining the broader social environment in which these developments have occurred.
This paper, "Economic Development and the Farm Economy: The Impact of Biotechnology," therefore focuses not upon the point of origin for biotechnology research (Iowa State University), but rather upon the market towards which the products of this research shall eventually be targeted—farmers.

As was previously stated, the advent of recombinant DNA in the mid 1970s led to considerable optimism regarding the potential application of this new technology to agricultural production. This strong desire for positive outcomes from biotechnology research was well reflected in the 1987 Iowa Farm Poll, which showed farmers expressing high hopes regarding the potentials of agricultural biotechnology on a wide range of subjects.

However, as farmers have continued to gain knowledge of, and experience with, both the pace of research and the applications that have occurred to date, questions have arisen as to whether the hopes expressed five years ago have been fulfilled by the biotechnology development project. In order to answer these questions, many of the same questions regarding farmers' opinions of biotechnology that were asked in the 1987 survey were repeated on the 1991 Iowa Farm Poll. An assessment of how well biotechnology has met the expectations of the Iowa farmers it was intended to help thus becomes possible.

The dissertation concludes with an overall assessment of
the biotechnology research project at Iowa State University, by drawing upon conclusions and findings from all four of the papers just discussed. References and literature cited in the introduction, literature review, and overall assessment shall follow this general summary.

In essence, then, this study seeks to examine the impacts of technological research from its beginning to ending points. At the beginning point, it is evident that universities will be increasingly forced to determine which factor will hold the most sway in determining university policies—academic freedom, or private control of the nature and usage of research and its results. And, if a primary purpose of the university is to impart the knowledge it creates, at what point does the emphasis upon research impinge upon the ability to convey that knowledge, both in terms of numbers of personnel allocated to perform that function (as manifested by shifts in the occupational make-ups of departments), as well as in terms of the qualifications or abilities displayed by such personnel to carry out this function effectively (as gauged by the degree to which faculty expertise is specialized in one narrow field)?

At the end point of the research process, many cursory investigations into the potential impacts of agricultural biotechnology on the farming sector have taken place, and touched on a wide variety of economic, social, environmental,
and ethical concerns. However, the results of these various analyses remain somewhat unclear: some purport that biotechnological advances in plant and animal production will result in a nearly universal benefit to farm producers, while others see a tremendous potential for harm in the utilization of such technologies. In light of such confusing and conflicting claims, it would seem that those who stand to benefit or lose the most--the farmers themselves--should be the ones who could most accurately assess these impacts to date, and project about likely outcomes in the future.

It is thus the intent in this dissertation to achieve a more comprehensive view of the structural and social impacts of the State of Iowa's program of biotechnology research and development. We have, for the most part, already received the assessments of governments and businesses regarding the economic implications of the program. However, as has been stated, the implications for others involved in the development process have not yet been fully explored. By examining the impacts both on those doing the research, and those consuming the products of the research, a more accurate assessment of the true and complete social impacts of agricultural biotechnology will hopefully be achieved.
PAPER 1. ECONOMIC DEVELOPMENT FUNDING AND THE PUBLIC UNIVERSITY: THE CHANGING NATURE OF UNIVERSITY PERSONNEL AND THEIR RESEARCH
Economic Development Funding and the Public University: The Changing Nature of University Personnel and Their Research

by

William J. Kinney
INTRODUCTION

Academic institutions have traditionally been charged with two basic instructional functions in our society; the provision of quality education, and the provision of adequate access to quality education. However, recent restrictions on both federal and state funding for universities may severely hamper their ability to continue adequately performing these functions. A recent issue of the *Chronicle of Higher Education* states:

Many academic leaders perceive that, even after the economy improves, their institutions will confront a major challenge involving tradeoffs between student access and academic quality. At least one of those traditional goals is likely to suffer, officials say, because neither state appropriations nor tuition rates will grow enough to finance them both as substantially as in the past. (Jacobson, 1991, p. 1).

It is proposed that these problematic 'tradeoffs' may take a wide variety of forms, including enrollment caps, cuts in faculty, larger class sizes, fewer course offerings, tuition increases, cuts in student services, and others (Jacobson, 1991). In essence, due to the current fiscal situation around the country, colleges and universities must be prepared to either limit their current accessibility to students, or risk decreasing the quality of instruction that is offered to them.

Apart from instruction, another important function of our institutions of higher education is the creation of knowledge through research. Research activities benefit academia in a
variety of ways. One fundamental benefit is that faculty involved in research supposedly enhance instructional quality by being 'current in their fields,' and in touch with the more practical applications of a given discipline. However, there is concern that research productivity may occur at the expense of instructional quality, in that time spent on research or publication efforts must necessarily detract from instructional activities such as course preparation.

Research is also becoming an increasingly important determinant of professional advancement for university faculty. Shao (1991) states;

In recent years, hiring and tenure decisions have come to be based largely on a professor’s ability to generate world-class research. The most important criteria in tenure decisions remain a professor’s publications record and reference letters, mostly from other researchers... If you’re a mediocre researcher but an excellent teacher, you’re unlikely to get tenure. (p. 126).

Faculty thus receive a clear professional--and fiscal--benefit through the pursuit of an active research agenda.

Another important aspect of research activity is that it often provides departments with demand-driven funding sources. In many ways, the research capacity of an academic institution is a valuable asset, in that it offers a specialized ability to government or industry that may be too expensive or difficult to develop independently. A research contract thus represents an investment by governments or industries in a university, since they are paying for a service, and expect an
eventual profit or benefit in return for that payment.

So, while instruction and research are both important functions of the university, it appears that instructional activities are in many ways bearing the brunt of the current financial difficulties facing so many universities. With opposition to tax and tuition increases at a peak and the economy in a state of uncertainty, the long-term benefits of instructional spending simply appear to have been placed at a low level of priority. Consequently, university administrators are anxious to increase the intake of 'self-financing' research dollars to assist in the maintenance of existing operational levels. And, with teaching being a far less important determinant of professional success than research, many faculty appear compliant in the face of this trend.

Rule (1988) underscores the benefit that the growing trend towards self-financing may hold for academia;

Since the 1970s, American higher education as a whole has been experiencing a recession, if not a depression. The often indiscriminate expansion of the 1960s quickly gave way to a period where student populations were falling and where government support for research was cut, but where operating expenses rose sharply. Under these circumstances, the idea of making university functions self-financing has taken on a special appeal. (p. 433).

As a result, Shulman (1987) concludes that, "...leading universities are turning more and more to corporate support as federal funding decreases." (p. 11).
However, not all forms of 'self-financed' research come from private corporations. While general research and development funds from the federal government have been cut substantially, 'earmarked' funds continue to flow. Earmarked research awards are made without a competitive review of the merits of a specific research program or project. Earmarked research appropriations to colleges and universities have increased dramatically over the last four years, from only $225 million in FY 1988 to more than $684 million in FY 1992 (Cordes et al., 1992).

Critics accuse earmarking of being 'pork barrel science,' and claim that its dramatic increase over the last four years is linked to both budgetary problems on campus, and a desperate attempt to spur economic recovery:

...the scope of the practice (earmarking)--and the link between many of the projects and economic development--reflects a severe financial squeeze on higher education and Congressional concerns about the faltering economy. (Cordes et al., 1992, p. 1).

Earmarking may thus represent a congressional attempt to 'kill two birds with one stone,' by awarding non-competitive research monies to financially-strapped universities, while channeling research awards into economic development projects. State governments have also turned towards investing in university research--particularly technological research--to inspire economic development. Blumenstyk (1992) states that,

By the end of the decade (the 1980s), nearly every state had created at least one program that provided grants to
universities for research with commercial potential...
In the 1980's, states sort of discovered technology...
(p. 1).

So, while federal and state appropriations for
instructional uses remain largely restricted due to concern
over tax and tuition rates, the hope of quick economic payoffs
has kept public funds for research (especially technological
research) in ample supply. With revenues declining and
operating costs increasing, many universities have therefore
been forced to 'hire-out' their research abilities to private
industries or governmental agencies in order to maintain
present levels of operation. However, while such arrangements
may be effective at maintaining a given level of operation for
financially-strapped universities and departments, uncertainty
exists as to what impact they will have on the style of
operation for these entities. It is the intent of this paper
to examine this issue.

Biotechnology: A Growing Research Emphasis

A prime example of the manner in which the trend towards
research enhancement may impact upon the structure and
operation of universities is evident in the effort to develop
practical applications for agricultural biotechnology. Due to
the promising nature of many preliminary efforts utilizing
recombinant DNA technologies (growth hormones, herbicide
resistance, disease resistance, reproduction enhancement, and
many others), federal and state governments, as well as a variety of private sector interests, have begun to invest heavily in research focussing upon genetic engineering and agricultural biotechnology. In 1988, for example, the federal government was spending approximately $2.7 billion dollars annually for basic research in biotechnology (Lacy et al., 1988). While only $150 million of that money was earmarked specifically for the development of agricultural biotechnology, the National Research Council's Board on Agriculture recommended in 1988 that this level of funding be dramatically increased over a very short period of time, to approximately $500 million annually by 1990 (Moses et al., 1988).

State governments have also increased their funding of biotechnology research programs dramatically, and were spending a combined total of approximately $150 million annually on such projects by 1987 (OTA, 1986). And, in comparison to the funding expenditures of the federal government, state governments are spending a considerably greater portion of these funds on the development of agricultural biotechnologies. Prime examples of projects established with these funds are New York State's Center for Biotechnology in Agriculture at Cornell University and Iowa's Biotechnology Council at Iowa State University (Lacy et al., 1988). The hoped-for result of such expenditures is most
often the establishment of research and development centers linking industry to universities. The anticipated result of such linkages is the enhancement of economic development.

In addition to research expenditures by federal and state governments, biotechnology industries have also invested heavily in university research. In 1984 for example, biotechnology companies awarded about $120 million in contracts and grants to universities (Lacy et al., 1988). As a result of these private investments, a variety of contractual linkages have also developed between these companies and individual faculty, departments, and institutes.

**The Biotechnology Research Effort at Iowa State University**

The state-supported push for biotechnology research in Iowa's university system was begun in 1985, when the Iowa Development Commission, at the behest of the Seventy-first Iowa General Assembly, allocated the sum of $10 million to the state's public Board of Regents, public universities, and/or independent colleges. These funds were supplied by revenues drawn from the State's lottery program. In fiscal year 1985, the Iowa General Assembly allocated $500,000 to Iowa State University for the purpose of agricultural biotechnology research. Additional appropriations were to follow, with the allocation of $3.75 million in 1986, and $4.25 million each for fiscal years 1987, 1988, and 1989 (for a total of $17
million in the first three years of the program—Shelley et al., 1990).

Research projects and products resulting from these appropriations have included the development of new biodegradable plastics, technologies for using cholesterol reductase to produce animal products with lower cholesterol content, and molecular and genetic techniques for the isolation of maize genes to control crop yields (among many others—Worthy, 1989).

As has been previously stated, the fundamental goal of many biotechnology research efforts—and many private and public research efforts in general—is economic development. Iowa State's program is no exception to this trend, with the explicitly-stated purpose of the General Assembly's allocation being the enhancement of economic development. That goal has remained intact throughout the implementation of the program, as evidenced by the remarks of Walter Fehr, Chairman of the Oversight Committee of the Iowa State Biotechnology Council:

With regard to the vision for biotechnology at Iowa State University, our ultimate goal is to use the new techniques of molecular biology to enhance the economic welfare of the state. We believe that this will occur through research in three primary areas: (1) the development of new products from our traditional commodities through bioprocessing; (2) improving the efficiency and profitability of crop and livestock production; and (3) development of new products and processes through the genetic modification of plants, animals, and microorganisms. The vision of Iowa State University's biotechnology program is strongly influenced
by the desire to fully utilize the agricultural resources of the state for the welfare of its constituents. (Fehr, 1987).

In order to bolster the effectiveness of this research-centric approach to economic development, technology transfer networks have also been put in place at I.S.U. These networks are designed to enhance the speed and accessibility with which innovations may be transferred from the lab to local industries desirous of the new biotechnological advancements (e.g., the Eastman Kodak fermentation plant in Cedar Rapids, the Cargill biotechnology facility in Eddyville, and the Ajinomoto Heartland Lysine feed-additive plant, also located in Eddyville--Worthy, 1989).

To date, state policy makers appear content with the results of the biotechnology-grounded economic development plan. Iowa’s General Assembly has extended appropriations for the operation of the Biotechnology Council, and for the entire program of biotechnology research, beyond the initial three-year implementation period. While, in assessing the general effectiveness of the project, the state’s governor, Terry E. Branstad, states,

Iowa is turning biotech breakthroughs into business success stories. Partnerships between private industry and Iowa’s two world-class research universities are resulting in innovative products and economic progress. (Worthy, 1989).

Governor Branstad has even proposed budget increases for economic development projects based on university research
like that taking place at Iowa State (Blumenstyk, 1992).

The effort to stimulate economic development through the creation of the biotechnology program at I.S.U. therefore appears to have met with a substantial degree of success. The university system in Iowa has been effectively used as a tool to promote this stimulation, and appears likely to continue the performance of this function for the foreseeable future.

In essence then, the state of Iowa's effort to stimulate economic development through funding university research in the ever-growing field of biotechnology serves as a model by which other states have, and may, attempt to undertake their own research-oriented programs of economic development in the future. As has been previously stated, by the end of the 1980's, nearly every state had at least one program that provided research grants to universities in the hope of spurring this kind of economic development. However, while state economies may receive a variety of benefits from this utilization of the university system, concerns have been raised regarding the effect that this growing tendency may have upon the universities themselves. Shulman (1987) states;

According to Tufts University science historian Sheldon Krimsky and others, corporate interests threaten to skew research priorities. Krimsky...believes that 'when a university has its own for-profit sector, it means that the institution has to manage according to very different rules.' (p. 11).

Rule (1988) also expresses concern about the trend, and states;
...what will exploitation of such profitable technologies do for--and to--the universities? Even if the more extravagant projections for biotechnology prove overblown, genetic engineering is bound to be among the biggest money-making activities associated with American universities in the 1990s. How will pursuit of such profits shape institutions supposedly predicated on values quite different from profitability?

...when universities accommodate themselves too thoroughly to the agenda of non-university institutions, they begin to lose the qualities that make universities worth having in the first place. (p. 432, 434).

Growing numbers of analysts are therefore coming to recognize some of the more negative aspects that may accompany the increasing influence of economic development and private funding for research in universities. Leslie Roberts (1983) states;

In the face of declining federal support, universities need money for research and instruments. For industry, such agreements mean access to the scientific expertise that is still centered in the universities and rights to any patentable discoveries. And both sides espouse the societal good arising from rapid technology transfer. There is less agreement, however, on how serious a threat corporate funds pose to the integrity of the university. (page 159).

A primary concern about this possible "threat" is that the increased trend towards university reliance on external research funds will redirect research efforts towards economic or corporate need, rather than academic merit (Caldart, 1983). More specifically, Caldart proposes that the biotech research push would result in increased pressure from industry and research administrators on public sector scientists to abandon varietal breeding and more applied forms of research. Another concern was that this trend would result in the reduction of
long-term research efforts, due to the short-term, profit-oriented emphasis of private sector investors or economic development programs.

A second major issue raised by Lacy et al. (1988) concerns the possibility that the expansion in biotechnology research may result in the neglect of research into other important disciplinary and methodological perspectives. For example, scientists may become so focussed on molecular methods of reproduction enhancement that more traditional forms of plant or animal breeding (which may be more cost effective and efficient than biotechnological methods) become underutilized and increasingly unexplored. Thus, economic development or profit-oriented research may not only redirect existing research efforts (the first primary concern), but also re-direct them at the expense of other areas of necessary research (the second fundamental concern).

A third set of concerns relates to the impact that the growing emphasis on research may have on the instructional abilities and capacities of academic institutions. Using Stanford University as an example, Maria Shao (1991) describes how research responsibilities tend to take precedence over instructional duties;

Grants represent 28% of the school’s research and instruction budget and make stars of the people who win them. Faculty can even ‘buy out’ of teaching by using grants to pay part of their salaries. Temporary teachers pick up the slack. (p. 126).
Rule (1988) examines this issue not only with regard to the general priority research appears to take over teaching, but also with regard to the way in which shifting research emphases may eventually result in shifting teaching emphases;

One form of responsibility incumbent on universities is to make available to students a wide array of intellectual possibilities. University collaboration with outside agencies may lead to distortion of such possibilities. There is the danger that curricula may be skewed toward the profitable, rather than the profound. Faculty absorbed in lucrative research ventures may be unwilling or unable to help students consider research problems whose merits are strictly intellectual. And all this may be true without conscious intent on the part of faculty. (p. 434).

Lending possible credence to this concern is the fact that curriculum offerings are being altered around the country, both to accommodate the needs of the burgeoning biotechnology industries (in order to provide them with trained personnel), as well as to serve as a vent through which the expertise of the growing number of university biotechnologists may find curricular release. Each year, growing numbers of universities, colleges, and institutes have incorporated courses in biotechnology into their curricular offerings, and have established undergraduate majors in biotechnological fields (Amatniek, 1983).

The push towards research may therefore affect instructional activities in two basic ways; by diverting from the amount of time or effort faculty are able to put into them, and by altering the nature or body of information that
research specialists are willing or able to convey to their students.

A final set of concerns relates to how the status of graduate students and faculty may be altered by their affiliation with profit-oriented research ventures. Rule (1988) states;

How is the university to treat faculty and students associated with such 'profit centers'? As ordinary university citizens, subject to the same rules as others in terms of promotion, tenure, teaching and academic freedom (for faculty) and grading, distribution requirements, fellowships and progress toward degrees (for students)? Can the university act as investment manager toward an organization consisting of its own people, while still maintaining its role as a university? Unable to answer in the affirmative, President Bok of Harvard, at the urging of his faculty, declined in 1980 to institute such a corporate experiment there. (p. 433).

In essence, universities will increasingly be faced with the question of whether the more 'profitable' faculty and graduate students will be held to the same standards and rigors as those of a less business-oriented character.

The overall trend towards 'self-financing' university operation through the attainment of private or public economic development research funds may therefore serve to alter the makeup of the modern university by placing a heavier emphasis on research-oriented activities than has been present in the past. Concern may also be warranted as to whether this more market-driven approach to university research may affect the social outcomes of research, and the future capacity for universities to adequately fulfill instructional
responsibilities, as well as undertake a broad base of independent, 'no strings attached' research activities.

An understanding of how economic development projects impact upon participant universities is thus not only of benefit or relevance to the State of Iowa, but to all states engaged in such programs--and all universities participating in these programs. The overriding hypothesis that therefore guides this research is that this recent alteration in operational emphasis will in turn alter the ability of the university to perform the instructional and research functions it was originally intended to perform.

By examining the situation at Iowa State University, it becomes possible to determine the likely impacts that biotechnology research in particular--and economic development research in general--will have upon participant universities. In essence, while biotechnology research represents but one means by which economic development may be attempted by state governments, the process by which such projects occur, and the outcomes that result from them, may be similar regardless of the specific means at hand (such as biotechnology). The utilization of Iowa State University therefore serves as a case-study by which the effects of such efforts may become more fully understood.
METHOD OF STUDY

The first step necessary in assessing the impact of the biotechnology research effort on Iowa State University was to determine: 1) which departments should be considered the primary beneficiaries of the biotechnology funding; 2) which departments benefitted—but to a lesser degree, and; 3) which received no benefits at all.

In order to achieve this determination, a technique known as 'snowball sampling,' or 'chain referral sampling,' was implemented among informed participants in the biotechnology research effort at Iowa State University. Under this method of examination, informed participants are questioned, not only with regard to their own knowledge of a given phenomenon, but also regarding their knowledge of other informed participants who may possess information relevant to the phenomenon. Thus, the sample begins with a small set of elements, and ends with a larger set of elements that are in some way connected to the initial set (Encyclopedia of Statistical Sciences, c.1982-1988).

In the Iowa State sample, the initial set of informed participants consisted of the Departmental Executive Officers (DEOs) of two departments acknowledged to be active in the biotechnology research effort (since interviewees were guaranteed confidentiality, names and departments of these interviewees shall not be listed). Interviews (conducted by
phone, or in person, if requested by the interviewee) focused primarily upon two basic questions: 1) 'Which departments would you describe as being central to the biotechnology research effort at Iowa State University (the 'Core'), and which are involved in the biotechnology research effort, but in a more supportive role (the 'Support' departments), and; 2) 'Could you name three other persons familiar enough with the biotechnology research program to offer informed opinions on this question?' In addition, general comments regarding other aspects of the biotechnology research effort (e.g., effectiveness of its administration, success in the attainment of stated goals, etc.) were welcomed from all interviewees who offered them.

Representatives (for the most part consisting of DEOs) were also contacted for all departments named as participants in either the Core or Supporting groups, but for whom a specific representative was not named in the course of the 'snowballing' process. All participating Core and Support departments were thus represented by at least one spokesperson over the course of the interviews. Ultimately, 22 interviews were conducted with DEOs and other departmental representatives.

As a result of these interviews, twelve departments were determined to operate within the Core of the biotechnology research effort: Biochemistry/Biophysics, Genetics, Zoology,
Horticulture, Agronomy, Chemical Engineering, Chemistry, Plant Pathology, Botany, Veterinary Microbiology and Preventive Medicine, Veterinary Pathology, and Veterinary Anatomy. Nine additional departments were determined to function within the Support group: Microbiology, Animal Science, Food Technology, Food and Nutrition, Forestry, Entomology, Veterinary Physiology and Pharmacology, Veterinary Clinical Sciences, and the Veterinary Diagnostic Laboratory (see Appendix I for departments not included in either the Core or Support categories). Since the goal of this research is to examine the academic impacts of the biotechnology project, six non-academic divisions of the University were not included in the analysis (Ames Laboratory, Statistics Laboratory, World Food Institute, Computation Center, Institute for Physical Research and Technology, and Iowa State Water Resources Research Institute).
Quantitative Analysis

The impacts of the push towards biotechnology research are evidenced, first, by the quantitative shifts that have occurred in 'full time equivalency' (FTE) job categorizations within the individual departments of the university. Comprehensive listings of these FTE categorizations were collected for the eight-year period from fiscal years 1983/1984 to 1990/1991, and were obtained with the cooperation of Iowa State University's Office of Institutional Research.

Under this system of employment categorization, occupational positions are grouped into several broad funding categories. Four of these categories are relevant to this study; Instruction, Contracts and Grants (C&G), Research, and Agricultural Experiment Station (AES). Within these broad categorizations, positions are more specifically grouped in terms of employee type; Merit, Professional and Scientific (P&S), Graduate Student, Pre and Post-Doctoral, Hourly, and Faculty.

In terms of these specific employee types, the raw numbers for the entire university reveal an overall decrease in the number of faculty over the eight year period under examination (Figure 1). Faculty FTEs were at a peak of 1558.62 positions in fiscal year 1985/1986, but dropped to 1478.12 positions by 1990/1991 (a net loss of approximately 80
Figure 1. FTE totals
positions). On the other hand, the combined number of Graduate Student and Pre/Post Doctoral FTEs rose from a low of 689.62 in 1984/1985 to 864.22 by 1990/1991 (a net gain of just under 175 positions). P&S and Hourly FTEs also rose significantly, with P&S FTEs increasing by approximately 100 positions, and Hourly FTEs increasing by just under 70 positions. Raw numbers of Merit FTEs held relatively constant during the period (Table 1).

Table 1. Raw numbers of university FTEs grouped by occupational category

<table>
<thead>
<tr>
<th></th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merit</td>
<td>477.5</td>
<td>455.8</td>
<td>476.7</td>
<td>490.0</td>
<td>482.8</td>
<td>443.3</td>
<td>467.8</td>
<td>474.8</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>121.0</td>
<td>138.9</td>
<td>142.3</td>
<td>147.0</td>
<td>164.9</td>
<td>177.1</td>
<td>202.1</td>
<td>220.6</td>
</tr>
<tr>
<td>Grad.</td>
<td>629.3</td>
<td>623.2</td>
<td>674.1</td>
<td>721.0</td>
<td>724.7</td>
<td>731.2</td>
<td>747.3</td>
<td>765.7</td>
</tr>
<tr>
<td>P/Doc</td>
<td>67.2</td>
<td>66.4</td>
<td>65.7</td>
<td>77.3</td>
<td>89.5</td>
<td>96.4</td>
<td>117.0</td>
<td>98.6</td>
</tr>
<tr>
<td>Hourly</td>
<td>148.0</td>
<td>165.0</td>
<td>166.3</td>
<td>182.0</td>
<td>191.2</td>
<td>224.5</td>
<td>222.6</td>
<td>215.2</td>
</tr>
<tr>
<td>Fac.</td>
<td>1506.0</td>
<td>1529.0</td>
<td>1559.0</td>
<td>1546.0</td>
<td>1489.0</td>
<td>1464.9</td>
<td>1496.4</td>
<td>1478.1</td>
</tr>
<tr>
<td>Total</td>
<td>2949.0</td>
<td>2979.0</td>
<td>3084.0</td>
<td>3163.0</td>
<td>3142.0</td>
<td>3137.3</td>
<td>3253.2</td>
<td>3253.9</td>
</tr>
<tr>
<td>Grad &amp; P/doc</td>
<td>696.5</td>
<td>689.6</td>
<td>739.9</td>
<td>798.0</td>
<td>814.2</td>
<td>827.6</td>
<td>864.3</td>
<td>864.2</td>
</tr>
</tbody>
</table>

This raw data thus reveals that Faculty FTEs—as a percentage of total FTEs—have declined considerably during the eight year period under study (Figure 2). Faculty positions constituted 51.34% of FTEs in FY 1984/1985, but steadily declined to represent only 45.42% of FTEs by FY 1990/1991 (a drop of about 6 percentage points). Conversely, while Graduate Students and Pre/Post Doctoral employees constituted only 23.15% of total FTEs in 1984/1985, they rose
Figure 2. Percentage of FTE totals by occupational category
to represent 26.56% of overall FTEs by FY 1990/1991 (a gain of about 3.5 percentage points). Hourly and P&S employees also increased slightly in comparison to the other occupational categories (approximately 1.5 and 2.5 points, respectively), while Merit employees decreased slightly (approximately 1.5 percentage points, Table 2).

Table 2. Occupational categories as a percentage of total FTEs

<table>
<thead>
<tr>
<th></th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merit</td>
<td>16.19</td>
<td>15.3</td>
<td>15.46</td>
<td>15.5</td>
<td>15.36</td>
<td>14.13</td>
<td>14.38</td>
<td>14.59</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>4.10</td>
<td>4.66</td>
<td>4.61</td>
<td>4.66</td>
<td>5.25</td>
<td>5.65</td>
<td>6.21</td>
<td>6.78</td>
</tr>
<tr>
<td>Grad</td>
<td>21.34</td>
<td>20.92</td>
<td>21.86</td>
<td>22.8</td>
<td>23.06</td>
<td>23.31</td>
<td>22.97</td>
<td>23.51</td>
</tr>
<tr>
<td>P/Doc</td>
<td>2.28</td>
<td>2.23</td>
<td>2.13</td>
<td>2.44</td>
<td>2.85</td>
<td>3.07</td>
<td>3.6</td>
<td>3.03</td>
</tr>
<tr>
<td>Hourly</td>
<td>5.02</td>
<td>5.54</td>
<td>5.39</td>
<td>5.76</td>
<td>6.09</td>
<td>7.15</td>
<td>6.84</td>
<td>6.64</td>
</tr>
<tr>
<td>Fac.</td>
<td>51.07</td>
<td>51.34</td>
<td>50.54</td>
<td>48.9</td>
<td>47.39</td>
<td>46.69</td>
<td>46.</td>
<td>45.43</td>
</tr>
<tr>
<td>Total%</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

While these findings indicate some alteration in the overall occupational structure of the University, an even more important set of findings occurs when these fluctuations are examined in the context of the aforementioned biotechnology departmental categorization. Within the Core (Figure 3), Graduate Student and Pre/Post Doctoral FTEs increased by approximately five percent (in relation to total Core FTEs), from a low of 27.87% in fiscal year 1984/1985 (the year prior to the implementation of the biotechnology research effort) to 32.87% in 1990/1991. During this same period, the Faculty
Figure 3. Core FTE breakdown
share of FTEs declined by 6.76%, from a high of 34.12% in 1984/1985, to a low of 27.36% in 1989/1990. The P&S share of FTEs also rose by approximately three percent during this period, while the Merit share declined by approximately 3.5% over the eight years under study. The Hourly share of Core FTEs increased slightly (Table 3).

Table 3. Occupational categories as a percentage of total Core FTEs

<table>
<thead>
<tr>
<th>Core FTE Breakdown</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad</td>
<td>24.7</td>
<td>22.97</td>
<td>25.27</td>
<td>26.77</td>
<td>27.15</td>
<td>26.04</td>
<td>25.45</td>
<td>25.81</td>
</tr>
<tr>
<td>Pdoc</td>
<td>5.16</td>
<td>4.9</td>
<td>5.04</td>
<td>5.83</td>
<td>6.1</td>
<td>6.61</td>
<td>7.69</td>
<td>7.06</td>
</tr>
<tr>
<td>Merit</td>
<td>18.65</td>
<td>18.85</td>
<td>18.11</td>
<td>18.07</td>
<td>17.52</td>
<td>14.95</td>
<td>14.83</td>
<td>15.01</td>
</tr>
<tr>
<td>Fac.</td>
<td>32.88</td>
<td>34.12</td>
<td>31.89</td>
<td>30.0</td>
<td>28.44</td>
<td>27.46</td>
<td>27.36</td>
<td>28.05</td>
</tr>
<tr>
<td>Total</td>
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<td>99.99</td>
<td>99.98</td>
<td>100.00</td>
<td>99.99</td>
<td>100.00</td>
<td>100.00</td>
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</tr>
<tr>
<td>Grads &amp; Pdocs</td>
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<td>27.87</td>
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<td>32.6</td>
<td>33.25</td>
<td>32.65</td>
<td>33.14</td>
<td>32.87</td>
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</tbody>
</table>

A similar trend is evident within the Support departments (Figure 4). Graduate Student and Pre/Post Doctoral FTEs rise steadily from a low of 16.62% in 1985/1986 (the first year of the biotechnology funding) to 22.51% in 1990/1991 (an overall increase of 5.89 percentage points). During this same period, Faculty FTEs steadily decreased from a high of 37.74% in 1985/1986 to a low of 32.61% in 1990/1991 (a decline of about five percentage points). Other occupational categories remain relatively stable (Table 4).
Figure 4. Support FTE breakdown
This same trend occurs in departments unrelated to the biotechnology research effort, though to a lesser degree (Figure 5). The comparative level of Graduate Student and Pre/Post Doctoral FTEs rise by a total of 2.89 percentage points during the eight-year period, Faculty FTEs fall by 5.54 points, and other categories hold relatively constant (Table 5).

The significance of these changes may be tested by constructing a comparison of beginning and ending points for each of the six occupational groupings (Table 6). Such a comparison is useful in that the first year of data (1983/1984) represents a period which saw no biotechnology funding, while the last year of data (1990/1991) reflects a period in which the project was well underway.

In Table 6, the mean value represents the Mean amount of change (+ or -) in the raw number of FTEs between FYs 1983/1984 and 1990/1991 for a given occupational category.
Figure 5. Non-Biotech FTE breakdown
### Table 5. Occupational categories as a percentage of total Non-Biotech FTEs

<table>
<thead>
<tr>
<th>Non-biotech FTE Breakdown</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
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<td>21.29</td>
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<td>23.29</td>
<td>23.13</td>
<td>23.68</td>
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<td>1.0</td>
<td>1.04</td>
<td>1.11</td>
<td>1.53</td>
<td>1.74</td>
<td>1.8</td>
<td>1.19</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>2.34</td>
<td>2.92</td>
<td>2.65</td>
<td>2.7</td>
<td>3.21</td>
<td>3.04</td>
<td>3.68</td>
<td>4.53</td>
</tr>
<tr>
<td>Merit</td>
<td>12.79</td>
<td>11.33</td>
<td>11.99</td>
<td>12.03</td>
<td>12.43</td>
<td>11.25</td>
<td>11.4</td>
<td>11.48</td>
</tr>
<tr>
<td>Hourly</td>
<td>2.12</td>
<td>2.88</td>
<td>2.34</td>
<td>2.91</td>
<td>2.99</td>
<td>3.35</td>
<td>3.59</td>
<td>3.89</td>
</tr>
<tr>
<td>Fac.</td>
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<td>60.14</td>
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<td>57.12</td>
<td>57.32</td>
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<tr>
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<td>100.00</td>
<td>100.01</td>
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<td>99.99</td>
<td>99.99</td>
<td>100.00</td>
<td>99.99</td>
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Table 6. A comparison of beginning and end-point mean differences between Core, Support, and Non-Biotechnology occupational categories

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<th>Mean</th>
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<th>Scheffe</th>
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<td>C-S .99</td>
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<tr>
<td>Support</td>
<td>1.48</td>
<td></td>
<td>C-N 1.4</td>
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<tr>
<td>Non-Biotech</td>
<td>1.06</td>
<td></td>
<td>S-N .42</td>
</tr>
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<td>.02*</td>
<td>C-S 1.64</td>
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<tr>
<td>Core</td>
<td></td>
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<td></td>
<td>S-N .00</td>
</tr>
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<td>Non-Biotech</td>
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<td></td>
</tr>
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<td>Faculty</td>
<td>Core</td>
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<td>Support</td>
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<td>Non-Biotech</td>
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<td>S-N .97</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>Core</td>
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<td>.0008*</td>
</tr>
<tr>
<td>Support</td>
<td>.54</td>
<td></td>
<td>C-N 2.78*</td>
</tr>
<tr>
<td>Non-Biotech</td>
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<td>Merit</td>
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<td>Non-Biotech</td>
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<tr>
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<td>Core</td>
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<td>.11</td>
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<tr>
<td>Support</td>
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<td>C-N 1.42</td>
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<td>Non-Biotech</td>
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<td></td>
<td>S-N .93</td>
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</table>

*p < .05
For example, the mean value of 2.47 for Core Graduate Students represents an average increase of 2.47 FTEs per department within the Core over the eight years of available data. The Pr>F value represents the overall level of significance for these changes. A Scheffe' Multiple Comparison was then utilized in order to determine the significance of Mean differences for each of the possible pairings of departmental categories: Core-Support (C-S); Core-Non-Biotech (C-N), and; Support-Non-Biotech (S-N) (Agresti and Finlay, 1986).

This general analysis yields statistically significant results for two of the occupational categories. Pre/Post Doctoral employees have increased substantially within the Core Departments (1.95 per department), and moderately within the Support and Non-Biotech departments (.31 and .3, respectively). Also, P&S employees have increased dramatically within the Core (3.25 FTEs per department, on average), and moderately within the Support and Non-Biotech groupings (.54 and .47, respectively). And, while the other analyses of occupational groupings were not found to be statistically significant (due to high variability) some of the findings do tend to lend credence to the trends described in Figures 3-5 (e.g., a substantial increase in Graduate Students per department, with the increase most pronounced among the Core, and least pronounced among the Non-Biotechnology Departments).
Beyond this basic analysis of the five occupational groupings, it is important to remember that each of these groupings may be further analyzed in terms of the occupational activity (Instruction, C&G, Research, and AES) in which a given employee was engaged. For example, it is clear that the Graduate Student share of FTEs increased in all three of the departmental categorizations. However, it is still unclear whether these graduate students are engaged in instructional or research activities. The data on professional activity is therefore useful in answering this question, and reveals some interesting trends.

As has been stated, within the Core categorization, the relative level of Graduate Student and Pre/Post Doctoral FTEs has increased by five percent, Faculty have decreased by nearly seven percent, and other occupational categories have held fairly constant. These trends appear even more dramatic in light of the occupational activity data. Among Core Graduate Students (Figure 6), there was a 20% drop in the proportional share of Graduate Students involved in Instructional activities between fiscal years 1984/1985 and 1989/1990. This same period saw an increase of over 26 percentage points in C&G related-activities for graduate students (a category reflective of the biotechnology funding). Research and Ag Experiment Station activities both declined slightly (Table 7). Similar trends are also present in the
Figure 6. Graduate FTE categorization (Core)
Support departments (Figure 7), which reveal a 31 percentage point increase in C&G related activities, and a 19.5 point drop in Instructional activities. AES positions also declined by approximately 11.5 percentage points (there were no Graduate Student Research FTEs in the Support group--Table 8). A similar trend, though less pronounced, was found among the Non-Biotech departments. The Instructional share of FTEs for Graduate Students declined by approximately 16.7% in comparison to the other occupational categories, while the C&G portion of FTEs increased by approximately 17.7 percentage points. AES and Research FTEs held relatively constant (Table 9).
Figure 7. Graduate FTE categorization (Support)
Table 7. Funding category as a percentage of all Core occupational titles

<table>
<thead>
<tr>
<th>CORE CATEGORIZATIONS</th>
<th>Merit Work Categorization</th>
<th>F&amp;S Work Categorization</th>
<th>Graduate Work Categorization</th>
<th>Pre and Post Doctoral Work Categorization</th>
<th>Hourly Work Categorization</th>
<th>Faculty Work Categorization</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
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<td>83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91</td>
<td>83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91</td>
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<td>83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91</td>
<td>83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91</td>
<td>83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91</td>
<td>83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91</td>
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<td>Instr.</td>
<td>37.11 40.12 36.6 35.05 37.02 38.68 40.6 42.35</td>
<td>41.02 39.16 38.21 35.22 31.08 26.59 27.63 28.82</td>
<td>52.82 55.28 44.22 41.06 37.2 34.98 36.97</td>
<td>0.91 0 5.28 4.32 2.03 3.62 1.54 1.83</td>
<td>5.73 7.16 6.89 5.26 4.36 2.22 5.18 5.01</td>
<td>63.76 64.43 65.37 65.0 64.1 62.47 72.52 72.19</td>
<td>44.47 46.18 42.86 40.53 39.34 36.0 38.71 40.14</td>
</tr>
<tr>
<td>C&amp;G</td>
<td>21.82 19.19 22.71 27.45 27.5 21.14 20.01 8.47</td>
<td>25.26 24.82 27.82 32.11 34.55 46.1 45.19 41.01</td>
<td>25.26 24.82 27.82 32.11 34.55 46.1 45.19 41.01</td>
<td>78.11 86.31 69.66 75.13 88.71 93.67 94.59 92.93</td>
<td>76.21 71.65 77.98 78.94 89.8 94.96 83.49 87.22</td>
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<td>14.15 19.09 12.42 12.84 5.84 2.82 9.35 5.85</td>
</tr>
<tr>
<td>Res.</td>
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<td>3.46 4.82 3.74 4.41 3.59 3.86 2.65 2.11</td>
<td>13.85 11.8 9.03 8.12 9.12 10.00 11.74</td>
<td>7.65 1.44 5.94 9.19 3.55 1.36 1.16 1.32</td>
<td>15.36 13.85 11.8 9.03 8.12 9.12 10.00 11.74</td>
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| Table 7. Funding category as a percentage of all Core occupational titles | 61 |
Table 8. Funding category as a percentage of all Support occupational titles

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<td>30.76</td>
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<td>Res.</td>
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<td>AES</td>
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<td>39.73</td>
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<td>29.53</td>
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<td>Table 9. Funding category as a percentage of all Non-Biotech occupational titles</td>
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<td>56.83</td>
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<td><strong>C&amp;G</strong></td>
<td>16.37</td>
<td>17.4</td>
<td>21.02</td>
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<td>29.99</td>
<td>32.72</td>
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<td>34.06</td>
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<tr>
<td><strong>Res.</strong></td>
<td>6.24</td>
<td>6.49</td>
<td>5.83</td>
<td>4.32</td>
<td>5.09</td>
<td>5.1</td>
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<td>6.76</td>
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<tr>
<td><strong>AES</strong></td>
<td>6.21</td>
<td>4.84</td>
<td>3.04</td>
<td>4.68</td>
<td>5.77</td>
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<td><strong>Pre and Post Doctoral Work Categorization</strong></td>
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<td>5.35</td>
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<tr>
<td><strong>C&amp;G</strong></td>
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<td>73.16</td>
<td>69.42</td>
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<td>86.73</td>
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<td>4.84</td>
<td>5.0</td>
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<td>4.81</td>
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<td>23.68</td>
<td>17.9</td>
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<td>22.26</td>
<td>12.08</td>
<td>7.92</td>
<td>4.17</td>
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<td><strong>Hourly Work Categorization</strong></td>
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<td>88/89</td>
<td>89/90</td>
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<td>31.62</td>
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<td>29.51</td>
<td>25.21</td>
<td>20.39</td>
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<td><strong>C&amp;G</strong></td>
<td>69.37</td>
<td>61.59</td>
<td>63.38</td>
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<td>62.75</td>
<td>64.93</td>
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<td>1.17</td>
<td>0.73</td>
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<td>0.34</td>
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<td>6.87</td>
<td>3.62</td>
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<td>9.13</td>
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<td>88/89</td>
<td>89/90</td>
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<td>2.86</td>
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</tr>
<tr>
<td><strong>Res.</strong></td>
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<td>4.59</td>
<td>4.49</td>
<td>4.78</td>
<td>4.77</td>
<td>4.63</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>AES</strong></td>
<td>2.68</td>
<td>2.88</td>
<td>2.92</td>
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<td>3.26</td>
<td>3.16</td>
<td>3.31</td>
<td>3.7</td>
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<td>88/89</td>
<td>89/90</td>
<td>90/91</td>
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</tr>
<tr>
<td><strong>Instr.</strong></td>
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<td>80.6</td>
<td>79.55</td>
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<td>75.15</td>
<td>77.00</td>
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</tr>
<tr>
<td><strong>C&amp;G</strong></td>
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<td>8.13</td>
<td>9.68</td>
<td>11.63</td>
<td>13.24</td>
<td>14.85</td>
<td>15.73</td>
<td>15.81</td>
</tr>
<tr>
<td><strong>Res.</strong></td>
<td>4.72</td>
<td>4.32</td>
<td>4.23</td>
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<td>4.53</td>
<td>4.13</td>
<td>1.16</td>
<td>1.43</td>
</tr>
<tr>
<td><strong>AES</strong></td>
<td>6.5</td>
<td>6.95</td>
<td>6.54</td>
<td>6.24</td>
<td>6.86</td>
<td>5.87</td>
<td>6.12</td>
<td>6.94</td>
</tr>
</tbody>
</table>
By again using a comparison of Means (on beginning and ending points for the eight years of data), test of significance, and Scheffe' Multiple Comparison test, the statistical significance of these trends may be analyzed (Table 10).

Table 10. A comparison of beginning and end-point mean differences for Graduate Student FTEs, grouped by funding category

<table>
<thead>
<tr>
<th>Funding Category</th>
<th>Core</th>
<th>Support</th>
<th>Non-Biotech</th>
<th>Core</th>
<th>Support</th>
<th>Non-Biotech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional</td>
<td>-1.4</td>
<td>-0.75</td>
<td>-0.29</td>
<td>4.37</td>
<td>2.39</td>
<td>1.46</td>
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<td></td>
<td>.29</td>
<td>.01</td>
<td>.04</td>
<td>.01*</td>
<td>.08</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>C-S -0.67</td>
<td>C-N -1.14</td>
<td>S-N -0.46</td>
<td>C-S 1.98</td>
<td>C-N 2.92*</td>
<td>S-N .94</td>
</tr>
<tr>
<td>C&amp;G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>4.37</td>
<td>2.39</td>
<td>1.46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.01*</td>
<td>.08</td>
<td>.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C-S 1.98</td>
<td>C-N 2.92*</td>
<td>S-N .94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research</td>
<td>-0.04</td>
<td>0.0</td>
<td>-0.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.80</td>
<td>.08</td>
<td>.12</td>
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<td></td>
<td>C-S -0.04</td>
<td>C-N 0.08</td>
<td>S-N 0.12</td>
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<td></td>
</tr>
<tr>
<td>AES</td>
<td>-0.44</td>
<td>-0.16</td>
<td>0.02</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>.12</td>
<td>.46</td>
<td>.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C-S -0.28</td>
<td>C-N -0.46</td>
<td>S-N -0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

This analysis reveals that C&G positions among Graduate Students have experienced a substantial and statistically-significant increase of 4.37 positions per department in the Core. The Support and Non-Biotech groupings also experience substantive increases, but not to the degree found in the Core. While the other funding category analyses failed to
reveal significant findings, they clearly indicate trends similar to those revealed in Figures 6 and 7 (slight decreases in Research and AES FTEs, and substantial decreases in Instructional FTEs that are most pronounced among the Core, and least pronounced among Non-Biotech departments).

Among Pre and Post Doctoral employees, all three departmental categorizations have experienced dramatic increases in the relative level of C&G-funded positions. Within the Core, 92.93% of Pre/Post Doctoral positions were funded through Contracts and Grants in FY 1990/1991 (up from 78.11% in FY 1983/1984--Table 7). Among Support Departments, 70.23% of Pre/Post Doctoral positions were based on C&G funds (up from 32.2% in FY 1983/1984--Table 8). Within departments unrelated to the biotechnology project, 86.1% of Pre/Post Doctoral positions were C&G-related (up from 58.42% in FY 1983/1984--Table 9).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for Pre/Post Doctoral employees is contained in Table 11. Significant findings verify the substantial increase in C&G related Pre/Post Doctoral positions among the Core, as well as a decrease in Research positions for Support and Core Departments.

Regarding Faculty, it is important to note that their activities are somewhat more difficult to classify than Graduate Students. For the Faculty, the difference between
Instructional and Research FTEs is largely a matter of bookkeeping—it is not reflective of a true distinction between teaching and research activities. With this in mind, it is evident that the official data record of Faculty

Table 11. A comparison of beginning and end-point mean differences for Pre/Post Doctoral FTEs, grouped by funding category

<table>
<thead>
<tr>
<th>Funding Category</th>
<th>Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>0.05</td>
<td>.73</td>
<td>C-S 0.05</td>
</tr>
<tr>
<td>Support</td>
<td>0.00</td>
<td></td>
<td>C-N 0.02</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.02</td>
<td></td>
<td>S-N -0.03</td>
</tr>
<tr>
<td>C&amp;G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>2.28</td>
<td>.003*</td>
<td>C-S 1.68</td>
</tr>
<tr>
<td>Support</td>
<td>0.6</td>
<td></td>
<td>C-N 1.94*</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.39</td>
<td></td>
<td>S-N 0.26</td>
</tr>
<tr>
<td>Research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-0.15</td>
<td>.03*</td>
<td>C-S 0.23</td>
</tr>
<tr>
<td>Support</td>
<td>-0.38</td>
<td></td>
<td>C-N -0.15</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.00</td>
<td></td>
<td>S-N -0.38*</td>
</tr>
<tr>
<td>AES</td>
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</tr>
<tr>
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<td>-0.23</td>
<td>.21</td>
<td>C-S -0.32</td>
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<tr>
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<td>C-N -0.17</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>-0.06</td>
<td></td>
<td>S-N 0.15</td>
</tr>
</tbody>
</table>

*p < .05

occupational activities has changed little over the eight year period under examination for any of the three departmental categorizations. The percentage levels hold relatively constant for each of the four occupational activity categories, for each of the three departmental categorizations.

With this in mind then, it does appear that increases in
the level of Instructional activity occur within the Core and Non-Biotech groupings during the last two years of data. However, these increases are largely offset by decreases within the Research category. These alterations were caused by a recategorization of state funding expenditures by the Office of Institutional Research, and did not reflect a true switch from Research to Instruction (according to Iowa State University's Office of Institutional Research).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test for Faculty failed to reflect significant findings in any funding category.

It is also important to note that, while the Merit, P&S, and Hourly percentages of FTEs failed to reflect the level of change present within the Faculty and Graduate Student-Pre/Post Doctoral categories (as evidenced in Figures 3-5), substantial alterations occurred within these categories. For example, among Professional and Scientific employees in the Core, a drop of approximately 15 percentage points in Instructional activity occurred between fiscal years 1983/1984 to 1988/1989 (Table 7). C&G positions for P&S employees rose by about 21 percentage points during the same period. Among P&S employees in the Support group, Instructional FTEs dropped by about four percentage points over the eight years of the data, while C&G increased by about 14 points (Research and AES FTEs also declined during the period--Table 8). The Non-
Biotech P&S category similarly experienced an eight percentage point drop in Instruction, and a 27 point increase in C&G FTEs (Table 9).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for P&S employees is contained in Table 12.

Table 12. A comparison of beginning and end-point mean differences for P&S FTEs, grouped by funding category

<table>
<thead>
<tr>
<th>Category</th>
<th>Core Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>0.42</td>
<td>.67</td>
<td>C-S 0.28</td>
</tr>
<tr>
<td>Support</td>
<td>0.14</td>
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<td>C-N 0.19</td>
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<tr>
<td>Non-Biotech</td>
<td>0.24</td>
<td></td>
<td>S-N -0.09</td>
</tr>
<tr>
<td>C&amp;G</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
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<td></td>
<td></td>
</tr>
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</tr>
<tr>
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</tr>
<tr>
<td>Research</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-0.01</td>
<td>.77</td>
<td>C-S -0.02</td>
</tr>
<tr>
<td>Support</td>
<td>0.01</td>
<td></td>
<td>C-N 0.03</td>
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<tr>
<td>Non-Biotech</td>
<td>-0.04</td>
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<td>S-N 0.04</td>
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<tr>
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<td>.24</td>
<td>C-S 0.5</td>
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<td>C-N 0.67</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>-0.01</td>
<td></td>
<td>S-N 0.17</td>
</tr>
</tbody>
</table>

*p < .05

Table 12 indicates a statistically-significant increase in C&G positions among P&S employees, with this increase most pronounced among the Core. Among Hourly employees, the same trend towards an increase in C&G, and a decrease in Instruction, was present among all three of the departmental categories. The trend was most pronounced among the Support
group, and least pronounced among the Non-Biotech group (Tables 7-9). A comparison of Means, test of significance, and Scheffe’ Multiple Comparison test, for Hourly employees is contained in Table 13. Once again, the increase in C&G positions is found to be statistically significant, and most pronounced among the Core.

<table>
<thead>
<tr>
<th>Table 13. A comparison of beginning and end-point mean differences for Hourly FTEs grouped by funding category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional</td>
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<tr>
<td>Support</td>
</tr>
<tr>
<td>Non-Biotech</td>
</tr>
<tr>
<td>C&amp;G</td>
</tr>
<tr>
<td>Support</td>
</tr>
<tr>
<td>Non-Biotech</td>
</tr>
<tr>
<td>Research</td>
</tr>
<tr>
<td>Support</td>
</tr>
<tr>
<td>Non-Biotech</td>
</tr>
<tr>
<td>AES</td>
</tr>
<tr>
<td>Support</td>
</tr>
<tr>
<td>Non-Biotech</td>
</tr>
</tbody>
</table>

*p < .05

Of the six occupational groupings (Faculty, Graduate Students, Merit, P&S, and Hourly), the only one to experience an overall increase in Instructional activity was Merit. Within the Core category, the Instructional share of Merit FTEs increased by approximately five percent. The
Instructional share of Support and Non-Biotech Merit FTEs also increased slightly (Tables 7-9). A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, failed to reveal statistically-significant findings among the Merit employees.

An overall analysis of the occupational activity data thus reveals that, within the Core, Instructional FTEs reached their peak during the 1984/1985 Fiscal Year, when they constituted 46.18% of the Core's total occupational activity (Figure 8). This percentage dropped to a low of 36% in Fiscal Year 1988/1989, but has since rebounded to just over 40%. Contract and Grant activity has risen dramatically, from a low of 24.97% of Core FTEs in 1984/1985 to 38.98% in 1990/1991. The Research and Ag Experiment Station shares of Core FTEs have declined by approximately 5 and 3 percentage points, respectively (Table 7).

In the Support category (Figure 9), Instructional activity has also dropped significantly, from a peak of 44.85% of Support FTEs in 1983/1984, to a low of 36.95% in 1990/1991. The Research and Ag Experiment Station share of Support FTEs has declined by approximately 2-3 percentage points each. Contract and Grant FTEs have approximately doubled, from a low of 13.6% of Support FTEs in 1983/1984 to 26.61% in 1990/1991 (Table 8).
Figure 8. Core FTE totals in terms of fund category percentages
Figure 9. Support FTE totals in terms of fund category percentages
And, once again, the same trend towards a decline in Instruction and an increase in Contract and Grant activity is present in the Non-Biotech category, but to a lesser degree. The Instructional share of Non-Biotech FTEs dropped from a high of 81% in 1983/1984, to 75.81% in 1990/1991 (a decline of just over 6 percentage points). Contract and Grant activity has risen from a low of 7.79% of Non-Biotech FTEs in 1983/1984, to a peak of 15.81% in 1990/1991 (an increase of just over 8 percentage points). The percentage of Research FTEs has declined by about 3 percentage points over the eight year period, while the Ag Experiment Station has held relatively constant (Table 9).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for all employees is contained in Table 14. The significant increase in C&G positions among the Core departments is reflected in this analysis.

Several basic conclusions are thus apparent from this data on occupational type and activity. First, the infusion of economic development research funds has had a considerable impact upon recipient departments, as displayed by the marked increase in research-oriented occupations (such as Graduate Students and Pre/Post Docs), and decreases in numbers of Faculty. Second, the funds have also had profound impacts in terms of the occupational activities in which employees are engaged. Again, the trend has been towards a substantial
Table 14. A comparison of beginning and end-point mean differences for Total FTEs grouped by funding category

<table>
<thead>
<tr>
<th>Category</th>
<th>Core</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>.18</td>
<td>.97</td>
<td>C-S 0.43</td>
</tr>
<tr>
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<td>.004*</td>
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<td>S-N 3.73</td>
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* p < .05

increase in Contract and Grant-related research activities, and away from Instructional activities. Third, while these trends have occurred on a university-wide basis, they have tended to be most pronounced among the Core and Support recipients of the economic development project funds, and least pronounced among departments unrelated to these funds. Thus, these figures constitute quantitative evidence of an increase in the level of C&G research, and relative decline in the level of Instruction, taking place at Iowa State University.
Qualitative Analysis

A second means by which changes in the internal structures of the Core and Supporting departments becomes evident is in the variety of opinions offered by departmental representatives during the interviews mentioned earlier (under METHOD OF STUDY). Over the course of these interviews, several of the DEOs attempted to convey the qualitative impact that these quantitative shifts have had on their departments.

For example, a Chairperson in one of the Core research departments states;

The most important aspect of the biotechnology funding is the competition for start-up funds. We have been able to hire good people with the funding, and that definitely affects the structure of the department. It also affects the nature of the people we hire, so it shifts the emphasis of the research they do, and that emphasis has shifted dramatically to biotechnology, to the neglect of other areas of research.

The biotechnology money is necessary but not sufficient because it restricts the scope of research to molecular biology. This may eventually do away with a good program on general biology and just leave us with a narrower expertise on molecular biology.

Concern over the changing internal research structures of the biotechnology departments was echoed by another Department Chair;

There is a 'have' and 'have-not' community that has developed around the biotechnology funding. Even though the funding has not been academic, it has had a significant role in shaping academic departments. It is a loose cannon on our deck... It has shifted departments' emphasis to this kind of money, and contributed to the reorganization of the biological sciences. It also raises questions of the utility of the existing structures of departments.
Another Chairperson of a Core department underscores that, even though this narrowing of research emphases among the biological science program at Iowa State may be beneficial to his own department, the benefit is indeed of a selective nature;

There is a dichotomy between people doing research at the molecular and organismic— or system—levels, and the funding has tended to favor the molecular emphasis... The funding has had an influence in that it may change the description of the positions we have to fill, in order to gear it towards that funding, but it's not a problem for this department because we fit very well into the molecular biology definition.

In essence then, some of the interviews conducted with the executive officers of the Core and Supporting biotech departments lend qualitative credence to the quantitative trends evidenced in the FTE data: 1) biotechnology research may be achieving the ascendancy at the expense of other, more broadly-based, areas of research, and; 2) funding-driven research demands are significantly altering the traditional status quos of these departments (particularly within the biotech Core), through targeted faculty selection and resulting shifts in instructional and research emphases.

In addition to the responses received by departmental executives and other departmental representatives, the biotechnology researchers themselves offered somewhat divergent perspectives on the impact that the biotechnology funding has had on their departments. Of the 26 biotechnology faculty hired at Iowa State University prior to the 1991-1992
academic year, 23 were interviewed by the authors regarding their opinions on this, and a variety of other issues (three faculty refused to be interviewed). Of those twenty three faculty, most were of the opinion that the biotechnology project had indeed altered the nature of their departments, but in a positive way. Some of the researchers' comments are as follows:

There has been a shift in the emphasis of my department, but I see this shift as a good thing. Molecular biology is a tool that can be used to study whatever subject you want. It was not established at I.S.U. prior to 1986.

This opposition to molecular biology and biotechnology is an antiquated idea. They (referring to Non-Biotech faculty) think molecular biology is not chemistry, but you can't compete without it. No reputable university neglects hiring people who know how to do molecular biology. I came here because of people doing molecular biology and they can help my research.

Biotech is a technique--not a research goal. It's a tool to look at the same questions we've always looked at, like the electron microscope. It's the questions we're asking that are important--not the ways we look at them. They're just afraid of change (referring to those expressing concerns over the possible shift in departments' emphases).

These concerns are not at all valid. This place had no molecular biology before this. It's only enhanced things.

A total of ten of the interviewees were of the opinion that structural shifts had occurred in their departments, but that these shifts had improved overall departmental quality.

But, a substantial minority expressed concerns about the long-term impact of the project. The following remarks are
indicative of these sentiments:

The impact of the biotech money is a very real danger. The research going on is now so cellular and so molecular that it's almost too basic to find a direct application. It's not serving the constituency it's meant for—the farmers. And it's expensive in terms of instruments and personnel, and the technical support people they have, such as lab technicians. So the State has had to come up with astronomical salaries and other funds, and that's bad for morale.

I'm biased. I don't think it (the biotech project) has had a beneficial effect. This department is breaking up into molecular biology and non-molecular biology... If it becomes a sole emphasis, this is a problem.

Yes, this is redirecting departments. I'm not a gene jockey, I'm a (occupation stated). Some hires have been based on 'where's the most money to be gotten,' rather than 'what's the biggest problem.'

This university is not in a net growth situation in terms of faculty. To the extent that biotechnology faculty have been hired, good progress is being made, but there is a lack of seed/start-up money for faculty in other areas. But this is less a problem with the biotechnology program than with not having enough money for other areas.

A total of five interviewees were of the opinion that the biotech monies had had an impact on their departments, and that this impact was of a negative nature.

A third theme was that the money had not really had an effect on departments:

There have definitely not been these types of changes in our department. The department is hiring on people from diverse areas. The potential for problems is there, but it hasn't happened yet.

I would really differ with those who say that this is re-directing departments. Molecular biology is just a tool. In the modern world, we must apply all the tools we have when we do an examination of something. The best
scientists use all of the tools that are available to them.

A good scientist must be broadly based. If a department just wanted to hire applied people, that would be bad. But the biotech people work at very different levels. They work together to make a good, general department.

I really don’t think it’s a problem. I don’t like to view molecular biology as apart from other science. It’s a tool and an expensive tool so we need funding for it.

A total of four interviewees were of the opinion that the structural impact of the biotech funding was not redirecting the emphasis of departments.

Four of the researchers declined to respond to this question.

Thus, while many DEOs and researchers either deny that the biotech funds have had an impact on their departments or believe that the impacts that have occurred are of a positive nature, a substantial minority also proposes that the increased research emphasis may be narrowing the base of instructional and research expertise within their departments.

Another important finding of the interviews with the biotech faculty regards the level of teaching activity in which they are personally involved. Interviewees were asked, 'In percentage terms, how is your job balanced between teaching and research activities?' On average, the biotech faculty spend 72.44% of their time on research activities,
while only 27.56% of productive time was devoted to teaching activity.

Summary

It is evident that this study has revealed several major findings:

1) The economic development biotechnology project has had a significant impact on recipient departments, primarily in terms of bringing about a marked proportional increase in research-oriented occupations (such as graduate students), and a proportional decrease in faculty.

2) The occupational activities of employees have also been substantially altered, as evidenced by a dramatic increase in Contract and Grant-related research activities, and a decrease in Instructional activities.

3) These trends have tended to be the most pronounced among those departments heavily involved in the economic development biotechnology project, and least pronounced among non-participant departments.

4) Some DEOs and researchers are critical of the impact that the biotech monies have had on their departments, due to the
creation of divisions among faculty and an over-concentration on issues related to molecular, rather than organismic, biology.

5) While both the raw number and proportional percentage of faculty has decreased during the period under examination, a growing proportion of remaining faculty are very research-oriented. Students may therefore be negatively affected not only in terms of having fewer faculty in departments, but also in terms of having this shrinking number of faculty be far more focussed on research than teaching.
DISCUSSION AND CONCLUSIONS

There are several theoretical levels from which these issues may be analyzed. On a broad level, a primary theoretical perspective which sheds considerable light on the implementation, operation, and impact of the biotechnology research effort at Iowa State University is Robert Merton's concept of 'manifest' and 'latent' functions (Merton, 1968).

Manifest functions are those outcomes, impacts, or results that are intended to occur as the result of a given action or activity. For example, in the case of the biotechnology research effort at Iowa State University, it was previously discussed that the fundamental manifest function of this effort has been the stimulation of economic development within that State. Another manifest function would be the development of a research program in an area that is acknowledged to stand at the 'cutting edge' of modern scientific technology.

Latent functions, on the other hand, are those outcomes, impacts, or results that are not intended or expected to occur as the result of a given action or activity. This is not to say that latent functions are of a negative nature; they are unexpected or unplanned, but positive in nature. For example, according to many of the biotech researchers, the I.S.U. program in molecular biology was underdeveloped prior to the implementation of the biotechnology research effort. While it
was not the manifest intent of the biotech appropriations package to resolve this apparent shortcoming at the university, it has certainly had that effect. Thus, the rectification of some academic inadequacies within the University appears to have been brought about by these appropriations.

Another form of latent outcome however, is the 'dysfunction'--an impact that is both unintended, and of a negative nature. Ironically, it appears that the fundamental dysfunctions that have resulted from the infusion of biotech research dollars at Iowa State have been evidenced among those departments that were the primary recipients of the money. These dysfunctions lend considerable credence to some of the general concerns mentioned earlier in the paper (under The Biotechnology Research Effort at Iowa State University).

One of these concerns was that the increased trend towards university reliance on external research funds would redirect research efforts towards economic or corporate need, rather than academic merit. Clearly, the striking growth of C&G positions within the university (in nearly all occupational categories) lends quantitative credence to concerns over the growing influence of external funds. Some of the interviews with DEOs and the biotech researchers also lend qualitative credence to the concern (e.g., "Some hires have been based on 'where's the most money to be gotten,'"
A second concern was that the economic development or profit-oriented research may be taking place at the expense of other areas of necessary research. Concern over these issues appears to be somewhat vindicated by the findings of this study, due to the feeling expressed by some DEOs and researchers regarding the priority the biotechnology project (with its specializing influence) may be taking over the traditional needs of a broadly-based program of scientific research and education. In quantitative terms, it is clear that when overall Faculty FTEs are decreasing, but a growing share of the remaining FTEs are allotted towards the biotech project, Core Faculty FTE levels are being maintained at the expense of more traditional, generalist positions.

A third issue was that the shift in research emphases created by this type of project may negatively affect instructional activities by diverting from the amount of time faculty are able to put into them, and by altering the nature of information that research specialists are able to convey to their students. The marked decrease in Instructional FTEs and increase in C&G FTEs clearly indicates that research activities have taken a numerical priority over instructional activities. Interviews with researchers also tend to verify the validity of this concern, with the average biotech researcher putting approximately three times as much time
and/or effort into research as is devoted to teaching. It would also stand to reason that the biotechnology faculty are not only more research-oriented than their predecessors, but also more specialized in terms of the level of instructional expertise they possess.

A fourth concern dealt with how the status of graduate students and faculty may be altered by their affiliation with profit-oriented research ventures. While this study did not focus specific attention on this issue, it is clear that it will be of growing importance as more research projects (and the dollars that accompany them) become concentrated in the hands of fewer and fewer faculty. Also, as the number of graduate students involved in these types of projects grow dramatically (as has been the case at Iowa State University), the question of their current status within the university setting will also grow in importance.

Another dysfunction not discussed earlier involves the division of faculty into opposing camps. Clearly, DEOs and researchers alike have expressed concerns regarding the intra-departmental divisions that have arisen since the beginning of the biotechnology program at Iowa State. The general nature of the antagonism between the biotech 'haves' and 'have-nots' is apparent in the comments listed earlier in the paper. While the impacts of such a division are difficult to quantify, the fact remains that the presence of such
antagonisms are not likely to facilitate a positive research or instructional work environment. DEOs and other administrators must therefore be prepared to dedicate time and effort towards the resolution of such divisions, or run the risk of encountering a variety of morale-related problems.

Thus, while some degree of success may have been achieved with regard to the manifest functions of I.S.U.'s biotechnology research effort (such as keeping the research in these departments on the 'cutting edge,' and contributing substantially to their on-going budgetary and professional needs), it is also clear that latent functions, and dysfunctions, have also arisen in the course of this implementation, and must be taken into consideration as the program continues to develop.

In terms of taking a more specific theoretical approach in analyzing these issues, an organizational theory of fundamental relevance in understanding the changing structure of Iowa State University (and other universities involved in similar ventures) focuses on the issue of strategic management and adaptation (Snow et al., 1980; Hrebiak et al., 1984).

According to the strategic management approach, difficulties in the operational environment of an organization force it to adapt by formulating new strategies for operation. In order to achieve this, organizational managers assess what opportunities and threats are present in the external
environment, as well as what strengths and weaknesses exist within the organization itself. Once such assessments are completed, the best fit between external opportunities and internal strengths is determined, and new strategies, missions, and goals are formulated with the intent of preserving optimal organizational operation.

With these new organizational missions and goals formulated, the organization then moves into the second stage of its adaptive process--strategy implementation (Hrebiniak et al., 1984). Strategy implementation basically involves redistributing organizational resources, and implementing operational changes, among the various elements within the organization; structures, control systems, human resources, technology, and corporate culture (Hrebiniak et al., 1984). The proposed result of this resource redistribution and operational alteration is the attainment of the adaptive pattern of operation deemed desirable in the 'strategy formulation' process.

In the case of Iowa State University, it is clear that severe environmental difficulties faced the university as a result of budget cutbacks from federal and state sources. These cutbacks created the need for an adaptation to maintain organizational operation. An external opportunity then became apparent to the university, in the form of the growing biotechnology industry, and the wide variety of means by which
this technology could be applied to the agricultural economy (or corporate culture) in the state of Iowa. The pursuit of this opportunity also matched closely with the internal strengths of the university, in that it possesses a high capacity for technological research, as well as the human resources to undertake such research.

A 'best fit' of internal strengths and external opportunities thus presented itself to university administrators, and the state government's appropriation of economic development funds allowed this structural adjustment, and organizational adaptation, to occur. A clear process of interaction is thus evident between four of the five organizational elements mentioned above: opportunities present in the (1) corporate culture resulted in an internal reallocation of resources towards (2) technology and (3) human resources, which has had the end result of altering (4) departmental structures within the university.

An important organizational problem with this process relates to the manner in which the biotechnology project is regarded by differing elements among the university. Shanklin et al. (1981) describe how the market share and growth potential of a venture may influence its receptivity by an organization. When a venture involves a new or rapidly-expanding share of a given market (as is the case with biotechnology), it tends to receive a high organizational
priority in terms of resource allocation. However, on-going ventures in mature markets (such as non-biotechnological research efforts in the Core and Support departments) tend to be of a lower organizational priority. Often, such efforts are used as 'cash cows' to finance newer ventures, or—if they fail to bring in substantial or comparable profits—may be considered for divestment.

This issue clearly relates to the apparent division that has occurred between many of the faculty in the Core and Support departments. DEOs and researchers alike have expressed concerns regarding the intra-departmental divisions that have arisen since the beginning of the biotechnology program at Iowa State. The general nature of the antagonism between the biotech 'haves' and 'have-nots' is apparent in the comments listed earlier in the paper.

Neilsen (1968) addresses the fact that scarce resources in an environment such as an academic department will tend to throw competing groups into conflict with one another. Factors related to inequity (e.g., unequal rewards, an unequal distribution of power, and the uncertainty that may result from such factors) also serve to exacerbate existing conflicts (Daft, 1988). In the case of the biotechnology project at Iowa State University, such conditions are present in that the new biotechnology faculty receive substantial salaries, 'start-up' funds, and equipment costs from the state, while
the older, non-biotechnology faculty members are subject to
the same budgetary restraints that apply to other members of
the university who are not involved in 'star' ventures.

While the impacts of this division are difficult to
quantify, the fact remains that the presence of such
antagonisms are not likely to facilitate a positive research
or instructional work environment. DEOs and other
administrators must therefore be prepared to dedicate time and
effort towards the resolution of such divisions, or run the
risk of encountering a growing body of morale-related
problems.

A broader organizational problem relates to the
previously-mentioned reformulation of strategies, missions,
and goals that organizations use to adapt to difficulties in
their operational environment. Once again, it must be pointed
out that instruction and research are the primary functions of
the university. And while it is true that the adaptive
processes implemented by universities such as Iowa State have
provided financially-strapped departments with the financial
means to survive, it may also be narrowing the body of
teaching and research expertise within these departments. The
university has therefore survived as an organization by
adapting to environmental difficulties, but it has been (and
is being) transformed by this process—with its primary
functions of teaching and research apparently becoming
secondary as a result.

It is therefore clear that some of the trends evidenced in the development of I.S.U.'s biotechnology program—whether they be labelled dysfunctional, or the products of adaptation to environmental hardship—may well be of a long-term detriment to the general functioning of the university. If the goals of the biotechnology program therefore work to the ultimate detriment of Iowa State University (in terms of negatively altering the disciplinary integrity of recipient departments, damaging the capacity for instruction, or altering the nature and direction of research), some degree of debate regarding the full extent and advisability of this course of organizational change should be undertaken.

With these concerns in mind, several questions result from the findings of this study. If one of the primary purposes of the university is to create new knowledge, when does a university administration determine that this creation process has become overly influenced by conditional funding sources (such as private investments or economic development appropriations)? At what point does the nature of research become so focussed on one area of specialization that it actually serves as a detriment to the general character of a department? If another primary purpose of the university is to impart the knowledge it creates, at what point does the emphasis on research impinge upon the ability to convey
knowledge in terms of numbers of personnel allocated to perform that function? And, along this same line, at what point does the emphasis upon research impinge on the ability or motivation displayed by such personnel to carry out the instructional function effectively? These are all questions that Iowa State University will eventually have to answer as a result of its involvement in the biotechnology research program, and the overall shift towards research.

With these questions in mind, it must also be said that it is not the intent of this paper to propose that the biotechnology project at Iowa State University, or other types of economic development projects around the country, are of no worth. Projects of this nature may provide many useful insights and breakthroughs that are of great importance to the long-term health of our economy and society. Indeed, over the course of the interviews conducted with the biotechnology researchers at Iowa State, the author was very impressed both with the quality of the researchers brought into the university, and the potential positive impact that their research may eventually have.

However, while the positive aspects of such programs tend to receive much attention and fanfare, their possible detriments often remain unnoticed or ignored. As such programs grow in size and number, we must therefore be wary of the fact that there may be negative—as well as positive—
implications for the universities and states that follow this program of economic development. The clear finding of this research is that universities participating in such an effort must be on guard for the structural changes that may result from it. As Jacobson (1991: 1) states:

Whatever may happen to the overall economy in the months ahead... it is already clear that higher education will never return to the boom days of the 1980's. At a minimum... many institutions--both public and private--are headed for a probing reassessment and realignment of what they can or should be, whom they should serve, and how they should attempt to handle all the tasks expected of them.

Universities must therefore come to terms with the nature of the economic and political changes facing them. It is true that academic activities--namely, teaching and research--may be seriously impaired by the kinds of budget cutbacks experienced in recent years. Research-oriented, economic development funds may thus alleviate the pressures created by budgetary restrictions, and allow academic institutions to continue operation in the manner to which many of them have grown accustomed. However, it must also be realized that utilizing universities for purposes such as economic development, or altering the motivation, style, and basic direction of academic research may create long-term patterns within the operation of the university that stray considerably from past methods of operation. Whether such deviations are of a desirable nature should therefore be debated, and the lessons learned through the experiences of universities such
as Iowa State should serve to clarify matters for both sides of this debate.
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Appendix
Non-Biotechnology Departments
(by college and department title)

AG=College of Agriculture
BS=College of Business
DS=College of Design
ED=College of Education
FCS=College of Family and Consumer Science

AG Economics
AG Ag Education
AG Ag Engineering
AG Animal Ecology
AG Center for Agriculture and Rural Development
AG Family and Consumer Science
AG Food Crops Center
AG Journalism
AG Meat Export Center
AG Meat Irradiation Center
AG Seed Science Center
AG Sociology and Anthropology
AG Special Research and Development
AG Statistics
BS Accounting
BS Finance
BS Management
BS Marketing
BS Transportation and Logistics
DS Architecture
DS Art and Design
DS Community and Regional Planning
DS Landscape Architecture
ED Elementary Education
ED Industrial Education
ED Physical Education
ED Professional Studies
ED Secondary Education
ED Research and Statistics
EG Aerospace Engineering
EG Biomedical Engineering
EG Bridge Engineering Center
EG Civil and Construction Engineering
EG EECpE
EG Engineering Science and

Mechanics
EG Freshman Engineering
EG Industrial Engineering
EG Material Science and Engineering
EG Mechanical Engineering
EG Nuclear Engineering
FCS Child Development
FCS FCS Education
FCS Family Environment
FCS HRIM
FCS Textiles and Clothing
SH Computer Science
SH Earth Sciences
SH Economics
SH English
SH Foreign Language and Literature
SH History
SH Material Science and Engineering
SH Mathematics
SH Music
SH Philosophy
SH Physics
SH Political Science
SH Psychology
SH Sociology and Anthropology
SH Speech Communication
SH Statistics
VM Biomedical Engineering
PAPER 2. ECONOMIC DEVELOPMENT AND THE PUBLIC UNIVERSITY: THE CHANGING FISCAL STRUCTURE OF ACADEMIA
Economic Development and the Public University: The Changing Fiscal Structure of Academia

by

William J. Kinney
INTRODUCTION

Over the last several decades, much attention has been focussed upon the changing nature of the modern university, particularly in terms of its purpose, role, and responsibilities in today's research-hungry, business-oriented social world. Some have argued for a 'pristine' model of university operation, wherein the creation of knowledge (through research) is a process which remains unpolluted by the influences of the external world. Proponents of such a model argue that these external influences may serve to alter the nature or character of new knowledge, and also impinge upon academic freedom. Others, however, view the university in a more utilitarian light, stressing that the knowledge created by universities must not only build in some way upon past knowledge or achievements to create a general advancement in the cumulative body of knowledge in a given field, but also be of substantial, practical use in the 'real world.'

Another debate regarding the operation of the nation's universities concerns their financial ability to adequately maintain these efforts at the creation of new knowledge through research. Over the last ten years, it has become increasingly clear that our nation's institutions of higher education are operating in a much harsher fiscal environment than has existed in previous decades. Shulman (1987) addresses how this situation has specifically affected the
research abilities of universities;

According to the U.S. Department of Education, federal funding for university research dropped nearly 50 percent between 1980 and 1985, the last year for which the department kept aggregate totals. This trend is especially worrisome since the government still accounts for 70 percent of university research funds. (p. 11).

Clearly, such dramatic cuts in research appropriations have the capacity to substantially alter both the level and nature of research taking place at our nation's universities.

Why is this growing trend important? It is important because academia benefits in a variety of ways from the research it engages in. One fundamental benefit is that faculty involved in research supposedly enhance instructional quality by being 'current in their fields,' and in touch with the more practical applications of a given discipline. Along this same line, it should be noted that faculty are not the only university personnel who engage in research. Graduate and undergraduate students also play an integral part in many faculty research projects, and receive valuable training and experience from their participation in such efforts.

Research is also becoming an increasingly important determinant of professional advancement for university faculty. Shao (1991) states;

In recent years, hiring and tenure decisions have come to be based largely on a professor's ability to generate world-class research. The most important criteria in tenure decisions remain a professor's publications record and reference letters, mostly from other researchers... If you're a mediocre researcher but an excellent teacher, you're unlikely to get tenure. (p. 126).
Therefore, when faculty reliant upon research for their professional advancement face greatly-reduced financial support from federal and state governments, they must seek out other sources of support to finance their on-going struggle for tenure and promotion.

And, the benefits of academic research are by no means limited to academia. Society in general benefits from the wide variety of medical, technical, and social innovations that result from university research. Society could indeed suffer long-term detriments should the research capacities of our academic institutions be further altered or restricted in the current fiscal environment.

It is also worth noting that it is not only the research activities of universities that have been affected by the current fiscal situation. Jacobson (1991) addresses the impact budget cuts have had on the instructional abilities of our nation’s universities;

Many academic leaders perceive that, even after the economy improves, their institutions will confront a major challenge involving tradeoffs between student access and academic quality. At least one of those traditional goals is likely to suffer, officials say, because neither state appropriations nor tuition rates will grow enough to finance them both as substantially as in the past. (p. 1).

It is therefore clear that both of the primary functions of our nation’s universities—research and instruction—have been negatively affected by this movement towards fiscal restraint and budgetary cutbacks. In response to this
situation, university administrators have been forced to seek alternate sources of replacement funding, in order to maintain previous levels of operation. To achieve this, some have sought to capitalize on another of the basic benefits that research provides academia—a demand-driven source of fiscal support.

Essentially, the research capacity of an academic institution is a valuable asset, in that it offers a specialized ability to government or industry that may be too expensive or difficult to develop independently. A research contract thus represents an investment by government or industry in the university, since they are paying for a service, and expect an eventual profit or benefit in return for that payment. The commodification of research facilities and personnel can thus result in a much needed source of income for financially-strapped universities, and alleviate some of the strains caused by budgetary cutbacks.

Rule (1988) underscores the special lure that this trend towards 'self-financing' university operations has taken on in recent years;

Since the 1970s, American higher education as a whole has been experiencing a recession, if not a depression. The often indiscriminate expansion of the 1960s quickly gave way to a period where student populations were falling and where government support for research was cut, but where operating expenses rose sharply. Under these circumstances, the idea of making university functions self-financing has taken on a special appeal. (p. 433).

As a result, Shulman (1987) concludes that, "...leading
universities are turning more and more to corporate support as federal funding decreases." (p. 11).

However, not all forms of 'self-financed' research come from private corporations. While general research and development funds from the federal government have been cut dramatically, 'earmarked' funds continue to flow. Earmarked research awards are made without a competitive review of the merits of a specific research program or project. Earmarked research appropriations to colleges and universities have increased dramatically over the last four years, from only $225 million in FY 1988 to more than $684 million in FY 1992 (Cordes et al., 1992). Critics accuse earmarking of being 'pork barrel science,' and claim that its dramatic increase over the last four years is linked to both budgetary problems on campus, and a desperate attempt to spur economic recovery:

...the scope of the practice (earmarking)--and the link between many of the projects and economic development--reflects a severe financial squeeze on higher education and Congressional concerns about the faltering economy. (Cordes et al., 1992, p. 1).

Earmarking may thus represent a congressional attempt to 'kill two birds with one stone,' by awarding non-competitive research monies to financially-strapped universities, while channeling research awards into economic development projects.

Many state governments appear to be using a similar technique in dealing with fiscal difficulties, by investing in university research--particularly technological research--to
inspire economic development. Blumenstyk (1992) states that,

By the end of the decade (the 1980s), nearly every state
had created at least one program that provided grants to
universities for research with commercial potential...
In the 1980’s, states sort of discovered technology...
(p. 1).

So, while general research appropriations from federal
and state governments remain restricted in the wake of
widespread budget cutbacks, the hope of quick economic payoffs
has kept public funds for economic development projects
(especially technological research) in ample supply. With
revenues declining and operating costs increasing, many
universities have therefore ‘hired-out’ their research
abilities to private industries or governmental agencies in
order to maintain fiscal solvency.

This development is of great interest in light of the
previously-mentioned debate over the role of the university in
today’s business-oriented social world. In a fiscal
environment as adverse to academia as the one that has
prevailed for the last decade or so, it is very difficult (if
not impossible) for universities to function in a ‘pristine’
mode of operation. How does an institution requiring massive
amounts of money for its continued operation remain unpolluted
by the influences of the external world when it must rely on
the external world for needed funds?

Clearly, financial difficulties have forced universities
into a more utilitarian mode of operation, as they
increasingly perform the research they are paid to perform rather than the research that is necessarily of the highest academic merit. Targeted or conditional funds from governmental or private sources (e.g., economic development and independent research projects, respectively) thus help universities maintain present levels of operation, but also serve to increase the influence of the suppliers of such funds on recipient universities.

Many view this development as cause for alarm. Shulman (1987) states;

According to Tufts University science historian Sheldon Krimsky and others, corporate interests threaten to skew research priorities. Krimsky...believes that 'when a university has its own for-profit sector, it means that the institution has to manage according to very different rules.' (p. 11).

Rule (1988) also expresses concern about the trend, and states;

When universities accommodate themselves too thoroughly to the agenda of non-university institutions, they begin to lose the qualities that make universities worth having in the first place. (p. 434).

In light of this growing trend (and the alarm with which it is viewed), it is the intent of this paper to examine a specific case of shifting research and funding patterns at a prominent research university. By examining the changes in structure and mode of operation at an institution that has undergone this cycle of self-financing, it will become
possible to ascertain whether the fears expressed by people like Shulman and Rule are warranted.

Biotechnology: A Growing Research Emphasis

A prime example of the manner in which the trend towards economic development research may impact upon the structure and operation of universities is evident in the growing national effort that has centered upon the development and practical application of agricultural biotechnology. Due to the promising nature of many preliminary efforts utilizing recombinant DNA technologies (growth hormones, herbicide resistance, disease resistance, reproduction enhancement, and many others), federal and state governments, as well as a variety of private sector interests, have begun to invest heavily in research focussing upon genetic engineering and agricultural biotechnology.

In 1988, for example, the federal government was spending approximately $2.7 billion dollars annually for basic research in biotechnology (Lacy et al., 1988). While only $150 million of that money was earmarked specifically for the development of agricultural biotechnology, the National Research Council's Board on Agriculture recommended in 1988 that this level of funding be dramatically increased over a very short period of time, to approximately $500 million annually by 1990 (Moses et al., 1988).
State governments have also increased their funding of biotechnology research programs dramatically, and were spending a combined total of approximately $150 million annually on such projects by 1987 (OTA, 1986). In comparison to the funding expenditures of the federal government, state governments are spending a considerably greater portion of these funds on the development of agricultural biotechnologies. Primary examples of projects established with the assistance of these funds are New York State's Center for Biotechnology in Agriculture at Cornell University and Iowa's Biotechnology Council at Iowa State University (Lacy et al., 1988). The goal of such expenditures is most often the establishment of research and development centers linking industry to universities, with the anticipated result of such linkages being the enhancement of economic development in these areas.

In addition to these research expenditures by the federal and state governments, biotechnology industries have also invested heavily in university research. In 1984, for example, biotechnology companies awarded about $120 million in contracts and grants to universities (Lacy et al., 1988). As a result of these private investments, a variety of contractual linkages have also developed between these companies and individual faculty, departments, and institutes.
The state-supported push for biotechnology research in Iowa’s university system was begun in 1985, when the Iowa Development Commission, at the behest of the Seventy-first Iowa General Assembly, allocated the sum of $10 million to the state’s public Board of Regents, public universities, and/or independent colleges. These funds were supplied by revenues drawn from the state’s lottery program. In fiscal year 1985, the Iowa General Assembly allocated $500,000 to Iowa State University for the purpose of agricultural biotechnology research. Additional appropriations were to follow, with the allocation of $3.75 million in 1986, and $4.25 million each for fiscal years 1987, 1988, and 1989 (Laws of the Seventy-first Assembly, 1986 session).

Research projects and products resulting from these appropriations have included the development of new biodegradable plastics, technologies for using cholesterol reductase to produce animal products with lower cholesterol content, and molecular and genetic techniques for the isolation of maize genes to control crop yields (among many others- Worthy, 1989).

As has been previously stated, the fundamental goal of many biotechnology research efforts--and many private and public research efforts in general--is economic development. Iowa State’s program is no exception to this trend, with the
explicitly-stated purpose of the General Assembly's allocation being the enhancement of economic development and research and development. That goal has remained intact throughout the implementation of the program, as evidenced by the remarks of the chairman of the oversight committee of the Iowa State Biotechnology Council, Walter Fehr:

With regard to the vision for biotechnology at Iowa State University, our ultimate goal is to use the new techniques of molecular biology to enhance the economic welfare of the state. We believe that this will occur through research in three primary areas: (1) the development of new products from our traditional commodities through bioprocessing; (2) improving the efficiency and profitability of crop and livestock production; and (3) development of new products and processes through the genetic modification of plants, animals, and microorganisms. The vision of Iowa State University's biotechnology program is strongly influenced by the desire to fully utilize the agricultural resources of the state for the welfare of its constituents. (Fehr, 1987).

In order to bolster the effectiveness of this research-centric approach to economic development, technology transfer networks have been put in place at I.S.U. to enhance the speed and accessibility with which innovations may be transferred from the lab to local industries desirous of the new biotechnological advancements (e.g., the Eastman Kodak fermentation plant in Cedar Rapids, the Cargill biotechnology facility in Eddyville, and the Ajinomoto Heartland Lysine feed-additive plant, also located in Eddyville-Worthy, 1989).

To date, state policy makers appear content with the results of the biotechnology-grounded economic development
plan. Iowa’s General Assembly has extended appropriations for the operation of the Biotechnology Council, and for the entire program of biotechnology research, beyond the initial three-year implementation period. And, in assessing the general effectiveness of the project, the state’s governor, Terry E. Branstad, states;

Iowa is turning biotech breakthroughs into business success stories. Partnerships between private industry and Iowa’s two world-class research universities are resulting in innovative products and economic progress. (Worthy, 1989).

Governor Branstad has even proposed budget increases for economic development projects based on university research like that taking place at Iowa State (Blumenstyk, 1992).

The effort to stimulate economic development through the creation of the biotechnology program at I.S.U. therefore appears to have met with a substantial degree of success. The university system in Iowa has been effectively used as a tool to promote this stimulation, and appears likely to continue the performance of this function for the foreseeable future.

In essence, the state of Iowa’s effort to stimulate economic development through funding university research in the ever-growing field of biotechnology serves as a model by which other states have, and may, attempt to undertake their own research-oriented programs of economic development in the future. As has been previously stated, by the end of the 1980’s, nearly every state had at least one program that
provided research grants to universities in the hope of spurring this kind of economic development.

However, while state economies may receive a variety of benefits from this utilization of the university system, concerns have been raised regarding the effect that this growing tendency may have upon the universities participating in such programs. As Rule (1988) states;

... what will exploitation of such profitable technologies do for--and to--the universities? Even if the more extravagant projections for biotechnology prove overblown, genetic engineering is bound to be among the biggest money-making activities associated with American universities in the 1990s. How will pursuit of such profits shape institutions supposedly predicated on values quite different from profitability? (p. 432).

Growing numbers of analysts are therefore coming to recognize some of the more negative aspects that may accompany the increasing influence of public and private economic development funding for universities. Leslie Roberts (1983) states;

In the face of declining federal support, universities need money for research and instruments. For industry, such agreements mean access to the scientific expertise that is still centered in the universities and rights to any patentable discoveries. And both sides espouse the societal good arising from rapid technology transfer. There is less agreement, however, on how serious a threat corporate funds pose to the integrity of the university. (page 159).

The primary concern about this possible 'threat' involves the fear that an over-reliance on external, conditional funds (public or private) may diminish the institutional autonomy of
universities. This attack on academic autonomy may take a variety of forms.

First, there is concern that the determination of what research is done—and how it is done—will come to be based more upon corporate/economic development needs than academic merit (Caldart, 1983). Shulman illustrates the potential for abuse that lies in this increased emphasis on economic outcomes and corporate needs:

Although it is unusual for corporations to dictate research topics, corporations do discourage certain research. John Longwell, a chemical engineer at M.I.T.'s Energy Lab, thinks pre-grant discussions with potential corporate funders often have such an effect. For example, he says Exxon discourages about 20 percent of the ideas for new projects for the lab. (Shulman, 1987: p. 12).

Economic or business concerns may thus take precedence over academic merit or the public interest, due to the powerful monetary influence that lies behind such concerns. Writing with specific regard to the academic impact of biotechnology research, Lacy et al. (1988) also stress that the growing influence of biotechnology projects in universities and colleges may increase the potential for conflicts of interest or scientific misconduct resulting from the clash between public and private occupational demands.

A second potential threat to university autonomy is that private interests may attempt to restrict the flow of information regarding research results (Lacy et al., 1988; Caldant, 1983). Where research findings unencumbered by the
control of private funds are free to be made public (e.g., through publication in professional journals), research based on private funds may be legally restricted due to the competitive interests of corporate sponsors.

The third concern over university autonomy is that long-term university plans and policies may increasingly be shaped by a growing acquiescence to the needs of private investors (Caldart, 1983). A possible example of such acquiescence could be the alteration of curriculum offerings to more adequately fit the needs of the private sector. Rule (1988) warns that universities must;

...ensure that new teaching ventures funded by, or in response to, lucrative forms of cooperation with outside agencies do not slight the less commercial elements of the liberal arts curriculum. If biotechnology firms want graduates who will serve as lab technicians and researchers, that possibility should hardly be denied to students planning careers. But undergraduates enrolling in programs conceived in response to such possibilities should have the same opportunities, or obligations, to study Plato's Republic or Shakespeare's sonnets offered to any undergraduate. (p. 435).

Apart from the specific question of autonomy, Lacy et al. (1988) also raise the inter-institutional concern that the biotechnology push may result in an over-concentration of research funds and scientific talent at a small number of universities and colleges.

Another concern specific to biotechnology research is that this industry is new, and in a very tenuous state. Over three-quarters of biotechnology firms continue to lose money,
and, in 1988, at least 24 biotechnology companies filed for bankruptcy—and five of these were publicly supported (Lacy et al., 1988). A 1989 poll (Kumar, 1989) reflects this uncertainty by showing that a majority of executives in biotechnology companies believe that, within ten years, roughly half of the nearly 500 biotechnology companies in the United States will fail, merge, or form cost-sharing alliances. Over-reliance on a research specialization in such a tenuous field (or any one field) may thus present serious dangers to those academic departments (and universities in general) that allow themselves to become structurally or fiscally reliant upon them.

Apart from the perils of the private sector, it appears that universities must also be wary of the publicly-based types of economic development funds that have sponsored projects such as the biotechnology research at Iowa State University. A recent issue of The Chronicle of Higher Education states that;

Many states are losing their ardor for economic-development programs based on research grants to universities. In the last few years several states have cut their financing for such research programs and shifted funds to projects designed to help small businesses and create jobs rapidly. More states are considering program cuts this year... state budget constraints, changes in political leadership, and a growing sense that pouring money into university laboratories is not the most efficient or effective way to help businesses and create jobs, have all put a damper on states’ love affairs with the programs. (Blumenstyk, 1992: p. 1).
Thus, the public sector offers little more security than the private sector in terms of providing stable, long-term financial support for this type of research project.

The overall trend towards self-financing through state and federal economic development funds, or independent corporate research projects, may therefore serve to alter the makeup of the modern university by creating a greater reliance on these conditional types of funds than has been present in the past. Concern may also be warranted as to whether this more market-driven approach to university research may affect the social outcomes of research, and the future capacity for universities to undertake a broad base of independent research activities.

An understanding of how such projects affect participant universities is thus not only of benefit or relevance to the State of Iowa, but to all states engaged in such programs of economic development--and all universities participating in these programs. In essence, while biotechnology research represents but one means by which economic development may be attempted by state governments, the process by which such projects occur, and the outcomes that result from them, may be similar regardless of the specific means at hand (such as biotechnology). The utilization of Iowa State University serves as a case-study by which the specific effects of such efforts may become more fully understood. Therefore, by
examining the situation at Iowa State University, it becomes possible to determine the likely impacts that biotechnology research in particular, and economic development projects in general, will have upon participant universities.

The overriding hypothesis that therefore guides this research is that the large infusions of research monies that have been received by Iowa State University have altered the overall fiscal structure of the university, and that this structural alteration has in turn affected other important functions of the university, such as the creation of knowledge through research.
METHOD OF STUDY

The first necessary step in assessing the impact of the biotechnology research effort at Iowa State University was to achieve a determination as to exactly which departments could be considered the primary beneficiaries of the biotechnology funding, which departments benefitted but to a lesser degree, and which received no benefits at all.

In order to achieve this determination, a technique known as 'snowball sampling,' or 'chain referral sampling,' was implemented among informed participants in the biotechnology research effort at Iowa State University (Kish, 1965: Kotz et al., 1982-1988). Under this method of examination, informed participants related to a given phenomenon are questioned not only with regard to desired information about the specific phenomenon under examination, but also in terms of referrals that may be given as to other informed participants whose knowledge of that phenomenon may be of additional use. Thus, the sample begins with a small set of initial elements, and ends with a larger set of elements connected with the initial set by one or more links of relationships (Kish, 1965: Kotz et al., 1982-1988).

In the Iowa State sample, the initial set of informed participants consisted of the Departmental Executive Officers (DEOs) of two departments acknowledged to be active in the biotechnology research effort (since interviewees were
guaranteed confidentiality, names and departments of these interviewees shall not be listed). Interviews (conducted by phone, or in person, if requested by the interviewee) focussed primarily upon two basic questions: 1) 'Which departments would you describe as being central to the biotechnology research effort at Iowa State University (the 'Core'), and which are involved in the biotechnology research effort, but to a lesser degree (the 'Support' category); and, 2) 'Could you name three other persons familiar enough with the biotechnology research program to offer informed opinions on this question?' In addition, general comments regarding other aspects of the biotechnology research effort (e.g., effectiveness of its administration, success in the attainment of stated goals, etc.) were welcomed from all interviewees who offered them.

Representatives (for the most part consisting of DEOs) were also contacted for all departments named as participants in either the Core or Support categories, but for whom a specific representative was not named in the course of the 'snowballing' process. All participating 'Core' and 'Support' departments were thus represented by at least one spokesperson in the course of the interviews. Ultimately, 22 interviews were conducted with DEOs and other departmental representatives.
As a result of these interviews, twelve departments were determined to operate within the Core of the biotechnology research effort: Biochemistry/Biophysics, Genetics, Zoology, Horticulture, Agronomy, Chemical Engineering, Chemistry, Plant Pathology, Botany, Veterinary Microbiology and Preventive Medicine, Veterinary Pathology, and Veterinary Anatomy. Nine additional departments were determined to function within the Support category: Microbiology, Animal Science, Food Technology, Food and Nutrition, Forestry, Entomology, Veterinary Physiology and Pharmacology, Veterinary Clinical Sciences, and the Veterinary Diagnostic Laboratory (see Appendix I for departments not included in either the Core or Support categories). Six non-academic divisions of the University were not included in the analysis (Ames Laboratory, Statistics Laboratory, World Food Institute, Computation Center, Institute for Physical Research and Technology, and Iowa State Water Resources Research Institute).
FINDINGS

With the determination of the Core, Support, and Non-Biotech departments made, it becomes possible to detect what differential impact the large infusions of biotechnology research monies have had upon these groupings. The determination of these impacts is based upon comprehensive records of all university research expenditures for the period beginning Fiscal Year (FY) 1983/1984, and ending FY 1989/1990. Thus, for purposes of comparison, the first three years of this period reflect a time in which no biotechnology funding was received by the university, and the last four years reflect a period of heavy biotechnology funding, as the research effort was implemented (data for this analysis was gathered with the cooperation of Iowa State University’s Office of the Associate Provost for Research). These expenditures fall into three separate groupings: General Research, Agricultural Experiment Station (AES), and Contracts and Grants (C&G). The biotechnology expenditures fall within the C&G category (according to Walter Fehr of Iowa State University’s Biotechnology Council).

In comparing these three categories, it is evident that C&G expenditures have experienced a dramatic increase over the seven year period under examination (Figure 1, Table 1). C&G expenditures were at their low in the first year of the study, amounting to only $18.4 million. However, by the
Figure 1. Academic research expenditures
end of the period, they had climbed to a peak of approximately $46 million—amounting to an increase of approximately 250% in just seven years. AES expenditures also increased during this same period, from about $11.8 million in FY 83/84 to $16.9 million in FY 89/90. General Research expenditures increased slightly for the first six years of the period, and decreased sharply in FY 89/90.

It is also useful to examine these categories in terms of the percentages they constitute of the overall research expenditures for the university (Figure 2, Table 2). Again, we see a dramatic increase in the percentage share of the C&G category, from a low of 51.5% of all research expenditures in FY 83/84 to a high of 70.1% in FY 89/90. While the dollar amount of AES expenditures increased as described in the previous paragraph, its percentage of overall expenditures actually declined over the seven year period, from 32.9% in FY 83/84 to 25.8% in FY 89/90. The percentage share of General Research expenditures held relatively constant for the first
Figure 2. Funding categories as a percentage of the overall academic budget.
Table 2. Funding categories as a percentage of overall budget

<table>
<thead>
<tr>
<th></th>
<th>Gen. Res.</th>
<th>AES</th>
<th>C&amp;G</th>
<th>Tot.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>15.53</td>
<td>32.96</td>
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<td>32.77</td>
<td>50.79</td>
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</tr>
<tr>
<td>86/87</td>
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<td>15.02</td>
<td>28.99</td>
<td>55.99</td>
<td>100</td>
</tr>
<tr>
<td>88/89</td>
<td>12.86</td>
<td>23.57</td>
<td>63.57</td>
<td>100</td>
</tr>
<tr>
<td>89/90</td>
<td>4.06</td>
<td>25.81</td>
<td>70.13</td>
<td>100</td>
</tr>
</tbody>
</table>

six years of the period, but decreased from approximately 12.8% to 4% in FY 89/90.

Another set of findings arises when these shifts in research expenditures are examined within the context of the aforementioned biotech departmental categorization. Within the Core departments (Table 3, Figure 3), the C&G share of research expenditures rises from a low of approximately 54.2% in FY 83/84 to a high of 66.5% in FY 89/90. AES expenditures hold relatively constant over the seven year period, while General Research expenditures also hold relatively constant except for a sharp decline of about 6.5 percentage points in FY 89/90.

In the Support category (Table 4, Figure 4), C&G expenditures experience an even more dramatic increase than is present in the Core category. C&G expenditures steadily increase from a low of 42.5% in FY 85/86, to a peak of approximately 66% in FY 89/90. The AES share of Support expenditures experiences a dramatic decline during this same
Figure 3. Core funding source analysis
Figure 4. Support funding source analysis
Table 3. Core funding source analysis

<table>
<thead>
<tr>
<th>Year</th>
<th>% from gen. res.</th>
<th>% from AES</th>
<th>% from C&amp;G</th>
<th>Total</th>
</tr>
</thead>
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<td>60.32</td>
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</tr>
<tr>
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<td>60.12</td>
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</tr>
<tr>
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</table>

Table 4. Support funding source analysis

<table>
<thead>
<tr>
<th>Year</th>
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<th>% from AES</th>
<th>% from C&amp;G</th>
<th>Total</th>
</tr>
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<td>0.1</td>
<td>33.89</td>
<td>66.02</td>
<td>100.01</td>
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</table>

period, falling from a peak of 55.54% in FY 85/86 to a low of approximately 33.9% in FY 89/90. General Research expenditures hold relatively constant throughout the period.

The dramatic increase in C&G funding is also present among the Non-Biotech departments (Figure 5, Table 5). C&G expenditures constitute only 52.6% of the Non-Biotech research expenditures in FY 83/84, but increase to 74.8% by FY 89/90. AES decreases from 28.3% of Non-Biotech research expenditures in FY 83/84, to 17.3% in FY 89/90. General Research also declines dramatically, from 19.1% in FY 83/84 to 3.3% in 89/90.
Figure 5. Non-Biotech funding source analysis
Table 5. Non-Biotech funding source analysis

<table>
<thead>
<tr>
<th></th>
<th>% from gen. res.</th>
<th>% from AES</th>
<th>% from C&amp;G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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<td>3.28</td>
<td>21.9</td>
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Another perspective on the data may be gained by examining these budget fluctuations as fund types rather than departmental categories. In other words, rather than looking at what percentage C&G funds constituted of total Core expenditures, it may be useful to examine what percentage the Core constituted of total C&G expenditures.

The significance of these changes may be tested by constructing a comparison of beginning and ending points for each of the three funding categories (Table 6). Such a comparison is useful in that the first year of data (1983/1984) represents a period which saw no biotechnology funding, while the last year of data (1989/1990) reflects a period in which the project was well underway.

In Table 6, the Mean value represents the Mean amount of change (+ or -) in the raw number of dollars expended between FYs 1983/1984 and 1989/1990 for a given funding category. For example, the Mean value of -$44,722 for Core General Research Funds represents an average decrease of $44,722 of General
Research Funds per department within the Core over the seven years of available data. The Pr>F value represents the overall level of significance for these changes. A Scheffe' Multiple Comparison was then utilized in order to determine the significance of Mean differences for each of the possible pairings of departmental categories: Core-Support (C-S); Core-Non-Biotech (C-N), and; Support-Non-Biotech (S-N) (Agresti and Finlay, 1986).

This general analysis yields statistically significant results only for the overall research expenditures of the university. In this category, it is demonstrated that, over the seven years of available data, Core research expenditures have increased by an average of $636,961 per department.
Support expenditures have increased by an even more dramatic $710,131 per department. Non-Biotech departments have averaged an increase of only $208,181 per department. And, while changes within the other funding categories were not found to be statistically significant (due to high variability), the dramatic increase in C&G funds for the Core and Support Departments is worth noting.

Another important aspect of the data is revealed when the three biotech categorizations are compared with one another, in terms of the percentage that each category constitutes of overall research expenditures (Figure 6, Table 7). These figures show that the percentages have fluctuated considerably during the six year period under examination, with Core expenditures steadily increasing in the three years prior to the appropriation of biotechnology funding, holding relatively constant in the first year of the program, and declining rapidly in the second, third, and fourth years of the program. Thus, while the per-department levels of research expenditures have increased in the manner described in Table 6, the percentage that the Core constitutes of overall research expenditures has actually declined considerably since the implementation of the biotech research program.
Figure 6. Core, Support, and Non-Biotech percentages of the total budget
Table 7. Core, Support, and Non-Biotech percentages of total budget

<table>
<thead>
<tr>
<th></th>
<th>Core</th>
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<th>Non-Biotech</th>
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<tr>
<td>83/84</td>
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<td>33.89</td>
<td>21.24</td>
<td>44.88</td>
<td>100.01</td>
</tr>
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</table>

The decline of research expenditures is even more dramatic with the introduction of a 'hypothetical alternative' scenario, in which research expenditures are examined as if biotechnology funding had not been appropriated during the 1986-1989 period (Figure 6--complete information for FY 89/90 appropriations is not yet available). These findings thus indicate that general expenditures have not only decreased on the whole for the Core departments during this period, but that non-biotechnological research has undergone a dramatic decline as well, from a high of 40.03% of expenditures in fiscal year 1985/1986, to a low of 34.13% in fiscal year 1987/1988. Much of this decline, then, is attributable to the absence of substantial increases in General Research and AES expenditures during the entire period under examination (Figure 3). As is evident, while C&G expenditures (again, the funding category which reflects the infusion of biotechnology money) have increased considerably, the percentage of expenditures attributable to General Research and AES sources
has declined to a comparable degree. The university therefore becomes more dependent on money from external sources, as research funds from sources internal to the university continue to decline. So, while increases in research expenditures attributable to biotechnology funding have been considerable, levels of funding from the university have held relatively constant, resulting in an overall decline in the percentage such monies contribute to total university research expenditures.

The specific result of these developments for the Core departments has been the creation of a substantial capacity to undertake biotechnology research, and an apparently-dramatic decrease in the ability (at least, in financial terms) to undertake other forms of non-biotechnological research. And, while the increased biotechnology expenditures have offset this general decline in Core expenditures to an extent, they have not been substantive enough to prevent an overall decline in the proportional budgetary level of representation that these departments held in the years prior to the establishment of the biotechnology research effort.

A second means by which changes in the fiscal structures of the Core and Supporting departments becomes evident is in the variety of opinions offered during interviews with departmental representatives. Over the course of these interviews, several of the DEOs attempted to convey the
qualitative impact that these quantitative, monetary shifts have had upon their departments.

For example, a Chairperson in one of the Core research departments states:

The most important aspect of the biotechnology funding is the competition for start-up funds. We have been able to hire good people with the funding, and that definitely affects the structure of the department. It also affects the nature of the people we hire, so it shifts the emphasis of the research they do, and that emphasis has shifted dramatically to biotechnology, to the neglect of other areas of research.

The biotechnology money is necessary but not sufficient because it restricts the scope of research to molecular biology. This may eventually do away with a good program on general biology and just leave us with a narrower expertise on molecular biology.

Concern over the changing internal research structures of the biotechnology departments was echoed by another Department Chair:

There is a 'have' and 'have-not' community that has developed around the biotechnology funding. Even though the funding has not been academic, it has had a significant role in shaping academic departments. It is a loose cannon on our deck... It has shifted departments' emphasis to this kind of money, and contributed to the reorganization of the biological sciences. It also raises questions of the utility of the existing structures of departments.

Another Chairperson of a Core department underscores that, even though this narrowing of research emphases among the biological science program at Iowa State may be a benefit to his own department, the benefit is indeed of a selective nature;

There is a dichotomy between people doing research at the molecular and organismic--or system--levels, and the
funding has tended to favor the molecular emphasis... The funding has had an influence in that it may change the description of the positions we have to fill, in order to gear it towards that funding, but it's not a problem for this department because we fit very well into the molecular biology definition.

In essence then, the interviews conducted with the executive officers of the Core and Supporting biotech departments lend some qualitative credence to the quantitative trends evidenced in the research expenditure data: biotechnology research may be achieving the ascendancy at the expense of other, more broadly-based, areas of research; research demands are significantly altering the traditional status quos of these departments (particularly within the biotech Core), in terms of faculty selection, the impact of these selections upon traditional departmental makeup, and the impact that this shifting makeup will have upon the overall research and instructional emphases of departments.

In addition to the responses received by departmental executives and other departmental representatives, the biotechnology researchers themselves offered somewhat divergent perspectives on the impact that the biotechnology funding has had on their departments. Of the 26 biotechnology faculty hired at Iowa State University prior to the 1991/1992 academic year, 23 were interviewed by the author regarding their opinions on this, and a variety of other issues (three faculty refused to be interviewed). Of those twenty three faculty, most were of the opinion that the biotechnology
project had indeed altered the nature of their departments, but in a positive way. Some of the researchers' comments are as follows:

The biological sciences are developing a more molecular orientation. I think it's very good that this is happening. That's where biology is going... Iowa State had no molecular biologists before 1986. It's really necessary that Iowa State increase in this area if it wants to keep its place in the world... It's easier to get a grant in molecular biology than other areas, and I think other areas get pissed off at molecular biologists because of this.

This university was way behind in molecular biology, and this (the biotechnology funding) has helped to catch it up. This is where the exciting science will happen over the next ten years... My department is not overly focussed on molecular biology.

Biotechnology funds have hired people we would not have otherwise been able to hire. It's something that was needed. It brought molecular biology onto campus.

There are certain areas of science clearly at the forefront. If you want to stay in the lead, you have to keep up. The biotech money has allowed us to do this.

This is just a case of sour grapes. Some scientists are failing to keep up with the science of the '90s, and are not using an integrated approach. If they are not willing to use an integrated approach, they can't get the money. They are using the science of 25 years ago, and they feel that time has passed them by.

A total of ten of the interviewees were of the opinion that structural shifts had occurred in their departments, but that these shifts had improved overall departmental quality.

But, a substantial minority expressed concerns about the long-term impact of the project. The following remarks are indicative of these sentiments:
The impact of the biotech money is a very real danger. The research going on is now so cellular and so molecular that it’s almost too basic to find a direct application. It’s not serving the constituency it’s meant for—the farmers. And it’s expensive in terms of instruments and personnel, and the technical support people they have, such as lab technicians. So the State has had to come up with astronomical salaries and other funds, and that’s bad for morale.

I’m biased. I don’t think it (the biotech project) has had a beneficial effect. This department is breaking up into molecular biology and non-molecular biology... If it becomes a sole emphasis, this is a problem.

Yes, this is redirecting departments. I’m not a gene jockey, I’m a (occupation stated). Some hires have been based on ‘where’s the most money to be gotten,’ rather than ‘what’s the biggest problem.’

This university is not in a net growth situation in terms of faculty. To the extent that biotechnology faculty have been hired, good progress is being made, but there is a lack of seed/start-up money for faculty in other areas. But this is less a problem with the biotechnology program than with not having enough money for other areas.

A total of five interviewees were of the opinion that the biotech monies had impacted their departments, and that this impact was of a negative nature.

A third theme was that the money had not really had an effect on departments:

There have definitely not been these types of changes in our department. The department is hiring on people from diverse areas. The potential for problems is there, but it hasn’t happened yet.

I would really differ with those who say that this is re-directing departments. Molecular biology is just a tool. In the modern world, we must apply all the tools we have when we do an examination of something. The best scientists use all of the tools that are available to them.
A good scientist must be broadly based. If a department just wanted to hire applied people, that would be bad. But the biotech people work at very different levels. They work together to make a good, general department.

I really don’t think it’s a problem. I don’t like to view molecular biology as apart from other science. It’s a tool and an expensive tool so we need funding for it.

Four interviewees were of the opinion that the biotech monies had not substantially altered the emphasis of their departments. Four of the researchers declined to respond to this question.

Thus, while many DEOs and researchers either deny that the biotech funds have had an impact on their departments or believe that the impacts that have occurred are of a positive nature, a substantial minority also proposes that the increased research emphasis may be narrowing the base of research expertise within their departments (due to the perception that the biotechnology faculty possess a more specialized professional focus).

Having said this, it is also important to note that the vast majority of researchers view the biotech ‘seed’ monies as being very successful in helping them to bring in additional external research monies. Nineteen of the 23 interviewees stated that, based on their own personal experiences, the monies had been very successful in this regard;

Yes--the seed monies to faculty have definitely been a success. Most faculty have already more than paid for themselves, and from this point on it’ll only get better.
But I don't know if it's really had any impact on the economy of the state.

Putting together federal and private funds, I've brought in two times as much as I was given for the start-up. Yes, for me it's been very successful.

In my case, I received $150,000 in start-up funds, and brought in about $700,000 in return. I think all of the biotech faculty have received outside funding.

Two researchers stated that they were too new to be able to accurately answer the question, while two others expressed the view that the monies for the most part "provided pork" to older faculty--but that they personally had put start-up monies to good use.

In summary, it is evident that this study has revealed several major findings:

1) C&G expenditures, reflective of external sources of research funding, have experienced dramatic increases in all departmental categorizations over the last seven years. These increases have occurred in terms of raw dollar amounts, as well as the percentage that such funds constitute of overall university research expenditures. Departments throughout the university have thus developed a greatly increased reliance upon external 'contract and grant' funding for their operation.

2) Ironically, the Core departments' overall share of university research expenditures has decreased since the
beginning of the biotech program, indicating a possible administrative overestimation of external returns on the biotech funds.

3) Core departments have also experienced a significantly reduced level of funding for non-biotech related research. While the receipt of the economic development funds has helped to cushion the impact of this decrease, it also increases the likelihood that Core departments may become structurally transformed as a result of these monies. This tendency may lead to a much higher level of financial dependence by Core departments on the biotech research and monies.

4) There is substantial agreement with the perception that some structural transformation has already occurred among departments participating in the biotech research effort. Many feel the structural changes are positive in nature, in that previously-neglected research areas or techniques have become highly developed and sophisticated. However, a substantial minority of DEOs and researchers are critical of the impact that the biotech monies have had on their departments, in terms of the creation of divisions among faculty and an over-concentration on issues related to molecular, rather than organismic, biology.
5) The vast majority of researchers view the economic development 'seed' monies as being very successful at helping them to bring in additional external sources of private and public funds.
DISCUSSION AND CONCLUSIONS

A broad theoretical perspective which sheds considerable light on the implementation and operation of the biotechnology research effort at Iowa State University- and its impacts- is Robert Merton’s notion of ‘manifest’ and ‘latent’ functions (Merton, 1968).

Manifest functions are those outcomes, impacts, or results that are intended to occur as the result of a given action or activity. For example, in the case of the biotechnology research effort at Iowa State University, it was previously discussed that the fundamental manifest function of this effort has been the stimulation of economic development within that state. Another would be the development of a research program in an area that is acknowledged to stand at the ‘cutting edge’ of modern scientific technology.

Latent functions, on the other hand, are those outcomes, impacts, or results that are not intended or expected to occur as the result of a given action or activity. This is not to say that latent functions are of a negative nature; they are unexpected or unplanned, but of a positive nature. For example, according to many of the biotech researchers, the I.S.U. program in molecular biology was underdeveloped prior to the implementation of the biotechnology research effort. While it was not the manifest intent of the biotech appropriations package to resolve this apparent shortcoming at
Iowa State, it has certainly had that effect. Thus, the rectification of some structural inadequacies within the university appears to have been brought about by these appropriations.

Another form of latent outcome however, is the 'dysfunction'--an impact that is both unintended, and of a negative nature. Ironically, it appears that the fundamental dysfunctions that have resulted from the infusion of biotech research dollars at Iowa State have been evidenced among those departments that were the primary recipients of the money. While it is true that these monies have indeed kept the research in these departments on the 'cutting edge,' and contributed substantively to meeting their on-going budgetary and professional needs, it also appears that it may have had a variety of negative results for recipient departments.

A primary problem appears to be that the infusion of biotechnology research monies may have enabled the university administration to cut other, non-biotech research funds to recipient departments (particularly within the Core). Funding for non-biotechnology research and personnel in these departments has thus decreased considerably during the initial three-year implementation of the research effort, as alternate sources of non-biotechnology replacement funding have apparently not been received to any substantial degree (Figure 6, Table 7). So, while departments have benefitted to a
degree from the receipt of the biotech funds, non-biotech funding has decreased dramatically. The concerns voiced by some DEOs and researchers regarding the narrowing focus of Core departments thus appears to have found quantitative grounding in the findings of this study.

A second possible problem is that there may have been an overestimation in the anticipated amount of external funds that would result from the biotech project (at least, in the short term). Two elements of the data lead to this possible conclusion. First, there has been a steady decline in total biotechnology research expenditures during the three-year implementation period (from $2,640,001 in FY 86/87, to $2,300,000 in FY 87/88, to $1,019,720 in FY 88/89—according to Glenda Webber, former Program Assistant with the I.S.U. Biotechnology Council). Second, the Core's proportion of overall academic research expenditures has decreased steadily during the first four years of the program.

In addition to these specific issues, it is useful to examine the relevance these findings hold in terms of the general concerns (university autonomy, financial over-reliance on economic development or private funds, etc.) mentioned earlier in the paper. Clearly, the increased reliance on C&G funds indicates that concerns over corporate influence on, and the flow of information from, university laboratories will grow in importance as the research program develops. It must
be remembered that the seed monies of the biotech program at Iowa State have only just taken root. As research efforts develop and more corporate monies flow in to support these efforts, faculty and administration alike will increasingly have to deal with this issue.

A more immediate concern may be the growing reliance of universities on these tenuous types of funds. Earlier, it was mentioned that a growing number of states have become increasingly skeptical of the link between university research and economic development. Blumenstyk (1992) raises this issue with specific regard for the situation in Iowa;

Some states, including New Jersey and Texas, still strongly support their research programs and have substantially maintained their financing. And some governors, notably Iowa's Terry Branstad, a Republican, are proposing budget increases for economic development based on university research. But examples of disenchantment abound... the states' research-oriented programs are suffering because the payoffs are too distant, and the programs lack techniques to measure their effectiveness in the short term. They also have depended too heavily on support from the governors who created them... (p. 24, 25).

So, while the Governor of Iowa remains a strong ally of this approach to research and development, it is clear that he is a member of a shrinking minority. Universities benefitting from such programs must therefore be wary not only of the market fluctuations related to specialized research efforts, but also of the political fluctuations that could terminate support for such efforts.

On a similar note, it bears mentioning that the
biotechnology program at Iowa State has been closely associated with the 'earmarking' of federal appropriations discussed earlier. In fiscal year 1992 alone, the Department of Agriculture awarded $2,865 million to Iowa State's Midwest Plant Biotechnology Consortium (to be shared with 17 other universities) and $1,953 million, also for an Iowa State biotechnology consortium to be shared with the University of Iowa and the Iowa Department of Economic Development (Cordes et al., 1992). In light of growing political concern with earmarking, a heightened reliance on this type of money may also put those dependent upon it in a precarious financial position.

Another dysfunction that was not discussed earlier involves the division of faculty into opposing camps. Clearly, DEOs and researchers alike have expressed concerns regarding the intra-departmental divisions that have arisen since the beginning of the biotechnology program at Iowa State. The general nature of the antagonism between the biotech 'haves' and 'have-nots' is apparent in the comments listed earlier in the paper. While the impacts of such a division are difficult to quantify, the fact remains that the presence of such antagonisms are not likely to facilitate a positive work environment. DEOs and other administrators must therefore be prepared to dedicate time and effort towards the resolution of such divisions, or run the risk of encountering
a variety of morale-related problems.

Thus, while some degree of success may have been achieved with regard to the manifest functions of I.S.U.'s biotechnology research effort, it is also clear that latent functions, and dysfunctions, have also arisen in the course of this implementation, and must be taken into consideration as the program continues to develop.

In terms of taking a more specific theoretical approach in analyzing these issues, an organizational theory of fundamental relevance in understanding the changing structure of Iowa State University (and other universities involved in similar ventures) focuses on the issue of strategic management and adaptation (Snow et al., 1980; Hrebinjak et al., 1984).

According to the strategic management approach, difficulties in the operational environment of an organization force it to adapt by formulating new strategies for operation. In order to achieve this, organizational managers assess what opportunities and threats are present in the external environment, as well as what strengths and weaknesses exist within the organization itself. Once such assessments are completed, the best fit between external opportunities and internal strengths is determined, and new strategies, missions, and goals are formulated with the intent of preserving optimal organizational operation.

With these new organizational missions and goals
formulated, the organization then moves into the second stage of its adaptive process—strategy implementation (Hrebiniak et al., 1984). Strategy implementation basically involves redistributing organizational resources, and implementing operational changes, among the various elements within the organization; structures, control systems, human resources, technology, and corporate culture (Hrebiniak et al., 1984). The proposed result of this resource redistribution and operational alteration is the attainment of the adaptive pattern of operation deemed desirable in the 'strategy formulation' process.

In the case of Iowa State University, it is clear that severe environmental difficulties faced the university as a result of budget cutbacks from federal and state sources. These cutbacks created the need for an adaptation to maintain organizational operation. An external opportunity then became apparent to the university, in the form of the growing biotechnology industry, and the wide variety of means by which this technology could be applied to the agricultural economy (or corporate culture) in the state of Iowa. The pursuit of this opportunity also matched closely with the internal strengths of the university, in that it possesses a high capacity for technological research, as well as the human resources to undertake such research.

A 'best fit' of internal strengths and external
opportunities thus presented itself to university administrators, and the state government's appropriation of economic development funds allowed this structural adjustment, and organizational adaptation, to occur. A clear process of interaction is thus evident between four of the five organizational elements mentioned above: opportunities present in the (1) corporate culture resulted in an internal reallocation of resources towards (2) technology and (3) human resources, which has had the end result of altering (4) departmental structures within the university.

An important organizational problem with this process relates to the manner in which the biotechnology project is regarded by differing elements among the university. Shanklin et al. (1981) describe how the market share and growth potential of a venture may influence its receptivity by an organization. When a venture involves a new or rapidly-expanding share of a given market (as is the case with biotechnology), it tends to receive a high organizational priority in terms of resource allocation. However, on-going ventures in mature markets (such as non-biotechnological research efforts in the Core and Support departments) tend to be of a lower organizational priority. Often, such efforts are used as 'cash cows' to finance newer ventures, or--if they fail to bring in substantial or comparable profits--may be considered for divestment.
This issue clearly relates to the apparent division that has occurred between many of the faculty in the Core and Support departments. DEOs and researchers alike have expressed concerns regarding the intra-departmental divisions that have arisen since the beginning of the biotechnology program at Iowa State. The general nature of the antagonism between the biotech 'haves' and 'have-nots' is apparent in the comments listed earlier in the paper.

Neilsen (1968) addresses the fact that scarce resources in an environment such as an academic department will tend to throw competing groups into conflict with one another. Factors related to inequity (e.g., unequal rewards, an unequal distribution of power, and the uncertainty that may result from such factors) also serve to exacerbate existing conflicts (Daft, 1988). In the case of the biotechnology project at Iowa State University, such conditions are present in that the new biotechnology faculty receive substantial salaries, 'start-up' funds, and equipment costs from the state, while the older, non-biotechnology faculty members are subject to the same budgetary restraints that apply to other members of the university who are not involved in 'star' ventures.

While the impacts of this division are difficult to quantify, the fact remains that the presence of such antagonisms are not likely to facilitate a positive research or instructional work environment. DEOs and other
administrators must therefore be prepared to dedicate time and effort towards the resolution of such divisions, or run the risk of encountering a growing body of morale-related problems.

A broader organizational problem relates to the previously-mentioned reformulation of strategies, missions, and goals that organizations use to adapt to difficulties in their operational environment. Once again, it must be pointed out that instruction and research are the primary functions of the university. And while it is true that the adaptive processes implemented by universities such as Iowa State have provided financially-strapped departments with the financial means to survive, it may also be narrowing the body of teaching and research expertise within these departments. The university has therefore survived as an organization by adapting to environmental difficulties, but it has been (and is being) transformed by this process—with its primary functions of teaching and research apparently becoming secondary as a result.

It is therefore clear that some of the trends evidenced in the development of I.S.U.’s biotechnology program—whether they be labelled dysfunctional, or the products of adaptation to environmental hardship—may well be of a long-term detriment to the general functioning of the university. If the goals of the biotechnology program therefore work to the
ultimate detriment of Iowa State University (in terms of negatively altering the disciplinary integrity of recipient departments, damaging the capacity for instruction, or altering the nature and direction of research), some degree of debate regarding the full extent and advisability of this course of organizational change should be undertaken.

Therefore, with these concerns in mind, several questions result from the findings of this study. If one of the primary purposes of the university is to create new knowledge, when does a university administration determine that this creation process has become overly influenced, restricted and/or specialized by forces external to the university? At what point do participating departments become altered by external forces to such a degree that they no longer meet the needs they were originally intended to meet? And, if universities are to become increasingly reliant upon external research monies (public or private) for their operation, does this reliance present a danger if the projects and their funding are focused in an area, on an industry, or from a source that is itself in a tenuous state? In other words, is it wise to tie the operation of our public universities this closely to the fluctuations and uncertainties of the marketplace or the ballot box?

With these questions in mind, it must also be said that it is not the intent of this paper to propose that the
biotechnology project at Iowa State University, or other types of economic development projects around the country, are of no worth. Projects of this nature may provide many useful insights and breakthroughs that are of great importance to the long-term health of our economy and society. Indeed, over the course of the interviews conducted with the biotechnology researchers at Iowa State, the author was very impressed both with the quality of the researchers brought into the University, and the potential positive outcomes that their research may eventually create.

However, while the positive aspects of such programs tend to receive much attention and fanfare, their possible detriments often remain unnoticed or ignored. As such programs grow in size and number, we must therefore be wary of the fact that there may be negative—as well as positive—implications for the universities and states that follow this program of economic development. The clear finding of this research is that universities participating in such an effort must be on guard for the structural changes that may result from it. Jacobson (1991) states:

Whatever may happen to the overall economy in the months ahead... it is already clear that higher education will never return to the boom days of the 1980’s. At a minimum... many institutions—both public and private—are headed for a probing reassessment and realignment of what they can or should be, whom they should serve, and how they should attempt to handle all the tasks expected of them. (p. 1).

Universities must therefore come to terms with the nature
of the economic and political changes facing them. It is true that academic research may be seriously impaired by the kinds of budget cutbacks experienced in recent years. Economic development and corporate funds may thus alleviate the pressures created by budgetary restrictions, and allow academic institutions to continue operation in the manner to which many of them have grown accustomed. However, it must also be realized that utilizing universities for purposes such as economic development, or altering the motivation, style, and basic direction of academic research may create long-term patterns within the operation of the university that stray considerably from past methods of operation. Whether such deviations are of a desirable nature should therefore be debated, and the lessons learned through the experiences of universities such as Iowa State should be taken into account by others involved in, or considering involvement in, a similar course of action.
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U.S. Congress, Office of Technology Assessment

Worthy, Ward
Appendix
Non-Biotechnology Departments
(by college and department title)
AG=College of Agriculture
BS=College of Business
DS=College of Design
ED=College of Education
EG=College of Engineering
FCS=College of Family and Consumer Science
AG Economics
AG Ag Education
AG Ag Engineering
AG Animal Ecology
AG Center for Agriculture and Rural Development
AG Family and Consumer Science
AG Food Crops Center
AG Journalism
AG Meat Export Center
AG Meat Irradiation Center
AG Seed Science Center
AG Sociology and Anthropology
AG Special Research and Development
AG Statistics
BS Accounting
BS Finance
BS Management
BS Marketing
BS Transportation and Logistics
DS Architecture
DS Art and Design
DS Community and Regional Planning
DS Landscape Architecture
ED Elementary Education
ED Industrial Education
ED Physical Education
ED Professional Studies
ED Secondary Education
ED Research and Statistics
EG Aerospace Engineering
EG Biomedical Engineering
EG Bridge Engineering Center
EG Civil and Construction Engineering
EG EECPDE
EG Engineering Science and Mechanics
SH=College of Science and Humanities
VM=College of Veterinary Medicine
EG Freshman Engineering
EG Industrial Engineering
EG Material Science and Engineering
EG Mechanical Engineering
EG Nuclear Engineering
FCS Child Development
FCS FCS Education
FCS Family Environment
FCS HRIM
FCS Textiles and Clothing
SH Computer Science
SH Earth Sciences
SH Economics
SH English
SH Foreign Language and Literature
SH History
SH Material Science and Engineering
SH Mathematics
SH Music
SH Philosophy
SH Physics
SH Political Science
SH Psychology
SH Sociology and Anthropology
SH Speech Communication
SH Statistics
VM Biomedical Engineering
PAPER 3. ECONOMIC DEVELOPMENT FUNDING AND THE PUBLIC UNIVERSITY: THE CASE OF BIOTECHNOLOGY AT IOWA STATE UNIVERSITY
Economic Development Funding and the Public University:
The Case of Biotechnology at Iowa State University

by

William J. Kinney
Academic institutions have traditionally been charged with two basic instructional functions in our society; the provision of quality education, and the provision of adequate access to quality education. However, recent restrictions on both federal and state funding for universities may severely hamper their ability to continue performing these functions adequately. A recent issue of the *Chronicle of Higher Education* states:

Many academic leaders perceive that, even after the economy improves, their institutions will confront a major challenge involving tradeoffs between student access and academic quality. At least one of those traditional goals is likely to suffer, officials say, because neither state appropriations nor tuition rates will grow enough to finance them both as substantially as in the past. (Jacobson, 1991, p. 1).

It is proposed that these problematic 'tradeoffs' may take a wide variety of forms, including enrollment caps, cuts in faculty, larger class sizes, fewer course offerings, tuition increases, cuts in student services, and others (Jacobson, 1991). In essence, due to the current fiscal situation around the country, colleges and universities must be prepared to either limit their current accessibility to students, or risk decreasing the quality of instruction that is offered to them.

Apart from instruction, another important function of our institutions of higher education is the creation of knowledge through research. As has been the case with instruction, many
universities have experienced considerable difficulty regarding their financial ability to adequately maintain research efforts. Shulman (1987) addresses how this situation has affected the research abilities of universities;

According to the U.S. Department of Education, federal funding for university research dropped nearly 50 percent between 1980 and 1985, the last year for which the department kept aggregate totals. This trend is especially worrisome since the government still accounts for 70 percent of university research funds. (p. 11).

Clearly, such dramatic cuts in research appropriations have the capacity to substantially alter both the level and nature of research taking place at our nation’s universities.

Why is this growing trend important? It is important because academia benefits in a variety of ways from the research it engages in. One fundamental benefit is that faculty involved in research supposedly enhance instructional quality by being ‘current in their fields,’ and in touch with the more practical applications of a given discipline. Along this same line, it should be noted that faculty are not the only university personnel who engage in research. Graduate and undergraduate students also play an integral part in many faculty research projects, and receive valuable training and experience from their participation in such efforts.

Research is also becoming an increasingly important determinant of professional advancement for university faculty. Shao (1991) states;
In recent years, hiring and tenure decisions have come to be based largely on a professor's ability to generate world-class research. The most important criteria in tenure decisions remain a professor's publications record and reference letters, mostly from other researchers. If you're a mediocre researcher but an excellent teacher, you're unlikely to get tenure. (p. 126).

When faculty reliant upon research for their professional advancement face greatly-reduced financial support from federal and state governments, they must therefore seek out other sources of support to finance their on-going struggle for tenure and promotion.

It is also important to note that the benefits of academic research are by no means limited to academia. Society in general benefits from the wide variety of medical, technical, and social innovations that result from university research. Society could indeed suffer long-term detriments should the research capacities of our academic institutions be further altered or restricted in the current fiscal environment.

It is therefore clear that both of the primary functions of our nation's universities--research and instruction--have been negatively affected by this movement towards fiscal restraint and budgetary cutbacks. In response to this situation, university administrators have been forced to seek alternate sources of replacement funding, in order to maintain previous levels of operation. To achieve this, some have sought to capitalize on another of the basic benefits that
research provides academia—a demand-driven source of fiscal support.

Essentially, the research capacity of an academic institution is a valuable asset, in that it offers a specialized ability to government or industry that may be too expensive or difficult to develop independently. A research contract thus represents an investment by government or industry in the university, since they are paying for a service, and expect an eventual profit or benefit in return for that payment. The commodification of research facilities and personnel can thus result in a much needed source of income for financially-strapped universities, and alleviate some of the strains caused by budgetary cutbacks.

Rule (1988) underscores the special lure that this trend towards 'self-financing' university operations has taken on in recent years;

Since the 1970s, American higher education as a whole has been experiencing a recession, if not a depression. The often indiscriminate expansion of the 1960s quickly gave way to a period where student populations were falling and where government support for research was cut, but where operating expenses rose sharply. Under these circumstances, the idea of making university functions self-financing has taken on a special appeal. (p. 433).

Shulman (1987) concludes that, "...leading universities are turning more and more to corporate support as federal funding decreases." (p. 11).

However, not all forms of 'self-financed' research come from private corporations. While general research and
development funds from the federal government have been cut substantially, 'earmarked' funds continue to flow. Earmarked research awards are made without a competitive review of the merits of a specific research program or project. Earmarked research appropriations to colleges and universities have increased dramatically over the last four years, from only $225 million in FY 1988 to more than $684 million in FY 1992 (Cordes et al., 1992).

Critics accuse earmarking of being 'pork barrel science,' and claim that its dramatic increase over the last four years is linked to both budgetary problems on campus, and a desperate attempt to spur economic recovery:

"...the scope of the practice (earmarking)--and the link between many of the projects and economic development--reflects a severe financial squeeze on higher education and Congressional concerns about the faltering economy. (Cordes et al., 1992, p. 1)."

Earmarking may thus represent a congressional attempt to 'kill two birds with one stone,' by awarding non-competitive research monies to financially-strapped universities, while channeling research awards into economic development projects. State governments have also turned towards investing in university research--particularly technological research--to inspire economic development. Blumenstyk (1992) states that,

"By the end of the decade (the 1980s), nearly every state had created at least one program that provided grants to universities for research with commercial potential. In the 1980's, states sort of discovered technology... (p. 1)."
So, while federal and state appropriations for instructional uses remain largely restricted due to concern over tax and tuition rates, the hope of quick economic payoffs has kept public funds for targeted research (especially technological research) in ample supply. With revenues declining and operating costs increasing, many universities have therefore been forced to 'hire-out' their research abilities to private industries or governmental agencies in order to maintain fiscal solvency. However, while such arrangements may be effective at maintaining a given level of operation for financially-strapped universities and departments, uncertainty exists as to what impact they will have on the style of operation for these entities. It is the intent of this paper to examine this issue.

Biotechnology: A Growing Research Emphasis

A prime example of the manner in which the trend towards research enhancement may impact upon the structure and operation of universities is evident in the effort to develop practical applications for agricultural biotechnology. Due to the promising nature of many preliminary efforts utilizing recombinant DNA technologies (growth hormones, herbicide resistance, disease resistance, reproduction enhancement, and many others), federal and state governments, as well as a variety of private sector interests, have begun to invest
heavily in research focussing upon genetic engineering and agricultural biotechnology. In 1988, for example, the federal government was spending approximately $2.7 billion dollars annually for basic research in biotechnology (Lacy et al., 1988). While only $150 million of that money was earmarked specifically for the development of agricultural biotechnology, the National Research Council’s Board on Agriculture recommended in 1988 that this level of funding be dramatically increased over a very short period of time, to approximately $500 million annually by 1990 (Moses et al., 1988).

State governments have also increased their funding of biotechnology research programs dramatically, and were spending a combined total of approximately $150 million annually on such projects by 1987 (OTA, 1986). And, in comparison to the funding expenditures of the federal government, state governments are spending a considerably greater portion of these funds on the development of agricultural biotechnologies. Prime examples of projects established with these funds are New York State’s Center for Biotechnology in Agriculture at Cornell University and Iowa’s Biotechnology Council at Iowa State University (Lacy et al., 1988). The hoped-for result of such expenditures is most often the establishment of research and development centers linking industry to universities. The anticipated result of
such linkages is the enhancement of economic development.

In addition to research expenditures by federal and state
governments, biotechnology industries have also invested
heavily in university research. In 1984 for example,
biotechnology companies awarded about $120 million in
contracts and grants to universities (Lacy et al., 1988). As
a result of these private investments, a variety of
contractual linkages have also developed between these
companies and individual faculty, departments, and institutes.

The Biotechnology Research Effort at Iowa State University

The state-supported push for biotechnology research in
Iowa's university system was begun in 1985, when the Iowa
Development Commission, at the behest of the Seventy-first
Iowa General Assembly, allocated the sum of $10 million to the
state's public Board of Regents, public universities, and/or
independent colleges. These funds were supplied by revenues
drawn from the State's lottery program. In fiscal year 1985,
the Iowa General Assembly allocated $500,000 to Iowa State
University for the purpose of agricultural biotechnology
research. Additional appropriations were to follow, with the
allocation of $3.75 million in 1986, and $4.25 million each
for fiscal years 1987, 1988, and 1989 (for a total of $17
million in the first three years of the program- Shelley et
al., 1990).
Research projects and products resulting from these appropriations have included the development of new biodegradable plastics, technologies for using cholesterol reductase to produce animal products with lower cholesterol content, and molecular and genetic techniques for the isolation of maize genes to control crop yields (among many others—Worthy, 1989).

As has been previously stated, the fundamental goal of many biotechnology research efforts—and many private and public research efforts in general—is economic development. Iowa State’s program is no exception to this trend, with the explicitly-stated purpose of the General Assembly’s allocation being the enhancement of economic development. That goal has remained intact throughout the implementation of the program, as evidenced by the remarks of Walter Fehr, Chairman of the Oversight Committee of the Iowa State Biotechnology Council:

With regard to the vision for biotechnology at Iowa State University, our ultimate goal is to use the new techniques of molecular biology to enhance the economic welfare of the state. We believe that this will occur through research in three primary areas: (1) the development of new products from our traditional commodities through bioprocessing; (2) improving the efficiency and profitability of crop and livestock production; and (3) development of new products and processes through the genetic modification of plants, animals, and microorganisms. The vision of Iowa State University’s biotechnology program is strongly influenced by the desire to fully utilize the agricultural resources of the state for the welfare of its constituents. (Fehr, 1987).

In order to bolster the effectiveness of this
research-centric approach to economic development, technology transfer networks have also been put in place at I.S.U. These networks are designed to enhance the speed and accessibility with which innovations may be transferred from the lab to local industries desirous of the new biotechnological advancements (e.g., the Eastman Kodak fermentation plant in Cedar Rapids, the Cargill biotechnology facility in Eddyville, and the Ajinomoto Heartland Lysine feed-additive plant, also located in Eddyville–Worthy, 1989).

To date, state policy makers appear content with the results of the biotechnology-grounded economic development plan. Iowa’s General Assembly has extended appropriations for the operation of the Biotechnology Council, and for the entire program of biotechnology research, beyond the initial three-year implementation period. And, in assessing the general effectiveness of the project, the state’s governor, Terry E. Branstad, states,

Iowa is turning biotech breakthroughs into business success stories. Partnerships between private industry and Iowa’s two world-class research universities are resulting in innovative products and economic progress. (Worthy, 1989).

And, Governor Branstad has even proposed budget increases for economic development projects based on university research like that taking place at Iowa State (Blumenstyk, 1992).

The effort to stimulate economic development through the creation of the biotechnology program at I.S.U. therefore
appears to have met with a substantial degree of success. The university system in Iowa has been effectively used as a tool to promote this stimulation, and appears likely to continue the performance of this function for the foreseeable future.

In essence then, the state of Iowa's effort to stimulate economic development through funding university research in the ever-growing field of biotechnology serves as a model by which other states have, and may, attempt to undertake their own research-oriented programs of economic development in the future. As has been previously stated, by the end of the 1980's, nearly every state had at least one program that provided research grants to universities in the hope of spurring this kind of economic development.

However, while state economies may receive a variety of benefits from this utilization of the university system, concerns have been raised regarding the effect that this growing tendency may have upon the universities themselves. Shulman (1987) states;

According to Tufts University science historian Sheldon Krimsky and others, corporate interests threaten to skew research priorities. Krimsky...believes that 'when a university has its own for-profit sector, it means that the institution has to manage according to very different rules.' (p. 11).

Rule (1988) also expresses concern about the trend, and states;

...what will exploitation of such profitable technologies do for--and to--the universities? Even if the more extravagant projections for biotechnology prove
overblown, genetic engineering is bound to be among the biggest money-making activities associated with American universities in the 1990s. How will pursuit of such profits shape institutions supposedly predicated on values quite different from profitability?

...when universities accommodate themselves too thoroughly to the agenda of non-university institutions, they begin to lose the qualities that make universities worth having in the first place. (p. 432, 434).

Growing numbers of analysts are therefore coming to recognize some of the more negative aspects that may accompany the increasing influence of economic development and private funding for research in universities. Leslie Roberts (1983) states;

In the face of declining federal support, universities need money for research and instruments. For industry, such agreements mean access to the scientific expertise that is still centered in the universities and rights to any patentable discoveries. And both sides espouse the societal good arising from rapid technology transfer. There is less agreement, however, on how serious a threat corporate funds pose to the integrity of the university. (page 159).

A primary concern about this possible 'threat' involves the fear that an over-reliance on external, conditional funds (public or private) may diminish the institutional autonomy of universities. This attack on academic autonomy may take a variety of forms.

First, there is concern that the determination of what research is done—and how it is done—will come to be based more upon corporate/economic development needs than academic merit (Caldart, 1983). The following excerpt illustrates the potential for abuse that lies in this increased emphasis on
economic outcomes and corporate needs;

Although it is unusual for corporations to dictate research topics, corporations do discourage certain research. John Longwell, a chemical engineer at M.I.T.'s Energy Lab, thinks pre-grant discussions with potential corporate funders often have such an effect. For example, he says Exxon discourages about 20 percent of the ideas for new projects for the lab. (Shulman, 1987: p. 12).

Economic or business concerns may thus take precedence over academic merit or the public interest, due to the powerful monetary influence that lies behind such concerns. Writing with specific regard to the academic impact of biotechnology research, Lacy et al. (1988) also stress that the growing influence of biotechnology projects in universities and colleges may increase the potential for conflicts of interest or scientific misconduct resulting from the clash between public and private occupational demands.

A second proposed threat to university autonomy is that private interests may attempt to restrict the flow of information regarding research results (Lacy et al., 1988; Caldart, 1983). Where research findings unencumbered by the control of private funds are free to be made public (e.g., through publication in professional journals), research based on private funds may be legally restricted due to the competitive interests of corporate sponsors.

The third concern over university autonomy is that long-term university plans and policies may increasingly be shaped by a growing acquiescence to the needs of private investors
A possible example of such acquiescence could be the alteration of curriculum offerings to more adequately fit the needs of the private sector. Rule (1988) warns that universities must;

...ensure that new teaching ventures funded by, or in response to, lucrative forms of cooperation with outside agencies do not slight the less commercial elements of the liberal arts curriculum. If biotechnology firms want graduates who will serve as lab technicians and researchers, that possibility should hardly be denied to students planning careers. But undergraduates enrolling in programs conceived in response to such possibilities should have the same opportunities, or obligations, to study Plato's Republic or Shakespeare's sonnets offered to any undergraduate. (p. 435).

Apart from the specific question of autonomy, a fourth set of concerns relates to how the status of graduate students and faculty may be altered by their affiliation with profit-oriented research ventures. Rule (1988) states;

How is the university to treat faculty and students associated with such 'profit centers'? As ordinary university citizens, subject to the same rules as others in terms of promotion, tenure, teaching and academic freedom (for faculty) and grading, distribution requirements, fellowships and progress toward degrees (for students)? Can the university act as investment manager toward an organization consisting of its own people, while still maintaining its role as a university? Unable to answer in the affirmative, President Bok of Harvard, at the urging of his faculty, declined in 1980 to institute such a corporate experiment there. (p. 433).

In essence, universities will increasingly be faced with the question of whether the more 'profitable' faculty and graduate students will be held to the same standards and rigors as those of a less business-oriented character.
A fourth set of concerns relates to the impact that the growing emphasis on research may have on the instructional abilities and capacities of academic institutions. Using Stanford University as an example, Maria Shao (1991) describes how research responsibilities tend to take precedence over instructional duties:

Grants represent 28% of the school's research and instruction budget and make stars of the people who win them. Faculty can even 'buy out' of teaching by using grants to pay part of their salaries. Temporary teachers pick up the slack. (p. 126).

Rule (1988) examines this issue not only with regard to the general priority research appears to take over teaching, but also with regard to the way in which shifting research emphases may eventually result in shifting teaching emphases:

One form of responsibility incumbent on universities is to make available to students a wide array of intellectual possibilities. University collaboration with outside agencies may lead to distortion of such possibilities. There is the danger that curricula may be skewed toward the profitable, rather than the profound. Faculty absorbed in lucrative research ventures may be unwilling or unable to help students consider research problems whose merits are strictly intellectual. And all this may be true without conscious intent on the part of faculty. (p. 434).

Lending possible credence to this concern is the fact that curriculum offerings are being altered around the country, both to accommodate the needs of the burgeoning biotechnology industries (in order to provide them with trained personnel), as well as to serve as a vent through which the expertise of the growing number of university
biotechnologists may find curricular release. Each year, growing numbers of universities, colleges, and institutes have incorporated courses in biotechnology into their curricular offerings, and have established undergraduate majors in biotechnological fields (Amatniek, 1983).

The push towards research may therefore affect instructional activities in two basic ways; by diverting from the amount of time or effort faculty are able to put into them, and by altering the nature or body of information that research specialists are willing or able to convey to their students.

A fifth, related concern raised by Lacy et al., (1988), concerns the possibility that the expansion in biotechnology research may result in the neglect of research into other important disciplinary and methodological perspectives. For example, scientists may become so focused on molecular methods of reproduction enhancement that more traditional forms of plant or animal breeding (which may be more cost effective and efficient than biotechnological methods) become underutilized and increasingly unexplored. Thus, economic development or profit-oriented research may not only redirect existing research efforts (the first primary concern), but also re-direct them at the expense of other areas of necessary research (the second fundamental concern).

Another concern specific to biotechnology research is
that this industry is new, and in a very tenuous state. Over three-quarters of biotechnology firms continue to lose money, and, in 1988, at least 24 biotechnology companies filed for bankruptcy—and five of these were publicly supported (Lacy et al., 1988). Also reflecting this uncertainty was a 1989 poll (Kumar, 1989) showing that a majority of executives in biotechnology companies believe that, within ten years, roughly half of the nearly 500 biotechnology companies in the United States will fail, merge, or form cost-sharing alliances. Over-reliance on a research specialization in such a tenuous field (or any one field) may thus present serious dangers to those academic departments (and universities in general) that allow themselves to become structurally or fiscally reliant upon them.

Apart from the perils of the private sector, it appears that universities must also be wary of the publicly-based types of economic development funds that have sponsored projects such as the biotechnology research at Iowa State University. A recent issue of The Chronicle of Higher Education states:

Many states are losing their ardor for economic-development programs based on research grants to universities. In the last few years several states have cut their financing for such research programs and shifted funds to projects designed to help small businesses and create jobs rapidly. More states are considering program cuts this year... state budget constraints, changes in political leadership, and a growing sense that pouring money into university laboratories is not the most efficient or effective way
to help businesses and create jobs, have all put a damper on states’ love affairs with the programs. (Blumenstyk, 1992: p. 1).

Thus, the public sector offers little more security than the private sector in terms of providing stable, long-term financial support for this type of research project.

And, lastly, Lacy et al. (1988) also raise the inter-institutional concern that the biotechnology push may result in an over-concentration of research funds and scientific talent at a small number of universities and colleges.

The overall trend towards ‘self-financing’ university operation through the attainment of private or public economic development research funds may therefore serve to alter the makeup of the modern university by placing a heavier emphasis on research-oriented activities than has been present in the past. Concern may also be warranted as to whether this more market-driven approach to university research may affect the social outcomes of research, and the future capacity for universities to adequately fulfill instructional responsibilities, as well as undertake a broad base of independent, ‘no strings attached’ research activities (among a wide variety of other concerns).

An understanding of how economic development projects impact upon participant universities is thus not only of benefit or relevance to the State of Iowa, but to all states engaged in such programs--and all universities participating
in these programs. The overriding hypotheses that therefore guide this research are: 1) The large infusions of research monies related to the biotechnology project have altered the fiscal and occupational structure of the university, and; 2) this recent alteration in operational emphasis has in turn altered the ability of the university to perform the instructional and research functions it was originally intended to perform.

By examining the situation at Iowa State University, it becomes possible to determine the likely impacts that biotechnology research in particular--and economic development research projects in general--will have upon participant universities. In essence, while biotechnology research represents but one means by which economic development may be attempted by state governments, the processes by which such projects occur, and the outcomes that result from them, may be similar regardless of the specific means at hand (such as biotechnology). The utilization of Iowa State University therefore serves as a case-study by which the specific effects of such efforts may become more fully understood.
METHOD OF STUDY

The first step necessary in assessing the impact of the biotechnology research effort on Iowa State University was to determine: 1) which departments should be considered the primary beneficiaries of the biotechnology funding; 2) which departments benefitted--but to a lesser degree, and; 3) which received no benefits at all.

In order to achieve this determination, a technique known as 'snowball sampling,' or 'chain referral sampling,' was implemented among informed participants in the biotechnology research effort at Iowa State University. Under this method of examination, informed participants are questioned not only with regard to their own knowledge of a given phenomenon, but also regarding their knowledge of other informed participants who may possess information relevant to the phenomenon. Thus, the sample begins with a small set of elements, and ends with a larger set of elements that are in some way connected to the initial set (Encyclopedia of Statistical Sciences, c.1982-1988).

In the Iowa State sample, the initial set of informed participants consisted of the Departmental Executive Officers (DEOs) of two departments acknowledged to be active in the biotechnology research effort (since interviewees were guaranteed confidentiality, names and departments of these interviewees shall not be listed). Interviews (conducted by
phone, or in person, if requested by the interviewee) focussed primarily upon two basic questions: 1) 'Which departments would you describe as being central to the biotechnology research effort at Iowa State University (the 'Core''), and which are involved in the biotechnology research effort, but in a more supportive role (the 'Support' departments), and; 2) 'Could you name three other persons familiar enough with the biotechnology research program to offer informed opinions on this question?' In addition, general comments regarding other aspects of the biotechnology research effort (e.g., effectiveness of its administration, success in the attainment of stated goals, etc.) were welcomed from all interviewees who offered them.

Representatives (for the most part consisting of DEOs) were also contacted for all departments named as participants in either the Core or Supporting groups, but for whom a specific representative was not named in the course of the 'snowballing' process. All participating Core and Support departments were thus represented by at least one spokesperson over the course of the interviews. Ultimately, 22 interviews were conducted with DEOs and other departmental representatives.

As a result of these interviews, twelve departments were determined to operate within the Core of the biotechnology research effort: Biochemistry/Biophysics, Genetics, Zoology,
Horticulture, Agronomy, Chemical Engineering, Chemistry, Plant Pathology, Botany, Veterinary Microbiology and Preventive Medicine, Veterinary Pathology, and Veterinary Anatomy. Nine additional departments were determined to function within the Support group: Microbiology, Animal Science, Food Technology, Food and Nutrition, Forestry, Entomology, Veterinary Physiology and Pharmacology, Veterinary Clinical Sciences, and the Veterinary Diagnostic Laboratory (see Appendix I for departments not included in either the Core or Support categories). Due to this project’s focus on the academic impacts of the biotechnology research project, six non-academic divisions of the University were not included in the analysis (Ames Laboratory, Statistics Laboratory, World Food Institute, Computation Center, Institute for Physical Research and Technology, and Iowa State Water Resources Research Institute).
FINDINGS

With the determination of the Core, Support, and Non-Biotech departments made, it becomes possible to detect what differential impact the large infusions of biotechnology research monies have had upon these groupings. The determination of these impacts is based upon comprehensive records of all university research expenditures for the period beginning Fiscal Year (FY) 1983/1984, and ending FY 1989/1990. Thus, for purposes of comparison, the first three years of this period reflect a time in which no biotechnology funding was received by the university, and the last four years reflect a period of heavy biotechnology funding, as the research effort was implemented (data for this analysis was gathered with the cooperation of Iowa State University's Office of the Associate Provost for Research). These expenditures fall into three separate groupings: General Research, Agricultural Experiment Station (AES), and Contracts and Grants (C&G). The biotechnology expenditures fall within the C&G category.

In comparing these three categories, it is evident that C&G expenditures have experienced a dramatic increase over the seven year period under examination (Figure 1, Table 1). C&G expenditures were at their low in the first year of the study, amounting to only $18.4 million. However, by the end of the period, they had climbed to a peak of approximately $46
Figure 1. Academic research expenditures
190

million—amounting to an increase of approximately 250% in just seven years. AES expenditures also increased during this same period, from about $11.8 million in FY 83/84 to $16.9 million in FY 89/90. General Research expenditures increased slightly for the first six years of the period, and decreased sharply in FY 89/90.

Table 1. Overall academic research expenditures

<table>
<thead>
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<th>Gen. Res.</th>
<th>AES</th>
<th>C&amp;G</th>
<th>Total</th>
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<td>18424670</td>
<td>35764238</td>
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<tr>
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<td>20365497</td>
<td>40096892</td>
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<tr>
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<td>6496972</td>
<td>11432037</td>
<td>21841883</td>
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<tr>
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<td>11547952</td>
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<td>28476857</td>
<td>50864190</td>
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<td>38943678</td>
<td>61261828</td>
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<tr>
<td>89/90</td>
<td>2664204</td>
<td>16931656</td>
<td>46012676</td>
<td>65608536</td>
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</table>

It is also useful to examine these categories in terms of the percentages they constitute of the overall research expenditures for the university (Figure 2, Table 2).

Table 2. Funding categories as a percentage of overall budget

<table>
<thead>
<tr>
<th></th>
<th>Gen. Res.</th>
<th>AES</th>
<th>C&amp;G</th>
<th>Tot.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>100</td>
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<tr>
<td>86/87</td>
<td>16.11</td>
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<td>87/88</td>
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<td>88/89</td>
<td>12.86</td>
<td>23.57</td>
<td>63.57</td>
<td>100</td>
</tr>
<tr>
<td>89/90</td>
<td>4.06</td>
<td>25.81</td>
<td>70.13</td>
<td>100</td>
</tr>
</tbody>
</table>
Figure 2. Funding categories as a percentage of the overall academic budget.
Again, we see a dramatic increase in the percentage share of the C&G category, from a low of 51.5% of all research expenditures in FY 83/84 to a high of 70.1% in FY 89/90. While the dollar amount of AES expenditures increased as described in the previous paragraph, its percentage of overall expenditures actually declined over the seven year period, from 32.9% in FY 83/84 to 25.8% in FY 89/90. The percentage share of General Research expenditures held relatively constant for the first six years of the period, but decreased from approximately 12.8% to 4% in FY 89/90.

Another set of findings arises when these shifts in research expenditures are examined within the context of the aforementioned biotech departmental categorization. Within the Core departments (Figure 3, Table 3), the C&G share of research expenditures rises from a low of approximately 54.2% in FY 83/84 to a high of 66.5% in FY 89/90. AES expenditures hold relatively constant over the seven year period, while General Research expenditures also hold relatively constant except for a sharp decline of about 6.5% in FY 89/90.

In the Support category (Figure 4, Table 4), C&G expenditures experience an even more dramatic increase than is present in the Core category. C&G expenditures steadily increase from a low of 42.5% in FY 85/86, to a peak of approximately 66% in FY 89/90. The AES share of Support
Figure 3. Core funding source analysis
Figure 4. Support funding source analysis
Table 3. Core funding source analysis

<table>
<thead>
<tr>
<th>Year</th>
<th>% from gen. res.</th>
<th>% from AES</th>
<th>% from C&amp;G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/84</td>
<td>17.36</td>
<td>28.48</td>
<td>54.16</td>
<td>100.00</td>
</tr>
<tr>
<td>84/85</td>
<td>16.92</td>
<td>27.34</td>
<td>55.73</td>
<td>99.99</td>
</tr>
<tr>
<td>85/86</td>
<td>15.89</td>
<td>26.22</td>
<td>57.89</td>
<td>100.00</td>
</tr>
<tr>
<td>86/87</td>
<td>16.14</td>
<td>23.54</td>
<td>60.32</td>
<td>100.00</td>
</tr>
<tr>
<td>87/88</td>
<td>15.97</td>
<td>23.91</td>
<td>60.12</td>
<td>100.00</td>
</tr>
<tr>
<td>88/89</td>
<td>14.2</td>
<td>23.4</td>
<td>62.4</td>
<td>100.00</td>
</tr>
<tr>
<td>89/90</td>
<td>7.58</td>
<td>25.92</td>
<td>66.49</td>
<td>99.99</td>
</tr>
</tbody>
</table>

Expenditures experience a dramatic decline during this same period, falling from a peak of 55.54% in FY 85/86 to a low of approximately 33.9% in FY 89/90. General Research expenditures hold relatively constant throughout the period.

Table 4. Support funding source analysis

<table>
<thead>
<tr>
<th>Year</th>
<th>% from gen. res.</th>
<th>% from AES</th>
<th>% from C&amp;G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/84</td>
<td>1.89</td>
<td>55.19</td>
<td>42.91</td>
<td>99.99</td>
</tr>
<tr>
<td>84/85</td>
<td>2.01</td>
<td>54.74</td>
<td>43.24</td>
<td>99.99</td>
</tr>
<tr>
<td>85/86</td>
<td>1.97</td>
<td>55.54</td>
<td>42.49</td>
<td>100.00</td>
</tr>
<tr>
<td>86/87</td>
<td>2</td>
<td>53.06</td>
<td>44.94</td>
<td>100.00</td>
</tr>
<tr>
<td>87/88</td>
<td>1.63</td>
<td>51.99</td>
<td>46.39</td>
<td>100.01</td>
</tr>
<tr>
<td>88/89</td>
<td>1.33</td>
<td>42.84</td>
<td>55.82</td>
<td>99.99</td>
</tr>
<tr>
<td>89/90</td>
<td>0.1</td>
<td>33.89</td>
<td>66.02</td>
<td>100.01</td>
</tr>
</tbody>
</table>

The dramatic increase in C&G funding is also present among the Non-Biotech departments (Figure 5, Table 5). C&G expenditures constitute only 52.6% of the Non-Biotech research expenditures in FY 83/84, but increased to 74.8% by FY 89/90. AES decreases from 28.3% of Non-Biotech research expenditures in FY 83/84, to 17.3% in FY 89/90. General Research also declines dramatically, from 19.1% in FY 83/84 to 3.3% in 89/90.
Figure 5. Non-Biotech funding source analysis
Another perspective on the data may be gained by examining these budget fluctuations from the perspective of the fund type rather than the departmental categories. In other words, rather than looking at what percentage C&G funds constituted of total Core expenditures, it may be useful to examine what percentage the Core constituted of total C&G expenditures.

The significance of these changes may be tested by constructing a comparison of beginning and ending points for each of the three funding categories (Table 6). Such a comparison is useful in that the first year of data (1983/1984) represents a period which saw no biotechnology funding, while the last year of data (1989/1990) reflects a period in which the project was well underway.

In Table 6, the Mean value represents the Mean amount of change (+ or -) in the raw number of dollars expended between FYs 1983/1984 and 1989/1990 for a given funding category. For example, the Mean value of -$44,722 for Core General Research

### Table 5. Non-Biotech funding source analysis

<table>
<thead>
<tr>
<th></th>
<th>% from gen. res.</th>
<th>% from AES</th>
<th>% from C&amp;G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/84</td>
<td>19.14</td>
<td>28.27</td>
<td>52.59</td>
<td>100.00</td>
</tr>
<tr>
<td>84/85</td>
<td>21.39</td>
<td>29.22</td>
<td>49.39</td>
<td>100.00</td>
</tr>
<tr>
<td>85/86</td>
<td>22.11</td>
<td>21.04</td>
<td>56.85</td>
<td>100.00</td>
</tr>
<tr>
<td>86/87</td>
<td>21.14</td>
<td>19.94</td>
<td>58.92</td>
<td>100.00</td>
</tr>
<tr>
<td>87/88</td>
<td>18.46</td>
<td>25.83</td>
<td>55.71</td>
<td>100.00</td>
</tr>
<tr>
<td>88/89</td>
<td>15.71</td>
<td>17.33</td>
<td>66.96</td>
<td>100.00</td>
</tr>
<tr>
<td>89/90</td>
<td>3.28</td>
<td>21.9</td>
<td>74.83</td>
<td>100.01</td>
</tr>
</tbody>
</table>
Funds represents an average decrease of $44,722 of General Research Funds per department within the Core over the seven years of available data. The Pr>F value represents the overall level of significance for these changes. A Scheffe'

Table 6. A comparison of beginning and end-point mean differences by funding category

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen.</td>
<td>Core</td>
<td>-$44,722</td>
<td>.63</td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>-$9,301</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Biotech</td>
<td>-$34,293</td>
<td></td>
</tr>
<tr>
<td>Res.</td>
<td>Core</td>
<td>$540,840</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>$597,381</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Biotech</td>
<td>$213,413</td>
<td></td>
</tr>
<tr>
<td>C&amp;G</td>
<td>Core</td>
<td>$140,843</td>
<td>.18</td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>$122,051</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Biotech</td>
<td>$29,060</td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>Core</td>
<td>$636,961</td>
<td>.03*</td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>$710,131</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Biotech</td>
<td>$208,181</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

Multiple Comparison was then utilized in order to determine the significance of Mean differences for each of the possible pairings of departmental categories: Core-Support (C-S); Core-Non-Biotech (C-N), and; Support-Non-Biotech (S-N) (Agresti and Finlay, 1986).

This general analysis yields statistically significant results only for the overall research expenditures of the university. In this category, it is demonstrated that, over
the seven years of available data, Core research expenditures have increased by an average of $636,961 per department. Support expenditures have increased by an even more dramatic $710,131 per department. Non-Biotech departments have averaged an increase of only $208,181 per department. And, while changes within the other funding categories were not found to be statistically significant (due to high variability), the dramatic increase in C&G funds for the Core and Support Departments is worth noting.

Another important aspect of the data is revealed when the three biotech categorizations are compared with one another, in terms of the percentage that each category constitutes of overall research expenditures (Figure 6, Table 7). These figures show that the percentages have fluctuated considerably during the six year period under examination, with Core expenditures steadily increasing in the three years prior to the appropriation of biotechnology funding, holding relatively

<table>
<thead>
<tr>
<th>Year</th>
<th>Core</th>
<th>Support</th>
<th>Non-Biotech</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/84</td>
<td>37.23</td>
<td>17.12</td>
<td>45.65</td>
<td>100</td>
</tr>
<tr>
<td>84/85</td>
<td>38.31</td>
<td>16.74</td>
<td>44.95</td>
<td>100</td>
</tr>
<tr>
<td>85/86</td>
<td>40.00</td>
<td>16.32</td>
<td>43.68</td>
<td>100</td>
</tr>
<tr>
<td>86/87</td>
<td>40.42</td>
<td>15.72</td>
<td>43.86</td>
<td>100</td>
</tr>
<tr>
<td>87/88</td>
<td>37.65</td>
<td>14.87</td>
<td>47.48</td>
<td>100</td>
</tr>
<tr>
<td>88/89</td>
<td>34.81</td>
<td>16.18</td>
<td>49.01</td>
<td>100</td>
</tr>
<tr>
<td>89/90</td>
<td>33.89</td>
<td>21.24</td>
<td>44.88</td>
<td>100.01</td>
</tr>
</tbody>
</table>
Figure 6. Core, Support, and Non-Biotech percentages of the total budget.
constant in the first year of the program, and declining rapidly in the second, third, and fourth years of the program.

The decline of research expenditures is even more dramatic with the introduction of a 'hypothetical alternative' scenario, in which research expenditures are examined as if biotechnology funding had not been appropriated during the 1986-1989 period (Figure 6--complete information for FY 89/90 appropriations is not yet available). Indication is thus present that general expenditures have not only decreased on the whole for the Core departments during this period, but that non-biotechnological research has undergone a dramatic decline as well, from a high of 40.03% of expenditures in fiscal year 1985/1986, to a low of 34.13% in fiscal year 1987/1988.

Much of this decline then, is attributable to the absence of substantial increases in General Research and AES expenditures during the entire period under examination (Figure 3). As is evident, while C&G expenditures (again, the funding category which reflects the infusion of biotechnology money) have increased considerably, the percentage of expenditures attributable to General Research and AES sources has declined to a comparable degree. The university therefore becomes more dependent on money from external sources, as research funds from sources internal to the university continue to decline.
Thus, while increases in research expenditures attributable to biotechnology funding have been considerable, levels of funding from the university have held relatively constant, resulting in an overall decline in the percentage such monies contribute to total university research expenditures.

The specific result of these developments for the Core departments has been the creation of a substantial capacity to undertake biotechnology research, and an apparently-dramatic decrease in the ability (at least, in financial terms) to undertake other forms of non-biotechnological research. And, while the increased biotechnology expenditures have offset this general decline in Core expenditures to an extent, they have not been substantive enough to prevent an overall decline in the proportional budgetary level of representation that these departments held in the years prior to the establishment of the biotechnology research effort.

A second means by which the impacts of the biotechnology research project become evident is through the quantitative shifts that have occurred in 'full time equivalency' (FTE) job categorizations within the individual departments of the university. Comprehensive listings of these FTE categorizations were collected for the eight-year period from fiscal years 1983/1984 to 1990/1991, and were obtained with
the cooperation of Iowa State University's Office of Institutional Research.

Under this system of employment categorization, occupational positions are grouped into several broad funding categories. Four of these categories are relevant to this study; Instruction, Contracts and Grants (C&G), Research, and Agricultural Experiment Station (AES). Within these broad categorizations, positions are more specifically grouped in terms of employee type; Merit, Professional and Scientific (P&S), Graduate Student, Pre- and Post-Doctoral, Hourly, and Faculty.

In terms of these specific employee types, the raw numbers for the entire university reveal an overall decrease in the number of Faculty over the eight year period under examination (Figure 7). Faculty FTEs were at a peak of 1558.62 positions in fiscal year 1985/1986, but dropped to 1478.12 positions by 1990/1991 (a net loss of approximately 80 positions). On the other hand, the combined number of Graduate Student and Pre/Post Doctoral FTEs rose from a low of 689.62 in 1984/1985 to 864.22 by 1990/1991 (a net gain of just under 175 positions). P&S and Hourly FTEs also rose significantly, with P&S FTEs increasing by approximately 100 positions, and Hourly FTEs increasing by just under 70 positions. Raw numbers of Merit FTEs held relatively constant during the period (Table 8).
Figure 7. FTE totals
Table 8. Raw numbers of university FTEs grouped by occupational category

<table>
<thead>
<tr>
<th></th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merit</td>
<td>477.5</td>
<td>455.8</td>
<td>476.7</td>
<td>490.0</td>
<td>482.8</td>
<td>443.3</td>
<td>467.8</td>
<td>474.8</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>121.0</td>
<td>138.9</td>
<td>142.3</td>
<td>147.0</td>
<td>164.9</td>
<td>177.1</td>
<td>202.1</td>
<td>220.6</td>
</tr>
<tr>
<td>Grad.</td>
<td>629.3</td>
<td>623.2</td>
<td>674.1</td>
<td>721.0</td>
<td>724.7</td>
<td>731.2</td>
<td>747.3</td>
<td>765.7</td>
</tr>
<tr>
<td>P/Doc</td>
<td>67.2</td>
<td>66.4</td>
<td>65.7</td>
<td>77.3</td>
<td>89.5</td>
<td>96.4</td>
<td>117.0</td>
<td>98.6</td>
</tr>
<tr>
<td>Hourly</td>
<td>148.0</td>
<td>165.0</td>
<td>166.3</td>
<td>182.0</td>
<td>191.2</td>
<td>224.5</td>
<td>222.6</td>
<td>216.2</td>
</tr>
<tr>
<td>Fac.</td>
<td>1506.0</td>
<td>1529.0</td>
<td>1559.0</td>
<td>1546.0</td>
<td>1489.0</td>
<td>1464.9</td>
<td>1496.4</td>
<td>1478.1</td>
</tr>
<tr>
<td>Total</td>
<td>2949.0</td>
<td>2979.0</td>
<td>3084.0</td>
<td>3163.0</td>
<td>3142.0</td>
<td>3137.3</td>
<td>3253.2</td>
<td>3253.9</td>
</tr>
<tr>
<td>Grad &amp;</td>
<td>696.5</td>
<td>689.6</td>
<td>739.9</td>
<td>798.0</td>
<td>814.2</td>
<td>827.6</td>
<td>864.3</td>
<td>864.2</td>
</tr>
</tbody>
</table>

These data thus reveal that Faculty FTEs—as a percentage of total FTEs—have declined considerably during the eight year period under study (Figure 8). Faculty positions constituted 51.34% of FTEs in FY 1984/1985, but steadily declined to represent 45.42% of FTEs by FY 1990/1991 (a drop of about 6 percentage points). Conversely, Graduate Students and Pre/Post Doctoral employees constituted only 23.15% of total FTEs in 1984/1985, but rose to represent 26.56% of overall FTEs by FY 1990/1991 (a gain of about 3.5 percentage points). Hourly and P&S employees also increased slightly in comparison to the other occupational categories (approximately 1.5 and 2.5 percentage points, respectively), while Merit employees decreased slightly (approximately 1.5 points—Table 9).
Figure 8. Percentage of FTE totals by occupational category.
While these findings indicate the occurrence of some alteration in the overall occupational structure of the University, an even more important set of findings occurs when these fluctuations are examined in the context of the aforementioned biotech departmental categorization. Within the Core (Figure 9), Graduate Student and Pre/Post Doctoral FTEs increased by approximately five percent (in relation to total Core FTEs), from a low of 27.87% in fiscal year 1984/1985 (the year prior to the implementation of the biotechnology research effort) to 32.87% in 1990/1991. During this same period, the Faculty share of FTEs declined by 6.76 percentage points, from a high of 34.12% in 1984/1985, to a low of 27.36% in 1989/1990. The P&S share of FTEs also rose by approximately three percent during this period, while the Merit share declined by approximately 3.5 percentage points over the eight years under study. The Hourly share of Core FTEs increased slightly (Table 10).
Figure 9. Core FTE breakdown
Table 10. Occupational categories as a percentage of total Core FTEs

<table>
<thead>
<tr>
<th>Core FTE Breakdown</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad</td>
<td>24.7%</td>
<td>22.97%</td>
<td>25.27%</td>
<td>26.77%</td>
<td>27.15%</td>
<td>26.04%</td>
<td>25.45%</td>
<td>25.81%</td>
</tr>
<tr>
<td>Pdoc</td>
<td>5.16%</td>
<td>4.9%</td>
<td>5.04%</td>
<td>5.83%</td>
<td>6.1%</td>
<td>6.61%</td>
<td>7.69%</td>
<td>7.06%</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>6.85%</td>
<td>8.0%</td>
<td>8.14%</td>
<td>8.14%</td>
<td>9.11%</td>
<td>10.61%</td>
<td>11.32%</td>
<td>11.14%</td>
</tr>
<tr>
<td>Merit</td>
<td>18.65%</td>
<td>18.85%</td>
<td>18.11%</td>
<td>18.07%</td>
<td>17.52%</td>
<td>14.95%</td>
<td>14.83%</td>
<td>15.01%</td>
</tr>
<tr>
<td>Hourly</td>
<td>11.75%</td>
<td>11.15%</td>
<td>11.53%</td>
<td>11.19%</td>
<td>11.67%</td>
<td>14.33%</td>
<td>13.35%</td>
<td>12.92%</td>
</tr>
<tr>
<td>Fac.</td>
<td>32.88%</td>
<td>34.12%</td>
<td>31.89%</td>
<td>10.0%</td>
<td>28.44%</td>
<td>27.46%</td>
<td>27.36%</td>
<td>28.05%</td>
</tr>
<tr>
<td>Total</td>
<td>99.99%</td>
<td>99.99%</td>
<td>99.98%</td>
<td>100.0%</td>
<td>99.99%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>99.99%</td>
</tr>
</tbody>
</table>

A similar trend is evident within the Support departments (Figure 10). Graduate Student and Pre/Post Doctoral FTEs rise steadily from a low of 16.62% in 1985/1986 (the first year of the biotechnology funding) to 22.51% in 1990/1991. During this same period, Faculty FTEs steadily decreased from a high of 37.74% in 1985/1986 to a low of 32.61% in 1990/1991. Other occupational categories remain relatively stable (Table 11).

This same trend occurs in departments unrelated to the biotechnology research effort, though to a lesser degree (Figure 11). The comparative level of Graduate Student and Pre/Post Doctoral FTEs rise by a total of 2.89 percentage points during the eight-year period, Faculty FTEs fall by 5.54 percentage points, and other categories hold relatively constant (Table 12).

The significance of these changes may be tested by constructing a comparison of beginning and ending points for each of the six occupational groupings (Table 13). As was the
Figure 10. Support FTE breakdown
Figure 11. Non-Biotech FTE breakdown
Table 11. Occupational categories as a percentage of total Support FTEs

<table>
<thead>
<tr>
<th>Support FTE Breakdown</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad.</td>
<td>15.78</td>
<td>15.18</td>
<td>14.54</td>
<td>14.47</td>
<td>15.85</td>
<td>17.19</td>
<td>17.29</td>
<td>18.53</td>
</tr>
<tr>
<td>Pdoc.</td>
<td>3.68</td>
<td>3.41</td>
<td>2.08</td>
<td>2.38</td>
<td>2.79</td>
<td>2.02</td>
<td>3.93</td>
<td>3.98</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>7.68</td>
<td>7.18</td>
<td>7.86</td>
<td>7.85</td>
<td>7.7</td>
<td>7.99</td>
<td>7.93</td>
<td>9.02</td>
</tr>
<tr>
<td>Hourly</td>
<td>6.38</td>
<td>8.43</td>
<td>9.02</td>
<td>9.57</td>
<td>10.5</td>
<td>10.73</td>
<td>9.17</td>
<td>7.61</td>
</tr>
<tr>
<td>FAC</td>
<td>37.65</td>
<td>37.03</td>
<td>37.74</td>
<td>36.99</td>
<td>36.61</td>
<td>34.82</td>
<td>34.14</td>
<td>32.61</td>
</tr>
<tr>
<td>Tot.</td>
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<td>99.99</td>
<td>99.99</td>
<td>100.00</td>
<td>99.98</td>
<td>99.99</td>
<td>100.00</td>
<td>99.99</td>
</tr>
</tbody>
</table>

Table 12. Occupational categories as a percentage of total Non-Biotech FTEs

<table>
<thead>
<tr>
<th>Non-biotech FTE Breakdown</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad.</td>
<td>21.09</td>
<td>21.29</td>
<td>21.85</td>
<td>22.73</td>
<td>22.71</td>
<td>23.29</td>
<td>23.13</td>
<td>23.68</td>
</tr>
<tr>
<td>Pdoc.</td>
<td>0.89</td>
<td>1.0</td>
<td>1.04</td>
<td>1.11</td>
<td>1.53</td>
<td>1.74</td>
<td>1.8</td>
<td>1.19</td>
</tr>
<tr>
<td>P&amp;S</td>
<td>2.34</td>
<td>2.92</td>
<td>2.65</td>
<td>2.7</td>
<td>3.21</td>
<td>3.04</td>
<td>3.68</td>
<td>4.53</td>
</tr>
<tr>
<td>Merit</td>
<td>12.79</td>
<td>11.33</td>
<td>11.99</td>
<td>12.03</td>
<td>12.43</td>
<td>11.25</td>
<td>11.4</td>
<td>11.48</td>
</tr>
<tr>
<td>Hourly</td>
<td>2.12</td>
<td>2.88</td>
<td>2.34</td>
<td>2.91</td>
<td>2.99</td>
<td>3.35</td>
<td>3.59</td>
<td>3.89</td>
</tr>
<tr>
<td>FAC</td>
<td>60.76</td>
<td>60.58</td>
<td>60.14</td>
<td>58.52</td>
<td>57.12</td>
<td>57.32</td>
<td>56.4</td>
<td>55.22</td>
</tr>
<tr>
<td>Totals</td>
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<td>100.00</td>
<td>100.01</td>
<td>100.00</td>
<td>99.99</td>
<td>99.99</td>
<td>100.00</td>
<td>99.99</td>
</tr>
<tr>
<td>Grads &amp; Pdocs</td>
<td>21.98</td>
<td>22.29</td>
<td>22.89</td>
<td>23.84</td>
<td>24.24</td>
<td>25.03</td>
<td>24.93</td>
<td>24.87</td>
</tr>
</tbody>
</table>

case with the budgetary information, such a comparison is useful in that the first year of data (1983/1984) represents a period which saw no biotechnology funding, while the last year of data (1990/1991) reflects a period in which the project was well underway.
### Table 13. A comparison of beginning and end-point mean differences between Core, Support, and Non-Biotechnology occupational categories

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
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<tr>
<td>Graduate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>2.47</td>
<td>.47</td>
<td>C-S  .99</td>
</tr>
<tr>
<td>Support</td>
<td>1.48</td>
<td></td>
<td>C-N  1.4</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>1.06</td>
<td></td>
<td>S-N  .42</td>
</tr>
<tr>
<td>Pre/Post Doc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>1.95</td>
<td>.02*</td>
<td>C-S  1.64</td>
</tr>
<tr>
<td>Support</td>
<td>.31</td>
<td></td>
<td>C-N  1.64*</td>
</tr>
<tr>
<td>Non-Biotech</td>
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<td></td>
<td>S-N  .00</td>
</tr>
<tr>
<td>Faculty</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-.62</td>
<td>.86</td>
<td>C-S  -1.44</td>
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<tr>
<td>Support</td>
<td>.81</td>
<td></td>
<td>C-N  -.46</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>-.16</td>
<td></td>
<td>S-N  .97</td>
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<tr>
<td>P&amp;S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>3.25</td>
<td>.0008*</td>
<td>C-S  2.71*</td>
</tr>
<tr>
<td>Support</td>
<td>.54</td>
<td></td>
<td>C-N  2.78*</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>.47</td>
<td></td>
<td>S-N  .07</td>
</tr>
<tr>
<td>Merit</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
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<td>.30</td>
<td>C-S  -1.93</td>
</tr>
<tr>
<td>Support</td>
<td>1.15</td>
<td></td>
<td>C-N  -.59</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>-.18</td>
<td></td>
<td>S-N  1.34</td>
</tr>
<tr>
<td>Hourly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>1.93</td>
<td>.11</td>
<td>C-S  .49</td>
</tr>
<tr>
<td>Support</td>
<td>1.45</td>
<td></td>
<td>C-N  1.42</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>.51</td>
<td></td>
<td>S-N  .93</td>
</tr>
</tbody>
</table>

*p < .05

In Table 13, the Mean value represents the Mean amount of change (+ or -) in the raw number of FTEs between FYs 1983/1984 and 1990/1991 for a given occupational category. For example, the Mean value of 2.47 for Core Graduate Students represents an average increase of 2.47 FTEs per department within the Core over the eight years of available data. The Pr>F value represents the overall level of significance for these changes. A Scheffe' Multiple Comparison was then utilized in order to determine the significance of Mean
differences for each of the possible pairings of departmental categories: Core-Support (C-S); Core-Non-Biotech (C-N), and; Support-Non-Biotech (S-N) (Agresti and Finlay, 1986).

This general analysis yields statistically significant results for two of the occupational categories. Pre/Post Doctoral employees have increased substantially within the Core Departments (1.95 per department), and moderately within the Support and Non-Biotech departments (.31 and .3, respectively). Also, P&S employees have increased dramatically within the Core (3.25 FTEs per department, on average), and moderately within the Support and Non-Biotech groupings (.54 and .47, respectively). And, while the other analyses of occupational groupings were not found to be statistically significant (due to high variability) some of the findings do tend to lend credence to the trends described in Figures 9-11 (e.g., a substantial increase in Graduate Students per department, with the increase most pronounced among the Core, and least pronounced among the Non-Biotechnology Departments).

Beyond this basic analysis of the five occupational groupings, it is important to remember that each of these groupings may be further analyzed in terms of the occupational activity (Instruction, C&G, Research, and AES) that a given employee is engaged in. For example, it is clear that the Graduate Student share of FTEs has increased in all three of
the biotech categorizations. However, it is still unclear whether these graduate students are engaged in instructional or research activities. The data on professional activity is therefore useful in answering this question, and reveals some interesting trends.

As has been stated, within the Core categorization, the relative level of Graduate Student and Pre/Post Doctoral FTEs has increased by five percent, Faculty have decreased by nearly seven percent, and other occupational categories have held fairly constant. These trends appear even more dramatic in light of the occupational activity data. Among Core Graduate Students (Figure 12), there was a 20% drop in the proportional share of Graduate Students involved in Instructional activity between fiscal years 1984/1985 and 1989/1990. This same period saw an increase of over 26% in C&G related-activities for graduate students (a category reflective of the biotechnology funding). Research and Ag Experiment Station activities both declined slightly (Table 14).
Figure 12. Graduate FTE categorization (Core)
Table 14. Funding category as a percentage of all Core occupational titles

<table>
<thead>
<tr>
<th>Core Categorizations</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merit Work Categorization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instr.</td>
<td>37.11</td>
<td>40.12</td>
<td>36.6</td>
<td>35.05</td>
<td>37.02</td>
<td>38.68</td>
<td>40.6</td>
<td>42.35</td>
</tr>
<tr>
<td>C&amp;G</td>
<td>21.82</td>
<td>19.19</td>
<td>22.71</td>
<td>27.45</td>
<td>27.5</td>
<td>21.14</td>
<td>20.01</td>
<td>8.47</td>
</tr>
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<td>16.94</td>
<td>16.17</td>
<td>15.56</td>
<td>15.0</td>
<td>16.02</td>
<td>15.06</td>
<td>14.8</td>
</tr>
<tr>
<td>AES</td>
<td>23.93</td>
<td>23.75</td>
<td>24.52</td>
<td>21.94</td>
<td>20.48</td>
<td>24.16</td>
<td>24.33</td>
<td>24.38</td>
</tr>
<tr>
<td>P&amp;S Work Categorization</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instr.</td>
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<td>39.16</td>
<td>38.21</td>
<td>35.22</td>
<td>31.08</td>
<td>26.59</td>
<td>27.63</td>
<td>28.82</td>
</tr>
<tr>
<td>C&amp;G</td>
<td>25.26</td>
<td>24.82</td>
<td>27.82</td>
<td>32.11</td>
<td>34.55</td>
<td>46.1</td>
<td>45.19</td>
<td>41.01</td>
</tr>
<tr>
<td>AES</td>
<td>19.79</td>
<td>20.97</td>
<td>18.35</td>
<td>16.86</td>
<td>20.56</td>
<td>19.26</td>
<td>20.06</td>
<td>23.93</td>
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<td>Graduate Student Work Categorization</td>
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</tr>
<tr>
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<td>55.28</td>
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<td>41.06</td>
<td>41.1</td>
<td>37.2</td>
<td>34.98</td>
<td>36.97</td>
</tr>
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<td>C&amp;G</td>
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<td>26.05</td>
<td>40.23</td>
<td>45.5</td>
<td>47.19</td>
<td>49.82</td>
<td>52.36</td>
<td>49.18</td>
</tr>
<tr>
<td>Res.</td>
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<td>4.82</td>
<td>3.74</td>
<td>4.41</td>
<td>3.59</td>
<td>3.86</td>
<td>2.65</td>
<td>2.11</td>
</tr>
<tr>
<td>AES</td>
<td>15.36</td>
<td>13.85</td>
<td>11.8</td>
<td>9.03</td>
<td>8.12</td>
<td>9.12</td>
<td>10.00</td>
<td>11.74</td>
</tr>
<tr>
<td>Pre and Post Doctoral Work Categorization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instr.</td>
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<td>4.32</td>
<td>2.03</td>
<td>3.62</td>
<td>1.54</td>
<td>1.83</td>
</tr>
<tr>
<td>C&amp;G</td>
<td>78.11</td>
<td>86.31</td>
<td>69.66</td>
<td>75.13</td>
<td>88.71</td>
<td>93.67</td>
<td>94.59</td>
<td>92.93</td>
</tr>
<tr>
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<td>1.44</td>
<td>5.94</td>
<td>9.19</td>
<td>3.55</td>
<td>1.36</td>
<td>1.16</td>
<td>1.32</td>
</tr>
<tr>
<td>AES</td>
<td>13.33</td>
<td>12.25</td>
<td>19.13</td>
<td>11.35</td>
<td>5.71</td>
<td>1.36</td>
<td>2.7</td>
<td>3.92</td>
</tr>
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<td>Hourly Work Categorization</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>7.16</td>
<td>6.89</td>
<td>5.26</td>
<td>4.36</td>
<td>2.22</td>
<td>5.18</td>
<td>5.01</td>
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<td>C&amp;G</td>
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<td>71.65</td>
<td>77.98</td>
<td>78.94</td>
<td>89.8</td>
<td>94.96</td>
<td>83.49</td>
<td>87.22</td>
</tr>
<tr>
<td>Res.</td>
<td>3.91</td>
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<td>2.71</td>
<td>2.95</td>
<td>0</td>
<td>0</td>
<td>1.98</td>
<td>1.92</td>
</tr>
<tr>
<td>AES</td>
<td>14.15</td>
<td>19.09</td>
<td>12.42</td>
<td>12.84</td>
<td>5.84</td>
<td>2.82</td>
<td>9.35</td>
<td>5.85</td>
</tr>
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<td>Faculty Work Categorization</td>
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<td></td>
</tr>
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<td>65.0</td>
<td>64.1</td>
<td>62.47</td>
<td>72.52</td>
<td>72.19</td>
</tr>
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<td>C&amp;G</td>
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<td>4.27</td>
<td>4.91</td>
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<td>3.97</td>
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<td>Res.</td>
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<td>11.31</td>
<td>9.13</td>
<td>11.54</td>
<td>10.94</td>
<td>10.9</td>
<td>3.7</td>
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<td>20.86</td>
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<td>21.72</td>
<td>20.6</td>
<td>20.66</td>
</tr>
<tr>
<td>Totals</td>
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<td>84/85</td>
<td>85/86</td>
<td>86/87</td>
<td>87/88</td>
<td>88/89</td>
<td>89/90</td>
<td>90/91</td>
</tr>
</tbody>
</table>
Similar trends are also present in the Support departments (Figure 13), which reveal a proportional increase of 31% in C&G related activities, and a 19.5% drop in Instructional activities. AES positions also declined by approximately 11.5% (there were no Graduate Student Research FTEs in the Support group—Table 15).

A similar trend, though less pronounced, was found among the Non-Biotech departments. The Instructional share of FTEs for Graduate Students declined by approximately 16.7% in comparison to the other occupational categories, while the C&G portion of FTEs increased by approximately 17.7%. AES and Research FTEs held relatively constant (Table 16).

By again using a comparison of Means (on beginning and ending points for the eight years of data), test of significance, and Scheffe' Multiple Comparison test, the statistical significance of these trends may be analyzed (Table 17).

This analysis reveals that C&G positions among Graduate Students have experienced a substantial and statistically-significant increase of 4.37 positions per department in the Core. The Support and Non-Biotech groupings also experience substantive increases, but not to the degree found in the Core. While the other funding category analyses failed to reveal significant findings, they clearly indicate trends similar to those revealed in Figures 12 and 13 (slight
Figure 13. Graduate FTE categorization (Support)
Table 15. Funding category as a percentage of all Support occupational titles

<table>
<thead>
<tr>
<th>SUPPORT CATEGORIZATIONS</th>
<th>Merit Work Categorization</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
<th>88/89</th>
<th>89/90</th>
<th>90/91</th>
</tr>
</thead>
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<td>Instr.</td>
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<td>31.09</td>
<td>30.76</td>
<td>28.84</td>
<td>29.57</td>
<td>32.03</td>
<td>29.37</td>
<td>33.28</td>
<td>33.68</td>
</tr>
<tr>
<td>Res.</td>
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<td>12.89</td>
<td>11.57</td>
<td>10.72</td>
<td>9.81</td>
<td>8.76</td>
<td>9.31</td>
<td>8.66</td>
</tr>
<tr>
<td>AES</td>
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<td>39.37</td>
<td>35.84</td>
<td>36.6</td>
<td>37.06</td>
<td>37.75</td>
<td>38.81</td>
</tr>
<tr>
<td>P&amp;S Work Categorization</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instr.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C&amp;G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Res.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduate Student Work Categorization</td>
<td></td>
<td>83/84</td>
<td>84/85</td>
<td>85/86</td>
<td>86/87</td>
<td>87/88</td>
<td>88/89</td>
<td>89/90</td>
<td>90/91</td>
</tr>
<tr>
<td>Instr.</td>
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<td>25.3</td>
<td>27.09</td>
<td>21.0</td>
<td>16.4</td>
<td>14.03</td>
<td>13.2</td>
</tr>
<tr>
<td>C&amp;G</td>
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<td>22.51</td>
<td>29.49</td>
<td>31.3</td>
<td>35.79</td>
<td>48.3</td>
<td>55.28</td>
<td>53.59</td>
<td>53.61</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>AES</td>
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Table 16. Funding category as a percentage of all Non-Biotech occupational titles

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Table 17. A comparison of beginning and end-point mean differences for Graduate Student FTEs, grouped by funding category

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<th>Support</th>
<th>Non-Biotech</th>
<th>C&amp;G</th>
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<td>.29</td>
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<td>.12</td>
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<td></td>
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<td>-0.18</td>
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</table>

*p < .05

decreases in Research and AES FTEs, and substantial decreases in Instructional FTEs that are most pronounced among the Core, and least pronounced among Non-Biotech departments).

Among Pre and Post Doctoral employees, all three departmental categorizations have experienced dramatic increases in the relative level of C&G-funded positions. Within the Core, 92.93% of Pre/Post Doctoral positions were funded through Contracts and Grants in FY 1990/1991 (up from 78.11% in FY 1983/1984--Table 14). Among Support Departments, 70.23% of Pre/Post Doctoral positions were based on C&G funds (up from 32.2% in FY 1983/1984--Table 15). And, within departments unrelated to the biotechnology project, 86.1% of Pre/Post Doctoral positions were C&G-related (up from 58.42% in FY 1983/1984--Table 16).
Table 18. A comparison of beginning and end-point mean differences for Pre/Post Doctoral FTEs, grouped by funding category

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
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</table>

*p < .05

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for Pre/Post Doctoral employees is contained in Table 18.

The substantial increase in C&G related Pre/Post Doctoral positions among the Core is found to be statistically significant, as is the decrease in Research positions for Support and Core Departments.

Regarding Faculty, it is important to note that their activities are somewhat more difficult to classify than Graduate Students. For the Faculty, the difference between Instructional and Research FTEs is largely a matter of bookkeeping--it is not reflective of a true distinction between teaching and research activities. With this in mind, it is evident that the official data record of Faculty
occupational activities has changed little over the eight year period under examination for any of the three departmental categorizations. The percentage levels hold relatively constant for each of the four occupational activity categories, for each of the three departmental categorizations.

With this in mind then, it does appear that increases in the level of Instructional activity occur within the Core and Non-Biotech groupings during the last two years of data. However, these increases are largely offset by decreases within the Research category. These alterations were caused by a recategorization of state funding expenditures by the Office of Institutional Research, and did not reflect a true switch from Research to Instruction (according to Iowa State University’s Office of Institutional Research).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test for Faculty failed to reflect significant findings in any funding category.

It is also important to note that, while the Merit, P&S, and Hourly percentages of FTEs failed to reflect the level of overall change present within the Faculty and Graduate Student-Pre/Post Doctoral categories (as evidenced in Figures 10-12), substantial alterations occurred within these categories. For example, among Professional and Scientific employees in the Core, a proportional drop of approximately
15% in Instructional activity occurred between fiscal years 1983/1984 to 1988/1989 (Table 14). The proportion of C&G positions for P&S employees rose by about 21% during the same period. Among P&S employees in the Support group, Instructional FTEs dropped by about four percentage points over the eight years of the data, while C&G increased by about 14 percentage points (Research and AES FTEs also declined during the period--Table 15). The Non-Biotech P&S category similarly experienced an eight percentage point drop in Instruction, and a 27% increase in C&G FTEs (Table 16).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for P&S employees is contained in Table 19.

Table 19 indicates a statistically-significant increase in C&G positions among P&S employees, with this increase most pronounced among the Core.

Among Hourly employees, the same trend towards an increase in C&G, and a decrease in Instruction, was present among all three of the departmental categories. The trend was most pronounced among the Support group, and least pronounced among the Non-Biotech group (Tables 14-16).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for Hourly employees is contained in Table 20. Once again, the increase in C&G positions is found
Table 19. A comparison of beginning and end-point mean differences for P&S FTEs, grouped by funding category

<table>
<thead>
<tr>
<th>Funding Category</th>
<th>Instructional Core</th>
<th>Instructional Support</th>
<th>Instructional Non-Biotech</th>
<th>C&amp;G Core</th>
<th>C&amp;G Support</th>
<th>C&amp;G Non-Biotech</th>
<th>Research Core</th>
<th>Research Support</th>
<th>Research Non-Biotech</th>
<th>AES Core</th>
<th>AES Support</th>
<th>AES Non-Biotech</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Pr&gt;F</td>
<td>Scheffe</td>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>Pr&gt;F</td>
<td></td>
<td>Mean</td>
<td>Pr&gt;F</td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>0.42</td>
<td>.67</td>
<td>C-S 0.28</td>
<td>C-N 0.19</td>
<td>S-N -0.09</td>
<td></td>
<td>2.18</td>
<td>.0003*</td>
<td>C-S 1.95*</td>
<td>0.22</td>
<td>C-N 1.9*</td>
<td>S-N 0.05</td>
</tr>
<tr>
<td>Support</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.01</td>
<td>.77</td>
<td>C-S -0.02</td>
<td>0.01</td>
<td>C-N 0.03</td>
<td>S-N 0.04</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.04</td>
<td></td>
<td></td>
<td>0.01</td>
<td>C-N 0.67</td>
<td>S-N 0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.66</td>
<td>.24</td>
<td></td>
<td>0.16</td>
<td>C-N 0.67</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

...to be statistically significant, and most pronounced among the Core.

Of the six occupational groupings (Faculty, Graduate Students, Merit, P&S, and Hourly), the only one to experience an overall increase in Instructional activity was Merit. Within the Core category, the Instructional share of Merit FTEs increased by approximately five percent. The Instructional share of Support and Non-Biotech Merit FTEs also increased slightly (Tables 14-16). A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, failed to reveal statistically-significant findings among the Merit employees.

An overall analysis of the occupational activity data thus reveals that, within the Core, Instructional FTEs reached...
Table 20. A comparison of beginning and end-point mean differences for Hourly FTEs, grouped by funding category

<table>
<thead>
<tr>
<th>Funding Category</th>
<th>Core</th>
<th>Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>0.07</td>
<td>.09</td>
<td>C-S</td>
<td>0.4</td>
</tr>
<tr>
<td>Support</td>
<td>-0.34</td>
<td></td>
<td>C-N</td>
<td>0.0</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.07</td>
<td></td>
<td>S-N</td>
<td>-0.41</td>
</tr>
<tr>
<td>C&amp;G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>2.05</td>
<td>.02*</td>
<td>C-S</td>
<td>0.29</td>
</tr>
<tr>
<td>Support</td>
<td>1.76</td>
<td></td>
<td>C-N</td>
<td>1.65</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.39</td>
<td></td>
<td>S-N</td>
<td>1.36</td>
</tr>
<tr>
<td>Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-0.08</td>
<td>.16</td>
<td>C-S</td>
<td>-0.08</td>
</tr>
<tr>
<td>Support</td>
<td>0.00</td>
<td></td>
<td>C-N</td>
<td>-0.07</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.00</td>
<td></td>
<td>S-N</td>
<td>0.00</td>
</tr>
<tr>
<td>AES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-0.11</td>
<td>.58</td>
<td>C-S</td>
<td>-0.13</td>
</tr>
<tr>
<td>Support</td>
<td>0.01</td>
<td></td>
<td>C-N</td>
<td>-0.16</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.05</td>
<td></td>
<td>S-N</td>
<td>-0.03</td>
</tr>
</tbody>
</table>

*p < .05

their peak during the 1984/1985 Fiscal Year, when they constituted 46.18% of the Core’s total occupational activity (Figure 14). This percentage dropped to a low of 36% in Fiscal Year 1988/1989, but has since rebounded to just over 40%. Contract and Grant activity has risen dramatically, from a low of 24.97% of Core FTEs in 1984/1985 to 38.98% in 1990/1991. The Research and Ag Experiment Station shares of Core FTEs have declined by approximately 5% and 3%, respectively (Table 14).

In the Support category (Figure 15), Instructional activity has also dropped significantly, from a peak of 44.85% of Support FTEs in 1983/1984, to a low of 36.95% in 1990/1991. The Research and Ag Experiment Station share of Support FTEs has declined by approximately 2-3 percentage points each.
Figure 14. Core FTE totals in terms of fund category percentages
Figure 15. Support FTE totals in terms of fund category percentages
Contract and Grant FTEs have approximately doubled, from a low of 13.6% of Support FTEs in 1983/1984 to 26.61% in 1990/1991 (Table 15).

And, once again, the same trend towards a decline in Instruction and an increase in Contract and Grant activity is present in the Non-Biotech category, but to a lesser degree (Figure 16). The Instructional share of Non-Biotech FTEs dropped from a high of 81% in 1983/1984, to 75.81% in 1990/1991 (a decline of just over 6 percentage points). Contract and Grant activity has risen from a low of 7.79% of Non-Biotech FTEs in 1983/1984, to a peak of 15.81% in 1990/1991 (an increase of just over 8 percentage points). The percentage of Research FTEs has declined by about 3 percentage points over the eight year period, while the Ag Experiment Station has held relatively constant (Table 16).

A comparison of Means, test of significance, and Scheffe' Multiple Comparison test, for all employees is contained in Table 21. This Table reflects a statistically significant increase of 10.41 C&G positions per department within the Core.

Several basic conclusions are thus apparent from this data on occupational type and activity. First, the infusion of economic development research funds has had a considerable impact upon recipient departments, as displayed by the marked
Figure 16. Non-Biotech FTE totals in terms of fund category percentages
Table 21. A comparison of beginning and end-point mean differences for Total FTEs, grouped by funding category

<table>
<thead>
<tr>
<th>Funding Category</th>
<th>Core</th>
<th>Mean</th>
<th>Pr&gt;F</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructional</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>.18</td>
<td>.97</td>
<td>C-S</td>
<td>0.43</td>
</tr>
<tr>
<td>Support</td>
<td>-0.25</td>
<td></td>
<td>C-N</td>
<td>-0.18</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.36</td>
<td></td>
<td>S-N</td>
<td>-0.61</td>
</tr>
<tr>
<td><strong>C&amp;G</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>10.41</td>
<td>.004*</td>
<td>C-S</td>
<td>4.48</td>
</tr>
<tr>
<td>Support</td>
<td>5.93</td>
<td></td>
<td>C-N</td>
<td>7.74*</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>2.66</td>
<td></td>
<td>S-N</td>
<td>3.26</td>
</tr>
<tr>
<td><strong>Research</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-1.86</td>
<td>.25</td>
<td>C-S</td>
<td>-1.46</td>
</tr>
<tr>
<td>Support</td>
<td>-0.4</td>
<td></td>
<td>C-N</td>
<td>-0.82</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>-1.03</td>
<td></td>
<td>S-N</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>AES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>-0.53</td>
<td>.82</td>
<td>C-S</td>
<td>-0.99</td>
</tr>
<tr>
<td>Support</td>
<td>0.46</td>
<td></td>
<td>C-N</td>
<td>-0.54</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>0.01</td>
<td></td>
<td>S-N</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>8.2</td>
<td>.19</td>
<td>C-S</td>
<td>2.47</td>
</tr>
<tr>
<td>Support</td>
<td>5.73</td>
<td></td>
<td>C-N</td>
<td>6.20</td>
</tr>
<tr>
<td>Non-Biotech</td>
<td>2.00</td>
<td></td>
<td>S-N</td>
<td>3.73</td>
</tr>
</tbody>
</table>

*p < .05

increase in research-oriented occupations (such as Graduate Students and Pre/Post Docs), and decreases in numbers of Faculty. Second, the funds have also had profound impacts in terms of the occupational activities that employees are engaged in. The trend has been towards a substantial increase in Contract and Grant-related research activities, and away from Instructional activities. And, third, while these trends have occurred on a university-wide basis, they have tended to be most pronounced among the Core and Support recipients of the economic development project funds, and least pronounced among departments unrelated to these funds. These figures constitute quantitative evidence of an increase in the level of C&G research, and relative decline in the level of
Instruction, taking place at Iowa State University.

A third means by which changes in the internal structures of the Core and Supporting departments becomes evident is in the variety of opinions offered by departmental representatives during the interviews mentioned earlier (under METHOD OF STUDY). Over the course of these interviews, several of the DEOs attempted to convey the qualitative impact that these quantitative shifts have had on their departments.

For example, a Chairperson in one of the Core research departments states;

The most important aspect of the biotechnology funding is the competition for start-up funds. We have been able to hire good people with the funding, and that definitely affects the structure of the department. It also affects the nature of the people we hire, so it shifts the emphasis of the research they do, and that emphasis has shifted dramatically to biotechnology, to the neglect of other areas of research.

The biotechnology money is necessary but not sufficient because it restricts the scope of research to molecular biology. This may eventually do away with a good program on general biology and just leave us with a narrower expertise on molecular biology.

Concern over the changing internal research structures of the biotechnology departments was echoed by another Department Chair;

There is a 'have' and 'have-not' community that has developed around the biotechnology funding. Even though the funding has not been academic, it has had a significant role in shaping academic departments. It is a loose cannon on our deck... It has shifted departments' emphasis to this kind of money, and contributed to the reorganization of the biological sciences. It also raises questions of the utility of the existing structures of departments.
Another Chairperson of a Core department underscores that, even though this narrowing of research emphases among the biological science program at Iowa State may be beneficial to his own department, the benefit is indeed of a selective nature:

There is a dichotomy between people doing research at the molecular and organismic--or system--levels, and the funding has tended to favor the molecular emphasis. The funding has had an influence in that it may change the description of the positions we have to fill, in order to gear it towards that funding, but it's not a problem for this department because we fit very well into the molecular biology definition.

In essence, then, some of the interviews conducted with the executive officers of the Core and Supporting biotech departments lend qualitative credence to the quantitative trends evidenced in the FTE data: 1) biotechnology research may be achieving the ascendancy at the expense of other, more broadly-based, areas of research, and; 2) funding-driven research demands are significantly altering the traditional status quos of these departments (particularly within the biotech Core), through targeted faculty selection and resulting shifts in instructional and research emphases.

In addition to the responses received by departmental executives and other departmental representatives, the biotechnology researchers themselves offered somewhat divergent perspectives on the impact that the biotechnology funding has had on their departments. Of the 26 biotechnology faculty hired at Iowa State University prior to the 1991-1992
academic year, 23 were interviewed by the authors regarding their opinions on this, and a variety of other issues (three faculty refused to be interviewed). Of those twenty three faculty, most were of the opinion that the biotechnology project had indeed altered the nature of their departments, but in a positive way. Some of the researchers’ comments are as follows:

There has been a shift in the emphasis of my department, but I see this shift as a good thing. Molecular biology is a tool that can be used to study whatever subject you want. It was not established at I.S.U. prior to 1986.

This opposition to molecular biology and biotechnology is an antiquated idea. They (referring to Non-Biotech faculty) think molecular biology is not chemistry, but you can’t compete without it. No reputable university neglects hiring people who know how to do molecular biology. I came here because of people doing molecular biology and they can help my research.

Biotech is a technique--not a research goal. It’s a tool to look at the same questions we’ve always looked at, like the electron microscope. It’s the questions we’re asking that are important--not the ways we look at them. They’re just afraid of change (referring to those expressing concerns over the possible shift in departments’ emphases).

These concerns are not at all valid. This place had no molecular biology before this. It’s only enhanced things.

The biological sciences are developing a more molecular orientation. I think it’s very good that this is happening. That’s where biology is going... Iowa State had no molecular biologists before 1986. It’s really necessary that Iowa State increase in this area if it wants to keep its place in the world... It’s easier to get a grant in molecular biology than other areas, and I think other areas get pissed off at molecular biologists because of this.

This university was way behind in molecular biology,
and this (the biotechnology funding) has helped to catch it up. This is where the exciting science will happen over the next ten years... My department is not overly focussed on molecular biology.

Biotechnology funds have hired people we would not have otherwise been able to hire. It’s something that was needed. It brought molecular biology onto campus.

There are certain areas of science clearly at the forefront. If you want to stay in the lead, you have to keep up. The biotech money has allowed us to do this.

This is just a case of sour grapes. Some scientists are failing to keep up with the science of the ’90s, and are not using an integrated approach. If they are not willing to use an integrated approach, they can’t get the money. They are using the science of 25 years ago, and they feel that time has passed them by.

A total of ten of the interviewees were of the opinion that structural shifts had occurred in their departments, but that these shifts had improved overall departmental quality.

But, a substantial minority expressed concerns about the long-term impact of the project. The following remarks are indicative of these sentiments:

The impact of the biotech money is a very real danger. The research going on is now so cellular and so molecular that it’s almost too basic to find a direct application. It’s not serving the constituency it’s meant for—the farmers. And it’s expensive in terms of instruments and personnel, and the technical support people they have, such as lab technicians. So the State has had to come up with astronomical salaries and other funds, and that’s bad for morale.

I’m biased. I don’t think it (the biotech project) has had a beneficial effect. This department is breaking up into molecular biology and non-molecular biology... If it becomes a sole emphasis, this is a problem.

Yes, this is redirecting departments. I’m not a gene jockey, I’m a (occupation stated). Some hires have been based on ‘where’s the most money to be gotten,’
This university is not in a net growth situation in terms of faculty. To the extent that biotechnology faculty have been hired, good progress is being made, but there is a lack of seed/start-up money for faculty in other areas. But this is less a problem with the biotechnology program than with not having enough money for other areas.

A total of five interviewees were of the opinion that the biotech monies had impacted their departments, and that this impact was of a negative nature.

A third theme was that the money had not really had an effect on departments:

There have definitely not been these types of changes in our department. The department is hiring on people from diverse areas. The potential for problems is there, but it hasn’t happened yet.

I would really differ with those who say that this is re-directing departments. Molecular biology is just a tool. In the modern world, we must apply all the tools we have when we do an examination of something. The best scientists use all of the tools that are available to them.

A good scientist must be broadly based. If a department just wanted to hire applied people, that would be bad. But the biotech people work at very different levels. They work together to make a good, general department.

I really don’t think it’s a problem. I don’t like to view molecular biology as apart from other science. It’s a tool and an expensive tool so we need funding for it.

A total of four interviewees were of the opinion that the structural impact of the biotech funding was not redirecting...
the emphasis of departments.

Four of the researchers declined to respond to this question.

Thus, while many DEOs and researchers either deny that the biotech funds have had an impact on their departments or believe that the impacts that have occurred are of a positive nature, a substantial minority also proposes that the increased research emphasis may be narrowing the base of instructional and research expertise within their departments.

Another important finding of the interviews with the biotech faculty regards the level of teaching activity in which they are personally involved. Interviewees were asked, 'In percentage terms, how is your job balanced between teaching and research activities?' On average, the biotech faculty spend 72.44% of their time on research activities, while only 27.56% of productive time was devoted to teaching activity.

Having said this, it is also important to note that the vast majority of researchers view the biotech 'seed' monies as being very successful in helping them to bring in additional external research monies. Nineteen of the 23 interviewees stated that, based on their own personal experiences, the monies had been very successful in this regard;

Yes--the seed monies to faculty have definitely been a success. Most faculty have already more than paid for themselves, and from this point on it'll only get better. But I don't know if it's really had any impact on the
economy of the state.

Putting together federal and private funds, I've brought in two times as much as I was given for the start-up. Yes, for me it's been very successful.

In my case, I received $150,000 in start-up funds, and brought in about $700,000 in return. I think all of the biotech faculty have received outside funding.

Two researchers stated that they were too new to be able to accurately answer the question, while two others expressed the view that the monies for the most part "provided pork" to older faculty--but that they personally had put start-up monies to good use.

In summary then, it is evident that this study has revealed several major findings:

1) C&G expenditures, reflective of external sources of research funding, have experienced dramatic increases in all departmental categorizations over the last seven years. These increases have occurred in terms of raw dollar amounts, as well as the percentage that such funds constitute of overall university research expenditures. Departments throughout the university have thus developed a greatly increased reliance upon external 'contract and grant' funding for their operation.

2) Ironically, the Core departments' overall share of university research expenditures has decreased since the
beginning of the biotech program, indicating a possible administrative overestimation of external returns on the biotech funds.

3) Core departments have also experienced a significantly reduced level of funding for non-biotech related research. While the receipt of the economic development funds has helped to cushion the impact of this decrease, it also increases the likelihood that Core departments may become structurally transformed as a result of these monies. This tendency may lead to a much higher level of financial dependence by Core departments on the biotech research and monies.

4) The economic development biotechnology project has had a significant impact on recipient departments, primarily in terms of bringing about a marked proportional increase in research-oriented occupations (such as graduate students), and a proportional decrease in faculty.

5) The occupational activities of employees have also been substantially altered, as evidenced by a dramatic increase in Contract and Grant-related research activities, and a decrease in Instructional activities.

6) These trends have tended to be the most pronounced among
those departments heavily involved in the economic development biotechnology project, and least pronounced among non-participant departments.

7) There is substantial agreement with the perception that some structural transformation has already occurred among departments participating in the biotech research effort. Many feel the structural changes are positive in nature, in that previously-neglected research areas or techniques have become highly developed and sophisticated. However, a substantial minority of DEOs and researchers are critical of the impact that the biotech monies have had on their departments, in terms of the creation of divisions among faculty and an over-concentration on issues related to molecular, rather than organismic, biology.

8) While both the raw number and proportional percentage of faculty has decreased during the period under examination, a growing proportion of remaining faculty are very research-oriented. Students may therefore be negatively affected not only in terms of having fewer faculty in departments, but also in terms of having this shrinking number of faculty be far more focussed on research than teaching.

9) The vast majority of researchers view the economic
development 'seed' monies as being very successful at helping them to bring in additional external sources of private and public funds.
DISCUSSION AND CONCLUSIONS

There are several theoretical levels from which these issues may be analyzed. On a broad level, a primary theoretical perspective which sheds considerable light on the implementation, operation, and impact of the biotechnology research effort at Iowa State University is Robert Merton's concept of 'manifest' and 'latent' functions (Merton, 1968).

Manifest functions are those outcomes, impacts, or results that are intended to occur as the result of a given action or activity. For example, in the case of the biotechnology research effort at Iowa State University, it was previously discussed that the fundamental manifest function of this effort has been the stimulation of economic development within that State. Another manifest function would be the development of a research program in an area that is acknowledged to stand at the 'cutting edge' of modern scientific technology.

Latent functions, on the other hand, are those outcomes, impacts, or results that are not intended or expected to occur as the result of a given action or activity. This is not to say that latent functions are of a negative nature; they are unexpected or unplanned, but positive in nature. For example, according to many of the biotech researchers, the I.S.U. program in molecular biology was underdeveloped prior to the implementation of the biotechnology research effort. While it
was not the manifest intent of the biotech appropriations package to resolve this apparent shortcoming at the university, it has certainly had that effect. Thus, the rectification of some structural inadequacies within the University appears to have been brought about by these appropriations.

Another form of latent outcome however, is the 'dysfunction'--an impact that is both unintended, and of a negative nature. Ironically, it appears that the fundamental dysfunctions that have resulted from the infusion of biotech research dollars at Iowa State have been evidenced among those departments that were the primary recipients of the money. While it is true that these monies have indeed kept the research in these departments on the 'cutting edge,' and contributed substantively to meeting their on-going budgetary and professional needs, it also appears that it may have had a variety of negative results for recipient departments.

A primary problem appears to be that the infusion of biotechnology research monies may have enabled the university administration to cut other, non-biotech research funds to recipient departments (particularly within the Core). Funding for non-biotechnology research and personnel in these departments has thus decreased considerably during the initial three-year implementation of the research effort, as alternate sources of non-biotechnology replacement funding have
apparently not been received to any substantial degree (Figure 6, Table 6). So, while departments have benefitted to a degree from the receipt of the biotech funds, non-biotech funding has decreased dramatically. The concerns voiced by some DEOs and researchers regarding the narrowing focus of Core departments thus appears to have found quantitative grounding in the findings of this study.

A second possible problem is that there may have been an overestimation in the anticipated amount of external funds that would result from the biotech project (at least, in the short term). Two elements of the data lead to this possible conclusion. First, there has been a steady decline in total biotechnology research expenditures during the three-year implementation period (from $2,640,001 in FY 86/87, to $2,300,000 in FY 87/88, to $1,019,720 in FY 88/89--according to Glenda Webber, former Program Assistant with the I.S.U. Biotechnology Council). Second, the Core's proportion of overall academic research expenditures has decreased steadily during the first four years of the program. This may be attributable to a re-direction of general university funds away from the Core departments, due to their receipt of the biotechnology funds.

Another dysfunction involves the division of faculty into opposing camps. Clearly, DEOs and researchers alike have expressed concerns regarding the intra-departmental divisions
that have arisen since the beginning of the biotechnology program at Iowa State. The general nature of the antagonism between the biotech 'haves' and 'have-nots' is apparent in the comments listed earlier in the paper. While the impacts of such a division are difficult to quantify, the fact remains that the presence of such antagonisms are not likely to facilitate a positive research or instructional work environment. DEOs and other administrators must therefore be prepared to dedicate time and effort towards the resolution of such divisions, or run the risk of encountering a variety of morale-related problems.

In addition to these issues, it is useful to examine the relevance these findings hold in terms of the general concerns (university autonomy, financial over-reliance on economic development or private funds, etc.) mentioned earlier in the paper (under The Biotechnology Research Effort at Iowa State University). One of these concerns was that the increased trend towards university reliance on external research funds would redirect research efforts towards economic or corporate need, rather than academic merit. Clearly, the striking growth of C&G positions within the university (in nearly all occupational categories) lends quantitative credence to concerns over the growing influence of external funds. Some of the interviews with DEOs and the biotech researchers also lend qualitative credence to the concern (e.g., "Some hires
have been based on 'where's the most money to be gotten,' rather than 'what's the biggest problem').

Another concern was that private interests may attempt to restrict the flow of information regarding research results. Clearly, the increased reliance on C&G funds indicates that concerns over corporate influence on, and the flow of information from, university laboratories will grow in importance as the research program develops. It must be remembered that the seed monies of the biotech program at Iowa State have only just taken root. As research efforts develop and more corporate monies flow in to support these efforts, faculty and administration alike will increasingly have to deal with this issue.

A third concern of a more immediate nature may be the growing reliance of universities on these tenuous types of funds. Earlier, it was mentioned that a growing number of states have become increasingly skeptical of the link between university research and economic development. Blumenstyk (1992) raises this issue with specific regard for the situation in Iowa;

Some states, including New Jersey and Texas, still strongly support their research programs and have substantially maintained their financing. And some governors, notably Iowa's Terry Branstad, a Republican, are proposing budget increases for economic development based on university research. But examples of disenchantment abound... the states' research-oriented programs are suffering because the payoffs are too distant, and the programs lack techniques to measure their effectiveness in the short term. They also have
depended too heavily on support from the governors who created them... (p. 24, 25).

So, while the Governor of Iowa remains a strong ally of this approach to research and development, it is clear that he is a member of a shrinking minority. Universities benefitting from such programs must therefore be wary not only of the market fluctuations related to specialized research efforts, but also of the political fluctuations that could terminate support for such efforts.

On a similar note, it bears mentioning that the biotechnology program at Iowa State has been closely associated with the 'earmarking' of federal appropriations discussed earlier. In fiscal year 1992 alone, the Department of Agriculture awarded $2.865 million to Iowa State's Midwest Plant Biotechnology Consortium (to be shared with 17 other universities) and $1.953 million, also for an Iowa State biotechnology consortium to be shared with the University of Iowa and the Iowa Department of Economic Development (Cordes et al., 1992). In light of growing political concern with earmarking, a heightened reliance on this type of money may also put those dependent upon it in a precarious financial position.

A fourth concern was that the shift in research emphases created by this type of project may negatively affect instructional activities by diverting from the amount of time faculty are able to put into them, and by altering the nature
of information that research specialists are able to convey to their students. The marked decrease in Instructional FTEs and increase in C&G FTEs clearly indicates that research activities have taken a numerical priority over instructional activities. Interviews with researchers also tend to verify the validity of this concern, with the average biotech researcher putting approximately three times as much time and/or effort into research as is devoted to teaching. It would also stand to reason that the biotechnology faculty are not only more research-oriented than their predecessors, but also more specialized in terms of the level of instructional expertise they possess.

A fifth concern dealt with how the status of graduate students and faculty may be altered by their affiliation with profit-oriented research ventures. While this study did not focus specific attention on this issue, it is clear that it will be of growing importance as more research projects (and the dollars that accompany them) become concentrated in the hands of fewer and fewer faculty. Also, as the number of graduate students involved in these types of projects grow dramatically (as has been the case at Iowa State University), the question of their current status within the university setting will also grow in importance.

And, lastly, a sixth concern was that the economic development or profit-oriented research may be taking place at
the expense of other areas of necessary research. Concern over these issues appears to be somewhat vindicated by the findings of this study, due to the feeling expressed by some DEOs and researchers regarding the priority the biotechnology project (with its specializing influence) may be taking over the traditional needs of a broadly-based program of scientific research and education. And, in quantitative terms, it is clear that when overall Faculty FTEs are decreasing, but a growing share of the remaining FTEs are allotted towards the biotech project, Core Faculty FTE levels are being maintained at the expense of more traditional, generalist positions.

Thus, while some degree of success may have been achieved with regard to the manifest functions of I.S.U.'s biotechnology research effort (such as keeping the research in these departments on the 'cutting edge,' and contributing substantially to their on-going budgetary and professional needs), it is also clear that latent functions, and dysfunctions, have also arisen in the course of this implementation, and must be taken into consideration as the program continues to develop.

In terms of taking a more specific theoretical approach in analyzing these issues, an organizational theory of fundamental relevance in understanding the changing structure of Iowa State University (and other universities involved in similar ventures) focuses on the issue of strategic management
According to the strategic management approach, difficulties in the operational environment of an organization force it to adapt by formulating new strategies for operation. In order to achieve this, organizational managers assess what opportunities and threats are present in the external environment, as well as what strengths and weaknesses exist within the organization itself. Once such assessments are completed, the best fit between external opportunities and internal strengths is determined, and new strategies, missions, and goals are formulated with the intent of preserving optimal organizational operation.

With these new organizational missions and goals formulated, the organization then moves into the second stage of its adaptive process—strategy implementation (Hrebiniak et al., 1984). Strategy implementation basically involves redistributing organizational resources, and implementing operational changes, among the various elements within the organization; structures, control systems, human resources, technology, and corporate culture (Hrebiniak et al., 1984). The proposed result of this resource redistribution and operational alteration is the attainment of the adaptive pattern of operation deemed desirable in the 'strategy formulation' process.

In the case of Iowa State University, it is clear that
severe environmental difficulties faced the university as a result of budget cutbacks from federal and state sources. These cutbacks created the need for an adaptation to maintain organizational operation. An external opportunity then became apparent to the university, in the form of the growing biotechnology industry, and the wide variety of means by which this technology could be applied to the agricultural economy (or corporate culture) in the state of Iowa. The pursuit of this opportunity also matched closely with the internal strengths of the university, in that it possesses a high capacity for technological research, as well as the human resources to undertake such research.

A 'best fit' of internal strengths and external opportunities thus presented itself to university administrators, and the state government's appropriation of economic development funds allowed this structural adjustment, and organizational adaptation, to occur. A clear process of interaction is thus evident between four of the five organizational elements mentioned above: opportunities present in the (1) corporate culture resulted in an internal reallocation of resources towards (2) technology and (3) human resources, which has had the end result of altering (4) departmental structures within the university.

An important organizational problem with this process relates to the manner in which the biotechnology project is
regarded by differing elements among the university. Shanklin et al. (1981) describe how the market share and growth potential of a venture may influence its receptivity by an organization. When a venture involves a new or rapidly-expanding share of a given market (as is the case with biotechnology), it tends to receive a high organizational priority in terms of resource allocation. However, on-going ventures in mature markets (such as non-biotechnological research efforts in the Core and Support departments) tend to be of a lower organizational priority. Often, such efforts are used as 'cash cows' to finance newer ventures; or--if they fail to bring in substantial or comparable profits--may be considered for divestment.

This issue clearly relates to the apparent division that has occurred between many of the faculty in the Core and Support departments. DEOs and researchers alike have expressed concerns regarding the intra-departmental divisions that have arisen since the beginning of the biotechnology program at Iowa State. The general nature of the antagonism between the biotech 'haves' and 'have-nots' is apparent in the comments listed earlier in the paper.

Neilsen (1968) addresses the fact that scarce resources in an environment such as an academic department will tend to throw competing groups into conflict with one another. Factors related to inequity (e.g., unequal rewards, an unequal
distribution of power, and the uncertainty that may result from such factors) also serve to exacerbate existing conflicts (Daft, 1988). In the case of the biotechnology project at Iowa State University, such conditions are present in that the new biotechnology faculty receive substantial salaries, 'start-up' funds, and equipment costs from the state, while the older, non-biotechnology faculty members are subject to the same budgetary restraints that apply to other members of the university who are not involved in 'star' ventures.

While the impacts of this division are difficult to quantify, the fact remains that the presence of such antagonisms are not likely to facilitate a positive research or instructional work environment. DEOs and other administrators must therefore be prepared to dedicate time and effort towards the resolution of such divisions, or run the risk of encountering a growing body of morale-related problems.

A broader organizational problem relates to the previously-mentioned reformulation of strategies, missions, and goals that organizations use to adapt to difficulties in their operational environment. Once again, it must be pointed out that instruction and research are the primary functions of the university. And while it is true that the adaptive processes implemented by universities such as Iowa State have provided financially-strapped departments with the financial
means to survive, it may also be narrowing the body of teaching and research expertise within these departments. The university has therefore survived as an organization by adapting to environmental difficulties, but it has been (and is being) transformed by this process—with its primary functions of teaching and research apparently becoming secondary as a result.

It is therefore clear that some of the trends evidenced in the development of I.S.U.'s biotechnology program—whether they be labelled dysfunctional, or the products of adaptation to environmental hardship—may well be of a long-term detriment to the general functioning of the university. If the goals of the biotechnology program therefore work to the ultimate detriment of Iowa State University (in terms of negatively altering the disciplinary integrity of recipient departments, damaging the capacity for instruction, or altering the nature and direction of research), some degree of debate regarding the full extent and advisability of this course of organizational change should be undertaken.

Therefore, with these concerns in mind, several questions result from the findings of this study:

1) If one of the primary purposes of the university is to create new knowledge, when does a university administration determine that this creation process has become overly influenced, restricted and/or specialized by conditional
funding sources external to the university (such as private investments or economic development appropriations)?

2) At what point does the nature of research become so focussed on one area of specialization that it actually serves as a detriment to the general character of a department?

3) At what point do participating departments become altered by external forces to such a degree that they no longer meet the needs they were originally intended to meet?

4) If another primary purpose of the university is to impart the knowledge it creates, at what point does the emphasis on research impinge upon the ability to convey knowledge in terms of numbers of personnel allocated to perform that function?

5) Along this same line, at what point does the emphasis upon research impinge on the ability or motivation displayed by such personnel to carry out the instructional function effectively?

6) And, if universities are to become increasingly reliant upon external research monies (public or private) for their operation, does this reliance present a danger if the projects and their funding are focussed in an area, on an industry, or from a source that is itself in a tenuous state? In other words, is it wise to tie the operation of our public universities this closely to the fluctuations and uncertainties of the marketplace or the ballot box?

These are all questions that Iowa State University will
eventually have to answer as a result of its involvement in the biotechnology research program, and the overall shift towards research.

With these questions in mind, it must also be said that it is not the intent of this paper to propose that the biotechnology project at Iowa State University, or other types of economic development projects around the country, are of no worth. Projects of this nature may provide many useful insights and breakthroughs that are of great importance to the long-term health of our economy and society. Indeed, over the course of the interviews conducted with the biotechnology researchers at Iowa State, the author was very impressed both with the quality of the researchers brought into the university, and the potential positive impact that their research may eventually have.

However, while the positive aspects of such programs tend to receive much attention and fanfare, their possible detriments often remain unnoticed or ignored. As such programs grow in size and number, we must therefore be wary of the fact that there may be negative—as well as positive—implications for the universities and states that follow this program of economic development. The clear finding of this research is that universities participating in such an effort must be on guard for the structural changes that may result from it. As Jacobson (1991) states:
Whatever may happen to the overall economy in the months ahead... it is already clear that higher education will never return to the boom days of the 1980's. At a minimum... many institutions--both public and private--are headed for a probing reassessment and realignment of what they can or should be, whom they should serve, and how they should attempt to handle all the tasks expected of them. (p. 1).

Universities must therefore come to terms with the nature of the economic and political changes facing them. It is true that academic activities--namely, teaching and research--may be seriously impaired by the kinds of budget cutbacks experienced in recent years. Research-oriented, economic development funds may thus alleviate the pressures created by budgetary restrictions, and allow academic institutions to continue operation in the manner to which many of them have grown accustomed. However, it must also be realized that utilizing universities for purposes such as economic development, or altering the motivation, style, and basic direction of academic research may create long-term patterns within the operation of the university that stray considerably from past methods of operation. Whether such deviations are of a desirable nature should therefore be debated, and the lessons learned through the experiences of universities such as Iowa State should serve to clarify matters for both sides of this debate.
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Snow, Charles C. and L. Hrebiniak
Spalding, B.J.

Stevens, Charles J.

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U.S. Congress, Office of Technology Assessment

Worthy, Ward
## Appendix
Non-Biotechnology Departments
(by college and department title)

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PAPER 4. ECONOMIC DEVELOPMENT AND THE FARM ECONOMY: THE IMPACT OF BIOTECHNOLOGY
Economic Development and the Farm Economy:
The Impact of Biotechnology

by

William J. Kinney
INTRODUCTION

Ever since the 1950s, there has been a global attempt to heighten agricultural productivity through the "intensification" of farming methods. Means of achieving this intensification include production specialization, organizational centralization, and the utilization of production-enhancing technologies, such as chemicals or feed additives (Sainsbury, 1979). Agricultural production has thus undergone a modernization process not unlike that experienced by non-agricultural sectors of the economy, whereby increased production and consumption yields higher profits for producers, as well as lower prices and a higher availability of goods for consumers.

A new variable in this growing trend has been the invention and dissemination of products utilizing recombinant DNA (rDNA) technology. Though this technology is relatively new, it has already contributed to production enhancement in a variety of ways. One fundamental application of rDNA technology involves heightening the capacity of plants and/or animals to create useable goods. Probably the most important example of such an application has been the creation of Bovine Somatotropin, or bST—a drug designed to enhance milk production in cows. A study conducted at Cornell University by a group of economists and animal scientists suggested that milk production could be heightened by at much as 25% in cows treated with BGH (Hansel,
1986). A report by the Office of Technology Assessment (1986) also projected a 25.6% increase in milk production after the adoption of bST, and predicted that almost all farmers would eventually come to use the hormone (OTA, 1986).

While this particular application of agricultural biotechnology involves enhancing the ability of the plant or animal to create more product, the second application involves enhancing the producer’s ability to create more plant or animal. In other words, by capitalizing upon the ability of products such as growth hormones to speed growth rates and enhance growth capacities, producers have sought to heighten their own capacity to create more product per animal or plant. A good example of this utilization of biotechnology is the development of the growth hormone porcine Somatotropin, or pST. The incorporation of pST into a hog-producing enterprise increases the rate and capacity of weight gain in treated animals, reduces feeding time, and increases the overall turn-around rate of pig production (Kliebenstein, 1989).

A third manner by which biotechnology is proposed to hold considerable promise is in its potential to protect and improve plant and animal health. Biotechnological techniques have produced promising vaccines related to the control of pseudorabies, hoof and mouth disease, Rift Valley fever, trichinosis, mastitis, and a variety of other viruses and disease-producing organisms (CAST, 1986). With the help of
biotechnological advancements, the toll incurred by these diseases and many others may be dramatically reduced in the future. Medical applications of agricultural biotechnology may also contribute to increased animal production through the prevention of loss of life due to injury, still-birth, premature death, and others.

Biotechnology may also serve to alter the reproductive capacities of plants and/or animals. Seidel (1989) states that;

In the next several years we can expect to see animals with genes from other species, offspring from either two female or two male parents, and animal clones numbering in the thousands. These creatures will resist diseases better, reproduce more efficiently, grow faster, and yield higher quality products. (p. 42).

A final means by which it is proposed that biotechnology may improve agricultural production is through its potential to decrease the cost of plant and/or animal production by obtaining higher rates of product output for lower levels of input (e.g., nitrogen fixing and improved feed conversion efficiency). For example, 80-85% of the nutrients consumed by cattle are from "forages" (crops harvested by grazing animals or harvested mechanically and fed or stored as hay or silage-- CAST, 1986). Since the systemic breakdown of forages is primarily caused by microorganisms in the animals' rumen, it could become possible to enhance the capabilities of such organisms so that they perform these functions more efficiently, resulting in more product for the same level of forage or feed (CAST, 1986). Thus, it becomes possible to maintain--or even increase--current
production levels while simultaneously lowering the level of feed input for animals (Kliebenstein, 1989; CAST, 1986; Riepe, 1989).

In light then, of this wide variety of potential impacts on agricultural production, some have proposed that biotechnology may play an important role in protecting the rural economy from events such as the widespread farm recession of the early-to-mid 1980s--and restore health to those sectors that still suffer the aftereffects of that period. Indeed, some have come to feel that agricultural applications of biotechnology may well serve as a panacea by which the ails of the rural economy may be largely alleviated. Rule (1988) states that;

Agricultural applications (of biotechnology) could well rival the medical in long-term economic and social impact. Genetic engineering offers the prospect of altering crops and livestock to fit human needs and environmental constraints. This can mean animals that grow faster or remain invulnerable to normally endemic diseases, of plants that thrive under normally inhospitable conditions. Success in even a small portion of the agricultural ventures now being attempted could have sweeping effects on food production--including significant benefits for farmers and consumers... (p. 431)

In recent years, many farmers have also expressed considerable hopes regarding the possible affect that biotechnology may have on their operations. The 1987 Iowa Farm and Rural Life Poll revealed that approximately 60% of farmers polled believed it would be desirable if biotechnology brought an improved standard of living to most farm families, while only
5% of those polled responded negatively to the question (Lasley, 1987).

As a result of this largely positive perception of biotechnology, considerable effort has been put into examining the role that biotechnology may play in spurring economic development and/or recovery in the nation's rural economy. Indeed, over the last decade many economic development projects around the country have sought to use technological research--and biotechnological research in particular--as a means by which to promote economic development in rural as well as industrial economic sectors (Blumenstyk, 1992). Biotechnology has thus become a tool for a variety of economic development projects around the country. It is the intent of this paper to examine one such project in particular, and to gauge whether the initial optimism regarding its implementation has remained intact.

The Role of Biotechnology in Economic Development

Due to these promising preliminary efforts utilizing recombinant DNA technologies, as well as a desire to maintain the healthy operation of this nation's rural economy, federal and state governments, as well as a variety of private sector interests, have begun to invest heavily in research focussing upon genetic engineering and agricultural biotechnology.

In 1988 for example, the federal government was spending approximately $2.7 billion dollars annually for basic research
in biotechnology (Lacy et al., 1988). While only $150 million
of that money was earmarked specifically for the development of
agricultural biotechnology, the National Research Council's
Board on Agriculture recommended in 1988 that this level of
funding be dramatically increased over a very short period of
time, to approximately $500 million annually by 1990 (Moses et
al., 1988).

A good example of the involvement of state governments in
agricultural biotechnology is that of the State of Iowa's
funding of a comprehensive program of biotechnology research and
development. In 1985, the Iowa Development Commission, at the
behest of the Seventy-first Iowa General Assembly, allocated the
sum of $10 million to the State's Board of Regents, public
universities, and/or independent colleges to explore the
potential for biotechnological industries, and their products,
to assist in the recovery of Iowa's ailing rural economy (Laws
After initial investments began to show promise, additional
biotechnology monies were appropriated to the State's
universities to further develop their growing proficiency in the
field. As a result, biotechnology has now become an area of
research expertise in many academic departments at the State's
universities.

The cornerstone of this effort in Iowa has been Iowa State
University, a land-grant institution with an enrollment of
approximately 25,000 students. In fiscal year 1985, the Iowa General Assembly allocated $500,000 to Iowa State University for the purpose of agricultural biotechnology research. Additional appropriations were to follow, with the allocation of $3.75 million in 1986, and $4.25 million each for fiscal years 1987, 1988, and 1989 (Laws of the Seventy-first General Assembly, 1986 session). Projects resulting from these appropriations have included the development of new biodegradable plastics, technologies for using cholesterol reductase to produce animal products with lower cholesterol content, and molecular and genetic techniques for the isolation of maize genes to control crop yields (among many others- Worthy, 1989).

With the explicitly-stated mission of the project being economic development, Walter Fehr, Chairman of the Oversight Committee of the Iowa State Biotechnology Council, describes the means by which this goal is to be achieved:

> With regard to the vision for biotechnology at Iowa State University, our ultimate goal is to use the new techniques of molecular biology to enhance the economic welfare of the state. We believe that this will occur through research in three primary areas: (1) the development of new products from our traditional commodities through bioprocessing; (2) improving the efficiency and profitability of crop and livestock production; and (3) development of new products and processes through the genetic modification of plants, animals, and microorganisms. The vision of Iowa State University's biotechnology program is strongly influenced by the desire to fully utilize the agricultural resources of the state for the welfare of its constituents. (Fehr, 1987).

In order to bolster the effectiveness of this research-centric approach to economic development, technology
transfer networks have also been put in place at I.S.U. These networks are designed to enhance the speed and accessibility with which innovations may be transferred from the lab to local industries desirous of the new biotechnological advancements (e.g., an Eastman Kodak fermentation plant in Cedar Rapids, a Cargill biotechnology facility in Eddyville, and a Ajinomoto Heartland Lysine feed-additive plant, also located in Eddyville, Iowa--Worthy, 1989).

The transfer of biotechnological innovation from the laboratory to the marketplace has thus followed a clear and logical progression: technological breakthroughs have occurred as a result of basic research in universities; these technological innovations and breakthroughs spark business interest and investment; applied research and development occurs in order to create an investment payoff; products are created and marketed by business and industry, and put to use by farmers and other agricultural producers.

State policy makers have appeared to be content with the results of the biotechnology-grounded economic development plan. Iowa's General Assembly has extended appropriations for the operation of the Biotechnology Council, and for the entire program of biotechnology research, beyond the initial three-year implementation period. In assessing the general effectiveness of the project, the state's governor, Terry E. Branstad, states,
Iowa is turning biotech breakthroughs into business success stories. Partnerships between private industry and Iowa’s two world-class research universities are resulting in innovative products and economic progress. (Worthy, 1989).

Governor Branstad has even proposed budget increases for economic development projects based on university research like that taking place at Iowa State (Blumenstyk, 1992).

The effort to stimulate economic development through the creation of the biotechnology program at I.S.U. therefore appears to have met with a substantial degree of success. But it is important to note that this type of project may have very different results for those at different stages or levels of the economic development process. While local industries may be satisfied with increased levels of profit and/or production, and the state government may be pleased with the increased revenues resulting from these profits, questions have arisen as to whether the project has had, and will have, a beneficial result for those it was originally intended to help--the state’s farmers. These questions have focussed on several key issues.

The fundamental concern related to the development of biotechnology is the general increase in production that will result from its use. Whether such increases take the form of higher milk production, higher yields, faster growth rates, more growth capacity, etc., it is clear that the ability to produce more product per plant or animal through the utilization of biotechnology may drastically alter current methods and standards of production (Riepe and Martin, 1988; Fallert, 1987;
For example, with specific regard to the utilization of bST, Alper (1987) states;

Bovine growth hormone, which is slated to come on the market in 1988, should increase milk production by about 30%. Yet dairy farmers are already plagued with surplus milk. So most farmers see little need for a product that will result in further surpluses. (p. 60).

Thus, to economic sectors in which supply is short and demand is strong, such production-enhancing technologies would be highly welcome and beneficial to producers as well as consumers. However, when supply is strong and demand is static, the productive enhancement may be of a detrimental nature. And this detriment may not be limited to the farmers. The initial lowering of costs due to overproduction may at first appear attractive to consumers. However, if prices drop too far, a system of government subsidization may be required, with funding for such subsidization obtained at the taxpayers’ expense (Alper, 1987; Hayenga, 1988; Wohlgenant and Lemieux, 1988).

A second, more specific set of concerns has been raised with regard to the effect of biotechnological production practices on small farms and the rural way of life. Patrick Madden and Paul Thompson (1987) illustrate the manner by which farmers may be acting to their own economic detriment through the widespread adoption of biotechnological means of production enhancement;

...dislocation associated with new technology may be associated not with the scale or type of technology, but
with the rapidity with which a farmer is able to adopt it. Early adopters reap profits, but as many adopt and prices go down, adoption becomes a necessity in order to remain competitive, and many who cannot afford to adopt the technology are forced out of farming. If this picture is correct, farmers themselves may be the agents with greatest causal responsibility for changing farm structure. (p. 103-104).

DuPuis and Geisler (1988) further summarize that;

...large farms would adopt the technique first, reaping innovators' benefits. And smaller farms would be left to make ends meet in an environment of lower milk prices and more expensive dairy technologies. Some of the small farms would be expected to go out of business. (p. 408).

Kalter (1985), similarly observes the potential for an eventual elimination of low-yield dairy farms from the productive environment, and discusses;

...the necessity to design policy to encourage the orderly exodus of resources, including farmers, from dairying.

Gary Comstock (1988) therefore concludes that,

To the extent that potentially displaced dairy farmers have done nothing for which they ought to be punished; to the extent that the research establishment has clearly favored large producers in its development of techniques and technologies; to the extent that fiscal, monetary and economic policies have disadvantaged small dairy producers; and to the extent that bGH will only exacerbate the unjust consequences of the past; to that extent we ought to oppose this particular biotechnology. (p. 49).

Considerable attention has also been devoted to this issue by Alper (1987); Pimentel et al. (1989); Fox (undated); Buttel (1988) and many others.

A third, and closely related, set of concerns was raised by Kliebenstein (1989), in an examination of the way in which various subgroup populations within the agricultural industry
would be affected by the widespread utilization of biotechnology. For example, through a combination of price reduction from increased production and product improvement through the lowering of fat and cholesterol content, pork producers may come to recapture the health-conscious and price-wary consumers that currently purchase poultry or fish products. It is also pointed out that biotechnological products may result in uneven impacts upon feed producers, for example, through heightening the demand for high-protein feeds such as soybeans, and decreasing the demand for traditional feeds such as corn.

Alper (1987) therefore states that:

Although pig farmers will benefit, grain farmers will be hurt, as PGH-treated pigs will consume less grain. And if consumers eat more pork, they will buy less beef, chicken and other meats, thereby hurting producers of these commodities. (p. 60).

How though, have these concerns been received among the farmers who stand to be affected by them? Earlier, it was stated that a 1987 poll of Iowa farmers indicated high expectations regarding the impact that biotechnology in general—and the economic development biotech project in Iowa in particular—would have on that state's farming operations. But clearly, the biotechnology industry is very new, and changing at a very rapid rate. It stands to reason that, just as this industry is developing and changing at a rapid rate, as farmers continue to gain experience with the pace, applications, and impacts of biotech research, their perceptions of biotechnology
may also change at a rapid rate.

Reichel et al. (1988) describe the manner in which farmers' perceptions of the potential of biotechnology may be greatly affected by the kinds of concerns just described:

...farmers appear to mediate their support for economic development initiatives and university biotechnology research through their perceptions of the actual consequences of biotechnology research. Hence, farmers are not quite so apt to recognize economic development initiatives and biotechnology research as solutions to state and local concerns without first taking into account the effects of biotechnology on their productive capacity... farmers are only willing to support economic development strategies, especially biotechnology research, to the extent they can be made to appear relevant to their particular situation. Farmers' support of economic development and biotechnology is dependent, to some degree on the extent to which it is rationalized as being an appropriate strategy. (p. )

When concern is raised that agricultural biotechnology may create the kinds of problems discussed above (overproduction, displacement, and the like), it essentially stands to reason that the popular perception of biotechnology will be filtered through the heightened awareness of these possible consequences.

In light of the rapidly changing nature of the biotechnology industry, increased attention and research into the potential detriments of biotechnological development, and an increased awareness on the part of farmers regarding these matters, it is the hypothesis of this study that farmers' attitudes towards biotechnology will reflect a growing degree of skepticism and concern regarding the likely impacts of the economic development biotechnology project in Iowa.
An important aspect of this study is also that Iowa farmers' changing perceptions of agricultural biotechnology is not only of benefit or relevance to the state of Iowa. In light of the vast nature of biotechnology, and the incredible diversity of practical applications for which it may be used, it is evident that all states--and all nations--stand to be affected by its development. The situation in Iowa therefore serves as a case-study by which the general dynamic of this development process may become more fully understood.
METHOD OF STUDY

The primary mechanism by which this issue shall be examined is the Iowa Farm and Rural Life Poll. The Iowa Farm and Rural Life Poll (IFRLP) is an annual survey of approximately 3,500 randomly selected farm operators within the state of Iowa. The IFRLP is funded by the Iowa State University Agriculture and Home Economics Experiment Stations, and the Cooperative Extension Service. It provides a representative sample of Iowa farmers based upon a statistical comparison with the 1987 Census of Agriculture (Lasley et al., 1990).

As has been previously discussed, respondents to the Iowa Farm Poll were first questioned regarding their opinions on biotechnology, and the biotechnology research effort at Iowa State University, on a 1987 survey. At that time, respondents were asked to rank their opinions on a variety of possible impacts of biotechnology on a five-point scale, including: 'Very Desirable,' 'Desirable,' 'Uncertain,' 'Undesirable,' and 'Very Undesirable.' The results appeared to indicate some hope that biotechnology would provide solutions to many problems currently facing agricultural producers.

Many of the same questions regarding farmers' opinions of biotechnology asked on the 1987 survey were then repeated on the 1991 Iowa Farm Poll. The 1991 Poll was sent to a random sample of 3,461 farmers in Iowa. Usable responses were numbered at 2,095, resulting in a response rate of 61 percent. On the 1991
survey, respondents were asked to rank their opinions on the
desirability of a given outcome on a five-point scale, with
responses including: 'Strongly Agree,' 'Agree,' 'Uncertain,'
'Disagree,' and 'Strongly Disagree.' Due to this alteration in
question format (from measuring perceived desirability in 1987
to personal agreement of desirability in 1991) response
variations may reflect either a change in the response category,
or a change in the assessment of biotechnology (Lasley, 1991).
For this reason, caution should be used in drawing any direct
comparisons between the two sets of responses.

A second mechanism by which the agricultural impact of
biotechnology is gauged is to measure the opinions not of those
for whom the products of biotechnology are targeted, but those
who play a large role in the creation of those products--
university researchers. As has been said, Iowa State University
has been a cornerstone in the economic development biotechnology
project in that state. Prior to the 1991/1992 academic year, 26
biotechnology faculty had been hired at the university in
conjunction with this effort. Of these 26 researchers, 23 were
interviewed by the author regarding their opinions on some of
the likely or eventual impacts their research may have on the
Iowa farming community--and the rural sector in general
(interviewees were questioned on a variety of other issues as
well). Three faculty refused to be interviewed.

The findings of this study thus represent a methodological
triangulation, in that the perceived or anticipated impacts of the biotech project in Iowa—and biotechnology in general—are being viewed from the perspectives of the creators, as well as the likely consumers, of these products.
FINDINGS

A summary of the findings of both the 1991 and 1987 surveys is contained in Table 1. Regarding the 1991 results, less than half of the respondents (47%) held agreement with the statement that biotechnology would assist in finding new uses for crops and livestock—which would in turn assist in solving the problem of farm surpluses. An even smaller minority (31%) agreed with the statement that biotechnology would help to improve the standard of living for farm families. A majority of respondents (53%) also agreed with statements that biotechnology would lead farmers to become more dependent upon large corporations, and benefit large producers more than persons on small and middle-sized farms (61%).

On the positive side, varying majorities held agreement with statements that biotechnology would eventually promote nitrogen fixation in corn (57%), increase the efficiency of feed conversion in livestock production (77%), allow farmers to become less dependent on agricultural chemicals (60%), and assist in promoting sustainable agriculture (54%).
Table 1. Questions and response rates from the 1987 and 1991 Iowa Farm and Rural Life Polls

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Biotechnology will help solve the problem of farm surpluses by finding new uses for crops and livestock</td>
<td>7</td>
<td>40</td>
<td>34</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>32</td>
<td>29</td>
<td>29</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>b. Through genetic changes, new varieties of corn will be able to fix their own nitrogen from the atmosphere, thus reducing the need for commercial fertilizer</td>
<td>11</td>
<td>46</td>
<td>37</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>50</td>
<td>31</td>
<td>13</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>c. Research in biotechnology will increase the efficiency of feed conversion in livestock production</td>
<td>8</td>
<td>69</td>
<td>21</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1991</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>26</td>
<td>46</td>
<td>20</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>d. Biotechnology will bring improved levels of living for most farm families</td>
<td>4</td>
<td>27</td>
<td>50</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>32</td>
<td>28</td>
<td>34</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>e. Biotechnology will enable farmers to become less dependent upon agricultural chemicals</td>
<td>8</td>
<td>52</td>
<td>31</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>52</td>
<td>29</td>
<td>15</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>f. Biotechnological research will assist the movement towards sustainable agriculture</td>
<td>5</td>
<td>49</td>
<td>36</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>1991**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>3</td>
<td>7</td>
<td>18</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td>g. Biotechnology will lead farmers to become more** dependent upon large corporations for many of their inputs, such as seeds, growth hormones, and feed additives</td>
<td>7</td>
<td>46</td>
<td>33</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>1991**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>3</td>
<td>7</td>
<td>18</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td>h. Advances in biotechnology will probably benefit persons with large farm operations more than persons on middle-sized and small farms</td>
<td>16</td>
<td>45</td>
<td>22</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>2</td>
<td>8</td>
<td>25</td>
<td>31</td>
<td>33</td>
</tr>
<tr>
<td>i. Confinement livestock producers will benefit more from biotechnological research than non-confinement livestock producers</td>
<td>5</td>
<td>33</td>
<td>45</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>1991**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td>13</td>
<td>49</td>
<td>30</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>j. Concern over the treatment of animals will be an increasingly important consideration in biotechnological applications</td>
<td>13</td>
<td>49</td>
<td>30</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>1991**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987*</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**— 1987 response categories were: 1=very desirable; 2=somewhat desirable; 3=uncertain; 4=somewhat undesirable; 5=very undesirable.

--- Items were included only on the 1991 survey.

***— 1987- this item was worded less dependent.
Beyond this descriptive analysis, the ten questions described in Table 1 were factor analyzed using a varimax rotation of the extracted factors (Harman, 1976). Two factors were generated; one dealing primarily with the specific potentials of biotechnology (containing questions a-f in Table 1), and the other dealing primarily with the threat biotechnology may present to small and medium-sized agricultural producers (containing questions g-j in Table 1). Reliability of the two scales was evaluated using Cronbach's Alpha (Cronbach, 1951).

The scale containing variables a-f (relating to the potentials of biotechnology) was determined to have a non-standardized Alpha of .77, and was therefore retained for correlation and regression analyses (Y1). The scale containing variables g-j was determined to have a non-standardized Alpha of .53, and was therefore not retained for further statistical analysis. However, three of the individual items within this factor retain their theoretical importance in understanding the overall perception farmers hold towards the potential impact of biotechnology: g--dependence on corporations (X1); h--benefit to large farmers (X2), and; i--benefit to confinement operations (X3). Three basic demographic factors also hold importance for an overall analysis of farmers' perceptions of biotechnology: age of Farm Poll respondent (X4); educational level of the
respondent (X5); and farm size, in number of acres (X6).

A correlation analysis of the relationships of these factors is contained in Table 2.

**Table 2. Correlation matrix for farmers’ perceptions of the potential outcomes of agricultural biotechnology**

<table>
<thead>
<tr>
<th></th>
<th>Y1</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X1</td>
<td>-.1448**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X2</td>
<td>-.2395**</td>
<td>.4542**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X3</td>
<td>.0324</td>
<td>.1524**</td>
<td>.2637**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X4</td>
<td>.0266</td>
<td>-.1134**</td>
<td>-.1488**</td>
<td>-.0969**</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X5</td>
<td>-.0664**</td>
<td>-.0049</td>
<td>.0408</td>
<td>-.0109</td>
<td>-.3236**</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>X6</td>
<td>-.0587**</td>
<td>.0300</td>
<td>.1167**</td>
<td>.0449*</td>
<td>-.1750**</td>
<td>.1692**</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*--- significant at the .05 level
**--- significant at the .01 level
Y1=farmers’ views on potential of biotechnology
X1=biotech will increase farmers’ dependence on corporations
X2=biotech will provide more benefits to large farms
X3=biotech will provide more benefits to confinement producers
X4=age
X5=educational level
X6=farm size (per number of acres)

The two factors that have the greatest impact on farmers’ perceptions of the potential of biotechnology (Y1) are their perceptions of whether biotechnology will make them more dependent upon large corporations (X1), and whether it will have a greater benefit for larger farms (X2). Both of these relationships are negative, statistically significant, and in the weak-to-moderate range. Fears over dependence on corporations are also moderately correlated with concerns over greater benefits for larger farms (.4542) and weakly correlated with the belief that biotechnology would result in greater
benefits for confinement producers (X3=.1524). Both of these relationships were positive, and statistically significant. The three demographic factors included in the analysis (age--X4; education level--X5; and size of farm by acres--X6) held some statistically-significant relationships with the other variables, but they were generally of a weak to very weak nature.

A path-model regression utilizing these variables was also constructed, where independent variables included age (X4), educational level (X5), and farm size by acres (X6). Intervening variables included concern over dependence on large corporations (X1), fear that biotechnology would result in greater benefits for larger farms (X2), and the belief that biotechnology would favor confinement producers (X3). The dependent variable (Y1) consisted of the first factor described earlier, regarding general perceptions of the potential impacts of biotechnology. Overall, the path analysis failed to reveal impressive findings (Table 3).

Generally speaking, while many of the regression calculations yielded statistically-significant findings, these findings were of a very weak nature. The notable exception arises when examining the relationship between farmers' perceptions of biotechnology and fears that it will result in greater benefits for larger farms. This relationship is statistically significant, of moderate strength, and negative.
<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Y1</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>-.049*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X2</td>
<td>-.246**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X3</td>
<td>.089**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X4</td>
<td>-.040</td>
<td>-.133**</td>
<td>-.139**</td>
<td>-.105**</td>
</tr>
<tr>
<td>X5</td>
<td>-.062**</td>
<td>-.049*</td>
<td>-.021</td>
<td>-.049*</td>
</tr>
<tr>
<td>X6</td>
<td>-.025</td>
<td>.015</td>
<td>.088**</td>
<td>.039</td>
</tr>
</tbody>
</table>

*--- significant at the .05 level  
**--- significant at the .01 level  

Y1=farmers' views on potential of biotechnology  
X1=biotech will increase farmers' dependence on corporations  
X2=biotech will provide more benefits to large farms  
X3=biotech will provide more benefits to confinement producers  
X4=age  
X5=educational level  
X6=farm size (per number of acres)

On the whole then, these findings indicate that Iowa farmers have substantial concerns over the affect biotechnology may have upon their farming operations. In basic descriptive terms, the raw data clearly indicates that farmers are concerned that biotechnology may have a negative affect on their standard of living, threaten their independence from corporate influence or control, and result in an inequitable distribution of benefits from its use. More advanced statistical tests then reveal that overall opinions regarding the potential of biotechnology tend to be filtered through these concerns—with the result being a more negative opinion of biotechnology in general, and a more skeptical opinion of the affect it will have
on their lives.

As was discussed earlier, a second mechanism by which this study seeks to examine the impact of biotechnology on the rural economy is to also gauge the opinions of those who are creating the products that will result in these impacts--the university researchers. Ironically, many of these researchers appear to share farmers' concerns regarding the uneven impact of biotechnological products.

Researchers were asked, "Will advances in biotechnology benefit persons with large farm operations more than persons on middle-sized and small farms?" Somewhat surprisingly, almost half of the researchers responded positively to this question. The following are indicative of their responses:

Some products have really been a disaster, because they've been so expensive. Yes, from what I've seen so far, people with more money are going to get more benefit from this.

Yes, this is a concern. The best opportunity to take advantage of biotechnological innovations will be for large wealthy growers and agribusinesses.

Some of the products coming out will be very expensive. Yes, if this is the case there may be some unequal benefits for the people with more money to buy the products.

Biotechnology goes against those who can't afford it. You need access to the technology if you're going to use it.

Yes, the initial expense on products will be high, but eventually these costs come down, and then the impact evens out some.

Eleven out of the twenty-three biotechnology researchers interviewed felt that this unequal impact was a real concern for
the biotechnology industry and agricultural producers.

Ten researchers responded that they simply didn't know if there would be a problem with uneven or unequal impacts:

They (the biotechnology companies) will have to decide this. I don't know. It's up to them.

This question doesn't arise at my level. It arises at the level of the companies selling seeds--the seed companies. Whether they out-price individuals would have no connection with anything I do.

I'm not well informed on it. The big companies are the ones who are into it... It's part of the current system and biotechnology won't really change it.

Only two of the researchers responded that this issue has little merit. One of these researchers explains that:

...there'll be no real difference in impact. For example, vaccines would be very cost effective, and provide access for all that need them--even in Third World countries.

The biotechnology researchers were asked a second question of relevance to this study: 'Will biotechnology lead farmers to become more dependent upon large corporations for their production inputs, such as seeds, growth hormones, and feed additives?' Seven researchers responded affirmatively to the question:

I think I'm a Philistine--I don't really think about these things. It depends on the demand--if it's small it leads to a bigger problem. And it can depend on the company. Some companies just have better ethics than others. I think it's quite possible. It sounds like another one of the seedier aspects of capitalism.

Yes, I see a danger in this. Especially if there's a connection between the company that produces, for example, the corn strain and the herbicide. I'm not totally opposed to that system, but it has to be monitored.
Yes, this could be a problem, but it's not a problem limited to biotechnology. It's just the economic system as a whole, and it's a bigger question than biotech.

In some cases, yes. In an area where you have very few producers—say two to three percent—controlling about 90% of the industry, there could be a problem. But with a product like vaccines, it wouldn't be a problem.

Nine of the biotechnology faculty felt that overdependence on companies or agribusinesses is not a real concern:

No. There are too many different mechanisms to produce these things, and other companies would simply do it. So there wouldn't be a problem with overreliance on one company or business.

There won't really be a significant impact. There are so many companies out there that farmers can jump around from one to the other.

This won't be a problem in our work. Different companies have it (the means for biotechnological production) so others can reproduce products. Biotechnology is a basic science that can be applied in many ways.

Seven of the researchers responded that they did not know if biotechnological products would increase the dependence of farmers on companies.

The responses of the biotechnology researchers thus lend credence to some of those issues raised by farmers in the Iowa Farm Poll. The possibility of unequal benefits, as well as of an increased reliance/dependence on corporate entities in the rural economy, were both acknowledged by a substantial minority of the researchers to be valid concerns for the rural sector. Farmers and researchers alike are thus in an apparent state of agreement that the impact of biotechnology on the rural economy
of Iowa may not be of the wholly positive nature some have perceived or promoted it to be. It may therefore be wise for rural economies in states and countries around the world to make note of the situation currently developing in Iowa, and take some heed as to the affect biotechnology may eventually have on them.
A theoretical framework that holds considerable relevance in explaining the development and impacts of the economic development biotechnology project in Iowa is multiple-constituent theory, or the 'constituency approach' (Connolly et al., 1980). The basic proposition of this approach is that an overall assessment of any venture (such as the biotechnology program in Iowa) is very difficult to achieve, in light of the fact that a wide variety of groups or constituents will experience vastly divergent benefits and drawbacks as the result of a given project. Each constituency essentially has a different criterion for assessing project effectiveness, since each constituent group will have a different set of interests, concerns, or expectations related to a project. With this in mind, it is clear that a variety of constituent groups are involved with the biotechnology project in Iowa: state government, local industries, universities, farmers, and possibly others.

As has been previously stated, many officials of the state government in Iowa appear to be very pleased with the preliminary outcomes of the biotechnology project. In a state currently facing severe budgetary problems, the prospect of increasing revenues by lowering the rate of unemployment, increasing industrial profits, and improving farm production (all supposed outcomes of the economic development project)
holds much appeal. It also bears mentioning that a vested interest of many of those involved in state government is re-election. Should the project proven to have been a waste a considerable amount of the taxpayers' money, this interest would have certainly suffered.

With regard to local industries, there is some evidence to indicate that production has at least begun to benefit from the preliminary results of the research taking place at institutions such as Iowa State University. There also appears to be optimism that, as the program continues to develop, profit and production levels will either maintain or increase growth levels. Therefore, with increased profits being a clear expectation of this constituent group, some grounds exist for a positive--albeit tentative--assessment of the biotechnology project.

The university system in Iowa has also benefitted to a substantial degree (at least, in financial terms) from the biotechnology effort. While the primary intent of the biotechnology appropriations was the stimulation of general economic development, the university system in Iowa served as the primary means by which this plan of economic development was to be carried out. Therefore, while the biotechnology appropriations were designed to assist the farming the industrial sectors of Iowa's economy, they also served to provide much-needed financial support to Iowa's public
universities in a time of severe financial difficulty. The glowing assessments of program officials such as Walter Fehr (described earlier) clearly demonstrate the positive view many university administrators hold towards the project.

These constituents—the state government, industrial producers, and the university system—thus appear to have benefitted from the implementation of the economic development research program in Iowa, and appear to hold positive views regarding its continued operation and potential social and economic impacts as a result.

However, it must be remembered that it was for the benefit of the farmers of the state of Iowa that the biotechnology project was supposedly established. Earlier, several major concerns related to the agricultural impacts of biotechnology were discussed (the potential for overproduction, displacement of small farms, disruption of the rural way of life, and negative secondary impacts on various subgroup populations in the agricultural industry). The fundamental concerns raised by farmers in this study—that biotechnology may have a negative affect on their standard of living, threaten their independence from corporate control, and provide large producers with disproportionate benefits—are closely related to these issues, and lend considerable credence to those who have raised them.

These findings also lend credence to the claim that those for whom the biotechnology project was to have the most benefit
have in fact received little benefit from it, and may even suffer long-term detriments as a result of its development. Based upon the findings of this study, it therefore appears that the farmers of Iowa—as a constituent group—hold considerable skepticism regarding the alleged benefits of the biotechnology project, and are in fact fearful of the long-term implications it may hold for their way of life.

The biotechnology project in Iowa has therefore created a considerable dilemma: several powerful constituent groups that were to have been secondary beneficiaries of the project appear to hold positive assessments of its impacts, while the primary constituent group for which the project was originally intended appears to have received little benefit from it, and may ultimately be harmed by it. It is evident that the assessments of the former constituents have taken priority over the assessment of the latter, in light of the continued growth and development of the project.

Summary

The relatively recent introduction of biotechnological products to the farming sector has to date rendered a full analysis of its possible social, economic, environmental, and other impacts difficult to ascertain. Many cursory investigations have taken place, touching on a wide variety of economic, social, environmental and ethical concerns. The
results of the cumulative body of these analyses remain somewhat unclear: some purport that biotechnological advancements in agricultural production will result in a nearly universal benefit to the overall society in which we live, while others see a tremendous potential for harm in the utilization of such technologies.

We have, for the most part, already received the assessments of governments and businesses regarding the implications of the economic development biotechnology program. However, in measuring the concerns of farmers, a somewhat different--and more skeptical--assessment of this program appears to be evident. This assessment is lent some credence through its apparent corroboration by some of the researchers involved in the biotechnology project. It is thus clear that, while this biotechnologically-grounded program of economic development may be of benefit to some, it may not necessarily hold equal benefits for others. Proponents of, and participants in, such a program must therefore take this fact into account when assessing its overall social impact.
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GENERAL CONCLUSIONS

The research contained in this dissertation demonstrates that any public program or policy may have a wide variety of impacts—intended as well as unintended.

With regard to the organizational impacts discussed in Papers 1-3, it is evident that universities around the nation have become increasingly desperate for alternative sources of funding as traditional sources of funds have decreased considerably. The need for funding is real, and the effort to attain it is valid. However, we as a society must acknowledge the transforming effect that alternative funding sources—and the specialized or targeted research projects that accompany them—may have upon the general structure of our universities. Against the historical backdrop of the traditional role and purpose of the university, we must examine whether this transformation may hinder universities and colleges from performing the social functions they were originally intended to perform.

With regard to the social impacts discussed in Paper 4, it is clear that the rural economy—as well as the economy in general—is in need of technological and structural improvements if it is to retain its effectiveness in today’s extremely competitive international environment. Efforts to
assist the rural economy such as that undertaken in the state of Iowa are indeed admirable in their intention to achieve this end. However, one must also focus careful scrutiny on such efforts, to insure that they are indeed bringing such an end about. Should the effort to assist the rural sector ultimately result in its long-term disruption, then the positive intentions behind such an effort are of little worth or consequence.

However, as has been stated several times throughout this dissertation, it is not my intent to propose that the biotechnology project at Iowa State University, or other types of economic development projects around the country, are of no worth. Projects of this nature may provide many useful insights and breakthroughs that are of great importance to the long-term health of our economy and society. Hopefully, this will be the end result of the biotechnology project in Iowa. As Rule (1988) states:

"The conclusion one must finally accept regarding biotechnology is scarcely that it should not be pursued, nor indeed that it should never be pursued within university settings. It is that its pursuit must not be allowed to erode those special qualities of openness to new ideas and primacy of intellectual values that make universities distinct." (p. 436).

So, I would argue, should the application of biotechnology not be allowed to erode the traditional aspects of rural life and the rural economy that make them equally distinct.
While biotechnology therefore shows considerable promise to positively affect our society in a wide variety of ways, we must also be on guard for the possible detriments that may result from its development.
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