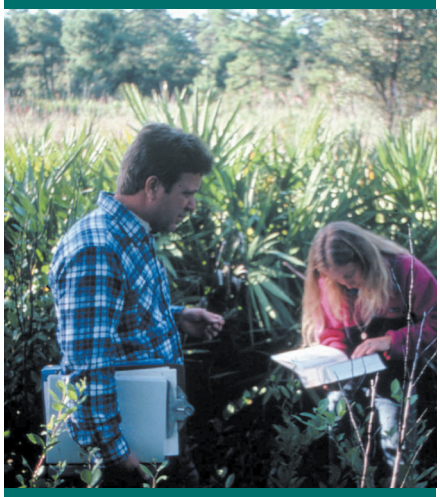

THE STATE OF IOWA:

BIOSCIENCES PATH FOR DEVELOPMENT: ECONOMIC AND CORE COMPETENCY ANALYSES

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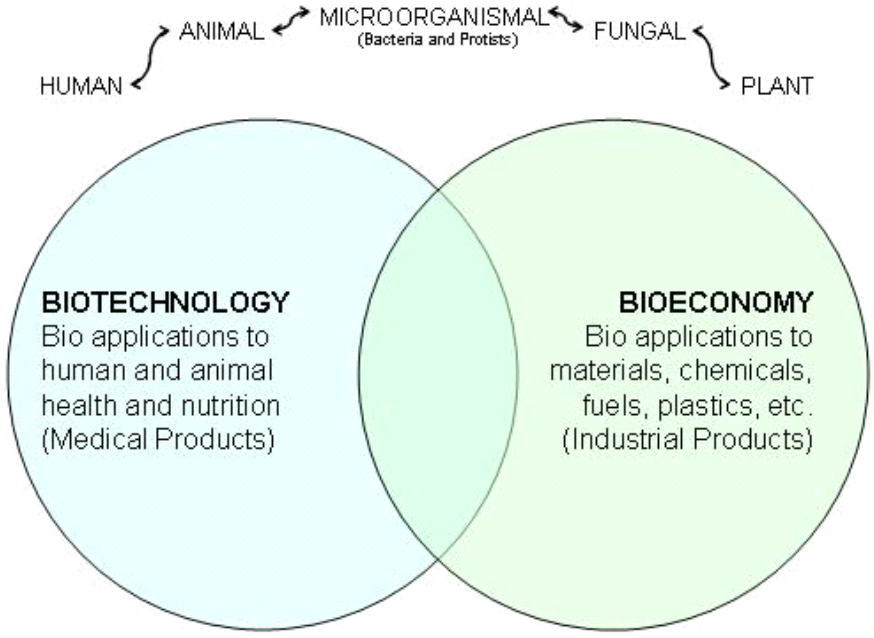
Battelle
The Business *of* Innovation

Executive Summary

Much attention has been paid in state economic development circles to the importance of biosciences as an engine for innovation and technology growth in the 21st century. The genomic revolution, and the resulting advances in bioscience knowledge, are generating multiple potential bio-pathways to innovation-based economic development.

Figure ES-1: Genomic and Biomass Resources for the Biosciences.



To facilitate understanding of Iowa's core bioscience competencies and opportunities and its current economic base, the Iowa Department of Economic Development engaged Battelle's Technology Partnership Practice (TPP) to perform economic and core competency analysis of the biosciences in Iowa.

Battelle examined the state's existing biosciences industry, broadly defined for this study to include most aspects of agriculture, e.g., agricultural machinery and equipment, agricultural processing, etc., because it is an important component of the "biosciences cluster" that also includes supplier chains and end customers. It includes key industry segments such as medical devices, drugs and pharmaceuticals, and research and testing. The economic analysis section of this report analyzes trends, current strengths, and emerging subsectors of the biosciences cluster in Iowa.

For the core competency analysis, Battelle used quantitative data sources (bioscience grant funding data, research output data, patent data, etc.) in combination with more than 220 qualitative fieldwork interviews in Iowa among faculty, administrators, trade and business associations, industry, and others to develop an in-depth profile of the State's core bioscience competencies. The results show that Iowa has broad and substantial bioscience expertise in each of the core bioscience areas. Because of the need for a strong research base as a prerequisite for any state to succeed in the biosciences, these documented competencies position Iowa with the potential to advance in bioscience-based economic development.

Iowa Paths to Biosciences Development: Leveraging Core Research Competencies and Technology Platforms

The purpose for gaining an understanding of Iowa's research core competencies is not only to identify the key research strengths and drivers for biosciences. To ensure economic impact the key technology platforms must be identified that move this research toward commercialization around products, processes, and market-driven niches. Core competencies identification also helps focus on the state's specific possibilities for becoming a bioscience growth center around major niches and opportunities. Of particular importance is the ability of a state to have specific areas for near-term (within the next two to five years) development that takes advantage of core research strengths that will contribute to economic growth. It is these near-term areas for development that identify how the state can be a thriving center for the biosciences and can provide the foundation for further, more longer-term investments needed to establish broader core competencies for growth in the longer term.

Given the close linkages of research and industry development in the biosciences and the extensive reliance on research for new bioscience products, it is helpful to focus on areas of primary research for near-term development. But research alone is insufficient to ensure bioscience development. The most likely areas for bioscience development can be found where research intersects with a state's industry base, competitive advantages, and market opportunities.

The criteria for selecting near-term opportunities for technology development include areas in which there are

- Existing research focus strengths
- Bases of commercial activity emerging or established within the state, or a genuine opportunity to create a base in the near future
- Distinct opportunities to leverage Iowa's comparative advantages to create competitive marketplace advantages
- Significant product market potential
- Links to, or reinforcements of, other bioscience strengths and core research competencies, thereby helping to enhance other fields as it expands.

Based on these criteria, the following technology development platforms are identified for near-term development, focus, and investment in Iowa:

- **BioEconomy Platform**
- **Integrated Drug Discovery, Development, Piloting, and Production Platform**
- **Advanced Food Products Platform**
- **Integrated Post-Genomic Medicine Platform**
- **Animal Systems Platform**
- **Integrated Biosecurity Platform.**

These six platforms represent the base from which a significant R&D, business base, and bioscience economy may be built. They each specifically draw upon Iowa's institutional expertise in multiple fields,

since it is multidisciplinary research that is increasingly gaining importance in driving new study areas, technologies, and commercializable innovations and discoveries. The assembly of multidisciplinary platforms is likely to increase the opportunity for winning federal agency grant awards. It is also a specific match to the type of cross disciplinary institute structure being formally adopted by Iowa State University and more informally used within The University of Iowa.

In addition to the main platforms, Battelle also identified several additional areas of opportunity that represent longer-term or less broad bioscience sector development potentials. The identified areas consist of relatively compact groups of people working in leading edge fields, new formative centers just recently pulled together, or established areas of expertise in which investment in infrastructure and/or personnel are required to sustain or accelerate development momentum. These additional opportunity areas include

- **Host-Parasite Biology and Systems**
- **Instrumentation, Devices and Sensors**
- **Formation of a Cardiovascular Research Institute**
- **Formation of a Free Radical Research Institute.**

Each of the main bioscience platforms and opportunity areas noted above are linked to multiple centers of bioscience excellence and related disciplines within Iowa's academic R&D institutions. Figure 20 summarizes the competency areas identified through quantitative research (the column of disciplines on the left) and those identified through the in-depth qualitative interviews (the column of disciplines on the right). The center column depicts the main technology platforms and opportunity areas that can result from the integration of these qualitative and quantitative strengths.

Figure 21 shows how Iowa's bioscience research strengths, determined and validated through both quantitative and qualitative analyses, lead to the recommended six specific technology platforms. Each of these six platforms, as well as the four emerging opportunity areas, are described in the following narratives. Each narrative includes a figure designed to show the specific linkages between the quantitatively based and qualitatively based core competency disciplines and recommended platforms and opportunity areas. The figures graphically illustrate the way in which these platforms are reinforced by the R&D talent across a wide range of strength disciplines in Iowa.

Figure 20: Quantitative and Qualitative Core Competencies and Resulting Biosciences Technology Platforms.

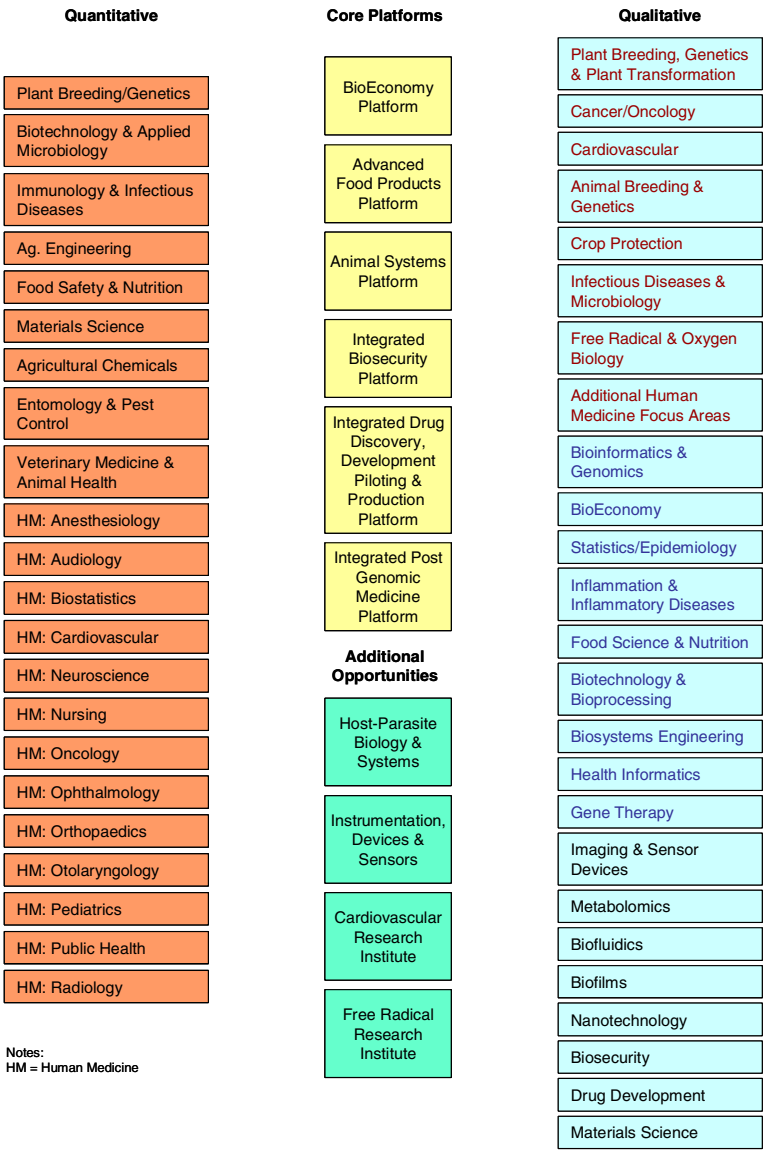
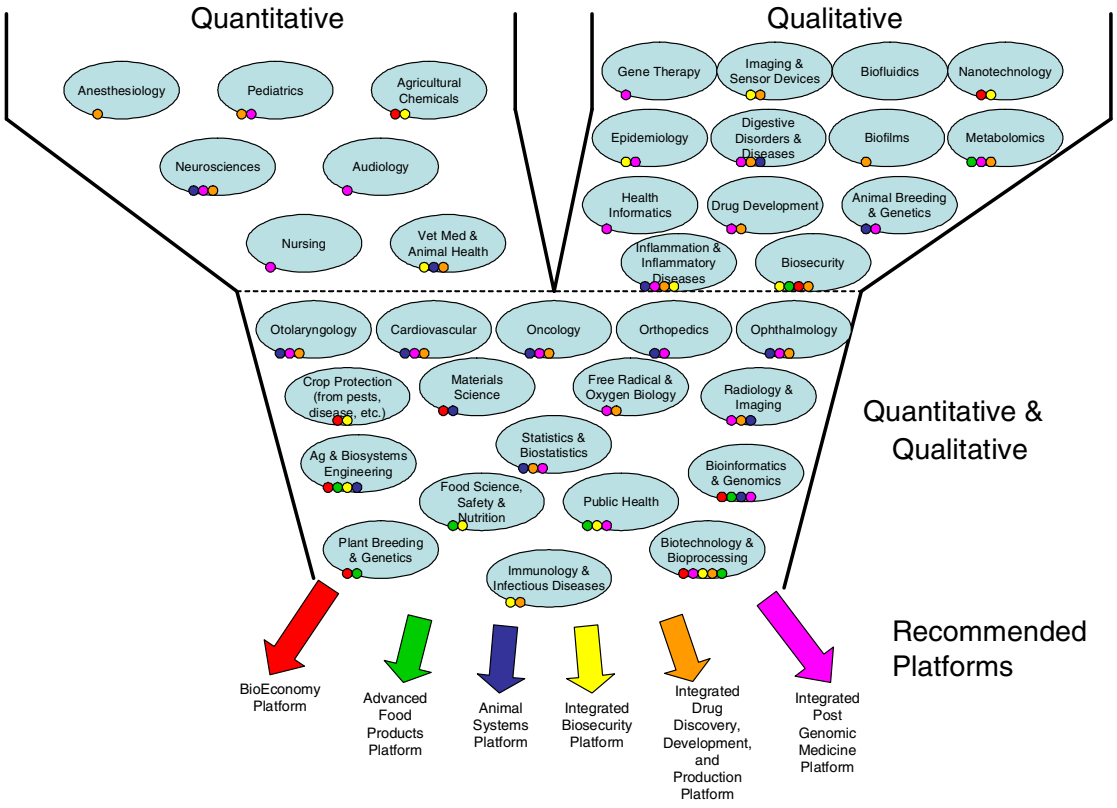


Figure 21: Iowa's Validated Research Strengths Leading to Recommended Platforms.



IOWA'S TECHNOLOGY PLATFORMS

In the pages that follow each of the six identified platforms are described and analyzed and gaps and opportunities discussed.

BIOECONOMY PLATFORM

Iowa's research institutions and industry already have aggressively moved forward in the platform area of "BioEconomy"—a term coined to describe the application of biosciences and biological resources to the production of biorenewable resources and products. The BioEconomy stands as distinct from biotechnology in that biotechnology can be defined as work on technologies targeting human, animal, and plant health, while **the BioEconomy is focused on the commercial application of bioresources to the production of energy, industrial commodities, and specialty products.** Examples include

- Biofuels (such as Ethanol, Biodiesel, Methane Gas)
- Biocomposite Materials (such as construction materials, insulation, sound deadening panels)
- Specialty Chemicals (such as plastics, adhesives, lubricants, catalysts) via bioresource pathways
- Fibers (for carpeting, clothing and other applications)
- Environmental Remediation and Protection Systems (such as microbes for toxic waste disposal).

The use of biorenewables has received considerable attention in Europe where the European Community-sponsored "Interactive European Network for Industrial Crops and Their Applications" (IENICA) has undertaken significant analysis of potential markets for biorenewables. IENICA segments the potential market into five main areas:

- Oils
- Fibers
- Carbohydrates (sugars, starches, glycogen)
- Specialty Products
- Proteins.

IENICA's research concludes that the first three of these (oils, fibers and carbohydrates) will have the greatest potential impact on agriculture because **they will require large production land acreage**. Independent of fuel production (such as ethanol and biodiesel), IENICA predicts that the main oil market opportunities will be in

- Bio-lubricants
- Bio-printing inks
- Bio-solvents
- Linoleum
- Surfactants
- Polymers
- Paints and Surface Coatings.

In terms of fiber applications, the Europeans predict opportunities in

- Matting based products (filters, growth media, textiles)
- Biocomposites (such as materials for use in vehicle manufacturing)
- Insulation products
- Wood-based panel substitution with annual constituents (such as straw)
- Paper and pulp manufacturing.

Non-food carbohydrates markets, especially those for starches, represent approximately 50 percent of total starch use in the European Community. These non-food uses are primarily in

- Paper and cardboard manufacturing
- Plastics and detergents
- Fermentation and technical uses
- Specialty areas including water purification, cosmetics, toiletries, pharmaceuticals, paints, and agrochemicals.

Proteins are predicted to have major applications (outside of food) in packaging and labeling industries, pharmaceutical and chemical production, adhesives, and cosmetics.

It is therefore evident that considerable opportunities exist for the commercial exploitation of biorenewables. Much of the future for these products depends on the development of processing technologies that will generate products at a price competitive to alternative (usually petroleum based) production pathways.

As noted previously, Iowa has, through the Industries of the Future program, already identified the BioEconomy as a component of the future world economy in which Iowa can gain an early and sustainable leadership position. Iowa State University research, sponsored by the U.S. Department of Energy, Iowa Department of Natural Resources, and the Iowa Energy Center, resulted in the Fall of 2002 publication entitled "Biobased Products and Bioenergy Vision and Roadmap for Iowa." The Roadmap provides a vision statement for Iowa's potential position in the BioEconomy stating that by 2020:

> *Iowa leads the nation in developing the BioEconomy. Growth of the BioEconomy had led to an unprecedented period of sustained economic growth in the state and has allowed Iowa to develop abundant amenities and a quality of life rated among the highest in the United States. Iowa biorefineries*[24] *enjoy widespread support from Iowans because they consistently*
>
> - *Produce superior products*
> - *Capture significant value for all segments of bioproduct value chains*
> - *Provide high rates of return to investors*
> - *Attract local and outside capital*
> - *Provide exciting, challenging and lucrative jobs*
> - *Improve environmental conditions and ecological diversity.*

The Iowa State University report for Industries of the Future specifically outlines the science and technology focus areas that need to be addressed to assure advancement of the BioEconomy and Iowa's leadership position within it. The science and technical focus areas include

- **Plant Science**—improving processing functionality; expression of desirable characteristics; plant vigor; durability of feedstocks; manure characteristics; uniformity of raw material; pest resistance; optimized yields; environmental impact; and genomics, bioinformatics, and metabolomics capabilities.
- **Production**—improving understanding of the impact of crop residue removal; developing best management practices; expanding planting and harvest windows; developing cost effective methods of harvesting, transporting, and storing biomass; adoption of appropriate farm policies; and developing a marketing system for crop residues and specialty crops.
- **Processing—**improving plant component separation; conversion processes; management and financing systems that reduce feedstock costs; quality and availability of feedstock; and developing decentralized preprocessing technologies.
- **End Use—**designing biorefineries that enhance functionality/performance of local biomass resources; exploiting specific markets for local/regional biobased products; adopting policies that encourage domestic consumption of biobased products; establishing certification programs that verify biobased content and product performance.

[24] The Iowa State University report defines biorefineries as "integrated processing plants that yield numerous products."

Focus products of the Iowa BioEconomy are anticipated to include

- Industrial Chemicals
- Ethanol
- Enzymes
- Biodiesel
- Hydrogen
- Carbohydrate-based chirals
- Building materials such as fiber board, ceiling tiles, etc.

While there are considerable scientific, technical and market hurdles to overcome, efforts are already underway for Iowa to implement this platform, with its advocates noting it has the opportunity to become a major contributor to the state's economic health. Indeed, the BioEconomy in Iowa is not some long-term dream; it is already becoming a reality as R&D advances in the state result in new companies being formed in the field. Iowa is already home to a growing biorefineries industry.

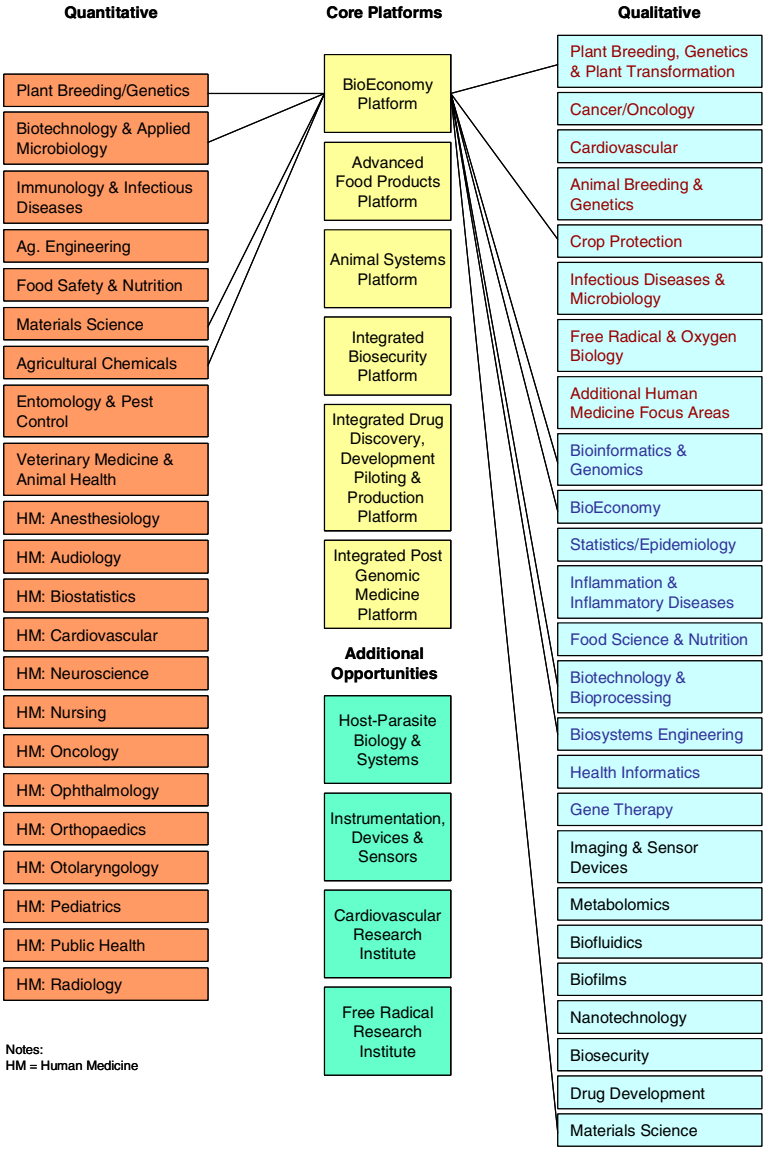
Figure 22 illustrates the key linkages between quantitative and qualitative core competency disciplines and the BioEconomy platform. This figure shows the importance of many core research areas to the success of this platform and the widespread expertise that will be needed to position Iowa to succeed in this arena.

Iowa State University is certainly central to the state's initiatives in the BioEconomy. **The University has put in place a structure of institutes and R&D centers that positions it well as the leader in driving the science and technology of the BioEconomy forward.** *The following components of Iowa State University are key elements in BioEconomy technology platform development:*

The Plant Sciences Institute—an umbrella organization comprising nine research centers and three task forces. Each of these centers and task forces has a role to play in the BioEconomy—but chief among them are six centers that in combination provide a vertically integrated chain of discovery, research and development:

- **Laurence H. Baker Center for Bioinformatics and Biological Statistics—**developing methods, programs, and algorithms for acquiring genomic data and analyzing it for use by plant scientists.
- **Center for Plant Genomics**—developing and using genomic technologies to provide the genetic understanding of plant resources that will form the underpinning of control over plant growth, development, and inherent characteristics.
- **Center for Plant Transformation and Gene Expression**—working to develop methods to efficiently insert and transfer genes in order to efficiently generate transgenic plants and assure their safety.

Figure 22: Quantitative and Qualitative Core Competencies and Resulting BioEconomy.



- **Center for Designer Crops**—working to understand and control the plant production of metabolites that produce useful applications (such as starch, oils or drug compounds).
- **Center for Plant Responses to Environmental Stresses**—working to help modify plants to withstand wider ranges of biotic and abiotic stress.
- **Raymond F. Baker Center for Plant Breeding**—integrating breeding techniques and germplasm enhancements to develop plant cultivars to meet the expression needs and plant characteristics as BioEconomy feedstocks.

The above centers provide a pathway of basic and applied science from fundamental genomic discoveries through to the exploitation of these discoveries expressed through new, optimized plant cultivars. Thus, there exists at Iowa State a basic fabric of interrelated research centers providing an applied and highly focused research and development engine for the BioEconomy. The work of the R&D scientists is further

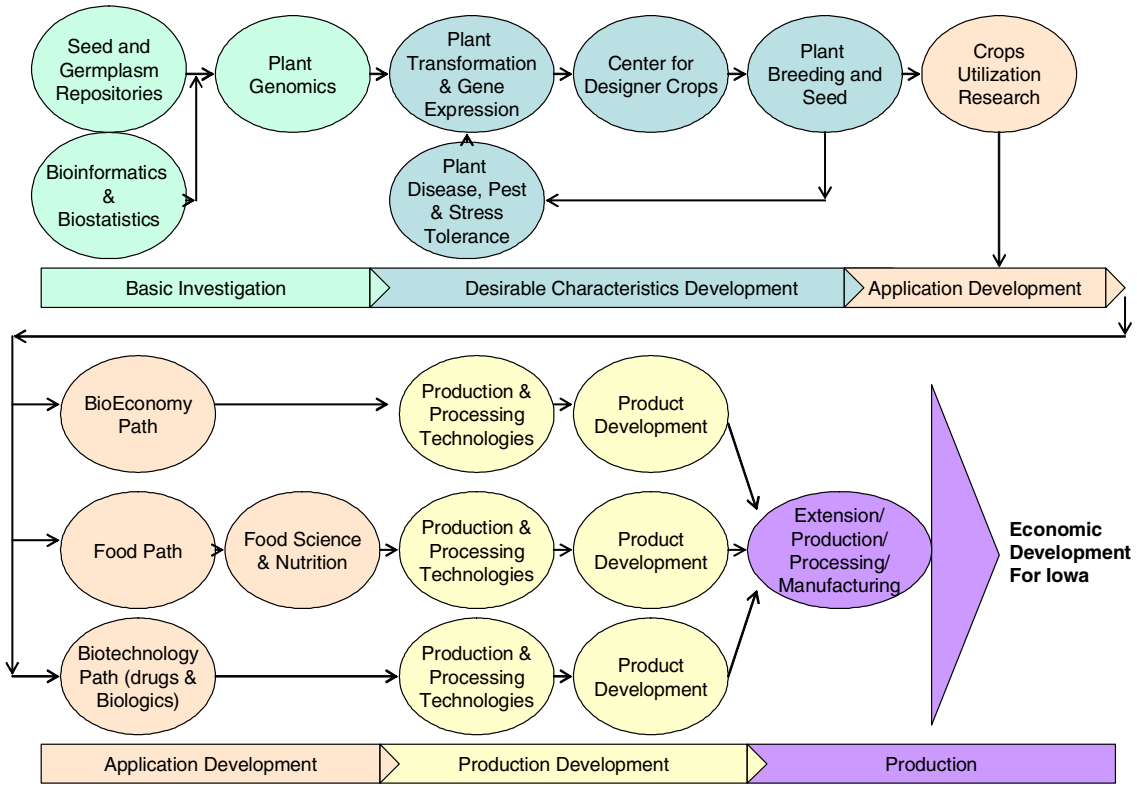
supported by additional centers and research institutes at Iowa State that can take the science output and direct it for optimal use in developing the BioEconomy. Examples of such pragmatic centers and supporting programs at Iowa State include

- **Center for Crops Utilization Research**—facilitating basic and applied mission-oriented research to find new uses for Midwestern crops and identify uses for potential crops (both food and non-food uses). The Center operates a Crop Products Pilot Plant including:
    - Wet pilot plant facilities
    - Dry pilot plant facilities
    - A hazardous solvents pilot plant
    - Fermentation facility
    - Sensor evaluation laboratory
    - Process development laboratory
    - Analytical services laboratory
    - Technology transfer pilot plant.
- **Center for Catalysis—**working on the catalytic chemistry of converting green feedstock's into BioEconomy products such as plastics and lubricants.
- **Center for Sustainable Environmental Technologies**—developing and demonstrating sustainable energy and environmental technologies, including the study of biomass-derived chemicals, fuel, and power. The Center has resources to specifically assist in the evaluation and scale-up of sustainable technologies, including
    - Fermentation reactor
    - Biomass gasifier, using biomass resources to generate heat and power
    - Virtual pilot plant (through ISU's Virtual Reality Application Center)
    - Biomass Energy Conversion Facility (BECON), a 12,000 sq. ft. research facility dedicated to pilot-scale testing of biomass-energy technologies.

These centers are interdisciplinary in their research and staffing and benefit not only from Iowa State's strong position in genomics and plant biosciences, but also the University's departmental strengths in chemistry, biochemistry, chemical engineering, and biosystems engineering. *The same pathway of basic through applied BioEconomy products also works at Iowa State for developing advanced food and nutrition products.*

The integrated approach to BioEconomy, Biotechnology, and Food Products R&D in Iowa is illustrated in Figure 23. It is evident that Iowa State University has put in place a structure well-suited for moving from basic science research to pragmatic commercializable products (assuming that the system is adequately funded, staffed, equipped, and organized).

Figure 23: Integrated Approach to BioEconomy, Biotechnology, and Food Products R&D in Iowa.



Within this basic structure of BioEconomy development in Iowa, both The University of Iowa and the University of Northern Iowa have contributions to make and expertise that should be engaged and integrated. The University of Iowa has considerable strengths in the biological sciences, bioinformatics, genomics, and proteomics. It also has the Center for Biocatalysis and Bioprocessing with skills and facilities directly relevant to the BioEconomy and biotech technology development paths, in addition to medical and health scientists with applicable skills to food science and nutrition. The Center for Biocatalysis and Bioprocessing at The University of Iowa is a unique facility and provides expertise relevant to both BioEconomy opportunities (in chemical catalysts and associated chemistry fields) and biotechnology opportunities (given established knowledge of, and facilities for, cGMP processes and practices).

Likewise, the University of Northern Iowa is making important contributions related to the BioEconomy. This is especially notable in the area of bio-based lubricants, where UNI operates the ABIL (Ag-Based Industrial Lubricants) research program. ABIL has more than a decade of operating experience in research and development of hydraulic and other industrial lubricants from soybean and other vegetable oils. The program receives support from state, federal, and private industrial partners. ABIL serves as a microcosm of the type of progress that may result in Iowa through BioEconomy research, development, and investment. Since its founding, ABIL discoveries have led to a portfolio of products commercialized by private industry, including

- Multi Grade Hydraulic Fluid
- Industrial Hydraulic Fluid

- Food-Grade Hydraulic Fluid
- Fifth Wheel Grease
- Chain Bar Oil
- Rail Curve Grease
- Food Grade Grease
- Cotton Picker Spindle Grease
- Viscosity Modifier/Property Enhancer
- Optimized Soybean Base Oils.

INTEGRATED DRUG DISCOVERY, DEVELOPMENT, PILOTING, AND PRODUCTION PLATFORM

Iowa has established piloting and production facilities within an academic research setting—The University of Iowa—that may form the basis of an integrated suite of piloting and production services for academia and industry. There is an opportunity to make this a more widely known and used technology platform as it represents a unique resource for bringing new drug discoveries from testing to market. Currently, there is a worldwide shortage of GMP quality facilities for the production of mid-scale volumes of drugs and biological preparations—the volumes required for clinical trials and for the production of orphan drugs. While there are contract commercial entities that service this market, there is likely to be an expanding shortage of facilities based on the large pipeline of compounds, drugs, and biologics starting to move into clinical trials.

The University of Iowa's Center for Advanced Drug Development (CADD) and the GMP production facilities of the Division of Pharmaceutical Services are fairly unique facilities in academe. Together these resources provide a substantive resource for drug development and production that is primarily used on a contract basis by small pharmaceutical and biotechnology companies located outside Iowa.

At the other end of the drugs pipeline, The University of Iowa has considerable breadth and depth in basic sciences research in a variety of medical disciplines. Work in cardiac and vascular systems, cancer, gastroenterology, neurology, and pulmonology, for example, could lead to discoveries of biological mechanisms that would be suited to drug screens.

The University of Iowa may be able to form an integrated pipeline of R&D for new drugs and biologics. It has the basic science, drug development, GMP production, and clinical trials structure required to conduct complete in-house projects. This would increase the likelihood of pharmaceutical and biotechnology companies forming and staying in the state. **One key element of an integrated pipeline, however, is missing —The University of Iowa lacks a drug discovery facility.**

By establishing a Drug Discovery Center, The University of Iowa would be equipped with a continuous model structure for facilitating the movement of basic science discoveries from the bench to the bedside. In combination with the University's identified strengths in genomics, and emerging strengths in proteomics and metabolomics, Iowa has almost all of the key required elements in place.

MARKET ANALYSIS

The ultimate goal for the State of Iowa in supporting the development of bioscience platforms is **economic development**. R&D, in and of itself, ***is*** economic development in that millions of dollars flow into Iowa each year from federal and other external funding sources to support research. These dollars, in turn, create jobs and income for Iowans in, and related to, the R&D sector. The goal of technology-based economic development, however, is to move into an integrated model where local research feeds a local commercialization and production cluster, thereby capturing increased value-added economic gains for the state from its R&D work. It is important, therefore, that the development of platforms be made with an eye to markets and commercialization opportunities related to each platform.

In this section, Battelle examines basic market forces and trends related to each of the key Iowa bioscience platforms.

Market Trends in the BioEconomy

The BioEconomy has been recognized by Iowa within its Iowa Industries of the Future program. The opportunity to convert agricultural crops and residues into biobased products and bioenergy presents entirely new value-added pathways for agriculture and industry in Iowa. Much of the opportunity for Iowa in the field has been detailed in the October 2002 report titled "Biobased Products and Bioenergy Vision and Roadmap for Iowa."[28] This report outlines potential markets for Iowa's biomass resources and sets realistic goals for progress. The BIOWA Development Association, an association composed of representatives from agriculture, industry and academe, has been formed to support and promote the growth and development of Iowa's Bioeconomy, an important step forward in generating progress in the sector.

Iowa is wise to pursue the opportunities presented in the BioEconomy. The Office of the Chief Economist at the USDA notes that biobased products potentially can compete in some truly huge markets.[29] For example,

- Lubricant sales is a $5.1 billion market
- Composite materials are a $14.6 billion market
- Paints and coatings represent a $43 billion market
- Plastics have a $77 billion market.

As the USDA notes, if the agricultural sector could capture between 5 and 10 percent of each of these markets, it would mean major gains in farm income and rural development in the United States. The above markets, of course, represent only part of a far larger opportunity for biorenewable resources in fuels and energy applications.

Power consumption has risen steadily in the United States during the past 50 years. According to the U.S. DOE, in 2001, the nation consumed 96.94 quadrillion Btu's of energy (approximately 18 times more than

[28] Iowa State University. "Biobased Products and Bioenergy Vision and Roadmap for Iowa." October, 2002. Available online at: http://www.ciras.iastate.edu/iof/pdf/IABioVisionRoadmap.pdf.
[29] Conway, Roger. "The USDA's Contribution to the President's Bioproduct and Bioenergy Initiative." Office of Energy Policy and New Uses. Office of the Chief Economist at the United States Department of Agriculture. Available online at: http://www.agbiotechnet.com/reports/nabc/nabc12/Conway.pdf.

consumed in 1950).[30] Energy consumption is projected to increase substantially by 2025, to 136.48 quadrillion Btu's. Consumption in 2003 was 98.08 quadrillion Btu's, of which only 5.98 quadrillion Btu's came from renewable energy sources (including biomass, hydroelectric power, solar power, wind power, and other renewable sources such as landfill gases and municipal wastes). Clearly there is a great opportunity, and national imperative, to reduce reliance on imported energy sources, which in 2003, was 30.53 quadrillion Btu's (over 25 quadrillion Btu's comprising crude oil and petroleum products).

Thirty-six percent of total energy consumption in the United States is used for manufacturing and other industrial purposes, 27 percent for operating the nation's transportation system, 20 percent for powering homes, and 16 percent for general businesses. Of all the oil consumed in the world in 1999, the United States accounted for 25.5 percent, according to the DOE. The powerful U.S. economy depends disproportionately on energy consumption, with the United States consuming

- 25.5 percent of world oil
- 26.9 percent of world natural gas
- 25.5 percent of world coal
- 30.4 percent of world nuclear energy.

The amount of power mined from fossil fuel sources in the United States is enormous, yet it is not enough to satisfy U.S. energy demand. For example, in 2000, Americans consumed 27.2 quadrillion more Btu's of fossil fuels than the United States produced. Crude oil, used for gasoline, diesel fuel, and a host of other products, is the most common form of energy imported into this country. Moreover, while energy demand is increasing in the United States, it also is projected to grow significantly throughout the world. The DOE's International Energy Outlook 2001 projects an increase in world energy consumption of 59 percent by 2020 (with much of the increase in demand occurring in developing nations).[31]

Eventually, the world's fossil fuels will run out, but before that happens the demand and supply curves will cross and price increases will force alternative energy sources to become more prominent. When these events will happen is the subject of considerable economic debate, but it eventually will happen and those economies that can supply renewable energy resources and technologies will be well-positioned for economic growth.

Freedonia Group foresees U.S. demand for fermentation chemicals to surpass $9 billion in 2007, with volume exceeding 30 billion pounds.[32] In terms of value and volume, the bulk of fermentation products is composed of ethanol for fuel usage, with production driven by environmental regulation, tax incentives, and the future ban on MTBE. While fuel is expected to remain the largest market segment for chemical fermentation products, other areas of bio-fermentation are also expected to grow:

- 1,3-propanediol (PDO) is an emerging new fermentation product for plastics and fibers
- Demand for Erythritol, a fermentation chemical used as an artificial sweetener in foods and beverage, is also expected to grow

[30] U.S. Department of Energy. "Energy Consumption by Sector and Source." Available online at: http://www.eia.doe.gov/oiaf/aeo/pdf/aeotab_2.pdf.
[31] Energy Information Administration (EIA). "Annual Energy Outlook 2001." DOE/EIA-0383(2001) (Washington, DC, December 2000).
[32] Freedonia Group. "Fermentation Chemicals to 2007 - Market Size, Market Share, Demand Forecast and Sales." Study #: 1662. May, 2003.

- Fermentation-based lactic acid (a primary feedstock) production is expected to grow with the rise in demand for polylactic acid-based biopolymer manufacturing
- Plastics and fibers are also predicted to experience double digit rapid growth through 2007
- Polylactic acid polymers reached the market in 2002, and POD polymers are forecasted to reach commercialization by 2007
- Natural polymer demand in the United States will grow by 6.4 percent annually through 2005.

According to the United Nations, the impact of the BioEconomy will increase in forthcoming years, spreading from the farm to the manufacturing sector.[33] Many of the products we currently touch, wear, and see are already produced, in one way or another, using biotechnology-derived reagents. The development of genetic engineering and recombinant DNA technology will lead to higher levels of productivity and economic viability.

The benefits of assuming leadership in the BioEconomy may be substantial for Iowa. According to the Institute for Decision Making at the University of Northern Iowa, a cluster of 10 biorefineries in the state would create 22,000 jobs, have an $11.6 billion economic impact, and generate $367 million in taxes.[34] These statistics are reinforced by the conclusions of BioEconomy Partners in New York, who found that one bioeconomy development initiative in California created more than 13,000 jobs, commercialized 250 new products, and led to the start-up of 45 new companies within a 5-year period.[35]

Market Trends in Advanced Food Products (Functional Foods and Nutriceuticals)

According to Decision Resources Market Research, by almost every measure, the markets for functional foods (defined as disease-fighting, whole or processed food products) and nutraceuticals (defined as bioactive ingredients and dietary supplements) are flourishing.[36] National Health Interview surveys show that retail sales of dietary supplements in the United States exceeded $10 billion in 1996, and consumption grew from 71 million users ten years ago to between 94 million and 130 million users by the close of the century.[37] Functional foods are far outpacing growth in the total food market; with nutritionally improved products accounting for 78 percent of total growth in more than 35 major food categories, according to Decision Resources Market Research.

Fry Foods International estimates the total market for functional foods in Japan, the United States, and Europe at approximately $38 billion.[38] Growth over the next five years has been estimated conservatively at 15 percent annually, while some predict the market will double. Functional foods is currently the largest growth area in the food industry.

The U.S. market for functional foods is still developing and also is evolving in a different way from Europe and Asia. Of particular interest are products that may improve the functioning of the immune

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[33] United Nations Conference on Trade & Development. "The New BioEconomy—Industrial and Environmental Biotechnology in Developing Countries." Ad Hoc Expert Group Meeting. Palais de Nations, Geneva. November, 2001.
[34] Iowa State University. "Biobased Products and Bioenergy Vision and Roadmap for Iowa." October, 2002. Available online at: http://www.ciras.iastate.edu/iof/pdf/IABioVisionRoadmap.pdf.
[35] BioEconomy Partners. http://www.bioeconomypartners.com/index.htm.
[36] Decision Resources Market Research. http://www.dresources.com/home.asp.
[37] Ibid.
[38] Fry Food Technologies International. "International Food Industry Trends—Functional Foods and Nutriceuticals." Available online at: http://www.fryfoodtech.com/images/trends.pdf.

To take full advantage of these technology platforms, Iowa's universities, private sector, and state government will need to address several gaps as well as seize opportunities outlined in the table below

Table 52: Platforms and Gap-Filling Needs and Opportunities.

Platform	Gap Filling Needs and Opportunities
BioEconomy Platform	• Fund, and scale up, the operations of the BIOWA Development Corporation. Build BIOWA into a fully staffed industry development association, linking o Iowa and non-Iowa BioEconomy industries o Existing and potential end-user companies for biorenewable commodity products and specialty products o Academic R&D and associated resources at Iowa State University, University of Northern Iowa, and The University of Iowa. • Develop, within BIOWA, subcommittees devoted to specific product line opportunity areas (markets), including but not limited to o Industrial Chemicals o Ethanol o Biodiesel o Hydrogen o Enzymes o Fibers o Carbohydrates (sugars, starches, glycogen) o Proteins. • Dedicate additional support and funding to the Iowa State University Plant Sciences Institute as the core driver of ag-based biomass development for the State. Director of the Plant Sciences Institute to be a BIOWA Executive Board member. • Place additional emphasis on R&D related to new processing technologies and projects to reduce the cost of bio-renewable products to be competitive with competing products (such as those that are petroleum based). Dedicate support and funding to Iowa State University to develop a BioEconomy Institute to serve as the umbrella organization for steering applied R&D in processing, engineering, product design, and production technologies. Place the key related ISU centers (Center for Crops Utilization Research, Center for Catalysis and Center for Sustainable Environmental Technologies) as core components of the Institute. Director of the ISU BioEconomy Institute to be a BIOWA Executive Board member. • Actively engage ISU ag-extension in BioEconomy production consulting with the Iowa farm sector, and in industrial extension consulting with potential processors and users of bio-renewable resources. Director of Iowa State Extension to be a BIOWA Executive Board member. • Invite and encourage relevant University of Iowa and University of Northern Iowa centers, institutes, and departments to be members of the Iowa BioEconomy Institute at ISU. It is especially important to include the expertise contained in UNI's Ag-Based Industrial Lubricants (ABIL) program and The University of Iowa's Center for Biocatalysis and Bioprocessing.

Platform	Gap Filling Needs and Opportunities
	• Develop and refine state incentive policies to encourage the active development of Biorefinery clusters in Iowa. • Actively promote Iowa as America's leader in biorenewables and BioEconomy development through a State-led marketing and promotions campaign and high visibility at key industry trade shows. • Organize a Midwestern States lobby for BioEconomy development purposes in lobbying the federal government. • Seek to develop a formal relationship with Canada's leading bio-renewables research and industry cluster in Saskatoon to leverage North American skills against growing European, Asian, and Latin American competition.
Integrated Drug Discovery, Development, Piloting and Production Platform	• Dedicate additional support and funding to build upon core strength areas at The University of Iowa, including the Center for Advanced Drug Development (CADD) and the GMP production facilities of the Division of Pharmaceutical Services. • Fund the development of a new Drug Discovery Center at The University of Iowa, thereby plugging a current resource gap and completing an integrated system for moving discoveries from bench to bedside. Iowa may be unique in having the opportunity to have a fully integrated "pipeline" of basic science research → drug discovery → drug development → pilot production → clinical trials → and drug production: all in-house at one major university. • Initial requirement for the new Drug Discovery Center is estimated at three full-time positions, plus instrumentation and equipment resources and development of compound libraries. • The University of Iowa may wish to appoint a Director of Pharmaceuticals and Biologics Development to guide the operations of The University of Iowa integrated drugs platform and further build and maintain close pharmaceutical and biotechnology industry linkages. • Areas of directly relevant strength at Iowa State University should be linked into The University of Iowa "pipeline." This would initially include ISU's expertise in veterinary medicine and combinatorial chemistry and the planned biologics production facility at the ISU research park.

Advanced Food Products Platform	• Iowa State University may wish to formalize its work in functional foods, nutraceuticals, and phytochemicals under a formal center or institute linked to existing platforms in plant and food animal sciences. Key programs to include would be Plant Genomics, Plant Transformation and Gene Expression, the Center for Designing Foods to Improve Nutrition, the NASA Food Technologies Commercial Space Center, and Food Science and Nutrition.
	• An Advanced Food Products Institute, based on Iowa's strengths, should likely concentrate on
	  ○ Value added Iowa transgenic crops expressing enhanced levels of beneficial nutrients, vitamins and phytochemicals
	  ○ Agricultural processing, separation and purification technologies for extracting beneficial nutrients, vitamins and phytochemicals from Iowa crops

Platform	Gap Filling Needs and Opportunities
	• Industry memberships in an Institute for Integrated Biosecurity should be encouraged, to help the potential development of a biosecurity industry cluster in Iowa. Initial focus should be on agricultural and processing equipment manufacturers and BioEconomy-related industry sectors.
Additional Gap Filling Activities & Opportunities	• Formation of a Host-Parasite Institute at The University of Iowa, linked to animal and plant biology expertise at Iowa State University could help build upon the emerging leadership of Iowa in this interesting medical and scientific field. • Formal funding should be considered for constructing and equipping a Cardiovascular Research Institute at The University of Iowa. This would anchor the strong base of existing research and development expertise of the University in cardiology, vascular systems, neuro-control and other related fields. A formal facility, allowing co-location of research scientists and clinician scientists along the lines of Iowa's Comprehensive Cancer Center, could foster significant advances. • A Free Radical Institute should be considered to formalize and facilitate interactions between the large base of scientists at The University of Iowa who are working in free radical biology. A few other states, such as Oklahoma, recently have recognized the importance of the study of free radicals and have formed formal centers. Iowa needs to cement its leadership position in the field and use an Institute to gain additional support and retain faculty excellence.

SUMMARY OF IOWA'S BIOSCIENCE TECHNOLOGY PLATFORM OBSERVED WEAKNESSES

While the goal of the core competency was to identify the key core research and technology competencies and platforms in biosciences, this review also served to highlight weaknesses and gaps that will also need to be addressed. The following were observed as general issues during the course of this study:

- Agricultural biosciences appear to have much higher legislative and public visibility in the state than human medical sciences. While it is good that agricultural bioscience is recognized for its significant value to the current and future health of the Iowa economy, attention also needs to be raised to the strong position of Iowa in human biosciences (where it actually holds higher rank in terms of research funding than it does in agriculture).
- Iowa higher education institutions appear to be making good attempts to link their research to the needs of industry in the state. However, these efforts are held back by a lack of a commercial base in many areas of biotechnology, pharmaceuticals, medical devices and even food processing.
- Research institutions vary in approaches to technology development, with Iowa State University demonstrating great flexibility in developing formal, institution-supported cross-disciplinary research institutes and centers—the type of structure best suited to modern scientific advancement and external funds attraction. The University of Iowa has developed a more traditional approach.
- State support for the Regent institutions has declined significantly during the last five years. The result has been predictable in terms of program cuts, faculty salary freezes, an inability to invest in new technologies and infrastructure and a general fear for the future among the Iowa education and

scientific community. At a time when higher education research institutions represent the best investment for a state, Iowa, for budgetary reasons, has had to lower, rather than increase, investment.

- There is an evident lack of pre-seed, seed and venture capital available in Iowa to fund new ventures in the biosciences. Lack of local capital resources is limiting entrepreneurship on campuses, reducing the volume of new innovation based companies in the state, and causing some of the companies that do spin-out of Iowa's universities to move out of the state closer to venture funding sources on the coasts.
- There is a lack of experienced bioscience entrepreneurs and managers who can fulfill management duties in new start-ups, or provide mentoring to new bioscience enterprises.
- There appears to be considerable variability in the level of commercialization and intellectual property protection services offered by Iowa's universities to their faculty. This variability in the ability to provide technology transfer support results from the fact that technology transfer services typically are funded by retained earnings from licensing successes or other "indirect" sources. Given the importance of technology transfer and commercialization operations to the future economic success of Iowa, it is very important that the major Iowa universities engaged in bioscience have sufficient resources to facilitate high performance in this area.
- Faculty in the state are confused as to what is expected of them in terms of faculty entrepreneurship, intellectual property generation and idea commercialization. Many feel that their traditional research and teaching roles are threatened by a perceived requirement to start and run companies. Reassurance needs to be provided that universities are expected to contribute to economic development as research and talent engines through the generation of commercializable discoveries, ideas, and a future work-force—not necessarily that the faculty themselves must be the founders and managers of any resulting commercial enterprises. A structure at each university is required that would relieve faculty of the burden of commercializing their concepts, whereby faculty can disclose their discoveries and have a team of university commercialization experts evaluate it, assess marketability, and ultimately form companies around the most viable concept. Faculty should be free to be investors and technical advisors to companies that their inventions promote, and to be as engaged in operations and management as their interests allow.
- The University of Northern Iowa is in a somewhat different position. The Iowa Board of Regents has agreed that UNI must actively participate in research related to academic niches, and the state provides $600 to faculty members each year to support their research. And, UNI has invested in facilities and scientific equipment. But the challenge for an institution like UNI, whose faculty have full-time teaching loads, is to find the time and resources to secure federal grants in the way other universities support their faculties' bioscience efforts. Iowa may want to consider providing incentive or "glue" funds to bioscience-related faculty at UNI that would allow them to leverage additional outside research dollars for financial support for bioscience research. A small amount of research funding annually for biotechnology, e.g., $300,000 made available on a competitive basis, might stimulate large potential returns for UNI.

THE COMMERCIALIZATION CHALLENGE: TRANSLATING CORE COMPETENCIES INTO IOWA ENTERPRISE

Critical to the translation of identified core competencies into the Iowa economy are the external elements that are participated in, but not controlled by, the universities. If maximum yield for the state's investment is to be achieved then it is important to understand and integrate these additional external elements. It will be important to evaluate strengths and weaknesses and make appropriate investments to fill in gaps. The issues and challenges are many.

Observations on Current Status—Interviews with start-up companies in Iowa indicate that venture capital is scarce. Further, many early stage companies are run by inventors who have little experience in managing or growing a biotech company. The key to success in a start-up biotech, biomed or ag-biotech company, or any company, is knowing what to do. If the CEO does the wrong thing in a start-up company it often causes the company to fail. There is little room for error when money is tight. The past two years in the U.S. have been difficult times for acquiring investment capital. Previously it was easier to obtain funding and entrepreneurs had more room to move around and learn while they were building their business. Those circumstances may return, but for now investors require clear product pathways with proven management leadership to obtain funding. CEOs that have experience and have guided this process successfully before have little reason to move to Iowa unless they are given adequate incentives. One strategy may be to search for alumni who have been successful entrepreneurs elsewhere. It may be possible to recruit them to return to the state where they grew up or were educated. Investors will have a particularly difficult time believing that the biotech or pharmaceutical industries can grow and flourish in Iowa until several successful companies emerge and are able to grow in the state.

Human Therapy Product Companies—The biotech facts of life are that human therapy product companies (generally this is pharmaceuticals or biomedical devices) command ten times more attention from investors than agricultural biotech companies because of the huge potential product sales. Even though the pathway for products generally includes long regulatory approvals, there is potential for investors to realize a large multiple on their investment when the drug or device comes to market or when a large pharmaceutical company acquires the company. A skilled CEO in the bio arena can use significant events or milestones to attract more and more funding into a promising, growth company. No real history of human therapy product companies exists in Iowa. Some start-ups are located in the state but are failing to grow at an acceptable pace due to lack of investment capital or inexperienced management. If there is a strong desire to change that dynamic it will require skillful and patient investment by the universities involved, by the private sector, and by state and local governments.

Ag Biotech Companies—There is great opportunity in Iowa for this kind of technology-based business. The challenge in this market sector is finding a technology that has a compelling enough story to command investors' attention. The key here is size and accessibility of markets as well as how quickly products can be brought to market. Iowa has the potential to dominate in commercialization of the BioEconomy Platform that has been identified. The products from this platform can fill the pipeline for new start-ups and existing mid-sized and even large companies. Universities will have to become closer in relationships to industry and be willing to work out new relationships that will benefit both. The bio-fuel, biomaterials, and bio-based lubricants products that are being commercialized now in Iowa are examples of this kind of activity. These entities could provide early successes that the State of Iowa needs in order to develop a track record.

All three universities (Iowa State, The University of Iowa and the University of Northern Iowa) have new initiatives to build stronger bridges to the private sector. Iowa State has strong liaison personnel at the Research Park and the Carver Co-Lab. The University of Iowa has made new commitments to economic development (including a special economic development appointment within the College of Medicine), while the University of Northern Iowa has a skilled economic development advisor to the President who has developed several important initiatives. All of these efforts are timely and commendable, but need bolstering and further financial support if the hope of the state is to convert the products of its core competencies into economic value for Iowa.

Real estate is a small component of a successful start-up business plan (often in the form of incubators). What is much more important is the quality of management that can be attracted, or the quality of business mentoring that can be made available to less experienced entrepreneurs. There is also no substitute for money. Lack of capital will starve any activity that is started in biotechnology commercialization. The Pappajohn Centers are excellent but are insufficient by themselves.

Present Status of Technology Transfer—Start-up companies exist around all three Regent universities in the state. To be successful in creating more start-up companies in the future will require that the universities be rewarded for licensing to start-ups.

One larger Iowa company (350 employees) has spun out of The University of Iowa's Biochemistry Department and a former professor of biochemistry runs the company today. This is a good start, but the future will require many of these successes to convince investors to invest in Iowa biomedical start-ups. Platform technologies in Drug Discovery, Development, Piloting, Trials and Production and in Integrated Post-Genomic Medicine may create patents that can be licensed to a new group of start-ups. Infrastructure for this kind of economic development is yet to be put in place in Iowa.

In interviews, larger bio-related companies in the state have indicated a strong reliance on Iowa's universities for recruiting new employees. Many of these companies also sponsor research programs in the universities. Most are funding graduate student research as good corporate citizens—not anticipating that they will benefit directly. One company indicated that they had built a major division of their operations in Iowa because of the expertise of Iowa State University and the College of Veterinary Medicine. Another company had a highly proprietary project being funded at Iowa State because of the expertise of the principal investigator.

COMPETITION IN BIOSCIENCE DEVELOPMENT

Other states and regions are aggressively pursuing life science development.

Other states are investing aggressively in a comprehensive range of bioscience programs to promote research and commercialization. A number of states also are aggressively pursuing bioscience development strategies, including strengthening research, increasing university-industry collaborations, and enhancing their business development support.

Examples of bioscience investments over the last few years include the following:

- California is investing $100 million in a bioengineering and biotechnology institute, and $500 million in pension funds toward the California Biotechnology Program.
- Pennsylvania has committed to invest $2 billion over a 20-year period in the biosciences including $100 million specifically for the Life Sciences Greenhouses initiative.

- Michigan, through its Life Sciences Corridor initiative, initially planned to invest $1 billion in the biosciences over a twenty-year period. However, this investment level may be scaled back due to programmatic modifications and budgetary concerns.
- Georgia has invested more than $300 million over a ten-year period to build core research facilities and to attract Eminent Scholars, the majority of whom are in the biosciences; and has created a $1 billion Georgia Cancer Coalition designed to make Georgia a national leader in cancer prevention, treatment, and research.
- Texas appropriated $800 million for seven new or expanded health science research centers.

Other states and regions of the country have allocated more state funding and secured significant federal dollars as the NIH budget has nearly doubled in the last several years. For example, as many as 41 states report technology initiatives that support the development of bioscience research and/or bioscience companies.[65]

[65] See Biotechnology Industry Organization, *State Initiatives in Biotechnology 2001*, September 2001.

Conclusion

The biosciences have been identified as the underlying technology platform for the growth of state and regional economies in the coming decades. States are realizing that their traditional economic bases may undergo significant change and increasingly are embracing the biosciences as a path to future economic progress. States such as Michigan, Pennsylvania and Wisconsin have recognized the opportunity to leverage their academic and non-profit bioscience research institutions to form growth hubs of innovation in this dramatically advancing field.

Significant bioscience economic activities in several specific technology platform areas are already showing promise—some of which have already begun to be mobilized as formal initiatives in the state and others that need to be further supported and built-up. These **near-term platforms** include:

- **BioEconomy—**Designing initiatives to make Iowa a leader in the application of bio-renewable resources to industrial commodities, products, and energy.
- **Drug Discovery, Development, Piloting, Trials and Production**—Leveraging Iowa's basic science and applied clinical research expertise in human medicine (and perhaps veterinary medicine) and proven track record in drug development and production services, into a vertically integrated pipeline of discovery and commercialization.
- **Advanced Food Products**—Leveraging skills in informatics, genomics, genomic transformation, metabolomics, nutrition, and food science to attain a leadership position in functional foods, phytochemicals, and nutraceuticals.
- **Integrated Post-Genomic Medicine**—Leveraging informatics, genomics, epidemiology and pathology, in combination with specific disease strengths, to create centers of excellence based on quantitative discovery and longitudinal data.
- **Animal Systems**—Using Iowa's skills in transgenics, animal genomics, food animal science, and biological sciences to develop a platform for the development and production of designer animals for gene/protein expression, xenotransplantation, and improved meat quality and productivity.
- **Integrated Biosecurity**—Building upon Iowa's proven strengths in plant, animal, and human infectious diseases, together with broad skills in agronomy, environmental sciences, engineering and other disciplines, to develop a holistic approach to the biosecurity of entire systems.

Additional **long-term** opportunities have been further identified in the following areas:

- **Host-Parasite Biology and Systems**
- **Instrumentation, Sensors and Devices**
- **Cardiovascular Institute**
- **Free Radical Institute.**

This assessment of Iowa's position in the biosciences highlights a state that has significant promise to be among the nation's bioscience leaders in selective fields. Iowa institutions have quite substantial strengths in the "three legs of the bioscience stool"— human, animal, and plant biosciences. In particular, the bioscience operations of both Iowa State University and The University of Iowa show fundamental

bioscience technology platform strengths that can be further enhanced by increased collaborations between the institutions and with industry.