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The Emergence of Biotechnology in the State of Mississippi: A Review

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THE EMERGENCE OF BIOTECHNOLOGY IN THE STATE OF MISSISSIPPI: A REVIEW

By
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A Thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

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Approved by

Advisor: Dr. Fred Dorn

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Reader: Dr. Ken Cyree

DEDICATION

For Mom, Dad and GA.
Without their support and encouragement
the completion of this thesis would not have
been possible.

ACKNOWLEDGEMENTS

After over a year of work with one goal in mind – to finish this thesis – I have several outstanding people to think. First and foremost, I want to acknowledge my parents and family—without their support, the completion of this task would not have been possible.

I owe many thanks to Dr. Fred Dorn, my advisor, who has offered continuous support and guidance. Without his deliberate optimism, my persistence would have long since ceased. I feel fortunate to have had the opportunity to have Dr. Dorn as a professor in the classroom and an honors thesis advisor, outside of the requisite Business School curriculum. He truly is a gifted professor who gives so much of himself for the benefit of his students. In addition, I would like to recognize Allyson Best of the National Center for Natural Products Research for giving so generously of her time.

All of these people and many, many more have contributed to the completion of a thesis I am proud to say I finished. Lastly, I would like to thank God my Father—to Him be the glory in all that I do.

ABSTRACT

This publication was written with the intention of performing an analysis of the present in-state bioscience initiative and subsequent Mississippi industry incumbents. Hopefully, this publication will be employed as an informative tool to Mississippi residents, universities, policy makers and private corporations considering investment in research and development in the state of Mississippi.

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Foreword

Although many researchers in the industry define biotechnology as the use of a recombinant DNA technique to synthesize proteins, for the purpose of this publication, the term "biotechnology" refers to the use of living organisms or their products to modify the human environment, particularly for the purpose of improving human health.

The use of recombinant DNA in the biotechnology industry did not emerge until the late 1970's, and more than two hundred new therapies and vaccines are now on the market, including cancer treatment products, along with diabetes and HIV treatments. In addition, more than four hundred drug products and vaccines are currently undergoing clinical trials. Biotechnology is also the basis of hundreds of medical diagnostic tests that insure a safe blood supply.

Although agricultural and aquaculture biotechnology directly benefits farmers, human consumers and the environment are the ultimate beneficiaries of biotech-enabled efficient agriculture and aquaculture techniques. In addition, environmental biotech products have increased the efficiency of hazardous materials clean-up through means such as harnessing pollution-eating microbes. The industrial applications of biotechnology continue to lead to the development of cleaner, more efficient manufacturing processes. Most laundry detergents developed in the United States contain biotech developed enzymes. DNA fingerprinting is a biotechnology process that has significantly improved the areas of forensics in criminal investigations, as well as anthropology and wildlife management.

As the biotech industry produces products for human consumption, it is regulated by the Food and Drug Administration and the Department of Agriculture, along with the

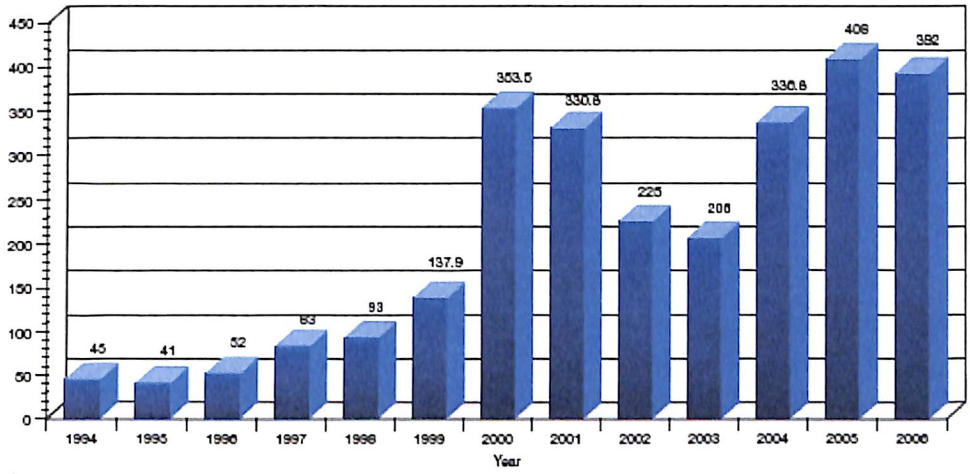
Environmental Protection Agency. As of January 2007, there were 1,452 biotech companies in the United States, 336 of which were publicly traded corporations. The total value of those publicly traded biotech companies was $360 Billion, as of April 2008. According to Ernst and Young, in 1992, the U.S. health care publicly traded biotech companies revenues of $8 billion had risen to $58.8 billion in 2006, spending a collective total of $27.1 billion on new research and development.

The large amounts of research and development expenditures have led to the necessity of corporate partnering for biotech companies' success. In 2007, the collective biotech industry struck 417 new partnerships with pharmaceutical companies, on top of 473 deals with other biotech companies. In 2004, the U.S. bioscience industry, including all life-science activities, employed 1.2 million individuals and indirectly generated an additional 5.8 million industry- related jobs in the United States.

The following graphs illustrate the U.S. Market capitalization and biotech industry statistics from 1994-2006. Amounts are in billions of U.S.

dollars[1]:

Market Capitalization, 1994–2006*



Sources:
Ernst & Young LLP**

U.S. Biotech Industry Statistics: 1994–2006*

Year	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994
Sales	45.3	39.7	28.1	28.4	24.3	21.4	19.3	16.1	14.5	13	10.8	9.3	7.7
Revenues	53.5	48.5	43.8	39.2	29.6	29.6	26.7	22.3	20.2	17.4	14.6	12.7	11.2
R&D Expense	22.9	16.6	19.6	17.9	20.5	15.7	14.2	10.7	10.6	9.0	7.9	7.7	7.0
Net Loss	3.5	1.4	6.8	5.4	9.4	4.6	5.6	4.4	4.1	4.5	4.6	4.1	3.6
No. of Public Companies	336	331	331	314	318	342	339	300	316	317	294	260	265
No. of Companies	1,452	1,475	1,346	1,479	1,466	1,457	1,379	1,273	1,311	1,274	1,287	1,308	1,311

Source:
Ernst & Young LLP, annual biotechnology industry reports, 1995–2006. Financial data based primarily on fiscal-year financial statements of publicly traded companies.**

*Amounts are U.S. dollars in billions.

In light of the increasing significance of the biotech industry in the U.S. economy, Mississippi governor Haley Barbour formed Momentum Mississippi in 2005 to promote the implementation of Blueprint Mississippi, "a strategic plan that identified the number of recommendations for promoting economic growth," primarily including an "increase in private R&D funding and improved effectiveness of technology transfer and capital

[1] Biotechnology Industry Organization. "Biotechnology Industry Facts." 2 Feb. 2009. <http://bio.org/speeches/ pubs/er/statistics.asp?p=yes>.

accessibility to help commercialize innovations." In addition, Barbour emphasized the necessity of the Mississippi Technology Alliance (MTA), a non-profit organization with the mission to "champion innovation and technology-based economic development for the state of Mississippi."[2]

The Mississippi Seed Fund was created by the Mississippi Technology Alliance in order to provide high-tech, start-up companies with pre-seed financing as well as early stage risk capital and product development capital in hopes of stimulating and accelerating the development of technology-based business ventures in the state of Mississippi.[3] The Seed Fund offers three different types of funding: The Research and Development Fund, The New Technology Business Fund and the Rural Innovation Fund.

While the Research and Development Fund provides funding for any small Mississippi company, companies seeking funding through the New Technology Business Fund must be currently engaged in a development stage prior to production. "This is further defined as any stage from idea conceptualization up to, and prior to, established and steady market sales,"[4] suggesting that the firms are in the developmental and prototype stages of their product's life cycle. The Rural Innovation Fund provides assistance to any small company located in a rural area in the state of Mississippi.

Eligible applicants for funding must be involved in the commercialization of advanced technology. Some examples of industries assisted by the Mississippi Seed Fund program include: life sciences, information technologies, communications technologies, aerospace, electronics and related fields, materials, robotics, medical

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[2] Mississippi Bioscience Initiatives. "Overview and Summary of Recent Initiatives." 2 Feb. 2009. <>.
[3] Mississippi Technology Alliance. "Mississippi Seed Fund". < http://www.technologyalliance.ms/seed-fund/>.
[4] Mississippi Technology Alliance. "Mississippi Seed Fund." < http://www.technologyalliance.ms/seed-fund/>.

devices and instruments, telecommunications, agri-sciences and energy services. The MTA is interested in firms whose products will have a significant competitive advantage in the marketplace and possess the potential for significant growth, relative to the national industry sector.

The following table expresses biotech industry subsectors of the state of Mississippi relative to total U.S. Industry in 2006, including the percent changes from 2001—

2006[i]:

Bioscience Industry Base, 2006

Industry Subsector	Mississippi		United States	
	2006	2001–06 Change	2006	2001–06 Change
Agricultural Feedstock & Chemicals				
Establishments	21	-5.6%	2,183	3.8%
Employment	1,237	-20.6%	105,846	-6.1%
Location Quotient	1.49		n.a.	
Direct-Effect Employment Multiplier	5.46		11.22	
Total Employment Impact	6,758		1,214,709	
Average Annual Wage	$43,512		$67,870	
Drugs & Pharmaceuticals				
Establishments	18	38.5%	2,654	1.9%
Employment	1,164	1.0%	317,149	4.0%
Location Quotient	0.47		n.a.	
Direct-Effect Employment Multiplier	3.36		9.92	
Total Employment Impact	3,908		2,880,242	
Average Annual Wage	$35,304		$86,892	
Medical Devices & Equipment				
Establishments	82	-3.7%	15,215	0.3%
Employment	828	-24.0%	422,993	-0.9%
Location Quotient	0.25		n.a.	
Direct-Effect Employment Multiplier	2.15		4.85	
Total Employment Impact	1,782		1,980,128	
Average Annual Wage	$31,298		$59,441	
Research, Testing, & Medical Laboratories				
Establishments	122	33.3%	22,857	32.7%
Employment	843	-9.9%	449,991	17.8%
Location Quotient	0.24		n.a.	
Direct-Effect Employment Multiplier	1.95		3.25	
Total Employment Impact	1,645		1,440,500	
Average Annual Wage	$42,260		$71,284	
Total Private Sector				
Establishments	64,687	8.4%	8,575,730	10.2%
Employment	889,931	0.6%	113,463,842	3.1%
Average Annual Wage	$30,641		$42,272	

Note: n.a. = metric is not applicable.

The following table offers a more specific breakdown of Mississippi bioscience-related performance metrics, including the state's relative national ranking:[ii]

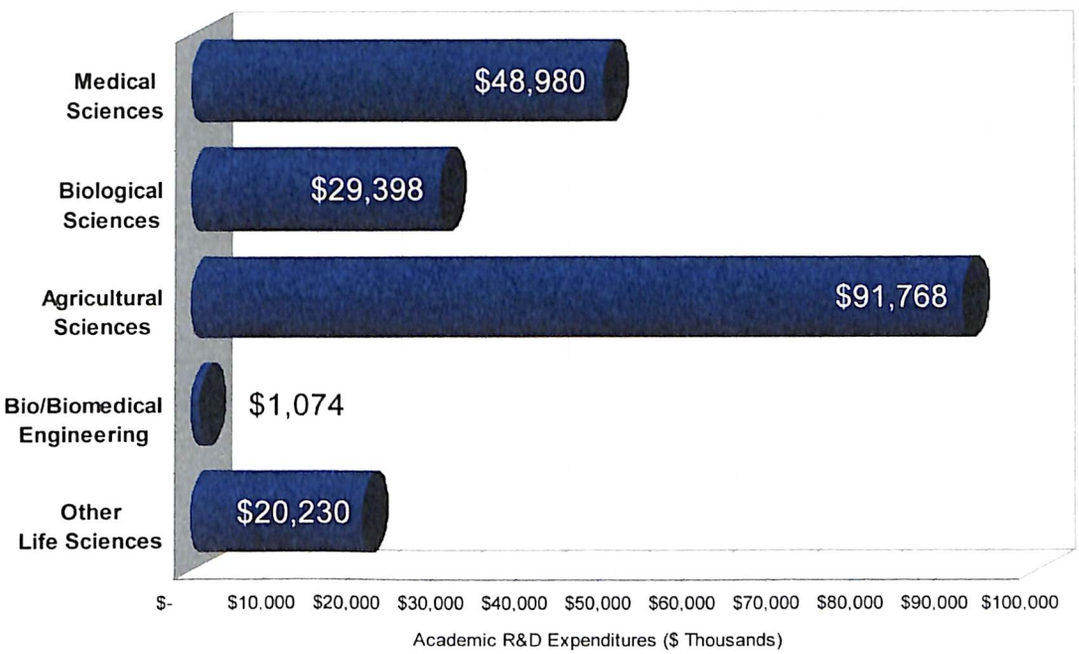
Additional Bioscience Performance Metrics

Summary of State Performance in Selected Bioscience-related Metrics

	Mississippi	United States	Rank
Academic R&D Expenditures, FY 2006			
Total ($ thousands)	$369,143	$47,760,402	32
Bioscience R&D ($ thousands)	$191,450	$29,307,628	33
Bioscience Share of Total R&D	51.9%	61.4%	
Bioscience R&D Per Capita	$66.04	$98.10	
Change in Bioscience R&D FY 2002–2006	47.1%	36.9%	
NIH Funding, FY 2007			
Total ($ thousands)	$27,914	$21,066,389	45
Per Capita Funding	$9.56	$69.84	
Change in Funding, FY 2002–2007	-18.3%	11.2%	
Higher Education Degrees in Bioscience Fields, AY 2006	1,316	143,433	34
Employment in Bioscience-related Occupations, 2006	4,390	588,520	35
Bioscience Venture Capital Investments, 2002-2007 ($ millions)	$11.4	$51,260.9	41
Bioscience and Related Patents, 2002-2007	267	121,817	42

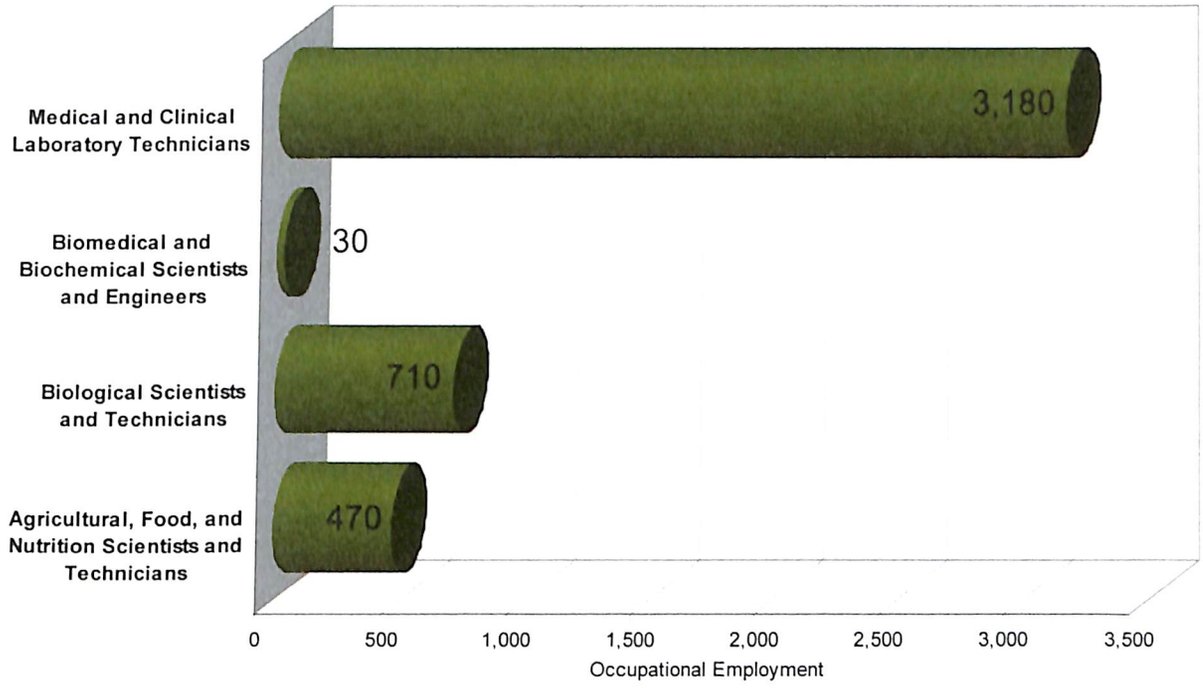
The following graph illustrates the bioscience academic R&D expenditures in Mississippi in 2006[iii]:

Bioscience Academic R&D Expenditures in Mississippi, FY 2006



The following graph illustrates the bioscience-related occupational employment in Mississippi in 2006[iv]:

Bioscience-related Occupational Employment in Mississippi, 2006

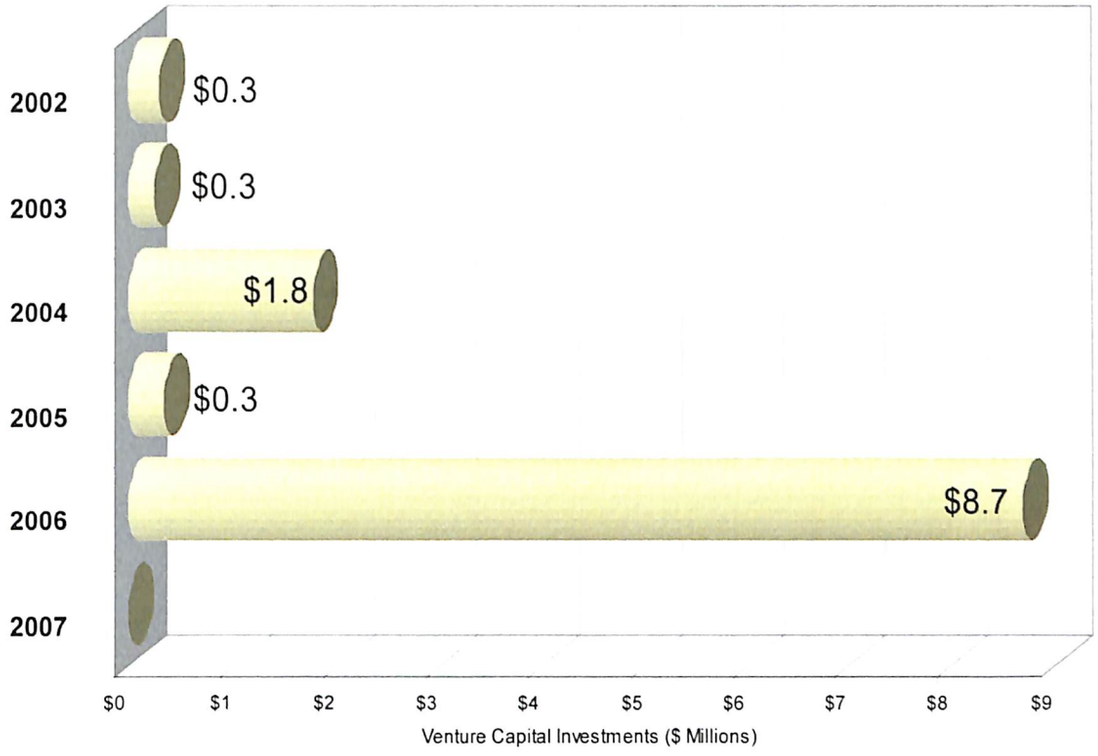


It should be noted that the label in the above graph, "Agricultural, Food, and Nutrition Scientists and Technicians," also includes aquaculture.

The Following Graph illustrates the overall bio-science related venture capital investments in Mississippi from 2002—2007[v]:

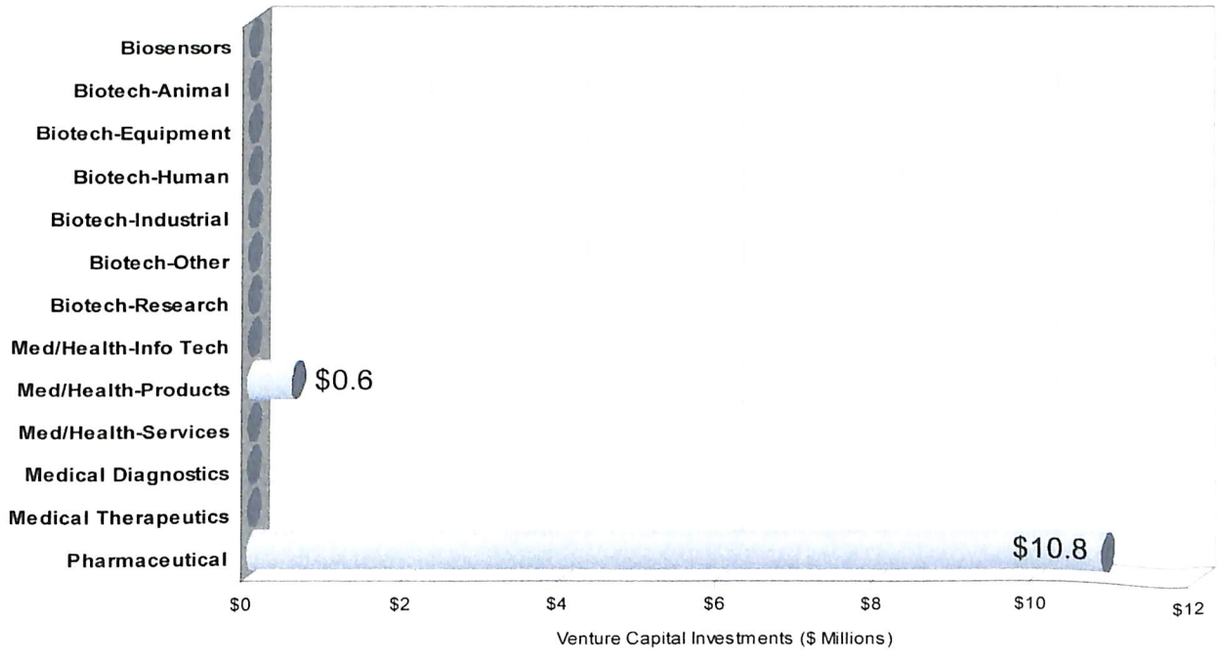
Bioscience Venture Capital

Bioscience-related Venture Capital Investments in Mississippi, 2002–2007



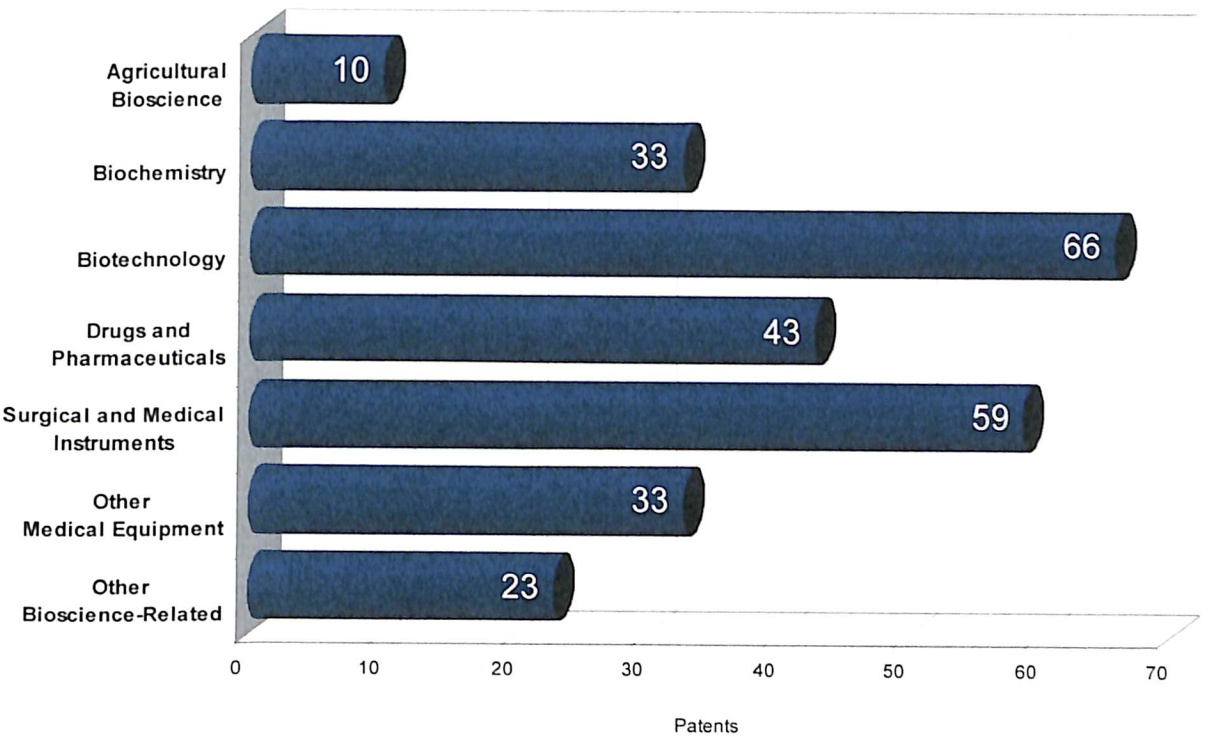
Whereas the graph below illustrates the bioscience-related venture capital investments in Mississippi by specific industry segments from 2002—2007[vi]:

Bioscience-related Venture Capital Investments in Mississippi by Segment, 2002–2007



The following graph depicts the bioscience-related patents by classification group in Mississippi from 2002—2007[vii]:

Bioscience-related Patents by Classification Group in Mississippi, 2002–2007



The bioscience industry is a vital sector of the state's economy, providing 889,931 jobs in the private sector with an average annual wage of $30,641. The direct-effect employment multiplier is indicative of the total household earnings generated by an initial one dollar fluctuation in household earnings. The direct-effect employment multiplier allows for the determination of the change in total earnings in the economy of a particular region by multiplying the initial change in earnings by the multiplier. In other words, "the direct-effect employment multiplier shows the total number of jobs per initial change in jobs. An estimate of the change in total number of jobs in a region's

economy is calculated by multiplying the initial change in jobs times the direct employment multiplier."[5]

The direct-effect employment multipliers in the "Bioscience Industry Base, 2006" table above enable the calculation of the total employment impact in the state of Mississippi.

- In the "Agricultural Feedstock and Chemicals" subsector, the direct employment of 1,237 individuals multiplied by the direct-effect employment multiplier yields a total employment impact of 6,758, indicative of the generation of 6,758 additional jobs in the state.
- In the "Drugs and Pharmaceuticals" subsector the direct employment of 1,164 individuals multiplied by the direct-effect employment multiplier equals a total employment impact of 3,908—the generation of 3,908 additional jobs.
- In the "Medical Devices and Equipment" subsector, the direct employment of 828 individuals multiplied by the direct-effect employment multiplier generates a total economic impact of 1,782, or 1,782 additional in-state jobs.
- Similarly, the direct employment of 122 individuals in the "Research, Testing, and Medical Laboratories" subsector multiplied by the direct-effect employment multiplier of 1.95 yields a total economic impact of 1,645, or the generation of 1,645 additional jobs in the state of Mississippi.

The National Institute of Health (NIH) is an agency in the Department of Health and Human Services whose mission is to employ the sciences in the pursuit of knowledge

[5] Bureau of Economic Analysis. "Regional Economic Accounts." 25 May, 2009. < https://www.bea.gov/regional/rims/rimsii/help.aspx>.

to improve human health.[6] It is the primary biomedical research agency of the federal government. Organizations within the state will receive funding based on the NIH's analysis of the projected generated health-research impact of the apportioned funding. The presence of pre-established facilities increases the attractiveness of the state to the NIH regarding the allocation of grants.

Although the state of Mississippi ranked 33rd in the U.S. for the total "Bioscience R&D Academic Expenditures," in 2006 according to the "Summary of State Performance in Selected Bioscience-related Metrics" above, the state ranked a relatively low 45th in terms of state receipts of NIH Funding in 2007. Furthermore, as the national trend from 2002 – 2007 is indicative of an increase in overall NIH receipts, the state of Mississippi saw a net decrease of 18.3% in NIH support. In order for the state to see an increase in the influx of NIH funding, the timely pursuit of the construction and expansion of research parks at state universities is imperative, regardless of the present state of the economy.

Although the amount received from the National Institute of Health was relatively lower in 2007, the allocated $36 million was responsible for the generation of $69 million of state economic activity and the generation of 627 new jobs, due to the high direct-effect employment multiplier of 1.9, which is typical of bioscience related capacities.[7] A decrease in NIH funding is detrimental to the state's economy.

Beyond industry and product development, in the agriculture sector alone, the employment of biotech seeds by farmers in the state theoretically generates a savings of

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[6] U.S. Department of Health and Human Services. National Institute of Health. "About NIH." 25, May 2007. <http://www.nih.gov/about/NIHoverview.html>.

[7] Family's USA Global Health Initiative. "In Our Own Backyard." June 2008. 26 April, 2009. <http://www.familiesusa.org/assets/pdfs/global-health/in-your-own-backyard.pdf>.

$86.369 million dollars annually based on the total statewide cultivated acreage of corn and cotton—630,000 acres of corn and 300,000 acres of cotton.[8] Before the advent of biotech seeds, cotton cultivation typically required the following annual planted-crop applications:

- 6 applications of weed control herbicide
- Between 10 and 14 applications of bollworm, budworm and armyworm insecticides
- 6 applications of boll weevil insecticide

The net result of 19 to 26 annual applications of chemicals on a cotton field required multiple laborers and labor hours, gallons of chemicals, machine hours and consequential excessive fuel consumption. The utilization of biotech cotton seeds has enabled farmers to reduce the number of chemical applications by 15. Factoring in the costs of total requisite activities and expenses per application, Monsanto representative farmers approximate the total cost of application per acre is $11.15. Thus, reducing the applications by 15 through the use of biotech cotton saves Mississippi farmers approximately $167.25 per acre.[9] A similar analysis for the use of biotech seeds for corn cultivation generates a net savings of $57.45 per acre. The environmental benefit as a result of a large-scale reduction in herbicide and pesticide application should also be noted.

As the agriculture and aquaculture industries comprise a significant portion of the state's economy, Mississippi offers investors interested in the field of biotechnology a

[8] Robinson, Elton. Western Farm Press. "Producers to plant lowest cotton acreage in 26 years." 21, May 2009. < http://westernfarmpress.com/cotton/cotton-production-0402/>.
[9] Monsanto. "Different Applications for Genetically Modified Crops: Prepared Remarks of Mr. Thomas H. Dollar." 22, May 2009. < http://www.monsanto.co.uk/news/ukshowlib.phtml?uid=9148>.

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[9] Monsanto. "Different Applications for Genetically Modified Crops: Prepared Remarks of Mr. Thomas H. Dollar." 22, May 2009. < http://www.monsanto.co.uk/news/ukshowlib.phtml?uid=9148>.

unique three prong perspective: agriculture, aquaculture and bio-science pharmaceutical research. Whether funded through federal or state grants or private entities, the majority of research takes place on some level through the state universities.

I. Mississippi State University

Mississippi State University is home to the Division of Agriculture, Forestry and Veterinary Medicine, which is comprised of six major units: the College of Agriculture and Life Sciences, the College of Forest Resources, the College of Veterinary Medicine, the Forest and Wildlife Research Center, the Mississippi Agricultural and Forestry Experiment Station and the MSU Extension Service. Also part of the university's Division of Agriculture, Forestry and Veterinary Medicine is the Life Sciences and Biology Institute (LSBI), which was created in part to "attract financial and intellectual capital to Mississippi that will improve economic development through the commercialization of new, enhanced biotechnology products," as well as to "promote scientific research and education that meets the needs of society and further enhances the unique strengths of [the] university."[10]

A division of the LSBI, the Department of Plant and Soil Science's Mississippi Genome Exploration Laboratory's (MGEL) mission is in part to "help sustain, protect, and improve world agriculture and forestry...and [to] discover and characterize economic and adaptive genes of agricultural organisms."[11] In 2004 a group of MGEL scientists lead by Daniel G. Peterson received a grant from the Plant Genome Research Program (PGRP) of the National Science Foundation to participate in a multi-institutional project, involving the eventual mapping of the loblolly pine genome.[12] The *Accelerating Pine Genomics* (APG) project has been instrumental in generating the physical mapping and

[10] Life Sciences and Biotechnology Institute, Mississippi State University. "Mission". <http://www.lsbi.mafes. msstate.edu/>.
[11] Mississippi Genome Exploration Laboratory. "Mission". <http://www.mgel.msstate.edu/mission.htm>.
[12] Mississippi Genome Exploration Laboratory. "Accelerating Pine Genomics". <http://www.mgel.msstate. edu/apg.htm>.

sequencing of the loblolly pine genome, providing critical information for the protection of the pines, as well as other forest trees whose preservation is essential to raw material and energy production and conservation. Loblolly pines are an economically important resource to the state. Through preserving and improving forestry yields, the APG hopes to facilitate the developing realization of conifers as "bioenergy feedstocks."[13]

The U.S. Department of Energy (DOE) recently announced in May that it would be contracting MGEL's Daniel G. Peterson to sequence 100 additional loblolly pine BAC clones. BAC clones, bacterial artificial chromosomes, are a cloning vector developed from artificial DNA constructs.[14]

Aquaculture

As a part of the Division of Agriculture, Forestry and Veterinary Medicine, the Mississippi State University National Warmwater Aquaculture Center (NWAC) in Stoneville, MS was developed to provide solutions to the aquaculture industry through applied research, in hopes of promoting the growth of the Mississippi economy. As channel catfish production and its related service industries contribute more than two billion dollars to the state's economy each year, aquaculture development is of utmost importance to the state of Mississippi. In northeast Mississippi, the Delta is in a unique position to take advantage of the increasing demand for aquaculture products, namely catfish. The NWAC seeks to solve short term problems as well as conduct research to develop solutions to problems that threaten the long-term viability of the aquaculture industry.

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[13] Accelerating Pine Genomics. "Long-Term Goals". <http://www.pine.msstate.edu/overview.htm>.
[14] O'Connor, M., M. Peifer, and W. Bender. 1989. Construction of large DNA segments in Escherichia coli. Science 244:1307-1312.

The NWAC research is divided into several divisions in order to solve both the short term and long-range problems facing the aquaculture industry. Researchers of the Nutrition and Feeding division seek to develop lower cost and higher efficiency feeding methods for catfish, while simultaneously optimizing nutrition. The Production Practices and Water Quality division seeks to improve production through the development of better managerial practices. The USDA Agricultural Research Service, Catfish Genetics Research Unit aims to improve catfish production through developing improved strains of catfish. The division of Applied Fish Health seeks to develop management strategies to optimize fish health and minimize the impact of disease on the catfish population, while the division of Disease Diagnostics seeks to provide a comprehensive disease diagnostic service, investigating the causes of emerging diseases. The Physiology and Behavior division studies the physiological side of stress and recovery, spawning behavior, energy use and swimming performance in different catfish species. The NWAC also has an entire division dedicated to the research of increasing harvest and catfish grade through the improvement of conventional gear and technologies.[15]

The U.S. Department of Agriculture partnered with Mississippi State University in 1986, developing the Catfish Genetics Research Unit at the NWAC, to insure the continued success in production of the catfish industry, realizing the large economic contribution of the aquaculture industry.[16] An example of a recent ARS Catfish Genetics Research Unit development at the NWAC in conjunction with the ARS National

[15] Thad Cochran National Warmwater Aquaculture Center. "NWAC Research". <http://msstate.edu/dept/tcnwac/ Research.htm>.
[16] US Department of Agriculture. Agricultural Research Service. < http://www.ars.usda.gov/AboutUs/AboutUs. htm?modecode=64-02-35-00>.

Coldwater Marine Aquaculture Center located in Orono, Maine, holds the patent title, "Test for Detecting Major Catfish Disease".

Enteric septicemia, caused by the bacterium *Edwardsiella ictaluri*, is one of the most prevalent diseases affecting channel catfish populations and is consequently responsible for substantial financial loss for catfish farmers. ARS and MSU researchers have developed a set of DNA primers along with a DNA probe, specific for the *Edwardsiella ictaluri* bacterium. The new development is a "real time polymerase chain reaction (RT-PCR) test [that] is very specific, accurate, and highly sensitive,"[17] and can be used as an effective means to detect the disease in live fish populations. In addition to identifying catfish with active *Enteric septicemia* infections, the innovative test enables the identification of surviving fish that may still harbor the *Edwardsiella ictaluri* bacterium, which provides tremendous benefits to disease management and selective breeding programs.

The early identification of the bacterium and the diagnosis of its resulting bacterial disease is essential to successful treatment, as the disease progression is usually quite rapid. Biotechnology companies, as well as companies that manufacture analytical tools utilizing such biotechnology developments could employ the "Test for Detecting Major Catfish Disease" to develop diagnostic instruments that enhance the detection of the catfish disease.[18] The subsequent implementation of this development offers a tremendous benefit to the U.S. aquaculture industry.

[17] USDA. Agricultural Research Service. Partnering. <http://www.ars.usda.gov/research/patents/patents.htm? serialnum=10252357>.
[18] Ibid

Mississippi State Technology Commercialization

MSU developed the Office of Technology Commercialization (OTC) to foster an entrepreneurial environment and identify, assess, protect, market and license the intellectual properties developed by the faculty and students of the university.[19] The mission of the OTC is the result of U.S. Public Law 96-517, known as the Bayh-Dole Act, enacted in 1980, which encouraged universities to "collaborate commercial concerns to promote the utilization of inventions arising from federal funding,"[20] and requires that inventions developed by universities under the sponsorship of the federal government be transferred to the private sector providing for the benefit of the general public. The OTC is the Mississippi State University equivalent to University of Southern Mississippi's Noetic Technologies, Inc.

[19] Office of Technology Commercialization. "Mission Statement". <http://iptl.msstate.edu/aboutus/whatwedo. php>.

[20] Office of Technology Assessment, United States Congress. "Commercial Biotechnology". < http://books.google .com/books?id=n0q-YrG0XOgC&pg=RA2-PA419&lpg=RA2-PA419&dq=Law+96-517&source=web& ots =QdmsXbx0Ou&sig=taEIlZ442kvnlPm0FAOU30rsCVE&hl =en&sa=X&oi=book_result&resnum=10&ct=result#PRA2-PA418,M1>.

II. The University of Southern Mississippi

The University of Southern Mississippi School of Polymers and High Performance Materials was established in 1970 as the Department of Polymer Science, while the High Performance Materials distinction was not established until 1999. USM was the first university in the United States to offer a polymer science degree and still remains a top ten nationally ranked institution of polymer science.[21]

The School of Polymers and High Performance Materials contains two centers, including the Materials Research Science and Engineering Center, whose objective is to understand the responses of biological systems, "development of synthetic routes for macromolecular chain responses, development of environmental stimuli functions enabling their film formation and analysis, development of techniques for predicting environmental responses, and understanding formation processes in polymeric films." This is of utmost developmental performance because, "materials' response to internal or external stimuli formulates the basis of novel materials for the 21st Century. Polymeric materials, and in particular polymeric films, have paced the evolution of technologies for the last 50 years."[22] In addition, polymers are the basis of groundbreaking developments of certain drugs, facilitating drug delivery to specific tissues in the body which would otherwise be impossible.

The National Science Foundation Industry/University Cooperative Research Center in Coatings (I/U CRC) is another center housed within the School of Polymers

[21] School of Polymers and High Performance Materials. "About Us". <http://www.usm.edu/polymer/research.php>.
[22] Materials Research Science and Engineering Center. "About Us". <http://www.usm.edu/mrsec/index.htm>.

and High Performance Materials at the University of Southern Mississippi. Established in 1973, the National Science Foundation Industry/University Cooperative Research Center (NSF/U CRC) program continues to sponsor more than fifty centers in the United States. The NSF/U CRC established the NSF/U CRC in Coatings in 1990, which currently provides the largest coatings consortium in the U.S. Funding for the Coatings Research Center is provided by National Science Foundation member companies and organizations.

Though not a designated "Research Center," the Mississippi Polymer Institute (MPI) is a significant institution within the USM School of Polymers and High Performance Materials. The MPI was established in 1993 by the state legislature for the purpose of, "helping the industry solve technical problems, train[ing] employees, and improv[ing] processes and products so the firms would be prosperous and would grow and contribute to the economic development of the state."[23] Three years later, the institute began receiving additional funding from the federal government's National Institute of Standards and Technology Manufacturing Extension Partnership program. The Mississippi Polymer Institute connects related industries with the academic resources of the School of Polymers and High Performance Materials by providing consultation services and expertise in the related sciences, product design, and the polymer materials manufacturing process to companies and organizations outside of the university.

The International Coatings and Formulations Institute (ICFI) was created in 1998 for the purpose of promoting interaction between USM's School of Polymers and High Performance Materials and the coatings industry, with the intent of facilitating industrial,

[23] USM. School of Polymers and High Performance Materials. Mississippi Polymer Institute. "A Resource to Know Well". <http://www.psrc.usm.edu/mpi/frames.htm>.

academic, and governmental partnerships for research and development in the coatings and formulations field.[24]

Marine Science

The University of Southern Mississippi's Department of Marine Science (DMS) was developed in 1984 after the state of Mississippi assigned USM the leadership role in marine sciences. The DMS is located at NASA's John C. Stennis Space Center (SSC), nearly seventy-five miles south of USM's main campus in Hattiesburg. Although the SSC is the most prominent U.S. rocket testing center, more oceanographers and hyrdrographers work at the Department of Marine Science facility at the SSC than any other location worldwide.[25] Hydrography is the science dealing with the measurement and description of the physical features of bodies of water and their adjacent land masses.[26]

The DMS offers B.S., M.S., and Ph.D. degree programs emphasizing a cross-discipline approach, requiring that all students obtain an understanding and appreciation of the four major fields of marine science, which are physical oceanography, geological and biological oceanography, and marine chemistry. The Department of Marine Science is responsible for a wide range of sub-discipline research including "data assimilation, ocean optics, coastal and marine sedimentology, micropaleontology, ocean productivity, remote sensing, acoustics, ocean modeling, molecular ecology, and biogeochemistry."[27]

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[24] USM. School of Polymers and High Performance Materials. International Coatings and Formulation Institute. <http://www.psrc.usm.edu/icfi/>.

[25] The University of Southern Mississippi. Department of Marine Science. "About". <http://www.usm.edu/ marine /location.php>.

[26] National Oceanic and Atmospheric Association. Office of Coast Survey. "Surveys and Wrecks". <http://www. nauticalcharts.noaa.gov/hsd/hydrog.htm>.

[27] The University of Southern Mississippi. Department of Marine Science. "Research". <http://www.usm.edu/ marine /location.php>.

DSM faculty conduct global research and maintain ongoing projects in geographic regions such as the Arabian Sea, the Chesapeake Bay, the Great Lakes, Coastal Taiwan, the Gulf of Mexico, the southern portion of the Mississippi and Pearl Rivers, Rocky Mountain National Park, the Sargasso Sea, and even the Yukon River basin located in Anchorage, AK. The University of Southern Mississippi has multiple research centers: the Center for Trace Analysis (CETA), the Hydrographic Science Research Center (HSRC), the Undersea Vehicles Technology Center (UVTC) and the Environmental Radioactivity Laboratory (ERL).

The Center for Trace Analysis (CETA) is responsible for coordinating analytical services provided by the USM Department of Marine Science. Through the utilization of the department's high resolution inductively coupled plasma-mass spectrometer (HR-ICP-MS), the CETA seeks to provide state of the art research, expertise and analytical services in trace chemical analysis. Using the HR-ICP-MS, the University of Southern Mississippi's CETA provides an unparalleled limit of detection in elemental analysis, particularly enabling the elemental analysis of waters and solids as well as nutrient and particulate carbon-Nitrogen Analyses.

The elemental analyses obtained through the use of the HR-ICP-MS provide a wide range of industry applications. The elemental analyses of waters, rocks, and soils enable vital information of isotope ratio determinations that are particularly useful to the Environmental and Earth Science field. The Semiconductor Industry uses the HR-ICP-MS data for the determination of reagent purity, while Forensic Sciences utilizes the analyses for the elemental fingerprinting of crimes scenes. The HR-ICP-MS analyses enable the Nuclear Industry to trace the location and dispersion of nuclear wastes,

promoting their confinement. The health and biological sciences fields and industries utilize the elemental analysis of drug purity and the presence of various trace elements in tissues and fluids in the body. The CETA charges $83.00 per hour for the provision of service to scholastic and government institutions, while charging the private, commercial sector a slightly higher rate of $104.00 per hour.

The Undersea Vehicles Technology Center (UVTC) is one of three divisions of the National Institute for Undersea Science and Technology (NIUST). The NIUST was established in 2002 in partnership with the National Oceanic and Atmospheric Administration (NOAA), through the NOAA's National Undersea Research Program (NURP), to generate and apply new technologies facilitating the enhancement of undersea research,[28]which encompasses the fields of biotechnology and resulting engineered technologies in the marine environment. The NIUST consists of two other divisions, in addition to the UVTC: the Ocean Biotechnology Center and Repository (OBCR) and the Seabed Technology Research Center (STRC), which are both located at the University of Mississippi.

As a part of the U.S. Department of Commerce, the NOAA is a federal agency focused on the condition of the oceans and the atmosphere, playing several distinctive roles regarding the stewardship of the United State's living marine and coastal resources. As a leader in applied science research, the NOAA serves as a principal supplier of environmental information products as well as environmental stewardship services.[29] The National Undersea Research Program (NURP) consists of a network of six various

[28] National Oceanic and Atmospheric Administration. NOAA's Undersea Research Program. "National Institute for Undersea Science and Technology". < http://www.nurp.noaa.gov/NIUST.htm>.
[29] U.S. Department of Commerce. National Oceanic and Atmospheric Administration. "NOAA Careers". <http:// www. careers.noaa.gov/about_noaa.html>.

regional centers of undersea science and technology enabling the coverage of the widely diverse U.S. geographic regions. The federal grant supported regional centers are primarily located at major universities, including both the University of Mississippi and the University of Southern Mississippi, which together, are jointly considered an individual regional center.

The goal of the program at the University of Southern Mississippi's Undersea Vehicles Technology Center (UVTC) is the development of viable technologies that involve interactive communication, systems control, data assimilation and processing, and artificial intelligence, ultimately appropriate for the operation of both remotely operated underwater vehicles (ROVs) and autonomous underwater vehicles (AUVs).[30] The technology developed at the UVTC helped enable the development of the Eagle Ray, the NIUST's autonomous undersea vehicle. The Eagle Ray is capable of producing high-resolution seafloor mapping at depths up to 2200 meters, as well as transporting both wet and dry payloads, facilitating future instrument and sensor development projects.

The University of Southern Mississippi Technology Commercialization

The University of Southern Mississippi has also developed Noetic Technologies, Inc., which is a commercial marketing company of the university. Noetic Technologies provides connections to USM's technology base and expertise, working closely with researchers to identify commercially viable opportunities. Noetic Technologies is also responsible for communicating with industries interested in conducting research through the university.

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[30] National Institute for Undersea Science and Technology. Undersea Vehicles Technology Center". <http:// www.niust.org/index.php/UVTC-Info/>.

Neonatal Developmental Care (NDC) is a specific example of a case study facilitated by Noetic Technologies, Inc. NDC is a company whose program provides an essential tool for the parents of premature infants. As NDC possessed the medical expertise but lacked the business development strategy, the company turned to Noetic for guidance on negotiating licensing agreements, company formation and branding of the product, as well as the development of a viable marketing plan.[31]

[31] Noetic Technologies, Inc. "About Us". <http://noetictechnologies.org/faq.html>.

III. The University of Mississippi

The National Center of Natural Products Research at the University of Mississippi hosts a wide variety of research programs. Housed in the Thad Cochran Research Institute, the NCNPR consists of the following departments and research programs: Natural Products Discovery, Medicinal Plant Research, Natural Resources and Environment and the Department of Technology Transfer and Commercialization.

"The Principal objective of the NCNPR's discovery and development program is to identify bioactive natural products from plant, marine or microbial sources that may serve as lead compounds for the development of new pharmaceuticals or agrochemicals."[32] Scientists from the NCNPR work in collaboration with the scientists from the University of Mississippi's School of Pharmacy Department of Pharmacognosy to collect and locally observe natural product specimens from around the world. Although some of the specimens are obtained directly from agricultural facilities on the local Oxford campus, a variety of samples are obtained through collaborations with federal agencies involving various botanical gardens and other universities. While drug discovery research emphasizes substances that control various infectious diseases, cancer, or immune disorders, the discovery and development program also includes agrochemical projects in collaboration with the USDA Agricultural Research Service that "seek to identify lead compounds for the development of environmentally benign and toxicologically safe pest management agents."[33]

[32] The University of Mississippi. National Center for Natural Products Research. "Natural Products Discovery". <http://www.olemiss.edu/depts/pharmacy/ncnpr/npd.html>.
[33] The University of Mississippi. National Center for Natural Products Research. "Natural Products Discovery". <http://www.olemiss.edu/depts/pharmacy/ncnpr/npd.html>.

The U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) developed the Natural Products Utilization Research Unit (NPURA) at the NCNPR at the University of Mississippi in 1996, which remains under the direction of the Mid-South Area Office of the ARS in Stoneville, MS. The NPURA was chartered with the primary mission of developing "natural products for use in agriculture in order to produce more toxicologically and environmentally benign pest management tools and to improve the nutriceutical value of crops." In addition, the NPURA engages in "fundamental research to aid in the development of alternative crops for production of pharmaceuticals and botanical supplements."[34]

Agricultural biotechnology and natural products development encompasses a growing area of scientific research and development offering a vast economic and environmental benefit. The basis of the objective of the NPURA is the fact that biotech developments can be used in agriculture to manage pests "with less risk than synthetic compounds that are toxicologically and environmentally undesirable."[35]

An example of a recent ARS development at the NCNPR holds the patent title, "Compounds to Reduce Off-Flavor in Catfish." After determining that the bacteria *Oscillatoria Perornata*, along with the cyanobacteria, blue-green algae, were responsible for the musty odor in ponds and thus, the consequential "off-flavor" in the catfish which they produced, ARS researchers discovered a family of natural products that is able to simultaneously eradicate both pestilences. In addition to the tremendous benefit afforded to the private aquaculture industry, the general public also receives an equal benefit from the implementation of the new development.

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[34] USDA. Agricultural Research Service. Natural Products Utilization Research Unit. <http://www.ars.usda.gov/ Main/site_main.htm?modecode=64-08-10-00>.

[35] ""

Though considered a potential carcinogen, Diuron was typically the only herbicide available for the treatment of blue-green algae in managed bodies of water, including rivers and lakes that provided public recreational access. The NCNPR's newly developed naturally based and non-carcinogenic technology is more selective towards the undesired blue-green algae and offers a much safer alternative to Diuron.[36]

In addition, current NPURA projects at the NCNPR include the following:

- "*Fusarium solani* - Extracts of this fungus were shown to be toxic to weeds such as sicklepod, velvetleaf, and morningglories. Dr. Dayan is currently investigating the mode of action of a phytotoxin Dr. Rimando isolated. This work is in collaboration with Dr. Hamed Abbas (Southern Weed Science Laboratory, USDA ARS, Stoneville, MS).
- 1,8 cineole and cinmethylin - 1,8 cineole is a natural product from which the herbicide cinmethylin was derived. The mode of action of either of these compounds on plants remains unknown. The NCNPR is investigating the possible site(s) of action of these compounds using physiological and biochemical approaches.
- Guayule - Current chemical treatments are not wholly effective towards protection against attack of wood by fungi, termites, and other organisms. The discovery of the active components of *Parthenium argentatum* (Guayule bush) has been undertaken, which are responsible for this plant's resin's highly fungicidal and termite protecting characteristics. The identification of these components will provide us with insights necessary

[36] USDA. Agricultural Research Service. Partnering. <http://www.ars.usda.gov/research/patents/patents.htm? serialnum=10320651>.

for development of effective and potent fungicides and termitacides derived from natural sources.

- *Leucophyllum frutescens* - This desert plant from Texas gave selective phytotoxicity against monocots in an in vitro screening of several other plant species. The NCNPR is isolating and testing the active compounds for herbicidal activity.
- *Castela taxana* – A promising plant which is highly phytotoxic. Isolated compounds from this plant were shown to have anti-malarial activity. The NCNPR is currently isolating and testing the active compounds for herbicidal activity.
- *Oryza sativa* (rice) - A specific rice variety from Taiwan which is highly allelopathic to barnyardgrass (the biggest weed problem in rice) in field tests. Identification of the allelochemicals in this variety could lead to further research on breeding allelopathic rice varieties. This project is in collaboration with Dr. Bob Dilday (National Rice Germplasm, Evaluation and Enhancement Center, Stuttgart, AR).
- Sorghum - Sorgoleone has been known as the active photosynthetic inhibitor in several species of sorghum. The NCNPR is currently using computer modeling techniques to design more potent herbicides with similar structure. There are indications of other phytotoxic constituent(s) in sorghum, which researchers are attempting to discover. Such a discovery could lead to breeding studies to give crops major advantages over weeds. The center is doing research to determine how these

compounds are produced in sorghum species and how they can be used to manage weeds. These studies are in collaboration with Dr. Leslie Weston (Cornell University).

- *Discula destructiva* - The phytotoxins of this plant pathogen that infects and kills dogwood are being isolated for evaluation for herbicidal activity.
- Fungicide discovery - All of the compounds discovered by our group and many of those made available by University of Mississippi personnel will be examined for activity against crop pathogens.
- *Flourensia cernua* (tarbush) - This plant is increasing in dominance within the Chihuahuan Desert of the U.S. It is quite unpalatable to livestock and contains poisonous compounds. To understand herbivore interactions with tarbush and in collaboration with the USDA-ARS' Jornada Experimental Range (JER), the center has undertaken discovering the components responsible for its unpalatability. This will provide information for the development of tools necessary for the management of our threatened rangelands and for the proper utilization of their resources.
- *Drymaria* - Several species of *Drymaria* are associated with the death of cattle in the southwestern US. Previous work has associated the toxicity of *Drymaria* with compounds known as saponins although, to date, this remains unproved. Work carried at the USDA-ARS's JER in connection with plant-animal interactions gave indications of the presence of a possible toxic component in the volatile fraction of *Drymaria pachyphylla*. In co-operation with JER the NCNPR has therefore undertaken to study

the isolation, identification, and possible bioactivity of this component of *Drymaria*.

- *Cyperin* - This phytotoxic natural product has been isolated from several plant pathogens. New modes of herbicide action are needed because of increased weed resistance to herbicides. An unusually rapid rate of chlorophyll degradation in plants exposed to cyperin has been observed. The NCNPR is investigating this potentially new mode of action.
- *Artemisia annua* (annual wormwood) - Annual wormwood produces artemisinin, an anti-malarial drug. This compound is also herbicidally active. Little is known of its mode of action as a pharmaceutical or an herbicide. The researchers are determining how it works as an herbicide and are interacting with university scientists to determine how our findings relate to its effects on the malaria parasite. Dr. Camilo Canel is working on the identification of genes involved in the biosynthesis of artemisinin and related compounds, while Dr. Franck Dayan is working with 3-D modeling to further understand this compound.
- *Hypericum* (St. John's wort) - Hypericin is a highly photodynamic compound produced by several St. John's wort species. The researchers are interested in understanding how hypericum compartmentalizes this compound and are investigating the potential use of this compound as a 'contact' pesticide.
- Peptidomimetic compounds – The NCNPR has found several of these compounds are highly phytotoxic. The researchers are interested in

discovering their mode(s) of action and plan on utilizing computer modeling techniques to maximize their activity. These molecules were synthesized by Dr. Jordan Zjawiony, of the University of Mississippi with whom the NUPRA is collaborating on this project.

- Terpenoid metabolism - Many pesticidal compounds from plants are terpenoids. A visiting scientist from Spain is investigating the enzymes of this pathway and how they might be manipulated. This work involves working with cloned genes and gene products. It will be useful to the scientists involved in the project below. Transgenic crops with natural pest resistance - The objective is to improve production of existing natural compound defenses of crops to pests and to put new natural compound defenses into crops.
- Anti-cancer ellagitannins from small fruits - This project is a multi-institutional collaboration involving cancer prevention using small fruits between Dr. David Wedge; Dr. Lyndon Larcom, (Clemson University, Clemson SC); and Dr. Daniel Nixon (Hollings Cancer Center, Medical University of South Carolina, Charleston SC.) The project will focus on isolation of natural compounds from strawberries, grapes and raspberries that have anticancer and antimicrobial activity. This work is funded by the USDA Fund for Rural America."[37]

[37] USDA. Natural Products Utilization Research Unit. "Current Research Projects." <http://www.olemiss.edu/ depts/usda/usdaproj.html>.

Marine Science

Marine biotechnology is a major priority of the NOAA's National Undersea Research Program (NURP). Within the mission of the NURP, biotechnology is defined as "the industrial use of living organisms or biological techniques developed through basic research."[38] The oceans cover approximately 71% of the surface of the earth and 99% of the biosphere, as organisms are found throughout the entirety of the water column, consequently representing the greatest extremes in temperature, light and pressure encountered by living organisms. Adaptation to such harsh environments has inevitably led to the development of a tremendous degree of bio and genetic diversity, offering a vast potential of biotechnological applications in the realm of drug discovery, new resource and industrial processes development, environmental remediation and increasing the seafood supply and safety.

Located in the University of Mississippi's National Center for Natural Products Research (NCNPR), the Ocean Biotechnology Center and Repository (OBCR) consists of a repository including approximately five thousand marine extracts from the Atlantic, Pacific, Indian and Southern Oceans. The "overall goal of the OBCR program is to create a national repository of biochemical/biomolecular products of marine organisms from US and international waters for use by the biotechnology research sector," facilitated through a new initiative focused on biosensor development, in hopes of developing, "new products from marine ecosystems to enhance human health and well-being."[39]

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[38] National Institute for Undersea Science and Technology. "Marine Biotechnology: A NURP Priority". <http://www.nurp.noaa.gov/Biotech.htm>.

[39] National Institute for Undersea Science and Technology. Ocean Biotechnology Center and Repository. "OBCR Goals". < http://www.niust.org/index.php/Ocean-Biotechnology-Center-and-Repository-OBCR/>.

The OBCR facilitates the NOAA research priorities, particularly the development of new value from the sea in terms of drug discovery and agrochemicals, eventually for commercial use. While traditional repositories are merely collections of cells or various extracts with limited data relative to specific samples, the OBCR is unique in that it collects a broad range of environmental data accompanying every field sample. Through the maximization of available data, the OBCR obtains insights into selective pressures that regulate the expression of significant, observed molecules. In addition, the OBCR obtains Genomic DNA for every sample, which is archived in a cryofreezer for additional genetic research. The OBCR's intensive data collecting processes provide an enhanced data mining opportunity, allowing for insights into interdisciplinary research areas through statistical Meta-analysis techniques. Environmental data examined within the context of certain extracts can help identify unique biomarkers that are relevant to marine toxicology. A biomarker is simply a "substance used as an indicator of a biologic state. It is a characteristic that is objectively measured and evaluated as an indicator of normal biologic"[40]or pathogenic processes, or pharmacologic responses to therapeutic intervention. In addition, the OBCR has a renowned Metabolomics program, which is based on chemical profiles as well as the genomic information of the extracts, obtained through research at the NCNPR repository.

Fist-sized pieces of each sample, such as algae, sponge, and gorgonian coral, are collected and identified in the field, before being lyophilized in order to promote their preservation and help make them more stable. Before being placed on growth plates in the National Center for Natural Products Research, the extracts are weighed and

[40] U.S. Department of Energy. Pacific Northwest National Laboratory. "Environmental Biomarkers". <http:// biomarkers.pnl.gov/>.

fingerprinted by the HPLC and GCMS processes (High performance liquid chromatography and Gas Chromatography/Mass Spectrometry).

In addition to the OBCR, the Seabed Technology Research Center is another division of the NIUST located at the University of Mississippi National Center for Natural Products Research. Although the STRC is a component of the Mississippi Mineral Resources Institute (MMRI), the organization receives federal funding from the NOAA, the U.S. Department of Energy and the Minerals Management Service (MMS).

The MMRI was established in 1972 by the Board of Trustees of the State Institutions of Higher Learning to promote and coordinate mineral-related research in the state. The MMRI seeks to provide both the public and private sectors with the necessary expertise to make responsible decisions regarding national mineral resources and the consequential environmental welfare.[41] Through the support of the MMS, the MMRI established the Center for Marine Resources and Environmental Technology (CMRET) in 1987 as one of six national research centers of the former U.S. Bureau of Mines to facilitate the study of marine minerals and related environmental issues. The CMRET facilitates the access of both academic and industrial expertise throughout the U.S. and Canada for the MMS.

The Minerals Management Service is a bureau of the U.S. Department of the Interior that was established as the federal agency responsible for the management of the nation's natural gas, oil and other mineral resources, particularly those on the outer continental shelf. The MMS is comprised of two major programs, the Minerals Revenue

[41] The University of Mississippi. The Mississippi Mineral Resource Institute. "Overview". < http://www.olemiss. edu/depts/mmri/welcome/welcome.html>.

Management, and the offshore Energy and Minerals Management, which is responsible for the management of the mineral resources on the outer U.S. continental shelf.[42]

With the support of the Minerals Management Service, National Oceanographic and Atmospheric Administration, the Department of Energy's National Energy Technology Lab and the Naval Research Lab, the CMRET established the Gas Hydrates Research Consortium in 2001 to "study gas hydrate mounds and active gaseous hydrocarbon vents in the Gulf of Mexico." In 2006, an observatory in the Gulf of Mexico was developed through the consortium to facilitate the study of the "dissociation / accumulation of gas hydrates and impacts on the adjacent seafloor, water column and marine biota." As many of the hydrates contain hydrocarbon gases, the research of the consortium is of particular interest to the energy community in hopes that natural gas may be produced and harvested from the hydrates.[43] Although the observatory's monitoring station consists of three types of data collection systems: geochemical, microbial, and seismo-acoustic, the independently collected data is all connected to the same data recording and transmission system.[44] In addition, the station's capabilities are currently being expanded to enable biological monitoring, permitting the study of "interactions between life forms and physical/chemical stimuli and of the ways biologic agents produce or modify geologic materials and processes."[45]

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[42] U.S. Department of the Interior. Minerals Management Service. < http://www.gomr.mms.gov/index.html>.

[43] Society of Exploration Geophysicists. "A Seafloor Observatory to Monitor Gas Hydrates in the Gulf of Mexico". < http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=LEEDFF000025000005000644000001&idtype=cvips&gifs=yes

[44] The University of Mississippi. Mississippi Mineral Resource Institute. "A Seafloor Observatory to Monitor Gas Hydrates in the Gulf of Mexico. <http://www.olemiss.edu/depts/mmri/programs/SEGLeadingEdge.pdf>.

[45] Minerals Management Service. Gas Hydrates Research Consortium. <http://www.mms.gov/offshore/GasHydratesResearchConsortium.htm>

IV. In-State Pharmaceutical Company Presence

There is a large pharmaceutical development and manufacturing presence in the state of Mississippi. Surprisingly, a variety of medications that have nearly become common household names were developed and are currently manufactured in Mississippi.

Wraser Pharmaceuticals is a Madison, Mississippi based pharmaceutical company, "committed to providing safe, effective, quality branded products at a reasonable cost for the benefit of patients." Furthermore, Wraser Pharmaceuticals, "is committed to generating superior returns to investors as well as providing a solid platform for professional sales representatives to be rewarded at the highest level possible based on exceptional individual performance."[46] As Wraser's sales office is located in Madison, the pharmaceuticals in-state presence inevitably produces an array of regional sales and marketing jobs in the biotech sector, beyond the research and development and its necessary funding.

Primarily prescribed by primary care practitioners, some of Wraser's products include: NuZon Gel, VazoTan Suspension, VazoBid Suspension, Vazol liquid, VazoTab tablets, Levacet Tablets and Lusonal liquid.

NuZon Gel is a "hydrocortisone Acetate gel with Aloe that provides control in pediatric eczema, atopic dermatitis, seborrehic dermatitis, contact dermatitis and intertrigo,"[47] in addition to a psoriasis maintenance therapy.

Wraser's "Vazo" line contains drugs that are used to treat various respiratory conditions. VazoTan Suspension is currently the "strongest non-narcotic cough

[46] Wraser Pharmaceuticals. "Welcome". 21 Jan. 2009. <http://www.wraser.com/default.asp>.
[47] Wraser Pharmaceuticals. "Products". 21 Jan. 2009. <http://wraser.com/products.asp?id=60>.

suppressant on the market," while VazoBid Suspension is a combination of antihistamines and decongestants, providing "multi-symptom relief of sneezing, runny nose, watery itchy eyes, nasal congestion, and post nasal drip." Vazol Liquid is "a single agent antihistamine liquid that provides multi-symptom relief of allergic rhinitis, runny noses, watery, itchy eyes, sneezing and post nasal drip." VazoTab is another antihistamine decongestant combination that is "indicated to relieve multi-symptom allergies and nasal congestion associated with the common cold, sinusitis, allergic rhinitis and other respiratory conditions." In addition to the "Vazo" line, Wraser's Lusonal liquid is a strawberry flavored "decongestant/expectorant liquid" that "clears congested sinuses and thins thick mucous," that can be administered concomitantly with antibiotics. As a respiratory illness product geared toward a younger audience, Lusonal liquid has a "great strawberry flavor without the aftertaste."[48]

An acne treatment gel combining "the moisturizing effects of a lotion in a gel," NuOx Gel is a "unique balanced formula" that is "easy to apply under make-up." Resulting in minimal irritation that "keeps patients on target," Wraser's NuOx Gel is "moisturizing yet effective."[49] Levacet is a "non-narcotic pain reliever that relieves pain associated with stress and tension headaches, body and muscle spasms, strains and back spasms, menstrual and premenstrual symptoms and cramps, and minor arthritis and rheumatic pain."[50]

In December of 2008, Wraser publicized an agreement with Ranbaxy Laboratories, Inc. to promote Ranbaxy topical dermatology products. Princeton, New Jersey based Ranbaxy Laboratories, Inc. (RLI) is an American subsidiary of India's

[48] Wraser Pharmaceuticals. "Products". 21 Jan. 2009. <http://wraser.com/products.asp?id=60>.
[49] Ibid
[50] Ibid

Ranbaxy Laboratories Limited (RLL), India's largest pharmaceutical company. While RLL was established in India 1961, the pharmaceutical company now exports its products to one hundred twenty-five countries, and is ranked in the top ten generic pharmaceutical companies worldwide.[51] American based RLI was established entirely for the sale and distribution of Ranbaxy branded generic prescription products in the United States.

In order to gain a basic understanding of Ranbaxy USA's market niche, it is necessary to first grasp a basic understanding of the concept of generic pharmaceuticals. A generic drug is the "bio-equivalent version of a brand name drug." In order for a substance to be labeled "bio-equivalent," as certified by the U.S. Food and Drug Administration, the generic drug "has the same dosage form, safety, strength, route of administration, quality and performance characteristics and intended use as the branded version of the drug."[52] Although the generic drug may differ slightly from the branded equivalent in inactive ingredients' composition, the active ingredient composition is identical, regardless of altered physical appearance due to the presence of fillers and dyes.

Although most branded drugs obtain a patent following discovery and initial market introduction, it is rare for a patent to last more than ten years. It is only reasonable to have some degree of patent rights in order to allow the pharmaceutical company to generate sales to cover the research and development expenditures. In addition, Congress can extend the patent of a specific pharmaceutical product to cover the losses incurred to do extensive government-required testing of the drug. However,

[51] Ranbaxy. "Ranbaxy USA". 21 Jan. 2009. <http://www.ranbaxyusa.com/genericfaqs.aspx#a>.
[52] Ranbaxy. Ranbaxy USA. "What are Generic Drugs?" 21 Jan. 2009 <http://www.ranbaxyusa.com/genericfaqs. aspx#a>.

following the expiration of the patent, pharmaceutical companies such as Ranbaxy Laboratories, Inc. have full rights to produce a generic equivalent of the branded drug.[53]

Through working with Wraser Pharmaceuticals, Ranbaxy Laboratories hopes to "significantly increase the value of these brands...while providing high-quality dermatological care to our customer base of physicians and their patients." Although none of Ranbaxy's product manufacturing will take place in the Madison, MS Wraser plant, Ranbaxy feels that Wraser's promotion will increase their dermatological market share. Through targeting primary care medical practitioners, Wraser hopes to increase the market level of Ranbaxy's Halog Cream and Ointment, which is a "class two high-potency topical steroid," along with Exelderm Cream and Solution, which is a "broad-spectrum imidazole anti-fungal" drug, and Eurax Cream and Lotion, a "non-steroidal, prescription anti-puritic."[54] In an attempt to increase their U.S. dermatological product market share, Ranbaxy USA recently acquired the drug patents from Bristol-Myers Squibb in 2007. While Ranbaxy did not initially market the products outside of the dermatology practice specialty, the India based company hopes that it will gain a significantly larger portion of the dermatological market share within the primary care market. As primary care practitioners account for a large percentage of U.S. dermatological prescriptions, Wraser's involvement in Ranbaxy's marketing program is quite considerable.

More recently, following an intellectual property forum and technology expo hosted by the Mississippi Research Consortium and the MTA on November 30th -

[53] Bellis, Mary. Patent, Trademark, and Copyright Primer for Students. "Patents in Brief". 21 Jan 2009. <http://inventors.about.com/cs/lessonplans/a/student_primer_2.htm>.
[54] Wraser Pharmaceuticals. "About Wraser Pharmaceuticals". 22 Jan. 2009. <http://www.wraser.com/default.asp>.

December 31st 2008 in Jackson, a partnership was established between Wraser Pharmaceuticals and the University of Mississippi. Assistant professor at Ole Miss' Department of Pharmaceutics, Dr. Michael Repka presented his development of "bioadhesive film platform technology," initially gaining the pharmaceutical company's attention at the forum. The following year, in April of 2009, a relationship was established between Wraser Pharmaceuticals and the university "designed to allow Wraser to work with the university to identify, develop, register and commercialize new pharmaceutical products."[55]

Also located in Madison, MS, Cypress Pharmaceutical, Inc. is a, "specialty pharmaceutical company that develops, markets and distributes generic prescription pharmaceutical products to the leading national pharmaceutical wholesalers, chain drug stores, distributors, and other retail merchandisers."[56] Backed by CEO Max Draughn, Cypress Pharmaceuticals, Inc. was established in 1983, drawing off of Draughn's vision and pharmaceutical industry experience. Although Cypress initially opened its doors producing only one cold symptom treatment product, today the company offers over one hundred fifty products, including cold medicines, nutritional supplements and dental health fluorides, along with urinary tract, gastrointestinal, and analgesic drugs.

In 1998, Cypress Pharmaceutical, Inc. started its own branded division, Hawthorn Pharmaceuticals, Inc. Hawthorn is "a specialty pharmaceutical company focused on the sales, marketing and development of branded prescription products primarily in specialty-driven markets including urology, dermatology and pediatrics." Hawthorn's

[55] Wraser Pharmaceuticals. "Press Room". 22 Jan. 2009. <http://wraser.com/press.asp?id=6>.
[56] Reuters. "Company Profile for Cypress Pharmaceutical, Inc." 26 Jan. 2009. <http://www.reuters.com/article/ pressRelease/idUS170493+18-Jan-2008+BW20080118>.

products have been developed around the concept of "practical innovation—improving existing products and creating new products."[57]

Hawthorn has several product lines, specifically for the areas of dermatology, iron deficiencies, nephrology, oncology, pain management, urology and orally administered steroids. The dermatology line contains three types of topical cleansers:

- Hylira Gel is a topical gel applied for the treatment of xerosis.
- Zaclir is a facial cleansing lotion containing the active ingredient benzoyl peroxide that is intended for the topical treatment of mild to moderate acne.
- Seuphera is another Hawthorn acne treating topical medication but with more extensive use, that can be applied for acne rosacea and seborrheic dermatitis.

In addition, Hawthorn sells the "Zaclir kit" containing both a benzoyl peroxide cleansing lotion and sodium hyaluronate gel. Hawthorns brilliant "kit" marketing allows consumers to treat facial acne as well as the resulting dry, itchy skin with one purchase.

Renatabs are Hawthorn's "renal vitamin therapy supplements" intended for the treatment of wasting syndrome as a result of chronic renal failure, along with uremia and impaired metabolic functions of the kidney. Hawthorn also produces "Renaltabs with Iron," allowing a patient suffering from iron deficiency to treat both problems with one drug.

Granisol is a drug intended for cancer patients for the prevention of nausea and vomiting resulting from emetogenic cancer therapy, including radiation. Veripred 20 is

[57] Hawthorn Pharmaceuticals, Inc. "Company Focus". 26 Jan. 2009. <http://www.hawthornrx.com/corporate. html>.

"a prescription drug product indicated for the control of severe or incapacitating allergic conditions intractable to adequate trials of conventional treatment in adult and pediatric populations with seasonal or perennial allergic rhinitis; asthmas; contact and atopic dermatitis; serum sickness; and drug hypersensitivity reactions." Zamicet is an oral solution hydrocodone itartrate and acetaminophen pain medication that is used to treat moderately severe pain. Utira-C is Hawthorn's urology drug that is prescribed for the "treatment of irritative voiding...indicated for the relief of local symptoms, such as inflammation, hypermotility, and pain, which accompany lower urinary tract infections."[58]

Today Hawthorn Pharmaceuticals, Inc. employs a sales and marketing force of one hundred twenty individuals through the United States and has established relationships with all major U.S. pharmaceutical purchasers. The company continues to pursue product development and applications through the research of their in-house drug development team and currently has thirteen new products in various stages of development, fueling future growth.

Hawthorn's branded pharmaceutical products have left plenty of room for Cypress' generic drug production and market. Cypress outsources all of its manufacturing and its manufacturing partners have grown from one to twenty plus from 1993 to 2003. The Madison facility includes 101,000 square feet of warehouse space and 8,000 square feet of office space. From 1997 to 2003, Cypress won the Cardinal Health Supplier Quality Award six out of seven years, joining the ranks of other recipients including Pfizer, Amgen and Barr Labs. Since its founding, the company's compounded

[58] Hawthorn Pharmaceuticals, Inc. "Product Categories". 26 Jan. 2009. <http://www.hawthornrx.com/corporate. html>.

annual growth rate has been over 60% annually, characterized by sales growth of 85% in 2002 and 2003."[59]

On the other hand, Canton, Mississippi based Allegis Pharmaceuticals is strictly a pharmaceutical preparations company, signifying that no research takes place at the Canton location. Allegis is "committed to bringing new products to market and expanding its sales force each year by partnering with physicians and manufacturers to provide optimal product development and patient care."[60]

Some of Allegis' better known products include:

- QFlex: Administered for the treatment of cold and flu symptoms, QFlex's active ingredients are acetaminophen and phenyltoloxamine.
- Allres G: A liquid Tannate Suspension, active ingredients: Carbetapentane Citrate and Guaifenesin; administered for the treatment of acute respiratory infections.
- Allres D: A liquid Tannate Suspension; active ingredients: Carbetapentane Citrate and Pseudophedrine; similar to Allres G, Allres D is a decongestant.
- Allres Pd: A liquid Tannate Suspension; active ingredients: carbetapentane Citrate and pseudoephedrine HCl; administered for the treatment of respiratory infections, similar to Allres D but the HCl salt provides an extended release.
- NY-Tannic; active ingredients: phenylephrine tannate and chloropeniramine tannate; as a combination decongestant and anti-histamine drug, NY-Tannic is administered for the treatment of the symptoms of congestion associated with an upper respiratory infection.

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[59] Mississippi Business Journal. "Mississippi's 40 Fastest Growing Companies: Cypress Pharmaceuticals earns top-notch reputation". 27 Oct. 2003. 26 Jan 2009. <http://www.allbusiness.com/business-planning/business-structures-corporations/1168641-1.html>.

[60] Allegis Pharmaceuticals. "About Us." 3 Feb. 2009. <http://www.allegispharma.com/aboutus.html>.

- Seradex LA; active ingredients: Brompheniramine and Phenylephrine; administered for symptoms of sinus congestion, pressure, runny nose, sneezing, and coughing associated with allergies and upper respiratory infections.

Although its headquarters are located in Deerfield, Illinois, Global healthcare icon Baxter International, Inc. (NYSE: BAX) has a manufacturing facility in Cleveland, MS. The company was founded in 1930 as the first commercial manufacturer of out-of-hospital- intravenous solutions. In 2006, Baxter employed fourty-eight thousand employees and boasted sales of $10.4 billion. The innovative bioscience company offers a diverse product line of blood collection products and blood plasma-derived pharmaceuticals ($4.4 billion in 2006), along with medication delivery products including intravenous therapy ($3.9 billion in 2006). Baxter is a world leader in dialysis products, and grossed $2.1 billion in sales for peritoneal dialysis and hemodialysis products in 2006.[61]

The company opened its second U.S. manufacturing plant in Cleveland, MS in 1950, and currently employees approximately eight hundred Mississippians. The Cleveland facility currently produces IV solutions and vaccines.

[61] Baxter. "About Baxter". 26 Jan. 2009. <http://www.baxter.com/about_baxter/company_profile/sub/history.html

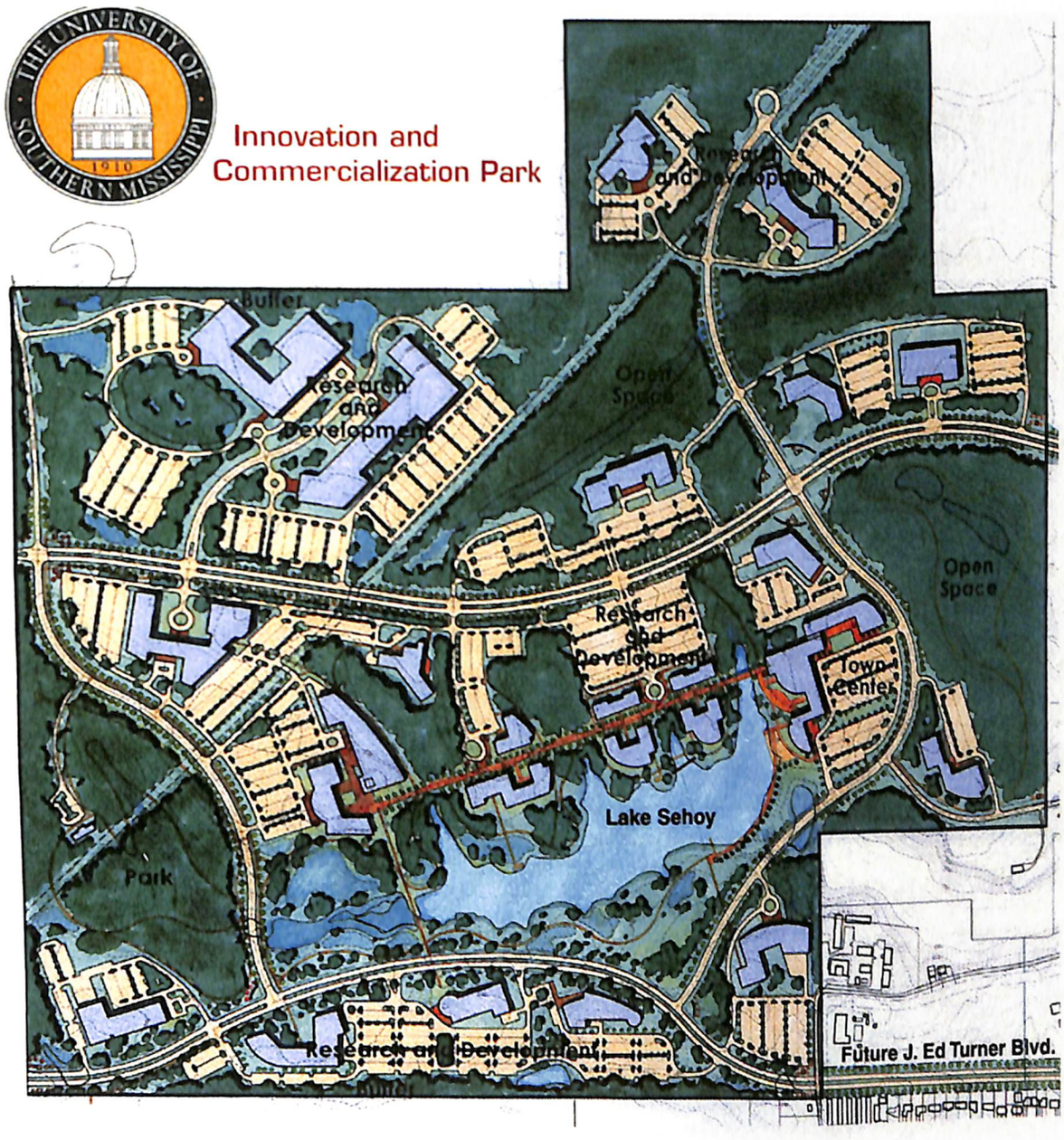
V. University Research Parks

According to the Association of University Research Parks (AURP) there are currently one hundred and ten university research parks in the United States. The majority of universities with significant research activities on campus already have a research park. Southeastern universities that have research parks include Auburn University, North Carolina State University, the University of Florida, South Florida University, Clemson University and Virginia Tech. Taking this into consideration, not only the University of Mississippi, but the state of Mississippi as a whole has fallen behind other southeastern universities in regard to presence and dominance in the research sector and the consequential generation of intellectual property and its resulting revenue.

The University of Mississippi, Mississippi State University and the University of Southern Mississippi are all in the process of developing research parks, adjacent to the main campuses of the universities. The initial developments of the research parks are entirely federally funded, and can be viewed as part of a national economic development tool. The state only provides funding for the salaries of employees of the research parks.

The University of Southern Mississippi celebrated the ground-breaking of its "Innovation and Commercialization Park" on May 14th, 2008. USM has received more than $30 million in initial federal funding and is "poised to transform south Mississippi into a haven for high-tech, high paying jobs." The aim of the park is to provide "sustained economic growth by creating new laboratories, offices, and scale up facilities for joint university and industry projects that turn research into marketable products for

new and explained business ventures."[62] The following image is a schematic of the plans of the completed park.

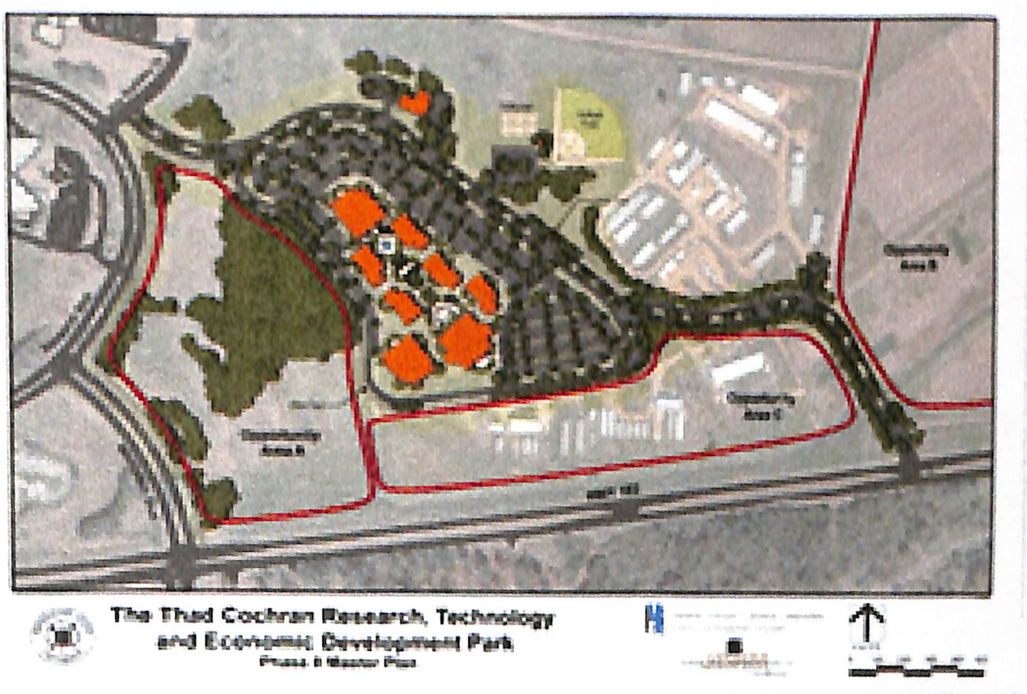


Adjacent to the main campus of Mississippi State, the Thad Cochran Research, Technology and Economic Development Park strives to be "an ideal environment to high technology and related businesses." University centers and institutes along with multiple businesses are currently located in the park. Presently, the completed Phase I of the park

[62] The University of Southern Mississippi. Innovation and Commercialization Park. 22 March 2009. <http://www.usm.edu/research2/icpark.php>.

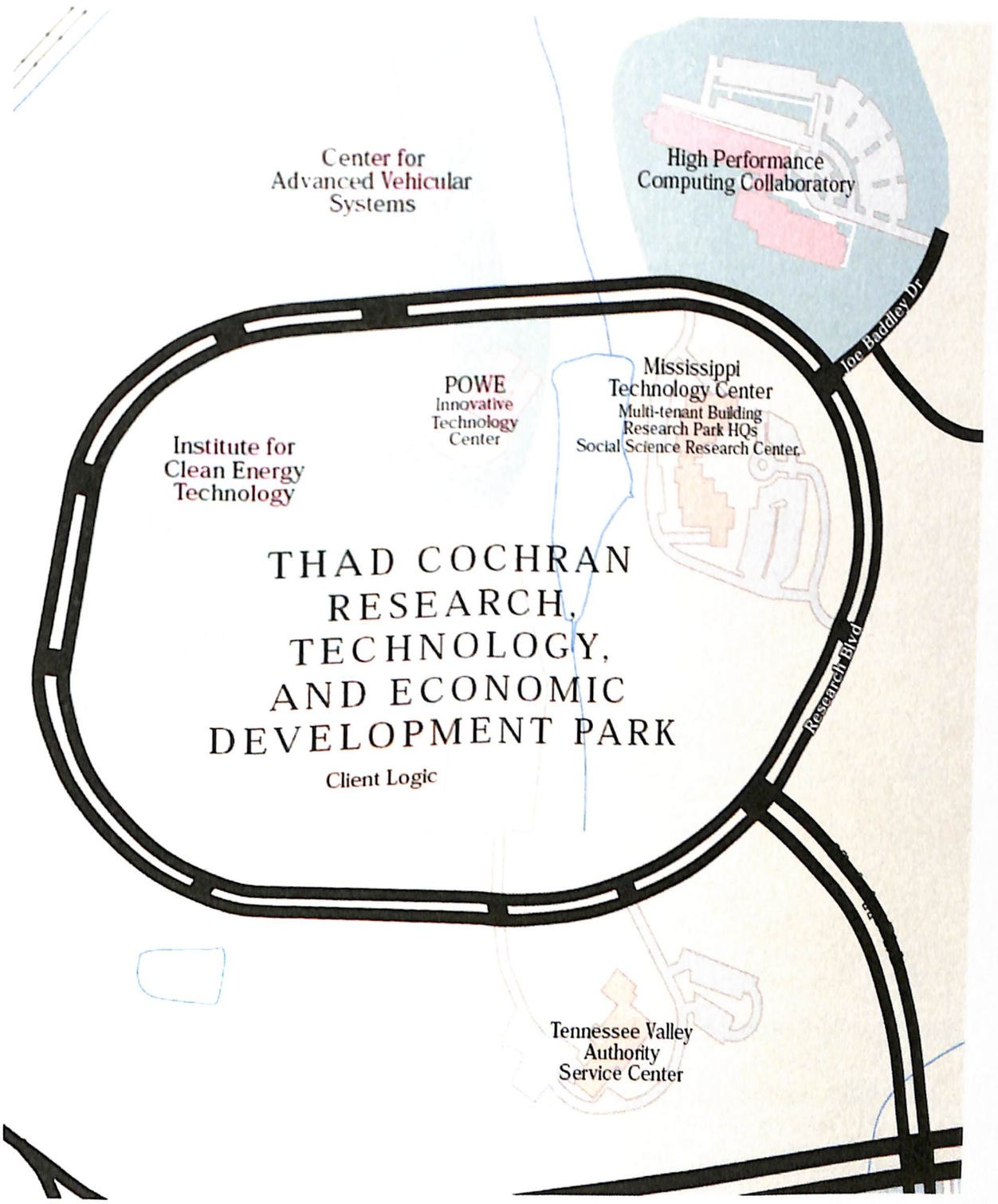
consists of 272 acres with seven buildings, housing approximately 1500 employees. Housed in the park, MSU's High Performance Computing Collabatory is currently ranked 18th among American universities for supercomputing power. The Phase II expansion of the park will include 52 additional adjacent acres.

Like the other major state universities of Mississippi, Mississippi State University's research park is federally funded, but unlike those of the University of Southern Mississippi and the University of Mississippi, MSU's is a joint university and city-county operation. As the city and county own the development, Mississippi State has had trouble with joint participation to grow income via the research side. The following image is a schematic of the plans of the completed park.[63]



[63] Mississippi State University. The Thad Cochran Research, Technology and Economic Development Park. "General Information". 22 March 2009. <http://www.cochranresearchpark.com/information/>.

The following images are of the presently completed park (Phase I), north of the main university campus. The first image is an aerial photo, followed by a labeled schematic:



Current Thad Cochran Research, Technology and Economic Development Park tenants include[64]:

- Center for Advanced Vehicular Systems - www.cavs.msstate.edu

[64] Mississippi State University. The Thad Cochran Research, Technology an Economic Development Park. "Current Tenants". 22 March 2009. <http://www.cochranresearchpark.com/information/>.

- Clear Orbit - www.clearorbit.com
- Cypress Semiconductor - www.cypress.com
- Harbinger - www.htgcorp.com
- High Performance Computing Collaboratory - www.hpc.msstate.edu
- II-VI Incorporated - www.ii-vi.com
- SemiSouth Laboratories, Inc. - www.semisouth.com
- Sitel - www.sitel.com
- Social Science Research Center - www.ssrc.msstate.edu
- Spatial Information Solutions
- Tennessee Valley Authority - www.tva.gov

Although the University of Mississippi Research Park is currently in the planning process, a resource analysis and market feasibility study has already been completed by George, Henry, George Partners, along with a cost estimate and utilities provision strategy prepared by Cooke, Doublass, Farr, Lemons, Ltd, in an effort to develop a master plan for the university park. The mission of the research park is as follows:

- Fosters intellectual exchange and showcases University-generated products and research.

- Establishes partnerships with the private sector to encourage collaborative innovation.
- Reinforces the University's academic and research mission.
- Contributes to the economic vitality of the state.
- The Research Park will serve as a regional hub for research and technology. As a center of collaboration for the University of Mississippi and its public/private partners, it will foster an environment of mixed uses that promotes collaboration through shared research, office, and support facilities.

In addition, the master plan also highlights the vision of the research park:

- The research park will be an extension of the main campus of the university.
- The research park will be an enabling space of "24-hour" activity, facilitating interdisciplinary collaboration and the exchange of creative ideas and knowledge.
- The research park will serve as an economic engine for the city of Oxford and the larger region by bringing ideas and research into the market.
- The research park will be a compact, walkable place that acknowledges the value of the land and its natural systems.

Furthermore, the long-term success and sustainability of the University of Mississippi Research Park depends not only on the vision and research goals, but on the

ability of the university to create a unique sense of place that will facilitate the ability of the park to serve as an information exchange hub of social/business interaction. "The research park will foster cooperation among its various partners and connect the intellectual pursuits with those of the main campus to create a cohesive learning and research environment." The University of Mississippi has developed the following goals and objectives to insure such a desired cohesive relationship:

- To create a physical environment that fosters intellectual exchange and creativity.
- To utilize the park to help the university achieve its academic and research mission.
- To provide facilities that showcase the products and research of the university.
- To establish partnerships with businesses with the intent of encouraging discovery and collaboration.
- To contribute to the economic vitality of the community and state.
- To create a sustainable endeavor, generating a legacy for the next generation of leaders.[65]

Regarding the design principles of the University of Mississippi Research Park, the preservation of the sense of place of the university is of utmost concern. The sight should serve as an extension of the campus with a mix of uses and amenities that will make it an attractive locus for both university and business partners. The plan describes,

[65] University of Mississippi Center for Innovation Excellence. Master Plan. "Mission, Vision, Goals and Objcectives". Feb. 7 2008.

"The landscape and building character should recall the Ole Miss campus to the extent possible. The site should be linked as directly as possible to the main campus. Small-scale commercial activity can serve to support the business, technology and research functions of the park.

"The aim is to create a place closely associated and linked with the positive qualities and identity of the Ole Miss campus, while also creating a unique identity and sense of place,"[66] drawing from the favorable qualities of the campus and town of Oxford.

The development of the research park should correspond to the site's preexisting natural systems and geographical features, including hydrology, landform and the present ecosystem. Although existing forest should be maintained as much as possible, in an effort to be mindful of the existing natural systems, stream corridors and ponds on the site should be preserved, protected and integrated into the design of the park. The plan calls for the incorporation of low maintenance landscape treatments, largely enabled through the utilization of native plants.

Another important aspect of the design principles focus on the research park site planning and a building design to maximize both energy efficiency and occupant comfort. The use of shading is essential to help minimize cooling loads. Green roofs can drastically reduce solar heat gain and decrease the load on HVAC cooling units. Proper building orientation has been taken into account when developing the research park plans, and where possible, the long facade of the buildings will be constructed with an east-west axis orientation to optimize sun lighting and passive heating and cooling of the

[66] University of Mississippi Center for Innovation Excellence. Master Plan. "Design Principles". Feb. 7 2008.

buildings. Additional external shading landscaping options have been pursued where such desired east-west axis orientation is not feasible.[67]

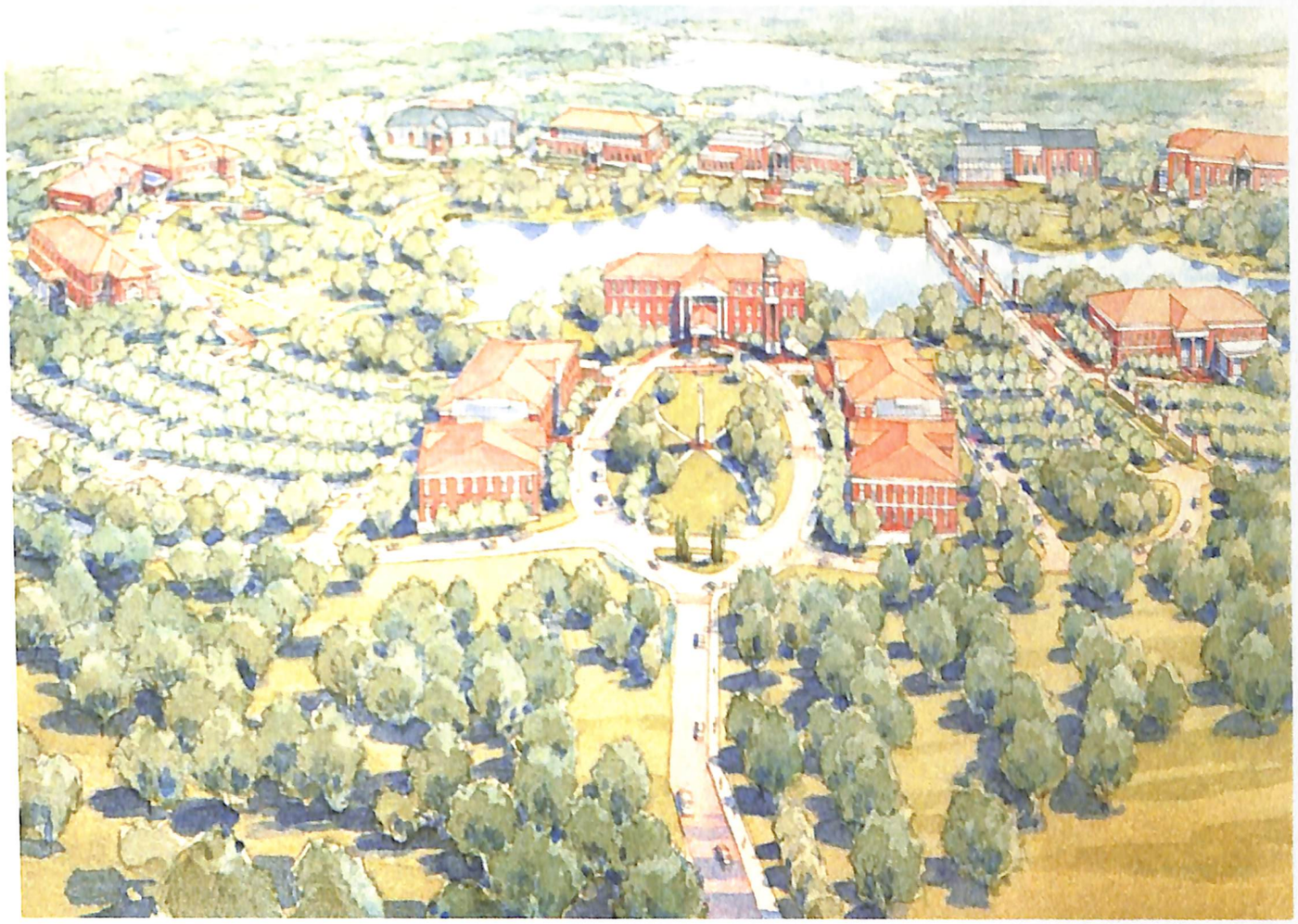
The university plans to employ the sustainable landscape and greenery options as a test to see if the native plant concepts will work on the university main campus as a whole. If largely successful, the university could drastically reduce landscape maintenance costs through the incorporation and transition of the more sustainable alternatives

The University of Mississippi has received twenty-two million dollars in initial federal grants. Although the university had initially planned on designating twenty million of this initial sum to develop infrastructure, including grounds, utility provisions, and roadways, and the remaining two million for an incubator building, the expensive bridge construction necessary for access to the sight over Highway 6 has resulted in a postponement and change of initial plans.

In light of the excessive access funding prerequisite, the initial grant could be put to better use if applied to enable the construction of facilities on campus on the north side of Highway 6. Immediate construction and consequential use is fiscally favored, as the leasing of facility space could generate additional capital to partially enable the funding of the eventual construction of the park on the south side of Highway 6. Therefore, the University of Mississippi currently plans to use the initial grant to build two buildings on the north, existing campus side of Highway 6, totaling an approximate combined fifty to sixty thousand square feet. One of the buildings will house a wet laboratory while the

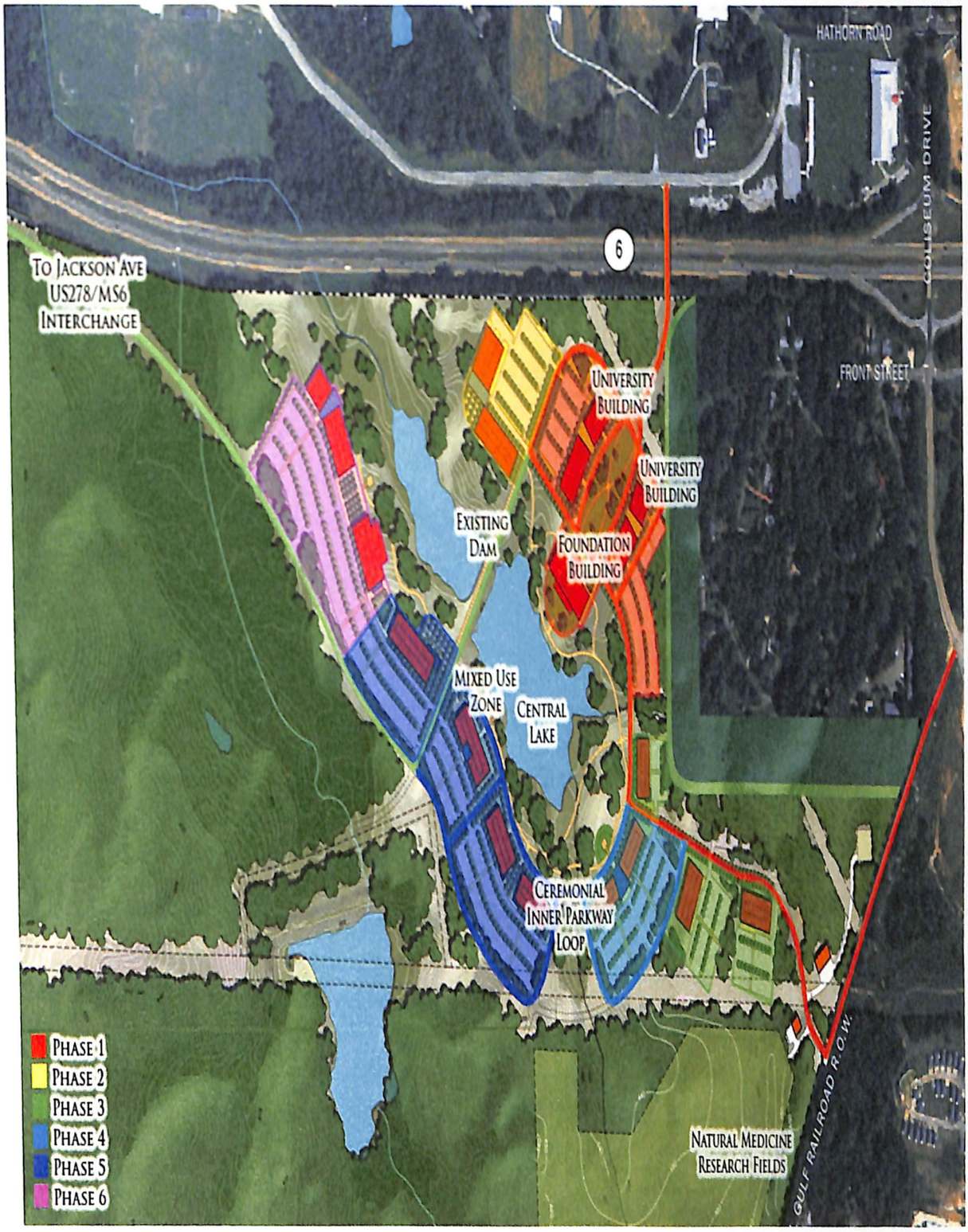
[67] University of Mississippi Center for Innovation Excellence. Master Plan. "Design Principles". Feb. 7 2008.

other will house a dry lab. The graphics below depict the projected completed research park on the south side of Highway 6.



Above: View toward the Southwest—Note the integration of the preexisting lakes on site.

Below: Alternative, "Birds Eye View" Towards the Southeast



Above: "Illustrative Master Plan"—Note: The site of the initial two buildings can be seen directly across Highway 6 near the present medicinal garden facility.

According to the projected economic forecast performed by Tennessee Valley Authority's Dr. Ralph Perhac, following completion, based on 690,000 gross square feet

of facilities, the University of Mississippi Research Park will have the following approximate impact on Lafayette and the surrounding north Mississippi counties:

Annual Impact	Direct Employment	Indirect Employment	Total
Retail Spending	$40,811,146	$17,419,050	$58,230,196
Sales Taxes	$2,856,780	$1,219,334	$4,076,113
Residential Property Taxes	$1,843,049	N/A	$1,843,049

Immediately following state funding and tuition receipts, research is presently the third largest source of university revenue. In preexisting university research parks, companies typically lease space in buildings from the universities. However, in some circumstances, companies lease the space from the university and build their own buildings, owning the facility for the life of the building. The Association of University Research Parks (AURP) discourages universities to use their own funding to tailor facilities according to the companies requests. Rather, it is advised that companies lease the buildings from the universities with customization options and provisions built into the contract.

Purdue University had trouble in this area several years ago when a research park facility-leasing company was acquired by a larger company after Purdue had custom tailored the space for the specific company. Consequently, a significant sum of university money was wasted because the space had been company-specific tailored and was no longer needed following the leasing company's acquisition.

VI. Conclusions and Subsequent Recommendations

Overall, the state and universities need to make a greater effort to leverage what they do well. The majority of necessary resources is already present or are in the development process. A synergistic relationship between different programs, whether in single or cross-university departments, is essential for maximum capitalization. It is necessary that universities focus on both horizontal and vertical cooperation, acknowledging the attraction of investing companies as the ultimate goal. The easier accessible the brain trust and intellectual capital and facilities become, the more desirable the situations for companies' investments become.

This can be done on a variety of levels, whether capitalizing on working collaboratively with another single department or school on campus, or working jointly with another in-state university. For instance, the faculty of two separate universities can each submit joint research proposals. A current example of a level of joint university research is the University of Mississippi and Mississippi State University working collaboratively with the USDA.

In addition, a company could work collaboratively with private labs and a university. For instance, a company could write a grant and work jointly with a lab like the private Elsohly, Labs in Oxford, MS and the University of Mississippi, capitalizing on various levels and areas of expertise. Elsohly, Labs is an analytical laboratory that was started by Dr. Elsohly, a former University of Mississippi Chemistry professor. Although Elsohly, Labs is a strictly for-profit operation, it serves as an example of how a university spin-off can generate revenue which ultimately contributes to the state's economy.

On a single university cross-departmental level, a collaborative effort between the School of Business and the pharmacy department would be mutually beneficial. It would be extremely helpful for students pursuing degrees in the sciences to learn about the finances and accounting procedures and regulations governing and consequentially determining the direction and nature of their work in a given science-related career field. On the other hand, it would be tremendously helpful for business students to have the opportunity to learn about technology based innovation and research and development. Although most current business students are largely unaware, many of their careers could involve some degree of working for a bio-science company, since there are multiple opportunities that seem to go unfilled.

Though separated in the value chain from the actual in-lab research and drug development, it would be beneficial for students and future business workforce incumbents to understand the major players in the overall process of the industry, have some since of perception of how long it takes to get a product from the in-lab discovery stage to market, and to have a grasp of the Food and Drug Administration regulatory environment. Individuals should not work with a narrow field of vision, and it is vital to have some sense of understanding and knowledge of the process.

Although The University of Mississippi's former three-year MBA program in pharmaceutical sales provided students with a knowledge of the pharmaceutical industry, a greater knowledge of the process and overall value chain, emphasizing in-lab research of a product to its appearance on pharmacy or supermarket shelves is necessary. Nevertheless, the university's provision of such a program was a step in the right direction. However, since the university's MBA program switched to the one-year

duration requisite for completion, the pharmaceutical sales aspect has been completely eliminated from the curriculum.

Multiple departments can each contribute to the movement of a product to market. The Business School can serve as an essential tool, educating students, facilitating fund acquisition and the subsequent efficient movement of laboratory scientists' and inventors' products to market.

Reporting directly to the Business School, the Small Business Development Center (SMDC) on the University of Mississippi campus exists for this very purpose. The SMDC works with universities all over the country, and the National Center for Natural Products research is working with them presently. Their expertise is necessary for the development of successful business plans providing maximum capitalization, utilizing the intellectual property of University of Mississippi lab scientists at the National Center for Natural Products Research.

Although I decided to add a chemistry minor to my business degree to obtain the necessary prerequisite courses necessary for medical school admission, how many business students understand the properties of a carbonyl, double bond or an aromatic ring? An understanding of the fundamentals is incredibly useful for the overall involvement in the industry, whichever end of the spectrum that may be—in-lab discovery, or marketing strategy and R&D funding. Should I decide not to pursue medical school and rather, utilize my business degree, my understanding of the process and mechanics of the bio-science industry will be extremely useful because of the inevitable correlation of science and business.

Graphics Works Cited

The following graphics are located in separate sources than their adjacent text, and therefore, are cited separate from the footnotes on the pages. If a graphic does not appear cited below, then it can be assumed that it came from the same source as the adjacent text.

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[i] Biotechnology Industry Organization. Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006. 7 Feb. 2009. <http://www.bio.org/local/battelle2006/>.

[ii] Biotechnology Industry Organization. Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006. 7 Feb. 2009. <http://www.bio.org/local/battelle2006/>.

[iii] Ibid

[iv] Biotechnology Industry Organization. Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006. 7 Feb. 2009. <http://www.bio.org/local/battelle2006/>.

[v] Biotechnology Industry Organization. Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006. 7 Feb. 2009. <http://www.bio.org/local/battelle2006/>.

[vi] Ibid

Biotechnology Industry Organization. Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006. 7 Feb. 2009. <http://www.bio.org/local/battelle2006/>.