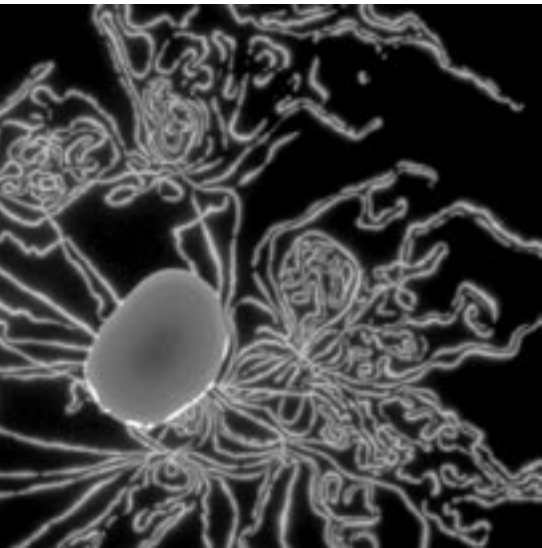


BIOTECHNOLOGY WORKS IN NORTH CAROLINA

Agricultural Biotechnology Takes Root Statewide



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**North Carolina
Biotechnology Center**

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Agricultural Biotechnology Takes Root Statewide

EXECUTIVE SUMMARY

AGRICULTURE HAS ALWAYS BEEN NORTH CAROLINA’S LARGEST INDUSTRY, as well as a way of life for many of the state’s people. It contributes \$59 billion annually to the state’s economy, accounts for one-fifth of its income, and employs almost 20 percent of the workforce. Modern agriculture, a fast-moving and challenging industry, has changed dramatically in recent years. These changes bring exciting and lucrative opportunities, particularly in the application of biotechnology to agriculture. With its strong research and education, rich agricultural tradition, and progressive farmers, North Carolina is at the forefront of agricultural biotechnology.

North Carolina is implementing a statewide plan for developing biotechnology: *New Jobs Across North Carolina: A Strategic Plan for Growing the Economy Statewide through Biotechnology*. This report is designed as a companion to the statewide plan. It describes what agricultural biotechnology is and how it’s used, looks at North Carolina’s leadership role in agricultural biotechnology, and calls for partnerships as North Carolina strengthens agricultural biotechnology statewide.

What is agricultural biotechnology?

Biotechnology is a broad collection of tools and technologies that involve the manipulation of living cells and/or biological molecules to solve problems and make useful products. Agricultural biotechnology is the application of biotechnology to agriculture. Agricultural biotechnology is increasingly involved in the foods we eat, the clothes we wear and other everyday products we use. It has the potential to produce more food and fiber and other commodities at lower cost and with less environmental impact. It can help improve existing products, find new uses for obsolete products, and develop entirely new products.

Biotechnology has broad applications in both plant and animal agriculture. This report focuses primarily on plant agriculture.

The tools and technologies of biotechnology have three main applications to plant agriculture:

- Creating new crops
- Making a tool to improve crops
- Finding new uses for old crops

Each of these categories is broad and has many opportunities for farmers and other members of the agricultural community to add value to what they are already doing. Following is an overview of each category, and how it is important to North Carolina.

Creating new crops

Ever since humans began cultivating crops instead of hunting and gathering food, we have been genetically improving our food. Until recently, this meant simply breeding crops with the best characteristics and saving those seeds to plant the next year.

As we’ve learned more about DNA — the molecule in every cell that gives the instructions for life — we understand better, for example, why some corn tastes sweeter and why squash and other plants can resist viruses. These traits are associated with genes, pieces of DNA that give a plant or animal specific traits.

Today we can insert into a plant cell a gene that carries a beneficial trait. That gene can come from the same type of plant, from a different plant or even from an animal. For example, a gene from citrus fruit may allow potatoes to grow in soil with high acid levels. Plants that have been developed in this manner are generally referred to as Genetically Modified (GM) or Genetically Modified Organism (GMO).

These advances represent great potential benefits for farmers, food processors, consumers and the environment. These GM crops have a new trait that was not present before but adds value for the farmer, the processor, or the consumer.

The accompanying table shows examples of these types of improvements.

The creation of crops with new traits has been occurring for many years. The humble corn chip, found in super-

markets across the U.S., actually contains multiple ingredients that are likely to have been made from genetically modified plants, as shown in the Figure, Anatomy of a corn chip.

The corn chip example is a demonstration of how many newly created foods are present in today's marketplace. More than 50 biotechnology crops have been approved for sale in the United States and Canada, and three have been approved in Mexico. The list includes enhanced soybeans, cotton, corn, canola, cantaloupe, papaya, potato, squash, sugar beets and tomatoes. Most of the biotech crops now on the market have been enhanced to make them resistant to harmful environmental factors.

Many farmers have deliberately chosen to plant biotech crops for very simple reasons: biotech crops give higher yields, have lower costs, and require less spraying. A 2002 study of biotech crops by the National Center for Food and Agricultural Policy found that six biotech crops planted in the United States — soybeans, corn, cotton, papaya, squash and canola — produced an additional 4 billion pounds of food and fiber on the same acreage, improved farm income by \$1.5 billion and reduced pesticide use by 46 million pounds.

The economic effects of these new crops extend beyond the farm. In Corn Belt states with higher adoption levels of biotech crops, there are more agriculture and food science jobs than in states with lower levels of adoption. In Iowa, there are 50 such jobs per 100,000 jobs, with an average salary of \$52,310 — more than 1.5 times the U.S. average salary of \$34,020. Although it's difficult to say if these results are the cause or effect of the adoption of agricultural biotechnology, it seems clear that states that are ag-biotech savvy are seeing benefits.

The North Carolina success story on page 10, *In Tall Cotton*, shows the positive economic impact of a biotech crop in North Carolina.

Agricultural Biotechnology

	Category	Specific Example
1	Resistance to harmful environmental factors such as insects, agricultural chemicals (including herbicides and pesticides), viruses and other diseases	Bt cotton, Round-up Ready soybeans
2	Modification of existing characteristic such as growth rate, fruit size, drought resistance	SunDance Genetics' drought-resistant corn
3	Added nutritional value such as increased vitamin content, increased inherent nutrition	Golden Rice increased Vitamin A content,
4	Totally new trait/biopharming such as plants or animals that make therapeutic products	Biolex's transgenic duckweed

Making a tool to improve crops

The second application of biotechnology to agriculture is to add value to agricultural commodities. Again, this type of agricultural biotechnology is already widespread and growing rapidly. Uses include animal vaccines, growth hormones, antibiotics, fertility applications, characterization of crop traits, feed additives and many other applications. (How biotechnology tools are used as feed additives is described more extensively on pages 9-10.)

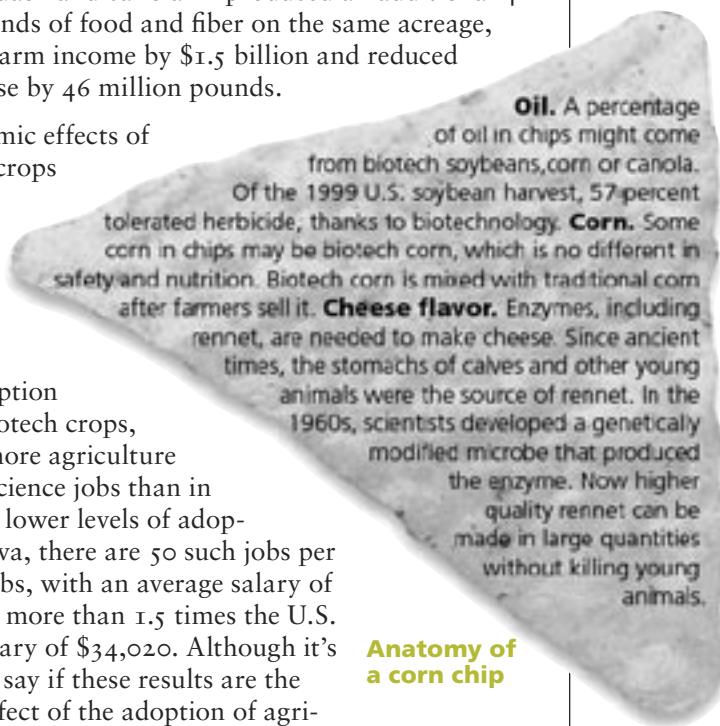
Animal vaccines are a great example of biotechnology applied to agriculture. For instance, vaccines that protect commercially grown fish from disease can result in a much greater commodity yield. Biotechnology tools have been widely used in the research laboratory to help create many new animal vaccines for diseases costly to the farmer.

In North Carolina, biotechnology tools have also been used to improve the way vaccines are delivered. In the old days of the poultry business, newborn chicks were vaccinated by hand, a cumbersome and expensive method that was also stressful to the birds. Today many poultry hatcheries around the world use an automated egg-injection system to vaccinate poultry in ovo, or in the egg. This technology was developed by a North Carolina company and is described more extensively on page 9 in the section, 'Of chickens and eggs.'

Biotechnology tools will help agriculture in many ways, some of which are yet to be foreseen. In the future, biotechnology tools will touch just as many lives as tools of the information technology industry do today.

Finding new uses for old crops

Biotechnology is applied to agriculture in a third way through the development of new uses for traditional crops. This application of agricultural biotechnology is



Anatomy of a corn chip

not as tied to GM technology, although crops already on the market (such as Roundup-ready and Bt varieties) might be used simply because of their prevalence. In the future, food crops may be specifically modified for industrial uses. For instance, soybeans could be genetically engineered for higher soybean oil production versus plant protein content, for use in biodiesel fuel production.

Industrial biotechnology begins with agriculture, using a renewable resource such as corn, soybeans, or other type of biomass as the starting material. An example of this type of industrial process is shown in the figure below. The starting material (corn) is processed into its components: protein, starch, oil, fiber, and lignin. After additional refining and synthesis, the components are turned into the end products. In this example, the end products include ethanol, solvents, pharmaceutical intermediates and surfactants.

Industrial biotechnology is of interest to both the chemical industry and the energy sector. In the chemical industry, current industrial biotech products include alcohols, fine chemicals, organic acids, amino acids, enzymes, flavors, and fragrances with a current sales value of around \$300 million. Experts project that the potential market for bio-based materials is up to \$1 trillion.

In addition to the chemical industry, the energy sector is experiencing renewed interest in the use of biomass to produce ethanol (sometimes referred to by the broad term industrial bioprocessing). Major multi-national corporations are beginning to test the waters in the bio-fuels sector of the economy. Additionally, recent legislation from the federal government to provide grant assistance for the construction of ethanol production plants from biomass should help subsidize remaining costs involved in building this infrastructure. Finally, technical advances from companies such as Novozymes (with its North American headquarters in Franklinton, N.C.) are making ethanol production far more economically feasible.

Industrial bioprocessing will grow in importance to North Carolina. This has been demonstrated by the \$5 million Golden LEAF investment in the Atlantic Bio-Energy biodiesel plant, the North Carolina Legislature's passage of a tax moratorium on biodiesel sales, and legislation introduced to provide tax credits for biodiesel production, and the planned construction of several ethanol plants.

Corn has been the first crop of choice for most ethanol production plants in existence and on the drawing board. North Carolina

Biotech's effect on the chemical industry

Adapted from Chemical Week, February 11, 2004

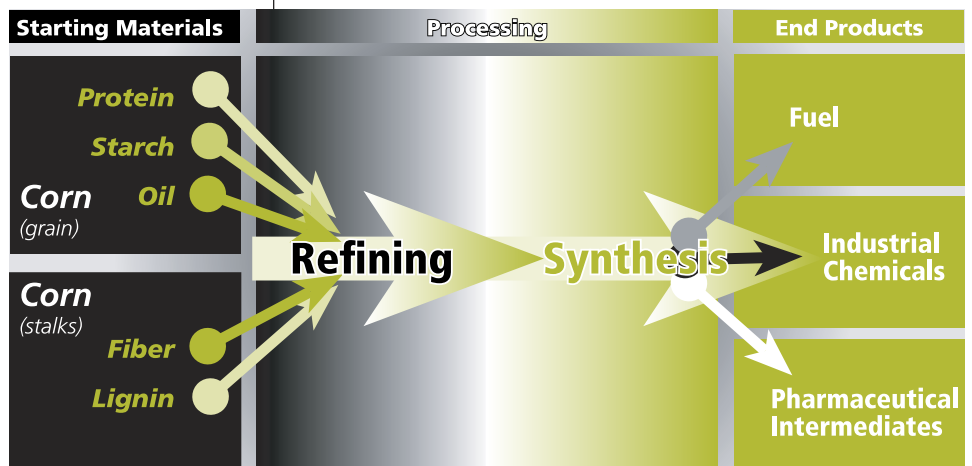
Sector	Market Size (in billions)	Current Biotech Impact	2010 Biotech Impact
Fine Chemicals	\$50	15%	30-60%
Polymers	\$250	1%	6-12%
Bulk Chemicals	\$300	3%	6-12%
Specialty Chemicals	\$400	0-15%	0-50%
Total	\$2000	5%	10-20%

will have to plan its strategy carefully, because it faces competition from the Corn Belt states, which are investing heavily in this sector. Fortunately, improvements in the technologies are making the use of biomass other than corn economically feasible.

It is encouraging that crops that have traditionally been for low-value uses such as animal feed may be increasingly used for bio-based applications. Depending on how ethanol production value chains are structured, much more of the economic return for biomass could accrue to North Carolina's growers.

North Carolina as a leader in agricultural biotechnology

North Carolina's farmers grow many economically important agricultural products and rank first in the nation in the production of many food, fiber, and forestry products. In the east, farmers raise sweet potatoes, watermelons, hogs, tobacco, cotton and many other important crops. In the west, other agriculture-related industries such as the forestry industry and wild-crafting (harvesting of medicinal herbs from the wild) thrive.



North Carolina has all the components for success in agricultural biotechnology: astute farmers, agricultural biotechnology companies, stellar research, committed teaching institutions, an entrepreneurial spirit, informed citizens, and strong state leadership. North Carolina leaders understood very early that the tools of biotechnology would impact many industries vital to North Carolina’s economy, including agriculture. North Carolina’s government leadership has been evident in the North Carolina Department of Agriculture and Consumer Services, funding for universities with a focus on agriculture, and also in the establishment and maintenance of the North Carolina Biotechnology Center and its programs.

North Carolina ranks in the top two states in the nation when it comes to agricultural biotechnology companies. North Carolina has more than 30 ag biotech-related companies employing at least 2,500 workers in the state. These companies include major multi-national corporations such as Bayer CropScience, Syngenta, Monsanto and BASF, established biotechnology companies such as Embrex, and small entrepreneurial ventures such as Sun Dance Genetics and BioResource International. (See the table on North Carolina agricultural biotechnology companies. Please note some companies fall into multiple categories.)

Because agricultural biotechnology is driven by innovation, it naturally clusters around excellent universities. North Carolina has world-class research in agricultural biotechnology at multiple institutions. In addition, North Carolina’s teaching institutions are committed to agricultural education. The North Carolina Community College System (NCCCS) recently announced a focus on agricultural biotechnology as part of the BioNetwork System, a new economic development initiative funded by the GoldenLEAF. Robeson Community College has been established as a NCCCS BioNetwork Center for BioAgriculture.

North Carolina’s model for biotechnology development and its application to agriculture

Wanting North Carolina to be at the forefront of biotechnology, the State in 1984 created the North Carolina Biotechnology Center to stimulate the biotechnology economy and create jobs for North Carolinians.

The Biotechnology Center’s mission is to provide long-term economic and societal benefits to North Carolina by supporting biotechnology research, business and education statewide. Although the Biotechnology Center works with all aspects of biotechnology, many of its resources have been devoted specifically to agricultural biotechnology.

North Carolina’s ag biotech companies

AgBio/ Natural Products/ Nutraceuticals	Veterinary/Pesticide
Advanced Animal Diagnostics	AgraSol
AgraSol	American Agricultural Services
Akkadix Genetics	Biogaia
Athenix	BioResource International
BASF	Cropsolution
Bayer Crop Sciences	Embrex
Cropsolution	Idexx
Jabb of the Carolinas	Jabb of the Carolinas
KHH BioSci	Medtox Diagnostics
Medtox Diagnostics	Novartis Animal Health
Monsanto	Piedmon’t Pharmaceutical
PhytoMyco	
Sun Dance Genetics	
Syngenta Biotechnology	
Syngenta Crop Protection	
Yellow Creek Botanicals	

Foods	Environmental/ Biofuels
Ajinomoto	Alderon
Biogaia	Athenix
Corn Products Interational	EcoGenomix
DSM Food Specialties	Ensolve
Novozymes	Hybrizyme
	Syntherica
	Xenobiotic Detection Systems

Industrial Biotech
Novozymes

From Research to Row Crop: putting agricultural biotechnology to work for North Carolina

North Carolina has become a leader in agricultural biotechnology because it has made the right investments to move biotechnology innovations from research to row crop. This section of this report looks at the work of the North Carolina Biotechnology Center and its partners that has helped make North Carolina a leader in agricultural biotechnology. Strategies used to achieve this leadership position have included generating new ideas, moving ideas to market, creating reasonable regulations, preparing teachers and educating the public.

Generating new ideas

Generating new ideas that can eventually lead to new companies and jobs is essential for North Carolina's economic prosperity. University research is the primary source of these ideas and drives innovative new businesses and job creation. The most immediate payoff comes from applied research, but even basic research can ultimately lead to commercial products. North Carolina has some of the world's foremost research universities of agricultural biotechnology. Nurturing this research and building infrastructure are critical to growth and innovation in agriculture.

A total of \$10,188,967 in agricultural biotechnology funding was awarded through multiple Biotechnology Center programs from 1984 to 2004. Funding was distributed through two broad categories: grants to North Carolina universities and loans to North Carolina companies. This investment has spurred more than \$173 million in follow-on funding from other sources. Grant funding is described on this page; loan funding is described on page 9, in the section on Moving Ideas to Market.

Overview of Biotechnology Center agricultural grant funding

The Biotechnology Center made more than 170 awards in agriculturally related research to universities from 1984 to 2004 through its Science and Technology Development Program. Many of the projects funded went on to garner subsequent funding (follow-on funding) for the research initiated by the original Biotechnology Center award. Total follow-on funding for grants awarded between 1984 and 2001 is currently \$76,624,250, or \$9 for every dollar invested by the Biotechnology Center. Follow-on funding continues to accumulate for as long as the project is active, so this figure (particularly for the more recent awards) is likely to increase.

Agriculture Awards to North Carolina Universities

Total of Grants Awarded:	\$8,545,803
Total Follow-on Funding:	\$76,624,250
For every dollar invested by the Biotechnology Center, amount these projects secured in subsequent funding from other sources:	\$8.97

Planting seeds for the future: six sneak previews

The Biotechnology Center has funded early stage research projects that may be pivotal for future innovation in agricultural biotechnology. Following are summaries of six recently funded Biotechnology Center research projects that may yield innovations with commercial potential for farmers.

Sweet potatoes for fuel

Researchers are developing sweet potatoes that can easily be processed for ethanol extraction. North Carolina is the national leader in sweet potato production, growing 40 percent of the nation's sweet potatoes, so our state could benefit tremendously from increased use of this crop.

Cleaner hog waste

Waste management has become a key environmental and regulatory issue in North Carolina's large hog industry. Researchers are developing ways to reduce phosphorous pollution from hog farms by adding a microbial enzyme to hog feed, which helps the animals absorb more phosphorous in the gut.

Better watermelons

Researchers are working with scientists at Syngenta to map the watermelon genome — all the genes that make up the plant. The genetic tools derived from these studies may enable scientists to develop disease-resistant watermelon. This would be good news for North Carolina farmers who grow watermelon. More acres of watermelons are planted than any other vegetable in North Carolina.

Natural products for Western North Carolina

The Western office of the Biotechnology Center helped form a collaboration among the North Carolina Arboretum, UNC-Asheville, the Mountain Horticultural Crops Research Station, and the North Carolina Natural Products Association. These groups have received a grant from the Biotechnology Center to develop a business and marketing model exploring the application of biotechnology to natural products in Western North Carolina.

New fish vaccines

Researchers are studying fish pathogens with an eye toward developing better diagnostics and vaccines to protect commercially grown fish from viruses and other pathogens in the state's fish farms.

Better trees

Researchers are developing new strategies for controlling a pest that attacks Fraser firs, the dominant tree in North Carolina's \$100 million Christmas tree industry. They are also working to develop other trees with better wood quality and greater volume of wood.

Research forums

In addition to funding new research, it is also important to create the right intellectual environment for the exchange of scientific information in agricultural biotechnology.

North Carolina Plant Molecular Biology Consortium

The Plant Molecular Biology Consortium emerged from the recognition that the field of plant molecular biology is vitally important to two of North Carolina's leading industries — agriculture and forestry — and from the awareness that the state's academic institutions are uniquely positioned to collaborate with each other and with corporations. This forum has thrived for almost two decades. The group commands active participation from both industrial and academic scientists, as well as generous corporate sponsorships.

Spotlight on agricultural biotechnology: Biopharming

The Biotechnology Center initiated the BioProcess & Process Development Group to address the needs of product-manufacturing in biotechnology industries. In October 2003, process development scientists and engineers met at the Biotechnology Center to discuss the development of therapeutic products in transgenic plants. Biopharming, as it is sometimes known, is an innovative development in the production of therapeutics in plants.

Forest biotechnology

The wood products industry is one of North Carolina's largest manufacturing industries with \$19 billion in annual shipments and employment of more than 135,000 North Carolinians. As demands on the forestry industry increase from foreign imports and less available logging on public lands, the industry is looking for innovative solutions. Forest biotechnology strives to engineer trees that are hardier, can be grown more quickly, produce more wood on less land, and require less chemical processing for pulp and paper making.

To address opportunities in forest biotechnology, the Biotechnology Center in 1999 sponsored an Advisory Committee on Forest Biotechnology composed of company officials, government advisors, researchers, and environmentalists. One of the Committee's recommendations led to the creation of the Institute of Forest Biotechnology. The Institute, an international non-profit group that does not conduct laboratory research, strives for societal, ecological and economic benefits from appropriate uses of biotechnology in forestry. The Institute works on a variety of projects including a Heritage Trees Project to help restore tree species that are threatened or endangered, and assessment of ecological risks associated with the use of genetically engineered trees.

In creating the Institute of Forest Biotechnology, the Biotechnology Center built on one of the largest and most successful forest biotechnology research groups in the world. This group at North Carolina State University has tremendous federal funding and an excellent history of industrial collaboration, intellectual property creation, and formation of multiple start-up companies. One key element in the success of this group is the leadership of Dr. Ronald Sederoff, who was recruited to NCSU with the assistance of a Biotechnology Center Faculty Recruitment Grant. This grant also provided funding for the initial establishment of the group. The Biotechnology Center has continued to be a resource for NCSU's Forest Biotechnology group, recently awarding it a grant for major, multi-user equipment for forestry biotechnology research.

Moving ideas to market: how agricultural biotechnology will help grow the economy for farm communities

Creating new ideas is only the beginning of agricultural economic development. The ways in which technology is transferred from universities into practical use is at the heart of the biotechnology economy. Biotechnology Center loan programs are designed to facilitate this process, and provide very early stage support for young companies that are taking new technologies to market.

Overview of Biotechnology Center agricultural loan funding

Over the years, the Biotechnology Center has made 24 loans or grants totaling \$1.6 million to agricultural and nutraceutical companies through its Business and Technology Development Program. These companies have secured \$97.5 million in follow-on funding from other sources, or \$60 for each dollar invested by the Biotechnology Center.

As a measure of impact, follow-on funding for companies is calculated by counting all funding a company receives in years following the Biotechnology Center’s initial investment in the company. Follow-on funding includes federal grants, venture capital, private capital, licensing and other collaborations, and money raised in public stock offerings.

Agriculture Awards to North Carolina Companies

Total amount awarded to agricultural and nutraceutical companies by the Biotechnology Center:	\$1,623,717
Total amount of follow-on funding from other sources:	\$97,450,258
For every dollar invested by the Biotechnology Center, amount these companies secured in subsequent funding from other sources:	\$60.02

Following are stories of long-term commercial success that began with the development of new technologies through loan funding from the Biotechnology Center.

Of chickens and eggs: Embrex transforms the poultry business

In the old days of the poultry business, newborn chicks were vaccinated by hand, a cumbersome and expensive method that was also stressful to the birds. Today many poultry hatcheries around the world use an automated

egg-injection system to vaccinate poultry in ovo, or in the egg. The system, developed by Embrex Inc. of Durham, saves time and money and gets the chicks off to a healthier start. It is used to vaccinate more than 80 percent of broiler birds raised in the United States and Canada against Marek’s disease.

Founded in 1985, Embrex received key initial funding from the Biotechnology Center for its research and development. The company went on to raise \$14 million in venture capital and gain \$27.5 million in two public stock offerings. Two private placements in 1991 and 1995 raised an additional \$5.5 million. Today, Embrex is a profitable company that employs more than 300 people worldwide, including many engineering and poultry science graduates of North Carolina State University. In addition to its Durham headquarters, Embrex has built a new vaccine-production plant in Laurinburg. The company continues to grow with several new products under development and plans to increase global markets for its existing products.

Success on the horizon: two stories

Following are two summaries of commercial projects on the verge of success.

Not just chicken feed

The discovery of a new enzyme has led to the founding of an agricultural biotechnology start-up company on North Carolina State University’s Centennial Campus, 10 U.S. and international patents, and hundreds of thousands of dollars in federal funding. This new enzyme is a protease — officially named Versazyme — that breaks down proteins. Researchers at the start-up company, BioResource International (BRI), and NCSU used funds from a Biotechnology Center grant to do some of the early studies on how Versazyme works. The poultry industry is now very interested in the enzyme’s potential.

Eight billion chickens are produced in the United States every year. With that many chickens to feed, the old term ‘just chicken feed’ takes on a new and pricey meaning. Anything that can improve feed conversion is economically valuable to the poultry industry. Feed conversion refers to the percentage of feed that is efficiently digested and converted to increased body weight for the chicken.

Directly adding Versazyme to poultry feed increases chicken body weight. The enzyme is responsible for this by improving the digestibility of proteins in poultry feed. Academic and commercial proof-of-concept trials have shown that feed costs can be reduced by adding the enzyme directly to feed. The market potential for Versazyme is predicted to be upwards of \$200 million globally. In addition to its uses as a direct feed additive for poultry,

**IN TALL COTTON:
Biotech crop rejuvenates
farming in eastern North
Carolina**

Milton Prince of Belhaven had long grown corn, wheat, and soybeans on his Beaufort County farm since the 1970s. But when American consumers turned from synthetic clothing to natural fibers in the 1980s, he added cotton to the mix.

He started on a small scale in 1991, but the rich, dark soil — known as the Black Lands — had other ideas. It sprouted cocklebur, morning glory, pigweed, sicklepod, smartweed and other weeds that overtook the cotton, stunting his crop yields.

“I fought that thing for four years,” Prince recalled. “I was about to throw in the towel. We really had no herbicides to control weed pressures.”

Then along came new cotton varieties genetically engineered to resist herbicides. Growers could apply herbicides that would kill the weeds, but spare the cotton plants. It was a revolutionary advance for growers like Prince.

“These genetically engineered cultivars gave us the opportunity to grow cotton and control weeds effectively,” he said. “Without biotechnology, cotton would not be grown in this area today — no question about it.”

Today, about 50,000 acres of biotech cotton

are grown in Beaufort County and neighboring Hyde, Tyrrell and Washington counties, a 50-fold increase from the 1,000 acres grown in 1991. Biotech cotton has become so profitable that Prince no longer grows soybeans and other crops. All of his 2,700 acres are planted with biotech cotton that resists the environmentally friendly but broadly effective herbicide Roundup.

To process all the locally grown biotech cotton, Prince and nine other growers joined together in the late 1990s to build two cotton gins — one in Beaufort County and one in Hyde County. The \$10 million investment in Coastal Carolina Cotton Gins has boosted the tax base of both counties and created 10 full-time jobs and another 48 seasonal jobs.

Versazyme has a wide variety of other agricultural and industrial applications, including feed manufacture, food processing, waste management, detergents, cosmetics, leather processing, animal care products, nutraceuticals, biomedical research, and forensics.

Versazyme has even been shown to be effective in treating the cause of Mad Cow Disease. Mad Cow Disease is caused by an infectious protein called a prion. Using BRI's enzymatic process, prions can be inactivated. The U.S. Department of Agriculture has shown great interest in Versazyme as a strategy for preventing the spread of the disease into the United States. There is also interest in the application of Versazyme for the treatment of Chronic Wasting Disease, a similar disease that affects deer and elk.

Drought-tolerant corn

With the help of Biotechnology Center funding, researchers at Sun Dance Genetics and Duke University have developed new strains of corn with increased drought tolerance. Drought can have devastating effects on crop growers in North Carolina, the U.S. and around the world. While several wild corn species have significant drought tolerance, commercial corn does not endure drought conditions very well. Attempts to transfer the drought tolerance trait from wild to commercial corn has been unsuccessful, resulting only in sterile hybrids.

Scientists at Sun Dance Genetics, however, obtained fully fertile hybrids by crossing *Tripsacum*, a species of wild corn highly tolerant to drought, with *Zea diploperennis*, wild corn. This hybrid is highly fertile and crossable with commercial corn. Further crossings have led to the development of hybrids with commercial potential. Preliminary tests have shown that the new hybrid lines of corn yield 10 to 25 percent more crop than normal commercial corn. In addition to drought tolerance, the new hybrids are also resistant to a fungal pathogen, aflatoxin.

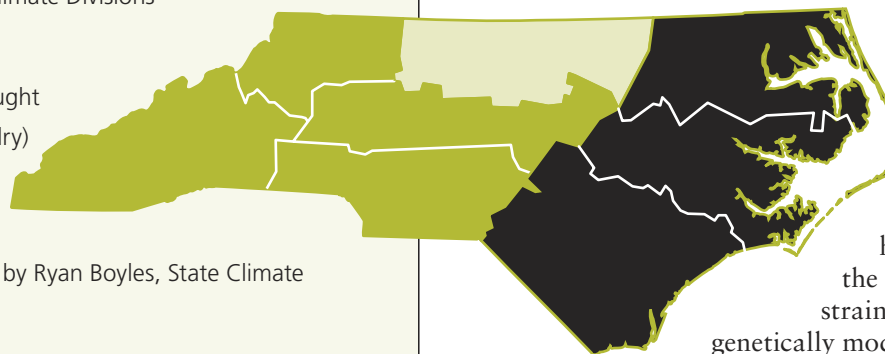
**North Carolina Drought
1998-2002**

Average Summer Palmer Drought Severity Index

From Dec 7 '02 to Jan 6 '03, more than one half of North Carolina was labeled as a drought area.

legend: United States Climate Divisions
Palmer Index (partial)

- moderate drought
- near normal (dry)
- normal



Prepared April 8, 2004, by Ryan Boyles, State Climate Office North Carolina

If field tests are successful, the new hybrid seeds will be put on the market for use by farmers. Although biotechnology tools have been used in the project, the new strains of corn are not genetically modified.

This advancement is of particular interest because in addition to the drought conditions experienced recently both locally and worldwide, water currently used for agriculture may be increasingly diverted for household and industrial use in the future. Drought-tolerant crops will be essential to staving off food shortages and even political disputes, according to biotechnology analyst and financier Steven Burrill of Burrill and Co. “If we do not take steps to develop drought-tolerant crops that will enable us to greatly improve our yields, we will surely be facing a global crisis that will not only cause famine and disease, but will also pit nations against one another for survival,” Burrill wrote in “Biotech 2003,” the 17th annual report on the biotechnology industry.

Reasonable Regulation

North Carolina knows how to create and maintain the right regulatory environment to attract and retain agricultural biotechnology companies. Creation of a consistent and transparent regulatory environment in agricultural biotechnology remains very important, particularly with regard to recruiting and retaining companies in this sector. The recent report from the Pew Initiative on Food and Biotechnology indicates that biotech companies are more inclined to move to states that provide well-structured regulatory climates to such enterprises. This report also praised North Carolina as a leader in this area, and commended the North Carolina Department of Agriculture and Consumer Services for its work in regulatory affairs.

North Carolina led the way in early agricultural biotechnology regulations

A few years after the Biotechnology Center was begun, a call came from a multi-national agricultural company. That company had a new question with regard to agricultural biotechnology, and needed assistance.

The company needed to conduct a field test of a genetically modified crop in North Carolina. However, at that time there was no state or federal framework regulating field tests. How should the company proceed?

The Biotechnology Center responded. The first step was to convene a committee of 29 North Carolinians to

represent industry, government, the environment, and research. The committee spent a year drafting the first consensus-based legislation for the testing of genetically modified field crops. The legislature also set up a Genetic Engineering Review Board to review future requests for field tests. This Board had a ‘sunset clause,’ and when national legislation was developed a few years later, the Board was discontinued. However, North Carolina’s framework served as a model for the development of rational, science-based regulation of plant biotechnology on the state and federal level.

Educating the public

North Carolina’s Department of Agriculture and Consumer Services reaches out to the public every year through the annual State Fair. North Carolina citizens visit the Fair for many reasons (including fun!), but this is also where new technologies can be showcased for the general public.

In 2001 the N.C. Department of Agriculture and Consumer Services’ State Fair division, with the assistance of many other parties, including corporations, universities, and non-profits, created BioFrontiers. Parents, school children, retirees and farmers saw a mock plant research lab, plots of field crops improved by biotechnology and some of the latest technologies for studying plant genes. In BioFrontiers’ two-year run, well over 300,000 people stopped in to learn about the science, benefits, and issues of agricultural biotechnology.

Because the public has many questions about agricultural biotechnology, the Biotechnology Center also publishes a brochure, “Considering the Nature and Issues of Food Biotechnology.” Since its release in March 2000 many copies have been distributed to the public, and the publication is also available for viewing on the Biotechnology Center’s Web site (www.ncbiotech.org/biotech101/hot-topics/foodbt.cfm). This publication has been particularly of interest to students and teachers.

Teaching the teachers

The Biotechnology Center reaches across the state every year to teachers who are eager to learn more about agri-

Which would you rather sleep on every night? A pillow made from corn or one made from oil?

Corn is the starting material for producing industrial-scale, commercial-grade plastics

at an innovative plant in Nebraska. This plant can produce more than 300 million pounds of polylactide (PLA) a year, using up to 40,000 bushels of locally grown corn per day as the raw material.

PLA fibers bridge the gap between natural and synthetic materials, combining the most

desired physical and performance qualities of each for high-quality textiles. PLA has the potential to improve synthetic products currently made from petrochemicals. PLA-based sleep products, including pillows, comforters, and mattress pads, are sold by mass market retailers.

Bio-based economy: An economy that uses renewable raw materials and biotechnology to produce products and energy.

cultural biotechnology topics through its ongoing Summer Workshops for Educators. These workshops have reached nearly twelve hundred North Carolina teachers, who in turn have taught hundreds of thousands of North Carolina students. For several years, these Biotechnology Center-sponsored workshops have included: Introductory Biotechnology, Biotechnology for Plants, Animals and the Environment (which includes Current Techniques in Animal Husbandry, Applications of Plant Science, and Environmental Protection), and Forensic DNA from the Irish Potato Famine Pathogen.

The workshop on the Irish potato famine is easy to relate to modern agriculture, given that the potato is ranked 17th in major North Carolina farm commodities and had 2002 cash receipts of \$32 million.

The Biotechnology Center has also funded the development of courses in agricultural biotechnology, including Biotechnology and Agriscience Research I, a high school course that was part of the Career and Technical Education curriculum, as well as a middle school course on Exploring Biotechnology that has an agricultural component.

Challenges in agricultural biotechnology

Although agricultural biotechnology holds much promise, it also faces two major challenges in North Carolina: public acceptance and competition.

Societal Issues

Advances in agricultural biotechnology carry many potential benefits for farmers, food processors, consumers

and the environment. But with these advances also come questions, such as environmental impact, food safety, and labeling issues.

Before foods developed with biotechnology can be marketed in the United States, there are nine separate steps in the regulatory process that typically take seven to 10 years to complete — a far more rigorous process than is required for conventional foods.

Many organizations, including the American College of Nutrition, the American Medical Association, the International Society of Toxicology, the General Accounting Office of the U.S. Congress, and the World Health Organization have attested to the safety of foods developed with biotechnology.

Still, certain interest groups as well as some consumers continue to have concerns about genetically modified foods. This has commercial impact, because some markets (the European Union and Japan among them) have resisted biotech crops.

Additional background on agricultural biotechnology and its challenges is available through the list of Web links included at the end of this report.

Competition

Competition for biotechnology growth and development is intense nationally and internationally. Forty-one states have initiatives in biotechnology to support economic growth, and some of those states have chosen to focus on agricultural biotechnology as a way to grow their state's economy. North Carolina also faces rising competition from other countries. For example, Chinese policymakers consider agricultural biotechnology as a strategically significant tool for improving national food security, raising agricultural productivity, and creating a competitive position in international agricultural markets. The growth of the Chinese government's investment in agricultural

Excerpt from *New Jobs Across North Carolina: A Strategic Plan for Growing the Economy Statewide through Biotechnology*

Recommendation: Assist communities statewide, particularly rural ones, to identify niche opportunities and target resources for building biotechnology-related activities.

North Carolina, varied in natural and institutional resources, is uniquely able to spread

a growing amount of its biotechnology development statewide. Doing so requires: realistic estimation of area capabilities and goals; recruitment or expansion of companies, strengthening of scientific, educational, support, company, agricultural and biomanufacturing capabilities; assistance to area agencies and institutions; and commitment from governmental, institutional, and economic development leadership. Results will be gained with sustained attention and appropriate strategies.

Recommendation: Provide funding for

the Biotechnology Center to establish and maintain permanent regional offices statewide.

Targeting biotechnology applications and development to communities statewide is feasible, but can best be accomplished with strong attention within specific regions rather than from a central, distant, location. Small offices of the Biotechnology Center, responsive to niche opportunities with a community-based approach and programmatic funding, will accelerate economic development in biotechnology.

Examples of state government funding for agricultural biotechnology

State	Program
Iowa	Iowa has a \$19.8 million project that includes a new biologics facility at the Iowa State University Research Park to extract and purify plant proteins for pharmaceuticals, nutritional value and industrial use.
	BIOWA plans to develop at least 10 regional biorefineries in Iowa by 2020 — a \$500 million commitment.
Mississippi	HB1617; enacted 3/30/01, appropriates funds to the State Forestry Commission for 2003. Includes funding for the handling of genetically improved seedlings.
New Hampshire	SB353 passed and signed by Governor on April 4, 2002, includes genetically engineered trees grown for short rotation tree fiber in the class of trees to be exempt from general property and timber yield taxes.
Ohio	Ohio Agricultural Research and Development Center, which in turn supports the Ohio Plant Biotechnology Consortium. State appropriation in 2003: \$35.5 million.
Texas	The state plans to contribute \$10 million to the \$50 million Cow Genome Project.

A more complete overview of state initiatives in biotechnology is presented in 'New Jobs Across North Carolina,' available at www.ncbiotech.org.

research has been remarkable. Brazil is another country that is aggressively adopting biotechnology. The South American nation is a huge producer of genetically modified crops that compete with U.S. commodities.

North Carolina needs to anticipate the future of agricultural biotechnology and provide the right environment for its growth to remain competitive with other states and nations.

Strengthening agricultural biotechnology across the state

In January 2004, the Biotechnology Center released *New Jobs Across North Carolina: A Strategic Plan for Growing the Economy Statewide through Biotechnology*. This plan was developed at the request of Governor Mike Easley and guided by a blue-ribbon steering committee chaired by former governors Jim Hunt and Jim Martin. With support from the Biotechnology Center, scientists, educators, business and government leaders, university and community college leaders, economic developers, and biotechnology experts from every corner of North Carolina worked to develop the plan. Their work resulted in 54

strategic recommendations for growing the state's biotechnology industry and creating jobs.

As a key step toward implementing the strategic plan statewide, the Biotechnology Center has begun opening small regional offices across the state. Four offices have been opened in the Piedmont Triad and Western, Eastern and Southeastern North Carolina, and a fifth office is planned for greater Charlotte. These offices will build on unique regional resources to strengthen biotechnology in their areas. Agricultural biotechnology will be an important part of their work.

Different regions will build upon unique resources, including agricultural resources. Biodiversity and trees can provide a unique emphasis for Western North Carolina, as can marine resources, biomedical applications, and agriculture for Eastern North Carolina. The richly varied culture and geography of North Carolina yield a wonderfully varied foundation for biotechnology statewide. Agricultural biotechnology in particular, with the creation of new crops, the use of new tools to improve existing crops, and the development of new opportunities for existing crops, will be at the forefront. A new grant program was launched in 2004, specifically to help develop these regional initiatives.

Agricultural biotechnology will be employed in many ways in the existing and evolving agricultural industry. The North Carolina Biotechnology Center is interested in partnering with organizations statewide to develop this vision. For additional information, please contact the Biotechnology Center.

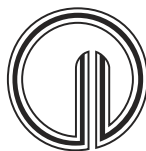
Other sources of information

Biotechnology Center Library

www.ncbiotech.org

Introduction to Genetically Modified Food	Hyperlinks
Food Biotechnology in the United States: Science, Regulation, and Issues — Congressional Research Service report, January 2001	cnie.org/NLE/CRSreports/Science/st-41.pdf
Transgenic Crops: An Introduction and Resource Guide — issues and technological aspects of genetically modified crops from Colorado State University	www.colostate.edu/programs/lifesciences/TransgenicCrops/
Poison Plants? — a look at both sides of the issue from Scientific American	www.sciam.com/article.cfm?SID=mail&articleID=0009632E-2481-1C75-9B81809EC588EF21
GM Food Special Report — the pros and cons of living in a genetically modified world from the weekly publication New Scientist (Great Britain)	www.newscientist.com/hottopics/gm/
Designer Seeds — article from Beyond Discovery	www.beyonddiscovery.org/content/view.article.asp?a=167
Biotechnology and Food backgrounder — from the Food Marketing Institute	www.fmi.org/media/bg/biotech.htm
<i>Tending the Fields: State & Federal Roles In the Oversight of Genetically Modified Crops</i> was prepared by Michael R. Taylor, Jody S. Tick and Diane M. Sherman of Resources for the Future, Pew Initiative on Food and Biotechnology	pewagbiotech.org/research/fields/
Government Resources	Hyperlinks
Acres of genetically modified crops and other statistics — published each June by the USDA's National Agricultural Statistics Service	usda.mannlib.cornell.edu/reports/nassr/field/pcp-bba/
Food Safety: Regulating Plant Agricultural Biotechnology in the United States — a report from the U.S. Department of State	usinfo.state.gov/products/pubs/archive/biotech/
Biotechnology: Food Safety and Security — October 1999 issue of Economic Perspectives from the U.S. Department of State	usinfo.state.gov/journals/ites/1099/ijee/bio-toc.htm
Information on Food Biotechnology from the FDA's Center for Food Safety and Applied Nutrition	www.cfsan.fda.gov/~lrd/biotechm.html
Genetically Engineered Foods: Fears and Facts — a 1993 interview with the FDA's Jim Maryanski	www.fda.gov/bbs/topics/consumer/Con00191.html
Genetically Modified Pest-Protected Plants — text of a book written by the Committee on Genetically Modified Pest-Protected Plants and the National Research Council	www.nap.edu/books/0309069300/html/
Environmental Effects of Transgenic Plants: The Scope and Adequacy of Regulation — book published by the National Academy Press	www.nap.edu/books/0309082633/html/
Impacts of Adopting Genetically Engineered Crops in the U.S. — report from the USDA's Economic Research Service	www.ers.usda.gov/whatsnew/issues/gmo/
Seeds of Opportunity: An Assessment of the Benefits, Safety, and Oversight of Plant Genomics and Agricultural Biotechnology — April 2000 report from the U.S. House Subcommittee on Basic Research	www.house.gov/science/smithreport041300.pdf
USDA Biotechnology Regulatory Services	www.aphis.usda.gov/brs/
North Carolina Department of Agriculture and Consumer Services	www.ncagr.com

Opposition to Genetically Modified Food	Hyperlinks
Genetic Engineering and Its Dangers — Collection of articles and links by a professor of Philosophy at San Francisco State University	online.sfsu.edu/%7Erone/GEessays/gedanger.htm
Genetically Modified Food — UK and World News — features news stories about genetically modified organisms in the food chain.	www.connectotel.com/gmfood/
CropChoice.com — Alternative source of news about genetically modified crops	www.cropchoice.com/
Center for Food Safety	www.centerforfoodsafety.org/
Greenpeace's True Food Network	www.truefoodnow.org/
Proponents of Genetically Modified Food	Hyperlinks
Food and Agriculture Biotechnology — from BIO (Biotechnology Industry Organization).	www.bio.org/foodag
CropGen.org — UK group making the case for crop biotechnology	www.cropgen.org/
Monsanto	www.monsanto.com/
Agricultural Biotechnology Support Project — international organization based at Michigan State University	www.iaa.msu.edu/absp/
Biotechnology Industry Organization	www.bio.org
Council for Biotechnology Information	www.whybiotech.com
AgBioWorld.org	www.agbioworld.org/
Genetically Modified Food Products	Hyperlinks
United States Regulatory Agencies Unified Biotechnology web site	usbiotechreg.nbii.gov
Greenpeace's "True Food" Shopping List	www.truefoodnow.org/shoppersguide/
The StarLink™ Controversy	Hyperlinks
CDC report (Jun 2001)	www.cdc.gov/od/oc/media/pressrel/r010613a.htm
Congressional Research Service report (Jan 2001)	cnie.org/NLE/CRSreports/Agriculture/ag-101.pdf
StarLinkCorn.com (includes facts & figures)	www.starlinkcorn.com/



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