

## Key Findings and Recommendations

At the request of the Research Triangle Regional Partnership (RTRP), RTI International<sup>1</sup> analyzed the Research Triangle region's technology strengths in light of trends and needs across relevant industry clusters (i.e., the industry itself and its supporting infrastructure, material supply, and knowledge base). The results of this analysis are designed to help RTRP's New Vision Task Force develop a prioritized list of action items that will support a shared vision for future economic development in the region.

RTI's detailed review identified 30 primary areas of technical strength across the academic, government, nonprofit, and for-profit organizations in the region, and identified in excess of 120 growth opportunities across these 30 technical areas. RTI mapped these growth opportunities to the industry clusters they impact and to the research and development (R&D) assets of the Research Triangle region. Further analysis resulted in a list of eight priority growth opportunities:

- Pharmaceuticals
- Biological agents and infectious diseases
- Agricultural biotechnology
- Pervasive computing
- Advanced medical care
- Analytical instrumentation
- Nanoscale technologies
- Informatics.

This document presents the key findings and recommendations developed by RTI for each growth opportunity. The region should focus attention and resources in these areas, leveraging its strengths to energize economic growth. Many other growth opportunities will be pursued by organizations in the normal course of business. However, these eight are judged to have the greatest potential when considering the following factors:

- Size of projected market opportunities
- Strength of existing R&D base and industry clusters in the region
- Prospects for job creation, cluster recruitment, new venture creation, and rural economic development
- Cross-cutting nature of research and technology to contribute to multiple clusters (or to enable growth at the intersection of existing clusters)
- Funding trends within government and private sectors
- Sustainability of job growth in the face of offshore competition.

RTI recommends that the Future Cluster Competitiveness Initiative and the New Vision Task Force develop targeted action items designed to grow and cultivate the research base in the Research Triangle region, and to build and attract industry around these growth opportunities.

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<sup>1</sup> RTI International is a trade name of Research Triangle Institute.

## 1. Pharmaceuticals

Pharmaceutical and biopharmaceutical R&D represents the most important research and technology intensive industry in the Research Triangle. The region offers resources to support the complete lifecycle of pharmaceutical development, including the following:

- Quality university life sciences programs and corporate research organizations produce discoveries that are transferred to emerging or existing companies, resulting in new therapies or R&D tools.
- Local research universities, medical schools, and nonprofits provide research services, as well as preclinical and clinical trials, in support of drug development efforts undertaken by companies ranging in size from small to large.
- The Triangle's contract research organizations (CROs) provide pharmaceutical research, testing, development, preclinical trials, clinical trials, and associated services to ensure compliance with Food and Drug Administration (FDA) regulations.
- Corporate and contract pharmaceutical and biomanufacturing plants are available.

The Research Triangle is one of very few places worldwide where such a critical mass exists. North Carolina receives substantial grant funds from the National Institutes of Health (NIH), and within North Carolina the Triangle receives the most NIH grants of any region. Despite flaws in the insurance system and cost-containment pressures, the public's desire for quality health care will continue to drive the search for new discoveries, new drugs, and advanced treatments. Demographics in most industrialized countries (i.e., aging populations) will also favor growth of the pharmaceutical industry.

Technological drivers provide great promise for the pharmaceutical industry. As the genetic bases for disease and disease intervention are better understood through fields such as genomics and proteomics, a profound increase in targeted, effective pharmaceutical therapies is expected. Advanced techniques—such as rational drug design and testing in advanced animal models—will drive the translation of basic research into tangible pharmaceutical therapies.

The path from genomic data to approved drug is long, requiring the interaction of specialists from a multitude of disciplines. The more efficient and effective the Research Triangle region can be in promoting cross-disciplinary interaction, the better it will be able to prosper in the “post-genomic” age.

## 2. Biological Agents and Infectious Diseases

Basic needs for safety and security have been highlighted since the terrorist events of 9/11, and near-term trends in government funding (from the Department of Homeland Security and other agencies) will stimulate new and targeted R&D. A tremendous opportunity exists for the Research Triangle region to leverage its strengths in the area of biological agents. The needs and opportunities in this area are not limited to bioterrorism, as disease outbreaks often result from natural causes. Opportunities not only include public health, but also protection of the environment, water supplies, and food sources (plant and animal) from natural or terrorist exposure to biological agents.

If the Research Triangle region can successfully harness its knowledge base in public health, infectious diseases, agriculture, sensors, environmental health, and data management, the region can become a leader in the prevention, detection/diagnosis, treatment/remediation, and impact assessment of biological agents across a spectrum of industry clusters.

Infectious disease is back in the spotlight due to a convergence of events and threats, including emerging or re-emerging infectious disease (e.g., HIV/AIDS, “mad cow” disease, West Nile virus, SARS), drug resistance across all classes of microbial pathogens, and bioterrorism. Successful solutions to such threats will pull from many technology sectors in which the Research Triangle region has or can establish leadership, including

- World-class public and environmental health research organizations
- Discovery and development of new infectious disease therapeutics
- Agricultural disaster research, exemplified by recent efforts to create a not-for-profit institute to catalyze the research, development, and growth of this industry
- Sensors and sensor webs, analytical instrumentation, and data mining, which will be critical to monitoring, early detection of outbreaks, and characterization of new strains of pathogens
- Nanomaterials research, which will provide improved barrier systems for infection control.

Universities should seek creative ways to partner with nonprofit and government laboratories in the region to develop leading-edge research programs. Industrial recruitment efforts should highlight the key assets of the region to provide solutions to needs in this sector.

### 3. Agricultural Biotechnology

Agricultural biotechnology (agbiotech) encompasses a set of technologies— genomic science, functional genomics, bioinformatics, and genetic engineering technology—that improves yields and enables new agricultural products when applied to crop plants and livestock. Examples include the creation of new animal breeds or crop varieties with improved characteristics, enhanced nutritional values, faster growth, and disease resistance. Advances in these technologies also enable expansion of agriculture into alternative, non-food, non-fiber products, including pharmaceuticals, chemicals, biomaterials, and enzymes. Although the agricultural commodities and alternative product markets have very different structures, to a great extent they are supported by the same underlying R&D.

The Research Triangle region is strongly positioned to capitalize on the growth opportunities in both markets. The region has several assets that work synergistically to create biotechnology applications for food and fiber products:

- NCSU's research program in agricultural biotechnology, one of the nation's largest
- Strong research programs in statistics, biology, botany, chemistry, genetics, medicine, and engineering at NCSU, UNC-Chapel Hill, Duke, and other universities
- Several programs focused on transferring university R&D to the large agricultural industry in the state, as well as NCSU's leadership role in efforts to facilitate commercialization of agricultural IP
- Three of the world's largest agribusiness companies—Bayer CropScience, Syngenta Biotechnology, and BASF
- Entrepreneurial environment and ready access to investment capital and incubator infrastructure, which combines to nurture small start-ups, such as Athenix, Biolex, CropSolution, and Paradigm Genetics
- Large agricultural industry and leadership in poultry and hog production, providing commercial pathways for launching improved agricultural commodities
- Novozyme (the world's largest manufacturer of industrial enzymes), Covance (a major contract manufacturer of recombinant proteins), and the research and product divisions of several major pharmaceutical companies including GlaxoSmith Kline, Wyeth-Lederle, and Biogen.

Taken together, this large research foundation and agricultural industry base provide a substantial resource to support agbiotech, whether applied to traditional or alternative products.

Strong growth is projected for both the traditional agricultural food and fiber markets and the new alternative product markets, and the market share of commodity agricultural products from genetically engineered animals and plants has been steadily increasing. Significant research milestones are being reached for advanced breeding using genetic maps and the creation of transgenic livestock and poultry species with improved traits.

Despite the current European Union moratorium on commercialization of transgenic plants and animals, the technology is expected to be embraced in 10-20 years.

Additionally, research indicates that over the next 20 years, crop production will need to double while using roughly the same land area and reducing water usage. Increasing yields and crop production adapted to arid conditions utilizing brackish water are major thrusts in biotechnology research with crop plants.

Growth in the alternative products market sectors is being fueled by a number of factors:

- Desire to exploit genomic science discoveries with medical applications for pharmaceuticals and cell and tissue engineering
- Desire to lessen the environmental impact of manufacturing (green manufacturing), and to recycle and reduce waste
- Ongoing R&D and commercialization of transgenic animal- and plant-based production of pharmaceuticals, enzymes, chemicals, polymers, novel materials and bioenergy feedstocks

Each of these industries represents multi-billion dollar markets, several with growth potential projected at more than 10% annually. As these markets develop, new agricultural industries will be created, with strong growth in manufacturing jobs in bioprocessing.

Analysis of the technical, market, and industry clusters indicates that agbiotech is an area of substantial economic opportunity for the Research Triangle region that merits investment. All the industry elements are present and poised for substantial growth.

## 4. Pervasive Computing

The ultimate embodiment of communication networks is pervasive computing, which will enable on-demand access to information from anywhere at anytime, changing the way information is gathered, stored, and shared. Creation of pervasive computing networks involves integrating wireless technologies, optical communications, and computational hardware and software—all areas of strength in the Research Triangle region. Pervasive computing networks will be accessed by a new generation of electronic devices including sensors, wearables, and advanced handhelds. These devices will deliver a variety of enhanced or new services over the network such as communications, data retrieval and exchange (including video), and remote monitoring.

The creation of pervasive computing networks is currently being driven by open standards created by multi-national corporations. Thus, although the region boasts telecommunications and networking clusters, it may not be able to exert a strong force on the creation of the network backbone. However, the rise of these networks will create opportunities for the region in new electronic products and services, including the following:

- Medical devices that enable monitoring of patients in real-time and improve the quality of health care in rural areas
- Wearable electronics that are either incorporated into textiles or miniaturized to be worn unobtrusively on the body
- Sensor networks deployed at remote locations for various uses, including inventory tracking, precision agriculture, and homeland security
- Laboratory information management systems (LIMS), especially to support pharmaceutical/biotech research and clinical trials. By integrating a wide variety of sensors that monitor ongoing research with databases of results and analytical techniques, virtual laboratories can be created that support greater productivity and improved collaboration.

R&D needs across these applications include improved sensors, continued miniaturization of electronics, wireless communications, networking, data compression technologies, ergonomics, and textile manufacturing.

Businesses developed around these and other electronic products that operate on pervasive computing networks may be headquartered in the Research Triangle region and may maintain R&D activities in the region to capitalize on the technology base, particularly in medicine. Manufacturing of these products would likely occur close to the end user, particularly devices designed for low-cost, highly automated manufacturing.

## 5. Advanced Medical Care

In the next 10–20 years, combined advances in several fields—medical devices and diagnostics, drugs and drug delivery systems, genomics and proteomics, biotechnology, telecommunications, and informatics—are expected to revolutionize medical care. Although in early stages of evolution, examples of advanced medical care may include use of genetic analysis to determine predisposition to certain diseases, to design a customized wellness program to counter such predisposition, to recommend periodic tests for monitoring patient status, and to develop an individualized therapeutic approach in the event of early onset of disease. Additional examples include

- Diagnostic tests to identify early cellular and molecular changes that are characteristic of a given disease
- Injectable nanomachines that deliver localized drugs, clean arteries, selectively destroy cancer cells, or repair organs
- Gene therapy to treat brain tumors or stimulate angiogenesis
- Remote, cost-effective monitoring of patient progress during and after treatment using wireless sensors and telecommunications (see Section 4, *Pervasive Computing*).

Trends supporting investment in advanced medical care include the following:

- Over the next 20 years (the same time frame during which advanced medical care is expected to become available), baby boomers will be reaching retirement age. Often, retirees choose a retirement location based on proximity to the best medical care.
- An increasing popular emphasis on preventive health care and healthy lifestyles will support heightened medical awareness and earlier testing. Consumers will prefer to reside in areas that host the most innovative health care.

The Research Triangle region offers world-class health care institutions that will continue to lead in the evolution of quality health care. The region also has strong R&D competencies in key fields that support advanced medical care—including therapeutics development, genomics/proteomics, gene therapy, medical devices, medical diagnostics, sensors, informatics, information technology (IT), and communications. The region also has infrastructure and supply chains across the pharmaceutical, health care services, biotechnology, IT hardware, and imaging industries. Leveraging these resources to lead advancements in medical care and establish dominance in personalized medicine will lure life sciences companies and health care consumers to the region, stimulate new investment, and foster growth of new and existing companies.

## 6. Analytical Instrumentation

Analytical instrumentation is increasingly incorporating advances in photonics, imaging, combinatorial methods, and informatics. The result will be a permeation of sensors and other analytical instrumentation in a variety of fields including chemistry, civil engineering, and security. The Research Triangle region is poised to contribute to this revolution in three main areas: optics/photonics, combinatorial methods, and informatics.

Photonic methods will continue to revolutionize analytical instrumentation by providing new radiation sources and sensors. Tunable lasers will replace traditional spectroscopic light sources and enable the miniaturization of chemical analysis equipment such as spectrometers. This trend will promote the rise of advanced, low-cost, lab-on-a-chip technologies that provide point analysis in the field (e.g., in a doctor's office). In addition, sensors made from optical fibers and gratings will be employed in a variety of applications, including corrosion monitors on bridges, chemical sensors in factories, and remote monitors for precision agriculture. The Research Triangle region's knowledge base in analytical chemistry—particularly high-throughput screening methods—and optical technologies provides a strong foundation for start-up companies targeting these applications.

Combinatorial methods and high-throughput screening have become commonplace in pharmaceutical and biotechnology laboratories. However, these methods have been slow to progress to other disciplines such as catalysis, polymer science, and nanotechnology. The pharmaceutical and biotechnology industries in the Research Triangle provide the region with a strong foundation in combinatorial methods. The region can continue to play a major role in developing and applying combinatorial methods and high-throughput screening to the health industry, and can spearhead the application of these methods to other technologies. Most likely, development of such advanced analysis methods in life sciences will be driven by large corporations conducting research in the region. However, development of combinatorial and high-throughput screening methods for other disciplines will likely be driven by start-up companies.

The rapid rise of high-throughput screening has been accompanied by an equally rapid advance in informatics technologies (see Section 8, *Informatics*). More efficient representation of data produced by analytical instrumentation is required to increase productivity. As a result, advanced techniques such as imaging, three-dimensional representation of data, statistical analysis, modeling and simulation, and data matching will dominate future analytical instruments. This trend will also impact health care, chemical assay research, and pharmaceutical development and manufacturing.

## 7. Nanoscale Technologies

Recent advances in chemistry enable molecular-level engineering of complex structures such as polymers, metals, ceramics, proteins, and genes. Novel electrical, mechanical, optical, and catalytic properties of nanostructured materials have garnered worldwide attention. Exploration of these capabilities has just begun, but the field has already produced advances in pharmaceuticals, composites, and biotechnology. Nanotechnology is an enabling technology, cutting across many industry sectors and potentially creating new industries. While commercial applications are in the early stages, the underlying nanoscience (i.e., understanding materials interactions at the nanometer or molecular level) is the basis for technology development.

The Research Triangle region is well positioned to capitalize on the emergence of these nanoscale technologies, particularly for life science applications.

Nanoparticle applications are the nearest to market and the most diverse. The use of self-assembled monolayers, nanoporous membranes, and other surface-science nanotechnologies will create a new paradigm in chemistry. These modified materials can serve as molecule-sized chemical factories for creating pharmaceuticals and biochemicals with tailored structure-property relationships (i.e., rational drug design) and optical activity, which will facilitate the creation of medicines personalized to individual DNA structures (see Section 5, *Advanced Medical Care*). In addition, nanoscale technologies will give rise to new composites useful in drug delivery, medical sensors, tumor labeling, cell transport agents, automotive materials, bio-compatibility agents, and architectural structures. Finally, controlled manipulation, assembly, and measurement of nanoscale materials is essential to creating new and useful products.

Development of nanoscale technologies is highly dependent upon the intended application, and will likely be driven by start-up companies. The initial cost of these nanoscale systems is expected to be high, given the complexity and accuracy required for molecular-level manipulation. As a result, pharmaceutical and biotechnology applications of nanoscale technologies may be the most promising applications for growth in the Research Triangle region.

## 8. Informatics

Informatics includes a broad range of information technologies, computer hardware, software, and IT services used to manage and analyze data to drive innovation and create business advantage. In the knowledge economy, competitive advantage derives largely from an organization's ability to make effective and timely use of internally and externally generated data.

Informatics is already firmly established in the Research Triangle region, home of the largest industrial employers of knowledge workers, and should provide sustainable growth into the future. R&D investments in IT provide synergistic cross-cutting benefits to other clusters; however, future opportunities will increasingly derive from software and related services rather than hardware. With some exceptions for general-purpose software like operating systems, investment should be focused on particular application areas. Three areas with significant cross-cutting potential are critical to the continued growth of the region's informatics sector:

- Distributed computing
- Analytical software techniques
- Imaging and visualization systems.

Distributed computing systems, including grid computing, are the next phase of computing platforms. Regional capabilities range broadly, including operating system expertise and advanced networking capabilities that support the North Carolina Research and Education Network (NCREN) and development of the next-generation Internet. Investments in distributed computing have excellent potential to provide direct payback via new start-up companies, and are likely to have the biggest dividend when focused on particular application areas (e.g., pharma/biotech). In particular, advancements in biotechnology and other nano- and molecular-level research efforts have created an information explosion in the laboratory that requires advanced informatics technologies—a strong driver for developing next-generation capabilities of grid computing systems.

The Triangle also has strengths in advanced analytical software and substantial statistical expertise supporting application areas like data mining and analyzing complex information. Investment in analytical techniques—including mathematics and statistics, geometry, modeling, simulation, and optimization—will be the basis for additional growth. For the best return, these investments should focus on bioinformatics, medicine, nanomaterials, environmental research, analytical chemistry, and flexible manufacturing.

Finally, nascent capabilities in the Triangle in imaging and visualization systems can provide the basis for future growth. New opportunities are most likely to be generated from medical diagnostics, relating to new image-processing techniques rather than hardware. Advanced visualization techniques can provide easier use of and greater insight into increasingly large and complex sets of data. Developments are likely to be driven by the need to understand molecular-level functionality in biotechnology; however, significant crossover potential exists in areas like commercial data mining.